Intraday Dynamics and Determinants of CCP and Bilateral General-Collateral Repos

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Abstract

We study the spread between the intraday general collateral repo rate on Italian Government bonds and the ECB deposit rate, using a novel dataset. We focus on overnight repos, both cleared by central counterparty (CCP) and traded bilaterally. We observe that collateral supply, liquidity and duration affect significantly the repo riskiness and spread, but they have a reduced impact after the ECB quantitative easing interventions. Increased margins during the European sovereign crisis (ESC) further deteriorate the repo funding costs (pro-cyclical effect). Once we control for the impact of margin costs, the CCP repo appears not be significantly cheaper than the bilateral repo. Finally, we show that bonds with lower liquidity, greater supply, longer duration, and lower specialness are more likely to be selected as collateral. However, during the ESC, CCP-repo buyers tend to provide as collaterals bonds with higher liquidity and lower duration to reduce margin and repo trading costs.

JEL Codes: E43, E51, G01, G12, G15, G24

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1. Introduction

The Basel Committee on Banking Supervision published in 2008 the Principles for sound liquidity management and supervision. Principle 8, which focuses in particular on intraday liquidity management, states that a bank should actively manage and monitor its intraday liquidity positions on a timely basis under both normal and stress conditions, arrange to acquire sufficient intraday funding to meet its intraday objectives, and manage and mobilise collateral as necessary to obtain intraday funds.

The centrality of intraday liquidity management highlighted by the 2007-08 crisis has brought a lot of attention to the money market instruments that allow the exchange of intraday funds. The overnight (ON) general collateral (GC) repos are the most common financial instruments for short-term overnight collateralized borrowing, used by banks for the efficient management of their intraday liquidity. Banks generally use ON GC repos to borrow or lend funds at lower interest rates than in the overnight unsecured markets. With the ON GC repo, a borrower-bank can choose the collateral to be delivered among a pre-defined basket of securities (generally treasuries) at a later time with respect to the repo trade, with a maximum permitted time lag of two hours.[1]

In this paper we study the dynamics, characteristics and determinants of the intraday interest rate of ON GC repos that use Italian Government bonds as collateral. We focus on both repos cleared by central counterparty (CCP) and traded bilaterally. In particular, we address three main questions. First, we test whether there is any intraday pattern in the ON GC repo rates. Secondly, we seek to determine the factors which can explain the variations of interest

[1] Because the exact nature of the collateral is unknown a priori, GC repos are mostly motivated by cash lending and borrowing and not by securities lending and borrowing. On the contrary, “special repos”, which specify the exact security that serves as collateral, are typically transactions in which the cash lender wants to obtain a specific security (for either short-selling/speculation or inventory management).

rates of centrally cleared (CCP) repos and bilaterally traded repos. Third, we study the characteristics of the bonds selected as collaterals for GC repo trades.

Although often interest rate is assumed constant throughout the day, several theoretical models (Van Hoose, 1991, Angelini, 1998, and Bech and Garrat, 2003, amongst others) justify the existence of *intraday* patterns for interest rates using two main arguments: the intraday liquidity management needs of banks and/or the time value of money. Within a day there is usually no exact time when a bank needs to settle a specific payment, as far as this is done by the end of the day. On the one hand, if banks perceive that there is high risk of not meeting their end-of-day liquidity needs, they will try to secure a larger amount of funding earlier in the day. This greater demand of funding in the morning however may lead borrowing banks to pay relatively higher interest rate in the morning with respect to what they could pay in in the afternoon. In addition to that, if there is a time value of money we would expect that intraday loans with longer duration will require relatively higher interest rates. On the other hand, if banks rely on the repo market to meet liquidity obligations and try to offset large liquidity unbalances at the end of the day they may generate large unbalanced order flows with effects on repo rates. Then we might expect relatively higher repo rates in the late afternoon when banks are time constrained. We therefore start this paper by testing the existence of an intraday pattern for the repo rate in the Italian sovereign ON GC repo market.

Furthermore, the repo rate is linked to the riskiness of the collateral basket. If the collateral basket becomes riskier (i.e. on average less safe, less liquid, more volatile, in lower supply, etc.), then the intraday funding costs in the repo market increase and the intraday liquidity management can be badly affected. The repo-lender banks will require a larger premium over the risk-free rate and may be willing to pay this premium in the early hours of the trading day for overnight secured funding in order to avoid the uncertainty (i.e. the collateral market risk). The sample period we examine covers important events, such as the European sovereign crisis (ESC) and the period when the European Central Bank implemented a series of unconventional monetary policy interventions, which have affected the liquidity and availability of Italian Treasuries as collateral. We define as *intraday repo spread* the difference between the intraday Italian ON GC repo rate and the daily interest rate set by the European Central Bank (ECB) for depositing liquidity at its facility. We measure the intraday repo spread at each time when a repo trade is executed on the *Mercato dei Titoli di Stato* (MTS) market over our sample period. This spread represents a risk premium and measures the additional riskiness of the GC repo contract over the ECB deposit rate that offers lender-banks a risk-free lending opportunity. In the paper we investigate whether the variations in the intraday GC repo spread are related to changes in collateral and repo market riskiness.

Finally, after having examined the dynamics and determinants of the intraday ON GC repo spread, we turn to explore the criteria for the selection of the repo collateral.

The Italian sovereign ON GC repo market is characterized by very large daily transaction volumes, as reported in Table 1 Panel A that presents MTS volume data. MTS is one of the largest European electronic bond and repo markets and the largest one for Italian Government bonds. During our sample period, from 4 January 2010 to 30 November 2015, the total volume and the daily average volume of all overnight Italian repo transactions executed on MTS are €9 trillion and €6 billion, respectively. Our data provide very good coverage of the interbank ON GC repo market for Italian sovereign collaterals, given that trading in Italian repos is mostly conducted on the MTS platform (Dunne, Fleming, and Zholos, 2015). On MTS traders can choose to execute trades either with or without central counterparty (CCP). We call these trades as CCP and non-CCP (or bilateral) repo trades, respectively. For this reason, MTS offers an ideal dataset to study and compare the two different types of repos, as we do in this paper.

Panel B of Table 1 reports the number of bonds used as collateral in CCP, non-CCP repos and in all GC overnight repos trades on MTS during the sample period, by instrument class and maturity group. Most bonds used as collateral for repo trades (179 out of a total 335 bonds) are short-term bonds (BOTs) which are issued with 1 year or less to maturity. The rest of the collateral bonds are long-term bonds, BTP (99). The BTPs issued during our sample period have maturities ranging from 3 to 30 years. Italian ON GC repos are used for intraday liquidity management of financial institutions (especially Italian banks) and they are widely traded on MTS throughout the sample period.

Table 1: The MTS GC repo market

The table reports summary statistics for the daily nominal volume of collateral used in MTS for general overnight centrally cleared and bilateral repo transactions in Panel A, and the number of Italian sovereign bonds according to different type of bonds, maturity group and type of repo, and used as collateral in general collateral overnight repo transactions on MTS in Panel B, over the period from January 4, 2010 to November 30, 2015. Panel B also reports the total number of Italian sovereign bonds used as collateral in repo transactions recorded on MTS over the same period (by maturity group and by repo type). The classes of bonds issued by the Italian Treasury are: Buoni del Tesoro Pluriennali (BTPs), which are fixed-coupon bearing bonds; Buoni del Tesoro Pluriennali Indicizzati (BTIs), which are inflation linked-coupon bearing bonds; Buoni Ordinari del Tesoro (BOTs), which are treasury bills; Certificati del Tesoro Zero-Coupon (CTZs), which are zero-coupon bonds; and Certificati di Credito del Tesoro (CCTs), which are floating notes.

Panel A: Transacted nominal amounts of collateral in MTS repo market

Cash Volumes	Centrally Cleared Repos (Euro Millions)	Bilateral Repos (Euro Millions)	Total (Euro Millions)
Daily Average	5,004.29	1,140.76	6,083.53
Standard Deviation	1,703.30	1,265.59	2,165.68
Minimum	465.00	5.00	1,484.00
Maximum	12,254.50	8,270.00	16,816.00
Trading Days	1,502.00	1,421.00	1,502.00
Total	7,516,449.00	1,621,013.50	9,137,462.50

Panel B: Number of bonds used in repo transactions

Bond Class	Maturity Group	Sample Bonds used as Repo Collaterals		
		CCP	Bilateral	All
BTP	3	22	21	22
	5	24	23	24
	10	31	31	31
	15	10	10	10
	30	12	12	12
	Total	99	97	99
BTI	3	-		-
	5	4	4	4
	10	5	5	5
	15	3	3	3
	30	2	2	2
	Total	14	14	14
BOT	0.25	16	16	16
	0.5	79	77	79
	1	84	81	84
	Total	179	174	179
CTZ	2	21	21	21
CCT	7	22	22	22
All classes	0.25 - 30	335	328	335

Our study contributes to two main streams of literature: the studies on intraday interest rates and bank intraday liquidity management and the studies on GC repos.

Within the first stream, some papers have tested the existence of 'positive intraday interest rates'[2] in the U.S. and European money markets, but the majority of these works are focussed on unsecured money markets. For the U.S., Furfine (2001) and Bartolini et al. (2005) find evidence of positive intraday interest rates respectively in the Fedwire system for the first quarter of 1998 and in the Fed funds for the period 2002- 2004. For the European money markets, Angelini (2000) studies the intraday interest rate in the Mid, the unsecured money market where mostly Italian banks trade, during the period from 1993 to 1996. He does not find any clear evidence for the existence of intraday patterns in the interest rate. Baglioni and Monticini (2008) find instead evidence of a downward pattern in the interest rate throughout the trading day in the Italian e-Mid trading platform[3] over the period from January 2003 until December 2004. These results are different from the evidence presented in Angelini (2000) and they are attributed to the introduction of the real-time gross settlement (RTGS) system[4] which made intraday liquidity a scarce resource. The willingness to avoid the risk arising from the settlement lag induces banks to charge a premium for intraday liquidity. Furthermore, Baglioni and Monticini (2010, 2013) and Jurgilas and Žikeš (2014) find even stronger evidence for intraday interest rate patterns during the recent global financial crisis (GFC), respectively for the e-Mid and CHAPS (the UK unsecured payment system).

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[2] In this context, a 'positive intraday interest rate' points at the time value of the money borrowed at specific times during the day and to intraday variation in the cost of the loans.

[3] The "Mid" market was created in 1990 and privatised in 1999 (e-Mid S.p.A). More information can be accessed at: http://www.e-mid.it/about-us/18-about-us/85-company-profile.html

[4] The Real Time Gross Settlement (RTGS) can be defined as the continuous (real-time) settlement of funds individually on an order by order basis (without netting). 'Real Time' means the processing of instructions starts at the time when they are received rather than at some later time. 'Gross Settlement' means the settlement of transferred funds occurs individually (on an instruction by instruction basis). The funds settlement takes place in the books of the Central Bank. RTGS applies for large-value interbank funds transfers. It has the advantage of lessening settlement risk because interbank settlement happens throughout the day, rather than just at the end of the day. This – however – generates an immediate liquidity need for the banks that have to settle their payments on a real-time basis.

Within the second stream (GC repo literature), several papers explore intraday patterns and/or determinants of different European GC repo markets. Kraenzlin and Nellen (2010) study the Swiss franc overnight repo market (on the Eurex trading platform) during the period from January 1999 until December 2009. They show that the introduction of a foreign exchange settlement system increased the differential between the hourly average interest rate for overnight loans and the overnight rate for the entire day. They also find that this Swiss repo market was less affected by the GFC than the unsecured money market. Abbassi, Fecht, and Tischer (2017) investigate the existence of intraday patterns in the interest rate for the German CCP-based general collateral repos (Eurex) over the period from January 2006 until June 2012. They find that the intraday repo rate is affected by lower liquidity in the repo market and greater funding uncertainty, particularly during the crisis periods. In addition, Boissel, Derrien, Ors, and Thesmar (2017) analyse the connection between country sovereign risk and *daily* repo spreads. They use countries' CDS spreads as proxies for sovereign risk, but do not control for other characteristics of the Treasury collateral market. They show a large sensitivity of the repo spread to the country sovereign risk for the GIIPS (Greek, Irish, Italian, Portuguese, and Spanish) GC repos. Mancini, Ranaldo and Wrampelmeyer (2016) focus on a different segment of the European market, the GC Pooling (GCP) repo from Eurex, which includes a large list of high-quality sovereigns (rated above A-/A3). Given the nature of this collateral, they document the resilience of this repo segment during the crisis.

We provide several additional contributions to the existing literature.

First, we confirm the theoretical predictions of Angelini (1998, 2000) and Van Hoose (1991) on the dynamics of the *intraday* repo spread for the Italian ON GC repos traded on MTS over the period from January 2010 to November 2015: we show that the repo spread tends to decrease steadily from the first hour of trading until market closure.

Second, we examine both centrally-cleared repos and bilateral repos. To the best of our knowledge, the differences between the two repo types have never been directly addressed in previous studies. Central clearance of Italian ON GC repos has been introduced by the *Cassa di Compensazione e Garanzia* (CC&G), the main Italian central counterparty (CCP), on November 2, 2009.[5] Since then, CCP-cleared transactions have become an increasing component of all ON repo transactions and reached 95% of the whole market by November 2015.[6] The comparative analysis reveals some interesting differences. We detect a particular pattern in CCP and non-CCP transactions. Although bilateral, non-CCP trading is allowed throughout the day, traders seem to prefer CCP trading. Only when the CCP repos are no longer available (after 12.30 p.m.), we observe an increased trading activity in non-CCP repos. In normal conditions, the CCP-repo spread is on average lower than the bilateral-repo spread, mostly due to CCP mitigation of counterparty credit risk. However, we show that during the European sovereign crisis this difference stops being effective and the CCP-repos behave more like bilateral repos. This result is very important in light of the current debate on the effectiveness of CCPs' risk mitigation at the peak of regional and/or systemic crises and the pro-cyclical effects of higher margin policies.[7]

Third, differently from previous studies, we look closely at how the characteristics of the underlying collateral (Italian Treasury bond market) at an *intraday* frequency affect the Italian GC intraday repo spread. As explained earlier, the collateral riskiness can be a potential determinant of the intraday interest rate in secured money markets, such as the ON

[5] More information on *Cassa di Compensazione e Garanzia* (*CC&G*) can be accesses at the following link: http://www.lseg.com/it/areas-expertise/post-trade-services/ccp-services/ccg/about-ccg-spa/ccg-history

[6] The average daily trading volume for CCP-based ON GC repos was 69% of the total in January 2010. Trading in CCP-based repos is anonymous.

[7] In a 2015 BIS paper, Domanski, Gambacorta, and Picillo analyse possible benefits and pitfalls of the post-GFC introduction of central clearing. The paper claims that - while mitigating counterparty credit risk - central clearing may give rise to other forms of systemic risk. In particular, the concentration of the risk management of credit and liquidity risk in the CCP may affect system-wide market prices and liquidity dynamics in ways that are not yet understood. The CCP may buffer the system against relatively small shocks at the risk of potentially amplifying larger ones.

GC repos. The sample period allows us to perform this analysis over the 2010-2011 European sovereign crisis (which prolonged to part of 2012) and the post-crisis period (2012-2015). We show that collateral availability and liquidity are significant factors to explain the intraday ON GC repo spread. We also find that repo net order flows, repo number of trades and repo volatility are additional significant explanatory variables. Furthermore, we show that the excess liquidity supplied by the ECB[8] has a non-linear relationship with the intraday repo spread: the excess liquidity impacts negatively on the repo spread; however, the sign of this relationship becomes positive as excess liquidity continues to increase. The effect of some of these factors changes during and after the European sovereign crisis period. We observe that all collateral and repo risk-factors, as well as the ECB excess liquidity, are statistically-significant determinants during the crisis period. Their absolute impact is much reduced during the post-crisis period (i.e. after the ECB Long-Term Refinancing Operation in February 2012). We interpret these results as evidence that major ECB quantitative easing interventions have served their purpose of reducing the dependence of intraday repo rate on the collateral riskiness dynamics. Finally, we show that increasing margin costs during the European sovereign crisis period have further deteriorated the repo funding conditions by increasing the intraday repo spread (negative pro-cyclical effect). Once we control for the impact of margin costs (in addition to the collateral and repo risk factors) we notice that the CCP repo may not be significantly cheaper than the bilateral repo. Interestingly, we see that during the European sovereign crisis margin costs are significant for both CCP and bilateral repos, although the impact on the CCP repos is higher. We check the possible rationale of the result: higher margins signal higher counterparty risk and so they affect also the bilateral repo

[8] Consistently with the European Central Bank (2002, 2010) definition, Mancini, Ranaldo and Wrampelmeyer (2016) measure excess liquidity as total credit institutions' account holdings plus funds in the ECB deposit facility minus reserve requirements. Data on ECB deposits and reserve requirements can be downloaded at the following link: http://www.ecb.europa.eu/stats/monetary/res/html/index.en.html

spread, even if traders do not pay CCP margins to trade bilaterally. Accordingly, we observe that the higher credit risk of the banks-counterparties increases the repo costs for both the CCP and bilateral segment, particularly during the European sovereign crisis. This is also an interesting and somehow surprising result, given that the CCP should reduce the exposure of the repo contract to counterparty risk.

Finally, we provide an analysis of which bond characteristics can determine the selection of a particular instrument to be used as collateral in GC repos. To best of our knowledge, this is the first paper to investigate this type of question. We estimate logit regressions for all type of repos and then separately for CCP and non-CCP repos. We look at the bond's total outstanding amount, liquidity, modified duration, and specialness as factors which are likely to influence the choice of collateral. Duffie's (1996) model predicts that bonds with higher liquidity are more in demand and trade more on special. Also he predicts that when bonds are scarcer (in lower supply) their specialness increases. We extend his prediction by hypothesising that this type of bonds should be used less in GC repos. Accordingly, we find that bonds with higher bid-ask spreads and greater market supply are more likely to be selected as collateral in GC repos. This relationship is further confirmed by the negative sign of bond specialness on the probability of a bond to be chosen as collateral in GC repos. The more a bond is on special, the cheaper its use in the special repo market, so the less likely it is that this bond would be used for GC repos. The impact of some factors in the logit regressions changes over different periods and according to the type of repo (CCP or non-CCP). We find that during the European sovereign crisis (2010-2012), particularly for CCP-based repos, repo buyers are more likely to choose bonds with lower modified duration and higher liquidity. This may be due to the higher level of margins imposed by the clearing houses: repo buyers prefer to use higher-quality and more liquid collateral in order to reduce the cost of repo central clearing. Accordingly, when we control directly for margin costs in the logit model, we find that during the ESC the higher the margin that needs to be paid for a specific collateral bond, the lower the probability that that bond is selected as collateral for CCP repos.

The paper is organized as follows. Section 2 provides a short introduction to the overnight GC repo market. Section 3 presents a description of our sample and some preliminary statistical analysis. Section 4 provides the study of the existence of intraday patterns in interest rates in centrally-cleared and bilateral repos. Section 5 presents the study of the determinants of the ON GC intraday repo spread. Section 6 illustrates the results of the empirical analysis for the determinants of the bond-collateral selection. Section 7 summarizes the main contributions and findings of the paper.

2. The General Collateral Overnight Repo Market

A repurchase agreement (repo) is a collateralized loan based on a simultaneous sale and forward agreement to repurchase a security at a future maturity date for its original value plus an interest rate for the use of the cash (the repo rate). The repo buyer borrows cash against a security used as collateral. The repo seller lends cash and then collects the repo interest rate. GC transactions are "cash-driven" and the collateral can be any security from a predefined basket of securities. ON GC repos are used by banks for managing their intraday liquidity needs and for financing their inventories.

The first leg of the ON repo contract is instantaneously settled at the time of the trade, while the collateral is repurchased on the next business day at around 7:00 a.m. Central European Time (CET). Traders can opt for either CCP-based ON GC repos or bilateral ON GC repos.

In CCP-based repos, a central clearing counterparty[9] becomes the credit provider for any repo buyer and the credit taker for any repo seller (or reverse repo buyer). In this setting, banks do not know the identity of their counterparties. CCP-based repos trade from 7:45 a.m.[10] until 12:30 p.m. (CET), with a maximum cut-off time for the selection of the collateral set at 12:45 p.m. Bilateral repos are instead executed as 'name-display' transactions. Counterparties know each other's identities and they trade from 7:45 a.m. until 3:30 p.m., with a maximum cut-off time set at 3:45 p.m. In CCP-based repos, the CCP bears the credit risk of the transaction, so the contracts are theoretically not hindered by counterparty risk.

For each GC repo trade, the cash settlement (or cash leg) is operated by TARGET2,[11] the Eurosystem real-time payment and settlement system, while the securities settlement (or collateral leg) is operated by Express II,[12] a real-time clearing and settlement system operated by *Monte Titoli*, the central securities depository (CSD) of Italian repo trades. Usually GC collateral securities are selected shortly after the trade time, and then Express II executes the delivery of the collateral on a delivery-versus payment basis.[13] The joint process implemented by these two settlement systems allows the GC ON repo market to function on a real-time gross settlement basis (RTGS system).[14]

In addition to the ON GC repo market, Italian banks can source intraday liquidity from the e-Mid unsecured money market (mostly a retail market), or they can borrow funds at the

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[9] *Cassa di Compensazione e Garanzia* (*CC&G*)and *LCH.Clearnet* are the two main central clearing counterparties for Italian sovereign bonds and repos.

[10] In our study we exclude however repo trades executed before 8:00 a.m. CET because there are not enough observations during this part of the trading day to allow for a meaningful analysis.

[11] For a complete description of TARGET2, see the following link: https://www.ecb.europa.eu/paym/t2/html/index.en.html

[12] See document at the following link: http://www.lseg.com/sites/default/files/content/documents/MonteTitoli/MonteTitoliENG/Rules_Regulation/SettlementSystems/expressrules09092013no.en_.pdf

[13] We thank representatives of the Bank of Italy for providing details of the clearing and settlement process for repo trades.

[14] The description of the RTGS system has been confirmed during conversations with Bank of Italy and MTS. (See also the document edited by BIS for an overview of payments, clearing and settlement systems in Italy at the following link: https://www.bis.org/cpmi/publ/d105_it.pdf)

unsecured EONIA rate, or rely on interbank bilateral OTC funding agreements. One more overnight liquidity source is provided by the ECB. Banks can borrow funds overnight in a collateralized form at the ECB marginal lending rate. The Italian sovereign bonds which are eligible as collateral in this overnight ECB lending facility are also eligible in GC repos in MTS.[15] In this sense, there are no constraints on the eligibility of Italian collateral. The interest rate on the ECB marginal lending facility normally provides a ceiling level for the overnight market interest rates (including the ON GC repo rate), while the ECB deposit rate normally provides a floor level.

3. Data Selection and Descriptive Analysis

In this paper we analyse GC repo contracts collateralized by Italian Government bonds. We look at all classes of bonds issued by the Italian Treasury: BTPs – i.e. *Buoni del Tesoro Pluriennali* – which are fixed-coupon bearing bonds; BTIs – i.e. *Buoni del Tesoro Pluriennali Indicizzati* - which are inflation linked-coupon bearing bonds; BOTs – i.e. *Buoni Ordinari del Tesoro* – which are treasury bills; CTZs – i.e. *Certificati del Tesoro Zero-Coupon* –which are zero-coupon bonds; and CCTs – i.e. *Certificati di Credito del Tesoro* – which are floating notes.

We use the rich intraday MTS (*Mercato dei Titoli di Stato*) Time Series database for bonds and repos. Our sample covers the period from January 4, 2010, the first date available on this dataset, until November 30, 2015. The MTS repo platform is the leading market venue for trading GC repo contracts collateralized by Italian Treasuries. The MTS repo data provide

[15] We have verified that all types of Italian sovereign bonds are accepted as eligible securities for ECB credit operations (see the following link: https://mfi-assets.ecb.int/queryEa.htm). Furthermore, we have confirmed the absence of news about possible exclusion of Italian sovereign bonds for our sample period from 4 January 2010 until 30 November 2015 – e.g. by using Bloomberg news. The only relevant exclusion was observed in GC ECB pooling basket in Eurex repo market on 27 January 2012 after a downgrade of the Italian debt (see Armakola et al., 2016 and Mancini et al., 2016), but not in other private repo markets.

intraday information on transacted repo nominal amounts, buyer-initiated (repo) volumes, seller-initiated (reverse repo) volumes, and on the total number of trades for each type of GC repo contract (CCP or non-CCP), each repo term and each bond used as collateral (identified by its unique ISIN code) within the GC repos basket. The MTS bond data contain all intraday updates of the best three bid quotes and ask quotes (with relative order size). In addition, for each bond we have intraday prices and yields, intraday modified duration,[16] and intraday trades. Other information about the specific characteristics of the instruments – e.g. issuance date, maturity date, coupon payment schedule, etc. – are provided by MTS in separate bond reference files. Using the bonds' ISIN numbers, we match the repo market information with the bond market information.

We concentrate in particular on Italian sovereign GC repos because of the size and relevance of this market and because of the large number of available observations in MTS (see also Table 1).[17] We select all GC repos on Italian Government bonds. We find that all instruments traded on the MTS bond platform during the sample period are used at least once as collateral in GC repos.

For each business day, we collect all intraday overnight general collateral Italian repo rates[18] (we observe in total 77,467 intraday trades) and subtract the corresponding interest rate at the deposit facility of the ECB. This difference measures the intraday spread for each repo trade.

[16] In the original MTS dataset there are several missing observations for the modified duration. We have computed the modified durations for all these bonds with missing information.
[17] The intraday repo rates for general collateral contracts for other main European issuers, such as France and Germany, are not always available on the MTS Time Series database.
[18] We discard only two repos out of about 253,496. These repos correspond to a bond which is not traded in the MTS secondary bond market during the sample period.

The repo rate spread captures the extra risk of the repo with respect to this ECB risk-free base rate.[19] The theoretical motivation of this intraday repo spread is further explained in section 5.

Finally, we compute the volume-weighted average of the intraday repo spread for each trading hour. Table 2 (Panel A and B) shows the summary statistics and distribution of the *hourly* repo spreads for different repo contracts over the sample period from January, 4 2010 to November, 30 2015. There are 335 different bonds that are used as collateral for CCP-based repo contracts and 328 bonds for non-CCP repos (see also Table 1 Panel B). The total number of hourly repo spread observations is 10,604. The CCP-based repos have the largest number of observations (5,980). The non-CCP repos have 4,624 observations. Table 2 shows that the mean and median (hourly) repo spread is lower for CCP-based repos than for non-CCP repos. The CCP repo has an average hourly repo spread of 16.936 basis points, almost 3 basis points lower than the non-CCP average hourly repo spread. Moreover, if we consider the proportion of observations with hourly repo spread greater than 25 basis points (see Table 2 Panel B) this is 18.83% for CCP-based repos and 25.26% for non-CCP repos, respectively.[20] Observations with negative hourly repo spread range from 1.35% for CCP-based repos to 3.03% for non-CCP repos. The hourly repo spread for the CCP-based repos has a smaller standard deviation (20.053 bps) than the non-CCP repo intraday repo spread (23.400 bps).

In Figure 1 Panel A we plot the daily volume-weighted average of the intraday repo rates for both CCP and bilateral repos, versus the daily ECB deposit and lending rates. From January 2010 until May 2010, the repo rate mainly follows the ECB deposit rate. In this period, the

[19] Given the virtually-zero default probability of the ECB, the ECB deposit rate could be considered as the best approximation of a Euro area risk-free rate.

[20] Extremely high values of intraday repo spreads are the result of high general repo rates on particular trading days during the peak of the European sovereign crisis. Moreover, on specific days dealers are willing to pay high repo rates in order to have access to funds which are scarce in the market, for instance when they are required to cover their regulatory liquidity needs at the end of the month, or at the end of the reserve maintenance period.

ECB intervenes with Main Refinancing Operations (MROs) which have the effect of aligning the repo rate with the main policy rate. In mid-2010, the Greek sovereign crisis becomes more acute and the repo rate increases, up to 75 bps above the ECB deposit rate, although the ECB does not scale down the size of its MROs. In the summer of 2011, the sovereign crisis spreads to Italy and Spain and the Italian GC repo rate reaches a peak at 150 bps above the ECB deposit rate. This phase of high repo rates lasts for about half a year, until the ECB Long-Term Refinancing Operation (LTRO) of December 2011 finally realigns the repo rate to the ECB deposit rate. In the first half of 2014, in a context of falling inflation and downward revision of the growth forecasts (see Dunne et al. 2015), the GC repo rate increases up to 60 bps over the ECB deposit rate. After the ECB announces the implementation of the Extended Asset Purchases Programmes on June 5, 2014, the GC repo rate again realigns with the ECB deposit rate. Finally, from March 2015 onwards, the discrepancy between GC repo rates and ECB deposit rate is negligible and sometimes the repo rate drops even below the ECB deposit rate.

Figure 1 Panel B shows that in our sample period, the average daily volumes of CCP-based ON GC repos are stable, ranging from €4.03 billion in January 2010 to €4.15 billion traded in November 2015, while the volumes of the bilateral ON GC repos progressively decrease from €1.78 billion in January 2010 to €0.22 billion traded in November 2015.

Table 2: Summary statistics and distribution of hourly repo spreads by repo type

The table reports summary statistics and distribution of hourly repo spreads for repos on Italian sovereign bonds over the sample period January 4, 2010 to November 30, 2015. The repo spread is given by the difference between the GC repo rate and the ECB deposit rate. The hourly repo spread is the volume-weighted average of all intraday repo spreads over each hour of the trading day. Panel A presents the summary statistics; Panel B reports the frequency of the distribution.

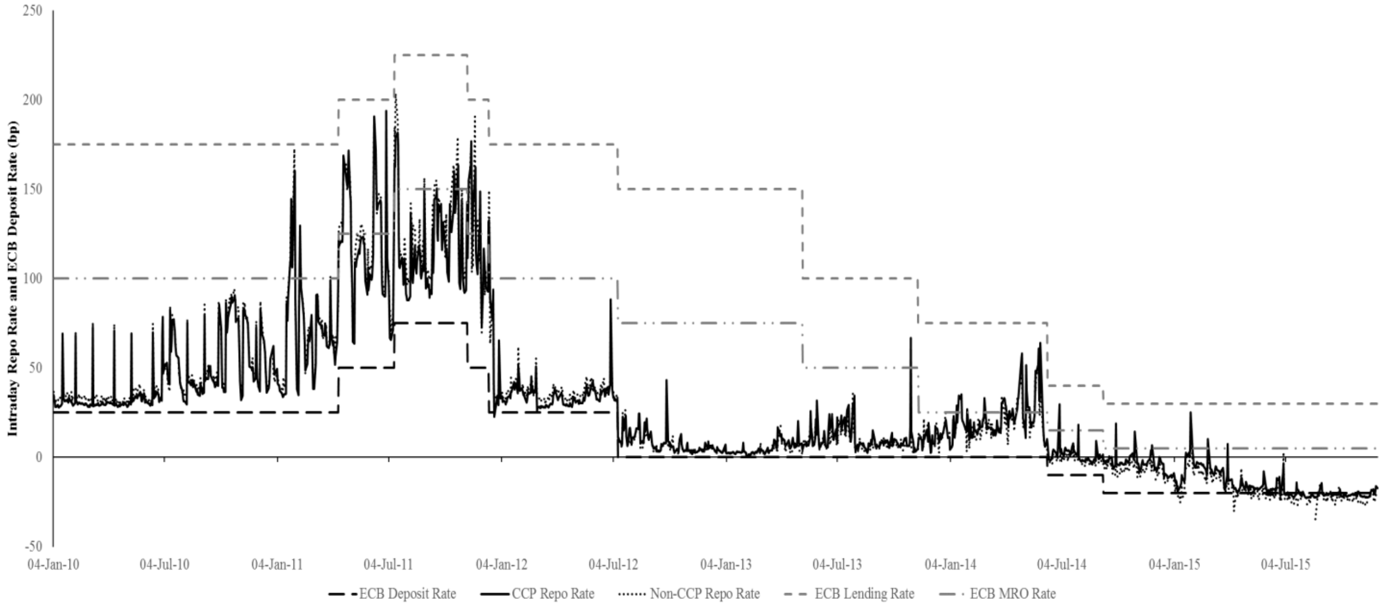
Panel A: Summary Statistics for Hourly Repo Spreads			
Repo Clearance	Central Clearing	Bilateral	All Types
Mean	16.936	19.746	18.161
Median	10.025	10.378	10.107
Standard Deviation	20.053	23.400	21.621
Kurtosis	10.201	7.486	8.835
Skewness	2.409	1.976	2.206
Range	159.016	175.237	175.237
Minimum	-8.383	-24.000	-24.000
Maximum	150.633	151.237	151.237
No. of Collateral Bonds	335	328	335
No. of Observations	5,980	4,624	10,604

Panel B: Distribution of Hourly Repo Spreads						
Hourly Repo Spread	Central Clearing		Bilateral		All Types	
(basis points)	No.	%	No.	%	No.	%
(-25, 0]	81	1.35%	140	3.03%	221	2.08%
(0, 25]	4,773	79.82%	3,316	71.71%	8,089	76.28%
(25, 50]	651	10.89%	630	13.62%	1,281	12.08%
(50, 75]	322	5.38%	360	7.79%	682	6.43%
(75, 100]	102	1.71%	121	2.62%	223	2.10%
> 100	51	0.85%	57	1.23%	108	1.02%
Total	5,980	100.00%	4,624	100.00%	10,604	100.00%

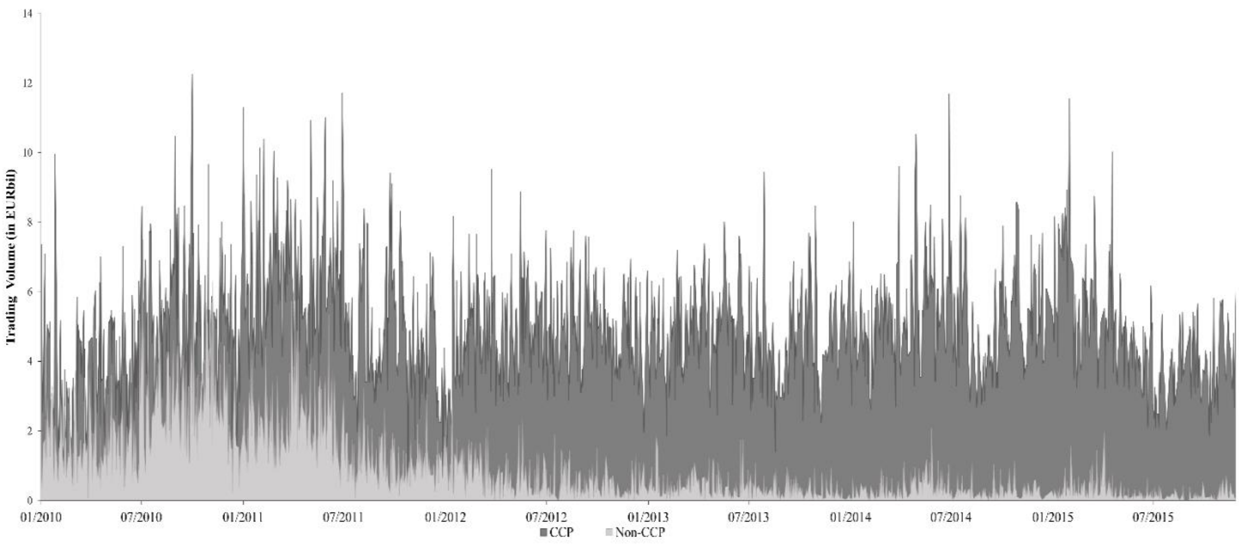
Figure 1: GC Repos

This figure shows the volume-weighted average repo rates (measured in basis points) for Italian ON GC CCP-based repos and non-CCP repos versus the ECB deposit rate, the ECB main refinancing operations (MRO) rate and the ECB lending rate in Panel A, and total daily trading volumes (measured in billions of Euros) of overnight general collateral centrally-cleared and bilaterally-traded repos on Italian sovereign bonds in Panel B, over the period from January 4, 2010 to November 30, 2015.

Panel A: CCP ON GC Italian repo rate, non-CCP ON GC Italian repo rate, and ECB deposit and lending rates



Panel B: Daily trading volumes of ON GC Italian repos



In our study we examine the relationship between the intraday GC repo spread and the intraday liquidity, modified duration, and supply of the collateral bonds. These bond variables are constructed using tick-by-tick intraday data from MTS and implementing the same sequence of steps as in Dufour, Marra, Sangiorgi, and Skinner (2017):

- We consider only bond quotes recorded during the regular daily trading hours from 8:15 a.m. until 5:00 p.m. Central European Time (CET) and discard the last 30 minutes of the trading day.
- In order to account for latency issues, we assign the same time stamp to quotes submitted to parallel platforms – MTS and Euro MTS – when they have the same price and are recorded with a small time delay of up to 3 milliseconds.
- We construct the consolidated order-book using both MTS and Euro MTS quotes and compute the overall best bid and ask prices.
- We discard consolidated quotes with negative bid-ask spreads. These may appear when the best quotes on the two alternative platforms diverge temporarily.
- We discard quotes with extremely high bid-ask spreads, since trade execution is unlikely to take place when bid-ask spreads are so large. On MTS, dealers with market making obligations cannot remove their quotes, but they are allowed to temporarily increase the spread to signal that they are not active. Short periods of unreasonably high bid-ask spreads are often the result of dealers increasing simultaneously their ask quotes and/or reducing their bid quotes. No trades are executed at these extreme quote levels. Therefore, we determine a maximum tradable spread level by conducting an ad-hoc analysis of the distributions over time of the relative bid-ask spreads observed in the consolidated order books before trade executions. We winsorise proposals with relative bid-ask spreads greater than the 99^{th} percentile of the distributions, for every maturity-bucket, every

quarter and for every instrument class. This technique ensures that no extreme bias from periods of low trading intensity during the day (e.g. from 8:15 a.m. to 9 a.m.), as well as from times of exceptional circumstances, can alter our results.[21]

4. The Intraday Repo Spread in CCP-based and Bilateral Repos

In this section we test whether there is an intraday pattern in the Italian ON GC repo spread.

First, we compute the intraday spread for each GC repo trade as the difference between the Italian general collateral rate for a repo transaction *j* on day *t* and the ECB deposit rate on the same day *t*:

$$GC\ Repo\ Spread_{j,t} = GC\ Repo\ Rate_{j,t} - ECB\ Rate_t \quad (1)$$

Second, we follow the approach of Baglioni and Monticini (2008), Kraenzlin and Nellen (2010), and Abbassi and al. (2017) to obtain a measure of hourly repo spread. Each day is divided into eight hourly time bands, denoted by $h = 1, 2, \ldots, 8$. The first band starts at 8:00 a.m. CET and the last at 15:00 p.m. CET.[22] Let us define *k* as the counter of all transactions, during hour *h* on day *t*, with $k_{h,t} = 1, \ldots, K_{h,t}$. The hourly repo spread is computed as the volume-weighted average of intraday repo spreads for all $K_{h,t}$ repo contracts traded during the corresponding hourly band *h* on day *t*:

$$GC\ Hourly\ Repo\ Spread_{h,t} = \sum_{k_{h,t}=1}^{K_{h,t}} \frac{Repo\ Spread_{k_{h,t},t} \times Vol_{k_{h,t},t}}{Vol_{h,t}} \quad (2)$$

[21]As expected, we observe that on average longer-maturity bonds are traded at higher relative bid-ask spreads than shorter-maturity bonds.

[22] We discard few trades before 8:00 a.m. and after 15:30 p.m. due to the limited number of observations available to obtain a meaningful hourly average for the intraday repo spread.

Third, we estimate the following econometric model:

$$GC\ Hourly\ Repo\ Spread_{h,t} = c + \sum_{h=1}^{7} \alpha_h x_{h,t} + \lambda' X_t + \sum_{h=1}^{7} \gamma'_h X_t x_{h,t} + \partial\ CCP_{h,t} + \epsilon_{h,t} \quad (3)$$

where: c denotes the fifth hourly band 12 p.m. – 13 p.m. (constant term); h refers to seven different hourly bands (excluding the hourly band 12 p.m. – 13 p.m.) on day t; $x_{h,t}$ is a dummy variable which takes value of one if the repo contract is traded during the hourly band h, and zero otherwise; α_h reflects the difference between the average repo spread at 12 p.m. – 13 p.m. and the average repo spread in the time band h; and ϵ stands for the i.i.d. error term. X_t is a vector of controls for seasonal effects which are standard in similar studies of money market rates: end of reserve maintenance period, end of month, end of year, and day of the week effects.[23] By including $\lambda' X_t$ in the equation we allow the constant c to vary with the seasonal controls. We also interact X_t with the hourly dummies $x_{h,t}$. Differently from Abbassi et al. (2017) who study only CCP repos, we study both CCP-based repos and bilateral repos. So we add a dummy CCP which is equal to one when the average hourly repo spread refers to centrally cleared repos, and zero otherwise. The coefficient ∂ captures the average marginal difference between the average hourly spread of CCP-based repos and bilateral repos. We expect ∂ to be negative since centrally cleared repos should trade at lower rates, due to the reduction of counterparty credit risk.

We estimate model (3) using pooled OLS with Newey-West (1987) HAC standard errors robust to heteroscedasticity and serial correlation, over the period from January 4, 2010 to November 30, 2015.[24]

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[23] See for example Jurgilas and Žikeš (2014) and Abbassi and al. (2017).

[24] We choose three trading days (for a total of 8 hours × 3 days= 24 hours) for the number of lags to be used in the Newey-West estimator. However, we have checked that the estimation is robust to alternative selection methods of the optimal number of lags.

We start by estimating the model using all repo contracts and then we re-estimate it separately for CCP-based and non-CCP repos (thereby dropping the CCP dummy from model (3)). The results are reported in Table 3.

Table 3: Regressions results for model (3) with time-of-day effects

This table reports the results of pooled OLS regressions estimated with HAC robust standard errors over the period January 4, 2010 to November 30, 2015. *** indicates 1% significance level (S.L.); ** 5% S.L.; and * 10% S.L., respectively.

Dep. Var. GC Hourly Repo Spread	All Repos	CCP	Bilateral
Time-of-day Effects			
Constant	19.769***	12.023***	20.527***
	(15.62)	(11.41)	(13.40)
8 - 9 am	2.389***	4.311***	-0.728
	(3.33)	(5.43)	(-0.24)
9 - 10 am	3.767***	5.816***	1.651
	(5.25)	(6.62)	(1.21)
10 - 11 am	3.428***	5.287***	2.010
	(4.79)	(6.06)	(1.34)
11 am - 12 pm	2.976***	4.918***	1.145
	(4.30)	(5.69)	(0.81)
13 - 14 pm	-0.300		-1.286**
	(-0.45)		(-2.02)
14 - 15 pm	-2.465***		-3.450***
	(-3.80)		(-5.64)
15 - 16 pm	-1.897***		-2.877***
	(-2.84)		(-4.58)
CCP	-6.109***		
	(-4.35)		
Seasonal Controls	Yes	Yes	Yes
Observations	10,604	5,980	4,624
Adj. R^2	0.0415	0.0344	0.0419

We observe that the adjusted R^2 differs only slightly across the three estimations in column (1) for the whole sample, and columns (2) for CCP-based repos and (3) for bilateral repos. The model explains 4.15% of intraday hourly repo spread variation for the whole sample of repos, while for CCP-based repos and bilateral repos it explains 3.44% and 4.19% respectively.

Furthermore, we observe a downward sloping pattern in the intraday repo spread over the business day, due to the incentive of banks to ensure funding liquidity at the beginning of the day (Angelini, 1998 and Van Hoose, 1991) and reduce the repo rate uncertainty that is also linked to the riskiness of its collateral. This downward pattern also relates to the time-value of money of the repo contract, since the shorter the duration of the loan, the lower the repo spread. The constant represents the average repo spread in the hourly band 12 p.m. - 1 p.m. For the whole sample of repos (first column) we find that the hourly dummies are almost all significant at the 1% level, with decreasingly positive coefficients in the morning hours (from 9 a.m. to 12 p.m.) and increasingly negative coefficients in the afternoon hours (from 1 p.m. to 3 p.m.). The repo spread increases slightly in the last hour 3-4 p.m. This is most probably due to the reduction of liquidity in the repo order book during the last hour, after most trades have been already concluded.[25] For the sample of CCP repos, we can only estimate the hourly dummies until the fifth hour of the trading day (12 - 1 p.m.), as this corresponds to the last hour of CCP-based repo trading on MTS. For bilateral repos, the hourly dummies of the morning (until 12 p.m.) are not significant, reflecting the low trading activity during this part of the trading day. Only the hourly dummies for the afternoon appear highly significant and negative.

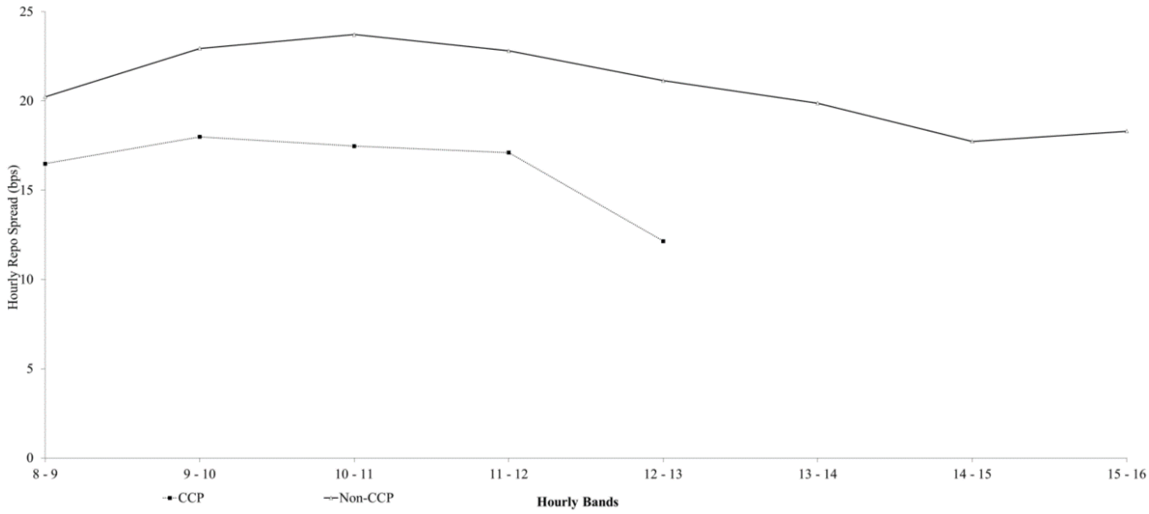
Finally, in column (1) the coefficient of the CCP dummy is negative and highly significant, as expected. In order to provide additional evidence in this respect, we plot the volume-weighted average hourly spreads for CCP and bilateral repos over the trading day in Figure 2 Panel A. For each hourly band, the spread for bilateral repos is always higher than for CCP-repos. Moreover, we can clearly observe the decreasing pattern of the repo spreads over the day.

[25] This explanation is supported by anecdotal evidence and discussion with an MTS repo trading expert.

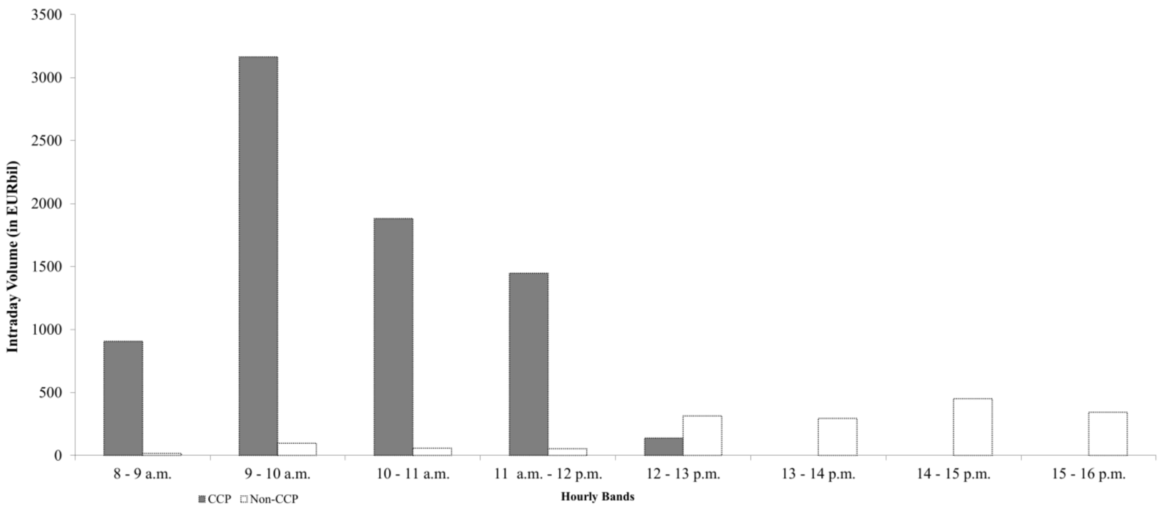
Figure 2: The GC hourly repo spread

This figure shows in Panel A the volume-weighted average hourly repo spread (measured in basis points) between the overnight general collateral repo rates on Italian sovereign bonds and the ECB deposit rate, for centrally-cleared and bilaterally-traded repos; and in Panel B the total intraday trading volumes (measured in billions of Euros) by hourly band of overnight general collateral repos on Italian sovereign bonds. The sample period goes from January 4, 2010 to November 30, 2015.The trading day ends at 12:30 p.m. CET for CCP repos and at 15:30 p.m. CET for bilaterally-traded repos. The cut-off times for the choice of collateral are 12:45 p.m. CET for CCP repos and 15:45 p.m. CET for bilaterally-traded repos. Total intraday trading volumes of overnight general collateral repos on Italian sovereign bonds (measured in billions of Euros) are calculated by hourly band over the period from January 4, 2010 to November 30, 2015.

Panel A: Realised pattern of hourly repo spread for Italian ON GC repos



Panel B: Intraday trading volumes of ON GC Italian repos by hourly band



In order to justify the insignificant hourly dummies for bilateral repos in the morning hours, in Figure 2 Panel B we explore the total repo volumes traded in the two segments at each hour. We can see that bilateral repos are not frequently traded in the morning, while their trading activity is higher from 12 p.m. to 4 p.m.

Lastly, we verify that the downward pattern in the intraday GC repo rate is obtained also using slightly different approaches, that is: (i) using individual GC repo trades (tick-by-tick data, as in Abbassi et al., 2017 and Jurgilas and Žikeš, 2014); and (ii) using as alternative measure of intraday repo spread the difference between each intraday repo rate and its daily volume-weighted average (as in Baglioni and Monticini, 2008, and Kraenzlin and Nellen 2010). These results are not reported for brevity but they are available upon request.

5. The Determinants of the Intraday Repo Spread

In the previous section we have studied the intraday hourly pattern in the repo spread for both CCP and bilateral repos. In this section we explore the determinants of the intraday repo spread. We first investigate the effects of collateral and repo market risk factors; then we explore the impact of regulatory changes in margin policy and CCP costs. Finally, we look into the impact of counterparty risk. The analysis is performed on the full sample of repo spreads as well as: (i) separately on CCP and bilateral repos; and (ii) during and after the European sovereign crisis (ESC) period.

5.1 Collateral and Repo Market Riskiness

We start by assuming, as in Boissel et al. (2017), that the lenders arbitrage between overnight lending on the repo market at $GC\ Repo\ Rate_{h,t}$ (where h indicates the hour of the repo transaction, t the day) and lending to the ECB with no risk at the deposit rate $ECB\ Rate_{t}$. If the repo loan is risk-free, it will be priced equal to $ECB\ Rate_t$. We conjecture that in the presence of collateral and repo market risks the price of repo loans $-$ $GC\ Repo\ Rate_{h,t}$ $-$ would be a function of such risks, as they were observed in the previous hour ($X_{h-1,t}^{BOND}$ and $X_{h-1,t}^{REPO}$). In particular, the expected GC repo spread is equal to the ECB rate plus the expected repo spread $S(X_{k,t,h-1}^{BOND}, X_{k,t,h-1}^{REPO})$ that represents the extra premium required by the lenders:

$$GC\ Hourly\ Repo\ Rate_{h,t} = ECB\ Rate_t + S(X_{h-1,t}^{BOND}, X_{h-1,t}^{REPO}) \quad (4)$$

We can re-write (4) as the following implicit regression model:

$$GC\ Hourly\ Repo\ Spread_{h,t} = \alpha + S\left(X_{h-1,t}^{BOND}, X_{h-1,t}^{REPO}\right) + \varepsilon_{i,h,t} \quad (5)$$

Differently from previous papers, we use a wider set of factors which capture the collateral riskiness (X^{BOND}). In the GC repo market, dealers have to price the repo before they know which security will be provided as collateral. The bonds to be used as collateral are selected after the execution of the repo trade, with a time delay ranging from a few minutes to a maximum of two hours. Thus, we assume that the dealers will price the repo based on the risk factors of a representative security in the collateral basket. More specifically, on each day *t* we assume they will look at the average characteristics of the bonds that have been selected as collateral over the previous month.

First, we control for the supply level of Italian Government bonds in the secondary MTS market. For each bond, we measure its supply as the time-weighted average volume of collateral bonds available for sale at the top three levels of the ask price for each hourly band, on each trading day. We then build a weighted average supply across all bonds, and separately for bonds used in CCP-based and bilaterally-traded repos. Figure 3 in Panel A plots the average supply of the bonds used as collateral against the total notional outstanding amount of Italian Government bonds. Both variables show an increasing trend over time, but the average bond supply displays greater variability around this trend, therefore capturing better the change in traders' endowments of bonds on the secondary MTS market. We expect that as the average supply of bonds increases, the total amount of collateral available for GC repos expands, the total demand of GC repos increases, and so does its intraday repo spread. If on average the borrowing-banks have more collateral available, they can use it to borrow at the cheaper GC repo rate instead of borrowing at the higher rates offered in the unsecured funding markets. When collateral supply is instead limited, there are fewer bonds to be used as collateral and thus the GC repo demand decreases.

We also expect that the more liquid the bonds used as collateral, the lower the intraday repo rate, as the riskiness of the repo trade decreases. We use as proxy for bond liquidity the relative bid-ask spread, measured as the time-weighted average bid-ask spread for each bond, over each hour, on each trading day. Then we build the weighted average bid-ask spread across all bonds, and separately for bonds used in CCP-based and for bilaterally-traded repos. In Figure 3 Panel B we plot the bond market average bid-ask spread over time. Pelizzon et al. (2016) show that the quoted bid-ask spreads of Italian treasuries are closely correlated with their credit risk, measured by the Italian CDS spread. As a consequence, controlling for other measures of sovereign risk would be redundant.

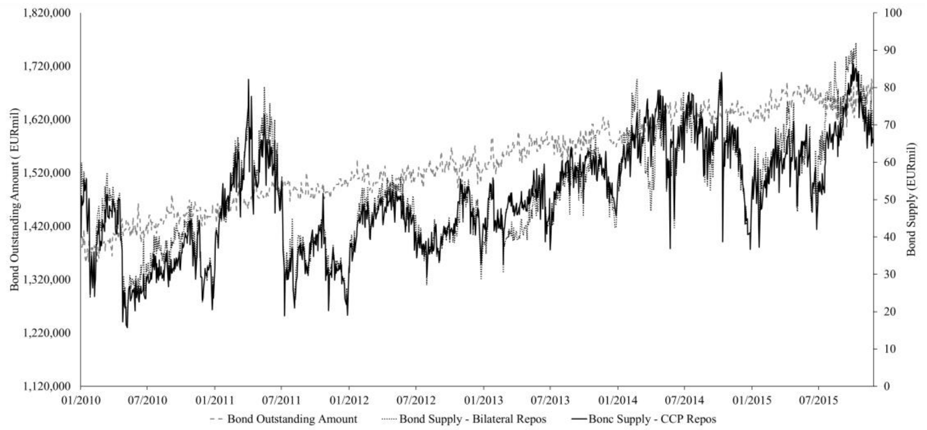
Given the collateralized nature of the repo transactions, the counterparty doing a reverse repo (i.e. the lender) can face losses due to higher bond credit and interest rate risk that can reduce the collateral value. In such circumstances, a higher intraday repo rate would be required to compensate the higher potential risk of the collateral. As mentioned above, the bond credit risk is already captured by the quoted bid-ask spread. We use the bond modified duration instead as measure of collateral interest rate risk. As a bond trades at different prices throughout the day, we measure its modified duration based on the last observed price of the bond for each hourly band on each specific day. We expect that the higher the average modified duration of the bonds used as collateral, the higher the interest rate risk exposure of the bonds, the greater the risk of the repo contracts. Consequently, the intraday GC repo interest rate will be higher. In Figure 3 Panel C we plot the daily bond weighted-average modified duration over time for both CCP and bilateral repos.

In addition to the bond risk factors, we consider three more factors that capture the repo market riskiness and the uncertainty in funding costs. We control for the repo net order flow, i.e. the difference between aggregate buyer-initiated volumes (repos) and aggregate seller-initiated volume (reverse repos) for each hourly band, day and repo contract. We expect that a higher net order flow indicates higher net demand pressure for GC repos, so it will lead to a wider repo spread. We also control for the number of trades in the repo market, for each day, hourly band and type of repo contract. An increase in the number of repo trades can happen when repo lending replaces riskier unsecured funding sources. In this case, repos work as a 'shock-absorber' when funding risk is higher (Mancini et al. 2016). This implies that a higher number of repo trades leads to a larger repo spread. Moreover, as in Abbassi and al. (2017), we use repo volatility as a proxy for uncertainty in funding costs. Repo volatility is measured as the standard deviation of all repo rates for each hourly band computed over a 22-day rolling window.

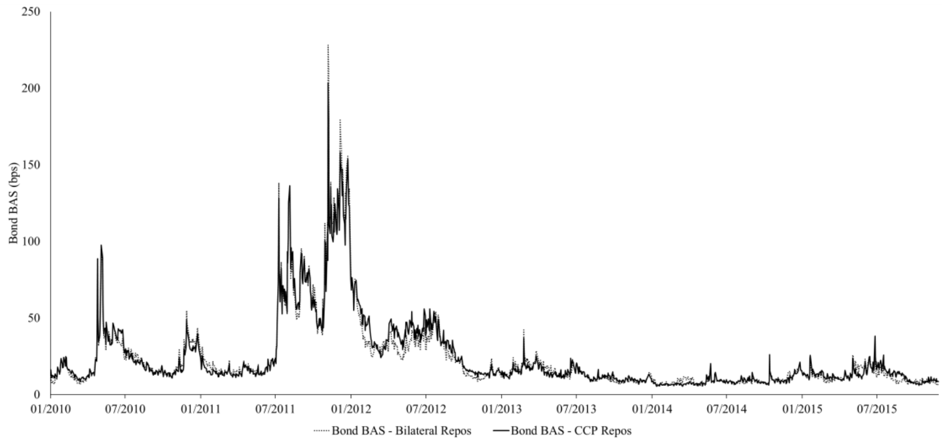
Fig. 3: Collateral Riskiness

This figure shows the daily average of Bond Supply (measured in Euro millions) versus the total outstanding amount of all Italian sovereign bonds (measured in Euro millions), the daily average of bonds' relative bid-ask spread (measured in basis points) in Panel B, and daily average of bonds' modified duration in Panel C, for bonds used in CCP and bilateral repos over the period from January 4, 2010 to November 30, 2015

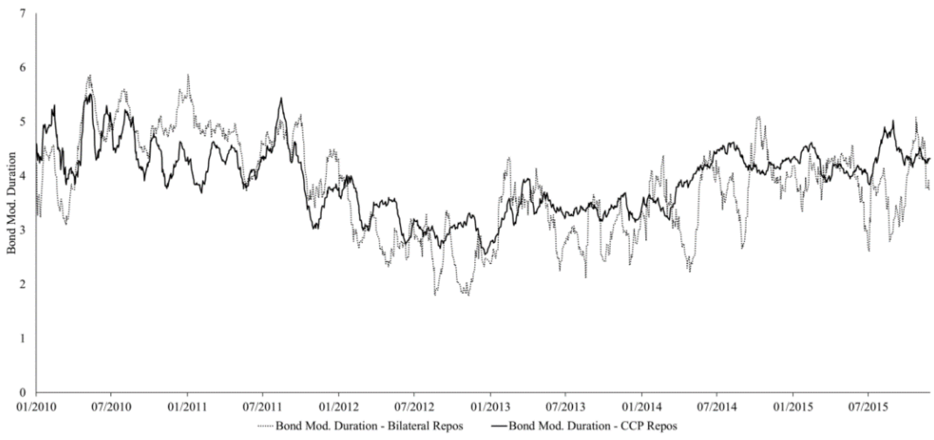
Panel A: Collateral Bond Supply and Outstanding Amount



Panel B: Collateral Bond BAS



Panel C: Collateral Bond Modified Duration

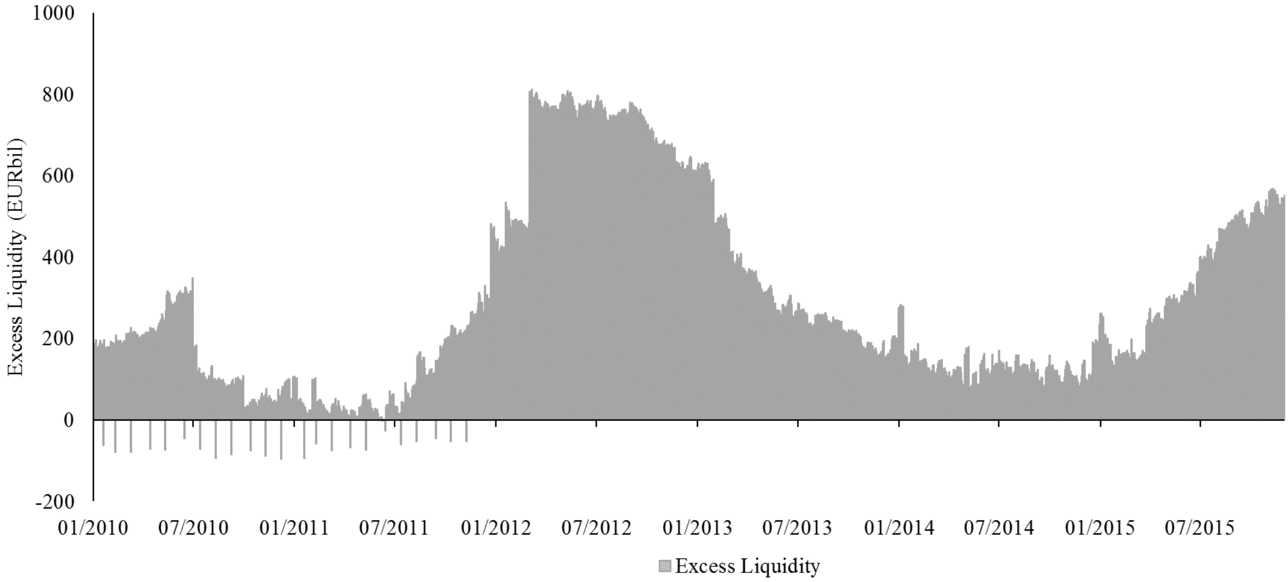


Finally, we consider the ECB excess liquidity. This is a measure of the extra liquidity injected in the system by ECB unconventional interventions and deposited by banks overnight at the ECB deposit facility. We compute the daily excess liquidity as the sum of credit institutions' current account holdings and funds deposited at the ECB deposit facility minus their reserve requirements. Figure 4 Panel A shows the dynamics of the excess liquidity over our sample period. A positive excess liquidity indicates a liquidity surplus in the financial system which reduces the repo spread. Mancini et al. (2016) observe that the excess liquidity is inversely related to Eurex GC Pooling (GCP) repo rate, but nonlinearly. When the GCP repo rate hits the bottom of the ECB's interest rate corridor – the deposit rate – it will be no longer responsive to additional liquidity provision. On the contrary, additional provisions could even deteriorate the secured interbank lending and repo volumes and the marginal excess liquidity can become positively related to the repo rate. Interestingly, we also observe a non-linear relationship between the ECB excess liquidity and the Italian ON GC repo rate (see Figure 4 Panel B).

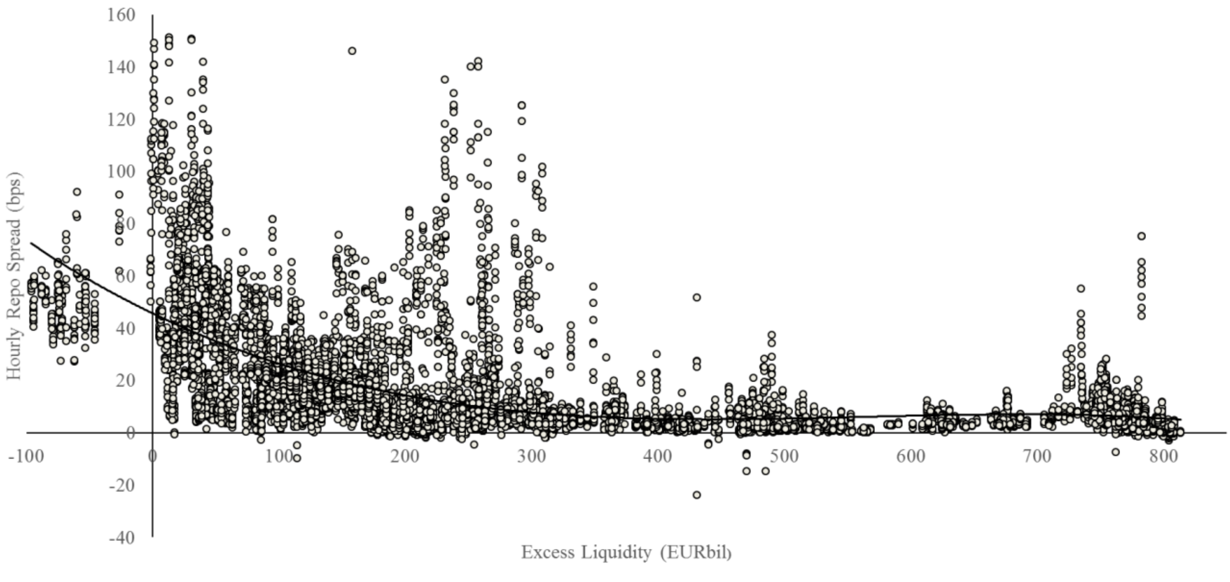
Figure 4: Excess Liquidity

This figure shows the total daily excess liquidity (measured in billions of Euros) deposited at ECB facility in Panel A, and total daily excess liquidity (measured in billions of Euros) deposited at ECB facility plotted against hourly repo spread (measured in basis points) in Panel B, from January 4, 2010 to November 30, 2015. The fitted line in Panel B is a cubic polynomial function which represents the non-linear relation between Excess Liquidity and the hourly repo spread.

Panel A: Excess Liquidity deposited at ECB Facility over time



Panel B: Excess Liquidity deposited at ECB Facility and Hourly Repo Spread



5.2 Model Specification

We estimate the following model (6), first for all repos and then separately for centrally-cleared and bilaterally-traded repos.

$$GC\ Hourly\ Repo\ Spread_{h,t} = \alpha + \beta_1\ Bond\ Supply_{h-1,t} + \beta_2\ Bond\ BAS_{h-1,t} + \beta_3\ Bond\ Mod.Duration_{h-1,t} + \beta_4\ Repo\ Net\ Order\ Flow_{h-1,t} + \beta_5\ Repo\ Trades_{h-1,t} + \beta_6\ Repo\ Volatility_{h-1,t} + \beta_7\ CCP_{h-1,t} + \beta_8\ EL_{t-1} + \beta_9\ EL_{t-1}^2 + \sum_{h=1}^{7} \alpha_h x_{h,t} + \lambda'^{X_t} + \sum_{h=1}^{7} \gamma'_h X_t x_{h,t} + \epsilon_{h,t} \quad (6)$$

We use all lagged variables (*h-1*) on the right-hand side of equation (6) to avoid endogeneity problems. We construct all proxies for collateral riskiness (Bond Supply, Bond BAS, and Bond Modified Duration) as portfolio-weighted averages. The reference portfolio comprises all bonds used as collateral in repo transactions over the previous trading month. The weights on day *t* are calculated as the ratio between the quantity of each bond used as collateral and the total quantity of transacted collateral over the previous month (i.e. previous 22 days starting from the day *t-1*).[26] The model in equation (6) extends the model in equation (3) by including:

- Proxies of collateral riskiness:

Bond Supply $_{h-1,t}$: β_1 is expected to be positive.

Bond BAS $_{h-1,t}$: β_2 is expected to be positive.

Bond Mod. Duration $_{h-1,t}$: β_3 is expected to be positive.

[26] In other words, on day *t* we use weights based on data until day *t-1*. The bonds to be used as collateral are selected after the execution of the repo trade, with a time delay ranging from a few minutes to maximum two hours. So in practice traders can build their expectations about collateral riskiness on day *t* by measuring the risk proxies in the bond market at the end of the previous day *t-1* and by exploiting information on the use of each instrument as collateral during the previous month.

- Proxies of repo riskiness:

Repo Net Order Flow $_{h-1, t}$: β_4 is expected to be positive.

Repo Trades $_{h-1, t}$: β_5 is expected to be positive.

Repo Volatility $_{h-1, t}$: β_6 is expected to be positive.

EL $_{t-1}$: β_8 is expected to be negative. We also include the squared term EL^2_{t-1} and expect the sign of its coefficient β_9 to be positive.

As in model (3), we also control for the time-of-day effects ($x_{h,t}$) and for the seasonal effects (X_t) interacted with the hourly dummies $x_{h,t}$. When we perform the regression on the aggregate sample of repos, we also include the dummy *CCP*.

5.3 Empirical Results

Table 4 Panels A, B, and C report summary statistics for all the explanatory variables (respectively for the aggregate repo sample and for CCP and non-CCP repos). In Table 5 Panels A, B, and C, we also check the sample correlations between all variables. With only two exceptions, all pair-wise correlations between the collateral and repo riskiness proxies are below 40%. The two exceptions are the correlations between Bond Supply and Bond Bas (for the whole sample: -59%, for CCP: -63%, for bilateral: -53%) and between Bond Bas and Repo Volatility (for the whole sample: 63%, for CCP: 60%, for bilateral: 70%). We also observe a high negative correlation between Bond Modified Duration and Excess Liquidity, ranging between 53% and 66%. We notice that this high level of negative correlation is recorded only over the post-crisis period (from February 2012 to June 2014), when the excess liquidity gradually decreases from its high levels of the sovereign crisis period, while the average bond modified duration gradually increases.

Table 4: Summary statistics for explanatory variables

The table presents the summary statistics for all independent variables over the aggregate repo sample (Panel A) and separately for CCP-based repos (Panel B) and bilaterally-traded repos (Period C) over the period that goes from January 4, 2010 to November, 30 2015. **Bond Supply** is measured by the portfolio-weighted hourly average of the sum of outstanding notional of bonds available for purchase at the top three levels of the ask-side (the measurement unit is millions of Euros). **Bond Bas** is the portfolio-weighted hourly average bond bid-ask spread. **Bond Mod. Duration** is measured by the portfolio-weighted hourly average bond modified duration. **Repo Net Order Flow** is equal to the hourly difference between buyer-initiated volume and seller-initiated volume of general collateral repo (measured in millions of Euros). **Repo Trades** is the total number of hourly repo transactions. **Repo Volatility** is measured by the standard deviation of repo rates for each hour over a rolling window of 22 days. **EL** is the total excess liquidity deposited daily at the ECB facility and it is computed as the credit institutions' current account holdings, plus funds in the ECB deposit facility minus reserve requirements (the measurement unit is billions of Euros). **Margin Costs** (measured in percentage) is the initial margin required by the Italian central counterparties for the Italian sovereign bonds for a duration ranging from 3.25 to 4.75 years. **The Excess Bank CDS** (measured in basis points) is the average difference between banks' daily (senior 5-year Euro–denominated) CDS premium and the 5-year Euro-denominated Italian CDS premium obtained from Bloomberg. The average measure is weighted by the market capitalization of the Italian banks.

Panel A: All Repos									
Variables	Obs.	Mean	Median	SD	Kurtosis	Skewness	Range	Min	Max
Bond Supply (€ M)	10,604	47.720	46.946	15.917	2.358	0.086	98.924	1.281	100.205
Bond BAS	10,604	26.093	15.082	28.222	13.836	2.854	259.046	0.110	259.156
Bond Mod. Duration	10,604	3.979	4.073	0.770	2.844	-0.277	5.713	0.161	5.874
Repo Net Order Flow (€ M)	10,604	-140.300	-66.000	747.979	7.366	-0.461	10,442.500	-4,730.500	5,712.000
Repo Trades	10,604	6.577	4.000	6.189	6.109	1.601	53.000	1.000	54.000
Repo Volatility	10,604	5.495	4.212	4.628	14.806	2.976	36.535	0.903	37.438
EL (€ B)	10,604	270.085	198.395	228.730	2.870	0.960	909.432	-96.221	813.211
Margin Costs	10,604	4.814	4.900	2.102	1.610	-0.207	7.200	1.500	8.700
Excess Bank CDS	10,604	49.616	36.246	48.949	2.495	0.589	254.594	-43.837	210.756
Panel B: CCP									
Variables	Obs.	Mean	Median	SD	Kurtosis	Skewness	Range	Min	Max
Bond Supply (€ M)	5,980	47.998	48.195	16.989	2.178	-0.037	98.924	1.281	100.205
Bond BAS	5,980	27.047	14.889	28.941	11.618	2.597	226.098	0.139	226.237
Bond Mod. Duration	5,980	3.938	4.055	0.611	3.123	-0.216	5.346	0.161	5.507
Repo Net Order Flow (€ M)	5,980	-183.755	-125.000	924.350	5.238	-0.253	10,442.500	-4,730.500	5,712.000
Repo Trades	5,980	9.701	9.000	6.511	4.938	1.166	53.000	1.000	54.000
Repo Volatility	5,980	4.889	3.616	4.106	15.736	3.105	29.920	0.903	30.823
EL (€ B)	5,980	285.173	209.743	226.685	2.688	0.885	909.432	-96.221	813.211
Margin Costs	5,980	5.155	4.900	1.935	2.004	-0.479	7.200	1.500	8.700
Excess Bank CDS	5,980	51.911	36.725	48.038	2.461	0.619	254.594	-43.837	210.756
Panel C: Bilateral									
Variables	Obs.	Mean	Median	SD	Kurtosis	Skewness	Range	Min	Max
Bond Supply (€ M)	4,624	47.361	45.875	14.407	2.641	0.316	92.061	3.078	95.139
Bond BAS	4,624	24.858	15.238	27.219	17.477	3.242	259.046	0.110	259.156
Bond Mod. Duration	4,624	4.032	4.139	0.934	2.323	-0.375	5.708	0.166	5.874
Repo Net Order Flow (€ M)	4,624	-84.102	-50.000	415.364	10.018	-0.977	5,806.000	-3,341.000	2,465.000
Repo Trades	4,624	2.536	2.000	2.015	8.378	1.986	16.000	1.000	17.000
Repo Volatility	4,624	6.278	4.917	5.122	13.288	2.802	36.313	1.125	37.438
EL (€ B)	4,624	250.572	185.172	229.908	3.166	1.078	909.432	-96.221	813.211
Margin Costs	4,624	4.373	4.200	2.223	1.459	0.155	7.200	1.500	8.700
Excess Bank CDS	4,624	46.648	34.689	49.950	2.522	0.572	254.594	-43.837	210.756

Table 5: Pearson correlation matrixes for the aggregate sample, the CCP-based repo and the bilateral repo samples

Correlation matrix of dependent and independent variables for the aggregate repo sample (Panel A) and separately for CCP-based repos (Panel B) and bilaterally-traded repos (Panel C) over the period that goes from January 4, 2010 to November 30, 2015. Variable definitions and measurements are explained in Table 4. *** indicates 1% significance level (S.L.); ** 5% S.L.; and * 10% S.L., respectively.

Panel A: All Repos

Variable	GC Hourly Repo Spread	Bond Supply	Bond BAS	Bond Mod. Duration	Repo Net Order Flow	Repo Trades	Repo Volatility	EL	Margin Costs
Bond Supply	0.022**								
Bond BAS	0.176***	-0.592***							
Bond Mod. Duration	0.203***	-0.077***	0.077***						
Repo Net Order Flow	0.068***	0.075***	-0.026***	-0.046***					
Repo Trades	0.029***	0.231***	-0.081***	-0.010	-0.122***				
Repo Volatility	0.441***	-0.223***	0.627***	0.097***	-0.005	-0.071***			
EL	-0.464***	-0.11***	0.115***	-0.59***	0.046***	-0.026**	-0.213***		
Margin Costs	-0.213***	0.161***	0.09***	-0.722***	0.059***	0.152***	0.052***	0.557***	
Excess Bank CDS	0.014	-0.061***	0.196***	-0.562***	0.06***	0.008	0.192***	0.533***	0.661***

Panel B: CCP

Variable	GC Hourly Repo Spread	Bond Supply	Bond BAS	Bond Mod. Duration	Repo Net Order Flow	Repo Trades	Repo Volatility	EL	Margin Costs
Bond Supply	-0.049***								
Bond BAS	0.197***	-0.633***							
Bond Mod. Duration	0.098***	0.068***	-0.044***						
Repo Net Order Flow	0.078***	0.082***	-0.025*	-0.038***					
Repo Trades	0.066***	0.366***	-0.178***	-0.042***	-0.086***				
Repo Volatility	0.481***	-0.241***	0.599***	-0.020	-0.020	0.003			
EL	-0.471***	-0.109***	0.147***	-0.527***	0.043***	-0.062***	-0.228***		
Margin Costs	-0.231***	0.153***	0.067***	-0.713***	0.065***	0.163***	0.001	0.503***	
Excess Bank CDS	-0.018	-0.123***	0.222***	-0.65***	0.063***	-0.014	0.158***	0.537***	0.636***

Panel C: Bilateral

Variable	Hourly Repo Spread	Bond Supply	Bond BAS	Bond Mod. Duration	Repo Net Order Flow	Repo Trades	Repo Volatility	EL	Margin Costs
Bond Supply	0.118***								
Bond BAS	0.16***	-0.53***							
Bond Mod. Duration	0.277***	-0.227***	0.195***						
Repo Net Order Flow	0.053***	0.067***	-0.025*	-0.098***					
Repo Trades	0.196***	-0.093***	0.04***	0.259***	-0.267***				
Repo Volatility	0.398***	-0.21***	0.701***	0.164***	-0.011	0.081***			
EL	-0.453***	-0.118***	0.067***	-0.661***	0.086***	-0.226***	-0.184***		
Margin Costs	-0.18***	0.175***	0.106***	-0.745***	0.115***	-0.283***	0.155***	0.614***	
Excess Bank CDS	0.055***	0.026*	0.158***	-0.507***	0.083***	-0.101***	0.248***	0.525***	0.695***

We estimate model (6) using pooled OLS with Newey-West HAC robust standard errors, first for the whole sample of repo trades, and then separately for CCP repos and bilateral repos. The results are reported in Table 6. In order to account for the highly correlated regressors, we introduce them sequentially. Namely, in the first specification (columns 1, 5, and 9) we only include the collateral riskiness proxies. In the second specification (columns 2, 6, and 10) we add the repo riskiness proxies, except the Repo Volatility due to its high correlation with Bond Bas. In the third specification (columns 3, 7, and 11) we drop Bond Bas, due to its high correlation with Bond Supply, but include Repo Volatility. In the fourth specification (columns 4, 8, and 12) we include the Excess Liquidity and its squared value, but we drop the Bond Modified Duration, given their high correlation. The most complete specification of model (6) in columns 4, 8, and 12 explains about 47%, 50%, and 46% of intraday repo spread variation respectively for all repos, CCP-based repos, and bilateral repos.

We start our discussion of the results from the proxies of collateral riskiness. As expected, the intraday repo spread increases with higher bond supply. Bond Supply presents significant positive coefficients for both CCP-based and bilaterally-traded repo contracts. In economic terms,[27] a one-standard deviation increase in Bond Supply induces an increase on the intraday repo spread of 5.14 bps, 3.07 bps and 7.83 bps for all repos, CCP and bilateral repos, respectively. Bond Bas is significant at the 1% level for all repos, CCP-based repos, and bilaterally-traded repos with the expected positive coefficient. The less liquid are the bonds, the costlier is to obtain repo funding. A one-standard deviation increase in Bond Bas induces an increase of 6.15 bps (All Repos), 5.47 bps (CCP), and 6.51 bps (Bilateral).

[27] The economic impact of an independent variable is calculated as the product between the standard deviation of that independent variable and the estimated coefficient (over the specific sub-sample considered). When calculating the economic impact of the proxies for collateral riskiness, we refer to their estimated coefficients in Table 6, column 1 (for the aggregate sample), 5 (for CCP-based repos) and 9 (for bilateral repos).

Table 6: Collateral risk and funding costs - Pooled regressions results for model (6)

This table reports the results of pooled OLS regressions estimated with HAC robust standard errors over the period January 4, 2010 to November 30, 2015. Variable definitions and measurements are explained at Table 4. **Repo Net Order Flow** is measured here in billions of Euros. $\mathbf{EL^2}$ is rescaled over 1,000. *** indicates 1% significance level (S.L.); ** 5% S.L.; and * 10% S.L., respectively.

Period	Full Sample 01/01/2010 - 30/11/2015											
Dep. Var. GC Hourly Repo Spread	All Repos				CCP				Bilateral			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Constant	-24.833***	-24.115***	-26.121***	18.707***	-17.376***	-18.749	-22.067***	19.835***	-41.524***	-41.806***	-39.264***	14.001***
	(-9.14)	(-8.86)	(-10.76)	(8.60)	(-4.19)	(.)	(-6.58)	(7.65)	(-9.87)	(-10.25)	(-10.13)	(3.81)
Lag Bond Supply	0.323***	0.297***	0.232***	0.157***	0.181***	0.137***	0.123***	0.106***	0.544***	0.551***	0.439***	0.234***
	(8.65)	(7.87)	(7.89)	(5.75)	(4.07)	(3.07)	(3.75)	(3.72)	(8.96)	(9.40)	(8.65)	(4.58)
Lag Bond BAS	0.218***	0.215***		0.046	0.189***	0.184***		0.054	0.239***	0.241***		0.024
	(7.27)	(7.26)		(1.53)	(4.81)	(4.76)		(1.52)	(5.18)	(5.32)		(0.41)
Lag Bond Mod.Duration	5.366***	5.389***	4.781***		3.673***	4.011***	3.845***		7.274***	6.416***	5.792***	
	(9.28)	(9.35)	(9.47)		(4.32)	(4.82)	(5.65)		(9.21)	(8.29)	(8.23)	
Lag Repo Net Order Flows		2.014***	2.097***	2.110***		2.018***	2.124***	2.141***		4.618***	4.245***	2.939***
		(4.70)	(5.31)	(6.34)		(4.33)	(4.98)	(5.99)		(4.59)	(4.58)	(3.60)
Lag Repo Trades		0.275***	0.144***	0.098**		0.273***	0.161***	0.132***		1.876***	1.600***	0.713***
		(5.01)	(2.80)	(2.31)		(4.56)	(2.77)	(2.81)		(8.35)	(7.36)	(3.94)
Lag Repo Volatility			2.138***	1.639***			2.445***	1.698***			1.839***	1.651***
			(12.01)	(10.37)			(9.29)	(7.55)			(8.36)	(6.86)
CCP	-5.803***	-7.520***	-3.314**	-0.553								
	(-4.43)	(-5.34)	(-2.56)	(-0.51)								
Lag EL				-0.141***				-0.136***				-0.138***
				(-17.61)				(-13.25)				(-11.09)
Lag EL^2				0.139***				0.132***				0.138***
				(15.65)				(11.70)				(9.99)
Seasonal Controls	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Time-of-Day Effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	10,602	10,602	10,602	10,602	5,979	5,979	5,979	5,979	4,623	4,623	4,623	4,623
Adj. R^2	0.132	0.139	0.280	0.474	0.0872	0.0991	0.287	0.500	0.205	0.229	0.325	0.457

As expected, Bond Bas becomes insignificant only when we control for Repo Volatility, due to the high correlation between the two variables. Finally, Bond Modified Duration is significant at the 1% level for all repos with the expected positive sign. The higher the interest rate risk of the bonds, the higher the modified duration, so the higher the intraday repo spread demanded by repo traders. A one-standard deviation change in Bond Modified Duration generates an increase of 4.13 bps (All Repos), 2.25 bps (CCP) and 6.79 bps (Bilateral) in the intraday repo spread, ceteris paribus.

Next, we consider the proxies for repo riskiness. Repo Net Order Flow displays the expected positive sign and it is significant at the 1% level. Greater repo net demand increases the intraday repo spread. The economic impact of Repo Net Order Flow on the intraday repo spread is of 1.57 bps (All Repos), 1.97 bps (CCP) and 1.22 bps (Bilateral) standard deviations.[28] Repo Trades have positive coefficients which are significant at the 5% level for the aggregate repo sample and at the 1% level for CCP-repos and bilaterally-traded repos. A one-standard deviation change in Repo Trades induces an increase of 0.61 bps (All Repos), 0.86 bps (CCP) and 1.44 bps (Bilateral) in the intraday repo spread. Finally, as expected, Repo Volatility is also positively related to the intraday repo spread and its coefficients are highly significant at the 1% level. The higher the repo volatility, the higher the uncertainty in funding conditions, and the higher the intraday repo spread. Repo Volatility has a high economic impact on the intraday repo spread: a one-standard deviation increase in Repo Volatility induces an increase of 7.59 bps (All Repos), 6.97 bps (CCP) and 8.46 bps (Bilateral) on the intraday repo spread.

[28] We refer to Table 6, columns 4, 8 and 12 for the purpose of discussing the economic impact of the proxies for repo riskiness and excess liquidity on the intraday repo spread of the aggregate sample, of CCP-based repos, and bilateral repos.

Excess Liquidity is significant at the 1% level with the expected negative sign: the higher the excess liquidity, the lower the repo rate. However, when EL increases excessively, additional liquidity in the system deteriorates repo volumes and increases the repo spread. That is why the coefficient of the squared term of the Excess Liquidity is positive and statistically significant. We are interested in the overall economic impact of the Excess Liquidity: a one-standard deviation change in EL generates a decrease of -7.02 bps (All Repos), -6.88 bps (CCP) and -6.75 bps (Bilateral) in the intraday repo spread as cumulative impact, ceteris paribus.

We observe that the dummy CCP has a significant negative coefficient only in Table 6, columns 1, 2 and 3. This indicates that on average CCP-based contracts have lower repo spreads than bilateral contracts, after controlling for collateral and repo risk factors. However, once we control in column 4 also for the excess liquidity, the CCP dummy variable retains the negative sign, but it is no more statistically significant.

Next, we investigate whether the impact of these factors has changed over different periods in our sample. We split the entire dataset into two sub-periods and re-estimate the complete model (6) over each of them. The results are reported in Table 7 for the aggregate sample of repos, for CCP-based repos and bilateral repos. The first sub-period starts on January 4, 2010 and ends on February 10, 2012: this is the core period of the European sovereign bond crisis. This period is characterized by several ECB non-standard monetary policy interventions: (i) from May 10, 2010 until March 25, 2011 the first activation period of the Securities Market Programme (SMP), involving the outright purchases by the ECB of government securities issued by Greece, Portugal, and Ireland; (ii) from August 8, 2011 until February 10, 2012, the second activation period of the SMP for Italian and Spanish government bonds; (iii) on December 21, 2011 the start of the first 3-year long-term refinancing operation (LTRO), granting secured loans with maturity of three years with an option of early repayment. The second sub-period, which runs from February 11, 2012 until, is a relatively more tranquil post-crisis period, supported by further ECB interventions. On February 29, 2012 a second 3-year LTRO is implemented by the ECB; while on July 26, 2012 Mr Mario Draghi, President of the ECB, announces the intention to implement all possible measures ('Whatever it takes') to restore normal market conditions. On June 5, 2014, the ECB Governing Council announced a package of measures to further ease monetary policy, among which the Extended Asset Purchase Programme (EAPP)[29] and two new 4-year LTROs on September 18, 2014 and December 11, 2014. In addition, on September 4, 2014 the ECB main refinancing rate was lowered by 0.10% and two new purchases programmes started for both asset-backed securities and covered bonds issued by Euro area financial institutions. On January 22, 2015 the ECB Governing Council announced the expansion of purchases programmes to the public sector[30] (PSPP) for a quantity of at least €60 billion per month starting on March 9, 2015 and covering all the rest of this sub-period until November 30, 2015.[31]

The explanatory power of model (6) is always over 40% for all sub-samples. The higher adjusted R^2s are observed during the post crisis sub-period (for the whole sample: 55%; for CCP: 57%; for Bilateral: 52%; versus an adjusted R^2 of about 43% for the European sovereign crisis period), probably because of the greater variability of the dependent variable during the crisis period.

[29]See Dunne et al. (2015) for a detailed analysis of the ECB's expanded asset purchase programme.

[30]Commentators start using the term 'Quantitative Easing' only after the announcement of the public sector purchases programme (see Dunne et al., 2015).

[31]Originally the PSPP was meant to last at least until September 2016. On 10 March 2016, the PSPP was increased from €60 billion to €80 billion per month. See the following link: https://www.ecb.europa.eu/press/pr/date/2016/html/pr160310.en.html

In Table 7 we observe three main additional findings with respect to the results already discussed for Table 6. First, the Bond Bas is significant over the ESC period, but insignificant in the post crisis period. This evidences that the higher repo costs due to the higher illiquidity in the collateral market appear specifically during the crisis period (it is however important to recall that Bond Bas is highly correlated with Repo Volatility, so its effect is also subsumed by the latter variable).

Second, there is a change in the sign of the estimated coefficient of Bond Supply: it is positive in the crisis period and negative in the post-crisis period. The negative impact of Bond Supply on the repo spread in the post-crisis period is probably an effect of the large amount of Italian Government bonds purchased by the ECB and the general scarcity of repo collateral on the secondary MTS market. The ECB Quantitative Easing programme has forcedly reduced the supply of bonds, while alleviating the pressure on funding markets and repo funding costs.

Third, during the crisis period all factors of repo riskiness, as well as the excess liquidity, have a stronger economic impact on the repo spread. In the post-crisis period these risk factors appear still significant, but have a much lower impact than during the sovereign crisis.

Overall, these sub-period results suggest that the ECB interventions and the high level of liquidity surplus provided by the ECB to the European financial system have contributed to reduce the influence of collateral and repo riskiness on repo spreads.

Table 7: Collateral risk and funding costs- Pooled regressions results for model (6) over two sub- periods

This table reports the results of pooled OLS regression results over two sub-periods. European sovereign crisis sub-period: January 4, 2010 to February 10, 2012. Post-crisis period: February 11, 2012 to November 30, 2015. Pooled regressions are estimated with HAC robust standard errors. Variable definitions and measurements are explained in Table 4. **Repo Net Order Flow** is measured here in billions of Euros. **EL^2** is rescaled over 1,000. *** indicates 1% significance level (S.L.); ** 5% S.L.; and * 10% S.L., respectively.

	All Repos		CCP		Bilateral	
Period	European Sovereign Crisis 01/01/2010 - 10/02/2012	Post-Crisis 11/02/2012 - 30/11/2015	European Sovereign Crisis 01/01/2010 - 10/02/2012	Post-Crisis 11/02/2012 - 30/11/2015	European Sovereign Crisis 01/01/2010 - 10/02/2012	Post-Crisis 11/02/2012 - 30/11/2015
Dep. Var. GC Hourly Repo Spread	(1)	(2)	(3)	(4)	(5)	(6)
Constant	-0.082	27.928***	1.797	25.733***	0.071	28.908***
	(-0.02)	(18.83)	(0.41)	(13.16)	(0.01)	(14.22)
Lag Bond Supply	0.545***	-0.066***	0.534***	-0.055***	0.552***	-0.075***
	(8.58)	(-4.61)	(6.44)	(-2.65)	(5.79)	(-4.15)
Lag Bond BAS	0.098**	0.007	0.111**	0.004	0.066	0.064
	(2.28)	(0.61)	(2.02)	(0.38)	(0.91)	(1.53)
Lag Repo Net Order Flows	3.827***	0.614***	3.896***	0.663***	3.161***	-0.887
	(6.22)	(4.32)	(5.40)	(4.57)	(3.41)	(-1.11)
Lag Repo Trades	0.418***	0.124***	0.523***	0.113***	0.310	0.539***
	(3.41)	(5.14)	(3.57)	(4.61)	(1.43)	(3.72)
Lag Repo Volatility	1.544***	0.942***	1.572***	1.199***	1.619***	0.461***
	(7.60)	(6.79)	(5.52)	(5.89)	(5.73)	(3.11)
CCP	1.321	-0.939				
	(0.79)	(-1.49)				
Lag EL	-0.122***	-0.093***	-0.110***	-0.091***	-0.130***	-0.092***
	(-7.34)	(-22.48)	(-4.98)	(-17.70)	(-5.39)	(-13.71)
Lag EL^2	0.080**	0.085***	0.032	0.084***	0.120**	0.080***
	(2.35)	(18.58)	(0.70)	(14.33)	(2.44)	(11.39)
Seasonal Controls	Y	Y	Y	Y	Y	Y
Time-of-Day Effects	Y	Y	Y	Y	Y	Y
Observations	4,446	6,156	1,858	4,121	2,588	2,035
Adj. R^2	0.430	0.549	0.432	0.573	0.427	0.523

Finally, in Table 7 we observe that although the CCP-based repos provide mitigation of counterparty credit risk, especially during the European sovereign crisis they behave rather like bilateral repos and are affected by the same risk factors. This result is consistent with Boissel et al. (2017) who show that – particularly at the peak of the sovereign crisis – CCP haircuts and their perceived reliability was not enough to prevent the repo market from reacting to increasing sovereign and funding stress.

5.4 Regulatory Changes and Margin Costs

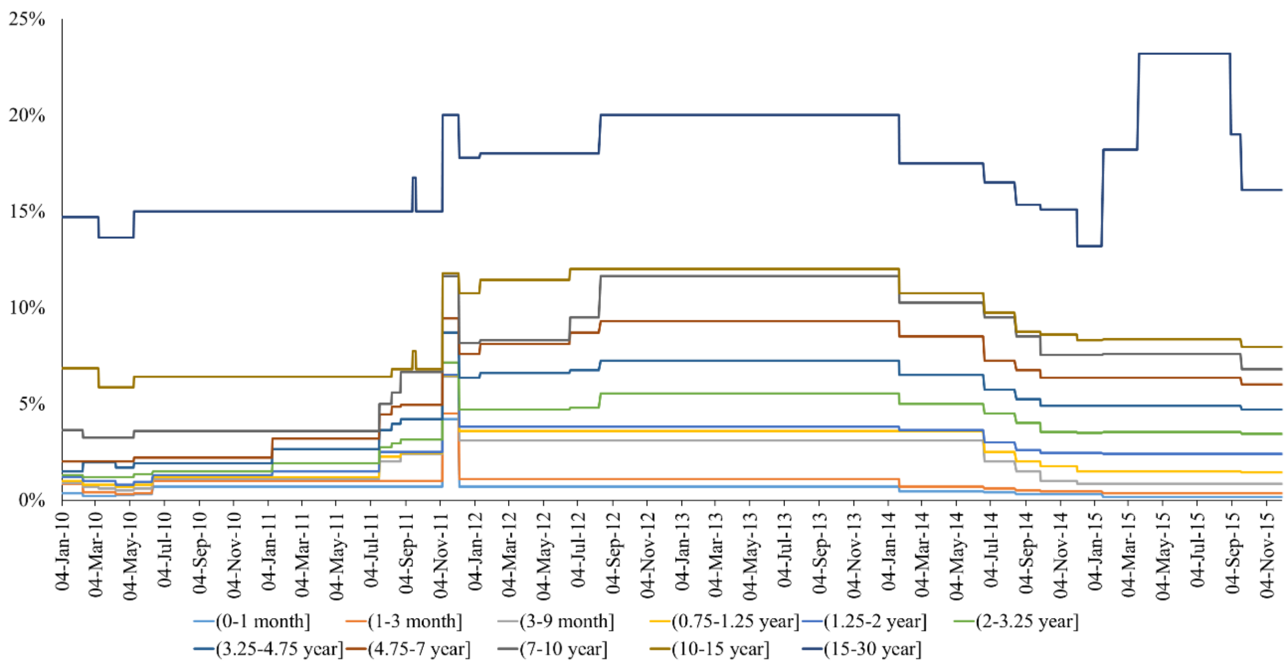
Margins are the preferred instrument adopted by the CCPs to mitigate the impact of counterparty risk in repos. During the period considered in our study there have been important changes in the regulatory environment and the margin policies set by the CCPs (see Figure 5 Panel A).

On 8 November 2011, at the peak of the Italian sovereign crisis, the CCP increased the margin required for Italian repos and sovereign bonds, as a reaction to the deterioration of the creditworthiness of the Italian government guarantees. The margin increase ranged from a minimum of 350 bps for bonds with duration less than 1 year to a maximum of 500 bps points for bonds with duration greater than 7 years. As a consequence, the total nominal amount of margins collected by CC&G for transacted Italian repos and sovereign bonds increased from €6.63 billion to €11.81 billion, an increase of almost 78% (see Figure 5 Panel B).

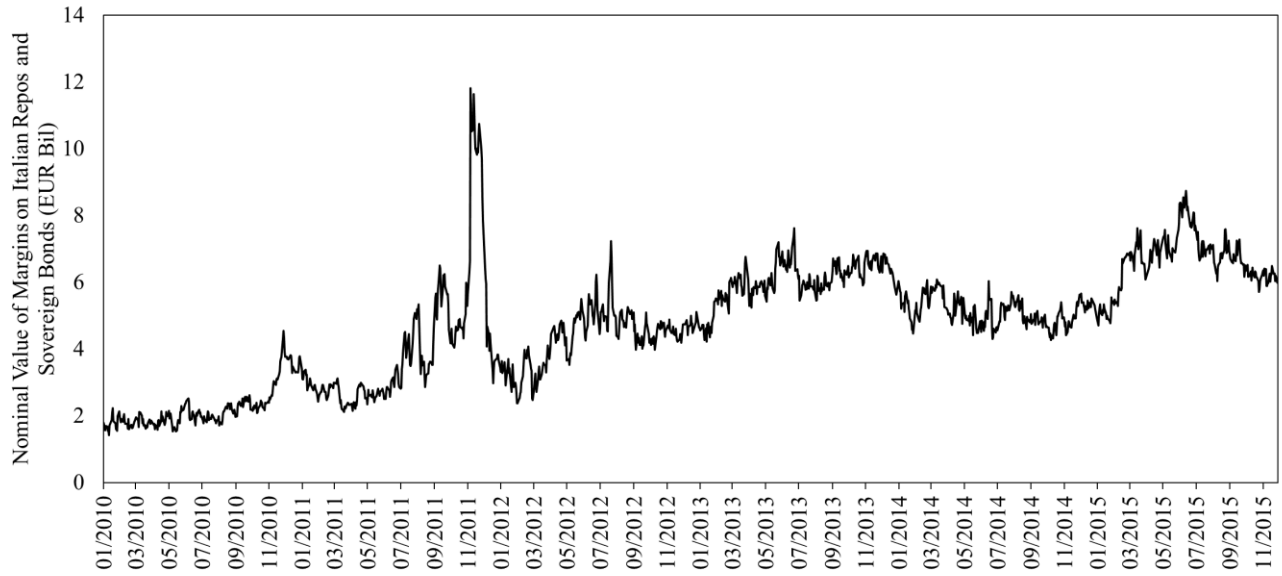
Figure 5: Margin Costs

Initial margins (measured in percentage points) required by the Italian central counterparties (CC&G and LCH) for Italian sovereign bonds of different duration buckets in Panel A, and total daily nominal quantity (billions of Euros) of initial margins collected by CC&G for transacted Italian repos and sovereign bonds in Panel B. Period: January 4, 2010 to November 30, 2015.

Panel A: CCP Initial Margins



Panel B: Nominal Quantity of Margins for Italian Repos and Sovereign Bonds



Some of the main regulatory authorities – i.e. the International Monetary[32] Fund and the Bank of Italy[33] – have criticized the margin policies adopted during the European sovereign crisis as being responsible for further deterioration in funding costs. The main idea is that introducing larger margins and triggering margin calls in an already-stressed market can cause counterparties' defaults and distressed sales of "more liquid" collateral, such as sovereign bonds, both of which can further raise funding costs. This warning has been echoed by the European Union (2012) which has required CCPs to "adopt measures to prevent and control possible *pro-cyclical* effects in risk-management practices adopted."[34] These policy considerations are supported by empirical and theoretical evidence, for example by the Brunnermeier and Pedersen (2009) model.

What we attempt to examine in this section is this alleged pro-cyclical behaviour of the CCP margin policies. If margins are endogenous - i.e. they simply reflect the higher riskiness of the collateral - then they should not appear significant when added to the right-hand side of equation (6), where we already control for higher bond riskiness. If instead the margins' increases are pro-cyclical, then we may expect that higher margin costs will have a further positive and significant effect on the intraday overnight GC repo spread.

Table 8 illustrates the results of this check. We observe that higher margin costs increase the repo spread in a statistically significant way only during the crisis period. The result indicates that increasing margin costs during the crisis period have further deteriorated the repo funding conditions (negative pro-cyclical effect), while in the post-crisis period margin costs

[32] International Monetary Fund (2013), "Italy: Financial System Stability Assessment", IMF Country Report No. 13/300, September.
[33] Bank of Italy (2012): "Financial Stability Report", n.3, April. In this report, the Bank of Italy states: *"in conditions of tension, in fact, a large, sudden increase in margin requirements can exacerbate market swings, obliging dealers to supply liquidity or supplementary collateral just when these are costliest and hardest to procure".*
[34] European Union (2012) "Regulation (EU) No. 648/2012 on OTC derivatives, central counterparties and trade repositories", July.

do not significantly impact the intraday repo spread. Despite margin costs have been changed by the CCPs also over the post-crisis period (see Figure 5 Panel A), the more favourable funding conditions then – e.g. high excess liquidity in the European banking system – may have alleviated their potential negative pro-cyclical effect on the intraday repo spread.

In addition, when looking at the aggregate sample of repos (Table 8, columns 1 to 6), we notice that the CCP dummy is always insignificant. Also the differential impact of margin costs on CCP repos that we try to capture using an interaction term between margin costs and CCP dummy is not statistically significant. These two results show that once we control for the impact of margin costs the CCP repo may not be cheaper than the bilateral repo.

In Table 8 we also look separately at CCP and bilateral repos, in particular to investigate whether: i) margin costs are only significant for the CCP segment, as they are a direct cost borne only by traders who do repos via the central clearing counterparty; or 2) they are significant also for bilateral repos, because they lead to pro-cyclical negative effects on the collateral market and signal higher counterparty credit risk (therefore traders on the bilateral segment will protect themselves by increasing the cost of the repo). We see that margin costs are significant during the ESC for both CCP and bilateral repos, but the impact on the CCP repos is higher. A one-standard deviation change in margin costs generates an increase of 9.79 bps (All Repos), 11.08 bps (CCP) and 8.31 bps (Bilateral) in the intraday repo spread during the ESC sub-period (Table 8, columns 2, 8 and 12), while the economic impact of changes in margin costs is almost null in the post-crisis period (Table 8, columns 5, 10 and 14).

Table 8: Regulatory changes and CCP costs - Pooled regressions results for model (6) over two sub- periods

This table reports the results of pooled OLS regression results over two sub-periods. European sovereign crisis sub-period: January 4, 2010 to February 10, 2012. Post-crisis period: February 11, 2012 to November 30, 2015. Pooled regressions are estimated with HAC robust standard errors. Variable definitions and measurements are explained in Table 4. **Repo Net Order Flow** is measured here in billions of Euros. **EL^2** is rescaled over 1,000. *** indicates 1% significance level (S.L.); ** 5% S.L.; and * 10% S.L., respectively.

	All Repos						CCP				Bilateral			
Period	European Sovereign Crisis 01/01/2010 - 10/02/2012			Post-Crisis 11/02/2012 - 30/11/2015			European Sovereign Crisis 01/01/2010 - 10/02/2012		Post-Crisis 11/02/2012 - 30/11/2015		European Sovereign Crisis 01/01/2010 - 10/02/2012		Post-Crisis 11/02/2012 - 30/11/2015	
Dep. Var. GC Hourly Repo Spread	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Constant	-0.082	1.563	2.352	27.928***	27.044***	27.374***	1.797	3.368	25.733***	25.722***	0.071	1.270	28.908***	28.173***
	(-0.02)	(0.45)	(0.61)	(18.83)	(13.41)	(12.48)	(0.41)	(0.82)	(13.16)	(10.06)	(0.01)	(0.24)	(14.22)	(10.78)
Lag Bond Supply	0.545***	0.386***	0.383***	-0.066***	-0.062***	-0.062***	0.534***	0.346***	-0.055***	-0.055**	0.552***	0.421***	-0.075***	-0.072***
	(8.58)	(5.87)	(5.82)	(-4.61)	(-3.78)	(-3.80)	(6.44)	(4.16)	(-2.65)	(-2.41)	(5.79)	(4.36)	(-4.15)	(-3.52)
Lag Bond BAS	0.098**	-0.011	-0.014	0.007	0.009	0.008	0.111**	-0.022	0.004	0.004	0.066	-0.016	0.064	0.067
	(2.28)	(-0.29)	(-0.38)	(0.61)	(0.82)	(0.79)	(2.02)	(-0.45)	(0.38)	(0.39)	(0.91)	(-0.28)	(1.53)	(1.56)
Lag Repo Net Order Flows	3.827***	3.393***	3.361***	0.614***	0.610***	0.610***	3.896***	3.406***	0.663***	0.662***	3.161***	2.946***	-0.887	-0.891
	(6.22)	(5.69)	(5.71)	(4.32)	(4.30)	(4.30)	(5.40)	(4.92)	(4.57)	(4.55)	(3.41)	(3.13)	(-1.11)	(-1.12)
Lag Repo Trades	0.418***	0.332***	0.310***	0.124***	0.125***	0.126***	0.523***	0.373***	0.113***	0.113***	0.310	0.304	0.539***	0.536***
	(3.41)	(2.76)	(2.61)	(5.14)	(5.20)	(5.17)	(3.57)	(2.61)	(4.61)	(4.68)	(1.43)	(1.39)	(3.72)	(3.72)
Lag Repo Volatility	1.544***	0.805***	0.816***	0.942***	0.915***	0.913***	1.572***	0.861**	1.199***	1.199***	1.619***	0.914**	0.461***	0.451***
	(7.60)	(2.86)	(2.89)	(6.79)	(6.57)	(6.54)	(5.52)	(2.36)	(5.89)	(5.59)	(5.73)	(2.03)	(3.11)	(3.01)
CCP	1.321	0.849	-0.440	-0.939	-0.936	-1.355								
	(0.79)	(0.51)	(-0.15)	(-1.49)	(-1.49)	(-0.78)								
Lag EL	-0.122***	-0.111***	-0.111***	-0.093***	-0.093***	-0.093***	-0.110***	-0.103***	-0.091***	-0.091***	-0.130***	-0.118***	-0.092***	-0.092***
	(-7.34)	(-6.62)	(-6.61)	(-22.48)	(-22.39)	(-22.39)	(-4.98)	(-4.68)	(-17.70)	(-17.61)	(-5.39)	(-4.63)	(-13.71)	(-13.59)
Lag EL^2	0.080**	-0.007	-0.007	0.085***	0.085***	0.085***	0.032	-0.046	0.084***	0.084***	0.120**	0.030	0.080***	0.080***
	(2.35)	(-0.17)	(-0.17)	(18.58)	(18.60)	(18.60)	(0.70)	(-0.91)	(14.33)	(14.34)	(2.44)	(0.43)	(11.39)	(11.43)
Margin Costs		5.734***	5.549***		0.127	0.081		6.347***		0.002		4.954**		0.093
		(4.10)	(3.70)		(0.66)	(0.34)		(3.55)		(0.01)		(2.22)		(0.36)
Margin Costs*CCP			0.489			0.067								
			(0.48)			(0.23)								
Seasonal Controls	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Time-of-Day Effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	4,446	4,446	4,446	6,156	6,156	6,156	1,858	1,858	4,121	4,121	2,588	2,588	2,035	2,035
Adj. R^2	0.430	0.449	0.449	0.549	0.549	0.549	0.432	0.458	0.573	0.573	0.427	0.440	0.523	0.523

5.5 *Counterparty Risk*

In the previous section we have established that higher margins affect the repo costs only during the crisis period, but they do so for both the CCP and the bilateral segment. The higher margin costs may be a sign and catalyst of higher counterparty risk and this could be one of the motives behind their significant impact on the bilateral segment. Therefore, in this section we check more directly the impact of counterparty risk using a measure of **Excess Bank CDS.** This measure is computed as the difference between the daily CDS mid-quote for the Italian banking sector[35] and the sovereign CDS mid-quote for Italy. CDS mid-quotes are sourced from Bloomberg. The Italian banking sector CDS mid-quote is calculated as the weighted average of CDS mid-quotes for Italian banks, with weights equal to their relative average market capitalisation over a 22-day rolling window.

Furthermore, we can observe in Figure 1 Panel A that the relationship between bilaterally-traded and CCP-based repo spreads changes over time. In the relatively more tranquil period before the Italian sovereign crisis (January 2010 – October 2011) we observe that for the same type of contract the bilateral repo rate is on average higher than the CCP-repo rate: intermediary banks' counterparty credit risk is mitigated by the CCP, so lenders charge a lower premium for CCP repos than for bilaterally-traded repos, ceteris paribus. In the more turbulent period from November 2011 to November 2015 instead we observe that the CCP repo rate is on average higher than the bilaterally-traded repo rate. Thus, we aim to understand how bilaterally-traded and CCP-based repo spreads vary systematically with the counterparty credit risk of Italian banks.

[35] To understand the importance of banks as counterparties in the repo sector, MTS repo specialists have confirmed that more than 60% of volume of GC ON Repo is traded by Italian banks.

We re-estimate model (6) with the addition of the Excess Bank CDS on the right-hand side of the equation. This measure has a correlation of 64% to 70% with the margin costs, so in our model we include the former and drop the latter. The results are presented in Table 9.

We would conjecture that CCP-based repos are covered from any counterparty risk exposure. In fact, in Table 5 we observe that the unconditional correlation between the Excess Bank CDS and the CCP repo spread is close to zero and statistically insignificant. However, in Table 9 we observe that higher credit risk of the banks-counterparties can increase the repo costs for both the CCP and bilateral segment, particularly during the ESC. The differential impact of the counterparty risk on the CCP/bilateral segment is not statistically significant (see the interaction term between Excess Banks' CDS premium and CCP dummy). Furthermore, the coefficients of the counterparty risk during the ESC are higher for the CCP than for the bilateral repos. This is an interesting and somehow surprising result, given that the CCP should reduce the exposure of the repo contract to counterparty risk. During the ESC period, a one-standard deviation change in the Excess Bank CDS generates an increase of 4.87 bps (All Repos), 5.02 bps (CCP) and 4.32 bps (Bilateral) in the hourly repo spread (Table 9, columns 2, 8 and 12).

We have also controlled separately for the excess CDS premium of larger and smaller Italian banks (by market capitalization) and observed that despite larger banks are considered in general 'safer' than smaller banks, their credit risk impact on the repo cost is higher because larger banks are more active counterparties in repo contracts, given their reputation and their wider network of contacts in the repo business. These results of this check are reported in Appendix (Tables A.1 and A.2).

Table 9: Counterparty Risk - Pooled regressions results for model (6) over two sub- periods

This table reports the results of pooled OLS regression results over two sub-periods. European sovereign crisis sub-period: January 4, 2010 to February 10, 2012. Post-crisis period: February 11, 2012 to November 30, 2015. Pooled regressions are estimated with HAC robust standard errors. Variable definitions and measurements are explained Table 4. **Repo Net Order Flow** is measured here in billions of Euros. **EL^2**is rescaled over 1,000. *** indicates 1% significance level (S.L.); ** 5% S.L.; and * 10% S.L., respectively.

	All Repos						CCP				Bilateral			
Period	European Sovereign Crisis 01/01/2010 - 10/02/2012			Post-Crisis 11/02/2012 - 30/11/2015			European Sovereign Crisis 01/01/2010 - 10/02/2012		Post-Crisis 11/02/2012 - 30/11/2015		European Sovereign Crisis 01/01/2010 - 10/02/2012		Post-Crisis 11/02/2012 - 30/11/2015	
Dep. Var. GC Hourly Repo Spread	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Constant	-0.082	4.335	4.338	27.928***	27.024***	27.301***	1.797	5.886	25.733***	25.033***	0.071	4.078	28.908***	28.270***
	(-0.02)	(1.04)	(1.04)	(18.83)	(17.41)	(16.87)	(0.41)	(1.21)	(13.16)	(12.34)	(0.01)	(0.63)	(14.22)	(13.10)
Lag Bond Supply	0.545***	0.441***	0.441***	-0.066***	-0.046***	-0.047***	0.534***	0.431***	-0.055***	-0.035	0.552***	0.457***	-0.075***	-0.064***
	(8.58)	(6.02)	(6.02)	(-4.61)	(-2.86)	(-2.90)	(6.44)	(4.58)	(-2.65)	(-1.54)	(5.79)	(4.12)	(-4.15)	(-3.01)
Lag Bond BAS	0.098**	0.086*	0.086*	0.007	0.013	0.012	0.111**	0.099	0.004	0.009	0.066	0.061	0.064	0.071*
	(2.28)	(1.79)	(1.78)	(0.61)	(1.18)	(1.10)	(2.02)	(1.64)	(0.38)	(0.83)	(0.91)	(0.76)	(1.53)	(1.66)
Lag Repo Net Order Flows	3.827***	3.645***	3.645***	0.614***	0.606***	0.605***	3.896***	3.720***	0.663***	0.651***	3.161***	2.998***	-0.887	-0.858
	(6.22)	(5.96)	(5.98)	(4.32)	(4.33)	(4.32)	(5.40)	(5.17)	(4.57)	(4.57)	(3.41)	(3.21)	(-1.11)	(-1.08)
Lag Repo Trades	0.418***	0.396***	0.396***	0.124***	0.130***	0.132***	0.523***	0.517***	0.113***	0.122***	0.310	0.248	0.539***	0.540***
	(3.41)	(3.27)	(3.27)	(5.14)	(5.41)	(5.53)	(3.57)	(3.57)	(4.61)	(5.08)	(1.43)	(1.15)	(3.72)	(3.73)
Lag Repo Volatility	1.544***	1.015***	1.015***	0.942***	0.878***	0.875***	1.572***	0.966***	1.199***	1.106***	1.619***	1.149***	0.461***	0.439***
	(7.60)	(4.17)	(4.17)	(6.79)	(6.23)	(6.17)	(5.52)	(2.64)	(5.89)	(5.33)	(5.73)	(3.53)	(3.11)	(2.89)
CCP	1.321	0.465	0.462	-0.939	-0.948	-1.188								
	(0.79)	(0.28)	(0.29)	(-1.49)	(-1.51)	(-1.52)								
Lag EL	-0.122***	-0.100***	-0.100***	-0.093***	-0.097***	-0.097***	-0.110***	-0.090***	-0.091***	-0.096***	-0.130***	-0.109***	-0.092***	-0.094***
	(-7.34)	(-6.39)	(-6.38)	(-22.48)	(-23.60)	(-23.69)	(-4.98)	(-4.31)	(-17.70)	(-19.04)	(-5.39)	(-4.79)	(-13.71)	(-14.05)
Lag EL^2	0.080**	0.028	0.028	0.085***	0.087***	0.087***	0.032	-0.007	0.084***	0.086***	0.120**	0.063	0.080***	0.081***
	(2.35)	(0.85)	(0.85)	(18.58)	(19.57)	(19.70)	(0.70)	(-0.15)	(14.33)	(15.51)	(2.44)	(1.33)	(11.39)	(11.67)
Lag Excess Bank CDS		0.112***	0.112***		0.014***	0.012*		0.115***		0.017***		0.100**		0.007
		(3.63)	(3.16)		(3.05)	(1.89)		(2.58)		(2.80)		(2.31)		(1.04)
Lag Excess Bank CDS*CCP			0.001			0.004								
			-0.01			(0.50)								
Seasonal Controls	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Time-of-Day Effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	4,446	4,446	4,446	6,156	6,156	6,156	1,858	1,858	4,121	4,121	2,588	2,588	2,035	2,035
Adj. R^2	0.430	0.440	0.440	0.549	0.551	0.551	0.432	0.442	0.573	0.577	0.427	0.435	0.523	0.523

5.6 Robustness Checks

We perform several robustness checks on our main results.

First, we evaluate the impact of the European systemic risk and monetary policy expectations on the repo spread. We estimate a parsimonious model that uses as explanatory variables only the excess liquidity, the squared excess liquidity, a proxy for systemic risk in the European financial markets and a proxy for monetary policy expectations (Table 10, column 1) without including any of the collateral and repo riskiness proxies.[36] In this way we can control for their specific and separate effect. We use the composite indicator of systemic stress (CISS) (see Hollo, Kremer and Lo Duca, 2012) on day *t-1* as a proxy for systemic risk in the European financial markets. This indicator aggregates 15 different financial stress measures. We find a positive and significant effect of CISS on the repo spread. In time of crisis, higher systemic risk induces repo lenders to charge a higher premium. Additionally, repo rates can be driven by expectations of interest rates set by the ECB. As proxy for the expected monetary policy changes (EMC) we use the difference between the one-month Eonia futures and the Eonia rate on day *t-1* (see Gürkaynak, Sack and Swanson, 2007). We expect a negative relation between EMC and repo spread. A negative EMC means lower expected future rates and signals higher future systemic risk at the Eurozone level: this worsens also the Italian repo market conditions. Our result confirms the significant negative impact of EMC on repos spread. When we jointly analyse the impact of these variables on the repo spread (Table 10, column 1), we observe a high adjusted R^2 of about 43% confirming their importance. Interestingly, in column 1 we also observe that the CCP dummy is insignificant. This suggests that when we account for systemic risk and changes in central bank policy, the

[36] We also control for the impact on the intraday repo spread of: Italian sovereign 5-year CDS, V-Stoxx EUR, Euribor-OIS spread and Eonia Volumes. Results are not reported for brevity, but are available upon request.

risk-mitigating function of the CCP becomes of 'second-order importance' for the Italian repo spread.[37] Next, in Table 10 column 2 we re-introduce the collateral and repo proxies along with EL, CISS, and EMC. As we use excess liquidity, we exclude the bond modified duration given their high correlation. The results for all the proxies of collateral and repo riskiness remain mostly invariant and consistent with our main regression results in Table 6. The model has higher explanatory power (adjusted R^2 of 52.6%). In addition, we find that the variable CISS is now only marginally significant: our more parsimonious model (6) without CISS already captures the effect of the Eurozone systemic stress.

Second, we control whether the impact of the explanatory variables changes over the day. In the regression model (6) we include interaction terms between each explanatory variable and the hourly dummies. In unreported results we notice that the impact of the proxies of collateral riskiness is decreasing over the first hours of the trading day and then it reaches a stable level after 11 a.m. However, we do not find any evidence that intraday patterns in collateral and repo riskiness proxies are able to explain any additional variation in the intraday repo spread.

Third, we replace the day-of-the-week effects with daily time fixed-effects (i.e. dummies for each calendar day) in order to control for unobservable effects which can cause variation in the levels of the repo spread. Our results remain unchanged.

Finally, we control for the impact of economic news on the intraday repo spread, but we do not find such impact.[38] We argue that macroeconomic news may be anticipated by banks and already reflected in the prices of repo trades.[39]

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[37] Boissel et al. (2017) provide evidence that CCPs can stabilize repo markets in time of moderate sovereign stress, but that only the central bank can restore the stability of the repo market in times of high sovereign stress.
[38] For this control we apply a methodology similar to Paiardini (2014).

Table 10: Pooled regressions results with alternative combinations of factors for overall sample period

This table reports the results of pooled OLS regressions estimated with HAC robust standard errors over the period January 4, 2010 to November 30, 2015. Variable definitions and measurements are explained in Table 4. **Repo Net Order Flow** is measured here in billions of Euros. **EL^2** is rescaled over 1,000. **CISS** is the composite indicator of systemic stress which aggregates 15 different financial stress measures (Hollo et al. 2012). **EMC** is the difference between the one-month Eonia futures and the Eonia rate and measures the expected monetary policy changes (basis points). *** indicates 1% significance level (S.L.); ** 5% S.L.; and * 10% S.L., respectively.

Dep. Var. GC Hourly Repo Spread	(1)	(2)
Ind. Variables:		
Lag Bond Supply		0.162***
		(12.00)
Lag Bond BAS		0.054***
		(3.78)
Lag Bond Mod. Duration		
Lag Repo Net Order Flows		1.930***
		(9.08)
Lag Repo Trades		0.075**
		(2.22)
Lag Repo Volatility		1.541***
		(20.64)
CCP	0.618	-0.961
	(1.01)	(-1.58)
Lag EL	-0.123***	-0.126***
	(-34.82)	(-39.04)
Lag EL^2	0.106***	0.123***
	(24.73)	(32.91)
Other Controls:		
Lag CISS	26.321***	0.358
	(14.92)	(0.21)
Lag EMC	-45.289***	-41.909***
	(-19.04)	(-18.11)
Seasonal Controls	Y	Y
Time-of-day Effects	Y	Y
Observations	10,602	10,602
Adj. R^2	0.426	0.526

[39] However, we do not have data on repo quotes – e.g. repo order book, so we cannot reject the hypothesis that repo quotes may be affected by macroeconomic news.

6. Collateral Selection for GC Repos

In this section we assess which bond's characteristics affect its probability of being selected as collateral in GC ON repos. Our rich matched GC repo - collateral bond dataset allows us to carry out this analysis, which – to the best of our knowledge – has never been investigated in previous studies.

We expect that the larger is the availability of a bond, the higher its probability of being selected as collateral. We also expect that the higher is the bond riskiness (so the higher its bid-ask spread and its bond modified duration), the more likely is for traders to select the bond as collateral for the GC repo. That is why we include as explanatory variables: the amount of bond outstanding,[40] the bond bid-ask spread, and the bond modified duration and its squared term to test whether the relationship is non-linear. Additionally, we include bond specialness[41] to account for bonds which are highly 'desirable' as collateral in special repos. We expect that the more a bond 'trades on special', the less likely it is for the bond to be chosen as collateral in GC repos, as it can be used for cheaper funding in the special repo segment. The other explanatory variables are also indirectly related to the bond specialness (see Duffie, 1996; Corradin and Maddaloni, 2015; and Dufour and al., 2017).

We estimate the following logit model:

$$\begin{aligned} \text{Prob. of Selection}_{i,t} &= \alpha + \beta_1 \text{ Bond Outstanding Amount}_{i,t-1} + \beta_2 \text{ Bond BAS}_{i,t-1} \\ &+ \beta_3 \text{ Bond Mod. Duration}_{i,t-1} + \beta_4 \text{ Bond Mod. Duration}^2_{i,t-1} \\ &+ \beta_5 \text{ Bond Specialness}_{i,t-1} + \gamma' X_t + \epsilon_{i,t} \end{aligned} \tag{7}$$

[40] The outstanding amount of bonds is calculated from data on auctions conducted in the primary market by the Bank of Italy in collaboration with the Italian Treasury. See the following link: http://www.dt.tesoro.it/en/debito_pubblico, http://www.bancaditalia.it/.

[41] We compute specialness as the difference between the GC rate and the special repo rate. For this variable, we use 'Tomorrow Next' (TN) GC and special repos, since TN repos are the most frequently traded special repos in MTS.

where *i* indicates the bond and *t* the day. The dependent variable in equation (7) is a binary variable which takes the value of one if the bond is selected at least once as collateral in a repo trade on day *t* and zero otherwise.[42] All explanatory variables in equation (7) are bond-specific and computed on a daily frequency.[43]

Repo sellers can observe the collateral they receive from the repo buyers only sometime after the repo trade is concluded (from few minutes to two hours); this is why on the right-hand side of equation (7) we do not include the bond characteristics on the day of the repo trade *t*, but we lag all variables by one day.

We estimate the logit model for equation (7) with HC robust standard errors and bond fixed effects[44] first for the whole sample of repos, and then separately for the sample of CCP-based repos and the sample of bilaterally-traded repos, over the period starting on January 4, 2010 and ending on November 30, 2015. The results are reported in Table 11. We have a total of 151,299 daily observations.

Table 11 shows that the logit model explanatory power is much higher for bilateral repos (pseudo R-squared of 14%, against 6% for the whole sample of repos and for CCP-based repos). All explanatory variables are highly significant at the 1% level in all regressions. Looking at the whole sample of repos, we observe that the higher the bond outstanding amount, the higher the probability that a repo trader will choose that specific bond as collateral for a GC repo. In addition, the more liquid is the bond (the lower its relative bid-ask

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[42] We have also employed two alternative measures for the dependent variable. The first measure is computed as the ratio between the daily nominal transacted volume for each bond-collateral and the nominal transacted volume for the all collateral bonds used on the same day. The second measure is the ratio between the daily transacted quantities of each bond-collateral (calculated as daily nominal transacted volume for the bond-collateral divided by its daily price) and the daily aggregate transacted quantities of all collateral bonds used on the same day. These measure indicate how many times a bond is chosen as collateral on day *t*. Results are qualitatively similar.

[43] The model has been estimated also at intraday frequency and results are robust.

[44] Since some bonds may be transacted more on special than others, especially if they have been targeted for particular trading strategies, we need to control for bond fixed effects. Also F-tests and Hausman (1978) tests confirm the need to control for bond fixed effects, but not for random effects.

spread), the less likely it is that a trader will choose it in a GC repo. Further, the higher the modified duration, the riskier the bond, the higher is the probability of this bond to be selected as collateral. Finally, the more the bond is special, the less probable it is that the bond will be used in a GC repo.

Table 11: Collateral Selection - Logit regressions results for model (7)

Logit model estimated with HC robust standard errors and bond fixed effects. Period: January 4, 2010 - November 30, 2015. **Outstanding Amount** is measured by the daily outstanding notional amount of each bond (the measurement unit is billions of Euros). **Bond BAS** is the daily time-weighted average bond's bid-ask spread. **Bond Mod. Duration** is measured by the daily average bond's modified duration. **Specialness** is measured by the difference between the daily GC tomorrow next repo rate and the special tomorrow next repo rates of the bond (the measurement unit is basis points). Marginal effects are reported in percentage and in italics. *** indicates 1% significance level (S.L.); ** 5% S.L.; and * 10% S.L., respectively.

Dep. Var. Weights - Logit	All Repos	CCP	Bilateral
Ind. Variables:			
Constant	-1.1047***	-0.2013**	-7.0863***
	(0.0945)	(0.0918)	(0.1387)
	-	-	-
Lag Outstanding Amount	0.0244***	0.0264***	-0.0257***
	(0.0036)	(0.0035)	(0.0040)
	0.5216	*0.6169*	*-0.2880*
Lag Bond BAS	0.0019***	0.0006***	0.0051***
	(0.0002)	(0.0002)	(0.0002)
	0.0402	*0.0150*	*0.0571*
Lag Bond Mod. Duration	0.0441***	-0.0884***	0.5931***
	(0.0115)	(0.0109)	(0.0159)
	1.095	*-1.9499*	*6.7402*
Lag Bond Mod. Duration^2	0.0070***	0.0049***	0.0095***
	(0.0009)	(0.0009)	(0.0012)
	-	-	-
Lag Specialness	-0.0073***	-0.0072***	-0.0059***
	(0.0005)	(0.0006)	(0.0006)
	-0.1566	*-0.1674*	*-0.0656*
Seasonal Controls	Yes	Yes	Yes
Bond Fixed Effects	Yes	Yes	Yes
Observations	151,299	151,299	151,299
Observations (DV = 1)	102,234	93,480	26,013
Pseudo R^2	0.0615	0.0566	0.141

The average size of an auction (or auction reopening) is about €3 billion of notional. Ceteris paribus, every additional €3 billion of notional issued by the Italian Treasury increases the probability for the bond to be chosen on average by 1.56%, so marginally. The average bond bid-ask spread is 26 bps. If the bid-ask spread increases by 1 bps, the marginal probability increases by 0.04%. A large increase in the Bond Bas of 250 bps during the crisis could trigger an increase in the marginal probability of 10% on average. For every additional year of modified duration, the probability increases in total by 1.095%.[45] Finally, for every additional 1 bps of specialness, the probability decreases by 0.16%. To understand the economic significance of this latter variable, we need to consider that the bond specialness reached a peak of more than 100 bps for 10-year BTPs during the European sovereign crisis (see Dufour et al., 2017). Although all the variables' marginal impacts look small in absolute terms, we must consider that the first criterion for a trader to choose a bond as collateral is to hold it in her portfolio. Despite a trader with a small portfolio is only allowed limited optionality, our results show that she will exercise it according to a rational logic.

Looking at the CCP and bilateral repo sub-samples, we see that the bond's modified duration for CCP-repos appears with a switch of sign (negative coefficient): so the lower the bond modified duration, the higher the probability of being selected as collateral for CCP-repos. This sign inversion is probably related to the higher margins set by the CCP for longer maturity collateral, which increase the cost of repo trading. Therefore, a repo buyer may be incentivized to reduce the margin costs by selecting shorter-maturity collateral. In addition, in Table 11 we find that the bond's outstanding amount carries a negative sign for bilateral repos: the lower the availability of a bond, the higher its probability of being selected for

[45] This total marginal probability for Bond Modified Duration includes both the effects from the linear term and the quadratic term.

bilateral repos. The sign of this variable for CCP-repos is instead positive. Taken together, these results suggest that longer maturity bonds with higher modified duration and relatively lower outstanding amount are mostly used for bilateral repo trading where there are no specific margin requirements, while bonds with relatively shorter durations and in higher supply are chosen more often as collateral in the CCP-repos to lower the margin costs.

We also explore whether the impact of these factors on the probability of collateral selection changes over time (see Table 12, columns 1, 3, 5, 7). We use the same two sub-periods of the previous analysis in section 5.

As illustrated by Table 12, the Bond Outstanding Amount is significant only for the choice of collateral of CCP repos, with the expected positive sign. The Bond Modified Duration has always a positive effect for bilateral repos: the probability that a longer maturity bond is chosen as collateral is higher. Instead, for the CCP segment a change of sign is detected only during the crisis period, when shorter duration bonds are preferred as collateral to longer duration bonds (the opposite after the crisis). Shorter duration bonds are also usually more liquid. As a result, we observe a negative coefficient for Bond Bas for the CCP segment over the crisis subsample. Thus, during the ESC crisis the bonds selected for CCP repos have greater liquidity and shorter duration.

As mentioned earlier, this may be due to the fact that when using long-term illiquid bonds traders incur in higher margin costs to be paid to the CCP. This was particularly problematic during the crisis, when the collateral riskiness and the margins became particularly high. On November 9, 2011, the CCP initial margins increased substantially for all Italian Treasury bonds. The increase went from a minimum of 3.5% for bonds with duration lower the 1 month to a maximum of 5% for bonds with duration greater than 15 years (see Figure 5). So it is possible that during the crisis period repo buyers have preferred using more liquid and shorter-maturity collateral in GC repos in order to avoid paying higher margins at the central clearing house. Finally, we observe that after the crisis longer-maturity risky bonds are again those with higher probability to be chosen as collateral for a CCP repo, despite this will increase the costs of using the CCP.

Since the CCP margins set by the clearing houses may have an important effect on the selection of Treasury bonds to be used as collateral in CCP-based GC repos during periods of high sovereign credit risk, we control directly for margin costs (dropping Bond Modified Duration). The results are reported in Table 12 at columns 2, 4, 6, and 8. We find that during the ESC the higher the margin that needs to be paid for a specific collateral bond, the lower the probability that that bond is selected as collateral for CCP repos. Margin costs are instead insignificant to explain the choice of collateral in bilateral repos. When we control for margins in CCP repos, the Bond Bas returns to display the expected positive coefficient.

For bilateral repos, the Bond Bas relates negatively to the probability of a bond to be selected as collateral during the ESC period. Given that these repos do not offer any protection against counterparty risk, more liquid collateral is preferred in order to reduce the exposure to higher collateral market risk– e.g. the risk of not being able to liquidate the collateral in case one's counterparty fails to return the borrowed funds. In the post-crisis period, when the pressure from the collateral market decreases, the Bond Bas presents again a positive coefficient: traders in the bilateral segment continue preferring to use more illiquid bonds as collateral in GC repo contracts as well as keeping more liquid bonds 'unencumbered' for regulatory purposes and management of unexpected liquidity needs.

Table 12: Collateral Selection - Logit regressions results for model (7) over two different sub-periods

Logit estimated with HC robust standard errors and bond fixed effects over two sub-periods for CCP and bilateral repos. Columns 1, 2, 5 and 6 report results for the European sovereign crisis sub-period, from January 4, 2010 to February 10, 2012. Columns 3, 4, 7, and 8 report results for the post-crisis period, from February 11, 2012 to November 30, 2015. **Margin Costs** (measured in percentage) is the initial margin required by the Italian central counterparties (CC&G and LCH.Clearnet) for the Italian Sovereign bonds of different duration buckets. Variable definitions and measurements are explained in Table 11. Marginal effects are reported in percentage and in italics. *** indicates 1% significance level (S.L.); ** 5% S.L.; and * 10% S.L., respectively.

	CCP				Bilateral			
Period	European Sovereign Crisis 01/01/2010 - 10/02/2012		Post-Crisis 11/02/2012 - 30/11/2015		European Sovereign Crisis 01/01/2010 - 10/02/2012		Post-Crisis 11/02/2012 - 30/11/2015	
Dep. Var. Weights - Logit	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Ind. Variables:								
Constant	3.2655***	-0.2342**	-2.0505***	-1.5105***	-2.4134***	-1.3113***	-5.6294***	-3.8536***
	(0.2458)	(0.1156)	(0.1300)	(0.0984)	(0.2504)	(0.1287)	(0.2659)	(0.2143)
	-	-	-	-	-	-	-	-
Lag Outstanding Amount	0.0227***	0.0470***	0.0634***	0.0606***	0.0145**	0.0049	0.0060	-0.0087
	(0.0065)	(0.0065)	(0.0046)	(0.0046)	(0.0060)	(0.0059)	(0.0072)	(0.0071)
	0.54489	*1.12941*	*1.45231*	*1.387*	*0.32747*	*0.11042*	*0.03599*	*-0.05257*
Lag Bond BAS	-0.0013***	0.0005**	-0.0005	0.0001	-0.0007**	-0.0022***	0.0033***	0.0041***
	(0.0003)	(0.0002)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0005)	(0.0004)
	-0.03003	*0.01301*	*-0.01105*	*0.00179*	*-0.01479*	*-0.05069*	*0.01943*	*0.02449*
Lag Bond Mod. Duration	-0.4833***		0.1680***		0.0517*		0.3869***	
	(0.0304)		(0.0181)		(0.0304)		(0.0333)	
	-11.3450		*3.67180*		*1.35220*		*2.26066*	
Lag Bond Mod-Duration^2	0.0108***		-0.0077***		0.0081***		-0.0079***	
	(0.0016)		(0.0014)		(0.0017)		(0.0028)	
	-		-		-		-	
Lag Specialness	-0.0064***	-0.0060***	-0.0088***	-0.0088***	-0.0075***	-0.0075***	-0.0013	-0.0016
	(0.0006)	(0.0006)	(0.0011)	(0.0011)	(0.0007)	(0.0007)	(0.0011)	(0.0011)
	-0.1536	*-0.14505*	*-0.20055*	*-0.20223*	*-0.16848*	*-0.17006*	*-0.00755*	*-0.00936*
Margin Costs		-0.0163**		0.0295***		0.0113		0.0707***
		(0.0071)		(0.0041)		(0.0073)		(0.0076)
		-0.39067		*0.67494*		*0.25595*		*0.42507*
Seasonal Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bond Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	51,798	51,798	99,501	99,501	51,798	51,798	99,501	99,501
Observations (DV = 1)	30,696	30,696	62,784	62,784	18,392	18,392	7,621	7,621
Pseudo R^2	0.0691	0.0650	0.0686	0.0682	0.0520	0.0511	0.0605	0.0576

7. Summary and Conclusions

In this paper we examine the dynamics and determinants of the intraday rate of overnight (ON) general collateral (GC) repos on Italian Government bonds, with respect to the European Central Bank deposit rate. The importance of this analysis lays on the fact that the ON GC repo is the main instrument used by banks for their intraday liquidity management. We use a rich intraday dataset of Italian repos and collateral bonds over the sample period from January 2010 to November 2015, which has not been used in previous literature.

First, we show that the intraday Italian ON GC repo spread presents a downward sloping intraday pattern. Due to the incentive of Italian banks to ensure funding liquidity at the beginning of the day, the repo spread tends to decrease steadily from the second hour of the trading day until closure. Second, we find that collateral market availability (supply), liquidity and modified duration are significant factors to explain the variation in the intraday repo premium (over the ECB deposit rate), as they induce higher riskiness in this secured funding instrument. This relationship has never been empirically tested in any previous repo study. In addition, we find that repo net order flows, repo number of trades and repo volatility are further significant explanatory variables and that the excess liquidity supplied by the ECB has a very strong effect on the intraday repo spread. The sub-sample analysis reveals however that the impact of some factors changes during and after the European sovereign crisis (ESC) period of 2010-2012. Despite the collateral risk factors, remain statistically-significant determinants both during the crisis and the post-crisis periods, their absolute impact is much reduced during the post-crisis period. We interpret this result as evidence that the ECB quantitative easing interventions were highly effective in reducing the influence of collateral riskiness on the repo spread.

Third, the MTS intraday database allows us to study both ON GC repos cleared by a central counterparty (CCP) and bilaterally-traded repos (non-CCP). The differences between the two types of repos have never been directly addressed in previous repo studies. We identify a pattern in centrally-cleared and non-centrally cleared transactions during the trading day: when CCP trading ends (at 12.30 p.m.), the non-CCP trading starts. Due to the mitigation of counterparty credit risk, the CCP-repo spread is on average lower than the bilateral repo spread. However, during the European sovereign crisis we observe a lack of cost-differentiation between the two market segments, possibly because of low effectiveness of the CCP in its risk-mitigating function or excessively high margin costs. We therefore control for the impact of margin costs on the intraday repo spreads for CCP-based and bilaterally-traded repos. We observe that the increased margin costs during the European sovereign crisis period further deteriorate the repo funding conditions by increasing the repo spread and creating a negative pro-cyclical effect. Despite margin costs have been changed by the CCPs also over the post-crisis period, the more favourable funding conditions then – e.g. high excess liquidity in the European banking system – may have alleviated their potential negative pro-cyclical effect on the intraday repo spread. Once we control for the impact of margin costs (in addition to the collateral and repo risk factors) we notice that the CCP repo may not be significantly cheaper than the bilateral repo. Interestingly, we see that margin costs are significant during the ESC for both CCP and bilateral repos, although the impact on the CCP repos is higher. We check the possible rationale of the result and observe that higher margins signals the higher counterparty risk, so they may have an impact on the intraday bilateral repo spread even if traders do not pay CCP margins to trade bilaterally. To prove this point, we show that the higher credit risk of the banks-counterparties increases the repo costs for both the CCP and bilateral segment, particularly during the ESC. This is an interesting and somehow surprising result, given that the CCP should reduce the exposure of the repo contract to counterparty risk.

Finally, in a logit model we study which bonds characteristics can determine the probability of selection of a particular government security to be used as collateral in Italian GC repos. To the best of our knowledge, this is the first paper which clearly uncovers this mechanism. We find that bonds with lower liquidity, greater market supply and higher modified duration are more likely to be selected as collateral in GC repos. We also show that bonds with higher specialness are less likely to be used for GC repos. However, during the European sovereign crisis, we observe that CCP-repo buyers are more likely to choose bonds with lower modified duration and higher liquidity. The higher level of margins imposed by the CCP in this period incentivizes repo buyers to select higher-quality and more liquid collateral in order to reduce the repo trading and CCP costs. In fact, when we control directly for margin costs in the logit model, we find that during the ESC the higher the margin that needs to be paid for a specific collateral bond, the lower the probability that the bond is selected as collateral for CCP repos. Margin costs are instead insignificant to explain the choice of the collateral in bilateral repos.

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APPENDIX

Table A.1: Counterparty Risk for Large and Small Banks - Additional Regressors in Model (6)

Full Repo Sample

This table reports the results of pooled OLS regression results over the period January 4, 2010 to November 30, 2015. Pooled regressions are estimated with HAC robust standard errors. Variable definitions and measurements are explained in Table 4. **Repo Net Order Flow** is measured here in billions of Euros. **EL^2** is rescaled over 1,000. **Excess Large Bank CDS** and **Excess Small Bank CDS** (measured in basis points) are the average difference between the daily volume-weighted average CDS (senior 5-year Euro-denominated, obtained from Bloomberg) of larger and smaller banks (weighted by their relative market capitalization) and the sovereign CDS**.** *** indicates 1% significance level (S.L.); ** 5% S.L.; and * 10% S.L., respectively.

Period	Full Sample 01/01/2010 - 30/11/2015						
Dep. Var. Hourly Repo Spread	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Constant	18.707***	19.757***	19.548***	20.252***	20.052***	18.566***	18.433***
	(8.60)	(9.00)	(8.76)	(9.15)	(8.94)	(8.63)	(8.37)
Lag Bond Supply	0.157***	0.149***	0.148***	0.150***	0.149***	0.153***	0.153***
	(5.75)	(5.52)	(5.51)	(5.56)	(5.55)	(5.64)	(5.64)
Lag Bond BAS	0.046	0.065**	0.066**	0.069**	0.070**	0.056*	0.057*
	(1.53)	(2.06)	(2.08)	(2.20)	(2.22)	(1.81)	(1.82)
Lag Repo Net Order Flows	2.110***	1.972***	1.979***	1.978***	1.987***	2.006***	2.009***
	(6.34)	(6.05)	(6.07)	(6.08)	(6.10)	(6.08)	(6.09)
Lag Repo Trades	0.098**	0.095**	0.097**	0.101**	0.103**	0.084**	0.086**
	(2.31)	(2.27)	(2.31)	(2.43)	(2.46)	(1.99)	(2.02)
Lag Repo Volatility	1.639***	1.304***	1.295***	1.284***	1.275***	1.442***	1.437***
	(10.37)	(7.89)	(7.81)	(7.75)	(7.66)	(8.80)	(8.73)
CCP	-0.553	-1.353	-1.009	-1.301	-0.976	-1.189	-0.971
	(-0.51)	(-1.25)	(-0.88)	(-1.21)	(-0.88)	(-1.09)	(-0.77)
Lag EL	-0.141***	-0.145***	-0.145***	-0.145***	-0.145***	-0.145***	-0.144***
	(-17.61)	(-17.95)	(-17.95)	(-17.98)	(-17.97)	(-17.74)	(-17.74)
Lag EL^2	0.139***	0.131***	0.131***	0.130***	0.130***	0.136***	0.136***
	(15.65)	(15.85)	(15.83)	(15.85)	(15.82)	(15.85)	(15.84)
Lag Excess Bank CDS		0.072***	0.077***				
		(8.50)	(6.46)				
Lag Excess Bank CDS * CCP			-0.009				
			(-0.76)				
Lag Excess Large Bank CDS				0.085***	0.092***		
				(8.52)	(6.43)		
Lag Excess Large Bank CDS * CCP					-0.013		
					(-0.86)		
Lag Excess Small Bank CDS						0.027***	0.029***
						(6.71)	(5.03)
Lag Excess Small Bank CDS * CCP							-0.002
							(-0.39)
Seasonal Controls	Y	Y	Y	Y	Y	Y	Y
Time-of-Day Effects	Y	Y	Y	Y	Y	Y	Y
Observations	10,602	10,602	10,602	10,602	10,602	10,602	10,602
Adj. R^2	0.4760	0.4910	0.4910	0.4930	0.4930	0.4830	0.4830

Table A.2: Counterparty Risk for Large and Small Banks - Additional Regressors in Model (6)

CCP-based repo and the bilateral repo samples

This table reports the results of pooled OLS regression results over the period January 4, 2010 to November 30, 2015. Pooled regressions are estimated with HAC robust standard errors. Variable definitions and measurements are explained in Table 4. **Repo Net Order Flow** is measured here in billions of Euros. **EL^2** is rescaled over 1,000. **Excess Large Bank CDS** and **Excess Small Bank CDS** (measured in basis points) are the average difference between the daily volume-weighted average CDS (senior 5-year Euro-denominated, obtained from Bloomberg) of larger and smaller banks (weighted by their relative market capitalization) and the sovereign CDS. *** indicates 1% significance level (S.L.); ** 5% S.L.; and * 10% S.L., respectively.

Repos	CCP				Bilateral			
Dep. Var. Hourly Repo Spread	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Constant	19.835***	21.090***	21.602***	19.866***	14.001***	14.834***	15.493***	13.390***
	(7.65)	(8.01)	(8.12)	(7.71)	(8.02)	(8.54)	(8.86)	(7.75)
Lag Bond Supply	0.106***	0.106***	0.108***	0.107***	0.234***	0.212***	0.210***	0.224***
	(3.72)	(3.71)	(3.78)	(3.73)	(10.24)	(9.46)	(9.38)	(9.95)
Lag Bond BAS	0.054	0.065*	0.070*	0.058	0.024	0.055**	0.058**	0.043*
	(1.52)	(1.81)	(1.94)	(1.61)	(0.96)	(2.12)	(2.23)	(1.70)
Lag Repo Net Order Flows	0.002***	0.002***	0.002***	0.002***	0.003***	0.003***	0.003***	0.003***
	(5.99)	(5.71)	(5.72)	(5.75)	(4.10)	(3.90)	(3.91)	(3.95)
Lag Repo Trades	0.132***	0.115**	0.121***	0.106**	0.713***	0.723***	0.700***	0.767***
	(2.81)	(2.47)	(2.63)	(2.26)	(4.40)	(4.50)	(4.36)	(4.74)
Lag Repo Volatility	1.698***	1.440***	1.413***	1.563***	1.651***	1.225***	1.219***	1.380***
	(7.55)	(6.29)	(6.16)	(6.83)	(15.19)	(10.39)	(10.37)	(11.73)
Lag EL	-0.136***	-0.141***	-0.142***	-0.140***	-0.138***	-0.140***	-0.140***	-0.140***
	(-13.25)	(-13.50)	(-13.52)	(-13.33)	(-27.46)	(-28.03)	(-27.98)	(-27.90)
Lag EL^2	0.132***	0.128***	0.128***	0.131***	0.138***	0.125***	0.125***	0.131***
	(11.70)	(12.02)	(12.04)	(11.90)	(24.72)	(23.88)	(23.81)	(24.49)
Lag Excess Bank CDS		0.061***				0.082***		
		(6.15)				(13.46)		
Lag Excess Large Bank CDS			0.073***				0.096***	
			(6.22)				(13.44)	
Lag Excess Small Bank CDS				0.023***				0.031***
				(4.70)				(10.30)
Seasonal Controls	Y	Y	Y	Y	Y	Y	Y	Y
Time-of-Day Effects	Y	Y	Y	Y	Y	Y	Y	Y
Observations	5,979	5,979	5,979	5,979	4,623	4,623	4,623	4,623
Adj. R^2	0.502	0.515	0.517	0.508	0.461	0.477	0.479	0.468