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*The views expressed are those of the authors and do not necessarily reflect those of the European Central Bank or the Banque de France. Nuno Cassola: European Central Bank, nuno.cassola@ecb.int. François Koulischer: Banque de France and Université Libre de Bruxelles (ECARES), francois.koulischer@banque-france.fr. We thank Estelle Cantillon, Daan Struyven, Benjamin Born, Paul De Grauwe, Mathias Dewatripont, Georg Duernecker, Michael Dickstein, Liran Einav, Domenico Giannone, Jakub Kastl, Ralph Koijen, Guillermo L. Ordoñez, Lasse Pedersen, André Sapir, Andreas Schabert, Alexandre Wagner, Jan Wrampelmeyer, Jan Zupanc and seminar participants at ULB, Leuven, Mannheim, the ECB and the National Bank of Belgium for useful discussions. Part of this research was conducted while Koulischer was visiting the ECB/DGM/MOA in Summer 2011 and Stanford University in Winter 2013.

**Abstract**

We build a model of collateral choice by banks to quantify how changes in the haircut policy of the central bank affect the collateral used by banks and the funding cost of banks. We estimate the model using data on assets pledged to the European Central Bank from 2009 to 2011. Our results suggest for example that a 5% higher haircut on low rated collateral would have reduced the use of this collateral by 10% but would have increased the average funding cost spread between high yield and low yield countries by 5% over our sample period.

**Keywords:** Collateral, Haircut, Central Bank, Money market

**JEL classification:** E52, E58, G01, F36

**Abstract**

Nous proposons un modèle de choix de collatéral qui permet d'évaluer l'impact de changements dans la politique de collatéral de la banque centrale sur le type de collatéral utilisé par les banques ainsi que sur l'accès des banques au financement. Nous utilisons des données sur les actifs utilisés comme collatéral auprès de la BCE de 2009 à 2011 pour estimer notre modèle. Nos résultats suggèrent par exemple qu'une hausse de la décote ("haircut") de 5% sur les actifs avec une note de crédit basse réduirait l'utilisation de ce type de collatéral de 10% mais augmenterait le différentiel de taux entre banques à taux élevé et celles à taux faibles de 5% sur notre période d'échantillonnage.

**Mots clés:** Collatéral, décote, banque centrale, marché monétaire

**Classification JEL:** E52, E58, G01, F36

## Non-technical summary

Collateral policy is an important aspect of the design of the operational framework for monetary policy implementation. The paper proposes a model of collateral choice that can be used to assess how changes in the collateral policy of the central bank affect the type of collateral used by banks as well as potential effects on the access of banks to funding. These two applications of our model reflect two key concerns faced by central banks when designing their collateral framework. First, it should protect the central bank against credit risk. Second, it must ensure that the central bank can implement its monetary policy.

We first review stylized facts on the banking sector of the Euro-area during our sample period (2009-11) and provide a brief overview of the collateral policy of the European Central Bank (ECB) over that period. Data from the European Banking Authority (EBA) suggest that the European banking system exhibits significant cross-country heterogeneity in their portfolios of government debt, with an average exposure to the domestic government of 50% of the total sovereign exposure. Since governments have differing credit ratings, the collateral portfolios of banks also differ across countries in terms of credit quality and value. During our sample period, the sovereign debt crisis has led to increased heterogeneity along this dimension. We then review the main elements of the collateral policy of the ECB over our sample period. While the collateral policy remained broadly unchanged, changes in market funding conditions varied widely across banks in the euro area and were also reflected in the value of the collateral used by banks.

We then build a model to better understand the interaction between the choice of collateral by banks, their access to the private market and the collateral policy of the central bank. In the model, a bank has several investment opportunities and simultaneously chooses its assets as well as whether to use the asset as collateral in the private market or at the central bank. The bank has an initial level of capital and faces a leverage constraint that determines the size of its balance sheet. We derive how the optimal use of collateral by banks at the central bank relates to simple proxies of the profitability of each option relative to the attractiveness of private market borrowing. We then show how the underlying benefit of each option relative to the private market can be recovered from the collateral effectively pledged by banks to the central bank. We regress the recovered benefit against asset and country characteristics as well as the haircut of the central bank.

The empirical model allows performing a range of policy counterfactuals. For example, we estimate the counterfactual impact of a 5% haircut increase on all collateral belonging to a specific asset class (e.g. government bonds or ABS) on the type of collateral used at the central bank. Our results suggest that

this would reduce the use of the asset class with higher haircut by around 10%. Around 70% of this fall would be replaced by private market funding and the rest would be substituted to other collateral types at the central bank. We also use our model to compare the effect of policy changes across two country groups, high yield countries (Spain, Greece, Ireland, Italy, Portugal) and low yield countries (Austria, Belgium, Germany, France and the Netherlands). We estimate how the collateral pool of each country group would be affected by an increase in the haircut on government debt with a credit rating below A and show that high yield countries would also be more affected since they use a larger amount of these assets as collateral.

We then use the underlying costs and benefits of using central bank collateral recovered from our model to gain some insight on the access of banks to the private market during the sovereign debt crisis. Since the crisis witnessed a relative increase in the use of debt from low rated government as central bank collateral, we compute the counterfactual haircut increase that would have been required on low rated government debt to keep the share of this type of collateral constant over the sample. This counterfactual haircut is useful as it provides an indication of refinancing conditions in the private market for this type of collateral. We find that the required haircut add-on would have reached 25% in the summer of 2010 and 2011. Finally, we compare the access to the private market of banks in high yield and low yield countries. Our estimates suggest that while the cost differential improved in early 2009, it widened substantially thereafter. In a final counterfactual, we compute the cost differential if the haircut on low rated government debt had been 30% point higher than its baseline level. Our estimates suggest that this could have substantially increased the differences in average funding costs across country groups.

On a broader level, these results allow to quantify the role of collateral requirements in the implementation of monetary policy. Our results suggest that while the use of lower rated collateral increased over this period, the collateral policy of the European Central Bank helped to smooth the transmission of monetary policy across the euro area.

# 1 Introduction

Central banks face two key concerns when designing their collateral policy. First, the collateral rules must be flexible enough to ensure that the central bank can effectively implement its monetary policy. Second, the rules should ensure that the collateral used by banks consists of high quality assets to limit the exposure of the central bank to its counterparties.[1]

In this paper, we build a model of collateral choice by banks that can be used to assess how changes in the collateral policy of the central bank affect the type of collateral used by banks as well as potential effects on the transmission of the monetary policy to the interbank market. These two applications of our model reflect the two key concerns faced by central banks when designing their collateral framework which both featured prominently in policy debates during the European sovereign debt crisis. Our results suggest for example that a 5% higher haircut on low rated collateral from 2009 to 2011 would have reduced the use of this collateral by 10% but would have increased the average funding cost spread between high yield (periphery) banks and low yield (core) banks by 5%.

We begin in sections 2 and 3 with relevant facts on the European banking system and a brief overview of the ECB's collateral policy. We show that the European banking system exhibits a significant home bias, with an average exposure to the domestic government of 50% of the total sovereign exposure. Our sample period coincides with several downgrades in the credit rating of the government debt of some euro area members. These downgrades, together with increased yields on bank and government debt in the downgraded countries, underlined the two key concerns of the design of collateral policy. The value of the collateral pledged by high yield countries for example fell by 15% over our sample period, while that of low yield countries increased by 5%. Since collateral is valued at market prices, this illustrates how lower asset values in some regions may have reduced the ability of banks to borrow from the central bank. On the other hand, the downgrades also created a possibility of lowering the quality of the collateral pool of the ECB which further underscores the potential interest of an empirical model.

We present the model in section 4. A bank has an initial level of capital and faces a leverage constraint that determines the size of its balance sheet. This constraint could be the consequence of a moral hazard problem (Holmström and Tirole, 2011), of value-at-risk constraints faced by the financiers of the bank

[1] Article 18.1 of the Protocol on the Statute of the European System of Central Banks and of the European Central Bank states that: "In order to achieve the objectives of the ESCB and to carry out its tasks, the ECB and the national central banks may conduct credit operations with credit institutions and other market participants, with lending being based on adequate collateral." As explained by Tamura and Tabakis (2013), "the concept of the adequacy of collateral has two notions. First, collateral must be able to protect the Eurosystem from incurring losses in its credit operations. Second, there must be sufficient collateral potentially available to ensure that the Eurosystem can carry out its tasks."

(Brunnermeier and Pedersen, 2009) or a regulatory obligation. The bank has several investment opportunities and simultaneously chooses its assets as well as a funding source where we distinguish the private market and the central bank as two funding options. If the bank chooses the central bank, the asset is then used as collateral to secure the loan. The bank therefore has $n+1$ funding - investment options: the private market or the central bank using one of the $n$ collateral types observed in our sample.

We derive how the optimal collateral use of banks relates to simple proxies of the attractiveness of the use of each collateral relative to private market funding. We then show that the underlying benefit of each option relative to the private market can be recovered from the collateral effectively pledged by banks to the central bank. We regress the recovered benefit against asset and country characteristics. One variable that is of particular interest is the haircut of the central bank, which is set in function of observable asset characteristics. We isolate the role of the haircut by including several asset characteristics to account for asset liquidity. Our controls include the asset type, dummies for each rating category, the maturity of the asset and the interaction between maturity and asset type.

We then use the recovered coefficient to compute several policy counterfactuals. We first assess how a 5% haircut increase on all collateral belonging to a specific asset class (e.g. government bonds or ABS) would affect the type of collateral used at the central bank. Our results suggest that this would reduce the use of the asset class with higher haircut by around 10%. Around 70% of this fall would be replaced by private market funding and the rest would be substituted to other collateral types at the central bank.

Since our model allows to study counterfactuals at the asset level and for specific counterparties, it also allows to compare the effect of policy changes across banks. In another policy counterfactual, we consider two country groups. High yield countries include Spain, Greece, Ireland, Italy, Portugal and low yield countries include Austria, Belgium, Germany, France and the Netherlands. We then estimate how the collateral pool of each country group would be affected by an increase in the haircut on government debt with a credit rating below A. As high yield countries use a larger amount of these assets as collateral, they would also be more affected.

We also use the underlying costs and benefits of using central bank collateral recovered from our model to gain some insight on the access of banks to the private market during the sovereign debt crisis. Since the crisis witnessed a relative increase in the use of debt from low rated government as central bank collateral, we compute the counterfactual haircut increase that would have been required on low rated government debt to keep the share of this type of collateral constant over the sample. This counterfactual haircut is useful as it provides an indication of refinancing conditions in the private market for this type of collateral.

We find that the required haircut add-on would have reached 25% in the summers of 2010 and 2011.

Finally, we compare the access to the private market of banks in high yield and low yield countries. Our estimates suggest that while the cost differential improved in early 2009, it widened substantially thereafter. In a final counterfactual, we compute the cost differential if the haircut on low rated government debt had been 30% point higher than its baseline level. Our estimates suggest that this could have substantially increased the differences in average funding costs across country groups.

To sum up, our model provides a tool to quantify how changes in the collateral policy of the central bank affect the composition of its collateral pool on the one hand and the funding costs of banks and the transmission of monetary policy to the interbank market on the other hand.

These two concerns were at the fore of the policy debate during the Sovereign debt crisis, and our results suggest that while the use of lower rated collateral increased over this period, the collateral policy of the European Central Bank helped to ensure a more level transmission of monetary policy across the euro area.

Our work suggests several avenues for future research, such as refining the estimation of the parameters of the model using asset- and bank-level data. This would also allow to study how bank characteristics interact with the design of monetary policy operations to influence the transmission of monetary policy.

The paper is structured as follows. In section 2 we provide key stylized facts on the European banking sector relevant to our analysis. In section 3 we describe our data and the collateral framework of the ECB. In section 4 we build a model of collateral choice and present our estimation strategy in section 5. We then perform several policy counterfactuals in section 6 and conclude in section 7.

### 1.1 Related literature

The European sovereign debt crisis has been the focus of a large literature. Dreschler et al. (2013) for instance use data on bank borrowing from the ECB during the crisis and find evidence for risk-shifting during this period. Acharya and Steffen (2015) find that banks from periphery countries increased their exposure to the government debt of their home country and argue that collateral policy may have contributed to this. Wolff (2014) argues that the adaptation of the collateral framework of the ECB during the crisis was necessary to provide liquidity to solvent banks.

The use of collateral policy as an additional instrument available to the central bank to influence the transmission of monetary policy has been discussed by Ashcraft et al. (2011) and the idea that collateral policy could be used to have a differentiated policy stance across countries in the euro area was first

proposed by Brunnermeier (2010). Bindseil (2013) studies the collateral policy of the central bank and argues that it can mitigate the negative welfare effects of asset fire sales, a point also emphasized by Acharya et al. (2012). Studies of the private repo market in Europe include Boissel et al. (2014) and Mancini et al. (2013).

On the theory side, Benmelech and Bergman (2012) propose a model of endogenous collateral values and show the existence of credit traps where firms hoard liquidity. Benigno and Nisticò (2013) compare the interest rate instrument with the expansion of the central bank's balance sheet and also show that a shock to the liquidity of some assets may raise interest rate spreads and cause a recession. The difference is the focus on asymmetric shocks, which was a key feature in the European sovereign debt crisis.

The key contribution of this paper is to provide a tool that can be used to quantify the risk-taking versus liquidity provision trade-off faced by collateral policy and a first set of results based on the collateral used by banks during the sovereign debt crisis.

## 2 The European banking sector (2009-2011)

We first review several key facts of the European sovereign debt crisis which spans our observation period (2009-2011). We show that bank portfolios vary across countries due to a home bias and that the debt crisis had an asymmetric effect on banks in the euro area. The European banking sector is characterized by a significant degree of home bias: banks are more exposed to assets issued in their home country. This point is illustrated in figure 1 which shows the net exposure of banks to their home country's sovereign debt, expressed as a proportion of their total exposure to sovereign debts. The sovereign debt of the home country accounts for 50% of the exposure of banks to sovereigns on average, and countries with low home bias like Cyprus have significant exposures to neighboring countries (in this case, Greece).[2] According to the aggregated balance sheet data of banks in the euro area, lending to governments accounts for roughly 10% of the asset of banks in the euro area, and it is likely that other asset types (e.g. loans to households and firms) are even more concentrated geographically.

Another related feature of the European banking sector is that the market remains segmented along national lines. Data from the European Banking Authority suggest for instance that the assets of foreign banks (i.e. non-domestic at country level) represent only 12.6% of total assets in the euro area's banking sector.[3] This suggests that if the domestic banking sector were to suffer a shock, foreign banks would not

[2] Acharya and Steffen (2015) show that home bias increased over time during the sovereign debt crisis.

[3] Source: EBA National Banking Data 2011. The 'Financial Integration in Europe' report (ECB, 2015) shows that despite

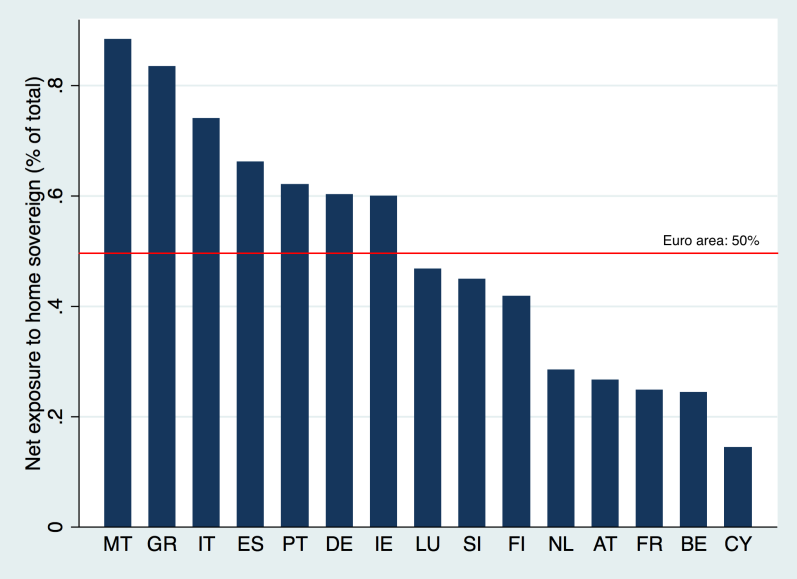


Figure 1: Net exposure to home country sovereign debt as % of total sovereign exposure (Source: EBA 2011 Stress Tests)

be able to entirely compensate a potential fall in lending by domestic banks.

The third fact is that the European sovereign debt crisis had very different effects across countries. The credit rating of government debt fell sharply for some countries while the rating of other countries remained stable. This is illustrated in Figure 2, where the ratings are expressed on a scale from 20 (AAA) to 0 (C) and each step corresponds to one notch (e.g. 19=AA+, 18=AA). While the rating of German, Dutch or Austrian sovereign debt remained stable at AAA throughout our sample, it fell sharply for countries such as Greece (from A to CC), Ireland (AAA to BBB+) or Portugal (AA- to BBB-). This shock to government debt in turn affected the value of the bonds held by banks and their capacity to borrow from the private market. Figure 3 shows for example the average credit default swap (CDS) spreads on euro area banks by country. The highest spreads are observed in countries where governments experienced the largest fall in their credit ratings.

# 3 ECB collateral policy and use of collateral by banks (2009-2011)

## 3.1 ECB collateral policy

We now describe the collateral policy of the ECB during our sample period.[4] When lending to banks, the ECB requires the use of collateral in order to mitigate counterparty risk. Only euro-denominated bonds

an improving trend, integration in the banking sector remains below pre-crisis levels.

[4]Eberl and Weber (2014) detail the collateral policy of the ECB from 2001 to 2013.

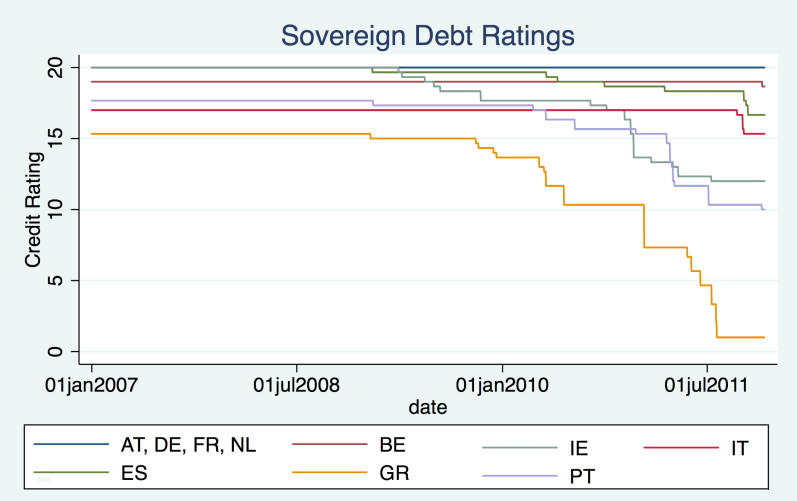


Figure 2: Sovereign debt ratings of selected euro area members.
This figure shows the evolution of the average credit rating of Sovereign debt (Fitch, Moody's and S&P). The ratings are measured on a scale from 20 (AAA) to 0 (default). Each unit corresponds to a notch, e.g. 19=AA+ and 18=AA.

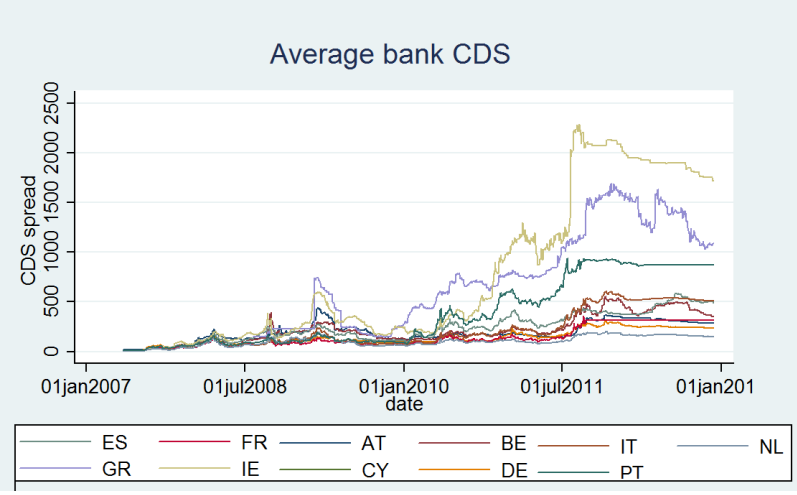


Figure 3: Average CDS spread of major banks in selected countries.

Table 1: ECB haircut levels

This table shows the valuation haircuts of the ECB over our sample period (2009-2011). The haircuts vary with asset characteristics (the asset type, its rating and its residual maturity). (*) The haircut schedule is for fixed coupon bonds. There is a specific schedule for zero-coupon bonds which we removed for clarity (see ECB General documentation for more details) (**) The haircut on ABS changed from 12% to 16% on January 1, 2011.

| Credit Quality | Residual Maturity (years) | Haircut in % by asset type (*) | | | | |
|---|---|---|---|---|---|---|
| | | Central government bonds | Regional gov. bonds and jumbos | Covered bonds, corporate bonds | Uncovered bank bonds | ABS |
| AAA to A- | 0-1 | 0.5 | 1.0 | 1.5 | 6.5 | |
| | 1-3 | 1.5 | 2.5 | 3.0 | 8.5 | 12.0 |
| | 3-5 | 2.5 | 3.5 | 5.0 | 11.0 | (<Jan. 2011) |
| | 5-7 | 3.0 | 4.5 | 6.5 | 12.5 | 16.0 |
| | 7-10 | 4.0 | 5.5 | 8.5 | 14.0 | (>Jan. 2011) |
| | >10 | 5.5 | 7.5 | 11.0 | 17.0 | (**) |
| BBB+ to BBB- | 0-1 | 5.5 | 6.0 | 8.0 | 15.0 | Not eligible |
| | 1-3 | 6.5 | 10.5 | 18.0 | 27.5 | |
| | 3-5 | 7.5 | 15.5 | 25.5 | 36.5 | |
| | 5-7 | 8.0 | 18.0 | 28.0 | 38.5 | |
| | 7-10 | 9.0 | 19.5 | 29.0 | 39.0 | |
| | >10 | 10.5 | 20.0 | 29.5 | 39.5 | |

are eligible as collateral.[5] The range of bonds accepted is relatively broad, with a total value around EUR 13.1 trillion, or 5 times the euro-area's GDP. This is in part due to the concatenation of the different collateral policies of the national central banks at the launch of the euro but also ensures that banks are not constrained by a lack of available collateral in their access to central bank liquidity.

The collateral is subject to valuation haircuts. The haircut specifies the amount that may be borrowed for a given amount of collateral and depends on the asset used as collateral. For example, an asset worth 100 with a net haircut of 5 % allows a bank to borrow up to $95 = 100 * (1 - 5\%)$. During our sample period, the ECB used a full-allotment procedure in its open market operations whereby any demand for liquidity is satisfied if the borrowing bank has sufficient collateral to secure its loan.

Table 1 provides an overview of the haircut policy of the ECB during our sample period.[6] The key principle is that less liquid collateral faces higher haircuts. Liquidity is measured by the collateral maturity, its asset class and its credit-rating. There are six maturity buckets, with categories up to one year, from one to 3 years, 3 to 5, 5 to 7, 7 to 10 and above ten years. Asset types are also assigned

[5] In November 2008, the ECB enlarged the eligibility criteria to non-euro denominated assets. This measure was phased out in January 2011 but reintroduced in December 2011.

[6] Some assets are subject to additional requirements. For example, the ECB also distinguishes between fixed- and zero-coupon bonds - see the ECB General Documentation 2010 for more information.

to "liquidity categories". The most liquid category includes central (sovereign) government bonds or bonds from supranational institutions. Regional government bonds follow with "Jumbos" which are large issuances of covered bonds. Covered bonds and corporate bonds belong to the third category.[7] The fourth category includes uncovered bank bonds. Finally, ABS are considered the less liquid asset type and face a fixed haircut of 16%. ABSs with a rating below A- are ineligible. The ECB uses two buckets for the credit rating: low rated bonds face higher haircuts.

Table 2 provides an overview of the main changes in the ECB's collateral policy from late 2008 to 2011. In October 2008, in the aftermath of the default of Lehman Brothers, the ECB reduced the minimum rating threshold for eligibility to BBB-, from A- initially and foreign-currency denominated collateral became eligible shortly thereafter. The ECB suspended the eligibility requirements on Greek government debt in May 2010, shortly after the Greek government had entered a €110 billion EU-IMF assistance program. In March 2011, the ECB suspended the rating threshold on Irish government debt and similarly acted 3 months later for Portugal. The ECB also tightened its collateral policy in some instances. For example, in January 2011 it increased the haircut on ABS to 16% from 12%.

[7] Asset-Backed Securities (ABS) are debt instruments collateralized by loans or receivables held by banks, credit card companies and other credit providers. Covered Bonds are "dual recourse" bonds similar to ABSs. They are issued by a credit institution and with priority recourse to a pool of collateral. The main differences with ABSs are that (1) they are kept on the issuer's balance sheet while ABSs are often transferred to a special entity. This provides a "dual recourse" to the lender who has access to the underlying loans or the issuer in case of default. (2) ABSs are generally tranched while covered bonds are not. (3) Covered bonds are more regulated with regard to the type of assets to be used, the management of the asset pool during the life of the security and the transparency of the security.

There are two categories of covered bonds: Jumbo and Pfandbriefe (jumbo are large issuances generally perceived of higher quality).

Table 2: Selected changes to the ECB's collateral policy, October 2008 to September 2011
(see appendix B for a complete list of changes to the ECB's collateral policy)

| Date | | | Change in collateral framework |
|---|---|---|---|
| 22 | October | 2008 | The credit threshold for collateral other than ABS is lowered to BBB-. |
| 14 | November | 2008 | Foreign denominated collateral becomes eligible. |
| 3 | May | 2010 | The minimum rating threshold of debt instrument issued or guaranteed by the Greek government is suspended |
| 15 | June | 2010 | Haircut on Greek government debt is increased by 5 %. |
| 1 | January | 2011 | New, higher haircuts for some asset types apply (including haircut on ABS increased to 16 % from 12 %). |
| 1 | January | 2011 | Expiry of the temporary measures of eligibility of assets denominated in foreign currency |
| 1 | March | 2011 | Over the life of the ABS, the second best rating must remain above A- regardless of the date of issuance of an ABS. |
| 31 | March | 2011 | The minimum rating threshold of debt instrument issued or guaranteed by Irish government is suspended. |
| 25 | May | 2011 | Haircut on Portuguese government debt is increased by 5 %. |
| 7 | July | 2011 | The minimum rating threshold of debt instrument issued or guaranteed by the Portuguese government is suspended |

### 3.2 Use of collateral by banks

We use four datasets. The first one is a proprietary dataset consisting of weekly snapshots of the collateral pledged to the ECB from January 2009 to September 2011 (142 weeks). For each country and each asset class, we observe the amounts pledged, the average haircut, the rating and whether the asset is guaranteed by the government or not. The asset classes include government bonds, asset-backed securities (ABS), covered bonds, uncovered bank bonds, jumbos, regional government bonds and non-marketable assets (appendix C provides a definition of each asset class).

The second dataset consists of the amounts borrowed by banks from the ECB, also aggregated at country level. Third, we use data on all the assets eligible as collateral to the ECB for the same period and at the same frequency. The database contains all assets issued in the euro area that could be used for the refinancing operations. For each issuer country, the data includes the total outstanding amounts of eligible assets issued in that country at a weekly frequency. Finally, we use the interbank market dependence ratio from the Statistical Datawarehouse of the ECB to measure the short-term money market funding of banks. This series is the ratio of total amount owed to credit institutions over total assets. We also use bond yield, credit ratings and CDS data on banks and sovereigns from Bloomberg. We transpose credit ratings to a numerical scale from 0 (C) to 20 (AAA) and we compute the average government credit ratings assigned

by Fitch, Standard and Poors and Moody's.

Table 3 provides an overview of our dataset. Our panel has three dimensions: time (142 weeks), countries (11) and assets.[8] There are 360 assets varying by asset class, maturity, rating and whether or not the collateral is guaranteed by a government, with a corresponding haircut for each asset type. In total we have 135,088 weekly country-level and asset-specific observations. This is less than the total potential observations ($360 \times 11 \times 142$) because many banks do not use all eligible collateral types at a given date.

The nominal value of eligible collateral, i.e. collateral that *could* be pledged, is € 13.1 trillion on average in our sample. Banks pledge € 2.1 trillion worth of assets (€1.96 trillion after haircut) and borrow € 610 billion from the ECB on average over our sample period. There are several reasons for the fact that banks pledge more collateral than strictly needed to cover their borrowing. First, banks also use the collateral for payment purposes and intra-day borrowing at the central bank. Second, a credit line from the central bank is viewed favorably by market participants. Finally, a collateral buffer allows banks to face unexpected liquidity shortfalls and reduces the operational risk of having to mobilize collateral in a short period of time. In practice banks tend to over collateralize their loans and pledge more collateral than necessary to the central bank. This effectively provides banks with a credit line that can be drawn upon in case of unexpected liquidity shock.

ABSs are the largest asset class used as collateral and account for almost a third of all collateral used (as documented in the last panel of table 3). The second category are non marketable assets (15%) and uncovered bank bonds (17%). Government bonds only account for 13% of the collateral used, which contrasts with the pre-crisis figures of around 50% (Cassola et al., 2013). The other columns document the differences in collateral pools across countries. For example, the amount of ABS pledged ranges from 67% to only 3% of some countries' collateral pools. Similar variations are observed for other asset types.

Figures 4 and 5 illustrate variations in the intensity of use of central bank liquidity across banks and asset types. Less liquid government debts (i.e. with a lower credit rating) tend to be used more intensively as central bank collateral. This is also true across asset classes (as shown in figure 12 in appendix), where up to 50% of illiquid assets like asset backed securities are pledged to the central bank. Figure 5 shows that a high level of distress (as measured by the Credit Default Swap) of a country's banks is associated with a higher use of central bank liquidity provision, and higher levels of collateral pledged as a share of the total balance sheet.

*Stylized evidence on the role of availability of collateral.* A large literature has shown the liquidity and

[8] We restrict our sample to 11 countries that account for 97.8% of the collateral pledged (Austria, Belgium, Germany, Spain, France, Greece, Ireland, Italy, the Netherlands and Portugal).

Table 3: Descriptive statistics

The first panel provides statistics on the number of asset types, countries and dates in our sample. The second panel describes the usage of collateral by banks. We provide over time statistics on the eligible collateral (that could be used as collateral), the collateral pledged (before and after the valuation haircut) and the amounts borrowed. The third panel illustrates the cross-country variations in the type of assets used by banks, which vary for ABS from 3% of the collateral used by banks in a country to 67% of the collateral used.

| **Key dimensions of the panel data** | | | | | |
|---|---|---|---|---|---|
| Assets (categories×maturities×gov. guar.×ratings) | 360=9×2×2×10 | | | | |
| Countries | 11 | | | | |
| Time periods (weeks) | 142 | | | | |
| Observations | 135,088 | | | | |
| **Aggregate Statistics on ECB Operations (time averages)** | | | | | |
| | N | Mean | Min | Max | SD |
| Eligible collateral (nominal value, € bn) | 142 | 13,131 | 11,732 | 14,039 | 549 |
| Collateral pledged (value before haircut, € bn) | 142 | 2,163 | 1,902 | 2,308 | 115 |
| Collateral pledged (value after haircut, € bn) | 142 | 1,964 | 1,692 | 2,181 | 127 |
| Amount borrowed from the ECB (€ bn) | 142 | 610 | 330 | 999 | 175 |
| **Collateral Pool of the ECB and Country Variation** | | | | | |
| For the ECB and at country-level (N=11), the amount of asset pledged as proportion of total pledged | | | | | |
| Asset | N | Mean | Min | Max | SD |
| Central government | 11 | 0.13 | 0.04 | 0.38 | 0.10 |
| ABS | 11 | 0.31 | 0.03 | 0.67 | 0.20 |
| Pfandbriefe / Covered bonds | 11 | 0.09 | 0.02 | 0.20 | 0.06 |
| Uncovered bank bonds | 11 | 0.17 | 0.03 | 0.37 | 0.11 |
| Non-marketable | 11 | 0.18 | 0.02 | 0.47 | 0.14 |
| Corporate bonds | 11 | 0.05 | 0.01 | 0.10 | 0.03 |
| Regional government bonds | 11 | 0.02 | 0.00 | 0.07 | 0.02 |
| Jumbos | 11 | 0.03 | 0.00 | 0.12 | 0.04 |
| Other | 11 | 0.01 | 0.00 | 0.03 | 0.01 |
| Financial Corp. bonds | 11 | 0.03 | 0.01 | 0.08 | 0.03 |

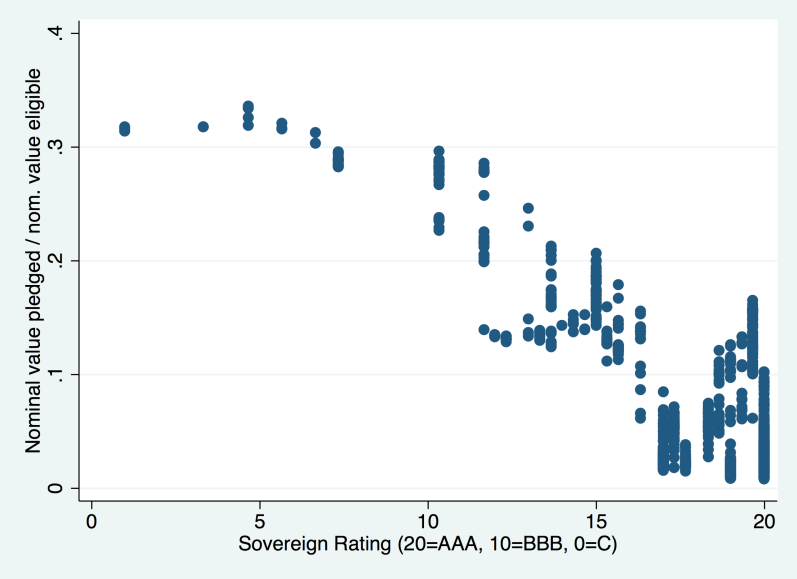


Figure 4: Proportion of eligible government debt used as collateral in function of the sovereign debt rating

The figure shows for each country and week in our sample the ratio of government debt that is pledged to the amount eligible. Less liquid assets (with lower rating) are used more intensively as central bank collateral.

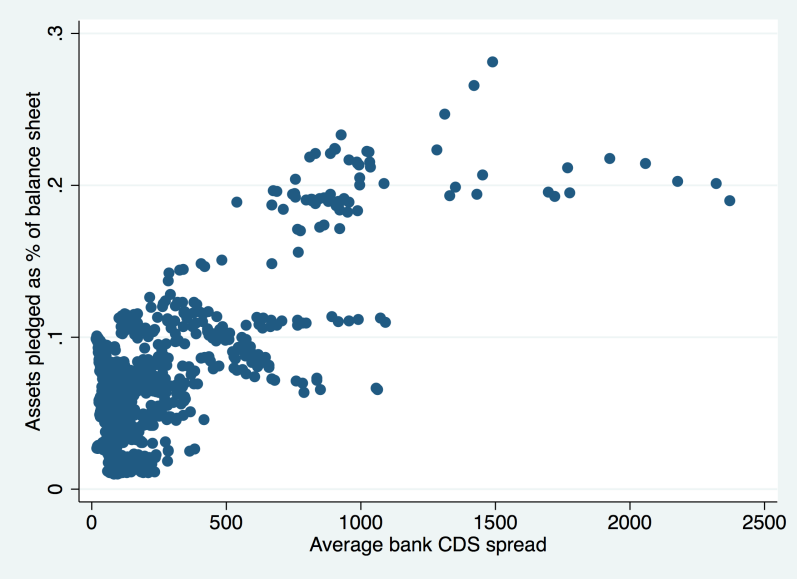


Figure 5: Assets pledged against bank CDS.

This figure shows for each country and period the amount of assets pledged to the ECB, as a proportion of the bank's total balance sheet size, plotted against the average CDS spread of the country's largest banks.

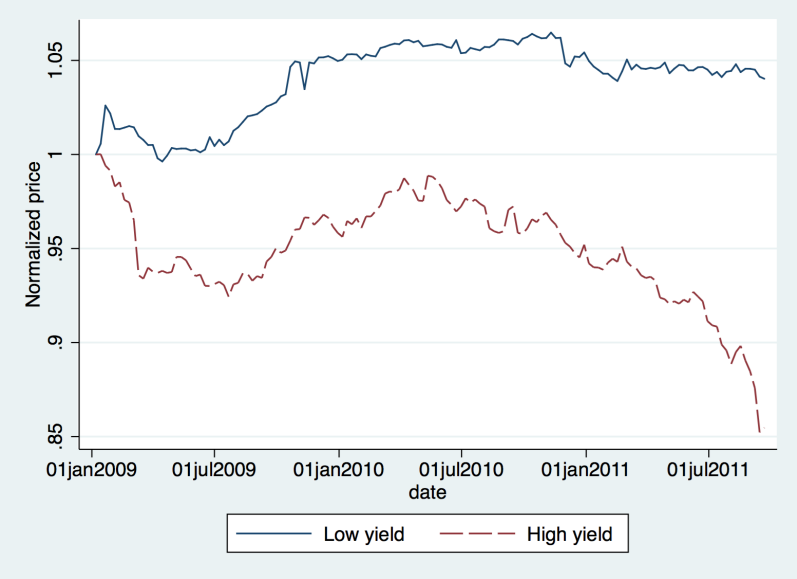


Figure 6: Value of collateral pledged by high- and low-yield countries

This figure shows the evolution of the average price of assets pledged to the ECB (measured as the ratio of market value to nominal value), normalized to 1 in January 2009. We divide in two samples: high-yield countries include Cyprus, Spain, Greece, Ireland, Italy, Portugal and Low yield countries are the other Euro-area countries.

value of the collateral owned by banks play an important role in the capacity of banks to lend to the real economy (Shleifer and Vishny, 1992; Kiyotaki and Moore, 1997; Geanakoplos, 2010). Focusing on central bank collateral policy, Bindseil (2013), Koulischer and Struyven (2014) and Koulischer (2015) similarly argue that the collateral availability is a key state variable to determine the effect of collateral policy on banks.

The fact that banks have a home-bias and own more domestic assets together with the asymmetric nature of the sovereign debt crisis would suggest that the availability of collateral in distressed high-yield countries might have been reduced with the shock. Figure 6 provides some evidence of the impact of lower collateral values on banks' collateral portfolios. It shows the average value of collateral pledged to the ECB, computed as the ratio of nominal value to market value. The value of the collateral pledged by high yield banks fell by more than 15% during the crisis while that of low yield banks increased by around 5%. In other words, for a same amount borrowed (and assuming identical haircuts), banks from high yield countries had to increase the nominal amount of collateral pledged by 15% to borrow the same amount.

The availability of collateral to banks is arguably a key component that provides them with an access to the interbank market. If banks run out of collateral, they may be unable to borrow from the private market and this could increase the lending rate (or reduce the availability of credit to firms and households). One specificity of the ECB's open market operations is that the total value of the collateral used by banks is

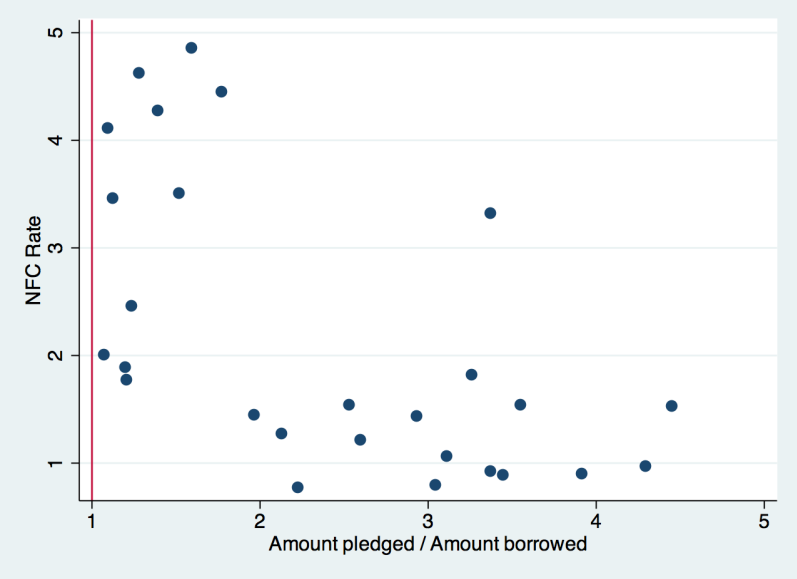


Figure 7: Interest rate on loans to non-financial corporations (NFC) and overcollateralization rate by country and quarter

The overcollateralization rate is the ratio of the amount of assets pledged to the amount borrowed and can be interpreted as a proxy for the availability of collateral. We exclude cases where the overcollateralization rate is higher than 5 and countries with less than € 4 billion of assets pledged.

generally higher than the amount borrowed, even after accounting for the valuation haircuts. As explained above, this could be due to the need of banks to use collateral for intra-day payments, or for contingency planning purposes as a credit line from the central bank.

The overcollateralization level, measured as the ratio of collateral pledged (after haircut) to the amount borrowed, can therefore provide some indication of the availability of collateral to banks: if collateral is scarce they are more likely to save on the unused collateral at the central bank. Although the aggregate, country level nature of our data prevents us from establishing definitive conclusion on the role played by collateral availability in the transmission of monetary policy, a simple scatter plot of the quarterly interest rate to non-financial corporations, aggregated at country-level, against the overcollateralization level does suggest a non-linear correlation pattern. As the overcollateralization approaches one, this indicates that more banks in the country are constrained by the availability of collateral and the interest rate to non-financial corporations in these countries tend to be higher.

Since the non-linear correlation may be driven by factors that are unrelated to the collateral policy of the central bank, it would be interesting to study a case where the central bank changed its policy and where this change did not coincide with changes in the market environment (table B in appendix B lists the main changes to the ECB's collateral policy during our sample). One change that arguably comes closest to this criteria is the March 2011 change in the eligibility of asset-backed securities (ABS) and

Table 4: Reduced-form evidence on the change in ABS eligibility requirement of March 2011

We regress the average CDS of banks for 10 countries (AT, BE, DE, ES, FR, GR, IE, IT, NL, PT), normalized to one at January 2011. The weekly observations are from January to May 2011 (17 periods). Explanatory variables: a dummy equal to one after 1 March 2011, the available collateral is measured as the ratio of assets pledged (value after haircut) to the amount borrowed, computed two years before the policy change (average ratio on 5 and 12 January 2009). We also interact these two variables. The results suggest that banks with low collateral available have a relatively higher CDS spread after the policy change.

| | (1) |
|---|---|
| | Bank CDS |
| Hi haircut (After March 2011) | -0.0629 |
| | (0.0386) |
| Available collateral | -0.0600*** |
| | (0.0122) |
| Hi haircut × collateral | -0.0281* |
| | (0.0167) |
| Constant | 1.121*** |
| | (0.0281) |
| Observations | 170 |
| $R^2$ | 0.504 |

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

the requirement that the second best rating of the ABS collateral must remain above A- regardless of the date of issuance of an ABS: the change occurred in a relatively stable market environment and had been announced several months in advance.

The change in eligibility criteria may have affected banks depending on two factors. The first factor is that banks may be constrained in their availability of collateral: if they have a high overcollateralization ratio one should not expect a change in the eligibility rules to have a large impact. A second criteria is the amount of ABS in banks' collateral pools. If banks are more reliant on ABS, they should be more affected.

To this end we divided the countries in our sample into 3 groups: group 1 includes countries with overcollateralization rate above 3, group 2 those with an overcollateralization rate below 3 but with less than 20% of ABS. Finally group 3 are the other countries with scarce collateral and more than 20% of ABS in their collateral pool. We then computed the interest rate on loans to non-financial corporations in the three months before the change versus the 3 months after the change. As predicted by models such as Koulischer (2015), we find that while the NFC rate fell by 10 basis points in group 1 and 2, the economy rate of countries in group 3 remained broadly flat on average.

We also perform reduced form regressions to illustrate potential differential effects of the change in eligibility criteria. We select a subsample starting 2 months before the eligibility change and ending 2 months later, in May 2011. We regress the average CDS spread of banks in 10 countries against a dummy equal to one after 1 March 2011, i.e. when the tighter eligibility rules come into force. To measure the availability of collateral, we compute the ratio of average assets pledged (value after haircut) to the average amount effectively borrowed before the policy change. To avoid potential endogeneity concerns regarding the decision to change the haircut, we use the overcollateralization ratio 2 years before the policy change (in the beginning of our sample), in January 2009. We then interact this variable with the policy change dummy. We also normalize the CDS spread of banks in each country to one at the beginning of the sample in January 2011.

Table 4 shows that all countries had lower CDS spreads towards the later periods and banks with more available collateral also had lower CDS spreads in general. After the policy change, we observe however that banks with larger collateral stocks experienced a larger fall in their CDS spreads. In other words, tighter collateral requirements are associated with higher CDS spreads for banks with low collateral available.

# 4 A model of collateral choice

When setting collateral policy, the central bank faces the following trade-off: on the one hand, banks must not be constrained by collateral availability in order to ensure a proper transmission of monetary policy. On the other hand, relaxing collateral policy may lower the quality of the collateral used by banks. In this section, we build a tractable model that relates the choice of collateral by banks to underlying costs and returns from the assets used as collateral. The model can be used to recover the underlying costs and benefits of using collateral from the data on collateral used by banks at the central bank. This in turn allows to quantify how a given collateral policy $(h_1, h_2, \ldots, h_n)$ (where $n$ is the number of eligible collateral) maps into a pool of collateral $(a_1, a_2, \ldots, a_n)$ pledged to the central bank and a distribution of funding costs for banks (which should feed in lending rates to firms and households).

The model allows to overcome a limitation of more reduced-form estimates of banks' collateral choice which is to recover the cross-elasticities of collateral pledged relative to policy variables such as the haircut of the central bank (e.g. how a change in the haircut on asset $j$ affects the amount of asset $k$ used as collateral). If there are many collateral types, the number of cross-elasticities to estimate can be excessively

Table 5: Bank balance sheet

| Assets | | Liabilities | |
|---|---|---|---|
| Used as central bank collateral | | Capital | $K$ |
| ... of which asset $j = 1, \ldots, n$ | $a_j$ | Private market loans | $L_p$ |
| Used to secure private market loans | | Central bank loans | $L_{cb}$ |
| ... of which asset $k = n+1, \ldots, 2n$ | $a_k$ | | |
| Total assets | $A$ | Total liabilities | $L$ |

large. For example, banks from a given country pledge on average 106 different asset types in a given week so we would have to estimate $106^2$ cross-elasticities to recover the full substitution matrix.

To address this challenge, we impose structure on the collateral choice problem of banks in order to reduce the number of parameters to estimate. This approach is similar to the one used by Koijen and Yogo (2016) who construct a model of demand for financial assets or to the models of demand for differentiated goods (Anderson et al., 1992; Berry, 1994; Verboven, 1996). In our model, banks choose among various types of collaterals and our goal is to recover the underlying costs of using each collateral type. As we will show, the haircut elasticities can be recovered from regressions of the quantities of collateral used by banks against the haircut of the central bank and various asset and borrower characteristics.

A bank has an initial amount of capital $K$ and maximizes its return on capital by investing in assets and using these assets as collateral to borrow from the central bank or the private market. The balance sheet of the bank is summarized in Table 5: the assets are used as collateral either at the central bank or in the private market, and the bank has 3 types of liabilities: capital, private market loans (or bonds) and central bank loans.

The bank has $n$ different investment opportunities (e.g. government bonds, covered bonds, ABS with different ratings or maturities). For each investment, the bank also chooses a funding source: it can either borrow from the private market or use the asset as collateral at the central bank, so it has $n \times 2$ investment-funding pairs available. We index the use of asset $i$ as central bank collateral as $i = 1, \ldots, n$ and let $i = n+1, \ldots, 2n$ refer to the use of the same assets in the private market so the bank has effectively $n$ assets to combine with 2 funding options.

For a total investment in asset $j$ of $a_j$, the bank earns the return

$$R_j(a_j) = r_j a_j - a_j \ln\left(\frac{a_j}{A}\right)$$

where $r_j$ is the return on asset $j$ and $-a_j \ln\left(\frac{a_j}{A}\right)$ is a diversification benefit. The cost of funding an

investment $a_j$ is related to the haircut by

$$\begin{aligned} C_j(a_j) &= a_j\left[(1-h_j)\,d + h_j e\right] \\ &= a_j f_j \end{aligned}$$

where $h_j$ is the haircut on asset $j$, $d$ and $e$ are the funding costs of debt and equity respectively. As in Ranaldo et al. (2016), higher haircuts are expensive for the bank if there is a positive wedge between its cost of equity and debt (as microfounded for instance by Dewatripont and Tirole (2012)). Since high haircuts limit the amount of debt financing that can be used to fund an investment, higher haircuts also increase the funding cost.

The profit of the bank is given by

$$\begin{aligned} \Pi(a_1,\ldots,a_{2n}) &= R_j(a_j) - C_j(a_j) \\ &= \sum_{j=1}^{2n}\left(r_j a_j - a_j \ln\left(\frac{a_j}{A}\right) - a_j f_j\right) \qquad (1) \\ &= \sum_{j=1}^{2n}\delta_j a_j - a_j \ln\left(\frac{a_j}{A}\right) \end{aligned}$$

where $\delta_j$ is the linear net return of the bank from investing in asset $j$ and $-a_j \ln\left(\frac{a_j}{A}\right)$ is the concave component of the profit function.

The bank is subject to an aggregate leverage constraint $\mathscr{L}$ so that the total size of its balance sheet has to be below a multiple of its available capital ($A < \mathscr{L}K$). This constraint could arise for instance from regulatory requirements such as capital requirements. A leverage constraint could also arise in the presence of information asymmetries which require the bank to have sufficient skin in the game (Holmström and Tirole, 2011; Koulischer and Struyven, 2014) or if private financiers have Value-at-Risk constraints (Brunnermeier and Pedersen, 2009).[9]

Letting $\mathscr{L}$ denote the leverage constraint of the bank, the total assets and liabilities of the bank in Table 5 must satisfy

$$\sum_{j=1}^{2n} a_j \leq \mathscr{L} \times K = A.$$

The leverage constraint $\mathscr{L}$ together with the level of bank capital $K$ determine the size of the balance

[9] In Brunnermeier and Pedersen (2009), margin requirements are set at the asset level. In practice, both asset level and bank level leverage constraints may be at play but we focus here on the bank level constraints.

sheet of the bank $A = \sum_{j=1}^{2n} a_j$. For now we treat the leverage and capital parameters as exogenous and focus on the allocation of the funds by the bank to compose the collateral portfolio.

The Lagrangian of the problem faced by the bank is

$$L = \sum_{j=1}^{2n} \left( \delta_j a_j - a_j \ln \left( \frac{a_j}{A} \right) \right) + \lambda \left( \sum_{j=1}^{2n} a_j - A \right).$$

The investment in option $j$ and its use as collateral is determined by

$$\Pi'_j = R'_j \left( a_j \right) - C'_j \left( a_j \right) = \lambda \ \forall j \tag{2}$$

If the capital constraint is slack, the bank equalizes the (constant) marginal net return of using collateral with its marginal cost. When the capital constraint binds, the Lagrangian multiplier $\lambda$ can be interpreted as the price that the bank is willing to pay to relax its total balance sheet size constraint by one unit.

The FOCs yield:

$$\frac{\partial L}{\partial a_j} : \ \delta_j - \ln \left( \frac{a_j}{A} \right) - 1 + \lambda = 0 \tag{3}$$

and

$$\frac{\partial L}{\partial \lambda} : \ \sum_{j=1}^{2n} a_j - A = 0.$$

Equation (3) can be rewritten as

$$\frac{a_j}{A} = \exp \left( \delta_j \right) \exp \left( -1 + \lambda \right).$$

Summing over the set of available options:

$$1 = \exp \left( -1 + \lambda \right) \sum_{j=1}^{2n} \exp \left( \delta_j \right).$$

Plugging this in equation (3) and rearranging, we obtain:

$$\frac{a_j}{A} = \frac{\exp \left( \delta_j \right)}{\sum_{j=1}^{2n} \exp \left( \delta_k \right)}, \tag{4}$$

so the share of capital allocated to option $j$ takes the standard logit form (Anderson et al., 1992). All else

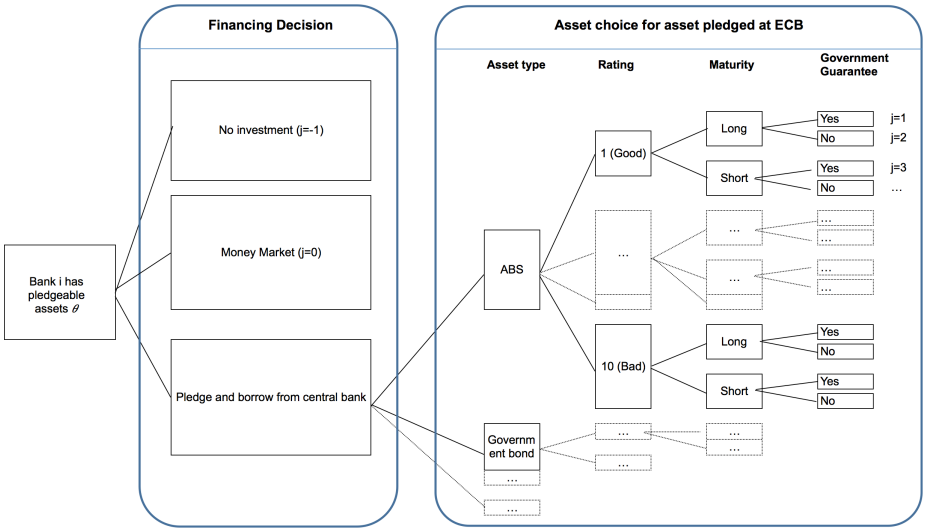


Figure 8: Collateral choice problem faced by borrowing banks

equal, an increase in the net return on capital from option $j$ will lead to a higher share of capital allocated to that investment and less capital allocated to the other options.

## 4.1 Comparative statics

Suppose that the net return is a function of observable and unobservable asset and bank characteristics as:

$$\delta_j = \beta_0 h_j + \beta_1 X_j + \epsilon_j. \tag{5}$$

where $h_j$ is the haircut of the central bank and $X_j$ and $\epsilon_j$ are observable and unobservable asset and bank characteristics. One of our objectives is to estimate how changes in the haircut of the central bank affect the composition of the collateral pool and the share of capital allocated to each option, $s_j = a_j/A$. The sensitivity of the capital use (which determines the amount of collateral used) to changes in the haircut can be computed from equations (5) and (4) as:

$$\frac{\partial s_j}{\partial h_j} = \beta_0 s_j \left(1 - s_j\right). \tag{6}$$

The sensitivity of the use of collateral $j$ to changes in the haircut of another collateral $k \neq j$ is the cross-haircut elasticity:

$$\frac{\partial s_j}{\partial h_k} = -\beta_0 s_j s_k. \tag{7}$$

An increase in the haircut on collateral $j$ will therefore lead to less use of collateral $j$ at the central bank and more use of other categories of collateral (including private market funding).

*Funding costs.* The cross-elasticities in equations (6) and (7) focus on the effect of the haircut on the quantities of collateral pledged to the central bank. Another potential question is whether we can use the model and our data to assess how changes in haircut affect the funding cost of banks.

In our model, the share of capital allocated to private market funding is

$$\sum_{j=n+1}^{2n} \frac{a_j}{A} = \frac{\sum_{j=n+1}^{2n} \exp\left(\delta_j\right)}{\sum_{j=1}^{2n} \exp\left(\delta_k\right)}.$$

Let $\delta_p = \log\left(\sum_{j=n+1}^{2n} \exp\left(\delta_j\right)\right)$ denote the aggregate attractiveness of private market funding and $a_p = \sum_{j=n+1}^{2n} a_j$ the collateral used in the private market. We have

$$\log\left(\frac{a_j}{a_p}\right) = \delta_j - \delta_p. \tag{8}$$

The log-ratio of the collateral used by the bank for pledging collateral $j$ to the central bank relative to the collateral used in the private market can be used to recover the benefit of option $j$ relative to the private market funding option (as in a logit model).

This suggests that the use of collateral by banks could be used to construct a proxy of funding conditions in private markets. The objective is thus to recover the marginal benefits of each option $\delta_j$ from the amounts pledged to the central bank to quantify to what extent changes in haircut could affect, for instance, the average marginal funding cost of banks $\sum_{j=0}^{n} \delta_j \times a_j/A$. One challenge however is that our model only identifies the benefit of each option relative to the benefit of going to the private market, $\delta_j - \delta_p$. This measure is scale free so that only differences in benefit influence the allocation of collateral.

A solution to quantify the role of the haircut in influencing funding costs is to make assumptions on the evolution of funding costs to allow comparisons across time or countries. A first assumption is that the average marginal cost (or benefit) of borrowing from the central bank stayed constant throughout our sample period, since the policy rate remained broadly unchanged over that period. This assumption allows to recover changes in funding cost in the private market, through changes in $\delta_p$.

Assume that $\frac{1}{n}\sum_{j=1}^{n} \delta_{jct} = K \ \forall t$. This implies that, for country $c$ at time $t$,

$$\frac{1}{n}\sum_{j=1}^{n} \log\left(\frac{a_{jct}}{a_{pct}}\right) = K - \delta_{pct}, \tag{9}$$

so we are able to track the spread in the benefit between two countries $c$ and $k$ over time as:

$$-\delta_{pct} + \delta_{pkt} = \frac{1}{n}\sum_{j=1}^{n} \log\left(\frac{a_{jct}}{a_{pct}}\right) - \frac{1}{n}\sum_{j=1}^{n} \log\left(\frac{a_{jkt}}{a_{pkt}}\right).$$

For a given haircut coefficient $\beta_0$ in equation (5) and a haircut change $\Delta h_j$, we can compute the change in the benefit of option $j$ relative to the private market as $\beta_0 \Delta h_{jt}$. If the cost on the private market is unaffected by the haircut change, $\beta_0 \Delta h_{jt}$ can be interpreted as the net change in benefit of using collateral $j$ at the central bank.

To compare it to private market funding, we compute the net change in the benefit of using private funding as

$$\Delta\delta_{pct} = \frac{1}{n}\sum \log\left(\frac{a_{jct}}{a_{pct}}\right) - \frac{1}{n}\sum \log\left(\frac{a_{jc1}}{a_{pc1}}\right),$$

i.e. we compute the change in the average private funding cost with respect to that of the first period, where $a_{jc1}$ is the amount of asset $j$ pledged in period 1. Using (9) we can rewrite the last equation as

$$\Delta\delta_{pct} = -\delta_{pct} + \delta_{pc1}.$$

By comparing the effect of the haircut $\beta_0 \Delta h_{jt}$ to changes in private funding cost $\Delta\delta_{pct}$, we may obtain some idea of how different haircut policies might have influenced the spread across country groups. To take into account the weight of the different funding sources in the overall funding profiles of banks, we compute the weighted counterfactual change in funding cost due to changes in private market and in the central bank haircut for each country group as:

$$Cost_{ct} = w_{pct}\Delta\delta_{pct} + \sum_{j=1}^{n} w_{jct}\beta_0 \Delta h_j \tag{10}$$

where $w_{jct} = a_{jct} / \left(\sum_{k=0}^{n} a_{kct}\right)$ is the weight of funding source $j$ in the bank's total funding.

# 5 Estimation

## 5.1 Estimating the model

The key prediction of our model is that the share of collateral $j$ takes the logit form in (4):

$$\frac{a_j}{A} = \frac{\exp(\delta_j)}{\sum_{j=1}^{2n} \exp(\delta_k)}.$$

All else equal, an increase in the net return on capital from option $j$ will lead to a higher share of capital allocated to that investment and less capital allocated to the other options.

The model states a direct relationship between the quantities of collateral pledged and the underlying costs and benefits in (8):

$$\log\left(\frac{a_{jct}}{a_{pct}}\right) = \delta_{jct} - \delta_{pct}.$$

The underlying cost of using collateral $j$ at the central bank can therefore be recovered from regressions of the capital share of each option against asset characteristics. Figure 8 summarizes the reduced form problem of the bank when all private options are grouped together.

## 5.2 Identification

For each country $c$, week $t$ and asset $j$, we observe the amount of collateral pledged to the central bank $a_{jct}$, the associated haircut at time $t$, $h_{jt}$ and the amount borrowed in the private market $L_{pct}$.[10] Since we do not have data on the use of collateral in the private market, we take the amount borrowed as a proxy for the collateral used.

As in equation (8), we recover the relative benefit of using collateral $j$ against the private option through the following linear regression:

$$\log\left(\frac{a_{jct}}{a_{pct}}\right) = \beta_0 h_j + \beta_1 X_{jct} + \epsilon_{jct}, \tag{11}$$

where $X_{jct}$ includes the price of the collateral (to account for mechanical valuation effects) and other country, time and asset observable characteristics. Since the haircut is the same for all banks in the euro area and the collateral policy of the ECB remained broadly unchanged during our sample period, the main

[10] We use the interbank market dependence ratio (in % of assets) from the ECB's statistical datawarehouse to measure money market borrowing. Since this series is available at a monthly frequency, we use the same value of interbank borrowing for all weeks in a given month.

source of variation we use are differences in haircuts across assets. As shown in Table 1, haircuts can vary from 0.5% in the case of short term government debt to 39.5% for long term government debt.

Since the main source of variation is in the cross-section of assets, a key concern for the identification of $\beta_0$ is that the haircut $h_j$ may be a function of unobserved asset characteristics $\epsilon_{jct}$. If assets with a higher haircut are also assets with a lower liquidity, the decision of banks to pledge collateral with higher haircut may be related to unobserved asset characteristics so the haircut coefficient capture both the effect of the haircut and that of the unobserved liquidity. Suppose for instance that our data only includes two assets: liquid government debt with low haircut and illiquid ABS with high haircut. By regressing the amount of collateral pledged against the haircut, the recovered coefficient $\hat{\beta}_0$ will be biased upwards: since less liquid assets are hard to use in the private market, they are more likely to be pledged to the central bank so $\hat{\beta}_0$ will capture both the effect of the higher haircut and that of tighter private market conditions.

To account for this it is important to understand how haircuts are determined in the private market. To this end, we collected data on haircut schedules on government debt applied by LCH Clearnet S.A., a major repo platform in Europe (Boissel et al., 2014). Table 6 shows the haircuts applied to some euro area government debts. The main difference between the haircut schedule in the private market and that of the central bank in Table 1 is that the former discriminates more finely among sovereigns of different credit ratings. For example, the government debt of Belgium and Germany have the same haircut at the ECB while the private market applies a higher haircut to the lower-rated Belgian debt. The same holds for debt in the second rating bucket, as illustrated by differences in the haircut on Italian and Portuguese debt.

Based on the private market haircut schedule of Table 6, we construct a proxy of the private market haircut (appendix D). Once we control for the private market haircut, the identification is driven by deviations of the central bank haircut from the private market haircut. The main source of variation in differential haircut is a consequence of the fact that the central bank uses a coarse haircut grid, and we will more specifically focus on the differences in haircut increases across maturities for different ratings.

Consider the following example of four assets with two ratings (AAA or A-) and two maturities (long or short). The two ratings belong to the same "rating bucket" for the central bank, but longer dated assets have a higher central bank haircut. The private market instead takes both maturity and rating into account to set the haircut. In particular, higher dated assets with a lower rating face a steeper increase in haircut in the private market than at the central bank. By controlling for both central bank and private

Table 6: Private market haircut levels. (Source: LCH Clearnet S.A. - Margin Collateral Haircut Schedule).

| Residual Maturity (years) | Haircut in % by asset type (*) | | | |
|---|---|---|---|---|
| | Gov bond rated AAA (DE) | Gov bond rated AA- (BE) | Gov bond rated BBB (IT) | Gov bond rated BB+ (PT) |
| 0-1 | 0.5 | 1.0 | 8.5 | 30 |
| 1-3 | 1 | 2.5 | 10.75 | 39.5 |
| 3-5 | 1.75 | 3.5 | 12.75 | 42 |
| 5-7 | 2.5 | 4.5 | 14.5 | 43 |
| 7-10 | 3.25 | 5.5 | 15.25 | 43 |
| 10-15 | 5 | 7.5 | 16.5 | 43 |
| 15-30 | 13 | 16.5 | 24 | 43.25 |

market haircut, the identification will arise from the non-linearity of the haircut schedule.[11] In other words, the analysis consists of comparing the share of short versus long term assets pledged for each rating. The identification assumption is thus that the haircut schedule in the private market is non-linearly decreasing function of the asset's credit rating.

To allow for the fact that our proxy for private market haircut may be imprecisely constructed (see appendix D), we saturate the regression with asset type fixed effects, we control for the asset rating and interactions between the private market haircut and the asset types. which allow to flexibly capture other variation in the private market haircut. We also control for time and country characteristics, exploring various specifications including a regression with country-time interaction effects.

### 5.3 Results

Table 7 shows the regression results. We consider four specifications. The first specification only controls for asset characteristics. We include the proxy for private haircut, the interaction between the private haircut and the rating, whether the asset is guaranteed or not by a government. We also include the price of the collateral, asset type fixed effects and interaction between asset types and the private market haircut. The second regression adds country characteristics, including the credit rating of the sovereign of the home country, the yield on 2 year sovereign debt, an interaction term between the government guarantee and the rating of the sovereign as well as country fixed effects. The third specification adds time fixed effects while the final one includes country-time as well as country-asset type interaction effects (we then drop variables varying at the country-time level such as sovereign yield and rating).

[11] This identification strategy is similar that of Koijen and Yogo (2015) who use difference between the regulatory and the private market discount factors combined with different time horizons of products to identify the cost of capital requirements for life insurers.

Table 7: Determinants of bank's collateral choice

The dependent variable $a_{jct}$ is the value of collateral $j$ pledged by banks from country $c$ at time $t$. $a_{pct}$ is the total amount borrowed in the private funding market (cf. equation (11)).

| | (1) $log(a_{jct}/a_{pct})$ | (2) $log(a_{jct}/a_{pct})$ | (3) $log(a_{jct}/a_{pct})$ | (4) $log(a_{jct}/a_{pct})$ |
|---|---|---|---|---|
| Haircut | -1.933*** | -2.371*** | -2.180*** | -2.194*** |
| | (0.424) | (0.417) | (0.419) | (0.413) |
| Rating | 0.0522*** | 0.0815*** | 0.0800*** | 0.0758*** |
| | (0.00699) | (0.00707) | (0.00711) | (0.00684) |
| Private haircut | -0.149*** | -0.143*** | -0.144*** | -0.158*** |
| | (0.00591) | (0.00593) | (0.00596) | (0.00573) |
| Priv. Hct. x rating | 0.00492*** | 0.00450*** | 0.00451*** | 0.00503*** |
| | (0.000243) | (0.000239) | (0.000239) | (0.000236) |
| Gov guarantee | -2.140*** | 1.419*** | 1.415*** | 2.145*** |
| | (0.0298) | (0.187) | (0.187) | (0.192) |
| Price | -0.388*** | 0.224* | 0.184 | -0.138 |
| | (0.126) | (0.127) | (0.129) | (0.132) |
| Sovereign rating | | -0.0416*** | -0.0759*** | |
| | | (0.0153) | (0.0165) | |
| Guarantee x rating interaction | | -0.195*** | -0.193*** | -0.238*** |
| | | (0.0101) | (0.0101) | (0.0103) |
| Sovereign yield | | -0.0316*** | -0.0348*** | |
| | | (0.00947) | (0.0101) | |
| Asset Class | Yes | Yes | Yes | Yes |
| Priv. hct. x asset | Yes | Yes | Yes | Yes |
| Country | No | Yes | Yes | Yes |
| Time | No | No | Yes | Yes |
| Time x country | No | No | No | Yes |
| Country x asset | No | No | No | Yes |
| Observations | 128589 | 128589 | 128589 | 128589 |
| $R^2$ | 0.184 | 0.217 | 0.218 | 0.252 |

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

The haircut coefficient is negative and remains statistically significant in all specifications, with broadly stable coefficients ranging from -1.933 to -2.371. The coefficient for our preferred specification with all control variables (4) is -2.194. The sign of the haircut coefficient is negative in all specifications which suggests, in line with intuition, that higher haircuts are associated with lower amounts of collateral pledged relative to the private market amounts.

When we do not control for country characteristics in column 1, we find that providing a government guarantee to an asset increases the likelihood of the bank using it in the private market. In columns 2-4, we decompose this effect by introducing an interaction term with the rating of the government providing the guarantee. The higher the rating, the more likely it is that the asset will be used as collateral in the private market so that government guarantees increase the likelihood of being used as collateral, but not if the guarantee is provided by highly rated governments (in our case ratings range from 20 for AAA to 0 for CC). Consider for example a government with a AAA credit rating (rating=20). If the government provides a guarantee on an asset we see in specifications (2) and (3) that the net relationship varies with the rating of the government. In the case of a rating equal to 20, the final combined role of the guarantee, the sovereign rating and the interaction is negative, i.e. the asset is more likely to be used in the private market. However if the government providing the guarantee has a low rating, for instance lower than 8 (BBB+), the asset is more likely to be pledged to the central bank. We also include the sovereign rating however this term becomes redundant in the fourth column since it is captured by the country-time interaction effects.

### 5.4 Robustness and alternative specifications

The baseline results provide an estimate of the average effect of the haircut. In Table 8, we first explore how the coefficient estimates vary across countries. In line with the stylized evidence on the role of collateral availability constraints, we estimate the model on two samples. In specification (1), we restrict the analysis to country-dates with a slack collateral constraint, defined as before as countries where the value of collateral pledged is more than three times larger than the amount borrowed. In specification (2) we only include collateral constrained banks with a collateral ratio lower than 3. We find that collateral constrained banks are less sensitive to changes in haircut. One reason for this could be that they have less room for arbitraging between differences in haircuts in the private and public markets: if they pledge all that is available to the central bank and have limited access to the private market, the collateral pledged is less sensitive to haircut changes.

In specification (3), we explore to what extent the results are robust to various specification of the rating-maturity haircut premium in the private market, by including a rating-maturity interaction term. The haircut coefficient remains broadly similar to our baseline estimate. Finally, in specification (4) we explore to what extent the baseline results could be driven by country outliers. Since large countries such as Germany are assigned the same weight as relatively smaller countries, one could be concerned that the regressions place an excessive weight on smaller countries. To address this concern beyond the country and country-time fixed effects included in the baseline, we collapse our sample to a single country: the euro area. The estimates in specification (4) are somewhat lower than the baseline but broadly similar in magnitude.

More generally, the robustness analysis underscores that the baseline result should primarily be interpreted as an average effect of the haircut across countries and asset types. In practice, finer measures could be obtained depending on the object of interest for policy making, for example by restricting the sample to specific counterparties or asset classes.

# 6 Policy counterfactuals

## 6.1 Impact of a 5% haircut increase by asset type

The regression results of table 7 can be used to compute the elasticities of collateral pledged to the haircut of the central bank that we derived in the empirical model (equations (6) and (7)). Table 9 shows the changes in the collateral pool of the ECB that would arise if the haircut on all assets from an asset class (e.g.. all covered bonds) were to increase by 5%. The first column is the average share of collateral pledged as % of banks' short term funding over our sample period. For example, the value before haircut of government bonds pledged to the ECB represents 3.96% of the interbank exposure of banks in the euro area and the total amount of collateral pledged to the central bank represents 27.42% of the total interbank exposure(=1-72.58%). ABSs are the largest asset class with 8.56% of the total. The next columns show the impact of increasing the haircut by 5% on all assets belonging to an asset class. The second column for instance shows that a 5% increase in the haircut on government bonds would trigger an absolute fall of 0.42% of government bonds, from 3.96% initially. The bulk of these assets would be substituted by increases in other collateral pledged, especially in the private market which would experience a 0.32% points increase in its share. The last two rows in table 9 provide the relative changes in collateral use induced by the haircut change. For government bonds for instance, the amount of government bonds

Table 8: Robustness tests and alternative specifications

The dependent variable $a_{jct}$ is the value of collateral $j$ pledged by banks from country $c$ at time $t$ $a_{pct}$ is the total amount borrowed in the private funding market (cf. equation (11)). (1) Sample = High collateral availability country-dates. (2) Sample = collateral constrained country-dates. (3) Robustness of private market haircut specification by including rating-maturity interaction term. (4) Robustness of results to a collapse of the sample across countries.

| | (1) $log(a_{jct}/a_{pct})$ | (2) $log(a_{jct}/a_{pct})$ | (3) $log(a_{jct}/a_{pct})$ | (4) $log(a_{jct}/a_{pct})$ |
|---|---|---|---|---|
| Haircut | -3.368*** | -1.956*** | -2.174*** | -3.056*** |
| | (0.535) | (0.604) | (0.413) | (0.803) |
| Rating | 0.218*** | -0.0317*** | 0.143*** | 0.225*** |
| | (0.00886) | (0.00994) | (0.0123) | (0.0136) |
| Private haircut | -0.125*** | -0.181*** | -0.120*** | -0.155*** |
| | (0.00737) | (0.00837) | (0.00822) | (0.0115) |
| Priv. Hct. x rating | 0.00292*** | 0.00667*** | 0.00502*** | 0.00240*** |
| | (0.000305) | (0.000344) | (0.000236) | (0.000484) |
| Gov guarantee | 4.843*** | 2.911*** | 2.143*** | -2.426*** |
| | (1.209) | (0.227) | (0.191) | (0.0553) |
| Guarantee x rating | -0.355*** | -0.301*** | -0.238*** | |
| | (0.0612) | (0.0130) | (0.0103) | |
| price | 1.289*** | -1.057*** | -0.175 | |
| | (0.177) | (0.188) | (0.132) | |
| Maturity x rating | | | -0.0347*** | |
| | | | (0.00528) | |
| Asset Class | Yes | Yes | Yes | Yes |
| Priv. hct. x asset | Yes | Yes | Yes | Yes |
| Country | Yes | Yes | Yes | No |
| Time | Yes | Yes | Yes | Yes |
| Time x country | Yes | No | Yes | No |
| Country x asset | Yes | Yes | Yes | No |
| Observations | 56238 | 72351 | 128589 | 19586 |
| $R^2$ | 0.284 | 0.250 | 0.252 | 0.286 |

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 9: Impact of a 5 % points increase in haircut by asset class

This table shows how a haircut change on all assets of a specific class would affect the collateral pledged to the Eurosystem (as a share of the interbank exposure). The first column is the collateral effectively pledged, and each column then shows the net change in share of the collateral pool induced by the new haircut.

| | | Impact of 5% haircut increase of | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial share | Gov | ABS | Pfand | Uncov | Corporate | Reg | Jumbos |
| Government | 0.0396 | -0.0042 | 0.0004 | 0.0002 | 0.0003 | 0.0001 | 0.0001 | 0.0000 |
| ABS | 0.0856 | 0.0004 | -0.0086 | 0.0003 | 0.0007 | 0.0001 | 0.0001 | 0.0001 |
| Pfandbriefe | 0.0358 | 0.0002 | 0.0003 | -0.0038 | 0.0003 | 0.0001 | 0.0000 | 0.0000 |
| Uncovered | 0.0767 | 0.0003 | 0.0007 | 0.0003 | -0.0078 | 0.0001 | 0.0001 | 0.0001 |
| Corporate | 0.0152 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | -0.0016 | 0.0000 | 0.0000 |
| Regional G | 0.0123 | 0.0001 | 0.0001 | 0.0000 | 0.0001 | 0.0000 | -0.0013 | 0.0000 |
| Jumbo | 0.0090 | 0.0000 | 0.0001 | 0.0000 | 0.0001 | 0.0000 | 0.0000 | -0.0010 |
| Private market | 0.7258 | 0.0032 | 0.0068 | 0.0029 | 0.0061 | 0.0012 | 0.0010 | 0.0007 |
| Own-haircut effect | | -10.5 % | -10 % | -10.6 % | -10.1 % | -10.8 % | -10.8 % | -10.9 % |
| Cross-haircut effect | | 0.4 % | 0.9 % | 0.4 % | 0.8 % | 0.2 % | 0.1 % | 0.1 % |

would fall by 10.5% (=0.42%/3.96%). Other types of collateral would increase by 0.4%, where all assets face the same relative change as a consequence of the functional form assumption in our empirical model.

To get a sense of the magnitudes involved, the average short term interbank funding of banks in our sample is €5 trillion, our figures therefore suggest that roughly €16bn worth of collateral would migrate to the private market if the haircut on all government debt was to increase by 5%.

As a further control of our results, we explored to what extent the counterfactual changes are consistent with the change in collateral used by banks after the haircut on ABS increased in January 2011 from 12% to 16%. We find that the average total amount of ABS pledged in the 2 months after the change fell by 6% relative to the amount pledged in the two months preceding the change. This fall is of the same order of magnitude as the prediction of our model (-8%). However, the analysis also highlights richer substitution patterns across asset types than suggested by our model. The use of covered bonds, which are relatively close substitutes for ABS, increased over the sample period while the use of other collateral fell. The analysis also suggests that substitution to the private market was limited (as could be expected since the use of ABS as collateral in the private market is rare). This underlines the importance of understanding the results as average effects, where future iterations of this model could include richer substitution patterns as well as predictions on the total amount of collateral pledged.

### 6.2 Impact of a 5% haircut increase on low rated assets

We showed in section 2 the existence of a "home bias" in the European banking sector where banks are more exposed to the government debt of their home country. Banks are therefore more likely to use assets from their own country as collateral. Since the government credit ratings strongly diverged during the

Table 10: Impact of a 5% haircut increase on low rated government debt

Low rated debt: credit rating below A or collateral with a government guarantee. Countries are divided into two groups. *High yield countries* include Spain, Greece, Ireland, Italy, Portugal and *Low yield countries* are Austria, Belgium, Germany, France and the Netherlands. Columns 1 and 4 *(Initial Share)* show the amount of collateral pledged to the ECB by asset type, as a proportion of their total short-term funding. Government bonds are divided in two categories: above and below A. Columns 2,3 and 5,6 show the impact of the haircut increase in *absolute* and in *relative* (percentage) terms (resp. col 2,5 and 3,6).

| | Impact on low yield countries | | | Impact on high yield countries | | |
|---|---|---|---|---|---|---|
| Asset | Initial share | Absolute | Relative | Initial share | Absolute | Relative |
| Gov. above A- | 2.09% | 0.00% | 0.11% | 3.96% | 0.02% | 0.57% |
| Gov. below A- | 1.01% | -0.11% | -10.86% | 5.23% | -0.54% | -10.40% |
| ABS | 6.10% | 0.01% | 0.11% | 12.81% | 0.07% | 0.57% |
| Pfandbriefe | 3.23% | 0.00% | 0.11% | 6.92% | 0.04% | 0.57% |
| Uncovered bank b | 4.97% | 0.01% | 0.11% | 6.53% | 0.04% | 0.57% |
| Corporate bonds | 0.57% | 0.00% | 0.11% | 2.35% | 0.01% | 0.57% |
| Regional governm | 1.76% | 0.00% | 0.11% | 0.72% | 0.00% | 0.57% |
| Jumbos | 0.77% | 0.00% | 0.11% | 0.49% | 0.00% | 0.57% |
| Total central bank | 20.50% | -0.09% | -0.43% | 39.01% | -0.35% | -0.90% |

sovereign debt crisis (figure 2), a natural question is to what extent changes in haircuts on assets of specific rating categories would differentially affect banks in the euro area.

In this subsection, we compute the counterfactual impact that a stricter collateral policy would have had on banks' collateral pools. We consider the case of a 5% haircut increase on government debt rated below A or with a government guarantee (which we call "low rated bonds"). We divide countries in two groups. High-yield countries includes countries whose yield on 2 year government bonds was above 4% at least once during our sample period (Spain, Greece, Ireland, Italy and Portugal). Low yield countries in our sample include Austria, Belgium, Germany, France and the Netherlands. Table 10 shows the initial shares of assets for each country group and the predicted impact of the haircut change in absolute and relative terms. Banks from high-yield countries use a higher proportion of low-rated government debt as collateral, which account for 5.23% of their total short term funding versus 1.01% for low-yield countries. They are therefore the most affected by the haircut change, which would trigger a larger substitution to other asset types and private market funding for high yield countries.

### 6.3 Private market haircut on high yield government debt

Our analysis has focused on how haircut changes affect the quantities of assets pledged to the central bank and banks' use of private market funding. Our model can also be used to shed light on the opportunity cost for banks of using collateral in the private market. The intuition is that, for unchanged conditions at the central bank, an increase in the use of one type of collateral by banks suggests that these assets have

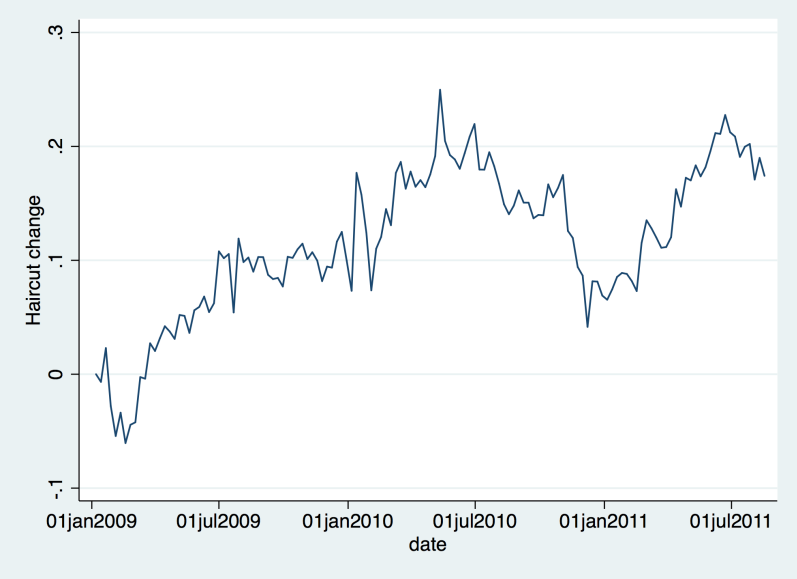


Figure 9: Required haircut increase on government debt of high yield countries
This figure shows the estimated additional haircut that the ECB should have imposed on government debt from high yield countries to prevent a substitution of these assets from the private market to the central bank.

become relatively more expensive to use at the central bank.

For example, a relative shift of high yield government debt from private markets to the ECB occurred during the sovereign debt crisis. In this subsection, we use our model to compute the increase in haircut on high yield government debt that would have been required to keep the share of that asset class constant throughout the sample period. This haircut can be interpreted as a proxy for the haircut prevailing in private markets for these assets.

Figure 9 shows the additional haircut that the ECB should have imposed on government debt of high yield countries to keep the benefit of banks from using this asset as collateral constant over time. The additional haircut would have reached 25% in mid-2010 and 2011, illustrates the fact that refinancing conditions in private markets for this asset class significantly worsened during the sovereign debt crisis. This figure seems broadly in line with observed market changes: LCH clearnet for instance increased the haircut on Italian and Spanish debt by 5 percentage points in 2011, while the debt of more stressed (but smaller) countries like Greece became ineligible as collateral in the private market.

### 6.4 Counterfactual funding costs

We explained in subsection 4.1 how the collateral use by banks could be used to construct a proxy of funding of banks. Figure 10 plots the spread in the private funding cost for the two country blocks (high

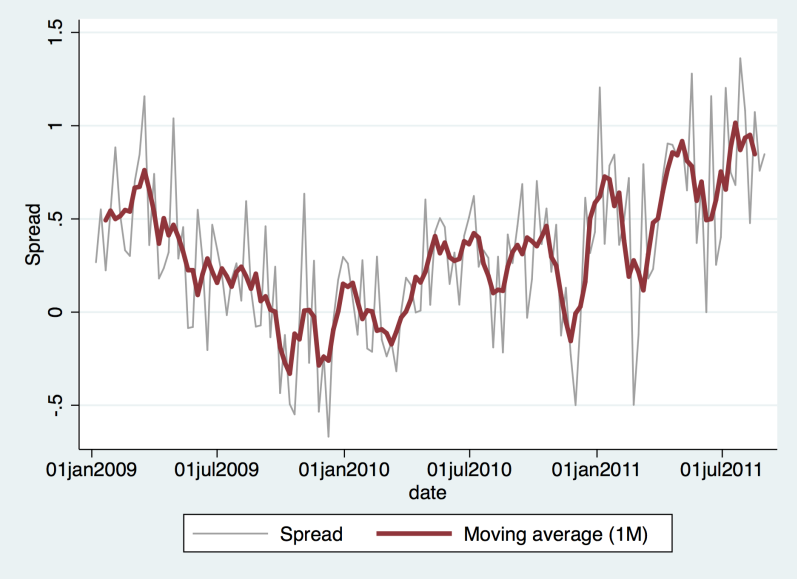


Figure 10: Spread of recovered funding cost in the private market between high and low yield countries
The moving average corresponds to the 5 week moving average of the spread. High yield countries include Spain, Greece, Ireland, Italy, Portugal and low yield countries are Austria, Belgium, Germany, France and the Netherlands.

yield and low yield countries) of equation (9).[12] Since the weekly measure is somewhat volatile, we also include the 5-week moving average. According to the counterfactual, the difference in the ease of access of high-yield versus low-yield countries improved in 2009. The trend however reversed in early 2010 so the spread reached unprecedented levels by the end of our sample period in July 2011.

The recovered funding costs may be used to compare the access of banks to the money market across countries. Figure 11 shows the difference in funding costs $Cost_{ct}$ between high-yield and low-yield countries under two scenarios. The costs for each country group are computed as in equation (10) of subsection 4.1. The baseline scenario corresponds to no change in haircut. The "high haircut" scenario shows the spread if the haircut on low-rated assets with a rating strictly below $A$ would have been 30% points higher.

The figure suggests that such a haircut increase would initially have had only a modest effect on the spread. The reason is that at the time low-rated securities represented only a relatively small proportion of the collateral used by banks (although high yield banks already used a larger proportion of this debt at the time, as suggested by Figure 13 in appendix). However over time high yield banks increased their use of low rated collateral, so a high haircut on these assets would have had a larger effect on these countries. In terms of magnitudes, the average spread is 0.16 on average over our sample period, versus 0.20 in the high haircut scenario, so that the counterfactual spread would have been 25% higher under the high haircut scenario.

[12] Funding cost here refers to the opposite of the benefit $\delta_{jct}$.

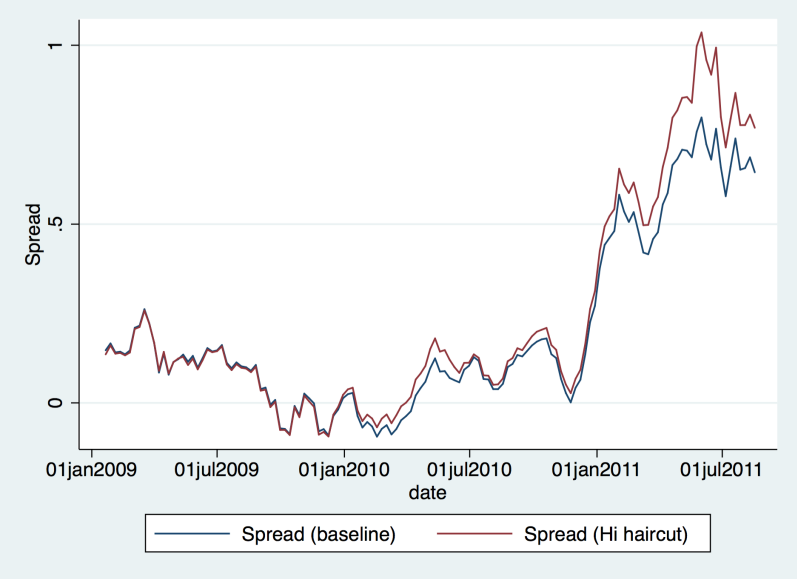


Figure 11: Difference in weighted funding cost of high- and low-yield countries under a baseline (unchanged) haircut policy and a high haircut policy (+30 p.p. haircut increase on low rated collateral (<A))

# 7 Conclusion

We build a model of collateral choice by banks that can be used to assess how changes in the collateral policy of the central bank affects the type of collateral used by banks as well as potential effects on the transmission of the monetary policy to the interbank market. These two applications of our model reflect two key concerns faced by central banks when designing their collateral framework. On the one hand, the collateral rules must be flexible enough to ensure that they do not interfere with the transmission of the monetary policy. On the other hand, the collateral policy should ensure that the collateral used by banks consists of high quality assets to limit the exposure of the central bank to its counterparties.

We use data on collateral pledged by banks to the European Central Bank from 2009 to 2011 to estimate our model. As we show in section 2, this period coincides with several downgrades in the credit rating of the government debt of some euro area members. The European banking system exhibits a significant home bias, with an average exposure to the domestic government of 50% of the total sovereign exposure. The downgrades, together with increased yields on bank and government debt in the downgraded countries, underlined the two key concerns of the design of collateral policy. The value of the collateral pledged by high yield countries for example fell by 15% over our sample period, while that of low yield countries increased by 5%. Since collateral is valued at market prices, this illustrates how lower asset values in some regions may have reduced the ability of banks to borrow from the central bank. On the other hand, the downgrades also created a possibility of lowering the quality of the collateral pool of the European Central

Bank which further underscores the potential interest of an empirical model.

In our model, a bank has an initial level of capital and faces a leverage constraint that determines the size of its balance sheet. This constraint could be the consequence of a moral hazard problem (Holmström and Tirole, 2011) or of value-at-risk constraints faced by the financiers of the bank (Brunnermeier and Pedersen, 2009). The bank has several investment opportunities and simultaneously chooses its assets as well as a funding source where we distinguish the private market and the central bank as two funding options. If the bank chooses the central bank, the asset is then used as collateral to secure the loan. The bank therefore has $n + 1$ funding - investment options: the private market or the central bank using one of the $n$ collateral types observed in our sample.

The bank constructs its collateral portfolio in order to maximize its profit. We show that when the profit of the bank combines a constant marginal cost and an exponential and convex cost component, the underlying benefit of each option relative to the private market can be recovered from the collateral effectively pledged by banks to the central bank. We then regress the recovered benefit against asset and country characteristics. One variable that is of particular interest is the haircut of the central bank, which is set in function of observable asset characteristics. We isolate the role of the haircut by including several asset characteristics to account for asset liquidity. Our controls include the asset type, dummies for each rating category, the maturity of the asset and the interaction between maturity and asset type.

We then use the estimated coefficient to compute several policy counterfactuals. (1) We assess how a 5% increase in all collateral belonging to a specific asset class (e.g. government bonds or ABS) would affect the type of collateral used at the central bank. Our results suggests that this would reduce the use of the asset class with higher haircut by around 10%. (2) We then estimate how the collateral pool of country groups would be affected by an increase in the haircut on government debt with a credit rating below A. As high yield countries (Spain, Greece, Ireland, Italy, Portugal) use a larger amount of these assets as collateral, they would also be more affected. (3) We compute the counterfactual haircut increase that would have been required on low rated government debt to keep the share of this type of collateral constant over the sample. We find that the required haircut add-on would have reached 25% in the summers of 2010 and 2011. (4) We compare the access to the private market of banks in high yield and low yield countries. Our estimates suggest that while the cost differential improved in early 2009, it widened substantially thereafter. Our estimates also suggest that a 30% points increase in the haircut on low rated government debt could have substantially increased the differences in average funding costs across country groups (by around 25% relative the the sample average spread).

To sum up, our model provides a tool to quantify how changes in the collateral policy of the central bank affect, on the one hand, the composition of its collateral pool and, on the other hand, the funding costs of banks and thus, ultimately, the transmission of monetary policy to the interbank market.

These two concerns were at the forefront of the policy debate during the Sovereign debt crisis, and our results suggest that while the use of lower rated collateral increased over this period, the collateral policy of the European Central Bank helped to smooth the transmission of monetary policy across the euro area.

Our work suggests several avenues for future research, such as refining the estimation of the parameters of the model using asset- and bank-level data. This would also allow to study how bank characteristics interact with the design of monetary policy operations to influence the transmission of monetary policy.

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# A Additional statistics on assets pledged to the ECB

Table 11: Descriptive statistics on the ECB's collateral framework

All figures are averages over the sample period (Jan 2009-Sep 2011). Eligible: nominal value of assets eligible as collateral. Pledged: nominal value pledged to the Eurosystem. Pledged market value: before haircut.

| Asset type | Eligible (EUR bn) Nominal value | Eligible (% of Tot) | Pledged (EUR bn) Nominal value | Pledged (% of Tot) | Pledged (EUR bn) Market Value | Pledged (% of Tot) | Haircut |
|---|---|---|---|---|---|---|---|
| Government | 5600.8 | 43 | 262.7 | 14 | 253.3 | 11.7 | 3.1 |
| ABS | 1233.0 | 9 | 651.6 | 34 | 512.7 | 23.7 | 12.8 |
| Covered Bond | 1417.8 | 11 | 287.9 | 15 | 277.4 | 12.8 | 3.2 |
| Uncovered bank bond | 2591.0 | 20 | 485.7 | 25 | 473.5 | 21.9 | 7.6 |
| Non-marketable asset | - (*) | - | - | - | 423.9 | 19.6 | 19.2 |
| Other | 2288.8 | 17 | 222.2 | 12 | 222.6 | 10.3 | 3.9 |
| Total | 13131.5 | 100 | 1910.1601 | 100 | 2163.4 | 100 | 9.6 |

# B Main changes to the ECB's collateral policy

Table 12: Main changes to the ECB's collateral policy (October 2008 - September 2011)

| Date | | | Change in collateral framework |
|---|---|---|---|
| 22 | October | 2008 | The credit threshold for collateral other than ABS is lowered to BBB-, debt instruments issued by credit institutions, traded on certain non-regulated markets as well as subordinated debt under certain conditions becomes eligible. |
| 14 | November | 2008 | Foreign denominated collateral becomes eligible under certain conditions. |
| 20 | January | 2009 | The collateral pool of a counterparty may not include a higher share |
| 1 | February | 2009 | Haircuts increased, in case of ABS up to 12% from much lower levels (depending on maturity of the ABS)... (see Sep. 2008 announcement) |
| 1 | March | 2009 | Newly issued ABSs must have a AAA rating at issuance and should not consist of tranches of other ABSs. |
| 1 | March | 2009 | Collateral pool of any counterparty should not contain more than 10% of unsecured bank bonds issued by a single counterparty or any counterparty with which this counterparty has close links. This limitation does not apply in case the value of the asset is less than 50 million or that the asset is guaranteed by the PSE. (see announcement) |
| 1 | March | 2010 | ABSs issued after 1 March 2010 require two AAA ratings at issuance. Over the life of the ABS, the second best rating must remain above A- for assets issued after 1 March 2010. |
| 1 | March | 2010 | The asset pool of any ABS should not consist of tranches of other ABS |
| 8 | April | 2010 | The eligibility of assets with a rating below A- but above BBB- was extended until further notice except for ABS. |
| 3 | May | 2010 | The minimum rating threshold of debt instrument issued or guaranteed by the Greek government was suspended (entered into force on May 8) |
| ... | | | (continued in table 13) |

# C Definition of Asset Classes

The following types of bonds are eligible as collateral.

Asset-Backed Securities (ABS) are debt instruments collateralized by loans or receivables held by banks, credit card companies and other credit providers.

Covered Bonds are "dual recourse" bonds similar to ABSs. They are issued by a credit institution and with priority recourse to a pool of collateral. The main differences with ABSs are that (1) they are kept on the issuer's balance sheet while ABSs are often transferred to a special entity. This provides a "dual

Table 13: Main changes to the ECB's collateral policy (October 2008 - September 2011)

| Date | | | Change in collateral framework |
|---|---|---|---|
| 15 | June | 2010 | Haircut on Greek government debt is increased by 5 % due to the rating downgrades. |
| 10 | October | 2010 | More stringent provisions on the cash flow generating assets backing asset-backed securities were introduced together with restrictions on the location of the ABS originator and underlying assets to the EEA. |
| 10 | October | 2010 | The introduction of additional exemptions from the prohibition of close links which relates to non-UCITS covered bonds that fulfill all criteria that apply to asset-backed securities, and are backed by residential real estate loans. |
| 10 | October | 2010 | Fungible tap issuances of ABS are considered to be new issuances of ABS. |
| 10 | October | 2010 | For structured issue where the prospectus provides for the delivery of acceleration and an enforcement notice, non-subordination of a tranche must be ensured under both acceleration and enforcement notice-related priority of payments. |
| 1 | January | 2011 | New, higher haircuts for some asset types apply (including haircut on ABS increased to 16 % from 12 %). |
| 1 | January | 2011 | Expiry of the temporary measures of eligibility of 1) assets denominated in USD, JPY and GBP 2) unsecured bank bonds listed on non-regulated and accepted markets 3) subordinated assets with a guarantee |
| 1 | March | 2011 | Over the life of the ABS, the second best rating must remain above A- irregardless of the date of issuance of an ABS. |
| 31 | March | 2011 | The minimum rating threshold of debt instrument issued or guaranteed by Irish government is suspended. |
| 25 | May | 2011 | Haircut on Portuguese government debt is increased by 5 %. |
| 7 | July | 2011 | The minimum rating threshold of debt instrument issued or guaranteed by the Portuguese government is suspended |
| 21 | September | 2011 | Change in the General Documentation: abolishment of requirement that debt issued by credit institutions is only eligible if admitted to trading on a regulated market. Reduction in the maximum share of close-link credit claims to 5 % from 10 %. |

recourse" to the lender who has access to the underlying loans or the issuer in case of default. (2) ABS are generally tranched[13] while covered bonds are not. (3) Covered bonds are more regulated with regard to the type of assets to be used, the management of the asset pool during the life of the security and the transparency of the security. There are two categories of covered bonds: Jumbo and Pfandbriefe (jumbo are large issuances generally perceived of higher quality).

Government securities are issued by central or regional governments.

Uncovered bank bonds are issued by banks and are not collateralized.

Non-marketable assets are assets that are not traded on a market, such as bank loan portfolios. Eligibility of these assets is often decided on a case by case basis at the national level.

# D Private market haircut schedule

We use the haircut schedule for government debt in Table 6 to infer the private market haircut for various asset types. The private market haircut is a function of the rating of the asset $rat_j$, its maturity $m_j$ (short or long term) and the asset type $type_j$.

Since we observe the haircut only for specific ratings, we linearly extrapolate the haircut for other rating based on the available haircuts. For example, suppose that we observe a rating of 0.5% for short term AAA (=1) rated debt and 1% for short term AA- (=4) rated debt, we set the haircut for AA and AA+ debt to 0.92% and 0.83% respectively. For asset types other than government debt, we consider the haircut schedule of Table 1 inside a rating bucket as the haircut for AAA, and use the recovered haircut spread to extrapolate the haircut for other rating. For example, the haircut for AAA and AA- regional government debt are 1% and 1.25% respectively.

Table 14 shows the specific haircut levels for the private market. We assume that ABSs are ineligible in the private market (with a 100% haircut). To allow for flexibility in our definition of the private market haircut, we also control for the credit rating, we add individual asset type dummies in the regressions and interact the private market haircut with the asset type dummies and the rating of the rating. This allows for a much more general definition of the private market haircut. For instance, suppose that we would change the haircut in table 14 by adding an add-on for a specific asset type. By including the asset type dummy, we capture also such a specification.

[13]Tranching consists in dividing the pool of assets into claims of different seniority. For example, the junior tranches may absorb the first 5 % of defaults in the loan portfolio, while senior tranches only default if more than 50 % of the loans are in default.

Table 14: Private market haircut by asset category and maturity (short or long (15-30y) term)

| Asset category | I | | II | | III | | IV | |
|---|---|---|---|---|---|---|---|---|
| Rating | Short | Long | Short | Long | Short | Long | Short | Long |
| AAA | 0.75 | 13 | 1 | 7.5 | 1.5 | 11 | 6.5 | 17 |
| AA+ | 0.83 | 14.17 | 1.08 | 8.67 | 1.58 | 12.17 | 6.58 | 18.17 |
| AA | 0.92 | 15.33 | 1.17 | 9.83 | 1.67 | 13.33 | 6.67 | 19.33 |
| AA- | 1 | 16.5 | 1.25 | 11.00 | 1.75 | 14.50 | 6.75 | 20.50 |
| A+ | 2.5 | 18 | 2.75 | 12.50 | 3.25 | 16.00 | 8.25 | 22.00 |
| A | 4 | 19.5 | 4.25 | 14.00 | 4.75 | 17.50 | 9.75 | 23.50 |
| A- | 5.5 | 21 | 5.75 | 15.50 | 6.25 | 19.00 | 11.25 | 25.00 |
| BBB+ | 7 | 22.5 | 7.25 | 17.00 | 7.75 | 20.50 | 12.75 | 26.50 |
| BBB | 8.5 | 24 | 8.75 | 18.50 | 9.25 | 22.00 | 14.25 | 28.00 |

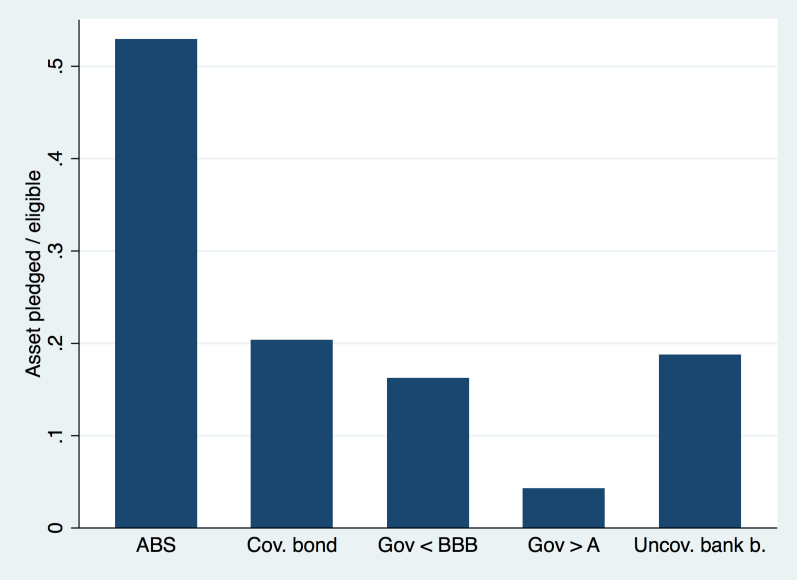


Figure 12: Ratio of assets pledged to the assets eligible
The figure shows for five asset types (ABS, covered bonds, government bonds, uncovered bank bonds and other assets) the proportion of assets used as collateral, which is a proxy for the attractiveness of using the asset at the central bank versus in private markets.

# E Additional Figures

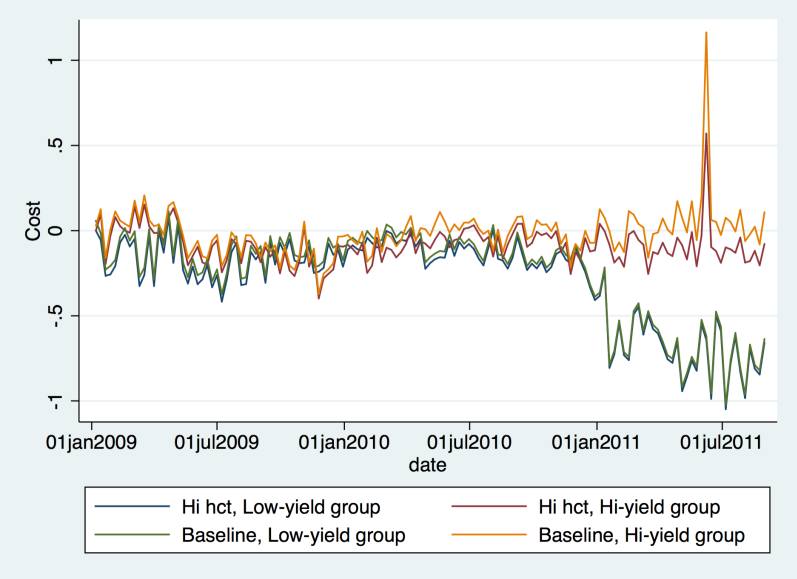


Figure 13: Counterfactual funding cost

Recovered change in average weighted funding cost (equation (10)) for high yield (CY, ES, GR, IE, IT, PT) and low yield (AT, BE, DE, FR, NL) country groups. The baseline scenario corresponds to no change in haircut policy while the Hi haircut scenario corresponds to an increase of the haircut on low rated (below A) debt of 30 percentage points.

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