Collateral scarcity premia in EU repo markets[♣]

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Abstract

Collateral plays a very important role in financial markets. Without easy access to high-quality collateral, dealers and market participants would find it more costly to trade, with a negative impact on market liquidity and the real economy through increased financing costs. This role has become increasingly significant since the global financial crisis, partly due to regulatory reforms. Using data from both repo and securities lending markets, this paper studies the drivers of the cost of obtaining high-quality collateral, i.e. the collateral scarcity premium, proxied by the degree of specialness of government bond repos. We find that the cost of obtaining high-quality collateral increases with demand pressures in the cash market (short-selling activities), even in calm financial market conditions. In bear market conditions - when good collateral is needed the most - this may lead to tensions in some asset market segments. We introduce a novel measure of collateral reuse and find that collateral reuse may alleviate some of these tensions by reducing the collateral scarcity premium under certain conditions. Yet, it requires transparency and monitoring due to the financial stability risks associated. Lastly, we find that the ECB Public Sector Purchase Programme has a statistically significant, albeit marginal, impact on sovereign collateral scarcity premia that is offset by the beginning of the ECB securities lending programme.

Keywords: Repos, securities lending, collateral, specialness, short selling, collateral reuse, negative interest rates, quantitative easing

JEL Classification: E52, G12, G23

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1. Introduction

Since the financial crisis, the demand for collateral assets has increased in the financial system, also due to recent market and regulatory developments[1]. Collateral flows lie at the heart of any proper understanding of market liquidity, and hence of financial stability (Singh, 2014). In Europe, securities financing transactions (SFTs)[2] account for more than 80% of collateral flows (ESRB, 2014) and therefore play a key role in supporting collateral fluidity - i.e. securities being in the right place, at the right time, for the right entity - by ensuring that collateral is efficiently allocated to counterparties that need it the most, for regulatory and business purposes. The objective of this paper is to shed further light on the functioning of SFTs in the European Union, by analyzing the drivers of the cost of obtaining high-quality collateral, proxied by the degree of specialness in repo markets.

We analyse the repo and securities lending markets for seven Euro Area sovereign issuers, between March 2013 and September 2015. We focus on the drivers of the cost of obtaining high-quality collateral, proxied by specialness. Specialness is defined as the difference between the rates on General Collateral (GC) repos and Special Collateral (SC) repos using similar bonds, and it is a proxy for the scarcity premium to be paid for procuring a specific security (Duffie, 1996). In repo markets, the collateral becomes special and trades at a lower rate when it is on high demand or in limited availability. We highlight how bond-specific supply and demand affect specialness in the repo market: In particular, we analyse the impact of short selling activity and collateral reuse on the collateral scarcity premium.[3]

We build on the results of the seminal paper of Duffie (1996) showing that specialness can be related to:

1) the **liquidity** of the instrument: of the two otherwise identical instruments, the most liquid one is the one more likely to be on special, that is, to be traded at lower repo rates;
2) **short selling activity**: specialness increases with the demand for short positions, for a given total supply.

We contribute to the recently growing literature analysing the functioning of repo markets in Europe. Mancini et al. (2015), empirically show that centrally-cleared repos secured by high-quality collateral acted as a shock absorber during financial crisis. Boissel et al. (2014) refined these conclusions using a broader range of data not limited to high-quality collateral, and found

[1] Drivers of increased collateral demand include: Basel III/CRD4 requirements, e.g. requirements to hold high-quality liquid assets for Liquidity Coverage Ratios; OTC derivatives reforms (EMIR) through the mandatory clearing of certain classes of derivatives and collateral and margin requirements for CCPs; expansion of central banks' balance sheet through increased collateral eligibility for central bank funding and securities purchases; and a broader market shift from unsecured to secured funding.

[2] SFTs include mainly repos and securities lending transactions.

[3] The reuse of collateral is relevant to capture the role of collateral in the overall financial plumbing.Indeed, the stock of available collateral and the intensity with which it is reused (and its velocity) are both relevant to understand the functioning of modern financial markets. The stock of collateral may decline as investors become more concerned about counterparty risk, making them less willing to lend securities in favour of buy-and-hold strategies. It can also be affected by central-bank measures, such as large-scale asset purchases or a widening of eligible assets for pledging as collateral (Singh, 2014).

that central counterparties (CCPs) provided some protection in periods of intermediate sovereign stress (2009-2010) but were unable to restore stability on the repo market at the peak of the sovereign debt crisis (2011). Both papers focused on GC repos, analyzing the role of the repo markets as financing means for counterparties. Our paper is closest to Corradin et al. (2016), which focuses on specialness in the repo market for Italian sovereign collateral over the period going from October 2009 to July 2012, and to Aggarwal et al. (2015), which analyses the role of securities lending market in the EU in both normal and crisis times.

We innovate with respect to the existing literature by carrying out, to our knowledge for the first time, an empirical analysis of both the repo and securities lending markets for several Euro Area countries, focusing on the drivers of specialness at bond level. The period analysed extends from 7 March 2013 to 21 September 2015 which, though relatively short, includes two important changes of monetary policy: the introduction of negative interest rates on the ECB deposit facility, and the launch of ECB quantitative easing (QE).

We complement this framework by introducing a novel measure of collateral reuse. Most SFTs in Europe are title-of-transfer agreements that give full right of reuse to the collateral receiver, which has become a widespread practice in EU financial markets over the last decade.[4] Collateral reuse increases the effective supply of collateral, which reduces the scarcity premium by lowering the price of special collateral.

The paper is organized as follows: Section 2 reviews the relevant literature and describes the European securities financing transactions market. Section 3 introduces the dataset and the empirical model and section 4 presents the empirical results. Section 5 provides evidence of the dynamic of specialness around monetary policy changes and Section 6 concludes.

2. Literature review and institutional background

2.1 Literature review

We investigate the drivers of the cost of obtaining high-quality collateral, i.e. the collateral scarcity premium, proxied by the degree of specialness in EU government bond repo markets. An increase in repo specialness may signal a shortage of high-quality collateral, with a potentially negative impact on liquidity, capital markets financing, bank lending and the real economy. A shortage of high-quality collateral may in turn reflect a combination of structural or cyclical factors. The structural factors that can impact the availability of collateral include technological changes, regulatory changes, changes in business models, and the development of collateral management services by various intermediaries. This paper focuses on the cyclical factors, such as higher collateral demand, e.g. in the context of safe-haven purchases and short sales, or reduced collateral availability, e.g. due to lower issuance, market participants withholding assets or central bank purchases. The repo specialness of a given instrument is defined as the difference between the GC rate and the SC rate for that instrument.

The seminal theoretical paper of Duffie (1996) shows that specialness is related to short selling: when traders short bonds in the cash market, they can enter reverse repo transactions to have

[4] This is different from the US, where reuse rights are strictly limited.

the securities delivered in time to cover the short position. More precisely, specialness is increasing in the amount of short selling activity in the cash market. Duffie also indicates that specialness is related to the liquidity of the instrument: of the two otherwise identical instruments, the most liquid one is more likely to be on special, that is, to be traded at lower repo rates. Clearly, liquid bonds are more frequently shorted and consequently are in greater demand as collateral in repo transactions. This insight is confirmed empirically by Vayanos and Weill (2008) who show that higher liquidity induces short-seller concentration and creates specialness.

Finally, Duffie (1996) points out the direct link between repo rates and the underlying cash market prices arguing that specialness increases the equilibrium price for the underlying instrument by the present value of savings in borrowing costs associated with the repo specials. Jordan et al. (1997) investigate this hypothesis and find clear evidence in support of it: specialness is priced in cash markets, and the magnitude of the premium reflects both the future duration and magnitude of repo specialness.

The auction cycle of a bond is also relevant for specialness. On-the run bonds are typically more special (i.e. they trade at lower rates) due to their liquidity premium (Duffie, 1996; Krishnamurthy, 2002). An alternative interpretation for the premium associated with liquidity is that on-the-run bonds trade as specials because they can easily be borrowed or purchased: risk averse short-sellers would rather short securities that can be easily sourced when they later need to purchase the security to close out the short position (Graveline et al., 2011). The difference in specialness between off-the-run and on-the-run bonds depends also on auction tightness and interest rate volatility (Moulton, 2004). Particularly, increases in interest rate volatility positively contribute to the degree of specialness (Dufur et al., 2005). Finally, the scarcity of the underlying collateral should be one of the main determinants of the repo rates. D'Amico et al. (2014) quantify the scarcity value of US Treasuries collateral by estimating the impact of security-specific demand and supply factors on the repo rates of all outstanding Treasuries securities. Their results point to the existence of an economically and statistically significant scarcity premium, especially for shorter-term securities. They also provide additional evidence of the scarcity channel based on the Federal Reserve's quantitative easing programmes and suggest that, through the same mechanism, the Fed's reverse repo operations could help alleviate potential shortages of high-quality collateral.

Repo rates may also be driven by a number of other factors. For example, repo rates increase with the maturity of the contract. Longstaff (2000) tested the expectation hypothesis using short-term repo rates. Contrary to evidence from other market segments, he finds that short-term repo rates (up to a month) are not significantly different from the average expected overnight rate, which supports the conclusion that no risk premia exist at the very short end of the repo market. Buraschi et al. (2002), focusing on German government repo market, tested empirically the relation between the current term structure of long-term repo spreads (defined as the difference between GC and SC rates) and the future collateral value of German government bonds. They found that current forward spreads overestimate changes in future specialness. Moreover, they found evidence that such deviations from the expectations hypothesis of interest rates are due to time-varying risk premium explained by the conditional volatility of the special repo spread.

In addition, according to Hordahl et al. (2008), during the crisis, repo rates were driven by collateral quality and the demand for safe assets. Gorton et al. (2012) found evidence that repo rates were correlated with counterparty risk in securitised bonds. More recently, there have been a number of theoretical studies on the relationship between repo rates and haircuts in the context of dealers providing financing to hedge funds, e.g. Eren (2014) and Infante (2014). These studies found a trade-off between repo rates and haircuts, i.e. hedge funds that pay higher haircuts are compensated by lower repo rates in equilibrium. When liquidity is abundant, haircut spreads are low. Conversely when liquidity is scarce, haircuts spread are high and hedge funds pay a lower repo rates to compensate for the increased exposure to the dealer. Building on this idea, Infante (2015) also demonstrates that haircuts and repo rates tend to be higher when the dealer's default risk is correlated with asset prices, because the expected loss of hedge funds when dealer defaults will be higher.

Our paper contributes to the recently growing literature analysing the functioning of repo markets in Europe. Dufour et al. (2005) examine repo specialness for bonds used as collateral in the Italian government BTP repo market. They conclude that supply and demand are significant factors determining the degree of specialness. Moreover, as in Duffie (1996) they show that more liquid bonds trade more frequently on special and, as in Moulton (2004) market conditions such as interest rate volatility increase the degree of specialness. Finally, they find that credit risk and information uncertainty also affect the degree of specialness for Italian government bonds.

Mancini et al. (2014), empirically show that centrally-cleared repos secured by high-quality collateral acted as a shock absorber in Europe during the financial crisis. Boissel et al. (2014) refined these conclusions, using a broader range of data not limited to high-quality collateral, and found that during the sovereign debt crisis of 2011, repo rates strongly respond to movements in sovereign risk, in particular for EU peripheral countries, indicating significant CCP stress (2011). Both papers focused on GC repos, analysing the role of the repo markets as financing means for intermediaries.

The securities lending market in the EU is examined by Aggarwal et al. (2015), who find that during crises, lenders prefer to hold high-quality government bonds unless the lending fee is excessively high. They also find that more borrowing of a bond in the securities lending market relates to higher trading activity for that bond in the repo market for the purpose of obtaining financing (although this last result is limited to the Italian market).

Our paper is closest to Corradin et al. (2015) that focuses on specialness in the repo market for Italian sovereign collateral over the period going from October 2009 to July 2012. They find the scarcity premium to be higher in the repo market for bonds when the amount of a security that is effectively available in the market is lower, showing that this effect is stronger during periods of significant market stress.

We innovate with respect to the existing literature by carrying out, to our knowledge for the first time, an empirical analysis of the drivers of specialness in several Euro Area countries, analysing at bond level the link between securities lending market and repo market. The period analysed extends from 7 March 2013 to 21 September 2015 which, though relatively short,

includes two important changes of monetary policy: the introduction of negative interest rates on the ECB deposit facility and the launch of ECB quantitative easing (QE) and ECB Securities Lending Programme.

We complement this framework by introducing a novel measure of collateral reuse. Most SFTs in Europe are title-of-transfer agreements that give full right-of-reuse to the collateral receiver, which has become a widespread practice in EU financial markets over the last decade. Collateral reuse increases the effective supply of collateral, which reduces the scarcity premium by lowering the price of special collateral.

2.2 Policy context and institutional background

Main features of European Securities Financing transactions (SFTs)

The main types of SFTs are repos and securities lending. Repos or repurchase agreements are contracts for collateralised borrowing and lending that are often used to finance long and short positions. A repo transaction combines a spot market sale of a security with a simultaneous forward agreement to buy back the same (or equivalent) security at a later date. The repo rate is an annualised interest rate capturing the difference between the spot and forward prices. There are two main categories of repos: GC repos, where the choice of collateral to be delivered is made after the trade, typically taken from an existing pool of collateral (i.e. a basket of securities that meet certain eligibility criteria predefined), and specific collateral repos, when the collateral sought is clearly identified.

GC assets are homogeneous liquid securities used indiscriminately by market participants for a certain rate (the GC rate) driven by standard supply and demand dynamics. In GC repos, the choice of collateral to be delivered is made after the trade, typically from a collateral pool (i.e. a basket of securities meeting certain eligibility criteria). Specific collateral repos, on the other hand, are repos in which the collateral is known before the trade is executed and has specific characteristics. When specific securities are in high demand, they become *special* and buyers bid competitively for them by offering a higher price, which implies that for a given forward price on a security (i.e. the second leg of any repo trade), special collateral (SC) rates are lower than GC rates.[5] Specific (and special) collateral repos are, therefore, security-driven transactions where the collateral is specifically sought for its characteristics, while GC deals are mainly cash-driven.[6]

Repos are bilateral or tri-party transactions mainly traded OTC that can be centrally cleared. CCP-cleared repos are transactions in which a clearing house bears the counterparty risk. In tri-party repos, a custodian bank facilitates the transaction while taking care of post-trading services such as settlement, as well as collateral valuation. Regardless of the transaction type, repos are intermediated via broker-dealers, or via anonymous electronic trading platforms.

[5] This is consistent with Duffie's (1996) framework, where simple arbitrage with cash bond markets automatically prevents the possibility that SC rates are higher than GC rates.

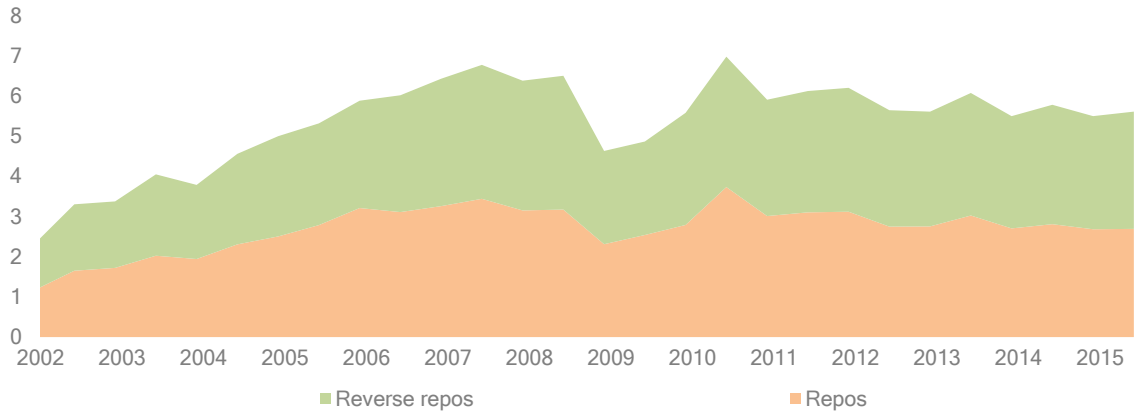
[6] This distinction has become a bit blurrier in the last 10 years since most GC repos are today security driven. The differences between GC and SC rates, however, remain.

These platforms are typically - but not necessarily - connected to a CCP, which arranges the settlement of the transaction.

The European repo market size is estimated to be EUR 5.6tn[7] down from a peak of EUR 6.8tn in June 2007 (based on a survey of large European financial institutions by ICMA). Overall, daily volumes in Euro Area (EA) centrally-cleared sovereign repos exceed EUR 300 bn.

The structure of European repo markets is different from that of the US and, given the lack of data, has not been fully explored yet. In the Euro repo market, transactions are mostly intermediated via automated trading systems and CCP-cleared (see Bakk-Simon et al., 2012; European Central Bank, 2012), while the share of the tri-party repo market segment is much smaller than in the US. As of 2015, 66% of the market consisted of CCP-based bilateral repos, 26% of non-CCP based bilateral repos and less than 10% of triparty repos (ECB, 2015)[8]. There are three main electronic trading platforms constituting the CCP-based Euro interbank repo market: Eurex Repo, BrokerTec and MTS.

Chart 1: Gross size of the European repo market



Note: Gross value of repos and reverse repos outstanding from around 65 European institutions, in EUR tn. Includes sell-buy backs and buy-sell backs. Given that transactions between same counterparties are not netted out, some double counting is likely.
Sources: ICMA, ESMA.

A securities lending transaction involves a counterparty lending a security to another counterparty for a period of time, against collateral in the form of other securities or cash. The security borrower pays a fee to the lender for the use of the loaned security. The two types of SFTs have many similarities and can often be used as substitutes.

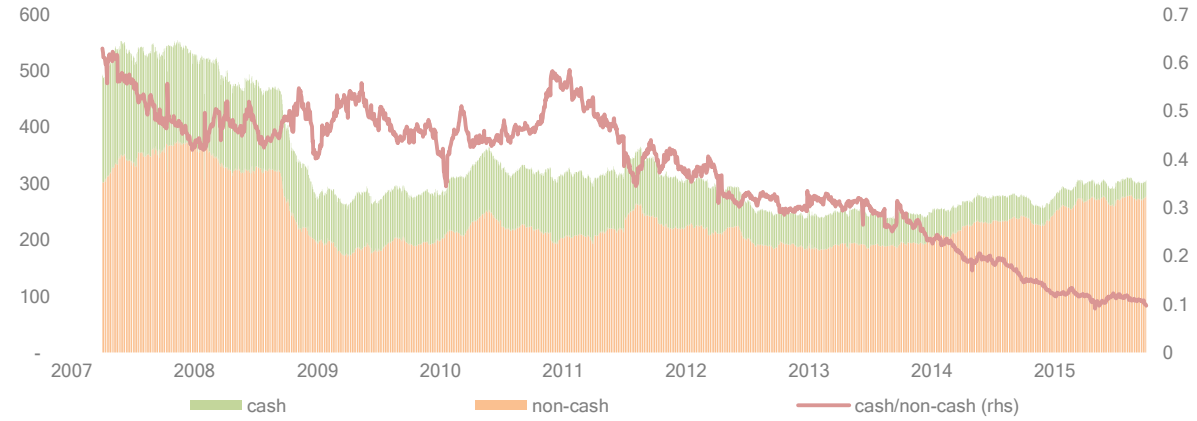
Securities lending is a transaction economically equivalent to repos in which securities are temporarily transferred from one counterparty to another for a fee, most of the time with the intermediation of an agent lender. The borrower is obliged to return the securities to the lender either on demand (open transactions) or at the end of an agreed term (term transactions). The transaction is collateralised by the borrower with cash or with other securities. The borrower is entitled to the economic benefits of the borrowed securities (i.e. receiving dividends or coupon payments) but the agreement with the lender obliges to "manufacture" payments back to the

[7] http://www.icmagroup.org/Regulatory-Policy-and-Market-Practice/short-term-markets/Repo-Markets/
[8] https://www.ecb.europa.eu/stats/money/mmss/html/index.en.html

lender. When cash is used as collateral, the lender pays a rebate rate to the borrower that is lower than the prevailing fee, so that the lender can reinvest the cash collateral and make an additional return. In the trade negotiation phase, the parties take into account factors such as availability and demand for the particular securities, collateral liquidity, expected dividends and the likelihood of the lender recalling the securities early.

While the large majority of repo transactions are done between banks (and CCPs), securities lending markets bring together a wide variety of financial entities. Asset owners are mainly buy-side companies such as mutual funds, insurance companies, pension funds and sovereign wealth funds. They lend securities in order to generate extra revenues, sometimes using agent lenders such as custodians, that manage large pool of securities and offer risk management and post-trading services. This is also an opportunity for e.g. mutual funds to temporarily swap equities or corporate bonds against higher-quality assets such as government bonds. On the borrowing side sit mainly banks and hedge funds (through prime brokers) that are looking for specific assets for collateral management purposes and to cover short positions hedge or avoid settlement fails.

Chart 2. EU Government bonds on loan, by type of collateral



Note: Outstanding value of European government bonds on loans against cash/non cash collateral, EUR billion. Ratio of cash/non-cash collateral on secondary axis.
Sources: Markit Securities Finance, ESMA.

As of the end of 2015, the value of EU securities on loan was around EUR 500bn composed of government bonds (EUR 300bn), corporate bonds (EUR 40bn) and equities (EUR 160bn), mostly against non-cash collateral. In our analysis, we use transactions collateralised with both cash and non-cash. Although cash-collateral transactions would arguably be more comparable to standard cash-for-securities repos, securities-for-securities trades are largely use to source specific assets, including high-quality collateral such as government bonds. Activity in this segment of the securities lending market is therefore directly related to specialness in the repo market, and to collateral scarcity premia.

Securities lending market activity peaked in 2007. As markets deteriorated in the course of 2008, there was a significant drop in demand for securities following deleveraging by funds and broker-dealers, driven primarily by the need to raise cash to meet investor redemptions and to shrink their balance sheet. In parallel, the beneficial owners of the assets (asset managers,

institutional investors and some public sector entities) became increasingly risk averse as the crisis unfolded and reduced their supply of securities by restricting the counterparties to which they were willing to lend their assets. Lastly, temporary and prolonged bans on short selling in the EU may have reduced demand for some securities. These dynamics caused the EU securities lending to fall by more than EUR 400bn in 2008, including 200bn for government bonds, EUR 50bn for corporate bonds and EUR 180bn for equities. Since the beginning of 2009, EU government bonds lending activities have been around EUR 270bn-300bn (of which more than 90% are collateralised with other securities).

Policy context

In the aftermath of the global financial crisis, global regulators set out several policy recommendations to address shadow banking risks specific to securities financing markets, which were perceived to have played a role in the crisis (FSB, 2013). The risks identified by the FSB (2013, 2014) and the ESRB (2013, 2014) were:

- **Securities lending cash collateral reinvestment**: the risks involved in cash collateral reinvestment stem from maturity and liquidity transformation, which if left unchecked can present negative externalities to firms beyond the lender in a stress event.
- **Facilitation of credit growth and build-up of leverage**: Securities lending markets contribute to the facilitation of credit growth and the build-up of leverage in the financial system allowing lenders to obtain relatively cheap and easy funding using their own assets.
- **Maturity transformation**: Securities lending transactions with open maturity are in vast majority. Open maturity transactions present a higher degree of risk than term maturity transactions: during a financial crisis lenders can recall the securities lent at short notice and lenders may not be able to return them.
- **Interconnectedness**: The significant exposures built across the different types of financial institutions (e.g. custodians, asset managers, credit institutions and insurances) clearly contribute to the formation of possible contagion channels and associated risks. For agent lenders who typically lend securities to other institutions on behalf of their clients and can reinvest the cash collateral in reverse repos with yet another entity, the resulting risks from a high degree of interconnectedness could become material (ESRB, 2014).

In particular, one of the FSB recommendations requires collecting more granular data on securities financing transactions. The recently adopted EU Regulation on transparency of SFTs and of reuse[9] will improve the transparency of SFTs mainly in the following three ways. First, it will require that all transactions are reported to trade repositories, including the type of SFT, transacting counterparties, maturity, nature and quality of collateral, etc. This will allow supervisors to better understand the links between banks and non-banks, shed more light on some of their funding operations, and to monitor the exposures and risks associated with SFTs.

[9] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32015R2365&from=EN

Second, the Regulation will improve transparency towards investors on the practices of investment funds engaged in SFTs and other equivalent financing structures by requiring detailed reporting on these operations, both in the regular reports of funds and in pre-investment documents[10]. This would lead to better-informed investment decisions by investors.

Finally, the Regulation will improve the transparency of the reuse[11] of collateral by setting minimum conditions to be met by the parties involved, including disclosure and written agreement. This would ensure that clients or counterparties have to give their consent before reuse can take place and that they make that decision based on clear information on the risks that it might entail.

A large part of these regulatory initiatives focus on the risks that SFTs may pose to financial stability, due to opacity of collateral reuse, collateral management practices and collateral valuation. For example, valuation is thought to increase system procyclicality: easier (tighter) conditions on secured lending transactions, e.g. changes in haircuts, tend to increase (decrease) leverage when market conditions are benign (deteriorating) (BIS, 2010).

Under this policy framework, specialness is of particular interest. Specialness contributes to increasing the price of the underlying collateral (Duffie, 1996), therefore understanding what the drivers of specialness are would help to single out individual factors or practices liable to increase procyclicality in the financial system.

This paper also contributes to on-going discussions on the measurement of collateral reuse, with the FSB (2016) recently proposing a set of possible measures. Due to the difficulty of measuring exactly the reuse of collateral, these proposals include possible approximations (direct and indirect). We contribute to the debate by introducing a new measure of the reuse of collateral in repo markets.

Moreover, the time period we analyse is particularly relevant from a policy perspective since it includes two important changes of monetary policy: the introduction of negative interest rates on the ECB deposit facility and the launch of ECB quantitative easing.

Negative deposit rate and low interest rate environment

These unconventional monetary policy tools have a different impact on repo rates and specialness. In normal times, SC rates can become negative due to exceptional demand or restricted supply of specific securities. In a low-interest-rate environment, GC rates (which are equivalent to the risk-free rate, as in Duffie (1996)) can also be negative, for example when yields on the collateral used are very low or negative.

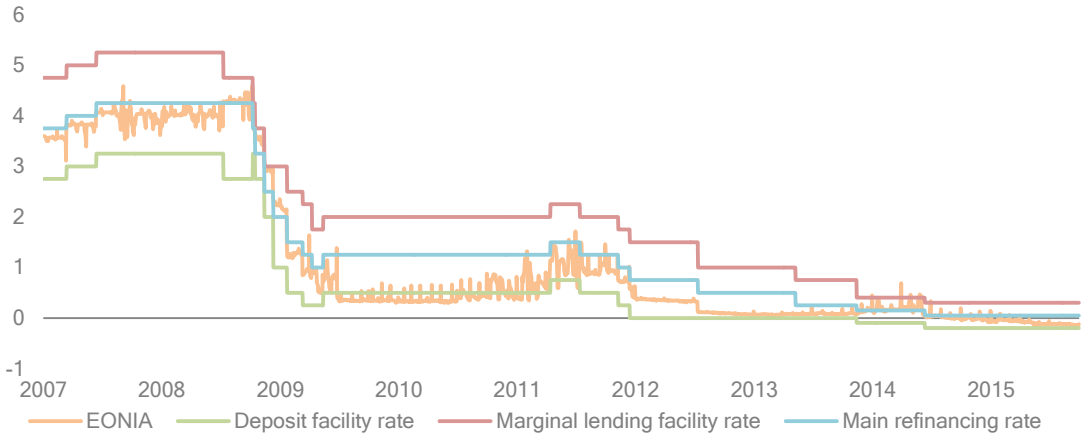
With negative repo rates, the collateral buyer should in theory pay interest to the seller. On 11 June 2014, the ECB set its interest rate on the deposit facility at -0.10%, gradually leading the

[10] The UCITS directive and subsequent ESMA guidelines had already taken steps in that direction.

[11] In the SFT Regulation, reuse also includes rehypothecation of collateral assets used e.g. in margin lending transactions, since these are economically equivalent to repos.

main unsecured overnight interbank rate (EONIA) below zero (Chart 3), which consequently drove short-term rates on secured transactions (e.g. repos) deeper into negative territory.

Chart 3: ECB key interest rates and EONIA



Note: ECB key interest rates and Euro Overnight Index Average (EONIA), in %.
Sources: European Central Bank, ESMA

In theory, since SC rates are set relative to GC rate, this should not have an impact on the scarcity premium which is calculated as the difference between GC and SC rates. However, as SC rates go deeper into negative territory, the incentive for the collateral seller to fail on its delivery increases. Under the General Master Repo Agreement, the standard contract governing repo markets, the repo rate agreed between parties is locked even in case of fail-to-deliver by the seller. With positive rates, when the seller fails to deliver, it still owes repo interest to the buyer, thereby creating a disincentive to fail[12].

With negative repo rates, however, the buyer pays interest on the money it is lending, therefore a seller could very well decide to fail, and still receive the repo rate. While the resulting incentives to fail are mitigated by penalties on delivery fails, penalties could hypothetically be compensated by a high enough interest payment from buyer to seller, which depends on how far into negative territory repo rates are. Therefore a seller may fail at no cost, or even make a profit from it.

In terms of the analytical framework for repo specialness, this has several implications. The incentive created by the possibility to fail at little or no cost (or even to profit from it) naturally limits the amount of money that buyers are ready to offer as they might be faced with a situation where they pay interest without getting the collateral they sought. This automatically creates a floor to repo rates, which will depend on both the level of repo rates and the penalty regime for fails in place. Given that specials trade at a lower rate than GC deals, this floor would primarily apply to SC trades. In turns, this implies that beyond a certain point:

- SC rates may become unresponsive to the repo rates determinants previously identified in the literature (e.g. exceptional demand due to short sales, or supply restrictions);

[12] Industry representatives indicated that market participants sometimes set repo rates to zero in order to remove this incentive to fail. This helps to ensure the proper functioning of repo markets.

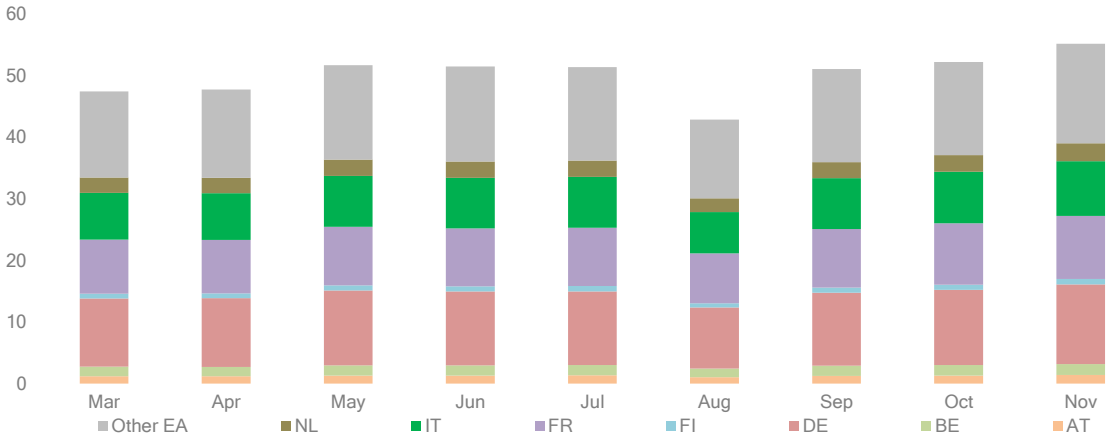
- Changes in market conditions that should have lowered both GC and SC rates (e.g. market risk) may only affect GC rates, therefore resulting in changes in specialness that are unrelated to the specific characteristics of the collateral that made it go on special.

As a consequence, we expect our variables of interest to respond differently before and after 11 June 2014.

Quantitative easing

With ECB quantitative easing, the main impact is on the available supply of collateral. On 22 January 2015, the ECB announced the public sector purchase programme, adding the purchase of sovereign bonds to its existing private sector asset purchase programme − in effect launching its own quantitative easing (QE) programme following similar actions previously taken by other large central banks (Federal Reserve, Bank of England, Bank of Japan). The combined asset purchases would amount to EUR 60bn per month until at least March 2017[13]. Between March and November 2015, purchases of government debt securities have averaged EUR 50bn (Chart 4).

Chart 4: ECB Monthly public asset purchases (2015)



Note: Monthly net purchases of public sector assets by thte European Central Bank, at book value., in EUR bn.
Sources: European Central Bank

Corradin et al. (2015) show that the unannounced central bank purchases under the Securities Markets Programme (SMP) increased the scarcity premium of the bonds targeted by reducing their effective available supply on markets. The impact of SMP purchases also increased with the scarcity premium of bonds *before* the purchases took place, therefore heightening the probability of delivery fails. While similar effects can be expected from the ECB QE purchases, there are key differences to consider:

- Unlike the SMP, where purchases were unannounced, the ECB has clearly set out that bonds would be purchased on a regular basis, therefore the overall impact of ECB purchases is anticipated and priced in by markets.

[13] http://www.ecb.europa.eu/press/pr/date/2015/html/pr150122_1.en.html.

- Although the ECB does not announce which bonds it is going to buy, the relative size of purchases in each Euro Area sovereign bond market should reflect the related country's participation to ECB's capital; therefore the relative impact in terms of volumes in each market can be estimated. This is also different from the SMP where purchases concentrated on stressed bond markets only.
- Bonds that have been purchased by the ECB and National Central Banks are then made available to market participants through a securities lending programme, started in April 2015[14].

The implication of the first two points for our paper is that the ECB QE programme may result in bonds going more frequently on special, or with a larger scarcity premium. However this effect may not be directly associated with specific ECB purchases (i.e. at the individual security level) but rather with the overall impact of the programme. Together with the ECB securities lending programme, we would expect QE purchases to have a milder effect than SMP purchases on collateral scarcity premia.

Finally, the interaction between these unconventional monetary policy measures has consequences on the behaviour of market participants and on market liquidity. A negative deposit rate acts as a disincentive for banks to place excess cash at the central bank. ECB QE purchases and long-term refinancing operations contribute on the other hand to increasing the amount of money available to banks and circulating in the financial system. Together with prudential requirements encouraging banks to hold high-quality collateral, these policies lead to a situation where large amounts of money chase few assets, increasingly requiring financial institutions to optimise their collateral allocation and reuse their high-quality collateral. While most of these assets are traded between banks (broker-dealers), some are exchanged with other market participants against lower quality assets through securities lending transactions (i.e. collateral downgrades).

3. Dataset and empirical model

In this section we describe the dataset used and the empirical model.

3.1 The dataset and variables description

Our dataset covers the period between 7 March 2013 and 21 September 2015. For repo data, we rely on ICAP RepoFundsRate (RFR) which includes information on repo transactions executed on BrokerTec or MTS two of the three CCP-based electronic trading platforms for Euro repos[15]. We use a bond level database including daily observations of CCP-cleared repo transactions collateralized with government bonds of seven EA countries (Austria, Belgium, Finland, France, Germany, Italy and the Netherlands).

[14] See ECB webpage for more details on ECB securities lending programme https://www.ecb.europa.eu/mopo/implement/omt/lending/html/index.en.html

[15] Therefore, we do not have the universe of the European SC repo market. Apart from Brokertec and MTS, there are also Eurex Repo and MEFF.

We analyse 3 different sub periods: between 7 March 2013 and 10 June 2014 (date of the introduction of negative interest rates on deposits); between 11 June 2014 and 21 January 2015 (the ECB quantitative easing announcement); between 22 January 2015 and 21 September 2015. We run our regressions separately in the 3 periods since, as explained, we expect our variables of interest to respond differently before and after the changes of monetary policy.

We define specialness as the difference between the related GC repo rate in country *i* and the volume-weighted average repo rate (VWAR) for bond *j* at time *t*[16]:

$$Specialness_{ijt} = GC_{it} - VWAR_{ijt}$$

Tables 1a-1d report descriptive statistics (mean, median, standard deviation, minimum and maximum) for specialness, volume-weighted average repo rate, total traded volume and average size of trading for the overall period, the period before the introduction of the negative deposit rate on deposits ("before"), the period between the introduction of the negative deposit rate and the launch of ECB QE ("between"), and the period after the introduction of the quantitative easing ("after"). Both GC rates and VWARs declined significantly after the introduction of the negative deposit rate, and after the launch of ECB QE. As a result specialness declined slightly after June 2014, decreasing from 0.030 to 0.026 and then to 0.021 after January 2015 (table 1a and Chart 4).

Table 1a: Specialness

	Overall period	before	between	after
mean	0.026	0.030	0.026	0.021
median	0.015	0.017	0.015	0.013
sd	0.039	0.046	0.040	0.025
min	0.0	0.0	0.0	0.0
max	0.787	0.787	0.787	0.270

Table 1b: Volume-weighted average repo rate

	Overall period	before	between	after
mean	-0.006	0.100	0.052	-0.167
median	0.001	0.079	0.034	-0.183
sd	0.143	0.103	0.114	0.073
min	-0.657	-0.350	-0.657	-0.400
max	1.685	1.685	1.685	0.269

[16] For each ISIN, the following variables are available in RFR: Total number of repo trade; Maximum transacted repo rate; Minimum transacted repo rate; Volume-weighted average repo rate; Total transacted volume.

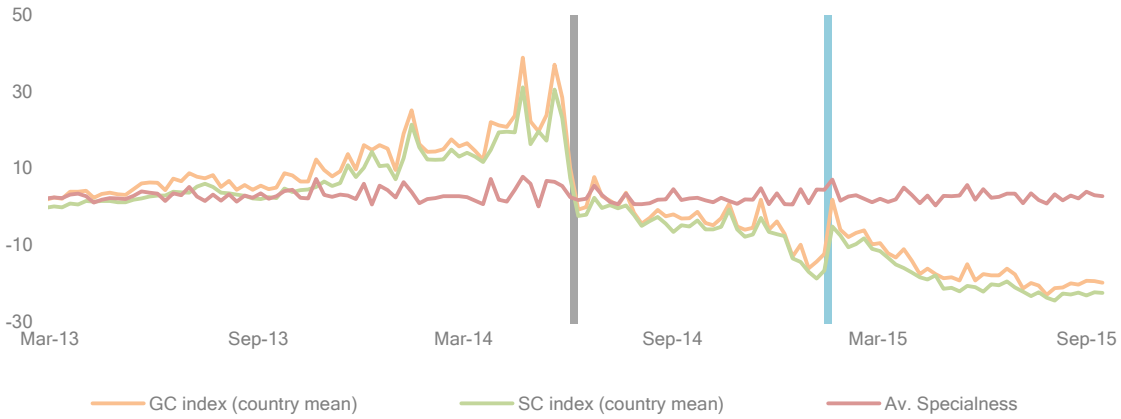
Table 1c: Traded volume by ISIN

	Overall period	before	between	after
mean	466	476	468	459
median	341	358	349	316
sd	454	442	442	487
min	1	1	1	1
max	6744	6270	6270	6744

Sources: ICAP RFR, BrokerTec, MTS, ESMA. Data for volume and average size of traded volume is in EURmn.

Note: sd= standard deviation.

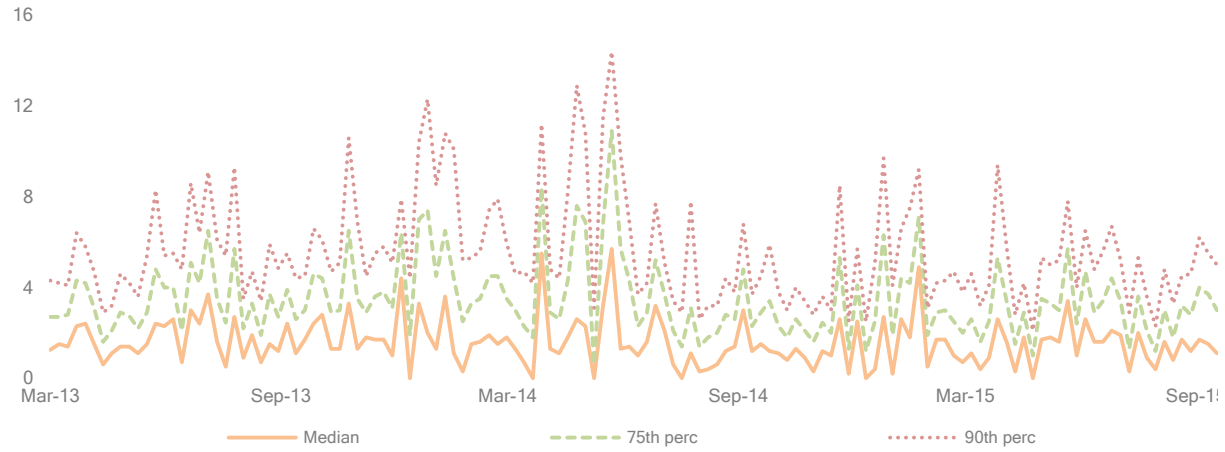
Chart 4: Evolution of specialness



Note: Weekly average Specialness , GC and SC rates. Basis point. The vertical lines indicate, respectively, the introduction of negative deposit rate (grey) and the starting of the QE programme (blue).
Sources: RepoFunds Rate (BrokerTec, MTS, ICAP), ESMA.

During crisis periods more bonds tend to become special and investors may pay larger premia to acquire some specific securities. At the same time, very special bonds - the upper tail of the distribution - are particularly sensitive to changes in market demand, especially in periods of market stress (Corradin et al, 2015). Therefore, in crisis period specialness distribution tends to become more dispersed. Looking at Chart 5, which provides a graphical illustration of the distribution of specialness in our data, this particular feature is hardly predominant since we analyse a time period mainly characterised by very low interest rates and reduced volatility.

Chart 5: Distribution of specialness



Note: Median, 75th and 90th percentile of weekly specialness.
Sources: RepoFunds Rate (BrokerTec, MTS, ICAP), ESMA.

After the introduction of the negative interest rate on deposits, the mean of VWARs dropped to a third of its value before June 2014 (-0.058 compared to 0.100%), and the decline has continued with the introduction of quantitative easing (-0.105%; Table 1b). Traded volumes on each ISIN declined after June 2014 (from EUR 476mn to EUR 468mn) and then decreased again after January 2015, reaching EUR 459mn (table 1d). The average size of traded volume slightly declined across the three periods, decreasing from around EUR 22mn to slightly less than EUR 20mn (table 1d).

Table 1d: Average size of traded volume by ISIN

	Overall period	before	between	after
mean	21.0	22.0	21.5	19.7
median	18.4	19.3	18.9	17.2
sd	14.3	15.0	14.5	13.7
min	0.5	0.5	0.5	1.0
max	539	539	539	250

Sources: ICAP RepoFunds Rate, BrokerTec, MTS, ESMA. Data for volume and average size of traded volume is in EURmn.
Note: sd= standard deviation.

For each day, we connect the data on repo market from RFR with data on securities lending market from Markit Securities Finance[17]. Table 2a-2d present standard descriptive statistics for securities lending variables: lender quantity on loan, broker–to-broker activity, utilisation rate, and borrower concentration.

[17] Markit collects securities lending information daily from 125 large custodians and 32 prime brokers, covering more than 85% of the securities lending market.

Table 2a: Lender quantity on loan

	Overall period	Before	between	After
mean	432	416	428	451
median	180	167	172	208
sd	694	652	674	760
min	0.00	0	0	0
max	9084	6308	7144	9084

Table 2b: Utilisation rate

	Overall period	Before	between	after
mean	28.8	27.5	28.3	32.1
median	21.8	19.6	21.1	27.2
sd	26.9	26.7	26.8	27.9
min	0.0	0.0	0.0	0.0
max	100.0	100.0	100.0	100.0

Table 2c: Broker-to-broker activity

	Overall period	Before	between	after
mean	437	376	373	645
median	23.5	12	15	93
sd	1997	2269	2040	1837
min	0	0	0	0
max	56903	34163	56903	20029

Table 2d: Borrower concentration

	Overall period	Before	between	after
mean	0.35	0.36	0.35	0.35
median	0.25	0.26	0.25	0.24
sd	0.31	0.32	0.31	0.30
min	0.00	0.00	0.00	0.00
max	1.00	1.00	1.00	1.00

Sources: Markit, ESMA. Note: sd= standard deviation. Data for Lender Quantity on loan and Broker-to-broker activity is in number of securities (mln).

Lender quantity on loan is the quantity of securities on loan from lenders: it represents the traditional securities lending channel with brokers borrowing assets from lenders. Lenders are mainly asset managers and institutional investors (e.g. pension funds, mutual funds, insurance companies, sovereign wealth funds and central banks) lending securities on a principal basis, or through agent lenders (e.g. custodian banks). Lender quantity on loan significantly increased after the introduction of the negative deposit rate (8.4%).

Utilisation rate is defined as the ratio between lender quantity on loan and lendable quantity. Lendable quantity, which declined in the analysed period, is the quantity of securities in lending programmes. It is therefore a proxy of the supply of collateral in the market (Chart 6). Utilisation

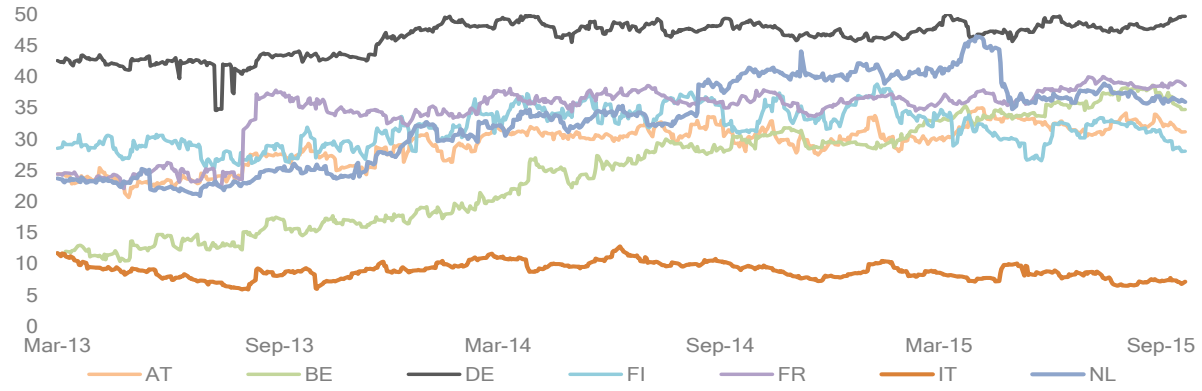
rate is used as a proxy for short-selling activities, as is done elsewhere in the literature[18]. Indeed, borrowing securities allows short sellers to deliver the securities they are betting against. The securities are then returned to the lender when the short position is closed.

Chart 6: Lendable quantity of EU government bonds

Note: Quantity of government bonds available for lending, in billion of securities.
Sources: Markit Securities Finance, ESMA.

The utilisation rate of EU government bond increased during the time period considered, from 27% before June 2014 to around 30% after the introduction of the negative interest rate on deposits, reaching 32% after the launch of ECB QE (table 2b). Utilisation rates are heterogeneous in the countries considered, with reference to both levels and trends. German sovereign bonds have the highest ratio at around 40%, while for Italian sovereign bonds the rate is less than 10%. For Austrian, Finnish and French sovereign bonds utilisation rates are relatively stable around 30%. Utilisation rates have increased significantly from 10% to around 30% from 2013 to 2015 (Chart 7).

Chart 7: Government bonds utilisation rates in selected EU countries

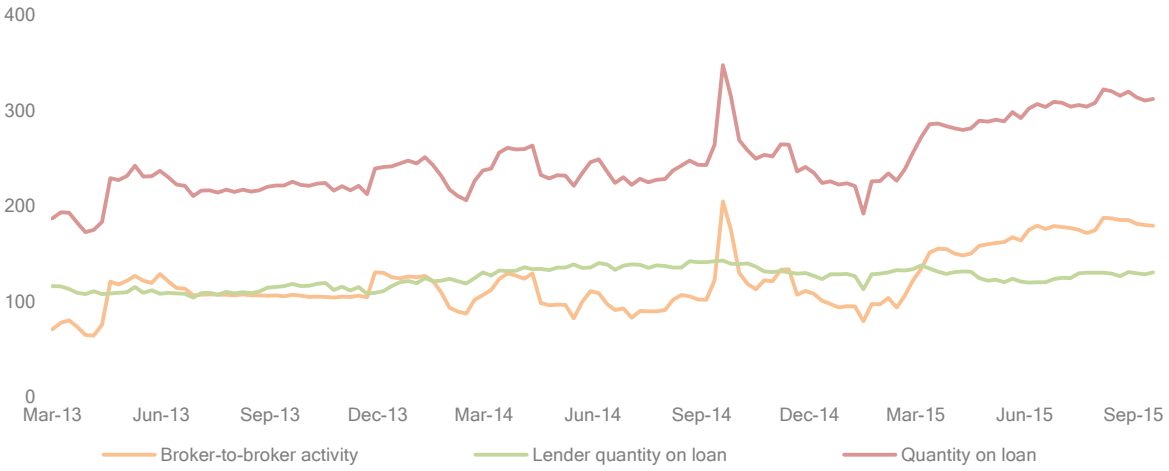


Note: Lender value on loan divided by lendable value, EA government bonds, in %.
Sources: Markit Securities Finance, ESMA

[18] See for example Engelberg et al. (2015), Luiz et al. (2014) and Aggarwal et al, (2015).

Our broker-to-broker proxy aims to capture repo activity between brokers. We define broker-to-broker activity as the difference between quantity on loan and lender quantity on loan[19]. Most of the movement in quantity on loans is explained by broker-to-broker activity, while lender quantity on loan is broadly stable in the analysed period (Charts 8).

Chart 8: EU quantity on loan, lender quantity on loan and broker-to-broker activity



Note: Quantity of European government debt securities on loan, in billion of securities.
Sources: Markit Securities Finance, ESMA.

We use broker-to-broker activity as a proxy for reuse of collateral in markets. There are several reasons to support this. First, lenders do not reuse non-cash collateral. This is the case not only for agent lenders[20], but also for buy-side investors that lend on a principal basis (such as UCITS and asset managers) and are prevented by regulation to reuse collateral. Second, brokers almost exclusively use non-cash collateral. In addition, both the lendable quantity of government bonds and the quantity of bonds on loan from lenders are broadly stable over time, therefore peaks in broker-to-broker activity reflect either high demand for securities, limited collateral availability, or a combination of both (Charts 6 and 8). Altogether, this suggests that the most likely adjustment variable is collateral reuse by brokers. This is also supported by recent discussions around European bank inventories, although there is currently no hard evidence to substantiate the claim that these inventories have declined.

Although there is likely some noise around this definition (since brokers may of course use their own securities rather than reuse collateral), we believe that this is a reasonable proxy[21]. Although most of the SFT market activity in government bonds between broker-dealers is concentrated in repo markets, the large volumes of government bonds on loan against non-cash collateral, the similarity of these transactions with SC repos (as described above) and the large substitutability of these markets suggest that our collateral reuse proxy should also reflect to a

[19] Quantity on loan includes loans from both brokers and lenders.
[20] Following the bankruptcy of Lehman Brothers, some agent lenders were unable to locate their clients' assets, which had been reused several times as collateral in other transactions, and had to offer indemnifications to compensate their clients.
[21] This has also been confirmed in meetings with various market participants.

large extent collateral reuse dynamics on repo markets. Broker-to-broker activity remained almost stable after the introduction of negative interest rates and then increased by 13% after the launch of ECB QE (Table 2c).

Borrower concentration takes a value comprised between 0 and 1 measuring the distribution of borrower demand. A very small number indicates a large number of borrowers with low borrowed values and 1 indicates a single borrower with all the broker demand. A zero means that there is no borrower demand. Borrower concentration slightly decreased during the analyzed period, declining from 0.36 to 0.34 after the introduction of negative interest rates on deposits (Table 2d).

As already mentioned in section 2.1, we follow the literature analyzing the impact of the auction cycle on specialness. We include it in our work distinguishing on-the-run from off-the-run bonds (Annex 1 tables A1a-h) and controlling for time to maturity of the bonds[22].

3.2 The empirical model

We employ panel data analysis to study how the degree of specialness of a specific bond in the repo market is affected by securities lending market, short selling activities, bond-specific characteristics and market dynamics. Our baseline model is the following:

$$Specialness_t = \alpha + \beta\,(broker\ to\ broker\ activity) + \gamma\,(short\ selling) + \delta\,(bond\ specific\ controls) + z\,(market\ controls) + \varepsilon$$

As explained above, we use broker-to-broker activity as a proxy for the reuse of collateral in the market. In normal times we expect a negative relation between broker-to-broker activity and specialness: greater reuse of collateral increases the supply of securities, in addition to the classic securities lending chain (brokers borrowing assets from lenders). This decreases the probability that these securities are on special and reduces the scarcity premium.

We proxy short-selling activity with utilisation rate: in line with previous literature we expect a positive relation between short selling and specialness. Indeed, if a trader sells short a bond in the cash market, he probably borrows in the securities lending market the same bond to cover the short position (see Duffie, 1996).

Borrower concentration is used to describe the structure of securities lending markets. A lower number of borrowers with high borrowed volumes – i.e. higher borrower concentration – is expected to be related to lower specialness.

We include 4 dummy variables equal to 1 when the bond is respectively on the run with 1-year maturity, on the run with 5-year maturity, on the run with 7-year maturity, or on the run with 10-year maturity, and 0 otherwise. We use the above dummies to investigate if among the on-the-run bonds some maturities tend to have a higher degree of specialness than others. Moreover,

[22] Main source for bond characteristics information is Thomson Reuters Datastream.

we add a dummy variable equal to 1 the first day a bond is off the run and 0 otherwise: we expect a negative relation between this dummy and specialness, in line with previous literature showing that on-the-run bonds are typically more special due to their liquidity premium (Duffie, 1996; Krishnamurthy, 2002).

We use time-to-maturity of a bond as a proxy for the liquidity of that specific bond deriving from its time-to-maturity. Generally, for comparable maturities, bonds that have been issued earlier tend to have lower liquidity, also because it is likely that significant amounts of these bonds are held by buy-and-hold investors and therefore not readily available for trading in the market.

We include in addition a time trend and a set of control variables to take into account common trends:

- Excess liquidity defined as deposits at the deposit facility net of the recourse to the marginal lending facility, plus current account holdings in excess of those contributing to the minimum reserve requirements.
- VSTOXX is based on EuroStoxx 50 real time options prices and is designed to reflect the market expectations of volatility by measuring the square root of the implied variance across all options of a given time to expiration.
- EONIA is a measure of the effective interest rate prevailing in the euro interbank overnight market. It is calculated as a weighted average of the interest rates on unsecured overnight lending transactions denominated in euro for a panel of contributing banks.

Finally, to avoid potential endogeneity issues all explanatory variables are included in the regression with a lag.

4. The empirical results

In this section we show the results obtained from panel regression. First, we analyse the drivers of specialness for the three sub periods identified (before the introduction of negative interest rates on deposits, between the introduction of the negative interest rate on deposits and the launch of the ECB QE, and after the launch of QE). The results are shown in table B1 in Annex B. Then, we estimate the same model separately for on the run and off the run bonds. The results are shown in Tables B2 and B3 in annex B.

Table B1 in Annex B shows the results for the whole sample. In the first period, before the introduction of negative interest rates on deposits, and in the third period, after the launch of ECB QE[23], we find that broker-to-broker activity is negatively related to specialness, as expected. However, in the second period, after the introduction of negative interest rates on deposits and before the launch of ECB QE, the relation between broker-to-broker activity and specialness turns positive. A possible interpretation is that, due to negative interest rates and

[23] ECB QE focuses on bonds that are usually liquid with a high degree of interdealer activity, and therefore such bonds would as a consequence tend to go more frequently on special.

prudential regulatory requirements, banks scaled back their repo business in general collateral bonds, and therefore interdealer activity fell. Lower activity in this repo market segment would translate into higher GC rates, and therefore a larger scarcity premium.

As expected and consistently with the existing literature, short selling activity has a positive and significant relation with specialness across different samples. Indeed, more short selling activity increases relative scarcity of the bond and therefore increases the degree of specialness.

Average size of repo transaction is negatively and generally significantly related to specialness, meaning that larger transactions volumes tend to decrease specialness. This result is in line with borrower concentration which also has a negative effect on specialness: a lower number of borrowers trading larger volumes is related to lower specialness

Results for on-the-run sample confirm across the three different subperiods the whole sample both with reference to the negative impact of broker-to-broker activity on specialness (being a proxy of reuse of collateral) and with respect to short selling activity (Table B2).

For off-the-run sample, short selling activity continues to be related positively and significantly with specialness while the relation with broker-to-broker activity becomes less robust (Table B3).

5. The dynamics of specialness around changes in monetary policy

To better investigate the dynamics of specialness around changes in monetary policy, including the introduction of the ECB Securities Lending Programme in April 2015, we focus our econometric exercise on the 1(2) month(s) before and after each of the following events: introduction of a negative deposit rate, the launch of quantitative easing (QE) and the introduction of the Securities Lending Programme of the ECB. As of 2 April 2015, the securities purchased under QE are made available for securities lending, either bilaterally, with the intermediation of agent lenders, or through central securities depositories. The aim of securities lending is to support bond and repo market liquidity without unduly curtailing normal repo market activity[24]. The Programme primarily targets market makers such as large broker-dealers, which makes it relevant from a collateral reuse perspective.

The model has the following specification:

$$Specialness_t = \alpha + \beta\,(broker\ to\ broker\ activity) + \gamma\,(short\ selling) + \delta\,(post\ event) + z\,(post\ event * on\ the\ run) + \varepsilon$$

where *Specialness*, *broker-to-broker activity* and *short selling* are defined as in section 3.2, *post event* is a dummy variable equal to 1 in the 1(2) month(s) after the event and *post*on the run* is the interaction between the dummy variables (post event and on the run).

[24] https://www.ecb.europa.eu/mopo/implement/omt/lending/html/index.en.html

In table B4 we report the results around the three events. We find that the scarcity premium is negatively related to broker-to-broker activity (though this link is not always statistically significant). Focusing on launch of QE, we find that the event is *positively* related to specialness when considering only one month before and after the event. From discussions with market practitioners, it emerged that many securities lending market participants removed their government bonds from lending programmes in anticipation of QE purchases. This led to a temporary increase in scarcity premia across lending channels (lenders, as well as brokers), offsetting the effect of reuse on the scarcity premia identified earlier. However, with a larger window, i.e. 2 months before and after the event, the correlation is negative. This can be explained by the fact that the larger window includes the beginning of the securities lending programme, contributing to the stabilisation of liquidity conditions in the repo market and therefore restoring the usual correlations between the two variables.

Short selling is always positively related to specialness, though it is never significant in the short temporal windows around the relevant events. The introduction of negative interest rates on deposits by the ECB overall decreased the scarcity premium, especially for on-the-run bonds. The impact of QE launch on specialness is particularly interesting[25]: indeed, with a 1-month window , QE seems to increase the scarcity premium of government bonds in the EU. However, the sign changes with the 2-month window which includes the beginning of the ECB securities lending programme. This result seems to confirm that the temporary shortage of EU sovereign collateral introduced by QE has been offset by the Securities Lending Programme.

6. Conclusions

This study analyses the drivers of the cost of obtaining high-quality collateral, proxied by specialness of government bond repos, in seven Euro Area countries between March 2013 and September 2015. Without easy access to high-quality collateral, market participants would find it more costly to trade, with a negative impact on financial stability through reduced market liquidity, and on real economy through increased frictions in bond market financing for non-financial corporations and reduced bank lending from higher funding costs.

Empirical results show that the cost of obtaining high-quality collateral increases with demand pressures in the cash market (short selling activities), even in calm financial conditions. In bear market conditions - when good collateral is needed the most - this could lead to tensions in some asset market segments. For this purpose, the distribution of specialness in repo markets is a useful indicator to detect the rise of financial stress in European repo markets, either from increased short-selling activity or from limited collateral availability.

On the other hand, the new measure of collateral reuse introduced in this paper shows that reuse can play an important role in reducing collateral scarcity premia, by alleviating demand pressures or supply restrictions, but requires transparency and monitoring due to the related

[25] For the analysis of the events we do not consider the launch of the ECB QE (22 January 2015) but the actual start of the programme on 9 March 2015, although both dates were tested. See https://www.ecb.europa.eu/mopo/implement/omt/html/index.en.html for more details.

risks[26]. This measure contributes to the debate on the measurement of collateral reuse, which remains problematic, by proposing a new alternative based on already existing data. This also suggests a possible role for countercyclical instruments, which would encourage reuse during stress periods and increase collateral flows, but discourage reuse in normal times to limit the development of long collateral chains in the system.

The period analysed in this study also includes ECB launch of quantitative easing in January 2015. We find that the ECB Programme has a significant, albeit marginal, impact on sovereign collateral scarcity premia that is offset by the beginning of the ECB securities lending programme.

The availability of new data on SFTs coming from the new EU regulation will significantly improve the transparency of repo markets and collateral reuse in European SFT markets, including the collateral scarcity premium, and allow for further research on this topic.

[26] Reuse may create risks to financial stability perspective and to investor protection. For more details on the risks faced by investors when granting the right of reuse, see http://www.isla.co.uk/wp-content/uploads/2016/04/SFTR-Information-Statement-final.pdf.

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Annex A: Descriptive statistics

ISIN level

Table A1a: Specialness for on-the-run sample

	Overall period	before	between	after
mean	0.027	0.032	0.028	0.022
median	0.016	0.019	0.016	0.014
sd	0.039	0.047	0.041	0.026
min	0.00	0.00	0.00	0.00
max	0.749	0.749	0.749	0.239

Table A1b: Volume-weighted average repo rate for on-the-run sample

	Overall period	before	between	after
mean	-0.016	0.090	0.041	-0.174
median	-0.005	0.066	0.026	-0.191
sd	0.138	0.095	0.109	0.068
min	-0.657	-0.346	-0.657	-0.372
max	1.166	1.166	1.166	0.242

Table A1c : Traded volume by ISIN for on-the-run sample

	Overall period	before	between	after
mean	486	478	479	503
median	337	344	341	323
sd	493	465	471	551
min	1.00	1.00	1.00	1.00
max	5736	5736	5736	5708

Table A1d: Average size of traded volume by ISIN for on-the-run sample

	Overall period	before	between	after
mean	21.5	21.8	21.7	21.2
median	18.4	18.6	18.6	17.6
sd	14.75	14.8	14.6	15.2
min	1.00	1.00	1.0	1.00
max	539	539	539	250

Sources: ICAP RepoFunds Rate, BrokerTec, MTS, ESMA. Data for volume and average size of traded volume is in EURmn.
Note: sd= standard deviation.
Note: Specialness = GC index – VWAP; GC index: General Collateral index for each country; VWAP: volume weighted average price aggregated by ISIN; Traded volume: volume exchanged, by ISIN; Average size of traded volume= traded volume/number of trades for each ISIN.

Table A2a: Specialness for off-the-run sample

	Overall period	before	between	after
mean	0.025	0.030	0.026	0.021
median	0.014	0.016	0.014	0.013
sd	0.039	0.046	0.040	0.025
min	0.00	0.00	0.00	0.00
max	0.787	0.787	0.787	0.270

Table A2b: Volume-weighted average repo rate for off-the-run sample

	Overall period	before	between	after
mean	-0.002	0.104	0.056	-0.164
median	0.003	0.082	0.037	-0.180
sd	0.144	0.105	0.116	0.074
min	-0.567	-0.350	-0.567	-0.400
max	1.685	1.685	1.685	0.269

Table A2c: Traded volume by ISIN for off-the-run sample

	Overall period	before	between	after
mean	486	475	464	443
median	343	365	352	314
sd	438	434	431	460
min	1.00	1.00	1.00	1.00
max	6744	6270	6270	6744

Table A2d: Average size of traded volume by ISIN for off-the-run sample

	Overall period	before	between	after
mean	20.8	22.1	21.5	19.1
median	18.4	19.5	18.9	17.1
sd	14.2	15.1	14.5	13.1
min	0.50	0.50	0.50	1.00
max	450	450	539	250

Sources: ICAP RepoFunds Rate, BrokerTec, MTS, ESMA. Data for volume and average size of traded volume is in EURmn.
Note: sd= standard deviation.

Note: Specialness = GC index – VWAP; GC index: General Collateral index for each country; VWAP: volume weighted average price aggregated by ISIN; Traded volume: volume exchanged, by ISIN; Average size of traded volume= traded volume/number of trades for each ISIN.

Annex B: Econometric results

Table B1: Whole sample ISIN-level estimates

	(1a)	(1b)	(2a)	(2b)	(3a)	(3b)
L_Broker-to-broker	-0.037*	-0.037*	0.049**	0.049**	-0.063**	-0.072**
	(0.021)	(0.021)	(0.024)	(0.024)	(0.028)	(0.028)
L_Utilisation	0.011***	0.010***	0.011***	0.011***	0.009***	0.007**
	(0.003)	(0.003)	(0.002)	(0.003)	(0.003)	(0.003)
L_Average size of repo transaction	-0.070***	-0.069***	-0.027*	-0.027*	-0.076***	-0.078***
	(0.021)	(0.021)	(0.016)	(0.016)	(0.029)	(0.029)
1y on-the-run	0.002	0.002	0.001	0.001	0.003**	0.004***
	(0.001)	(0.001)	(0.004)	(0.004)	(0.002)	(0.001)
5y on-the-run	0.006*	0.006*	0.001	0.001	-0.001	-0.001
	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)
7y on-the-run	-0.001	-0.001	-0.000	-0.000	-0.007**	-0.007**
	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)
10y on-the-run	0.003	0.003	-0.002	-0.002	-0.005	-0.005
	(0.004)	(0.004)	(0.003)	(0.003)	(0.005)	(0.005)
first day off	-0.006***	-0.006***	0.005	0.005	0.005	0.006
	(0.002)	(0.002)	(0.003)	(0.003)	(0.004)	(0.004)
time-to-maturity	-0.002***	-0.002***	-0.002***	-0.002***	0.000**	0.000**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
time trend	-0.002***	-0.002***	-0.003***	-0.003***	-0.000***	-0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
L_Borrower Concentration		-0.004***		-0.002		-0.005**
		(0.002)		(0.002)		(0.002)
Constant	4.764***	4.738***	7.130***	7.140***	0.034***	0.038***
	(0.400)	(0.399)	(0.416)	(0.418)	(0.005)	(0.005)
Observations	67,605	67,605	36,382	36,382	35,417	35,417
R-squared	0.031	0.032	0.017	0.017	0.010	0.011
Number of isin	454	454	391	391	464	464
Ad. R-squared	0.0312	0.0314	0.0169	0.0169	0.00966	0.0106

Note: Robust standard errors in parentheses;***p<0.01, **p<0.05, *p<0.1. (1a) and (1b) refer to the first subperiod (before the introduction of negative deposit rates); (2a) and (2b) refer to the second subperiod (between the introduction of negative interest rates and the launch of quantitative easing); (3a) and (3b) refer to the third subperiod (after the launch of quantitative easing). Broker-to-broker activity, utilisation rate, average size of repo transactions and borrower concentration are all included in the estimates with a lag to avoid endogeneity issues.

Table B2: On-the-run ISIN-level estimates

	(1a)	(1b)	(2a)	(2b)	(3a)	(3b)
Broker-to-broker activity	-0.065***	-0.064***	-0.072	-0.075	0.057	0.055
	(0.020)	(0.020)	(0.122)	(0.123)	(0.090)	(0.090)
Utilisation rate	0.021***	0.022***	0.018**	0.017**	0.005	0.005
	(0.006)	(0.006)	(0.007)	(0.007)	(0.008)	(0.008)
Average size of repo transaction	-0.053	-0.054	-0.085**	-0.085**	-0.124**	-0.125**
	(0.035)	(0.035)	(0.036)	(0.035)	(0.048)	(0.049)
1y on-the-run	0.003	0.002	-0.008***	-0.008***	0.008***	0.008***
	(0.003)	(0.003)	(0.001)	(0.001)	(0.002)	(0.003)
5y on-the-run	0.007*	0.006*	0.001	0.001	-0.003***	-0.003***
	(0.004)	(0.004)	(0.005)	(0.005)	(0.001)	(0.001)
7y on-the-run	0.001	0.001	-0.000	-0.000	0.001	0.000
	(0.003)	(0.003)	(0.001)	(0.001)	(0.008)	(0.008)
10y on-the-run	0.004	0.004	0.006***	0.007***	-0.005***	-0.005***
	(0.004)	(0.004)	(0.002)	(0.002)	(0.001)	(0.001)
time-to-maturity	-0.002***	-0.002***	-0.002***	-0.002***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
time trend	-0.003***	-0.003***	-0.003***	-0.003***	-0.000**	-0.000**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Borrower Concentration		0.003		-0.002		-0.002
		(0.003)		(0.003)		(0.005)
Constant	6.622***	6.630***	10.372***	10.373***	-0.008	0.038***
	(0.810)	(0.808)	(1.276)	(1.277)	(0.013)	(0.014)
Observations	19,470	19,470	10,399	10,399	5,401	5,401
R-squared	0.038	0.038	0.025	0.025	0.007	0.007
Number of isin	255	255	183	183	158	158
Ad. R-squared	0.0377	0.0377	0.0241	0.0241	0.0052	0.0051

Note: Robust standard errors in parentheses;***p<0.01, **p<0.05, *p<0.1. (1a) and (1b) refer to the first subperiod (before the introduction of negative deposit rates); (2a) and (2b) refer to the second subperiod (between the introduction of negative interest rates and the launch of quantitative easing); (3a) and (3b) refer to the third subperiod (after the launch of quantitative easing). Broker-to-broker activity, utilisation rate, average size of repo transactions and borrower concentration are all included in the estimates with a lag to avoid endogeneity issues.

Table B3: Off-the-run ISIN-level estimates

	(1a)	(1b)	(2a)	(2b)	(3a)	(3b)
Broker-to-broker activity	-0.032	-0.031	0.054**	0.054**	-0.049	0.065
	(0.024)	(0.024)	(0.023)	(0.023)	(0.035)	(0.059)
Utilisation rate	0.007**	0.005*	0.008***	0.008***	0.009**	0.001
	(0.003)	(0.003)	(0.002)	(0.002)	(0.004)	(0.005)
Average size of repo transaction	-0.077***	-0.078***	-0.008	-0.008	-0.076**	-0.134***
	(0.025)	(0.025)	(0.018)	(0.018)	(0.032)	(0.036)
Time-to-maturity	-0.002***	-0.002***	-0.002***	-0.002***	0.000**	-0.003***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Time trend	-0.002***	-0.002***	-0.003***	-0.003***	-0.049	-0.004***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.035)	(0.000)
Borrower Concentration		-0.007***		-0.001		-0.011***
		(0.002)		(0.002)		(0.003)
Constant	4.357***	4.315***	6.056***	6.063***	8.923***	8.903***
	(0.376)	(0.375)	(0.372)	(0.372)	(0.732)	(0.729)
Observations	48,135	48,135	25,983	25,983	10,179	10,179
R-squared	0.027	0.028	0.015	0.015	0.050	0.052
Number of isin	405	405	331	331	272	272
Ad. R-squared	0.0270	0.0278	0.0151	0.0151	0.0493	0.0512

Note: Robust standard errors in parentheses;***p<0.01, **p<0.05, *p<0.1. (1a) and (1b) refer to the first subperiod (before the introduction of negative deposit rates); (2a) and (2b) refer to the second subperiod (between the introduction of negative interest rates and the launch of quantitative easing); (3a) and (3b) refer to the third subperiod (after the launch of quantitative easing). Broker-to-broker activity, utilisation rate, average size of repo transactions and borrower concentration are all included in the estimates with a lag to avoid endogeneity issues.

Table B4: The dynamic of specialness around policy changes

	Negative deposit rates	ECB QE		ECB Securities lending Programme
	(1M b/a)	(1M b/a)	(2M b/a)	(1Mb/a)
Broker-to-broker activity	-0.086	0.105	-0.045*	-0.072*
	(0.070)	(0.071)	(0.024)	(0.043)
Utilisation rate	0.008	0.005*	0.008***	0.008***
	(0.005)	(0.003)	(0.002)	(0.002)
Post event	-0.026***	-0.078***	-0.008	-0.008
	(0.001)	(0.025)	(0.018)	(0.018)
Post event* on the run	-0.004***	-0.002***	-0.002***	-0.002***
	(0.001)	(0.000)	(0.000)	(0.000)
Time FE	YES	YES	YES	YES
Bond FE	YES	YES	YES	YES
Observations	9,546	9,025	17,936	9,190
Number of isin	342	337	460	448
Ad. R-squared	0.145	0.0174	0.0106	0.0854

Note: Robust standard errors in parentheses;***p<0.01, **p<0.05, *p<0.1. (1M b/a) refers to an estimation window of 1 month before and after the event. (2M b/a) refers Broker-to-broker activity and utilisation rate are included in the estimates with a lag to avoid endogeneity issues.