Essays on the Repo Market

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Declaration

I confirm that this is my own work and the use of all material from other sources has been properly and fully acknowledged.

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Abstract

This thesis contributes to the broad body of research in the area of money markets, and focuses on repurchase agreements (repos). In the three main chapters of the thesis, I empirically investigate the determinants of the funding liquidity in the repo markets, and the interconnections between the repo markets and the sovereign bond markets. First, I evaluate the impact of sovereign bond riskiness, repo riskiness and treasury auctions on the security-specific costs of procuring Italian government bonds as collaterals (which I call repo specialness) for 1-day repo contracts. I provide evidence that bond supply and riskiness, repo liquidity, speculative demand, bond fire-sales and the unconventional interventions by the European Central Bank (ECB) drive the repo specialness. Additionally, I identify recurrent patterns for specialness around bond auctions, which are consistent with an overbidding behaviour of primary dealers.

Next, I explain the intraday variations of the spread between the rate of Italian GC overnight repos and the ECB deposit rate. The intraday repo spread is higher in the morning than in the afternoon, suggesting that banks ensure funding liquidity at the beginning of the day for prudential liquidity management. Collateral riskiness, repo riskiness, and the excess liquidity provided by the ECB affect the intraday repo spread. Moreover, bond supply, liquidity, modified duration, repo specialness and the margin costs determine the selection of bonds used in GC repos.

Finally, I analyse which factors explain the use of CCP-based repos with respect to bilaterally-traded (BIL) repos on Italian Treasuries, as well as the difference of their repo rates. When general market uncertainty increases, CCP repos are preferred to bilateral-traded repos. However, banks demand a risk premium on top of the BIL repo rate when the margin costs are above their median value, suggesting that higher margins make it less attractive to trade via CCPs.

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List of Abbreviations

BAS	Bid-Ask Spread
BIL	Bilaterally-traded
BIS	Bank for International Settlements
BOT	Buoni Ordinari del Tesoro
bps	basis points
BTI	Buoni del Tesoro Pluriennali Indicizzati
BTP	Buoni del Tesoro Pluriennali
CC&G	Cassa di Compensazione e Garanzia
CCP	central clearing house / central clearing counterparty
CCT	Certificati di Credito del Tesoro
CDS	credit default swap
CET	Central European Time
CHAPS	U.K. large-value payment system
CISS	composite indicator of systemic stress
CSD	central securities depository
CTZ	Certificati del Tesoro Zero-Coupon
e-Mid	Electronic Market for Interbank Deposits
EAPP	Extended Asset Purchase Programme
ECB	European Central Bank
EMIR	European Market Infrastructure Regulation
EONIA	Euro OverNight Index Average
ESC	European Sovereign Crisis
Eurex	European Derivatives Exchange
Euribor	Euro Interbank Offered Rate
FED	Federal Reserve System
GC	general collateral
GCP	general collateral pooling
GFC	Global Financial Crisis
GIIPS	Greece, Ireland, Italy, Portugal and Spain
ISIN	International Securities Identification Number
LTRO	Long-Term Refinancing Operation

MRO	Main Refinancing Operation
MTS	Mercato dei Titoli di Stato
OMT	Outright Monetary Transactions
ON	overnight
ON1	overnight (only in Chapter 2)
OTC	over-the-counter
PSPP	Public Sector Purchases Programme
RTGS	real-time gross settlement
SMP	Securities Markets Programme
SN	spot next
TARGET2	Trans-European Automated Real-time Gross Settlement Express Transfer system (second generation)
TN	tomorrow next
U.K.	United Kingdom
U.S.	United States of America

1 INTRODUCTION

1.1 Motivation for the Thesis

The last decade has seen dramatic changes in the refinancing patterns of banks in the interbank market. The main function of the interbank market is to facilitate the reallocation of funds within the banking sector by allowing banks to borrow funds from each other (Boissay and Cooper, 2014). However, during the recent financial crisis of 2007-2008, a considerable number of banks has struggled to obtain liquidity at reasonable market conditions. Both in Europe and in the U.S., the unsecured money market segments were significantly impaired by heightened concerns about counterparty credit risk of borrowers, as well as by increased demand for liquidity (Angelini, Nobili, and Picillo, 2011; and Miglietta, Picillo and Pietrunti, 2015). As a consequence, the trading activity via unsecured borrowing has dropped over time, stabilising at very low levels. The cumulative quarterly turnover of European unsecured money market decreased from € 27 trillion in 2007 to € 5 trillion in 2015, a reduction equal to 81.48% (ECB, 2015). While unsecured money markets have experienced significant disruptions, the financing activity of banks has shifted to the secured segments. In particular, banks have heavily relied on the interbank repo market to obtain secured short-term funding, both in Europe as well as in the U.S. During the period December 2008 to December 2016, the total value of repos and reverse repos in the euro area increased from € 4.633 billion to € 5.656 billion, a growth amounting to 22.08% of the trading activity observed at the end of 2008 in the immediate aftermath of the general financial crisis (ICMA, 2017).

In the euro area, repos are the banks' main source of money market funding, and the magnitude of the European repo market is comparable with the estimate available for the U.S. of about USD 5.5 trillion (see Copeland, Davis, LeSueur, and Martin, 2012).

These developments have stimulated research into the drivers of the use of repos as well as into the funding costs faced by banks in the European repo market. Given the relevance of this market, the work presented in this thesis aims to contribute to the growing body of research on repos.

A repurchase agreement (repo) is essentially a collateralized loan based on a simultaneous sale and forward agreement to repurchase securities at the maturity date (Mancini, Ranaldo and Wrampelmeyer, 2016).[1] In the euro area, the majority of repos are traded in the interbank repo market segment, and only a small fraction is executed outside the banking sector, either with customers or via intragroup trades (Bakk-Simon, Borgioli, Girón, Hempell, Maddaloni, Recine, and Rosati, 2012).[2] The two main participants in this market segment include banks (investment, commercial and retail) as well as specialized financial institutions – e.g. national central banks, cooperative banks, etc. (Mancini et al., 2016). The repo market is crucial for the functioning of the overall secured interbank market (Comotto, 2010). It allows banks and broker-dealers to efficiently allocate liquidity and collateral among themselves by facilitating the price discovery for funding liquidity (Mancini et al., 2016). Moreover, repos are also used by banks for the management of the assets (and collaterals) in their inventory. To summarize the main functions of repos, financial institutions can: (a) obtain cash via secured funding, (b) finance the purchases of assets in the secondary market, (c) earn interest for lending cash, (d) acquire the temporary ownership of bonds, and (e) take short positions. Furthermore, repos have become the main instrument for open market operations conducted by the vast majority of the central banks worldwide (Gorton and Metrick, 2012). Additionally, central banks can use repos to provide emergency liquidity to the market in times of crisis. In doing so, central banks redistribute liquidity to banks and non-banks through the interbank repo market.[3]

A repo is a safer way to lend cash than unsecured forms of lending. In particular, the function of the collateral used in a repo transaction is to hedge the credit risk in case one of the counterparty defaults

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[1] In this section I provide a general overview of the relevance of the repo market. I describe the specific features of repos in more detail in Chapters 2, 3 and 4.
[2] While the list of participants is specific to the euro interbank repo markets, overall repos are also used by asset managers, hedge funds, mutual funds, pension funds, insurance companies, corporate treasuries, and local authorities (Thiessenhusen, 2014).
[3] A detailed summary of the ways in which repos are used can be found on the following website: https://www.icmagroup.org/Regulatory-Policy-and-Market-Practice/repo-and-collateral-markets/frequently-asked-questions-on-repo/2-how-is-repo-used/

or simply fails to re-pay the borrowed amount of cash. To explain, in the event of default of her counterparty, the repo seller can liquidate the collateral and reduce her exposure to the (defaulting) repo buyer. Moreover, collateralisation can also mitigate liquidity risk. For instance, a liquid collateral can be easily sold to a third party to meet an unforeseen need for cash. As a consequence, the conditions incurred by borrowers when trading via repos are generally better than via unsecured lending instruments. Sovereign debt instruments are typically used as collaterals to borrow funds via repos. By the end of 2016, government securities constituted the highest share of repo collaterals in the euro area, amounting to 42.08% of all assets, followed by corporate bonds (16.3%), bonds of public agencies / sub-national governments (14.8%), equity (14.15%), and covered bonds (8.5%) (ICMA, 2017).

The safety of a repo contract is ultimately dependent on the adequacy of its collateral. However, during the recent crisis in the sovereign debt market, there was an increased demand for sovereign collaterals perceived as safe, for instance issued by countries with relatively low credit risk (Hördahl and King, 2008). Moreover, recent regulations explicitly require greater amounts of safe assets on the balance-sheets of banks, with policymakers aiming to render the banking sector more resilient to shocks (Cœuré, 2012).[4] Overall, these safe sovereign debt instruments have become relatively 'scarce' and difficult to obtain via repos. This problem was exacerbated by the European Central Bank (ECB) which has used both repos and purchases of government bonds to transmit liquidity into the market (Corradin and Maddaloni, 2017). For all these reasons, shedding light on the transmission mechanism between the funding liquidity of the European banking sector, the riskiness of the sovereign bond markets, and the impact of unconventional monetary policies is critical for understanding the functioning of the euro interbank market.

[4] According to Cœuré (2012), a structural change in the demand for collateral would be the result of regulatory changes: (a) the liquidity coverage ratio under Basel III –i.e. the requirement to hold high-quality liquid assets, (b) regulatory changes on derivatives trading (European Market Infrastructure Regulation (EMIR)) –i.e. through the mandatory clearing of certain classes of derivatives and margin requirements for CCPs, (c) the capital charges in Solvency II for insurers, and (d) the Dodd-Frank Act.

In the three empirical chapters of the thesis, I investigate the dynamics of repos on Italian government bonds, which are executed on the *Mercato dei Titoli di Stato* (MTS).[5] There are several reasons which motivated me to study the Italian repo market. First, Italy is the country with the largest amount of sovereign debt in Europe (and the third largest worldwide after U.S. and Japan) (Pelizzon, Subrahmanyam, Tomio, and Uno, 2016). The Italian sovereign bonds also represents a high share (10.8%) of the European treasuries used as collateral via repos (ICMA, 2017). Second, the Italian market experienced substantial stress during the recent sovereign crisis. This is confirmed by the instability of the Eurozone sovereign bond market which reached its peak during the summer of 2011, following a severe downgrade of the Italian sovereign-specific country credit rating (Pelizzon et al., 2016). Third, when assessing the importance and quantity of academic published works based on the relevance of the capital markets in the world, Italy is the most underrepresented country in Europe, and in the top positions worldwide (Karolyi, 2016).[6]

Given the strong attention for repo markets by market practitioners, and their widespread use in the banking sector, a growing body of academic work has been dedicated to understanding the drivers as well as the consequences of using repos as tools for managing banks' short and long term liquidity needs. Arguably, most academic interest has been devoted to the U.S. repos, as confirmed by the great number of studies published on this market (e.g. Duffie, 1996; Jordan and Jordan,1997; Sundaresan, 1994; Keane, 1995; Fisher, 2002; Krishnamurthy, 2002; Graveline and McBrady, 2011; D'Amico, Fanz, and Kitsul, 2015; Furfine, 2001; Bartolini, Gudell, Hilton, and Schwarz, 2005). However, there are surprisingly few studies that empirically investigate the interlinkages between the funding liquidity in the euro repo market, the riskiness of the sovereign bond markets and the impact of unconventional central banking monetary interventions. For instance, Mancini et al. (2016)

[5] There are three main electronic platforms which constitute almost all the euro interbank repo market, namely MTS, BrokerTec and Eurex Repo. MTS is the leading trading platform for Italian repos and sovereign bonds. The majority of trading volumes on BrokerTec consists of special repos on (non-Italian) sovereign bonds. Eurex repo is the leading electronic trading platform for the euro GC repos (see Mancini et., 2016 and the description therein).

[6] Karolyi (2016) shows that Italian capital markets are the most under-researched capital market relative to the size of its capital markets in Europe – i.e. given that the Italian capital market is quite sizeable, few academic studies have been dedicated to investigating this particular market.

point out that there are fundamental differences in the market design of European and U.S. repos. Since little research exists on the European interbank repo market, there are fundamental questions which are still unexplored. Why are some specific collaterals more desirable for banks than others? What is the impact of the intraday trading activity of repos on the liquidity and collateral management for banks? Why do banks make use of centrally-cleared repos and prefer them to bilaterally-traded repos as source of bank funding? These are important questions that need to be addressed in order to better understand the growth in the use of the repo market, its relevance for the liquidity management of banks, as well as its impact on financial markets.

1.2 Related Literature

The literature on repos which I refer to covers three main topics: (a) the degree of specialness which is a measure of the additional costs required in order to obtain a specific bond via repos (Duffie, 1996); (b) the intraday patterns of repo rates, which indicate the trading behaviour of banks for managing their end-of-day liquidity needs (Kraenzlin and Nellen, 2010; Abbassi, Fecht, and Tischer, 2017); and (c) the use of Central Clearing Counterparties (CCPs) in order to borrow and lend funds among banks (Mancini et al., 2016; Affinito and Piazza, 2015).

U.S. special repos on sovereign debt instruments are the focus of most of the existing studies within the stream of literature on the degree of specialness. The seminal work by Duffie (1996) provides the theoretical framework and develops a model which explains the dynamics of specialness. Specialness can arise when legal/institutional requirements or opportunity costs/frictions limit the supply of collateral via repurchase agreements. In this case, the supply curve for repo collateral would be so small relative to the demand curve to drive specialness up. Specialness increases also when short-hedging and speculative demand in the cash market are high, in particular when the issued amount of the security is considered. Furthermore, when a large portion of investors buy-and-hold the security, they take collateral away from the repo market. In doing so, they reduce the supply of collateral and specialness increases. Finally, Duffie (1996) points out the existence of a direct link between special repo rates and the underlying cash market prices. He argues that specialness increases the equilibrium price for the underlying instrument, and that this increase is equal to the present value of savings in borrowing costs associated with the special repos. This latter prediction is supported by the evidence provided by Jordan and Jordan (1997) for the U.S. repo market. Not only specialness is priced as a premium in the cash market, but this cash premium is a function of both the magnitude and duration of specialness. Several other studies focus on specialness in the U.S. repo market. Sundaresan (1994), Keane (1995), and Fisher (2002) find that repo specialness exhibits periodic patterns related to the auction cycles in the primary market. Krishnamurthy (2002), Moulton (2004), and Graveline and McBrady (2011) provide evidence on the positive relation between specialness and the on-the-run status of the U.S. sovereign bonds. Finally, D'Amico et al. (2015) show that the Federal Reserve System (FED) programs influence specialness by the amounts of bonds purchased and sold by the FED. The variation of repo specialness in the European markets has been studied by few academic works. Buraschi and Menini (2002) focus on repos on German sovereign bonds. They find that the current forward spread on the future collateral value of German government bonds overestimate changes in future specialness, and that these deviations are due to the existence of a time-varying liquidity risk premium. Corradin and Maddaloni (2017) investigate specialness in the repo market for Italian sovereign debt instruments. They find that specialness negatively relates to the amount of a security available in the market, and that this effect is stronger during the European sovereign debt crisis. Additionally, they show that the Italian repo market was significantly affected by the ECB unconventional interventions.

Regarding the relevant literature on the dynamics of intraday repo rates and the intraday liquidity management of banks, Van Hoose (1991), Angelini (1998) and Bech and Garrat (2003) build models which theoretically predict the existence of ‘positive intraday implicit interest rates’. To explain, banks demand higher amounts of funding in the morning than in the afternoon when they perceive a high risk of not meeting their end-of-day liquidity needs on time. As a consequence, higher demand of funding earlier in the day implies that banks pay greater interest rates in the morning than in the afternoon. This prediction has been tested in the U.S. and European money markets. Most of these works study unsecured money markets. In the U.S. market, Furfine (2001), and Bartolini et al. (2005)

show the existence of patterns of intraday interest rates in the Fedwire system. The works by Angelini (2000), Baglioni and Monticini (2008, 2010, 2013), and Jurgilas and Žikeš (2014) are the main influential studies which focus on the European unsecured money markets. Angelini (2000) does not find evidence supporting the existence of intraday patterns of interest rates in the Mid market – i.e. the unsecured money market mainly dominated by Italian banks – during the period from 1993 to 1996. However, Baglioni and Monticini (2008) test the presence of intraday dynamics of interest rates in the same market from January 2003 to December 2004. This period is characterised by the introduction of a real-time-gross-settlement (RTGS) system. They show the existence of a downward pattern of interest rates throughout the trading day. This finding is explained by the willingness of banks to avoid the risk of not obtaining the requested funding in a timely manner due to the settlement risk of the newly introduced RTGS system. Baglioni and Monticini (2010, 2013) and Jurgilas and Žikeš (2014) show that during the recent global financial crisis period, the intraday patterns of interest rates are more pronounced, for the E-Mid and the U.K. large-value payment system (CHAPS). While several studies are focussed on the unsecured money markets, few works investigate the general collateral (GC) repo markets. The Swiss franc overnight repo market is analysed by Kraenzlin and Nellen (2010). First, their findings show that the intraday rates increase due to the introduction of a foreign exchange settlement system. Second, they show that the impact of the general financial crisis on the intraday interest rates is stronger for the unsecured money market than the secured repo market. Abbassi et al. (2017) provide evidence of the presence of an intraday pattern of interest rates for German CCP-based GC repos (Eurex) over the period 2006-2012. According to their results, this pattern is more distinct during periods of crisis, and when the repo market is more illiquid.

The stream of literature on the use of CCPs in the interbank market mainly consists of theoretical works. There is not a clear consensus about the resilience of the CCP-based interbank markets. On the one hand, CCPs eliminate direct counterparty exposures via anonymous trading (Martin, Skeie and Von Thadden, 2014b). Additionally, in case of default of a participating bank, CCPs can liquidate collateral. In this way, losses are distributed among banks (Oehme, 2014). Indeed, the safety and liquidity of collateral both alleviate the risk of systemic and individual runs by banks (Martin, Skeie and Von Thadden, 2014a). On the other hand, CCPs are characterised by a large concentration of credit risk (e.g. Singh 2010). The overall counterparty exposures of the banking sector could increase in case banks do not make use of the bilateral alternatives, and almost exclusively trade via CCP-based repos (Duffie and Zhou, 2011). Pirrong (2011) theoretically shows that if margins are set too high, safer banks could trade less via CCPs. Indeed, safer banks could perceive that their risk is overpriced with respect to riskier borrowers, and thus leading the former to use bilateral transactions and avoid the margin costs set by the CCPs. Furthermore, when margin requirements are increased during a period of financial stress, banks face additional liquidity constraints, which further deteriorate their funding conditions (Pirrong, 2011; Brunnermeir and Pedersen, 2009). Few empirical works study the resilience to risk of the CCP-based interbank markets. Boissel, Derrien, Örs, and Thesmar (2017) investigate the relation between daily CCP-based repos and sovereign credit risk. Their results show that the sovereign risk for GIIPS (Greece, Ireland Italy, Portugal, and Spain) positively affects the costs of trading via GC CCP-based repos. Miglietta, et al. (2015) find that margin costs increase the funding costs in the Italian GC repo market. Mancini et al. (2016) study the GC Pooling (GCP) repos from Eurex, which are characterised by the use of high-quality sovereign collaterals. They provide evidence of the positive effects that the market design of CCPs as well as the quality of sovereign collaterals have on the resilience of the European interbank repo market. They show that the higher the quality of the sovereign collateral, the more the CCP-based repos are resilient to risk. Related to the use of CCPs, Affinito and Piazza (2015) investigate the determinants of the use of CCP-based interbank exposures over the total liabilities for Italian banks. Their results indicate that general uncertainty is positively related to the use of CCPs. This finding suggests that CCPs contribute to the interbank market by providing banks with an additional way to obtain safe funding.

1.3 Intended Contributions

This thesis contributes to the growing body of research on repos by investigating the interlinkages between the repo market and the sovereign bond market. In particular, I focus on three questions that I will address throughout the three main empirical chapters of this thesis:

(1) What drives the costs for procuring specific collateral instruments, and their relative 'market desirability'?

(2) What are the determinants of the intraday interest rate for centrally-cleared and bilateral repos and what are the bond's characteristics that explain the selection of sovereign debt instruments in GC repos?

(3) What are the factors which explain the use of CCP-based repos in comparison to bilaterally-traded repos and the difference of their funding costs?

The dynamics and the relevance of these matters depend on a variety of factors, including the riskiness of the bonds used as collaterals, the uncertainty in the interbank repo market, the impact of central banking monetary interventions, and the regulatory changes adopted by CCPs. To account for these different facets of the repo market, each of the three empirical chapters of this thesis focuses on one particular topic, and answers relevant questions regarding the literature in each of them. Thus, the three chapters, when considered together, form a comprehensive analysis of some of the most important topics discussed in the literature on the repo market, and the findings are relevant to banks and regulators.

A major contribution of the thesis is the attempt to reorient the research on repo specialness from analysing the U.S. repo market towards investigating the European repo market. The main institutional features of the European repo market substantially differ from the characteristics of the U.S. repo market – i.e. the legal treatment of the collateral, the use of CCP versus tri-party repos, the Treasury auction cycles, the implementation of unconventional central banking operations via repos by the ECB, and the sovereign debt crisis in Europe (e.g. Bakk-Simon et al., 2012; Copeland, Martin, and Walker, 2013; Mancini et al., 2016; D'Amico et al., 2015; Buraschi and Menini, 2002; and

Corradin and Maddaloni, 2017).[7] Most studies on repo specialness, and particularly the most 'influential' ones, are focused on the U.S. repo market (Duffie, 1996; Jordan and Jordan,1997; Sundaresan, 1994; Keane, 1995; Fisher, 2002; Krishnamurthy, 2002; Graveline and McBrady, 2011; D'Amico et al., 2015). However, very few studies have analysed which factors drive the repo specialness in the European sovereign bond and repo markets (Buraschi and Menini, 2002; and Corradin and Maddaloni, 2017). Given the relevance of the European interbank repo market as a source of funding for the banking sector, it is an interesting yet mainly unexplored question, whether the factors which determine repo specialness differently affect the use of repos in Europe.

Relatedly, another major contribution of the thesis is the development of a model which comprehensively explains repo specialness on sovereign bonds issued by the Italian Treasury. By doing so, I provide novel evidence in the first empirical chapter (Chapter 2) which shows that degree of specialness varies over time and according to the maturity of the bonds. Furthermore, I confirm Duffie's (1996) prediction that bonds with higher supply are related to higher repo specialness.[8] Additionally, I show recurrent patterns of specialness which relate to the auction cycles of the bonds in the primary market. The short-selling activity of primary dealers, conducted via reverse-repos, is higher ahead of auctions, and is indicated by higher repo specialness prior to the auction settlement date. Furthermore, this pattern differs according to the timing of the collateral exchange for the specific repo contract. While neither the U.S. nor European repo studies in the literature on repo specialness report a similar comparative investigation, this study instead sheds lights on some interesting variations of repo specialness across the repo terms.

Regarding the management of the liquidity needs by banks, an additional important contribution of the thesis is the analysis of the intraday interest rates of repos. While the most relevant existing

[7] In Chapter 2, I explain in more detail the differences between U.S. and European repos.
[8] Duffie's (1996) prediction that bonds with higher liquidity (lower bid-ask spread) are positively related to repo specialness is verified when we consider cross-sectional effects.

studies in the literature on the intraday price of money focus on unsecured money markets (Furfine, 2001; Bartolini et al., 2005; Angelini, 2000; Baglioni and Monticini, 2008, 2010, 2013; and Jurgilas and Žikeš, 2014), very few works have investigated which factors drive the intraday variations of secured forms of borrowing such as GC repos. Differently from the main studies of the GC intraday repo market (Kraenzlin and Nellen, 2010; Abbassi et al., 2017), in Chapter 3 I show that collateral riskiness – i.e. bond supply, bond illiquidity and duration - drives the intraday rates of GC repos on Italian Treasuries. Relatedly, I provide evidence that bonds in higher supply, more illiquid bonds, bonds with higher duration and lower repo specialness are less probable to be used as collaterals in GC repos. To the best of my knowledge, the determinants of the collateral selection have never been investigated in academic studies on repos. Additionally, while several works investigate GC repos traded via CCPs (Mancini et al., 2016; Boissel et al., 2017), I conduct an investigation on both intraday CCP and bilaterally-traded GC repos. The comparative analysis is novel to the literature on GC repos, and reveals some interesting differences. I show that traders seem to prefer CCP trading, and use bilateral repos only in the afternoon when CCP repos are no longer available. Furthermore, on average, banks demand a risk premium on top of CCP repos for trading bilateral repos, reflecting the CCP mitigation of counterparty risk.

The final conceptual contribution of this thesis relates to the use of CCPs in the repo market, and represents an analysis into the factors that lead banks to prefer CCP-based repos to bilaterally-traded repos. The empirical literature does not reach an obvious consensus on the determinants of the use of CCPs in the interbank market (Mancini et al., 2016; and Affinito and Piazza, 2015). Indeed, recently several scholars have introduced the idea that margin policies adopted by CCPs (Pirrong, 2011; Wendt, 2015) as well as the self-selection of riskier banks into CCPs (Cappelletti, De Socio, Guazzarotti, and Mallucci, 2012; Arnsdorf, 2012; Heider, Hoerova, and Holthausen, 2015; Affinito and Piazza, 2015), could disincentivise the use of CCPs, and favour bilateral trading. This study represents one of the first attempts to empirically test these hypotheses by assessing the different trading volumes and funding costs of CCP and bilateral repos, and to evaluate the underlying motivations for such differences. Overall, both the difference between the trading volumes of CCP repos and bilateral repos, and the spread between the bilateral repo rates and CCP repo rates, increase with general uncertainty and risk. However, Chapter 4 represents the first study which shows that the margin policies implemented by the CCPs could discourage the use of CCP repos as well as increase the funding costs that banks incurred when trading via CCPs with respect to the bilateral alternative.

The nature of the research presented in this thesis is empirical. The aim of this work is to investigate the factors which determine the funding conditions of the interbank repo market, and to link them to the implications for banks and policy makers. It is important to note that, although I explain how the contributions of this thesis are relevant for regulators, this work is not aimed at laying out a menu of macroprudential policies regarding the use of repos. Additionally, although the work touches upon how regulatory changes affect repos, this thesis does not represent a comprehensive assessment of the repercussions that regulation and legislative norms might have on the interbank repo market.

In each empirical chapter, the methodological design of the analyses has been carefully considered. Furthermore, several robustness checks and sensitivity tests have been conducted to confirm the validity of the results presented in this thesis. The majority of these robustness checks are reported in this work.

Overall, this study intends to make several contributions to the literature on repos by providing original empirical evidence on the drivers which affect the repo market, and which ultimately determine how banks make use of this market for the well-functioning of their liquidity management.

1.4 Outline of the Thesis

The main body of the thesis is presented in Chapters 2, 3 and 4. Each of the chapters is an independent study which focuses on one relevant topic for the interbank repo market, and provides original findings for the respective literature.[9]

In Chapter 2, I investigate which factors explain the variations of repo specialness, which is the cost incurred by banks – i.e. lower interest received - to obtain a specific collateral via repos. In particular, I analyse whether collateral riskiness, repo riskiness, ECB unconventional interventions and bond auctions influence the repo specialness. After a review of the related literature and a description of the features of repo markets relevant to the study in Chapter 2, I describe the data used in the empirical analysis and explain how I measure the degree of specialness. The main data sources used in this chapter are the MTS Time Series database for bonds and repos, and the Bank of Italy and the Italian Treasury websites for information on primary market auctions, the auction calendar and all related communications, which I combine to create my sample of 130 Italian sovereign bonds and three different types of 1-day repo contracts. Then, I conduct an analysis of the effect of auction cycles on repo specialness, as well as of the term structure of the degree of specialness. I continue by explaining the research design and the construction of the proxies of the main factors, before discussing the empirical findings. In this chapter, I employ as a benchmark model a fixed-effect panel regression that relates repo specialness to proxies for collateral riskiness, repo riskiness, central banking unconventional interventions and primary market bond auctions. To determine which are the factors that explain the dynamics of repo specialness over time, I estimate the model of repo specialness over four distinct sub-periods, namely the period before the crisis of 2007, the general financial crisis period of 2007-2008, the 2010-2012 European sovereign crisis period, and the post-crisis period of 2013. After that, I test the robustness of the main results to alternative model

[9] I make use of "we" instead of "I" in Chapters 2, 3 and 4. These chapters are joint works, and are co-authored with Dr. Alfonso Dufour (Chapters 2, 3 and 4), Dr. Miriam Marra (Chapters 2 and 3), and Prof. Frank S. Skinner (Chapter 2).

specifications and sub-samples of bonds. The chapter ends with a summary of the main findings and implications.

Chapter 3 focuses on the intraday interest rates of overnight (ON) GC CCP and bilaterally-traded repos on Italian sovereign debt instruments. After a brief discussion of the motivation for the study, I introduce the particular features of the intraday repo market and of the data obtained from MTS. Based on the prior literature on intraday interest rates in money markets, I first test the existence of an intraday pattern for all ON GC repos, and separately for CCP and bilateral repos. Second, based on the prior literature on GC repos, I explain which factors affect the difference between the average hourly repo rate and the ECB deposit rate. I conduct this analysis via hourly time-series regressions. Third, I evaluate which collateral characteristics lead to the selection of a particular bond in GC repos. I conclude Chapter 3 by summarizing and discussing the implications of these findings.

In Chapter 4, I concentrate on the use of ON GC CCP repos compared to that of bilateral repos on Italian Government bonds. In addition, I analyse the factors which explain the differences between them. In order to evaluate the overall drivers of the use of CCPs in the Italian interbank repo market, I consider two possible channels of risk mitigation used by banks: the *repo volume channel*, as measured by the difference between the daily trading volumes of CCP and bilateral repos (repo volume spread), and the *repo rate channel*, which is defined as the spread between the daily repo rates of bilateral and CCP repos (repo rate spread). This allows me to investigate whether the repo volume spread and the repo rate spread increase with sovereign risk, repo riskiness, counterparty risk and margin costs. After introducing the literature and motivations, I describe the data and sample construction. In doing so, I especially focus on the differences between CCP and bilateral repos from the MTS Time Series database for ON repos. Following this, I present the empirical methodology and the results. I first analyse the impact of the determinants on the repo volume spread, followed by robustness checks specific to this section. I then focus on the factors which affect the variation of the repo rate spread. Chapter 4 closes with a summary of the findings and a discussion of their main implications.

I provide an overview of the contributions of the thesis in Chapter 5, in which I bring the findings and conclusions of each chapter together. The thesis concludes with a brief discussion of possible routes for future research that builds on the results presented in this thesis.

2 EXPLAINING REPO SPECIALNESS

2.1 Introduction

The aim of this paper is to explain the variation in the degree of specialness of repurchase agreements (repos) that use Italian Government coupon bonds BTPs (*Buoni del Tesoro Pluriennali*) as collateral. Repos are financial instruments for collateralized borrowing and they are essential for well-functioning and efficient bond markets. Repos are used by bond market participants to either finance long bond positions or initiate short bond positions. Repo markets are also a preferred monetary transmission channel used by Central Banks to conduct money market operations and regulate financial markets' liquidity.[10] Repo markets are characterized by huge transaction volumes, as reported in Table 2.1 which presents data for the *Mercato dei Titoli di Stato* (MTS). MTS is one of the largest European electronic bond and repo markets and the largest for Italian debt instruments. During our sample period from April 1, 2003 to December 6, 2013, the overall value and the daily average volume of all repo transactions executed on MTS are about €179 trillion and €65 billion, respectively.

Table 2.1: Nominal amount of transacted collateral in the MTS repo market

The Table reports summary statistics for the nominal volume of collateral in MTS general and special repo transactions over the period April 1, 2003 to December 6, 2013.

	General Collateral (Euro Billions)	**Special Collateral** (Euro Billions)	**Total** (Euro Billions)
Daily Average	28.90	36.57	65.45
Standard Deviation	9.54	11.27	13.98
Minimum	0.75	0.06	0.06
Maximum	99.28	130.66	189.53
Trading Days	2,735.00	2,735.00	2,735.00
Total	79,035.66	100,044.69	179,080.35

Traders can choose between two types of repo contracts: the GC and the special repos. With the GC repo traders can specify the securities to be used as collateral after the repo trade is agreed. The

[10] In our analysis we consider operations conducted by both the Bank of Italy and the ECB.

collateral is to be chosen from a pre-defined basket of Treasuries. The special repo instead requires traders to specify a unique security as collateral at the onset of a repo transaction and pay a (generally) lower "special" repo interest rate on the loan. At each point of time, the difference between the general and the special collateral repo rates measures the 'degree of specialness' of the bond used as collateral in the special repo. Positive specialness is generally considered as a signal of greater 'market desirability' or relatively scarce supply of the specific instrument used as collateral in the repo contract. In this paper, we provide novel empirical evidence on Italian Treasury bonds and develop a comprehensive model for explaining repo specialness. We observe that the degree of specialness changes over time and across bonds and often exhibits some recurrent patterns which are correlated with bond auction cycles.

Most of the existing literature on the determinants of repo specialness is focussed on the U.S. government bond special repos. However, there are notable differences between the U.S. and the European repo markets. First, in Europe the repo contract transfers the legal title to the collateral from the seller to the buyer by means of an outright sale; in the U.S. the collateral is pledged, but there is no legal transfer of the title. As a consequence, the collateral is treated differently during insolvency and bankruptcy procedures. Second, while the U.S. market is largely intermediated by dealers and by tri-party repos (repo management and settlement, but not counterparty risk, are outsourced to an agent) as well as by bilaterally-traded repos, the European repo market is dominated by interbank transactions conducted on electronic platforms and cleared via a central clearing counterparty (CCP), especially when the repo collateral is represented by safe government bonds (Bakk-Simon et al., 2012; Copeland, et al., 2013; and Mancini et al., 2016).[11] Third, there are differences between Treasury auction mechanisms in the U.S. and Europe that can lead to different special repo rate dynamics in the respective markets. For instance, while a Treasury auction for

[11] The U.S. tri-party repo market it is roughly the same size as the bilateral market as source of funding for dealers. While the U.S. tri-party repo market is set up to facilitate cash-driven transactions (GC repos), bilateral repos are commonly used by dealers either as a source of funding or as a way to obtain specific securities (special repos) (see Adrian, Begalle, Copeland and Martin, 2013).

Italian bonds often involves several subsequent reopenings for the same issued bond, in the U.S. this is much less common and reopenings are lower in number (see D'Amico et al., 2015). Fourth, the European repo market is central to the conduct of monetary policy. It is in fact an active interbank market where the ECB intervenes directly via Main Refinancing Operations (MRO), Long Term Refinancing Operations (LTRO) and/or unconventional interventions, such as the Securities Markets Programme (SMP), providing secured loans to banks who can pledge eligible collateral (Buraschi and Menini, 2002; and Corradin and Maddaloni, 2017). Finally, the distinctive period of high turbulence during the sovereign bond crisis of 2010-12 has likely impacted European repo markets. Given these differences, it is important to study and understand the specific characteristics of European repo markets and our paper represents a step in this direction.

The theoretical underpinning of our empirical investigation on Italian bond repo specialness is provided by the model developed by Duffie (1996) for the U.S. repo market. In particular, Duffie (1996) explains that specialness can arise when collateral owners are inhibited from supplying the collateral in repurchase agreements because of legal/institutional requirements or frictional/opportunity costs. Moreover, repo specialness can increase the equilibrium price for the underlying instrument by an amount which equals the present value of the savings in borrowing costs associated with the use of special repos. Jordan and Jordan (1997) empirically test Duffie's model using data on overnight repos that have U.S. Treasuries as collateral. They find strong support for overnight specialness being reflected in a cash premium in the bond market. They also find that lower supply of collateral for repos (measured by higher auction tightness and lower ownership by dealers) causes higher repo specialness. Several other studies investigate the U.S. Treasury repo market. For instance, some authors document periodic patterns in repo specialness related to the auction cycles (see Sundaresan, 1994; Keane, 1995; and Fisher, 2002). Krishnamurthy (2002) explains the degree of specialness using long-term Treasury supply as the main explanatory variable, but he also controls for auction cycles, liquidity demand, and credit risk factors. Moulton (2004) studies the difference between the specialness of on-the-run and off-the-run U.S. Treasuries. The on-the-run specialness is also studied by Graveline and McBrady (2011) for 5 and 10 year bonds. D'Amico et al. (2015) focus mostly on the effects of FED programs on U.S. overnight special repo rates during the period 2009-2013 by looking at the amounts of Treasuries purchased and sold by the FED.[12]

A few papers have looked at repo specialness in the European markets. Buraschi and Menini (2002) find that spreads on long-term special repos with German bonds as collateral overestimate the future relative scarcity value (also called convenience yield) of German bonds on special. They explain that this finding is due to the existence of a time-varying liquidity risk premium. Corradin and Maddaloni (2017) analyse the Italian sovereign repo market over a relatively short-period, from October 2009 to July 2012. This is the period of the sovereign crisis which has greatly affected the credit valuation of Italian government bonds and increased the margin requirements requested by the CCP on Italian treasuries. During this period, the ECB implemented a series of non-standard monetary policy measures: in August 2011 the Securities Markets Programme (SMP) involving the outright purchase of government securities; in December 2011 and March 2012 two 3-year long-term refinancing operations (LTROs), where secured loans with maturity of three years (with an option of early repayment) were provided to banks pledging eligible collateral. Using data over this exceptional period, Corradin and Maddaloni (2017) show that the ECB interventions, in particular the outright purchases of government bonds in the SMP framework, had an important effect on the repo markets. Our paper explores the determinants of Italian repo specialness over a longer sample period, from April 2003 to December 2013. This allows us to test whether Duffie's (1996) theoretical predictions hold for the Italian government bond repo market and whether the effects of some key variables on specialness have changed over time. This paper largely extends the initial analysis by Dufour and Skinner (2005) that uncovered possible effects of speculative demand on Italian treasuries during the period from 2003 to 2005. We consider a richer dataset of intraday bond data and repo daily data from MTS and analyse the dynamics of the degree of specialness over the sample that covers the

[12] These authors use changes in the special repo rates as proxy for changes in specialness, hence assuming no changes in the GC rate. They argue that time-dummies can be used to control for the effects of changes in the GC rates, but this approach cannot be easily applied to the Italian market. ECB money market rates act as benchmarks for all GC repos which use Treasuries issued by countries in the Euro-zone as collaterals. Thus, similarly to the US, the dynamics of the main refinancing rates in the Euro-zone are affected by ECB decisions. However, the Italian GC rate also captures country-specific risks.

relatively tranquil period of 2003-06; the 2007-09 global financial crisis; the 2010-12 European sovereign bond crisis; and the post-crisis period of 2013. Furthermore, our empirical analysis compares and contrasts specialness for three different repo-term contracts: Overnight, Tomorrow-Next and Spot-Next repos. We also provide a detailed analysis of the dynamics of specialness for these three different repo terms over the Italian Government bonds' auction cycles. This comparative analysis has never been reported either in U.S. or European repo studies and it reveals some interesting differences across the repo terms.

With respect to the auction cycle effects on specialness, we find that our sample repo contracts on Italian BTPs exhibit persistent and significant patterns which are related to the reopening of existing bond issues. With a reopening auction on date T, the amount of bonds outstanding increases starting from the auction settlement date T+2 onwards. We observe that on average specialness tends to increase steadily for all repo terms from the announcement date of the reopening until a few days before the actual auction settlement day, and then it decreases. The effect of auctions on specialness tends to decrease over consecutive reopening auctions and it varies also across bond maturities. Interestingly, we observe that the pattern of repo specialness around auctions differs across the three repo contracts, consistently with their contractual differences in the timing of collateral exchange and with higher dealers' short-selling activity via reverse-repos ahead of auctions.

In our empirical analysis of the drivers of the Italian sovereign repo specialness, we estimate panel regressions which include proxies for various factors that we expect to affect repo specialness, in particular collateral supply, collateral liquidity, and collateral risk-exposure. In addition, we analyse the impact of repo liquidity and auction cycles on specialness. Our results support Duffie's (1996) theoretical prediction that bond's supply is an extremely significant factor for explaining repo specialness. However, we also find that the realized volatility of bond returns (proxy for information uncertainty), bond fire-sales and repo liquidity are additional significant explanatory variables. Interestingly, the impact of some factors on specialness changes before, during, and after the two crisis periods of 2007-09 (global financial crisis - GFC) and 2010-12 (European sovereign crisis - ESC). For instance, we find that during the two crisis periods the importance of both realized bond volatility and fire-sales increases. Furthermore, we notice that the relationship between bond liquidity (measured by the bid-ask spread) and specialness is negative: more liquid bonds with lower bid-ask spreads tend to have lower specialness on average. This contradicts Duffie’s (1996) prediction that more liquid bonds tend to have larger specialness than other bonds. Hence, our bond liquidity proxy seems to reflect changes in information uncertainty and speculative demand rather than changes in bond market frictions, at least when used in panel analysis. Higher information uncertainty and higher speculative demand increase bond bid-ask spreads, but they also increase the demand for special repos and therefore repo specialness. When we only consider cross-sectional effects instead, Duffie’s (1996) prediction that bonds with higher liquidity (lower bid-ask spread) are also traded more on special seems to be verified. Our comprehensive analysis appears therefore very relevant to understand how shocks on demand and supply of collateral and on the behaviour of Italian treasury dealers/traders in good and bad times can affect a major secured money market instrument.

This chapter is organized as follows. Section 2.2 provides a short introduction to the repo market and to MTS. Section 2.3 presents a description of our sample and some preliminary statistical analysis. Section 2.4 provides a study of the effects of auction cycles on specialness. Section 2.5 presents a comprehensive empirical model for the determinants of repo specialness. Section 2.6 illustrates the results of the empirical analysis and provides further robustness checks. Section 2.7 summarizes the main contributions and findings of the paper.

2.2 The 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, the repo rate, for the use of the cash. The repo buyer borrows cash after pledging a security as collateral. The repo seller lends cash and collects the repo (interest) rate. Repo transactions are typically used for financing purposes via GC repos or to obtain specific securities via special repos. GC repos are mainly cash-driven as the collateral can be any security from a predefined basket of securities, whereas special repos are security-driven as the collateral is restricted to a single security. If an asset is in strong demand, dealers/traders may be willing to offer ‘cheap’ cash to get hold of this asset in the special repo market. In this case, special repo rates can fall close to zero or even become negative.

Because a repo is a safer way to lend cash, lenders are generally willing to lend more and at better conditions than in an unsecured lending agreement. In addition, institutions lending through repos are generally required by the regulator to hold less regulatory risk capital than in the case of unsecured lending. Consequently, over the last 10 years there has been a gradual shift of liquidity from deposit markets to repos. However, the safety of a repo contract ultimately relies on the adequacy of its collateral. Repo traders prefer liquid collaterals and accept illiquid collaterals only subject to appropriate initial margins and haircuts. The repo collateral is continuously revaluated and, if its value falls, the repo seller can require extra collateral (this process is called margin maintenance). Moreover, the repo seller (i.e. the lender) needs to be sure that, in the event of a default of her counterparty, she can: i) sell the collateral easily and without interference from the other creditors of the defaulter; and ii) reduce her exposure to the defaulter by ‘netting’ debts owed by the defaulter against debts owed to the defaulter. Because of the burden of all these operational requirements, some repo traders outsource the management of their collateral to agents: this system is called tri-party repo and it is the most common arrangement in the U.S. repo market. Margin requirements and maintenance, collateral valuation, and counterparty risk management can be also delegated to a Central Clearing Counterparty (CCP). This system is more common in the European repo markets.

Central Banks set benchmark interest rates. Repo rates are affected by changes in these benchmark rates but ultimately they are determined by private institutions which trade on secondary markets (such as MTS). Most Central Banks (including the ECB) use repos as tools for open market operations to control short-term interest rates.

A repo contract entails an agreement for selling the bond on the repo settlement date (first leg) and repurchasing it at a future date (second leg) which differs according to the ‘repo term’ specified in the contract (see Table 2.2). We consider three types of 1-day repo contracts in our analysis:

overnight (ON1), tomorrow next (TN) and spot next (SN). The ON1 repo contract is settled on the same date when it trades (T) and the collateral is repurchased on the next business day (T+1). The TN repo contract is instead settled at T+1 (one business day after the repo trade date), while the bond is repurchased at T+2. The SN repo is settled at T+2 (two business days after the repo trade date), while the bond is repurchased at T+3.

Table 2.2: Description of repo terms

T represents the day when the repo contract is traded on MTS. The repo settlement date is the date when the bond collateral is sold by the repo buyer/borrower to the repo seller/lender

Repo Term	Repo Settlement Date	Repurchase Date
Overnight (ON1)	T	T+1
Tomorrow Next (TN)	T+1	T+2
Spot Next (SN)	T+2	T+3

A bond purchase can be funded using the repo contract. The trader can match the first leg of the repo trade – i.e. the settlement date of the bond sale — with the date of the bond purchase in the primary or secondary markets. The bond is used as collateral in the repo trade to get the cash needed to purchase it. So the repo buyer purchases the bond and delivers it to the repo seller. Afterwards, the repo buyer repurchases the bond from the repo seller at a higher price than what received in the first leg of the repo trade: this step represents the second leg of the repo transaction. The repo rate is obtained from the difference between the (higher) repurchase price and the starting lower bond price. In case the repo buyer fails to repurchase the collateral, the counterparty (repo seller) can dispose of the collateral and use it to compensate her losses. In the Italian GC repos, various Italian Treasury bonds can be pledged and delivered, whereas in the special repo the collateral is uniquely identified by its ISIN number.

Generally, repos are classified as "buy sellback" or "classic" repos. A buy sellback repo is often undocumented and structured as two separate legal transactions, whereas a classic repo includes both legs together in one legal transaction. Buy sellback and classic repos are precisely the same in terms of their economic function and in Europe they both transfer the legal title on the bond to the counterparty-lender via an outright sale. However, a classic repo offers greater protection against counterparty credit risk for the lender. For instance, the lender can demand additional collateral if the interest rate spikes and the value of existing collateral falls below the outstanding loan amount. This is not possible with buy sellback repos. All repo transactions we study are buy sellback repos, as these are the only repo contracts used in Italy.

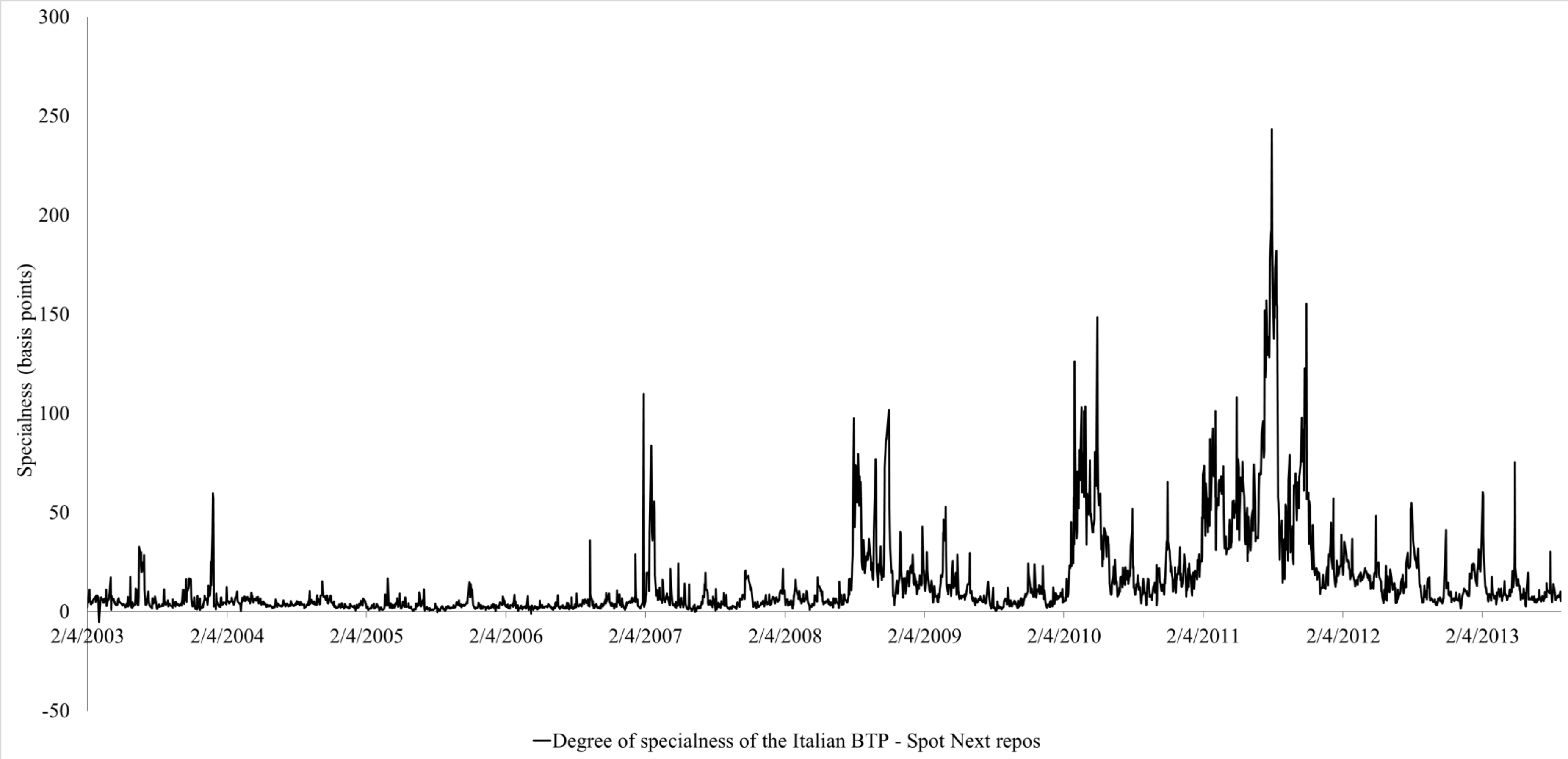
The counterparty to the repo contract provides a collateralised loan. We say that she enters in a reverse repo contract. While a reverse GC repo is performed simply to earn interest, in a special reverse repo the bond purchased in the first leg of the transaction can be used to cover an outstanding short position in that bond. It is precisely this need to obtain temporary ownership of a given bond that often motivates special repo contracts: the stronger the need for covering short positions in the bond, the lower its special repo rate. As a consequence, while the repo rate charged on GC repos is a market rate that mainly reflects the short-term interest rate environment, the rate on special repos, being also driven by the unique demand for the specific bond, can be far below the GC rate.

In this paper we study the repo specialness which is defined as the difference between the GC repo rate and the special repo rate. Figure 2.1 shows the time variation of the volume-weighted average specialness of Italian treasuries with 10-year residual maturity used as collateral in spot-next special repos. We observe that often specialness is relatively low (i.e. general and special repo rates are very close). However, there are times – for instance during the global financial crisis and the sovereign crisis – when specialness is very large, reaching up to 250 basis points (i.e. the special repo rate is much lower than the GC rate). In addition, specialness is characterized by several peaks throughout the sample period which are often associated with reopening auctions.

The aim of this paper is to explain how the repo specialness for Italian treasuries changes over time for different repo terms and different collateral maturities.

Figure 2.1: Degree of specialness of Italian BTP bonds with 10 year residual maturity

Volume-weighted average specialness (measured in basis points) for spot next special repos on Italian BTP bonds with 10-year residual maturity over the period from April 1, 2003 to December 6, 2013.



2.3 Data

In this paper we analyse a large sample of Italian government bonds and repo contracts which use these bonds as collateral. Bond and repo data are extracted from the MTS Time Series database. Our sample covers the period from April 1, 2003, the first date available on this dataset, until December 6, 2013. The MTS repo platform is the leading market venue for repo contracts collateralized by Italian Treasuries. The MTS repo data provide daily aggregate information on transacted nominal amounts, buyer-initiated (repo) volumes, seller-initiated (reverse repo) volumes and total number of trades. This information is available for each type of repo contract (special or GC), each repo term (ON1, TN or SN) and for each bond pledged as collateral for the repo transaction (identified by its unique ISIN code). The MTS bond data contains all intraday updates to prices and sizes of the best 3 bid and ask quotes. In addition, for each bond we have daily prices and yields (sampled at 17:00 – Central European Time - CET), modified duration,[13] and number of daily trades. Other information about the specific characteristics of the instruments – e.g. issuance date, maturity date, coupon payment schedule, etc. - are provided in separate bond reference files. Using the bonds' ISIN numbers, we match the repo market information with the bond market information.

First, we select all repos on Italian BTP bonds. BTPs are simple, semi-annual, coupon-paying bonds with no optionalities or inflation-linked pricing components. We concentrate on Italian sovereign repos because of the large number of observations available on MTS for Italian GC repo rates.[14]

For each business day and each repoed bond, we collect the Overnight, Tomorrow Next and Spot Next GC Italian repo rates and subtract the corresponding special repo rate. The resulting measure is the degree of specialness. Bonds with non-zero specialness are said to be trading *on special*. Table 2.3 (Panel A and B) shows the summary statistics and distribution of specialness for the three different repo contracts over the sample period from April 1, 2003 to December 6, 2013. There are

[13] In the original MTS dataset there are several missing observations for the modified duration (e.g. BTPs with residual maturity lower than 6 months). We have computed the modified durations for all these bonds with missing information.
[14] The daily repo rates for GC contracts for other main European issuers, such as France and Germany, are not always available in the MTS Time Series database.

130 different bonds that are used as collateral for TN and SN repo contracts. The number of bonds used as collateral for ON1 repos is slightly smaller, 115. The SN repos have the largest number of trades (127,585) followed by the TN and ON1 repos with 90,222 and 29,022 trades, respectively. In Table 2.3 we observe that the mean and median of specialness decrease when moving from the ON1 to the TN and to the SN repos. The ON1 repo has an average specialness of 33 basis points, almost 20 basis points higher than the TN average specialness and 25 basis points higher than the SN average specialness. Moreover, if we consider the proportion of observations with specialness greater than 25 basis points (see Table 2.3 Panel B), this is 38.26% for ON1 repos, but only 11.76% and 6.29% for TN and SN repos, respectively.[15] Observations with negative specialness range from just 1.08% for ON1 repos, to 2.29% for TN repos, and to 3.24% for SN repos. Specialness for the ON1 repos has the largest standard deviation (47.85 bps, basis points), while the SN repo specialness presents the lowest standard deviation (20.64 bps).

In Figure 2.2, we consider all sample repo trades and show how the median ON1, TN, SN repo specialness varies with respect to the residual maturity of the collateral. We consider all BTPs used as collateral for repo trades on MTS. We observe that: 1) the specialness curve of the ON1 contract is much higher than the corresponding curves of the TN and SN contracts for all levels of collateral maturity; and 2) for each repo term specialness increases monotonically with the collateral residual maturity, it peaks at the 10-year maturity level and then it decreases for longer maturities of the collateral. This is consistent with a relatively higher scarcity of the 10-year bonds.

As mentioned earlier, the ON1 repo specialness is the highest on average among the three repo contracts we study. This finding is expected as this is the contract with the shortest term. Often, traders urgently needing a particular bond have limited options available for securing it and hence are willing to lend cash at low rates in order to obtain the desired bond through an overnight reverse repo transaction.

[15] Note that high peaks in specialness could be the results of negative special repo rates. Dealers would be willing to accept negative repo rates in order to have access to a bond which is scarce in the market, but it is required to cover their short-positions.

Table 2.3: Summary statistics and distribution of specialness for different repo terms

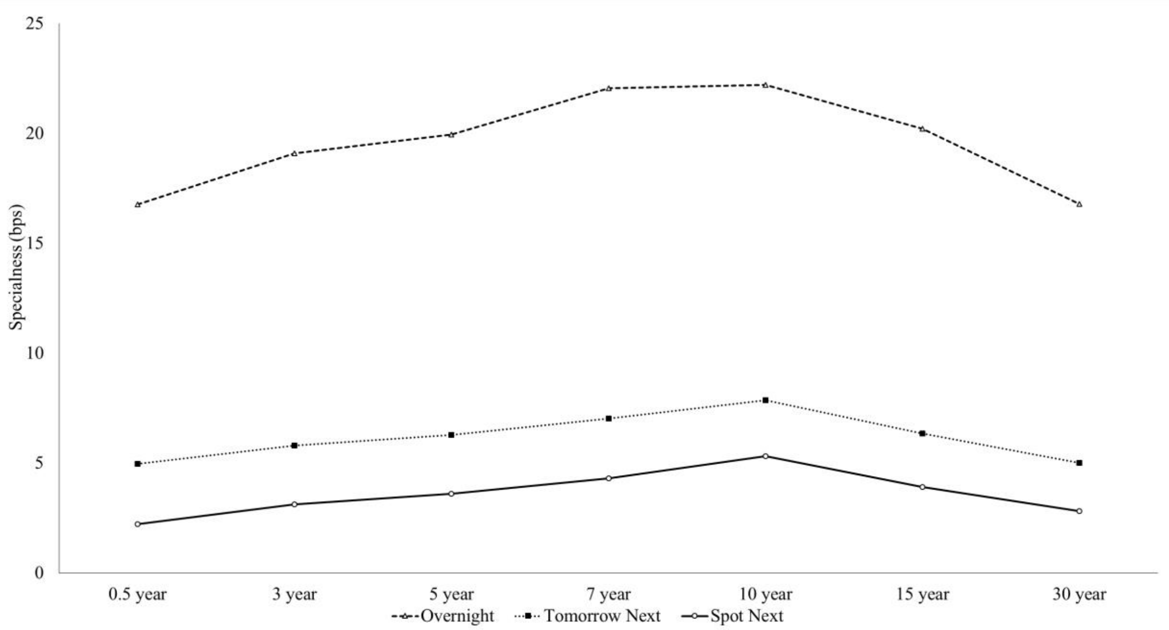
The Table reports summary statistics and distribution of specialness for repos on Italian BTP bonds over the period that goes from April 1, 2003 to December 6, 2013. The specialness is measured in basis points and it is the difference between the daily volume-weighted average Italian GC rate and the daily volume-weighted average special rate on a given Italian BTP bond. Panel A presents the summary statistics; Panel B reports the frequency of the distribution.

Panel A: Summary Statistics for Degree of Specialness				
Repo Term	*Overnight*	*Tomorrow Next*	*Spot Next*	*All Terms*
Mean	33.154	13.526	8.304	13.134
Median	19.807	6.1	3.451	5.3
Standard Deviation	47.854	28.912	20.639	29.227
Kurtosis	111.602	221.646	355.097	228.555
Skewness	7.461	10.622	13.523	10.64
Range	1,291.86	1,175.47	1,028.97	1,324.87
Minimum	-36.565	-69.568	-41.339	-69.568
Maximum	1,255.30	1,105.90	987.631	1,255.30
No. of Collateral Bonds (BTPs)	115	130	130	130
No. of Trading Days	2,500	2,734	2,734	2,734
No. of Observations	29,022	90,222	127,585	246,829

Panel B: Distribution of Degree of Specialness						
Specialness	*Overnight*		*Tomorrow Next*		*Spot Next*	
(basis points)	No.	%	No.	%	No.	%
(-75, -50]	0	0.00%	2	0.00%	0	0.00%
(-50, -25]	7	0.02%	9	0.01%	2	0.00%
(-25, 0]	309	1.06%	2,060	2.28%	4,131	3.24%
(0, 25]	17,601	60.65%	77,531	85.93%	115,429	90.47%
(25, 50]	6,358	21.91%	6,291	6.97%	5,125	4.02%
(50, 75]	2,067	7.12%	1,979	2.19%	1,364	1.07%
(75, 100]	1,014	3.49%	866	0.96%	554	0.43%
> 100	1,666	5.74%	1,484	1.64%	980	0.77%
Total	29,022	100.00%	90,222	100.00%	127,585	100.00%

Figure 2.2: Specialness and residual maturity of the collateral bonds

Median degree of specialness for ON1, TN, and SN repos plot against the residual maturities of the collateral bonds. All BTPs used as collateral for repo trades on MTS are considered.



Second, we study tick-by-tick bond data which are filtered implementing the following sequence of steps:

- We consider only quotes recorded during the regular daily trading hours from 8:15 AM until 5:00 PM Central European Time (CET) and discard the last 30 minutes of the trading day ending at 5:30 PM.
- Many of our sample bonds trade on a local market, MTS, and on a European market, Euro MTS. Market makers can submit a quote revision simultaneously to both markets, but the quote update may reach the two trading systems at slightly different times. In order to account for these latency issues, we assign the same time stamp to quotes submitted to these parallel platforms – MTS and Euro MTS – when they have the same price and are recorded either at the same time or 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 excessive misalignments between special and GC repo rates (only four outliers are detected with specialness lower than -100 bps).[16]
- 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 significantly increasing the 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 considering the distribution of the relative bid-ask spreads observed in the consolidated order books right before trade executions. We conduct this analysis over seven residual-maturity buckets for every year of the sample. We discard proposals with relative bid-ask spreads greater than the 99th percentile of the distributions, for every maturity-bucket and every year. As expected, we observe that on average, longer-maturity bonds are traded at higher relative bid-ask spreads than shorter-maturity bonds.

Finally, we retrieve information on primary market auctions, auction calendar and all related communications from the Bank of Italy and the Italian Treasury websites.[17] Table 2.4 reports the number of bonds issued either via primary market auctions or syndicate placements during the sample period for each maturity group. In particular, 83 out of 130 sample bonds are either first

[16] Several observations show negative specialness. We discard only four outliers out of about 250,000 observations (two observations for TN repos and two for SN repos). We keep all the other negative values as these are plausible observations. For example, a downward movement of the GC rate at the end of the day can result in negative specialness for a special repo traded more heavily earlier in the day.

[17] The Bank of Italy and the Italian Treasury cooperate closely when managing the debt operations: see http://www.dt.tesoro.it/en/debito_pubblico/; http://www.bancaditalia.it/.

issued or have reopening auctions. Most of the bonds issued during our sample period have maturities of 3, 5 and 10 years.[18]

Table 2.4: Number of bonds issued via ordinary auctions and syndicate placements and used in repo transactions

The Table reports the number of BTP bonds issued via ordinary auctions and syndicate placements, according to different repo terms and maturity groups, and used as collateral in repo transactions on MTS over the period from April 1, 2003 to December 6, 2013. It also reports the total number of BTPs used as collateral in repo transactions recorded on MTS over the same period (by maturity group and by repo term).

Maturity Group	Issued Bonds	Sample Bonds used as Repo Collaterals		
		Overnight	Tomorrow Next	Spot Next
3	26	32	37	37
5	22	28	33	33
10	20	36	41	41
15	8	8	8	8
30	7	11	11	11
Total	83	115	130	130

2.4 The Effect of Auction Cycles On Repo Specialness

We expect Treasury auction cycles to have a strong influence on the degree of repo specialness as they affect the supply of collateral. We perform a detailed analysis to investigate this issue. In particular, we consider only ordinary auctions (and reopening auctions) and the syndicate placements, while we do not consider Central Bank's exchange transactions and buybacks, given their marginal importance (see Table 2.4).

Keane (1995) and D'Amico et al. (2015) report some evidence of auction cycle effects, but only for U.S. overnight repos. We investigate whether these results are true also for Italian Treasury repos and extend the analysis by considering the dynamics of specialness over the auction cycle for different repo terms and for different collateral maturities.

It seems reasonable to expect no shortage of a particular bond for trading in the secondary market right after the bond has been issued. Thus, the repo specialness for this bond should be very low.

[18] We do not consider 7 year bonds since there is just one instrument available in the primary market and another one traded in MTS. Moreover, 7-year bonds are not proper BTPs; they are defined as 'Certificates'.

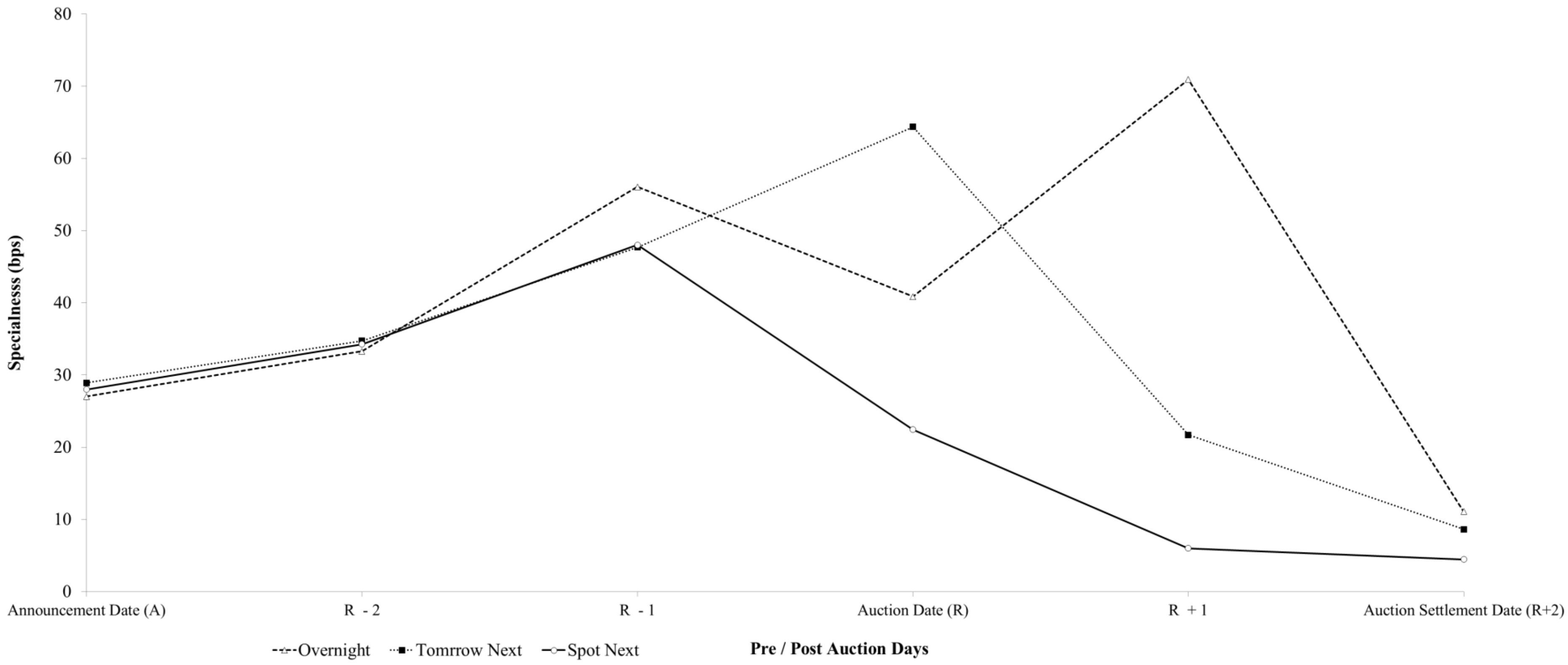
However, as time passes, a larger amount of the issued bond is purchased by buy-and-hold investors. Consequently, the availability of the bond for repo trading becomes lower and specialness increases. This pattern is observed at the first reopening auction, as well as at following reopening auctions, albeit to a lower extent. Moreover, the auction-cycle pattern of specialness changes according to the maturity of the bond-collateral. Bonds with shorter maturities (3, 5 and 10 years) have relatively more frequent reopening auctions (although a lower total number of reopenings for each bond) than longer-maturity bonds (15 and 30 years) which present reopening auctions more irregularly distributed over the longer life of the bond.

For each bond issue, we look at the first six consecutive reopening auctions across different bond maturities and repo terms. The largest effects of the auction cycle on specialness are observed for the shortest term, overnight repos. Not only the overnight repos reach the highest average level of specialness before reopening auctions compared to the other repo terms, but also its specialness starts increasing sooner than the specialness of TN and SN repos.

As an example, in Figure 2.3 we consider the pattern of repo specialness around the first reopening auction of all 3-year BTPs issued during our sample period and for all three repo terms. We can observe that for all repo terms (ON, TN, SN), specialness tends to increase from the announcement date (A) of the reopening auction, always peaking before the auction settlement day (R+2) and from there it decreases. The peak day changes according to the repo term. The average overnight repo specialness remains relatively ‘high’ until one day before the settlement date when it reaches 70.93 bps. The average tomorrow-next repo specialness displays a peak two days before the auction settlement at a level of 64.59 bps and the average spot-next repo specialness peaks three days before settlement when it reaches 48.03 bps. We attribute this behaviour to the different timing of the collateral exchange for the three repo terms (see Table 2.2). In overnight repos the first leg of the repo (bond sale) is settled on the same day as the repo trade (T) and the repurchase happens on the next business day (T+1). In tomorrow-next repos, both sale and repurchase of the collateral bond

Figure 2.3: Specialness and repo term effects at the first reopening auction after issuance for BTP with 3 year maturity

Average ON1, TN, and SN degree of specialness (measured in basis points) over auction cycles for all 3-year maturity BTPs traded in both the primary and secondary market from April 1, 2003 until December 6, 2013. The auction cycle includes: 3 days before auction date (i.e. auction announcement date), two days before auction date, one day before auction date, auction date, one day after auction day, two days after auction day (i.e. auction settlement date, when the bond is delivered to primary dealers).



happen with a one-day 'delay' with respect to the overnight repo, whereas the spot-next repos have a two-day delay.

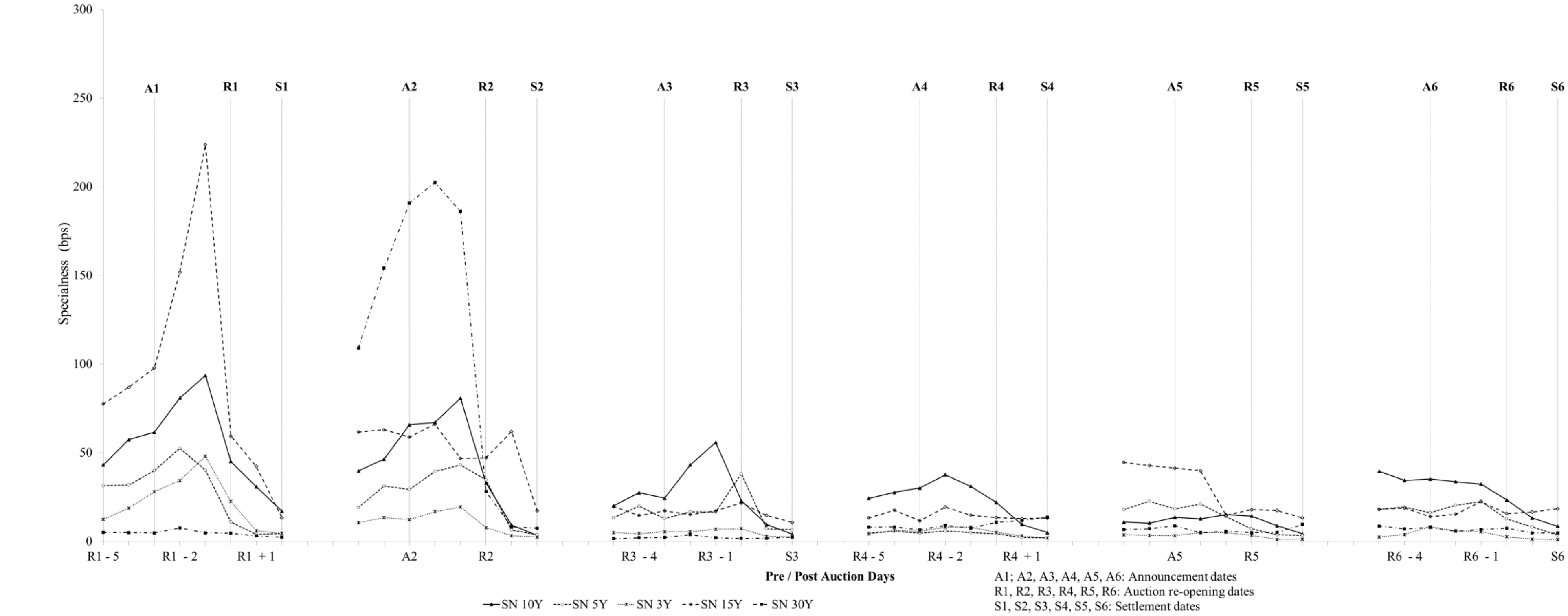
In advance of a reopening auction, primary dealers hedge the risk of winner's curse (being allocated too many bonds at a low yield) by short-selling the already-issued bond. To do so, they enter into a special reverse-repo. Specifically, they lend cash to their counterparties and take the Treasury bond as collateral, which they then short-sell in the secondary market. If they are allocated too many bonds at auction, they can reduce their exposure by covering their short position in the cash market and closing out the reverse repo by delivering the bond for the second leg of the repo transaction.

Because of this hedging of the winner's curse, the required special reverse-repo has its second leg (collateral delivery and receipt of cash with interest) set on the auction settlement date, when the additional bond supply becomes available to primary dealers. So, for example, if primary dealers hedge using a tomorrow next (TN) reverse-repo, they enter into the contract two days before the auction settlement. At this time, there will be an increase in the demand of TN reverse-repos for the specific bond; its special repo rate will decrease and its specialness will rise. Consistently, we find that the TN repo specialness on average peaks two days before the bond auction settlement. For the same reason, we find that the ON repo average specialness peaks one day before the bond auction settlement date and the SN repo average specialness peaks three days before the bond auction settlement. This evidence is consistent with: i) an increased demand for short positions in the newly-issued bond tranche before the reissuance date; and ii) dealers' concern of winner's curse leading to overestimating the amount of bonds they will be allocated at auction and hedging aggressively by initiating many reverse repos. The effect of primary Treasury dealers' hedging on repo contracts is also described by Lou, Yan and Zhang (2013) for the U.S. Treasury market. However, the regular pattern for specialness of different repo terms around auctions has never been fully explained and controlled for in previous repo studies.

Moreover, we observe that the effect of auctions on specialness tends to vary both over reopening

Figure 2.4: Spot-next specialness at six consecutive reopening auctions for different bond maturities

Average spot next repo specialness over auction cycles for bonds at different residual maturities (3, 5, 10, 15 and 30-year). Each reopening auction cycle includes: five days before auction date, four days before auction date, three days before auction date (i.e. auction announcement date), two days before auction date, one day before auction date, auction date, one day after auction day, and two days after auction day (i.e. auction settlement date, when the bond is delivered to primary dealers).



auctions and across bond maturities. Figure 2.4 plots the average SN specialness at subsequent reopening auctions. For each collateral maturity group, the auction cycle effect on specialness is higher for the first reopening auction and then it gradually decreases over subsequent auctions. One reason for this finding is that with a larger amount of bond outstanding, the risk of collateral scarcity decreases and this leads to a lower degree of specialness. The SN repo specialness for bonds with 10-year maturity is on average higher than the specialness for 5-year and 3-year bonds. This is consistent with the relationship between repo specialness and collateral maturity observed for the whole sample and presented in Figure 2.2. Surprisingly, for the first two reopening auctions of the issue cycle, we observe peaks for the specialness of 15 and 30-year maturity bonds rising above the specialness of 10 year bonds. Thus Figure 2.4 suggests particularly high scarcity of the riskiest, longer-maturity bonds around auctions possibly driven by strong hedging demand.

2.5 The Model

2.5.1 Driving Factors of Specialness

The difference at time *t* between the GC rate and the special repo rate for bond *i* measures the degree of specialness of bond *i* (Specialness_{it}):

$$Specialness_{it} = General\ Collateral\ Rate_{t} - Special\ Rate_{it}.$$

A bond that is "on special" has a special repo rate that is below the GC rate. The lower the special repo rate compared to the GC repo rate, the greater the specialness.

Our aim is to understand and explain why a bond becomes special. First, we identify the main factors that affect specialness. Then, we construct proxy variables for each of these factors and, finally, we test empirically their relevance for the degree of specialness of bonds repoed in the marketplace.

Duffie (1996) and Jordan and Jordan (1997) suggest that the supply of bonds to be used as collateral in repo transactions is one of the main factors for explaining specialness. If investors need temporary ownership of the bond but face restrictions in the collateral market, they may offer a low special rate (or even negative rates) to finance the inventory of bond-holders. Sundaresan (1994) and Keane

(1995) use the degree of 'auction tightness' measured as the bid-to-cover ratio for 'on-the-run' bonds as proxy for restrictions in bond supply. Another proxy used for supply conditions is the portion of newly-issued 'on-the run' bonds which is allocated to dealers at auction with respect to buy-and-hold investors. The larger the portion allocated to buy-and-hold investors, the greater the probability of restrictions in supply, the higher the specialness of the collateral bonds. Krishnamurthy (2002) uses instead the total 'on-the-run' amount outstanding for long-term debt instruments. These measures are well suited to the U.S. Treasury repo market, but less so for a European one. In some European countries (such as Italy) the auction frequency is more irregular and Treasury auctions are subject to several re-openings which alter the traditional definition of "on-the-run" bonds issued over a predetermined schedule as in the U.S. Additional tranches of already-issued BTPs can be re-auctioned several times after the first issuance; this implies that the amount outstanding of the on-the-run bond increases over time with each reopening auction. To overcome the limitation of the existing proxies of bond supply, we use a secondary market measure of supply taken from the intraday quote updates recorded on MTS. We measure supply as the time-weighted average volume of collateral bonds available for sale at the top three levels of the ask price for each trading day. An inverse relation between specialness and supply of a bond is expected. As the supply of a bond decreases, the amount available for purchase is lower. When facing restrictions in supply, dealers needing temporary ownership of the bond must compete more vigorously in the repo market by offering lower special repo rates, so specialness increases.

An additional measure of supply and demand in the collateral market is given by the bond trade imbalance, computed as the daily aggregate buyer-initiated volume minus the daily aggregate seller-initiated volume of repoed bonds (a.k.a. cash trades) in MTS. A higher trade imbalance is a measure of net collateral buying pressure and indicates that the aggregate supply of the bond is lower than its aggregate demand. This condition may induce more traders who need the specific collateral to initiate reverse repos, for instance to cover their short positions. This may lead to lower special rates and higher specialness. Therefore, as the trade imbalance of a bond increases, its specialness increases too. The excess demand for bonds linked to short positions can be also captured by the repo net order flow – as in D'Amico et al. (2015) – which is measured as the daily aggregate buy-initiated volume minus aggregate sell-initiated volume of repo transactions. The daily aggregate buy-initiated volume indicates the total amount of repos used for refinancing, while the daily aggregate sell-initiated volume indicates the total amount of reverse repos that are usually associated to short-selling. Thus, this variable should be inversely related to repo specialness.

An additional factor which has been rarely explored in the literature – and never in studies of European government bonds and repos – is the fire-sales of bonds. To build this measure of extreme selling pressure, we construct daily rebalanced bond portfolios by maturity-groups and define fire-sales as extremely large negative net bond order flows on days with large negative bond returns. The fire-sales proxy is equal to the portfolio's relative trade imbalance when both portfolio's relative trade imbalance and returns are below the respective thresholds; otherwise, it is equal to zero. We use as threshold the 5^{th} percentile of the distribution for both imbalances and returns. Further details on the construction of this measure and on the determination of the thresholds are provided in the Appendix.

Once we identify fires sales, we then study the relationship between portfolio fire-sales and the specialness of those bonds included in the portfolio. We think there may be two types of relationships between fire-sales and specialness, depending on the external conditions of the credit and sovereign bond markets. On the one hand, fire-sales are generally caused by very high liquidity needs of traders who sell off their bond holdings in order to obtain cash. The massive selling pressure increases the supply of bonds. If there are well-functioning repo markets for collateral borrowing and bond traders have the option to choose which bonds to fire-sell first from their inventories, then they would give lower priority to bonds trading on special in the repo market, as these can be used both for obtaining cheaper funding (i.e. by using them as collateral in low-interest special repos) and as preferred bonds for speculative trading. In this case, the fire-sale pressure would hit 'substitute' bonds and increase their supply (relatively to the special bond), whilst keeping the supply of the special bond relatively scarce and its demand high. This type of fire-sale effect, which we call 'substitute effect', would be associated with a positive relationship between fire-sale (large negative net order flows) and bond specialness. Namely, the bonds sold in a large fire-sale have lower average specialness. However, on the other hand, if the repo market for collateral borrowing is no longer accessible because of high credit risk, margins, haircuts, etc. and if the fire-sale is motivated by speculative reasons, as during the GFC period, then bond holders may prefer to sell the most valuable and desirable bonds, i.e. those with high specialness. We call this effect the ‘high-value-sale’ effect. This type of fire-sales would be associated with a negative relationship between fire-sale (large negative order flows) and specialness. Namely, the bonds sold in a large fire-sale have higher average specialness. Which relationship prevails between fire-sale and specialness remains therefore an empirical question.

Another factor which can help to explain specialness is the bond volatility. Higher volatility can increase bond speculative demand and short positions in Treasuries which need to be covered with higher amounts of reverse repos. Ultimately, this may lead to greater specialness. We measure bond volatility using the intraday bond realized volatility, given by the total sum of squared log bond returns computed using tick-by-tick mid prices (average of best bid and ask prices) during each day, as observed at each quote update in the consolidated bond order book. We use a 20-day rolling average of realized volatility to reduce the effect of large outliers.

Furthermore, we use a proxy for repo demand: i.e. the total daily amount of bond face value sold as repo collateral in special repos. This volume-based measure includes both repo and reverse-repo transactions. We expect a downward sloping demand curve: when the amount of a given repoed bond increases, its repo specialness decreases.

Given that BTP repos on MTS are buy sellback repos, we may expect counterparty credit risk to be priced in special repo rates. The trader doing a reverse repo faces potential losses linked to counterparty credit risk. For example, a loss could materialize if the counterparty fails to repurchase a bond in a repo transaction and the original value of the pledged collateral suddenly plummets because of higher interest rates. Thus, we use the bond modified duration as measure of collateral quality and credit risk connected to the repo contract. Krishnamurthy (2002) uses the spread between the commercial paper interest rate and the repo interest rate as a proxy for market credit risk. D'Amico et al. (2015), and Corradin and Maddaloni (2017) use residual maturity as a proxy for credit quality.

As a bond trades at different prices throughout the day, we measure the modified duration based on the average volume-weighted price of the bond on that day. We expect that the higher the modified duration of a bond, the higher the interest rate risk exposure and the greater the credit risk of the repo contract. Hence, high duration bonds will trade less on special.

It is quite likely that repo specialness is related to the level of the margins set by clearing houses for trading repos. However, we do not use this variable because margins are not revised very frequently and usually they are computed as functions of bonds' modified duration and historical volatility which are already controlled for in our model.[19]

Duffie (1996)'s model predicts that given two bonds that are otherwise identical, the more liquid bond trades more on special. We test Duffie's prediction using two time-varying proxies for bond liquidity. Liquid bonds are more often shorted and are in greater demand as collateral in repo transactions. Speculators who want to short a bond would choose in fact the most liquid one in a selected category, as it would be easier for them to repurchase it when they need to close their short position. This implies that reverse repo transactions would be concentrated on these target liquid bonds. Therefore, not only the most liquid bonds may be traded more 'on special', but they are also more frequently repoed. We expect that as the number of daily repo trades for a given bond goes up, its specialness increases as well.

In addition, we look at the bond's relative bid-ask spread (measured as the daily time-weighted average spread). The bid-ask spread can capture two possible types of effects. On the one hand, the smaller the bid-ask spread, the more liquid the bond, and the higher its specialness. On the other hand, a higher bid-ask spread can be also caused by higher information asymmetry, rather than only illiquidity. Information asymmetry drives speculative demand, leading to higher demand for reverse repos and an increase in specialness. In summary, our measure of relative bid-ask spread can have a

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[19] A document explaining the procedures for setting margins for Italian sovereign repos and prepared by *Cassa Compensazione e Garanzia* is available at the following link: https://www.lseg.com/sites/default/files/content/documents/3.01.01.01.02%20Methodology%20for%20determining%20the%20parameters%20used%20in%20margin%20calculation%20for%20fixed%20income%20instruments.pdf.

different impact on specialness, depending on whether it is mainly driven by liquidity or information asymmetry. We also control for the on-the-run and first-off-the-run bond's status. An on-the-run bond should be in greater demand; thus, it should present lower special rates and higher degree of specialness.

In addition, we control for the effect of auction cycles discussed in Section 4 using dummies for each day of the auction cycle, from three days before the auction (announcement date) to two days after the auction (settlement date).[20] We expect the collateral to be in high demand (hence trading on special) from around the auction announcement date until three days, two days or one day before the auction settlement for the spot next, tomorrow next and overnight repos respectively (see Section 2.4).

Finally, Corradin and Maddaloni (2017) show the importance of controlling for the effect of the Securities Markets Programme. In particular, the second 'activation period' of the SMP has mainly involved the outright purchases of Italian bonds by the ECB. This has reduced the number of Italian bonds available for trading in the secondary market, thus resulting in lower special rates and greater specialness. Therefore, we include a further dummy variable which controls for this SMP second activation period.[21]

2.5.2 Model Specification

This section describes the regression model we use to assess the impact of all relevant factors on specialness.

We estimate our model separately for each repo term (ON1, SN, and TN) and also (as robustness check) for each bond-maturity class. The model is described as follows:

[20] The Bank of Italy used to release a first announcement on the identity of the instruments 5 days before the auction date, followed by the main announcement 3 days before the auction date with all details about the allocated amounts. Nowadays, all communications are given in a single announcement which takes place 3 days before the main auction.

[21] Unfortunately, we do not know the ISINs of the bonds purchased by the ECB because this information was not disclosed to the public.

$$
\begin{aligned}
Specialness_{it} = {} & \alpha_i + \beta_1\, Bond\ Supply_{it} + \beta_2\, Bond\ Trade\ Imbalance_{it} + \beta_3\, Bond\ Fire\ Sales_{it} \\
& + \beta_4\, Bond\ BAS_{it} + \beta_5\, Bond\ Quality_{it} + \beta_6\, Bond\ Realized\ Volatility_{it} \\
& + \beta_7\, Repo\ Quantity_{it-1} + \beta_8\, Repo\ Trades_{it-1} + \beta_9\, Repo\ Net\ Order\ Flow_{it-1} \qquad (2.1) \\
& + \beta_{10}\, ONTR_{it} + \beta_{11}\, OFTR_{it} + \beta_{12}\, SMP_{it} + \beta_{13}\, Rm3_{it} + \beta_{14}\, Rm2_{it} + \beta_{15}\, Rm1_{it} \\
& + \beta_{16}\, R\_0_{it} + \beta_{17}\, Rp1_{it} + \beta_{18}\, Rp2_{it} + \beta_{19}\, A1_{it} + \beta_{20}\, A2_{it} + \varepsilon_{it}
\end{aligned}
$$

Specialness $_{it}$ is defined as the GC repo rate minus the special repo rate for bond '*i*' on day '*t*'. α_i indicates a different intercept for each bond. The model is estimated via panel least squares regression with bonds' fixed effects.

The explanatory variables included in the regression equation are described in section 5.1 and summarized below into six categories.

- **Proxies of collateral scarcity:**

Bond Supply $_{it}$: Daily average of the face value of the bond available for purchase at the top three levels of the ask side for bond '*i*' on day '*t*'. β_1 is expected to be negative.

Bond Trade Imbalance $_{it}$: Daily buyer-initiated volume less seller-initiated volume for bond '*i*' on day '*t*'. β_2 is expected to be positive.

Bond Fire Sales $_{it}$: This is a truncated variable and it is equal to the relative trade imbalance on day '*t*' of the residual maturity portfolio which bond '*i*' belongs to. The variable takes non-zero value only when the relative trade imbalance is lower than the 5^{th} percentile of its distribution and also when the equally-weighted portfolio return for all bonds with the same residual maturity as bond '*i*' on day '*t*' is below the 5^{th} percentile of its distribution. β_3 is expected to be positive if the 'substitute' effect dominates or negative if the 'high-value-sale' effect dominates.

- **Proxies of collateral liquidity:**

Bond BAS $_{it}$: Daily time-weighted average of the relative bid-ask spread of bond '*i*' on day '*t*'. β_4 is expected to be negative if Bond Bas mainly reflects frictional trading costs, or positive if it mainly reflects information asymmetry and speculative demand.

- **<u>Proxies of collateral riskiness:</u>**

Bond Quality $_{it}$: Average modified duration of bond '*i*' on day '*t*'. β_5 is expected to be negative.

Bond Realized Volatility $_{it}$: Sum of squared returns over a 20-day rolling window for bond '*i*'. Returns are computed using tick-by-tick mid-prices during each day '*t*', observed at each quote's update in the consolidated bond order book. β_6 is expected to be positive.

- **<u>Proxies of repo liquidity:</u>**

Repo Quantity $_{it-1}$: Sum of face value of bond '*i*' sold as repo collateral on day '*t-1*'. β_7 is expected to be negative.

Repo Trades $_{it-1}$: Number of repo transactions on day '*t-1*' involving bond '*i*' as repo collateral. β_8 is expected to be positive.

Repo Net Order Flow $_{it-1}$: Value of the daily buyer-initiated volume minus seller-initiated volume of special repos for bond '*i*' traded on day '*t-1*'. The buyer-initiated volume corresponds to the volume of repos (or collateral sold via repo trades), while the seller-initiated volume corresponds to the volume of reverse repos (or collateral purchased via repo trades). β_9 is expected to be negative.

- **<u>Dummies for on and off-the-run:</u>**

ONTR $_{it}$: Dummy equal to 1 if bond '*i*' is an 'on-the-run' bond on day '*t*' (within its residual-maturity group), or zero otherwise. β_{10} is expected to be positive.

OFTR $_{it}$: Dummy equal to 1 if bond '*i*' is the first off-the-run bond on day '*t*' (within its residual-maturity group). β_{11} is expected to be positive, as the bond is in relatively higher demand than other off-the-run bonds within the same maturity group.

- **<u>Dummies for auction cycle effects and SMP:</u>**

SMP $_{t}$: Dummy to control for the Securities Markets Programme intervention period with ECB's purchases of Italian sovereign bonds. The period starts on August 8, 2011 and ends on February 10, 2012.[22] If day '*t*' is included in this period, than the dummy variable takes the value of one, zero otherwise. β_{12} is expected to be positive.[23]

R_0 $_{it}$: Dummy equal to 1 if day '*t*' is the auction date for bond '*i*', zero otherwise.

Rm3 $_{it}$, **Rm2** $_{it}$, **Rm1**$_{it}$: Dummy variables equal to 1 if day '*t*' is respectively three days, two days and one day before the auction date in the primary market for bond 'i', zero otherwise. **Rm3** $_{it}$ is also the announcement date of the bond auction.

Rp1 $_{it}$, **Rp2** $_{it}$: Rp1 $_{it}$ is a dummy variable which is equal to one if day '*t*' is the day after the auction for bond '*i*', zero otherwise. This is the date of the supplementary auction reserved to specialists.[24] Rp2 $_{it}$ is a dummy variable which is equal to 1 if day '*t*' is two days after the auction in the primary market for bond '*i*', zero otherwise. This is the auction settlement date.

A1 $_{it}$ and **A2** $_{it}$: Dummies indicating respectively the cycle periods for the first and second auction re-openings after bond '*i*' first issuance. They take value 1 if day '*t*' corresponds to any of the days included in the relevant auction cycle (i.e. from three days before to two days after the reopening auction), zero otherwise.

Table 2.5 reports the sample summary statistics for all the independent variables and for each repo term (ON1, TN and SN). Average daily bond supply, imbalance and spread are relatively larger for the ON repo sample. The bonds traded as collateral in ON repo trades have slightly higher riskiness

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[22] On September 6, 2012 the Securities Markets Programme (SMP) was replaced by the Outright Monetary Transactions programme (OMT), which was never used by ECB in our sample period. The main purchase of Italian bonds ended in February 2012.

[23] The average residual maturities of BTPs purchased by the ECB was 4.5 years, thus we could expect this dummy to be more significant for shorter residual maturities. See: https://www.ecb.europa.eu/press/pr/date/2013/html/pr130221_1.en.html

[24] The specialists are intermediaries selected by the Italian Central Bank and the Italian Treasury (Ministry of Economics and Finance) amongst the primary dealers displayed on the MTS electronic market for government securities; they are allowed to take part in supplementary auctions, exchange transactions and buyback operations with the specific mandate to supply liquidity. The supplementary auction is an additional non-competitive placement of bonds which is reserved to the selected specialist primary dealers. Specialists can take part to this non-competitive placement only if they have submitted at least one application at a valid price in the corresponding competitive placement (ordinary auction). Usually, supplementary auctions take place one day after the corresponding ordinary auction and settle on the same date. It is not mandatory for specialists to trade in supplementary auctions.

Table 2.5: Summary statistics of independent variables for different repo-term sub-samples (ON1, TN and SN)

Summary statistics for all independent variables over different repo-term samples (Overnight, Tomorrow Next and Spot Next) and over the period April 1, 2003 to December 6, 2013. Panel A reports the statistics for the sample of Overnight repos, Panel B for Tomorrow Next repos and Panel C for Spot Next repos. **Bond Supply** is measured by the daily sum of outstanding notional of bond available for purchase at the top three levels of the ask-side (the measurement unit is millions of Euros). **Bond Trade Imbalance** is equal to the difference between buyer-initiated volume and seller-initiated volume (measured in millions of Euros). **Bond Fire-Sale** is the relative trade-imbalance for residual-maturity portfolios and takes a value different from zero only if: i) the corresponding portfolio trade imbalance is below the 5th percentile of its relative distribution; and ii) the corresponding portfolio equally-weighted returns are below the 5th percentile of the relative distribution of returns (truncated variable). **Bond BAS** is the daily time-weighted average bond's bid-ask spread. **Bond Quality** is measured by the daily average bond's modified duration. **Bond Realized Volatility** is computed over a 20-day rolling window from daily log returns which are obtained as sum of squared returns based on tick-by-tick bond's mid-prices observed at each quote update in the bond's consolidated order book. **Repo Quantity** is measured in millions of Euros and it represents the nominal quantity of bond sold as repo collateral. **Repo Trades** is the total number of daily repo transactions (involving the specific bond). **Repo Net Order Flow** is equal to the difference between buyer-initiated volume and seller-initiated volume of special repo (measured in millions of Euros).

Repo Term	Panel A: Overnight								
Variables	Observations	Mean	Median	Stand. Dev.	Kurtosis	Skewness	Range	Minimum	Maximum
Bond Supply (€ M)	29,022	72.204	58.488	45.404	-0.632	0.74	260.813	3.039	263.853
Bond Trade Imbalance (€ M)	29,022	0.643	0	49.542	16.764	0.403	1,248.50	-570	678.5
Bond Fire Sales	29,022	-0.017	0	0.229	355.518	-17.01	7.237	-7.237	0
Bond BAS	29,022	17.468	9.051	24.249	15.441	3.275	227.245	0.1	227.345
Bond Quality	29,022	5.937	5.231	4.155	-0.326	0.711	17.225	0.003	17.227
Bond Realized Volatility (%)	29,022	0.335	0.268	0.271	4.365	1.754	2.077	0.003	2.08
Repo Quantity (€ M)	29,022	29.392	14	43.41	29.063	4.022	783.5	0	783.5
Repo Trades	29,022	1.785	1	1.401	43.599	4.018	41	1	42
Repo Net Order Flow (€ M)	29,022	-5.671	-3	42.847	24.854	0.084	1,492.50	-709.00	783.50

Repo Term	Panel B: Tomorrow Next								
Variables	Observations	Mean	Median	Stand. Dev.	Kurtosis	Skewness	Range	Minimum	Maximum
Bond Supply (€ M)	90,222	69.896	57.586	44.892	-0.377	0.802	261.353	2.5	263.853
Bond Trade Imbalance (€ M)	90,222	-0.339	0	49.643	50.541	-0.369	2,645.00	-1,187.50	1,457.50
Bond Fire Sales	90,222	-0.012	0	0.145	325.376	-16.139	6.202	-6.202	0
Bond BAS	90,222	15.704	7.333	23.899	17.585	3.53	227.246	0.099	227.345
Bond Quality	90,222	5.379	4.143	4.228	-0.352	0.799	17.348	0	17.348
Bond Realized Volatility (%)	90,222	0.306	0.236	0.271	4.379	1.765	2.156	0.002	2.158
Repo Quantity (€ M)	90,222	59.947	34	76.393	18.475	3.144	1,265.50	0	1,265.50
Repo Trades	90,222	3.065	2	2.514	25.195	2.942	67	1	68
Repo Net Order Flow (€ M)	90,222	-13.983	-4.5	75.496	15.339	-1.086	2,403.50	-1,168.50	1,235.00
Repo Term	Panel C: Spot Next								
Variables	Observations	Mean	Median	Stand. Dev.	Kurtosis	Skewness	Range	Minimum	Maximum
Bond Supply (€ M)	127,585	66.611	55.356	42.915	-0.031	0.912	267.852	2.5	270.352
Bond Trade Imbalance (€ M)	127,585	-0.874	0	47.641	59.152	-0.487	2,905.00	-1,447.50	1,457.50
Bond Fire Sales	127,585	-0.011	0	0.131	334.013	-16.006	5.052	-5.052	0
Bond BAS	127,585	16.578	8.071	24.453	16.01	3.364	227.246	0.099	227.345
Bond Quality	127,585	5.298	4.002	4.269	-0.431	0.784	17.348	0	17.348
Bond Realized Volatility (%)	127,585	0.308	0.236	0.276	3.88	1.678	2.178	0.002	2.18
Repo Quantity (€ M)	127,585	454.905	380	322.683	6.49	1.781	5,956.50	0	5,956.50
Repo Trades	127,585	21.878	21	10.168	3.677	1.103	164	1	165
Repo Net Order Flow (€ M)	127,585	-20.136	-7.5	253.316	5.11	-0.246	6,046.50	-2,791.00	3,255.50

as measured by bond quality (5.937); namely, they have slightly longer average duration. SN repos are traded much more frequently and have much larger traded volume than the other two repo contracts. The absolute value of average fire sale is larger for ON repos.

2.6 Empirical Results

2.6.1 Main Results from the Model

In Table 2.6 we present the sample correlations between all our variables over different repo-term samples. In particular, we check the correlations between explanatory variables. With only three exceptions, all pair-wise correlations are below 0.50. The exceptions are the correlations between: Repo Trades and Repo Quantity, Bond Realized Volatility and Bond Bas, and finally Bond Quality and Bond Realized Volatility.

The high correlation between Repo Trades and Repo Quantity (ranging from 64% for ON repos to 80% for SN repos) is expected because with more repo trades the total amount of a given bond used in repo transactions also increases. As these two variables can measure slightly different effects on the degree of specialness (i.e. the pure liquidity effect and the realized demand effect), we first try to include both as independent variables, using their first lags in order to control for potential endogeneity. As robustness check, we then exclude one of the two variables and re-estimate the regression to check whether multicollinearity significantly affects the results. We see no relevant change.

Table 2.6: Pearson correlation matrix for different repo-term sub-samples (ON1, TN and SN)

Correlation matrix for all variables over the period April 1, 2003 - December 6, 2013 for ON1, TN and SN repos samples. **Specialness** is the difference between the GC and special collateral repo rates. **Bond Supply** is measured by the daily sum of outstanding notional of bond available for purchase at the top three levels of the ask-side (the measurement unit is millions of Euros). **Bond Trade Imbalance** is equal to the difference between buyer-initiated volume and seller-initiated volume (measured in millions of Euros). **Bond Fire-Sale** is the relative trade-imbalance for residual-maturity portfolios and takes a value different from zero only if: i) the corresponding portfolio trade imbalance is below the 5th percentile of its relative distribution; and ii) the corresponding portfolio equally-weighted returns are below the 5th percentile of the relative distribution of returns (truncated variable). **Bond BAS** is the daily time-weighted average bond's bid-ask spread. **Bond Quality** is measured by the daily average bond's modified duration. **Bond Realized Volatility** is computed over a 20-day rolling window from daily log returns which are obtained as sum of squared returns based on tick-by-tick bond's mid-prices observed at each quote update in the bond's consolidated order book. **Repo Quantity** is measured in millions of Euros and it represents the nominal quantity of bond sold as repo collateral. **Repo Trades** is the total number of daily repo transactions (involving the specific bond). **Repo Net Order Flow** is equal to the difference between buyer-initiated volume and seller-initiated volume of special repo (measured in millions of Euros). *** indicates 1% significance level S.L.; ** 5% S.L.; * 10% S.L.

Variable	Specialness	Bond Supply	Bond Trade Imb.	Bond Fire-Sales	Bond Real. Volatility	Repo Quantity	Bond Quality	Repo Trades	Bond BAS	Repo Net Order Flow
Repo Term	Panel A: Overnight									
Specialness	1									
Bond Supply	-0.1243***	1								
Bond Trade Imbalance	0.0207***	0.0256***	1							
Bond Fire Sales	-0.0136**	0.0469***	0.0625***	1						
Bond Realized Volatility	0.1952***	-0.4971****	-0.0071	-0.0587***	1					
Repo Quantity	0.0603***	0.0957***	0.0194***	0.0199***	-0.0136**	1				
Bond Quality	0.0027	-0.3546***	0.0028	-0.0018	0.6273***	0.0388***	1			
Repo Trades	0.1193***	0.0947***	0.02***	0.0142**	-0.0104*	0.6397***	0.0447***	1		
Bond BAS	0.2153***	-0.4576***	-0.0158***	-0.1045***	0.7932***	-0.0454***	0.3270***	-0.0588***	1	
Repo Net Order Flow	-0.0554***	0.0274***	-0.0019	0.0041	-0.0294***	-0.0542***	-0.0108**	-0.0228***	-0.0373***	1

Repo Term	Panel B: Tomorrow Next									
Specialness	1									
Bond Supply	-0.1210***	1								
Bond Trade Imbalance	0.0302***	0.0371***	1							
Bond Fire Sales	-0.0271***	0.0483***	0.0647***	1						
Bond Realized Volatility	0.2259***	-0.4255***	0.0048	-0.0677***	1					
Repo Quantity	0.1544***	0.1193***	0.0261***	0.005	-0.0037	1				
Bond Quality	0.0403***	-0.3304***	0.0152***	-0.011***	0.685***	0.0378***	1			
Repo Trades	0.2724***	0.1091***	0.0341***	0.0015	0.0298***	0.7227***	0.0474***	1		
Bond BAS	0.2523***	-0.3910***	-0.0031	-0.1054***	0.7963***	-0.0421***	0.3843***	-0.0145***	1	
Repo Net Order Flow	-0.0901***	0.0485***	-0.0038	0.0112***	-0.0612***	-0.2921***	-0.0071**	-0.1513***	-0.0869***	1

Repo Term	Panel C: Spot Next									
Specialness	1									
Bond Supply	-0.1061***	1								
Bond Trade Imbalance	0.0218***	0.037***	1							
Bond Fire Sales	-0.0251***	0.0457***	0.0572***	1						
Bond Realized Volatility	0.2204***	-0.4064***	0.0097***	-0.0701***	1					
Repo Quantity	0.1408***	0.2802***	0.0521***	0.0047*	-0.0073***	1				
Bond Quality	0.0496***	-0.3236***	0.0185***	-0.0132***	0.707***	0.0474***	1			
Repo Trades	0.2316***	0.2262***	0.0622***	-0.0115***	0.1238***	0.7986***	0.0899***	1		
Bond BAS	0.2374***	-0.3806***	0.001	-0.1142***	0.8058***	-0.0867***	0.4232***	0.0469***	1	
Repo Net Order Flow	-0.0625***	0.0231***	-0.0005	-0.0032	-0.0263***	-0.0728***	-0.0157**	-0.0512***	-0.0383***	1

The high correlation between Bond Realized Volatility and Bond Bas (around 80%) is also largely expected, as both variables are related to speculative demand and liquidity of the instrument. Speculators generally wish to trade bonds with higher volatility and higher uninformed trading activity. However, since these two variables can also measure different effects (realized bond price risk and liquidity) we keep them both in the main analysis of the determinants of specialness.[25] As part of the robustness tests we re-run our panel estimation with either realized volatility or the bid-ask spread in the regression. The effects of these variables on specialness remain qualitatively the same.[26]

We observe a high correlation between Bond Quality and Bond Realized Volatility (ranging between 63% for ON and 71% for SN repos) which could be explained by the uncertainty of future price changes increasing with the maturity of the collateral.

Finally, we note that the unconditional correlation between Specialness and Bond Fire-Sales is negative, although very small (around -2% and -3%). This seems to provide preliminary support to the high-value sale effect, but we need to run our regression model to exclude the influence of other factors.

We estimate the model separately for each repo contract: overnight, tomorrow next and spot next. The sample period starts on April 1, 2003 and ends on December 6, 2013. Since some bonds may be transacted more on special than others, especially if they have been targeted by particular trading strategies, we control for bond fixed effects. F-tests and Hausman (1978) tests confirm the need to control for fixed effects, but not for random effects. We use OLS with clustered standard errors (first by bond, then by time, as in Arellano, 1987). The results with bond-clustered standard errors are reported in Table 2.7.[27]

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[25] We find that, despite the high sample unconditional correlation between these two variables, they both appear highly significant in the regressions.

[26] For brevity, we do not report the results for the robustness checks on the multicollinearity issues discussed in this section, but they are available upon request.

[27] The results with time-clustered standard errors are qualitatively consistent with those reported in Table 2.7.

Table 2.7: Panel regression Eq. (2.1) results for the overall sample period

Panel regression Eq. (2.1) estimated with bond fixed effects separately for ON, TN, and SN repos. Period: April 1, 2003 to December 6, 2013. T-statistics are computed using bond-clustered standard errors. Variables' definitions are explained at Table 2.5. Bond Supply, Bond Trade Imbalance, and Repo Quantity are measured here in billions of Euros whereas Repo Net Order Flow in millions of Euros. The remaining variables are explained at Table 2.8. *** indicates 1% S.L.; ** 5% S.L.; * 10% S.L.

Dep. Var. Repo Specialness	**Overnight**		**Tomorrow Next**		**Spot Next**	
Bond-clustered S.E. and Bonds' Fixed Effects						
Ind. Variables:	Coeff.	t-stat.	Coeff.	t-stat.	Coeff.	t-stat.
Intercept	28.806***	8.47	8.202***	5.29	-1.448	-0.90
Bond Supply	-170.007***	-6.62	-81.523***	-6.78	-72.137***	-7.37
Bond Trade Imbalance	14.582**	2.45	8.895***	2.74	4.606**	2.53
Bond Fire Sales	3.401**	2.55	1.009	1.47	1.104***	3.12
Bond BAS	0.162***	2.78	0.132***	4.00	0.092***	3.86
Bond Quality	0.105	0.15	-0.510	-1.35	0.211	0.70
Bond Realized Volatility	19.112***	2.89	10.126***	3.17	7.133***	3.01
Lag Repo Quantity	0.196	0.01	-16.570***	-4.88	0.290	0.19
Lag Repo Trades	2.438***	3.70	2.624***	7.81	0.387***	7.96
Lag Repo Net Order Flow	-14.556*	-1.72	-10.496***	-3.16	-5.493***	-3.39
On-the-run	0.986	0.20	0.568	0.18	0.529	0.20
Off-the-run	1.190	0.43	1.614	1.18	1.114	1.10
SMP	26.731***	6.03	16.499***	5.77	13.305***	6.10
Rm3	8.927	0.97	9.770*	1.98	9.896**	2.25
Rm2	36.469**	2.02	19.112***	2.83	18.613***	3.54
Rm1	41.287***	3.08	27.695***	2.94	31.216***	4.10
R_0	29.158**	2.18	30.209***	3.69	-6.206*	-1.76
Rp1	26.387**	2.37	-21.108***	-3.99	-17.163***	-4.73
Rp2	-14.505	-1.62	-26.768***	-4.59	-15.056***	-4.08
A1	23.865	1.45	32.040***	3.12	24.761***	3.58
A2	9.185	0.77	18.736*	1.90	15.249**	2.06
Observations		29,022		90,222		127,585
Adj. R^2		0.1598		0.2194		0.2073

The overall percentage of explained variation in repo specialness differs only slightly across repo-terms. For tomorrow next, the model explains 21.94%, while for spot next and overnight, it explains respectively 20.73% and 15.98% of specialness variation.

As expected, specialness increases with higher demand pressure for the collateral bond and decreases with higher bond supply. Bond Trade Imbalance is significant, with the expected positive sign for all repo terms and with an economic impact on specialness of nearly 0.72 bps (ON1), 0.44 bps (TN) and 0.22 bps (SN) for a one-standard deviation increase. Bond supply presents negative and highly significant coefficients for all repo terms, with lower absolute impact for spot next specialness and greater absolute impact for overnight specialness. A one-standard deviation increase in Bond Supply induces a decrease of specialness of 7.72 bps, 3.66 bps, and 3.1 bps for ON1, TN and SN, respectively. The fire-sales proxy is significant for overnight and spot next repos, but not for tomorrow next repos. It presents a positive coefficient: the more extreme (i.e. the more negative) the fire-sales, the lower the specialness. In terms of economic significance, a one-standard deviation increase in fire-sales induces an increase of 0.78 bps (ON1) and 0.14 bps (SN) in specialness. The ON1 repos are more strongly affected by fire-sales than the spot next repos, probably because the collateral exchange happens on the same day as the repo settlement. Extreme fire-selling activity seems to be associated with lower specialness. When facing liquidity needs, traders sell bonds with lower specialness. Hence, once we control for all factors affecting specialness the empirical evidence is consistent with the ‘substitute’ effect rather than the ‘high-value sale’ effect.

According to Duffie (1996)’s predictions, specialness increases with bond liquidity, everything else being equal. Our proxy of collateral bond liquidity (Bond Bas), however, seem to capture something different from the pure liquidity effect. The relative bond bid-ask spread (Bond Bas) is strongly significant across all repo terms, both statistically and economically. However, a one-standard deviation increase in Bond Bas generates an increase (not a decrease) in specialness of 3.93 bps (ON1), 3.16 bps (TN), and 2.24 bps (SN), ceteris paribus. Since the coefficients of Bond Bas are always positive, information uncertainty, rather than liquidity, seems to be the main driver of the relationship.[28] We therefore conclude that information uncertainty attracts speculative demand, which in turn increases Italian sovereign bond specialness.

Lag Repo Trades seem to capture instead pure liquidity effects. The more frequently a bond is traded via repos, the more it becomes special, with 1% level of statistical significance for all repo terms. For one standard-deviation increase in Lag Repo Trades, the economic impact on specialness is 3.41, 6.6 and 3.93 bps for ON1, TN and SN, respectively. Repo trades tend to cluster on particular bonds, possibly because these bonds are more liquid and better suited to execute trading strategies. Thus, their specialness tends to be higher on average. The Lag Repo Quantity is significant with the expected negative sign only for tomorrow next repos. However, there is high correlation between this variable and Lag Repo Trades. When the variables are used together in the regression Lag Repo Trades partially subsumes the effect of Lag Repo Quantity. If we exclude Lag Repo Trades from the model, then we find that Lag Repo Quantity is highly significant and negative for all repo terms, as expected. Finally, the Lag Repo Net Order Flow is significant and displays the expected negative sign for all repo terms with a one-standard deviation economic impact on specialness of -0.62, -0.79 and -1.39 bps, respectively for ON1, TN, and SN repos.

Next, we consider the proxies for collateral riskiness. The bond realized volatility is strongly significant and positive for all repo contracts. For Bond Quality, the collateral bond's modified duration, in Table 2.7 we do not find instead supporting evidence of significant negative coefficients for any of the repo term.

Interestingly, also the on-the-run and first off-the-run dummies do not have a significant effect on specialness. Unlike the US Treasury market, the supply of a given newly-issued bond can increase over time as new tranches of the same bond are issued. Thus, being recently issued (or on-the-run) has no particular importance in the Italian bond market. In contrast, the Securities Markets Programmes dummy is significantly positive for all repo terms. When the ECB actively buys Italian

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[28] It is worth to mention that the instruments traded on MTS are bonds which have already significant levels of liquidity in order to be admitted for trading among dealers and for pledging of collateral.

bonds in the Italian Treasury market, these bonds get scarcer and more desirable, so their specialness increases.[29]

The auction cycle has a significant effect on repo specialness, as evidenced in Section 4. For all repo terms, the coefficients of the pre-auction dummies Rm3, Rm2 and Rm1 are all positive, monotonically increasing and significant. The coefficient of the auction day R_0 is also positive for ON1 and TN repos. The dummies become negative starting from the auction date R_0 for SN, one day after the auction date Rp1 for TN, and two days after the auction date Rp2 for ON1. Post auction, dealers will realise whether they have fallen victim of the winner's curse. Strikingly, repo specialness is aligned with the collateral bond auction and it varies according to the term of the repo contract. Specifically, the repo remains on special one day after the auction, on the day of the auction, and one day before the auction day for the ON1, TN and SN repos, respectively. This means that the special repo settlement days are aligned with the settlement day for the collateral bond auction allowing the dealer to off load overbought bonds via reverse repos. Finally, the influence of auction cycles decreases with the number of re-openings, and therefore with an increasing supply of the collateralised bond. For the longer term Tomorrow Next and Spot Next repos, the auction-cycle dummies A1 and A2 are positive, significant, and monotonically decreasing. Their impact is greater for Tomorrow Next than for Spot Next specialness. For ON1 specialness, the auction dummies A1 and A2 are also positive and monotonically decreasing, but not significant.

Lastly, we investigate whether the impact of the factors which explain the variation in specialness changes over time. For the sake of brevity, we report the results only for SN in Table 2.8.[30] We choose to report the results for the SN repo for this analysis and all of our subsequent robustness tests, as Table 2.3 reports that the SN repo has the largest number of observations.

For each of the three types of repo contracts (ON1, TN and SN) we estimate our model of repo specialness over four distinct sub-periods. First we have the "pre-crisis" sub-period which starts on

[29] Corradin and Maddaloni (2017) find that the effects of other ECB liquidity operations, such as the 3-year LTROs, are insignificant for specialness. We therefore decide to use only the SMP dummy in our models.

[30] The results for ON and TN repos are available from the corresponding author upon request.

Table 2.8: Panel regression Eq. (2.1) results over different sample periods (for spot-next repo specialness)

Panel regression Eq. (2.1) results over four sub-periods. First period: April 1, 2003 to August 8, 2007. Second period: August 9, 2007 to December 31, 2009. Third period: from January 1, 2010 to February 10, 2012. Fourth period: February 11, 2012 to December 6, 2013. Panel regressions are estimated with bond-clustered standard errors and bonds' fixed effects. Variables' definitions and measurements are explained in Table 2.5 and 2.7. On-the-run dummy=1 if bond is on-the-run; 0 otherwise. Off-the-run dummy=1 if the bond is the *first* off the run; 0 otherwise. SMP is a dummy equal to 1 if the day is within the period 01/01/2010 -10/02/2012. Rm3, Rm2, Rm1 are dummies equal to 1 if the observed day is respectively 1, 2, or 3 days before an auction's date (otherwise they are equal to 0); R_0 is equal to 1 if the observed day is an auction's date, 0 otherwise; Rp1, Rp2 are dummies equal to 1 if the observed day is respectively 1 or 2 days after an auction's date otherwise they are equal to 0). A1 and A2 are dummies equal to 1 if the observed day is included respectively in the first reopening auction cycle and second reopening auction cycle (cycle=3 days before to 2 days after reopening auction). *** indicates 1% significance level (S.L.); ** 5% S.L.; * 10% S.L.

Dependent Variable: Spot Next Repo Specialness								
Period	Pre-Crisis 01/04/2003 - 08/08/2007		Global Financial Crisis 09/08/2007 - 31/12/2009		European Sovereign Crisis 01/01/2010 -10/02/2012		Post-Crisis 11/02/2012 - 06/12/2013	
Ind. Variables:	Coeff	t-stat.	Coeff	t-stat.	Coeff	t-stat.	Coeff	t-stat.
Intercept	-4.043**	-2.48	-3.144	-0.69	28.408	1.56	-20.876***	-5.59
Bond Supply	-19.458*	-1.94	-78.667***	-4.92	-99.585***	-3.15	-26.568	-1.45
Bond Trade Imbalance	5.708***	3.14	2.567	1.05	5.377	0.68	1.674	0.63
Bond Fire Sales	-1.456	-0.67	-1.753**	-2.27	1.363**	2.31	-0.196	-0.47
Bond BAS	0.643*	1.84	0.106***	3.69	-0.002	-0.08	0.112**	2.59
Bond Quality	0.216	0.61	0.246	0.30	-5.473**	-2.07	3.682***	5.73
Bond Realized Volatility	3.530	1.16	12.855***	4.22	13.596***	3.42	0.097	0.02
Lag Repo Quantity	-5.316***	-4.34	-4.146**	-2.62	11.076**	2.01	1.196	0.66
Lag Repo Trades	0.478***	5.09	0.416***	6.78	0.554***	3.17	0.250***	3.55
Lag Repo Net Order Flow	-0.593	-0.64	-5.109***	-2.77	-10.771***	-2.67	-0.937	-0.96
On-the-run	-4.387**	-2.58	-0.178	-0.14	-2.947	-0.97	-1.493	-1.50
Off-the-run	-2.899**	-2.53	0.465	0.40	4.516**	2.14	0.679	0.84
SMP	-	-	-	-	4.103	1.24	-	-
Rm3	3.620	1.32	8.319**	2.22	16.789	1.01	7.473	0.83
Rm2	9.909**	2.16	18.110***	3.06	26.665	1.50	18.677	1.40
Rm1	24.581**	2.16	26.686***	3.09	41.633*	1.76	27.022**	2.02
R_0	-6.386	-1.46	-3.459	-1.48	-7.154	-0.60	-13.919	-1.60
Rp1	-9.227*	-1.72	-10.050***	-2.78	-37.810***	-5.59	-23.901**	-2.05
Rp2	-5.961	-1.14	-7.946**	-2.05	-36.361***	-4.53	-19.750*	-1.79
A1	13.618	1.19	20.660**	2.32	56.709***	3.46	17.346	1.01
A2	1.760	0.35	-1.652	-0.39	40.308*	1.98	29.435	1.12
Observations		50,106		25,879		26,401		25,199
Adj. R^2		0.1484		0.2033		0.2924		0.1687

April 1, 2003 and ends on August 8, 2007: this is a relatively tranquil period before the global financial crisis (GFC).[31] During this pre-crisis period, the ECB implemented tight monetary policies and kept relatively high borrowing rates. Next, we consider the GFC sub-period, which runs from August 9, 2007 until December 31, 2009. During this period, dramatic changes in the ECB policies are associated with substantial drops in borrowing costs. Third, we study the European Sovereign Crisis (ESC) sub-period, which starts on January 1, 2010 and ends on February 10, 2012. This period is characterized by several ECB interventions, mainly by the first activation period of the Securities Markets Programmes for Greece, Portugal, and Ireland and by the second re-activation period for the Securities Markets Programmes, characterized by the ECB outright purchase of Italian and Spanish government bonds. Finally, we have the "post crisis" sub-period which starts on February 11, 2012 and ends on December 6, 2013.

For SN and TN repos, the model has the highest explanatory power during the ESC with an adjusted R^2 of 29.24% and 28.55%, respectively. For ON1 repos, the highest adjusted R^2 is instead recorded for the GFC sub-period (19.87%).

As reported in Table 2.8, for SN repos, the variable Bond Supply is significant in all sub-periods except, rather surprisingly, in the post-crisis. In the ESC sub-period, the economic significance of Supply is particularly high reaching a -2.45 bps standard deviation (SD) impact. It is likely that in this period the variable also captures the additional effects on bond supply induced by the SMP purchases, which reduced the availability of bonds to be used as collateral in the secondary market.

Looking at Bond Fire-Sales, we note that the aggressive selling has a positive and significant coefficient during the ESC sub-period, clearly indicating that large sales are associated to lower specialness and hence that the 'substitute' effect prevails over the 'high-value' effect. The economic significance of the variable is 0.27 bps SD impact. In contrast, Bond Fire-Sales has a negative

[31] On August 9, 2007 BNP Paribas announced the decision to cease three major hedge-funds which were specialized in US mortgage debt. This date is considered as the start of the global financial crisis.

estimated coefficient ('high-value' effect) on SN specialness during the GFC sub-period. This is consistent with the presence of speculative pressure on the Italian bond market and problems in the collateralized borrowing markets during the GFC sub-period.

The Bond Realized Volatility presents the expected positive sign in all sub-samples, but it is highly significant at the 1% level only in the two crisis sub-samples (GFC and ESC). Furthermore, we observe that Bond Quality has a significant effect on SN specialness only in the ESC sub-period, with the expected negative coefficient, and in the post crisis sub-period, but with an unexpected positive coefficient (it was insignificant for SN in the all-sample analysis of Table 2.7). When interest rate risk is very high due to serious tensions in European sovereign markets, there is lower demand for bonds with large modified duration and thus these bonds trade less on special. For SN repos, the relation between modified duration and specialness is altered in the post crisis sub-period. After the crisis, ceteris paribus, bonds with longer modified duration trade more on special.

We do not observe major differences across the sub-sample regressions (in Table 2.8) and the all-sample regression (in Table 2.7) for speculative demand and liquidity. Specifically, when significant, the bid-ask spread has always a positive sign. This clearly indicates that the bid-ask spread proxies speculative demand rather than liquidity. Meanwhile, liquidity is consistently explained by the variable Repo Trades: in all sub-periods the more frequently a bond is repoed, the higher its specialness. Repo Net Order Flow, given by the difference between repo orders and reverse-repo orders, affects always negatively the spot next specialness, but more so during the European sovereign crisis period, with a peak economic impact of -2.8 bps. The effect in the ESC is higher than the average economic impact of -1.23 bps during the GFC sub-period. Ceteris paribus, a larger demand for reverse repos during the ESC period, due to traders' willingness to speculate on Italian government bonds, determines a larger negative value for the Repo Net Order Flow: this is associated with lower repo rates and wider specialness.

Finally, the auction cycle and consecutive re-opening auction dummies on specialness are more important over the GFC and ESC sub-periods. It is possible that during the two crisis periods, dealers were particularly concerned with the winner's curse in the bidding of re-opened bond issues, so prompting more reverse-repos. This result for the repo market is consistent with the findings of Lou et al. (2013) for the bond market.

2.6.2 Robustness Checks

We perform several robustness checks on our main results. First, we re-estimate our model with heteroskedasticity and serial correlation robust standard errors which are computed using the Newey-West (1987) methodology.[32] Bond Quality and OFTR are now significant at 1% S.L. for both SN and TN. We observe no other change in the significance of the explanatory variables.

Second, in order to understand the stability of the estimated coefficients and their interaction with other explanatory variables, we estimate a parsimonious univariate model for each explanatory variable and then gradually add the larger set of remaining explanatory variables. The only puzzling result from this check comes when controlling for the effect of fire-sales in a univariate model. Initially, we find a negative and significant impact on specialness which is consistent with the 'high-value sale' effect. That is, the bond on special is a desirable instrument and it preferred for speculative trades, so it is the first to go on fire-sale amongst a group of similar bonds. However, when we also control for the bond bid-ask spread as additional explanatory variable, the sign of the fire-sale impact changes to positive, supporting the 'substitute' effect (that is, special bonds can be used to obtain cash at lower rates, so they are the last to go on fire-sale amongst a group of similar bonds). In Table 2.6 we notice that fire-sales are negatively correlated with the bid-ask spread (-11%) and with specialness (-2%). Namely, large fire-sales (negative net order flows triggering highly negative returns) are associated with wide bid-ask spreads and large specialness. However, once we control for illiquidity then the bonds selected for the fire-sales tend to be those with relatively lower specialness.

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[32] The nature of data – daily time series – suggests a choice of three lags for the Newey-West estimator.

Third, we estimate the model using residual maturity sub-samples. Seven residual maturity groups are constructed: 6 months, 3 years, 5 years, 7 years, 10 years, 15 years and 30 years.[33] Every day we sort the sample bonds into the seven residual maturity buckets and estimate the model for specialness for each bond sub-sample. The estimation results for spot next repos are reported in Table 2.9.

We find that, on average, the model explains more of the variation in specialness for sub-samples of repos with lower residual maturity of the collateral. When considering only bonds with residual maturity greater than one year, the highest adjusted R^2 is obtained for five-year bonds (31.92%) and the lowest adjusted R^2 is obtained for 30-year bonds (17.8%). The results reported in Table 2.9 are for SN repos only, but they are consistent with the results obtained for other repo terms.[34]

All results so far recorded for bond collateral supply, bond information uncertainty as proxied by Bond Bas and repo liquidity as proxied by Repo Trades, remain invariant across all maturity-portfolios. The Bond Fire-Sales and Bond Realized Volatility variables are mainly significant for the shorter term 6-month and 3-year residual maturity sub-samples. Bond Quality presents the expected negative and significant coefficients only for 3 and 7-year residual maturity sub-sample. The SMP dummy is strongly significant for 3, 5 and 7-year BTPs. This is in line with the 4.5-year average modified duration of Italian instruments purchased during the SMP, as disclosed by the ECB. The SMP dummy is insignificant for portfolios with 10 and 15 year maturities.

Fourth, because our previous analysis suggests that fire-sales are stronger during the ESC sub-period, we re-estimate the model for bond sub-samples of different residual maturities over the ESC period. We find that the importance of the fire-sales proxy for ON1, TN and SN is mainly driven by the fire-sales of 30-year, 10-year and 3-year bond portfolios respectively.[35]

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[33] It is important to note that instruments with just six months to maturity could be subject to specific liquidity and trading dynamics when approaching the maturity date. Specifically, as they are not involved in reopening auctions, they cannot be associated with possible on-the-run/off-the-run status. Also, 7-year bonds are never on-off the run and never involved in reopening auctions over our sample period.

[34] The results for other repos are available from the authors upon request.

[35] These results are not reported for brevity, but are available from the authors upon request.

Table 2.9: Panel regression Eq. (2.1) results (for spot-next repo specialness) over different bonds' sub-samples based on residual-maturity

Panel regression results by residual maturity buckets (6 months, 3, 5, 7, 10, 15 and 30-year maturity). The estimation period goes from April 1, 2003 to December 6, 2013. Panel regressions are estimated with bond-clustered standard errors and bonds' fixed effects. Variables' definitions and measurements are explained at Tables 2.5, 2.7, and 2.8. *** indicates 1% significance level (S.L); ** 5% S.L.; * 10% S.L.

Dependent Variable: Spot Next Specialness														
Residual Maturity of Bond Portfolios	6 months		3 years		5 years		7 years		10 years		15 years		30 years	
Ind. Variables:	Coeff	t-stat.	Coeff	t-stat.	Coeff	t-stat.	Coeff	t-stat.	Coeff	t-stat.	Coeff	t-stat.	Coeff	t-stat.
Intercept	1.282*	1.70	-1.049	-0.74	-24.225*	-1.87	18.202	1.59	-18.046	-0.87	-1.875	-0.21	7.282	0.63
Bond Supply	-11.505**	-2.24	-13.700*	-1.74	-63.935**	-2.36	-40.118**	-2.44	-138.307**	-2.28	-163.306*	-2.05	-138.732*	-2.15
Bond Trade Imbalance	1.046	0.98	9.372***	3.27	-0.367	-0.11	10.861**	2.76	-0.930	-0.17	28.801*	1.81	1.759	0.22
Bond Fire Sales	-1.595***	-3.22	3.237***	4.45	0.899	0.54	0.774	0.75	-2.357	-1.32	0.345	0.44	0.988	1.48
Bond BAS	0.063***	3.03	0.207***	6.44	0.262*	1.84	0.202***	4.02	0.118	0.95	0.073**	2.62	0.092***	4.73
Bond Quality	0.209	0.17	-1.548***	-3.44	6.690*	2.01	-3.658*	-1.81	2.550	0.89	0.141	0.24	-0.377	-0.52
Bond Realized Volatility	28.758***	3.64	24.234***	3.67	-13.292	-0.89	9.935*	1.77	-1.229	-0.19	6.049	1.66	-2.021	-0.59
Lag Repo Trades	0.247***	4.36	0.323***	4.65	0.491***	3.70	0.269***	5.07	0.380	1.52	0.622***	3.19	0.378**	2.99
Lag Repo Net Order Flow	-0.676	-0.52	-1.450	-1.25	-8.526**	-2.49	-5.070**	-2.67	-14.588**	-2.63	-4.062	-1.06	0.400	0.22
Other Controls:														
On-the-run	N/A		Y		Y		Y		Y		Y		Y	
Off-the-run	N/A		Y		Y		Y		Y		Y		Y	
SMP	Y		Y		Y		Y		Y		Y		Y	
Reopening Auction Days (R)	N/A		Y		Y		N/A		Y		Y		Y	
First and Second Reopenings (A)	N/A		Y		Y		N/A		Y		Y		Y	
Observations		8,461		50,127		13,816		12,437		14,424		16,263		12,057
Adj. R^2		0.3337		0.3121		0.3192		0.2837		0.2378		0.2517		0.1780

A fifth robustness check is inspired by the surprising consistently positive coefficient for the bond bid-ask spread on specialness. We conjecture that our panel results are driven by time-series effects, while Duffie (1996)'s model makes cross sectional predictions. More specifically, if at the same time two bonds have similar characteristics but different liquidity, the most liquid bond is the more desirable and more likely to go on special. Therefore, we now focus on a cross sectional model for specialness. We compute between-effect panel estimates for SN repos and present the results in Table 2.10. The coefficient for the bid-ask spread becomes negative in all the sub-samples, but it is significant at the 1% level only in the post-crisis period. Notably, it appears insignificant during the crisis periods. This evidence seems to indicate that Duffie's prediction of a negative relationship between bond illiquidity and repo specialness does not hold at times of high uncertainty.

To conclude, we perform a number of additional robustness checks. We run regressions that include day-dummies for the first six auction re-openings' cycles, instead of only the first two auction re-openings.[36] We observe that the effects of the auctions' cycles are insignificant after the third reopening and the effect of the third reopening is so small that it does not change the quality of the results. Also, we run regressions that include additional day-dummies for five and four days before the auction dates. We observe that the effects of the auctions' cycles are insignificant before the announcement date Rm3 which is three days before the auction date. We use an alternative Bond Fire-Sales variable computed for each single bond, rather than for maturity-portfolios, but we find that this variable is insignificant. Then, we conduct an analysis of the effects of fire-sales using the 1st and the 10th percentile instead of the 5th percentile threshold. The fire sale variable computed using the 1st percentile is consistently significant for all repo term, but when we use the 10th percentile the fire sale variable is significant only for ON1 and TN repos. The estimated coefficients for these alternative fire-sales proxies are positive, thereby confirming the 'substitute effect' (see also Table

[36] Note that the first issue day is not considered, since trades and proposals on the collateral bond market usually start some days after the issue day.

Table 2.10: Robustness checks: Regressions - Model estimated over different periods - Between Effects Estimator

Panel regression results over four sub-periods. First period: from April 1, 2003 to August 8, 2007. Second period: from August 9, 2007 to December 31, 2009. Third period: from January 1, 2010 to February 10, 2012. Fourth period: from February 11, 2012 to December 6, 2013. Panel regressions are estimated using robust standard errors and a between-effects estimator which only accounts for cross-sectional variability. Variables' definitions and measurements are explained at Tables 2.5, 2.7, and 2.8. *** indicates 1% significance level (S.L.); ** 5% S.L.; * 10% S.L.

Dependent Variable: Spot Next Specialness								
Robust S.E. and Between-Effects Estimator								
	01/04/2003 - 08/08/2007		09/08/2007 - 31/12/2009		01/01/2010 - 10/02/2012		11/02/2012 - 06/12/2013	
Ind. Variables:	Coeff	t-stat.	Coeff	t-stat.	Coeff	t-stat.	Coeff	t-stat.
Intercept	-1.284	-0.88	-3.170	-1.20	-24.246**	-2.29	26.145***	3.85
Bond Supply	-77.714***	-4.52	-117.331***	-3.38	-12.099	-0.11	-311.190***	-3.49
Bond Trade Imbalance	14.398*	1.75	50.504	0.51	-194.855	-0.79	-274.078	-1.52
Bond Fire Sales	442.525	1.55	250.954*	1.81	-30.968	-0.32	280.118**	2.59
Bond BAS	-0.747	-1.10	-0.012	-0.05	-0.151	-0.59	-0.600***	-4.42
Bond Quality	-1.603	-1.50	-0.453	-0.40	-1.353	-0.69	2.683***	2.83
Bond Realized Volatility	54.399**	2.05	6.582	0.25	54.594	1.56	-9.687	-0.52
Lag Repo Quantity	-32.364***	-5.36	-23.731***	-2.89	-9.260	-0.48	-5.234	-0.68
Lag Repo Trades	1.348***	6.19	1.404***	6.09	1.637**	2.51	0.411*	1.68
Lag Repo Net Order Flow	-17.176*	-1.93	1.335	0.10	-57.373***	-2.83	8.262	0.99
Other Controls:								
On-the-run	Y		Y		Y		Y	
Off-the-run	Y		Y		Y		Y	
SMP	Y		Y		Y		Y	
Reopening Auction Days (R)	Y		Y		Y		Y	
First and Second Reopenings (A)	Y		Y		Y		Y	
Observations		50,106		25,879		26,401		25,199
Adj. R^2		0.0896		0.1572		0.2076		0.0959

2.7). Next, we use an alternative measure of bond volatility: the 10-year interest rate cap implied volatility available in Datastream, instead of the bond realized volatility. The implied volatility is significant only for ON1 repos, but with a counterintuitive negative sign. When we exclude Bond BAS from the model (highly correlated with the implied volatility), the estimated coefficient of the latter variable becomes significantly positive, but again only for ON1 repos. As seen in Table 2.7, the bond realized volatility is instead significant for all repo terms, even after controlling for Bond BAS, with the expected positive sign. Finally, we analyse the effect on specialness of the average bid-to-cover ratio for each auction, but we do not observe any regular pattern associated with variations in specialness.

2.7 Summary and Conclusions

We examine several factors that determine the variation in the degree of specialness of repos with Italian Government coupon bonds as special collateral. We use a much richer dataset of intraday bond and daily repo data over a longer sample period, from April 2003 to December 2013, than any previous work in the literature. We conclude that the supply of the bonds used as collaterals and the liquidity of the repo contracts have a fundamental influence on the degree of specialness for all repo terms (ON1, TN and SN) before, during and after the global financial crisis (GFC) and the European sovereign crisis (ESC). The order flow dynamics in the bond and repo markets unveil the effects on repo specialness of high demand pressure for collateral and high short-selling activity via reverse-repos.

The collateral bonds' volatility along with the collateral bonds' relative bid-ask spreads are important factors for explaining specialness. After controlling for bond supply, we find that increases in the bid-ask spreads are mostly associated with increases in specialness. Thus, the bid-ask spread seems to reflect information uncertainty and speculative demand rather than liquidity. Additionally, we study a novel variable that captures the fire-sales of bonds at portfolio levels and we find that on average larger negative values for this variable (i.e. heavier sales) tend to be associated with lower bond specialness.

The sub-sample analysis reveals however that the impact of some factors changes in magnitude and direction before, during, and after the GFC and the ESC. For instance, fire-sales and volatility in the bond market have the highest impact on specialness during the 2007-09 crisis and during the ESC. During the ESC sub-period bond fire-sales are associated to lower specialness: hence, the ‘substitute’ effect prevails over the ‘high-value’ effect. In contrast, the same variable is associated to higher specialness (‘high-value’ effect) during the GFC sub-period. This is consistent with the presence of speculative pressure on the Italian bond market and problems in the collateralized borrowing market during the GFC.

The bond purchases undertaken by the ECB as unconventional monetary interventions during the ESC have also a great impact on Italian bonds’ specialness. Thus, the sub-sample analysis allows us to enhance our understanding of the determinants of the time-variation of specialness.

Finally, our study suggests that a detailed control for the dynamics of bonds’ auctions is essential to understand the time-variation of specialness for different repo terms. First, we observe that the effect of auctions on specialness tends to decrease over consecutive auction re-openings (which are characteristic of the Italian Treasury bonds) and it varies also across bond maturities. Second, we find that specialness tends to increase steadily for all repo terms from the auction announcement date until three, two, and one day before the collateral bond auction settlement day, respectively for SN, TN, and ON1 repos. Afterwards, specialness tends to decrease, sometimes very sharply. Evidently, when a new auction is announced, Treasury primary dealers start bidding and they hedge the risk of winner’s curse (i.e. of acquiring too many of the new tranches of an existing bond) by short-selling the already-existing instrument. The short-selling is carried out in conjunction with a reverse repo. If the winner’s curse is realised, the dealers’ inventories of over-purchased bonds can be reduced by covering short sales and delivering collateral on the reverse repos. Primary dealers are happy to accept lower special rates in order to get temporary ownership of the collateral and short-sell it. Consequently, the demand for reverse repos and the repo specialness increase prior to the bond auction. Strikingly, we observe that the pattern of the repo specialness is aligned with the collateral bond auction settlement day, allowing the dealer to off load overbought bonds via reverse repos. That is why the specialness varies according to the term of the repo contract. Specifically, the repo remains on special until three, two, and one day before the collateral bond auction settlement day, respectively for SN, TN, and ON1 repos. The required special reverse-repo has its second leg (collateral delivery and receipt of cash with interest) set on the auction settlement date, when the additional bond supply becomes available to primary dealers. So, for example, if primary dealers hedge using a tomorrow next (TN) reverse-repo, they enter into the contract two days before the auction settlement, as the second leg of TN is set two days after the repo trades. At this time, there will be a sharp increase in the demand of TN reverse-repos for the specific bond; its special repo rate will decrease and its specialness will rise. While this mechanism has been suggested by previous literature when studying the dynamics of bond yields around actions, it has never been clearly explained as we do in this paper where we examine the term structure of repos.

APPENDIX TO CHAPTER 2

Construction of the Fire-Sale Variable

To obtain a fire-sale measure, we first construct daily rebalanced bond portfolios, based on their residual maturity.[37] The reason why we construct portfolios based on the bonds' residual maturity is that we expect that lower-maturity BTPs are preferred to longer-maturity ones during fire-sales, due to their relatively higher liquidity that reduces the negative price impact of the fire-sale. Second, we compute for each portfolio the trade imbalance as the difference between the daily aggregate buyer-initiated volume minus the daily aggregate seller-initiated volume from all repoed bonds included in the portfolio. Then, we divide the portfolio trade imbalance by the monthly average of the total daily exchanged volumes for all bonds in the same portfolio. This variable represents a 'relative' portfolio trade imbalance. The reason why we standardise the trade imbalance measure by the monthly average of the total exchanged volume of bonds in the portfolio is to 'distinguish' a fire-sale accompanied by an extreme selling pressure from a general scarcity of similar and highly-substitutable instruments in the secondary market. Third, we look at the distribution of each *portfolio's relative trade imbalance* for different repo terms and select as threshold value the fifth percentile of the distribution, which detects high selling pressure. Fourth, we compute daily returns for each bond using the mid-price observed at the last quote's update before 5 pm in the consolidated bond order book. Fifth, we compute the *equally-weighted portfolio returns* and look at the distribution of each portfolio's mean return for each repo term. We select the fifth percentile of the distribution, which detects extreme price drops. Finally, we discard from the fifth percentile of the distribution of the 'relative' portfolio trade imbalance the observations which do not belong also to the 5th percentile of the distribution of the equally-weighted portfolio returns. The rationale of this last condition is to select as proxy for fire-sales only the extreme aggressive selling pressure which is also reflected in extreme negative returns. Table A.2.1 (Panel A and B) shows the fire-sales thresholds for different repo terms and

[37] We create seven portfolios based on bonds' residual maturities equal to 3 years, 5 years, 7 years, 10 years, 15 years, 30 years, and equal or inferior to six months. The six-month portfolio is included to control for liquidity noise (see Darbha and Dufour, 2013) and potential presence of coupon-stripping operations.

bond maturities.[38]

Table A.2.1: Bond fire sales

Panel A reports the 5th percentile values of relative trade imbalance for each residual-maturity bond portfolio. Panel B reports the 5th percentiles of the portfolio returns for each residual-maturity bond portfolio. The reported values correspond to the selected thresholds for the construction of the Bond Fire Sales variable. Portfolios are rebalanced every day.

Panel A: Relative Portfolio Trade Imbalance, 5th Percentile			
Residual Maturity	ON	TN	SN
6 months	-1.3191	-1.4765	-1.2737
3 years	-0.8990	-0.5188	-0.4786
5 years	-1.0331	-0.7881	-0.6755
7 years	-1.4515	-1.0941	-0.9640
10 years	-0.8178	-0.6752	-0.6536
15 years	-1.4531	-0.9820	-0.9305
30 years	-1.4272	-1.1172	-0.9831

Panel B: Portfolio Returns , 5th Percentile			
Residual Maturity	ON	TN	SN
6 months	-0.0004	-0.0004	-0.0004
3 years	-0.0023	-0.0020	-0.0021
5 years	-0.0050	-0.0047	-0.0049
7 years	-0.0055	-0.0060	-0.0062
10 years	-0.0071	-0.0072	-0.0074
15 years	-0.0081	-0.0080	-0.0082
30 years	-0.0092	-0.0095	-0.0099

[38] Coval and Stafford (2007) consider the 10th percentile as threshold of general selling pressure (fire sales). However, they construct this measure for the equity market, which is more volatile than Treasuries and more easily subject to selling pressure. We think that taking the fifth percentile of the bond portfolios' relative trade imbalance is a more suitable choice for our case.

3 THE INTRADAY INTEREST RATE IN THE GC REPO MARKET

3.1 Introduction

The 2007-08 crisis has highlighted the importance of liquidity management for the well-functioning of financial institutions. 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.

This centrality of intraday liquidity management has brought a lot of attention to the money market instruments that allow the exchange of intraday funds. The overnight (ON) 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 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.[39]

In this chapter we study the dynamics, characteristics and determinants of the intraday interest rate of ON GC repos that use Italian Government bonds as collateral. In particular, we address three main

[39] 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 exactly the 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).

questions. First, we test whether there is any intraday pattern in the GC repo rates. Secondly, we seek to determine the factors which explain the variations of interest rates of centrally cleared repos and bilaterally traded repos. Third, we investigate which are the bonds' characteristics that determine the selection of a specific bond in GC repos.

Although there is no explicit *intraday* repo market in which counterparties can agree on a specific time for delivery of funds and collateral over the day, the theoretical models of Van Hoose (1991), Angelini (1998) and Bech and Garrat (2003), amongst others, predict the existence of patterns in 'positive intraday interest rates' connected to the intraday liquidity-management needs of banks. 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 on time, they can demand a higher amount of funding in the morning, when they can observe the interest rate, than in the afternoon. Greater demand of funding in the morning implies greater interest rate paid by banks in the morning than in the afternoon. In addition to that, the duration of the intraday loan would be longer and therefore it would warrant a higher rate. On the other hand, if banks rely on the repo market to meet liquidity obligations and decide to borrow funds only at the end of the trading day, then we might expect relatively higher rates in the late afternoon when banks have fewer funding options and are time constrained. We therefore start this chapter by testing the existence of a daily pattern for the Italian sovereign ON GC repo market.

The Italian sovereign ON GC repo market is characterized by huge transactions volumes, as reported in Table 3.1 Panel A that presents volume data for the *Mercato dei Titoli di Stato* (MTS). 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 ON Italian repo transactions executed on MTS for end-of-day liquidity needs are €9 trillion and €6 billion, respectively. Overall, our data should account for the largest fraction of the interbank ON GC repo market for Italian sovereign collateral, given that trading in Italian repos is mostly conducted on the MTS platform (Dunne, Fleming, and Zholos, 2014). Panel B of Table 3.1 reports the number of bonds used as collateral in CCP, non-CCP repos and in all GC ON repos on MTS during the sample period, by instrument class and maturity group. 179 bonds out of the total 335 used are BOTs with maturity inferior to 1 year, while 99 are BTPs. Most of the BTPs issued during our sample period have maturities of 3, 5, and 10 years.

Table 3.1: The MTS GC repo market

The table reports summary statistics for the daily nominal volume of collateral used in MTS for GC ON CCP and BIL 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 GC ON 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).

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

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. Importantly, the interest rate for these instruments 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. The repo-borrower banks 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 and the period when the ECB 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 Italian intraday ON GC repo rate and the daily interest rate set by the ECB for depositing liquidity at its facility. We measure the intraday repo spread at each time when a repo trade is executed on the 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 chapter we investigate whether the variations in the intraday GC repo spread are related to changes in collateral and repo market riskiness. Notably, we also explore the criteria for the selection of the repo collateral.

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 and determinants of positive intraday interest rates in the U.S. and European money markets, but the majority of these works are focussed on unsecured money markets.[40] 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. However, they do not examine which factors affect the intraday interest rates. 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 a positive intraday interest rate. Baglioni and Monticini (2008) find instead evidence of a significant intraday interest rate in the Italian e-Mid trading platform over the period from January 2003 until December 2004, with a downward pattern throughout the trading day.[41] These results are different from the findings presented in Angelini (2000) and they are attributed to the introduction of the real-time gross settlement (RTGS) system which made intraday liquidity a scarce resource.[42] 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 that larger positive intraday interest rates appear during the recent global financial crisis (GFC) period respectively for the e-Mid and CHAPS (the UK unsecured payment system).

Within the GC repo literature, two papers explore the intraday patterns in two 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 intraday rate. Moreover, they

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[40] 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.

[41] 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

[42] 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.

show that during the GFC the intraday interest in this repo market was less affected by the crisis than that in an unsecured money market. Abbassi et al. (2017) investigate the existence of a positive intraday interest rate for the German CCP-based GC repos (Eurex) over the period from January 2006 until June 2012. They find that the positive intraday interest rate is the result of lower liquidity in the repo market and greater funding uncertainty, particularly during the crisis periods. In addition, Boissel et al. (2017) analyse the connection between country sovereign risk and *daily* repo spreads. They use countries' credit default swap (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 et al. (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.

Our study of the determinants of the *intraday* repo spread in Italian ON GC repos traded on MTS over the period from January 2010 to November 2015 provides several additional contributions to the existing literature. First, we test the theoretical predictions of Angelini (1998, 2000) and Van Hoose (1991) on the dynamics of the intraday Italian GC repo spread. Our results for the Italian Treasury GC repo market are consistent with those models. We observe that the intraday overnight 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. 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.[43] Since then, CCP-cleared transactions

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[43] More information on *Cassa di Compensazione e Garanzia* (*CC&G*) can be accesses at the following link:

have become an increasing component of all ON repo transactions and reached 95% of the whole market by November 2015.[44] The comparative analysis reveals some interesting differences. We detect a particular pattern in centrally-cleared transactions and non-centrally-cleared 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, 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.[45]

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 GC repos. The sample period allows us to perform this analysis over the 2010-11 European sovereign bond 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. We also show that the excess liquidity supplied by the ECB has a non-linear relationship with the intraday

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http://www.lseg.com/it/areas-expertise/post-trade-services/ccp-services/ccg/about-ccg-spa/ccg-history

[44] 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.

[45] In a 2015 BIS (Bank for International Settlements) 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.

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.[46] The effect of some of these factors changes during and after the European sovereign crisis period. We find 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 (negative pro-cyclical effect) by increasing 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 European sovereign crisis for both CCP and bilateral repos, although the impact on the CCP repos is higher. We check the possible rationale of this result: higher margins signal higher counterparty risk and so they affect also the bilateral repo spread, even if traders do not pay CCP margins to trade bilaterally. 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

[46] Consistently with the ECB (2002, 2010) definition, Mancini et al. (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

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. Consistently, 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. Consistently, 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 chapter is organized as follows. Section 3.2 provides a short introduction to the ON GC repo market. Section 3.3 presents a description of our sample and some preliminary statistical analysis. Section 3.4 provides the study of the existence of positive intraday interest rates in centrally-cleared and bilateral repos. Section 3.5 presents the study of the determinants of the ON GC intraday repo spread. Section 3.6 illustrates the results of the empirical analysis for the determinants of the bond-collateral selection. Section 3.7 summarizes the main contributions and findings of the paper.

3.2 The Overnight GC 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 after pledging a security as collateral. The repo seller lends cash and 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 becomes the credit provider for any repo buyer and the credit taker for any repo seller (or reverse repo buyer).[47] In this setting, banks do not know the identity of their counterparties. CCP-based repos trade from 7:45 a.m. 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.[48] 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. 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.

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

[48] 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.

For each GC repo trade, the cash settlement (or cash leg) is operated by TARGET2,[49] the Eurosystem real-time payment and settlement system, while the securities settlement (or collateral leg) is operated by Express II,[50] 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.[51] 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).[52]

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 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.[53] 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.

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[49] For a complete description of TARGET2, see the following link: https://www.ecb.europa.eu/paym/t2/html/index.en.html
[50] See document at the following link: http://www.lseg.com/sites/default/files/content/documents/MonteTitoli/MonteTitoliENG/Rules_Regulation/SettlementSystems/expressrules09092013no.en_.pdf
[51] We thank representatives of the Bank of Italy for providing details of the clearing and settlement process for repo trades.
[52] 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)
[53] 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, Douady, Laurent, and Molteni, 2016 and Mancini et al., 2016), but not in other private repo markets.

3.3 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 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 3 bid and ask quotes (with relative order size). In addition, for each bond we have intraday prices and yields, intraday modified duration, and intraday trades.[54] 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.

[54] 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.

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 3.1).[55] 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 ON GC Italian repo rates (we observe in total 77,467 intraday trades) and subtract the corresponding interest rate at the deposit facility of the ECB.[56] This difference measures the intraday spread for each repo trade. The repo rate spread captures the extra risk of the repo with respect to this ECB risk-free base rate.[57] The theoretical motivation of this intraday repo spread is further explained in section 3.5.

Finally, we compute the volume-weighted average of the intraday repo spread for each trading hour. Table 3.2 (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 3.1 Panel B). The total number of hourly repo spread observations is 10,624. The CCP-based repos have the largest number of observations (5,988). The non-CCP repos have 4,636 observations. Table 3.2 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 17 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 3.2 Panel B) this is 18.94% for CCP-based repos and 25.45% for non-CCP repos,

[55] The intraday repo rates for GC contracts for other main European issuers, such as France and Germany, are not always available on the MTS Time Series database.
[56] 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.
[57] 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.

respectively.[58] 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 (20.057 bps) than the non-CCP repo intraday repo spread (23.390 bps).

In Figure 3.1 we plot the volume-weighted average intraday repo rates for both CCP and bilateral repos, versus the daily ECB deposit rate. From January 2010 until May 2010, the repo rate mainly follows the ECB deposit rate. In this period, the 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, Everett, and Stuart, 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.

In our study we consider 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

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[58] 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.

using tick-by-tick intraday data from MTS and implementing the same sequence of steps described in Chapter 2.[59]

Table 3.2: 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

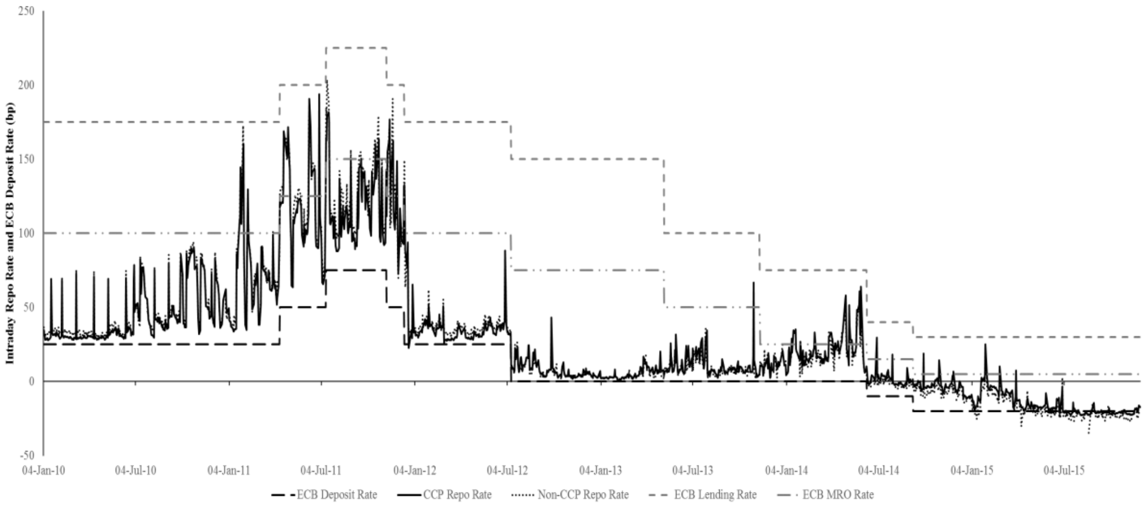
Panel B: Distribution of Hourly Repo Spreads						
Hourly Repo Spread	*Central Clearing*		*Bilateral*		*All Types*	
(basis points)	No.	%	No.	%	No.	%
(-25, 0]	81	1.35%	140	3.03%	221	2.08%
(0, 25]	4,773	79.82%	3,316	71.71%	8,089	76.28%
(25, 50]	651	10.89%	630	13.62%	1,281	12.08%
(50, 75]	322	5.38%	360	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%

[59] Furthermore, we winsorise proposals with relative bid-ask spreads greater than the 99th 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. As expected, we observe that on average longer-maturity bonds are traded at higher relative bid-ask spreads than shorter-maturity bonds.

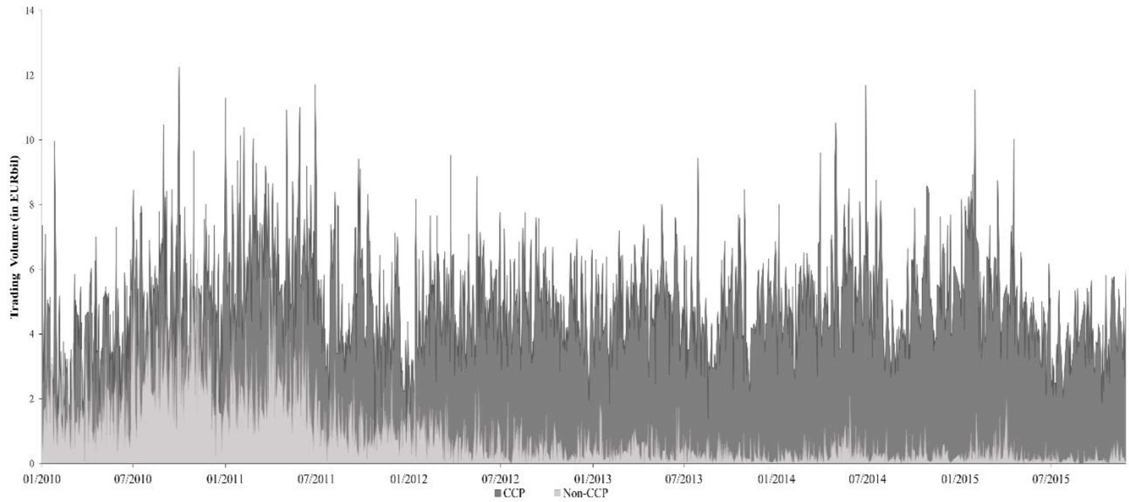
Figure 3.1: GC Repos

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 ON GC 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



3.4 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 GC rate for a repo transaction *j* on day *t* and the ECB deposit rate on the same day *t*:

$$Repo\ Spread_{j,t} = GC\ Repo\ Rate_{j,t} - ECB\ Rate_t \quad (3.1)$$

Second, we follow the approach of Baglioni and Monticini (2008), Kraenzlin and Nellen (2010), and Abbassi et al. (2017) to obtain a measure of hourly repo spread. Each day is divided into 8 hourly time bands, denoted by h = 1, 2, …, 8. The first band starts at 8:00 a.m. CET and the last at 15:00 p.m. CET.[60] 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*:

$$Hourly\ Repo\ Spread_{h,t} = \sum_{k_{h,t}=1}^{K_{h,t}} \frac{Repo\ Spread_{k_{h,t},t} \times Vol_{k_{h,t},t}}{Vol_{h,t}} \quad (3.2)$$

Third, we estimate the following econometric model (see also Abbassi et al., 2017):

$$Hourly\ Repo\ Spread_{h,t} = c + \sum_{h=1}^{7} \alpha_h x_{h,t} + \lambda' X_t + \sum_{h=1}^{7} \gamma'_h X_t x_{h,t} + \partial\ CCP_{h,t} + \epsilon_{h,t} \quad (3.3)$$

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

[60] 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.

period, end of month, end of year, and day of the week effects.[61] 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 intraday 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 idiosyncratic counterparty credit risk.

We estimate model (3.3) 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.[62]

We use all repo contracts and then we re-estimate the model separately for CCP-based and non-CCP repos (thereby dropping the CCP dummy from model (3.3)). The results are reported in Table 3.3.

First, 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.

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. The constant represents the average repo spread in the hourly band 12 p.m. - 1 p.m. Consistently, for

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

[62] 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.

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. to12 p.m.) and increasingly negative coefficients in the afternoon hours (from 1 p.m. to3 p.m.). The repo spread increases slightly in the last hour 3-4 p.m. This last result at the closure of the trading day 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.[63] 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 sense, we plot the volume-weighted average hourly spreads for CCP and bilateral repos over the trading day in Figure 3.2 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 spread over the day.

In order to justify the insignificant hourly dummies for bilateral repos in the morning hours, we also explore the total repo volumes traded in the two segments at each hour in Figure 3.2 Panel B.

We can see that bilateral repos are not frequently traded in the morning, while their trading activity is higher from 12 (noon) to 4 p.m.

Finally, 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

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

difference between each intraday repo rate and its daily volume-weighted average (as in Baglioni and Monticini, 2008, and Kraenzlin and Nellen 2010).

Table 3.3: Regressions results for model (3.3) with time-of-day effects

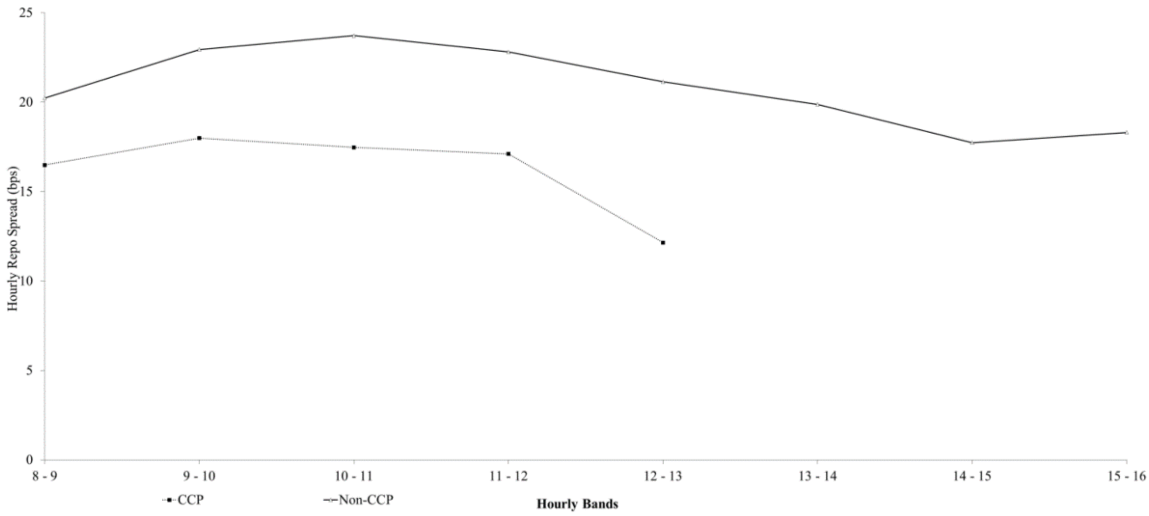
This table reports the results of pooled OLS regressions estimated with HAC robust standard errors over the period January 4, 2010 to November 30, 2015. *** indicates 1% significance level (S.L.); ** 5% S.L.; and * 10% S.L., respectively.

Dep. Var. Intraday 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	Y	Y	Y
Observations	10,604	5,980	4,624
Adj. R^2	0.0415	0.0344	0.0419

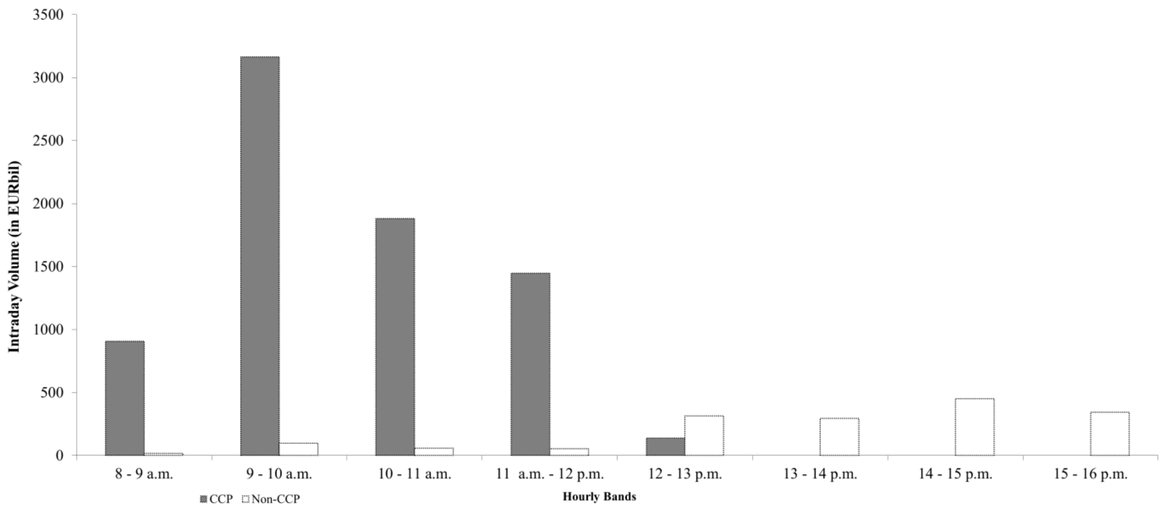
Figure 3.2: The intraday repo spread

This figure shows in Panel A, the volume-weighted average hourly repo spread (measured in basis points) between the ON GC 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 ON GC 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 ON GC 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



3.5 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.

3.5.1 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 $GC\ Repo\ Rate_{h,t}$ (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:

$$GC\ Repo\ Rate_{h,t} = ECB\ Rate_t + S(X_{h-1,t}^{BOND}, X_{h-1,t}^{REPO}) + \varepsilon_{h,t} \quad (3.4)$$

We can re-write (3.4) as the following implicit regression model:

$$Intraday\ Repo\ Spread_{h,t} = \alpha + S\left(X_{h-1,t}^{BOND}, X_{h-1,t}^{REPO}\right) + \varepsilon_{h,t} \quad (3.5)$$

Differently from previous papers, we use a wider set of factors which capture the collateral riskiness (X^{BOND}). Moreover, we add further controls for repo market riskiness (X^{REPO}) and for the general funding market conditions, some of which have been used in the previous literature. 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 3.3 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 3.3 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 interest 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 3.3 Panel C we plot the daily bond weighted-average modified duration over time for both CCP and bilateral repos.

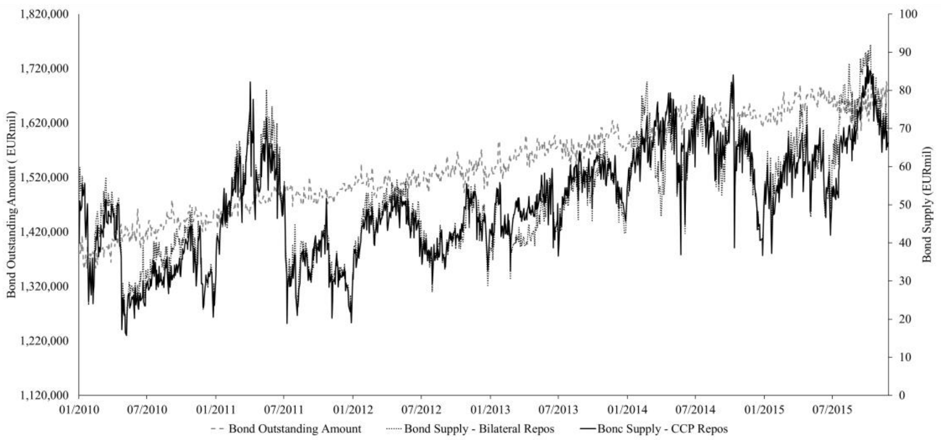
In addition, we consider three factors that capture the repo market riskiness and the uncertainty in funding costs. We control for the repo net order flow, i.e. the difference between aggregate buyer-initiated volumes (repos) and aggregate seller-initiated volume (reverse repos) for each hourly band, 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 et 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.

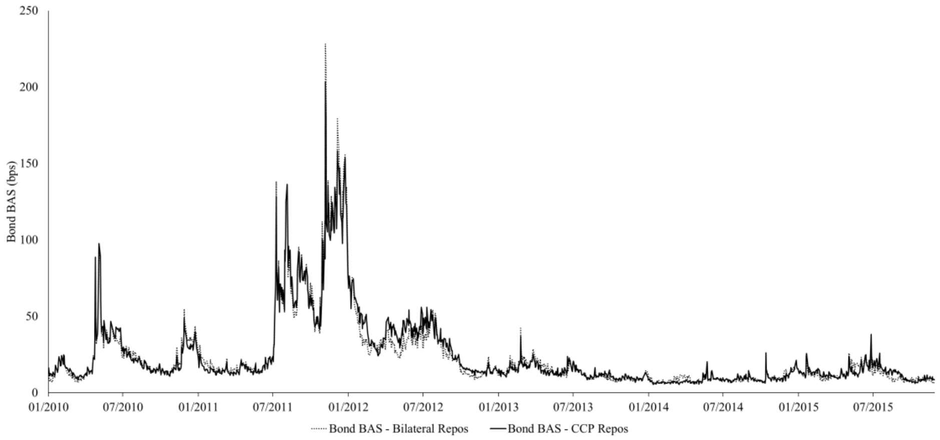
Figure 3.3: Collateral Riskiness

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

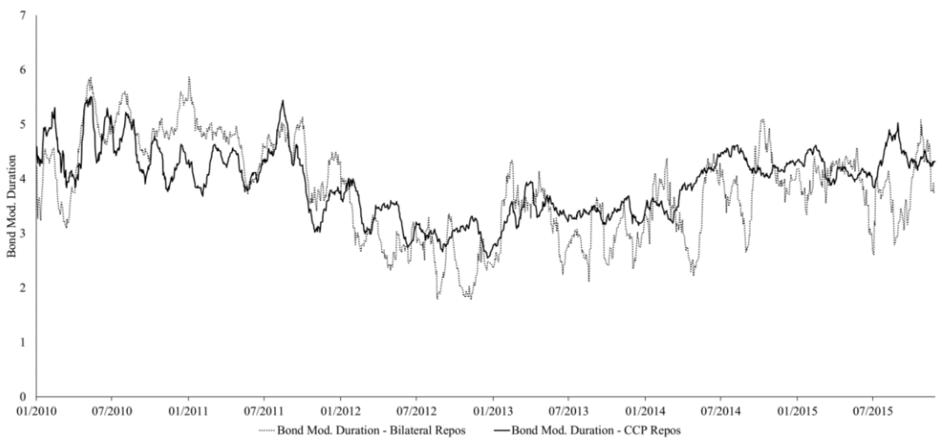


Figure 3.4: Excess Liquidity

This figure shows the total daily excess liquidity (measured in billions of Euros) deposited at ECB facility and the threshold of €300 billion (dash line) in Panel A, and total daily excess liquidity (measured in billions of Euros) deposited at ECB facility plotted against intraday 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 Intraday Repo Spread, and the he vertical line is the threshold of €300 billion (Mancini et al. 2016).

Panel A: Excess Liquidity deposited at ECB Facility over time

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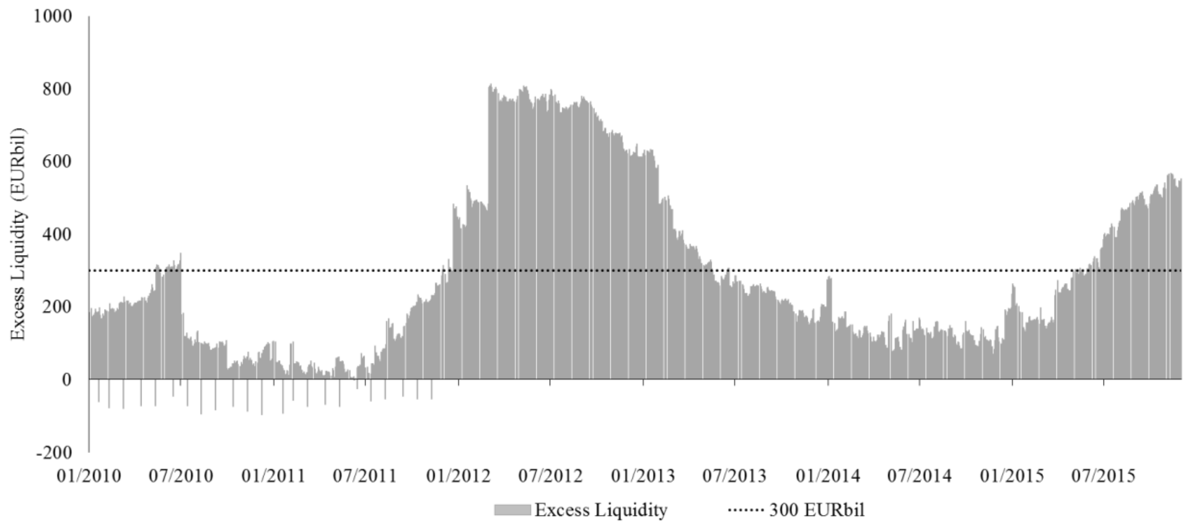

Panel B: Excess Liquidity deposited at ECB Facility and Intraday Repo Spread

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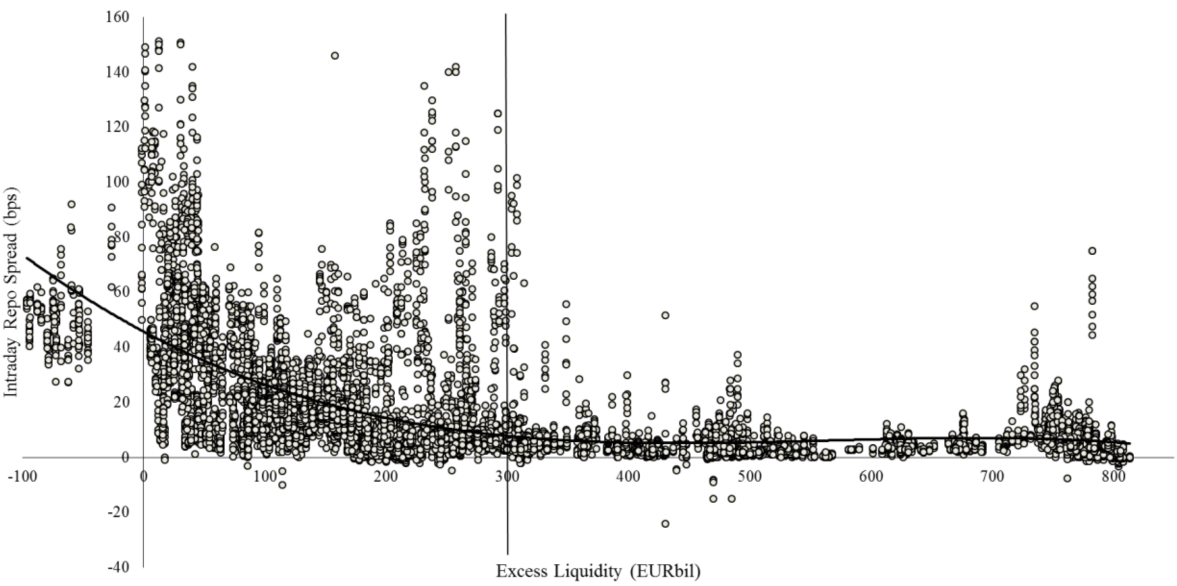

Finally, we also consider the ECB excess liquidity. This is a measure of the extra liquidity injected in the system by ECB unconventional interventions and deposited by banks overnight at the ECB deposit facility. We compute the daily excess liquidity as the sum of credit institutions' current account holdings and funds deposited at the ECB deposit facility minus their reserve requirements. Figure 3.4 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. As a consequence, once this empirical threshold is reached, the marginal excess liquidity can become positively related to the repo rate. Interestingly, we also observe a non-linear relationship between ECB excess liquidity and the Italian ON GC repo rate (see Figure 3.3 Panel B).

3.5.1.1 Model Specification

We estimate the following model (3.6), first for all repos and then separately for centrally-cleared and bilaterally-traded repos.

$$\begin{aligned}
&\textit{Intraday Repo Spread}_{h,t} = \alpha + \beta_1\, \textit{Bond Supply}_{h\text{-}1,t} + \beta_2\, \textit{Bond BAS}_{h\text{-}1,t} \\
&+ \beta_3\, \textit{Bond Mod. Duration}_{h\text{-}1,t} + \beta_4\, \textit{Repo Net Order Flow}_{h\text{-}1,t} + \beta_5\, \textit{Repo Trades}_{h\text{-}1,t} \\
&+ \beta_6\, \textit{Repo Volatility}_{h\text{-}1,t} + \beta_7\, \textit{CCP}_{h\text{-}1,t} + \beta_8\, \textit{EL}_{t\text{-}1} + \beta_9\, \textit{EL}^2_{t\text{-}1} + \sum_{h=1}^{7} \alpha_h x_{h,t} + \lambda' X_t \\
&+ \sum_{h=1}^{8} \gamma'_h X_t x_{h,t} + \epsilon_{h,t} \qquad (3.6)
\end{aligned}$$

We use all lagged variables (*h-1*) on the right-hand side of equation (3.6) to avoid endogeneity problems. We construct all proxies for collateral riskiness (Bond Supply, Bond BAS, Bond Mod. 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*).[64]

Thus, to summarize, the model in equation (3.6) extends the model in equation (3.3) by including the following additional factors:

- **Proxies of collateral riskiness:**

Bond Supply $_{h-1,\,t}$: First, for each bond, on day *t* at hour *h-1*, we compute the hourly average of the sum of the notional available for purchase at the top three levels of the ask side. Then, we compute the portfolio-weighted average bond supply across all bonds used as collateral for all repos, and separately for CCP-based repos and bilateral repos. β_1 is expected to be positive.

Bond BAS $_{h-1,\,t}$: First, for each bond, on day *t* at hour *h-1*, we compute the hourly time-weighted average of the relative bid-ask spread. We then compute the portfolio-weighted average bid-ask spread across all bonds used as collateral for all repos, and separately for CCP-based repos and bilateral repos. β_2 is expected to be positive.

Bond Mod. Duration $_{h-1,\,t}$: We compute the average modified duration of each bond on day *t* at hour *h-1*.[65] We then compute the portfolio-weighted average modified duration across all bonds used as collaterals for all repos, and separately for CCP-based repos and bilateral repos. β_3 is expected to be positive.

- **Proxies of repo riskiness:**

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[64] 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.
[65] We use as reference prices the last mid-point quote updates observed at the end of each hour.

Repo Net Order Flow $_{h-1,\,t}$: Total buyer-initiated volume less seller-initiated volume of GC repo traded on day *t* at hour *h-1*, calculated for all repos, and separately for CCP-based repos and bilateral repos. β_4 is expected to be positive.

Repo Trades $_{h-1,\,t}$: Total number of repo transactions on day *t* at hour *h-1*, calculated for all repos, and separately for CCP-based repos and bilateral repos. The coefficient β_5 is expected to be positive.

Repo Volatility $_{h-1,\,t}$: Standard deviation of repo rates for each hourly band h-1, computed over a 22-day rolling window for all repos, and separately for CCP-based repos and bilateral repos. β_6 is expected to be positive.

EL $_{t-1}$: Total daily excess liquidity deposited at the ECB facility on day *t-1*. The excess liquidity is computed as credit institutions' current account holdings, plus funds in the ECB deposit facility minus reserve requirements. 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 (3.3), 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*.

3.5.1.2 Empirical Results

Table 3.4 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 3.5 Panels A, B, and C, we check the sample correlations between all variables (respectively for the aggregate repo sample and for CCP and non-CCP repos). 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

Table 3.4: Summary statistics for explanatory variables over the aggregate sample, the CCP-based repo and the bilateral repo samples

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 GC 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 3.5: 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 3.4. *** indicates 1% significance level (S.L.); ** 5% S.L.; and * 10% S.L., respectively.

Panel A: All Repos

Variable	Hourly Repo Spread	Bond Supply	Bond BAS	Bond Mod. Duration	Repo Net Order Flow	Repo Trades	Repo Volatility	EL	Margin Costs
Bond Supply	0.022**								
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	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***

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.

We estimate model (3.6) 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 3.6. 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 (3.6) 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, but with higher absolute impact for the latter. In economic terms,[66] 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

[66] 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 sample or sub-sample considered). When calculating the economic impact of the proxies for collateral riskiness, we refer to their estimated coefficients in Table 3.6, columns 1 (for the aggregate sample), 5 (for CCP-based repos) and 9 (for bilateral repos).

Table 3.6: Collateral risk and funding costs - Pooled regressions results for model (3.6)

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 3.4. **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.

Period	Full Sample 01/01/2010 - 30/11/2015											
Dep. Var. 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

bps (All Repos), 5.47 bps (CCP), and 6.51 bps (Bilateral). So also the impact of Bond Bas is higher for bilaterally-traded repos than for CCP-traded repos.

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 which is 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.

We now 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 (Table 3.6, columns 4, 8 and 12).[67] 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 generates 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.

[67] We refer to Table 3.6, columns 4, 8 and 12 for the purpose of commenting the economic impact of the proxies for repo riskiness and excess liquidity, respectively 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 is, 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 3.6, 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. Once we control – however – also for the excess liquidity in columns 4, the 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 (3.6) over each of them. The results are reported in Table 3.7 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

Table 3.7: Collateral risk and funding costs- Pooled regressions results for model (3.6) 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 3.4. **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. 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

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) and two new 4-year LTROs on September 18, 2014 and December 11, 2014.[68] 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 [69] (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.[70]

The explanatory power of model (3.6) 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.

In Table 3.7 we observe three main additional findings with respect to the results already discussed for Table 3.6. First, while the Bond Bas is significant over the ESC period, it is instead 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

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

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

[70] 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

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.

Finally, in Table 3.7 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.

3.5.2 Regulatory Changes and Margin Costs

Margins are the preferred instrument adopted by 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 3.5 Panel A).

On 8 November 2011, at the peak of the Italian sovereign crisis, the CCPs increased the margins 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 3.5 Panel B).

Main regulatory authorities – i.e. the International Monetary[71] Fund and the Bank of Italy- have criticized the regulatory framework and the margin policies adopted during the European sovereign crisis as being responsible for further deterioration in funding costs.[72] 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."[73] These policy considerations are supported by empirical and theoretical evidence, for example by Brunnermeier and Pedersen (2009) model.

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[71] International Monetary Fund (2013), "Italy: Financial System Stability Assessment", IMF Country Report No. 13/300, September.

[72] 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".*

[73] European Union (2012), "Regulation (EU) No. 648/2012 on OTC derivatives, central counterparties and trade repositories", July.

What we attempt to examine in this section is the 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 (3.6), 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 ON GC repo spread.

Table 3.8 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 has further deteriorated the repo funding conditions (negative pro-cyclical effect), while in the post-crisis period margin costs 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 3.5 Panel A), the more favourable funding conditions – 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 3.8, 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 the 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.

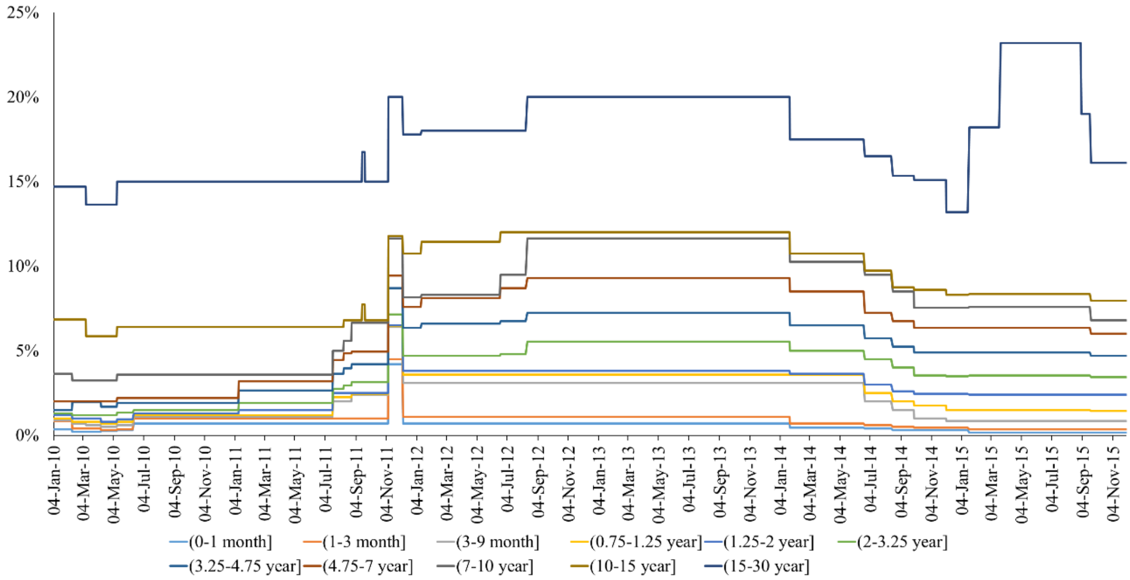
In Table 3.8 we also look separately at CCP and bilateral repos, in particular to investigate whether: i) margin costs are only significant for the CCP segment, as they are a direct cost borne only by traders who do repos via the central clearing counterparty; or ii) they are significant also for bilateral 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 3.8, columns 2, 8 and 12), while the economic impact of changes in margin costs is almost null in the post-crisis period (Table 3.8, columns 5, 10 and 14).

Figure 3.5: 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

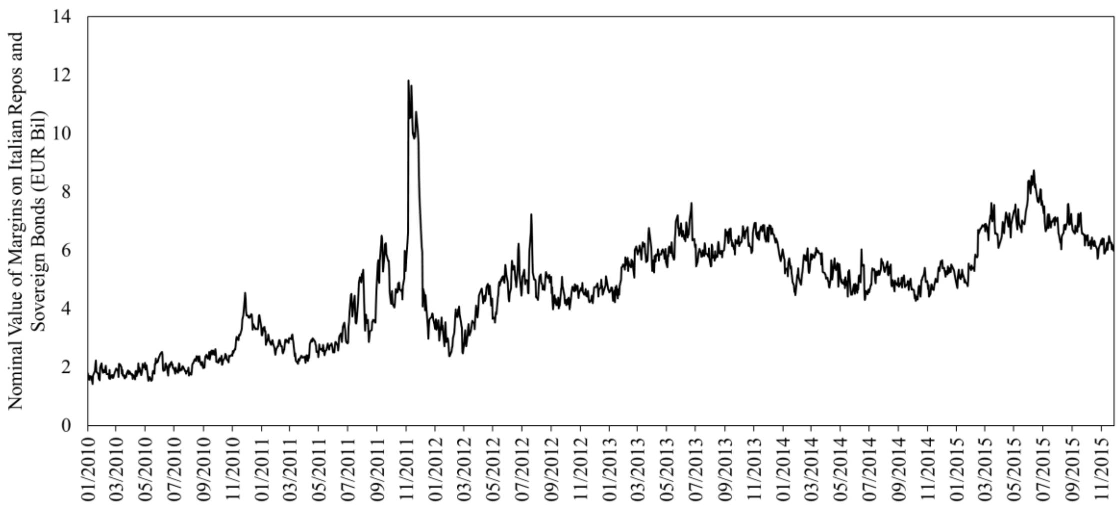


Table 3.8: Regulatory changes and CCP costs - Pooled regressions results for model (3.6) over two sub- periods

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 3.4. **Repo Net Order Flow** is measured here in billions of Euros. **EL²** 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. 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

3.5.3 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 and the sovereign CDS mid-quote for Italy. CDS mid-quotes are sourced from Bloomberg.[74] 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 have observed in Figure 3.1 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.

We re-estimate model (3.6) 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 we include the former in our model and drop the latter. The results are presented in Table 3.9.

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[74] 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.

Table 3.9: Counterparty risk - Pooled regressions results for model (3.6) 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 3.4. **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. 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

We would conjecture that CCP-based repos are covered from any counterparty risk exposure. In fact, in Table 3.5 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 3.9 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). In addition to that, 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 intraday repo spread (Table 3.9, 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.3.1 and A.3.2).

3.5.4 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 3.10, column1) without including any of the collateral and repo riskiness proxies.[75] 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, 2012). 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 3.10, column 1), we observe a high adjusted R-squared of about 43% that confirms 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 risk-mitigating function of the CCP becomes of 'second-order importance' for the Italian repo spread.[76] Next, in Table 3.10 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 3.6. The model estimated 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 (3.6) - without CISS - already captures the effect of the Eurozone systemic stress.

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[75] 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.
[76] 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.

Table 3.10: 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 3.4. **Repo Net Order Flow** is measured here in billions of Euros. **EL²**is a 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. 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

Second, we control whether the impact of the explanatory variables changes over the day. In the regression model (3.6) 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 (as in Abbassi et al., 2017). 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.[77] We argue that macroeconomic news may be anticipated by banks and already reflected in the prices of repo trades.[78]

3.6 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, the bond modified duration and its squared term to test whether the relationship is non-linear, and the bond

[77] For this control we apply a methodology similar to Paiardini (2014).
[78] 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.

bid-ask spread.[79] Additionally, we include bond specialness to account for bonds which are highly 'desirable' as collateral in special repos.[80] 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. The other explanatory variables are also indirectly related to the bond specialness (see Duffie, 1996; Corradin and Maddaloni, 2017).

We estimate the following logit model:

$$\text{Prob. of Selection}_{i,t} = \alpha + \beta_1 \text{ Bond Outstanding Amount}_{i,t-1} + \beta_2 \text{ Bond BAS}_{i,t-1} + \beta_3 \text{ Bond Mod. Duration}_{i,t-1} + \beta_4 \text{ Bond Mod.Duration}^2_{i,t-1} + \beta_5 \text{ Bond Specialness}_{i,t-1} + \gamma' X_t + \epsilon_{i,t} \quad (3.7)$$

where *i* indicates the bond and *t* the day. The dependent variable in equation (3.7) 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.[81] All explanatory variables in equation (3.7) are bond-specific and computed on a daily frequency.[82]

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 (3.7) 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 (3.7) with HC robust standard errors and bond fixed effects first for the whole sample of repos, and then separately for the sample of CCP-based repos and the

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[79] 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/.

[80] 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.

[81] 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.

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

sample of bilaterally-traded repos, over the period starting on January 4, 2010 and ending on November 30, 2015.[83] The results are reported in Table 3.11. We have a total of 151,299 daily observations.

Table 3.11 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 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. In fact, the bond can be better employed for raising funds via a cheaper special repo than via a GC repo.

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 by 0.94% for the linear term and by 0.15% for the squared term, so for a total of 1%. 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

[83] 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.

more than 100 bps for 10-year BTPs during the European sovereign crisis (see Chapter 2). Although all the variables' marginal impacts look small in absolute terms, we must consider that the main criterion for a trader to choose a bond as collateral is to have it in her portfolio. A trader with a small portfolio is only allowed limited optionality, yet our results show that she will exercise it according to a rational logic.

Looking at the CCP and bilateral repo subsamples, 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, repo buyer may be incentivized to reduce the margin costs by selecting shorter-maturity collateral. In addition, in Table 3.11 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 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 explore whether the impact of these factors on the probability of collateral selection changes over time (see Table 3.12, columns 1, 3, 5, 7). We use the same two sub-periods of the previous analysis in section 3.5.

As illustrated by Table 3.12, 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. Consistently, 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 3.5). 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.[84] Finally, we observe that after the crisis longer-maturity risky bonds are again those with higher probability to get collateralized into 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 3.12 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 the collateral in the bilateral repos. When we control for margins in CCP repos, the Bond Bas returns to display the expected positive coefficient.

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[84]A positive and significant effect of CCP initial margins on the cost of funding is found for the GC Italian repos by Miglietta, et al. (2015).

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 the 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 and to keeping more liquid bonds 'unencumbered' for regulatory purposes and management of unexpected liquidity needs.

Table 3.11: Collateral selection - Logit regressions results for model (3.7)

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)
	0.9442	*-2.0644*	*6.6426*
Lag Bond Mod- Duration^2	0.0070***	0.0049***	0.0095***
	(0.0009)	(0.0009)	(0.0012)
	0.1508	*0.1145*	*0.1066*
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

Table 3.12: Collateral selection - Logit regressions results for model (3.7) 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 3.11. 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)	
	-11.6044		*3.84764*		*1.16903*		*2.30802*	
Lag Bond Mod-Duration^2	0.0108***		-0.0077***		0.0081***		-0.0079***	
	(0.0016)		(0.0014)		(0.0017)		(0.0028)	
	0.25944		*-0.17584*		*0.18317*		*-0.04736*	
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

3.7 Summary and Conclusion

In this paper we examine the dynamics and determinants of the intraday rate of GC ON repos on Italian Government bonds, with respect to the ECB deposit rate. The importance of this analysis lays on the fact that the GC ON 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, 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 all collateral risk factors, as well as the repo factors and the ECB excess liquidity, 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 GC ON 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, 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 increasing 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 higher counterparty risk, so they have an impact on the intraday bilateral repo spread even if traders do not pay CCP margins to trade bilaterally. Furthermore, 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 also 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 initial margins and repo trading costs. Consistently, 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. Margin costs are instead insignificant to explain the choice of the collateral in the bilateral repos.

APPENDIX TO CHAPTER 3

Table A.3.1: Counterparty risk for large and small banks - Additional regressors in model (3.6) - 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 3.4. **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.3.2: Counterparty risk for large and small Banks - Additional regressors in model (3.6) - 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 3.4. **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

4 THE USE OF CENTRAL CLEARING COUNTERPARTIES IN GC REPOS.

4.1 Introduction

The recent financial crisis has exacerbated the liquidity issues of banks to obtain funding. However, the increasing use of secured lending via CCPs, in particular in the European repo market, shows the resilience of the CCP-based repos to risk, both in terms of trading activity (*repo volume channel*) and funding costs (*repo rate channel*) (Mancini et al., 2016). The possibility of reducing counterparty credit risk in the lending transactions attracts banks towards CCP repos (Affinito and Piazza, 2015).[85] CCPs mainly mitigate such risk by demanding margins from their counterparties (Pirrong, 2011). Simultaneously the interbank market activity of less secured forms of lending, such as bilaterally-traded repos (BIL repos), has exhibited a significant drop over time, making these markets unstable sources of bank funding. The cumulative quarterly turnover of European unsecured money market dropped from € 27 trillion in 2007 to € 5 trillion in 2015, amounting to a decrease equal to 81.48% (ECB, 2015).[86] During the same period, the overall cumulative quarterly turnover of repos increased from € 43.3 trillion in 2007 to € 50.3 trillion in 2015 (ECB, 2015).[87] Within the secured market, the trading activity of all BIL repos in the euro area dropped from representing more than 50% of all repo transactions to around 20% in 2015, a reduction mainly compensated by the rise of CCP-based transactions, which represented more than 65% of the secured market in 2015 (ECB, 2015).

The ON GC repo market for Italian sovereign bonds provides an example for the aforementioned situation. Table 4.1, Panel A and Figure 4.1, Panel A both illustrate different trends of the Italian ON GC CCP repo market activity compared to BIL repos. The daily CCP trading volumes increase over

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[85] CCPs act as third parties which mediate the lending transactions between two banks See Affinito and Piazza (2015) for a detailed description of the role of CCPs in the repo market.
[86] The cumulative quarterly turnover refers to the sum of unsecured lending and borrowing (ECB, 2015).

time, ranging from €4.42 billion in 2010 to €4.97 billion in 2015 (Table 4.1, Panel A), and peak during the European Sovereign Crisis (€5.66 billion). In contrast, the daily trading volumes for BIL repos drop from €2.88 billion to €0.26 billion during the same period. Overall, the decrease for the daily traded volumes in BIL repos is equal to 90.7% of the bilateral trading activity observed in 2010, while the daily market activity in CCP repos significantly increases by 12.4%. As a result, the difference in the trading activity between CCP and BIL repos dramatically increases over time. The decreasing trend for BIL repo volumes reflects a more general trend where banks move away from unsecured funding and rely more on secured funding/repos.

Therefore, the Italian ON GC repo market provide a unique opportunity for analysing the factors which explain the use of CCP repos with respect to BIL repos. When risk is high and the overall funding conditions tighten, does the market design of CCP encourage lending via CCP repos relative to the bilateral alternative? Additionally, what are the factors which affect the difference of funding costs incurred by banks when preferring BIL repos to CCP repos?

In order to answer these questions, we use the framework adopted by Mancini et al. (2016) and analyse which factors affect the difference between trading volumes and rates of CCP repos and BIL repos. Indeed, repo volumes and repo rates are the main channels of risk mitigation used by banks or CCPs in the repo market (Mancini et al., 2016). To explain, money market theory predicts that banks reduce lending during a period of crisis, for instance, when aggregate risk (Allen, Carletti, and Gale, 2009) or uncertainty increase (Caballero and Krishnamurthy, 2008).[88] However, CCPs should reduce the credit risk of the counterparties which trade via repos, incentivising banks to lend more.[89] When this happens, the CCP interbank repo market can act as *shock absorber*, in the sense that repo lending

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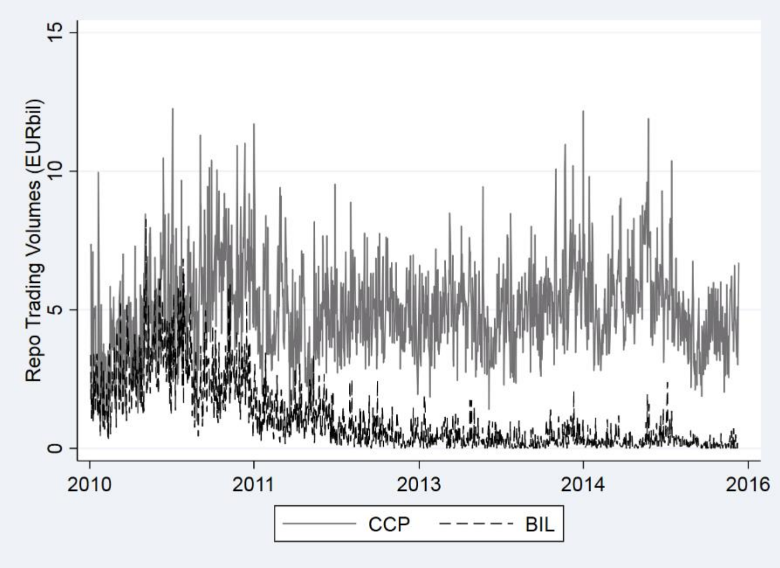
[88] See Mancini et al. (2016), and the literature therein, for a discussion of different factors which could affect the lending activity in crisis times.

[89] The anonymity of CCP repos, the presence of margins/haircuts set by the CCPs, and the use of safe securities are the main features which make CCP repos attractive to banks and that incentivise lending (Mancini et al., 2016).

Figure 4.1: The use of CCP and bilaterally-traded GC repos

Panel A shows the total daily trading volumes (measured in billions of Euros) of ON GC centrally-cleared (CCP) and bilaterally-traded (BIL) repos on Italian sovereign bonds. Panel B illustrates the spread between the daily trading volumes of ON GC CCP and BIL repos on Italian sovereign bonds (measured in billions of Euros). The fitted line in Panel B shows the time trend of the spread between the trading volumes of CCP and BIL repos. Sample period: from January 4, 2010 to November 30, 2015.

Panel A: Daily trading volumes of ON GC Italian repos



Panel B: Daily volume spread between CCP and total ON GC Italian repos

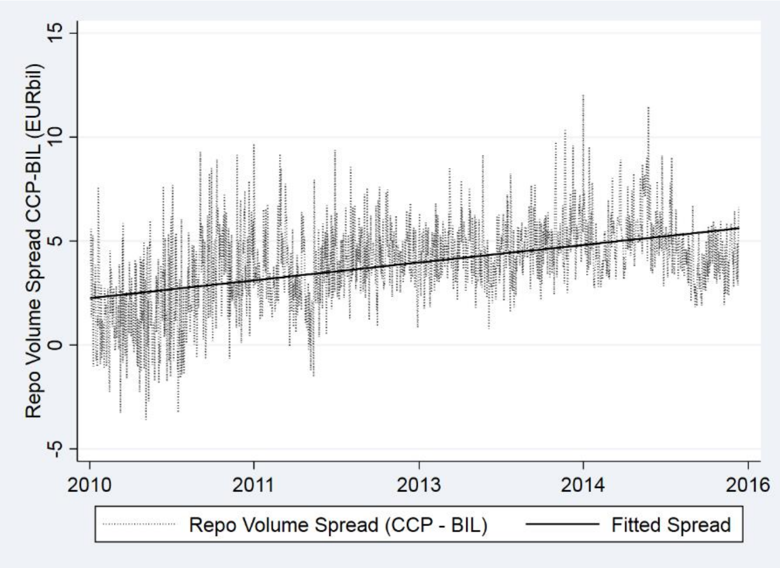


Table 4.1: The use of GC ON repos

Panel A reports the sample total and average daily nominal transacted volumes of collateral used in MTS for general ON CCP repos, BIL repo transactions and their daily spread (**Repo Volume Spread $_{\text{CCP-BIL}}$**) over time (years). Panel B shows summary statistics of the average daily nominal transacted volumes of collateral for GC, ON, CCP repos, BIL repo transactions and their spread. Sample period: from January 4, 2010 to November 30, 2015. All proxies are measured in billions of Euros. Panel A also reports the significance of a t-test under the hypothesis of the Repo Volume Spread $_{\text{CCP-BIL}}$ being equal to zero. Italian sovereign bonds are used as collateral in repo transactions. *** indicates 1% significance level (S.L.); ** 5% S.L.; and * 10% S.L.

Panel A: Transacted nominal amounts of collateral in repo market over time

Year	Total Trading Volumes (EURbil)			Average Daily Trading Volumes (EURbil)		
	Repo Volume $_{\text{CCP}}$	Repo Volume $_{\text{BIL}}$	Repo Volume Spread $_{\text{CCP - BIL}}$	Repo Volume $_{\text{CCP}}$	Repo Volume $_{\text{BIL}}$	Repo Volume Spread $_{\text{CCP - BIL}}$
2010	1,126.61	734.51	392.10	4.42	2.88	1.54***
2011	1,448.50	476.05	972.45	5.66	1.86	3.80***
2012	1,225.21	182.98	1,042.23	4.82	0.72	4.10***
2013	1,194.78	88.98	1,105.81	4.76	0.35	4.41***
2014	1,376.06	81.03	1,295.03	5.46	0.32	5.14***
2015	1,159.00	61.74	1,097.26	4.97	0.26	4.71***
All	7,530.16	1,625.29	5,904.87	5.02	1.08	3.93***

Panel B: Transacted nominal amounts of collateral in the GC repos – Summary statistics

Variable	Summary Statistics							
	No. of Trading Days	Mean	STD	Min	25th Pct	Median	75th Pct	Max
Repo Volume Spread $_{\text{CCP - BIL}}$	1,501	3.93	2.07	-3.60	2.78	4.10	5.29	12.04
De-Trended Repo Volume Spread $_{\text{CCP - BIL}}$	1,501	0.00	1.83	-6.14	-1.21	-0.08	1.11	7.23
Repo Volume $_{\text{CCP}}$	1,501	5.02	1.71	0.47	3.82	4.88	5.99	12.25
Repo Volume $_{\text{BIL}}$	1,501	1.08	1.26	0.00	0.18	0.55	1.58	8.27

increases with risk, while repo rates remain stable (Mancini et al., 2016).[90] If both these two conditions are satisfied, then CCP repos are said to be resilient to risk.

First, we study the factors driving the difference between the daily traded volumes of CCP and BIL repos (*repo volume channel* of risk mitigation).[91] Secondly, we analyse the determinants of the daily spread between the rates of BIL and CCP repos (*repo rate channel* of risk mitigation).

The debate about the consequences of the use of CCPs in the interbank market has not reached a clear consensus. According to the current state of the literature, an increased use of CCPs may have both positive (Mancini et al., 2015; Chatterjee, Embree and Youngman, 2012; Affinito and Piazza, 2015) and negative effects (Affinito and Piazza, 2015; Wendt, 2015, and Pirrong, 2011). CCPs eliminate direct counterparty credit risk of the banks via anonymous trading (Martin et al., 2014b). Furthermore, in case of default of one participating bank, the collaterals can be liquidated by the CCPs, which in this way distribute losses among banks (Oehme, 2014). Overall, the safety and liquidity of collateral can reduce the risk of systemic and individual runs by banks (Martin et al., 2014a). Mancini et al. (2016) investigate the resilience of repos (Eurex platform) for the period from January 2006 until February 2013. When the repo collateral is safe – e.g. German sovereign bonds - the repo trading volumes increase with risk. In this sense, the CCP repos absorb shocks of different nature: the systemic risk of the European financial system, the effects of unconventional monetary interventions undertaken by the ECB, and changes in the regulatory polices– i.e. haircuts or margins. However, the resilience of the GC repos ultimately depends on the creditworthiness of the collateral used in the repo transactions. Indeed, the volume of Italian 1-day GC CCP repos negatively relates to systemic risk, indicating that the Italian GC repo market is not resilient to shocks in times of crisis.

[90] We use the term 'shock' to indicate the impact of risk on variation of the repo volume spread and the repo rate spread. This definition of shock is provided by Mancini et al. (2016). In this context, shocks do not refer to the use of impulse-response functions standard for vector-autoregressive models.

[91] In this paper, I specifically focus on GC CCP and BIL repo markets. As a consequence, we do not include alternative unsecured funding sources such as the E-Mid market (see for instance Baglioni and Monticini, 2008).

The resilience of the interbank market may be negatively affected by risks linked to the use of CCPs (see, for example, Affinito and Piazza, 2015, Wendt, 2015, and Pirrong, 2011, for a discussion of these issues). First, when a whole part of the financial sector - Italian banks in our paper – makes use of the same clearing houses for obtaining funding, CCPs become highly interconnected with the risks borne by the market participants of this system (concentration risk). In extreme circumstances, potential default risk of the CCPs – e.g. in case the margins and default funds are not sufficient to repay the CCP members – may expose the participating banks to unexpected credit losses (Wendt, 2015), or shortage of funding liquidity (Pirrong, 2011, Brunnermeir and Pedersen, 2009). This makes CCPs systemically important institutions and as such, subject to ad-hoc supervision by the regulatory authorities (Cœuré, 2014). Additionally, the CCPs' risk increases when banks, which would not gain access in the bilateral segment – such as the bilateral repo market – obtain funding by taking advantage of the anonymity provided when using the third-party intermediation of the clearing houses (Affinito and Piazza, 2015). Affinito and Piazza (2015) analyse the determinants of the monthly share of interbank borrowing exposures through CCPs over total liabilities of Italian banks over the period from June 2004 until June 2013.[92] They show that the use of CCPs by Italian banks is driven by both general uncertainty and counterparty risk. However, counterparty risk is positively associated with variations in CCP volumes only for the riskier borrowers.[93] For all the other banks the use of CCPs is rather motivated by a general increase in uncertainty and risk aversion, implying that CCPs provide a useful additional funding channel to banks.

Ultimately, the evaluation of the impact of the use of centrally-cleared transactions on the resilience of the repo market, is related to the underlying reasons which explain this recourse (Affinito and Piazza, 2015). One the one hand, the credit risk of the banking sector is concentrated in the CCPs (e.g. Singh 2010). Additionally, the overall counterparty exposures of banks could increase if banks

[92] Data are obtained from Banca d' Italia prudential supervisory reports.
[93] This result is valid for the 10% riskiest banks in the dataset analysed in Affinito and Piazza (2015).

do not make use of bilateral transactions and only obtain funding via the CCP repo market (Duffie and Zhou, 2011). If rising counterparty credit risk drives the shift from bilateral to centrally cleared transactions, the externality on the financial system could be negative. Riskier borrowers, willing to elude market discipline via the anonymity of trading granted by the CCP market design (Cappelletti et al., 2012), might "self-select" into the CCP-based interbank market segments and make the whole financial system riskier by increasing the risk of the CCPs. Furthermore, the level of margins set by the clearing-houses might have adverse effects on banks' recourse to CCP-based trades. When margins are set too high, the risk of safer banks could be overpriced with respect to less creditworthy ones, leading the former to trade less via CCPs than the latter (Pirrong, 2011). Moreover, margin requirements could be raised during a period of financial stress, imposing additional funding liquidity constraints (Pirrong, 2011; Brunnermeir and Pedersen, 2009). A similar disincentive to CCP-based markets for safer banks is provided by the mutualisation of losses in case of default (Arnsdorf, 2012). If too many risky counterparties trade anonymously in the CCPs, the overall CCP default risk might increase. Safer banks could prefer to transact via bilateral segments and choose more creditworthy counterparties, thus reducing their exposure to the CCP default risk (Heider et al., 2015).

On the other hand, where banks trade via CCPs to avoid general market uncertainty, CCPs provide banks with an additional way to obtain safe funding. Indeed, while general uncertainty of borrowing banks might limit the well-functioning of the interbank lending, CCPs facilitate the lending activity among otherwise risk-averse banks, for instance by reducing the impact of clearing member failure (Pirrong, 2011). The resilience of money markets is also guaranteed by the features of the market structure of CCP-based trading venues. The anonymity of CCP trading, the use of margins, and the netting of positions are the main risk mitigating tools. These could all decrease the sensitivity of banks to the individual credit risk of the counterparties (see Carapella and Mills, 2012; Mancini et al., 2016; Cœuré, 2014; Pirrong, 2011; Affinito and Piazza, 2015).

The relative costs of CCP-based repo transactions with respect to BIL repos (repo rate channel) also constitute an important dimension to comprehensively assess the factors which explain the increasing importance of CCPs for the interbank repo market. Within the GC repo literature, there are no papers which explicitly compare the CCP and BIL GC repos. However, few papers examine how market liquidity or credit risk affect the costs of trading via GC CCP repos. The interconnection between daily repo rates and sovereign credit risk is analysed by Boissel et al. (2017). They study GC CCP repos from two large electronic platform (MTS Repo and ICAP BrokerTec) for the period from January 2008 until June 2012.[94] They show that country specific CDS spreads have a large impact on the funding costs of GIIPS countries. Miglietta et al. (2015) analyse the impact of initial margins on Italian GC CCP repos (MTS) during the period from January 2011 to April 2014. They find that the costs of funding increase with the initial margins, the systemic illiquidity of the Italian financial sector and the credit risk of the Italian banking sector. Abbassi et al. (2017) investigate the dynamics of the intraday repo rates for the German CCP-based GC repo market (Eurex) over the period from January 2006 until June 2012. In their study, the authors provide evidence that both repo market illiquidity and funding uncertainty significantly explain the variations in intraday repo rates.

It is clear that the literature on repo market is mainly focused on CCP repos, while the relationships between CCP and BIL repos has never been investigated. Indeed, it is not obvious *a priori* that CCP repos are more resilient to shocks than BIL repos, and little is known about the conditions that make CCP repos less desirable than BIL repos. Our study of the determinants of the use of CCP and BIL repos traded on MTS over the period from January 2010 to November 2015 makes several original contributions. To the best of our knowledge, this study is the first to investigate the difference in the resilience of CCP and BIL repos, and the first to study the factors which determine the recourse to CCP versus BIL repos. First, we show that the CCP ON GC repo market activity increases with risk,

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[94] ICAP Broker Tec provides data on repos for most of the countries, but covers only a small fraction of repos for the Italian sovereign bond market. MTS Repos is the main electronic trading platform for Italian repos.

while the opposite is true for the trading volumes of BIL repos. In line with these findings, we document that the difference in trading activity between CCP and BIL repos (*repo volume spread*) positively relates to sovereign credit risk, counterparty risk, repo funding illiquidity and high levels of excess liquidity injected by the ECB into the European financial system. We interpret these results as signals of positive contributions of the role played by CCPs to the resilience of the Italian interbank repo market. In this sense, the operations conducted by the CCPs reduce the risk undertaken by clearing members (Pirrong, 2011, Mancini el al., 2016). However, we find that when margins are relatively high (above the median value), banks reduce their exposures to CCP repos. This finding highlights a pro-cyclical effect of margin policies (as in Brunnermeir and Pedersen, 2009). Banks reduce their exposure to CCPs and prefer BIL repos in order to reduce margin costs (Pirrong, 2011).

Second, when assessing the evolution of funding costs, the *repo rate spread* between BIL and CCP repos negatively or positively relates to risk according to whether margins are high or low – i.e. above or below their median value. Indeed, we provide evidence that margins also have pro-cyclical effects on the repo rates and increase the costs of CCP repos with respect to BIL repos. When margins are low (below the median value), the repo rate spread positively relates to risk proxies. This result signals the well-functioning of the CCPs in mitigating risks.[95] However, when margins are high (above the median value), the rate spread between BIL and CCP repos decreases with risk, and CCP repos are more costly than BIL repos. This pricing anomaly signals that banks charge a risk premium to transact via CCPs when margins are above their median value. In this case, sovereign credit risk and funding risk increase with the risk premium charged by banks for using CCP instead of BIL repos, indicating that the margin policies adopted by CCPs lead to greater risk for the clearing banks.

[95] For instance, sovereign credit risk is also positively related to the repo rate spread. This signals the effectiveness of CCPs in ‘transforming systemic risk’ by decreasing the impact of default of clearing banks (Pirrong, 2011).

The rest of this chapter illustrates the main features of our investigation. Section 4.2 starts with a descriptive analysis of our data. Section 4.3 presents the methodology and the main empirical results. Section 4.4 concludes.

4.2 Data and Methodology

4.2.1 Data Summary of GC ON Repos

This paper utilises a dataset which represents the trading activity for GC ON CCP and BIL repos transactions on Italian sovereign bonds. This dataset has not been used so far in the existing studies. Indeed, the vast majority of the existing research in this area focuses only on CCP repos (for example Mancini et al., 2016; Abbassi et al., 2017), and does not exploit the information available for BIL repos.

The database is obtained from the MTS, the largest electronic market for repos, and the leading trading venue for repos on Italian Treasuries. Our sample period starts on 4 January 2010 and ends on 30 November 2015. This period is of particular interest since it is characterised by the sovereign debt crisis in the Eurozone periphery, and by the unconventional interventions of the ECB, adopted to abate the crisis (Pelizzon et al., 2016).

We select all GC repos which make use of Italian sovereign bonds as collaterals (in total 77,467 intraday trades). We choose the Italian sovereign collaterals for several reasons. First, despite the increasing use of CCP repos, BIL repos are still actively traded (albeit at smaller trading volumes). Second, the GC ON repo market represents a unique opportunity to evaluate the determinants of the use of repos on Italian sovereign debt instruments. Indeed, the Italian sovereign bond market experienced substantial stress during the European sovereign crisis (Pelizzon et al., 2016). The implications about the resilience of the Italian interbank repo market might differ with respect to countries which did not suffer a similar stress during the GIIPS crisis –e.g. Germany and France.

The MTS database provides intraday information about the repo rate, the nominal trades' quantity, the type of repos (CCP or BIL), the repo term (e.g. Overnight), and the execution time of the trade; all information which we exploit in the remainder of this chapter.[96]

For each business day, we compute the daily total nominal quantity (measured in billions of Euros) of ON GC Italian repo trades for CCP repos and subtract the corresponding values for BIL repos. This difference, which we name the ***Repo Volume Spread*** $_{CCP\text{-}BIL}$, measures the use of CCP repos with respect to BIL repos.[97]

Table 4.1 and Figure 4.1 present the summary statistics and the evolution of the repo volumes for CCP and BIL repos, respectively. Unless otherwise stated, the focus of our investigation is on the *Repo Volume Spread* $_{CCP\text{-}BIL}$, since it captures the interactions between the trading activity of CCP and BIL repos. In Table 4.1, Panel A and B, the mean *Repo Volume Spread* $_{CCP\text{-}BIL}$ is equal to €3.93 billion, and significantly positive over time. In 2015, the mean difference in daily trading volumes between CCP and BIL repos is €4.71 billion, roughly three times bigger than the value observed in 2010 (€1.54 billion).

Finally, we compute the daily average repo rates for CCP and BIL repos, weighted by the transacted nominal quantity. We then subtract the daily volume-weighted average CCP repo rate from the daily volume-weighted average BIL repo rate. In Table 4.2 and Figure 4.2, we report this proxy, which we call ***Repo Rate Spread*** $_{BIL\text{-}CCP}$. It measures the risk premium costs required by a bank for trading via BIL repo with respect to CCP repos. BIL repos do not benefit from the same features of CCP repos, such as the risk mitigation tools in case of a default of the counterparty or the anonymity of trading

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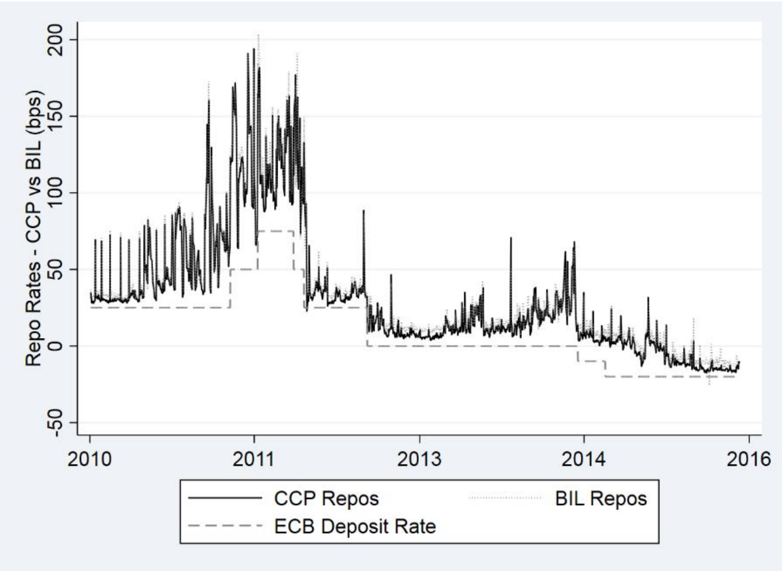
[96] A detailed descriptive analysis of the Italian ON GC repo market is provided in Chapter 3 and omitted here for brevity.

[97] Other alternatives to repos trading are described in Chapter 3. Among those, the E-Mid market represents the traditional unsecured overnight funding alternative for Italian banks (see for instance Baglioni and Monticini, 2008). However, we do not have data on this market. A second unsecured option is the Eonia market. However, once we control for Eonia volumes, we do not find any significant effect on the trading activity of Italian CCP and BIL repos. Third, the excess liquidity injected by the ECB is also a substitute for the demand for CCP repos (Mancini et al., 2016). Thus, we explicitly consider the surplus of liquidity in the Eurozone banking system in our models (Section 4.2).

Figure 4.2: The difference between GC bilateral and CCP repo rates

Panel A 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. Panel B illustrates the daily difference between the rates of ON GC BIL and CCP repos (**Repo Rate Spread** $_{\text{BIL-CCP}}$, measured in basis points) on Italian sovereign bonds. Sample period: from January 4, 2010 to November 30, 2015.

Panel A: CCP ON GC Italian repo rate, BIL ON GC Italian repo rate, and ECB deposit



Panel B: Repo Rate Spread between CCP and BIL repos

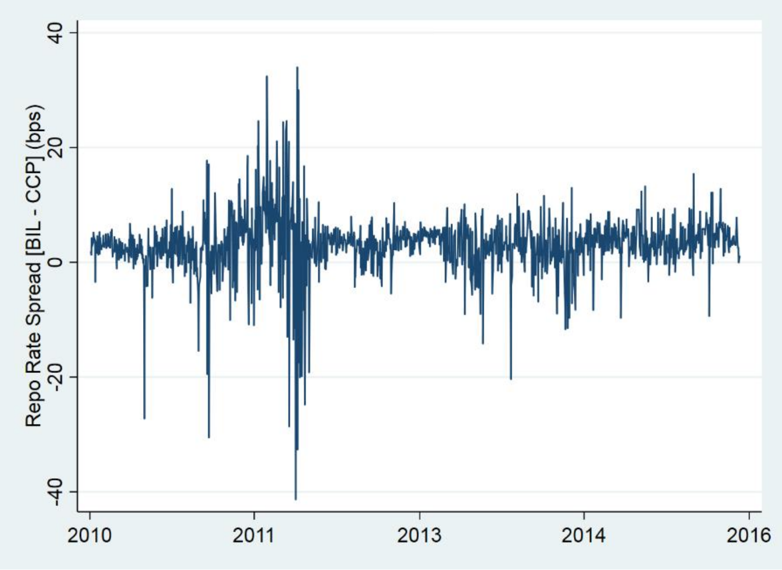


Table 4.2: The difference between ON GC BIL and CCP repo rates

The Table reports summary statistics and the evolution over time of the repo rate spread (**Repo Rate Spread $_{BIL-CCP}$**) between BIL and CCP GC ON repos on Italian sovereign bonds over the sample period January 4, 2010 to November 30, 2015. The Repo Rate Spread $_{BIL-CCP}$ (measured in basis points) is the daily difference between the volume-weighted average rates of BIL and CCP GC ON repos. Weights are computed as the daily relative transacted nominal quantities. Panel A presents the summary statistics; Panel B reports the daily average over time (year). Panel B also reports the significance of t-tests under the hypothesis of the Repo Rate Spread $_{BIL-CCP}$ being equal to zero. *** indicates 1% significance level (S.L.); ** 5% S.L.; and * 10% S.L, respectively.

Panel A: The difference between ON GC BIL and CCP repo rates – Summary statistics

Variable	Summary Statistics							
	No. of Trading Days	Mean	STD	Min	25th Pct	Median	75th Pct	Max
Repo Rate Spread $_{BIL - CCP}$	1,501	3.05	5.19	-41.29	1.43	3.32	5.08	33.96
Repo Rate $_{CCP}$	1,501	31.96	40.61	-17.42	5.91	20.08	40.09	193.96
Repo Rate $_{BIL}$	1,501	35.02	40.50	-25.72	10.34	23.54	42.14	203.53

Panel B: The difference between ON GC BIL and CCP repo rates over time

Year	Average Daily Repo Rates and Spread (bps)		
	Repo Rate $_{CCP}$	Repo Rate $_{BIL}$	Repo Spread $_{BIL - CCP}$
2010	43.95	45.88	1.93***
2011	103.59	107.16	3.58***
2012	23.52	26.61	3.04***
2013	12.11	15.31	3.10***
2014	13.90	16.63	2.72***
2015	-9.76	-5.87	4.00***
All	31.96	35.02	3.05***

granted under CCP repos. These additional costs are priced in the average Repo Rate Spread $_{\text{BIL-CCP}}$. Banks demand 3.05 bps more as risk premium for trading via BIL repos with respect to CCP repos. This proxy is the focus of section 4.3.2 where it is described in more detail.

4.2.2 Methodology

In the following analysis we run two econometric exercises in order to answer two main questions. First, we investigate the extent to which risk factors can explain the variation in the use of CCP repos with respect to BIL repos. Second, we analyse the impact of those proxies of risk on the difference between the repo rates of BIL and CCP repos. Overall, the joint investigation of both the repo volume and rate channels will help us to shed light on the contributions that the use of CCPs has to the resilience of the interbank repo market. In doing so, we use the evaluation criteria described by Mancini et. al, (2016). First, if repo volumes increase with risk, we interpret this a sign that the repo market is resilient to shocks, and it is not otherwise. Similarly, if repo rates decrease with risk, repos appear to absorb negative shocks and are thought to be resilient. If both the two aforementioned conditions are satisfied, the CCP repos are more resilient to shock than BIL repos.

First we control for the Italian country-specific sovereign credit risk as measured by the Euro-denominated 5-year CDS (Boissel et al., 2017; Pelizzon et al., 2016). We expect that the higher the sovereign credit risk, the riskier the collateral and the higher the recourse to CCP with respect to BIL repos. We also expect that the higher the counterparty credit risk of the Italian banks, the higher the Repo Volume Spread $_{\text{CCP-BIL}}$. To explain, while in CCP repos counterparty credit risk should be mitigated with different tools - with initial margins being the preferred risk mitigation technique –, BIL repos do not require posting margins. Furthermore, trading via BIL repos does not allow anonymity while CCP repos do, thus in CCP repos the counterparty risk should be diversified by the mutualisation of losses. We use the Excess Bank CDS as a proxy of counterparty credit risk. It is measured as the difference between the weighted-average CDS of the Italian banking sector and the Italian sovereign-specific CDS.[98]

Third, we control for several proxies of riskiness in the repo market. We include the surplus of liquidity available to banks in the Euro-system, and we expect that the higher the liquidity surplus, the lower the funding uncertainty, the lower the demand for CCP repos with respect to BIL repos, and the lower the Repo Volume Spread. Indeed, the central bank liquidity provision can be detrimental to secured interbank lending, meaning that the CCP repo volume decreases with excess liquidity (Mancini et al., 2016). In this sense, the central bank liquidity is a substitute for secured funding (Bolton, Santos, and Scheinkman, 2009). We measure the liquidity surplus as daily excess liquidity (EL, billions of Euros) deposited to the ECB facility (see Mancini et al., 2016, and the literature therein for a discussion of the dynamics of this proxy over time). We also include the square term of EL to allow for non-linear effects.

We expect that the longer the volume-weighted average duration (in hours) of the overnight loan, the higher the funding uncertainty of banks.[99] If banks fear not-meeting their end-of-day liquidity needs, they execute more repos in the early morning of the trading day than in the afternoon (Angelini, 1998; Van Hoose, 1991; Abbassi et al., 2017; and Baglioni and Monticini, 2008, 2010, 2013).[100]

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[98] We use as weights the relative market caps of each banks over the last 22 days (rolling window).

[99] We use as weights the relative nominal quantity of each trade of the same trading day.

[100] Longer average loan durations could also be due to banks easily satisfying all liquidity needs in the morning with no additional funding requirements for later in the day. Shorter average loan duration could reflect high funding uncertainty, large competition amongst borrowers who are still trying to execute repo trades later in the day. To account for possible additional funding needs which are not satisfied later in the day, we have preliminary included in both model (4.1) and (4.2) the volume-weighted average loan duration of GC ON BIL repos. BIL repos are usually executed in the afternoon, once CCP repo trading ends and it is no more available to banks. If banks obtain liquidity BIL repos towards the closure of the trading day, the average loan duration of BIL repos decreases reflecting higher funding uncertainty (Jurgilas and Žikeš, 2014). Thus we also expect a negative relation between the average loan duration of BIL repos and the Repo Volume Spread $_{\text{CCP - BIL}}$. However, we omit this variable from the final models since not significant.

Finally, the higher the illiquidity of the BIL repo market with respect to the illiquidity of the CCP-based repo market, the higher the Repo Volume Spread $_{\text{CCP-BIL}}$. We measure the different liquidity as the spread between the Amihud (2002) ratio of BIL and CCP repos (Amihud Spread $_{\text{BIL-CCP}}$).

The dependent variable of the first regression is the *Repo Volume Spread* $_{CCP\text{-}BIL,\,t}$, and it is computed as the spread between the daily trading volumes (nominal quantities, measured in billions of euros) of GC ON CCP repos and GC ON BIL repos on day *t*.[101] The core model specification is:

$$Repo\ Volume\ Spread_{CCP\text{-}BIL,\,t} = \alpha + \beta_1\, Trend_{t} + \beta_2\, CDS_{t\text{-}1} + \beta_3\, Excess\ Bank\ CDS_{t\text{-}1}$$
$$+ \beta_4\, EL_{t\text{-}1} + \beta_5\, EL^{2}_{t\text{-}1} + \beta_6\, AT_{CCP,\,t\text{-}1} + \beta_7\, Amihud_{BIL\text{-}CCP,\,t\text{-}1} + \gamma'\, X_{t} + \epsilon_t \qquad (4.1)$$

The dependent variable of the second regression is the *Repo Rate Spread* $_{BIL\text{-}CCP,\,t}$, and it is measured as the daily spread between the volume-weighted average GC ON BIL repo rate and the volume-weighted average GC ON CCP repo rate on day *t*.[102] The model specification of this regression is:

$$Repo\ Rate\ Spread_{BIL\text{-}CCP,\,t} = \alpha + \beta_1\, CDS_{t\text{-}1} + \beta_2\, Margin\ Costs_{t\text{-}1} + \beta_3\, Margin\ Costs^{2}_{t\text{-}1}$$
$$+ \beta_4\, AT_{CCP,\,t\text{-}1} + \beta_5\, Amihud_{BIL\text{-}CCP,\,t\text{-}1} + \beta_6\, EL_{t\text{-}1} + \gamma'\, X_{t} + \epsilon_t \qquad (4.2)$$

In both model specifications (4.1) and (4.2), α is a constant term, ϵ_t is the standard normal error term, and X is a vector of seasonal controls which are standard in the literature on money markets.[103] In model (4.1), *Trend* is a linear time trend which we include to account for the increasing recourse to

[101] Results are qualitatively similar when using the de-trended repo volume spread and the volume ratio of CCP repos over the total sum of CCP and Bilateral GC ON Repos (both de-trended and not de-trended). For ease of presentation, we only report results where the repo volume spread is used as the dependent variable. In Section 4.3.1.2, we show an example of this robustness check. The choice of the repo volume spread as dependent variable is consistent with the model specification adopted by Mancini et al. (2016) and Affinito and Piazza (2015).
[102] In order to obtain the weights, we divide the nominal quantity of each repo trade over the total sum of the nominal quantities of all repos traded on the same day t for BIL and CCP repos, respectively.
[103] X includes end-of-month, end-of-maintenance period, year-end and day of the week dummies. See for instance Demiralp, Preslopsky and Whitesell (2006), Mancini et al. (2016) and Jurgilas and Žikeš (2014).

CCPs over time. It is also a proxy for the effects of expected regulatory interventions which are not captured by the model (Mancini et al., 2016).[104] We use all variables in lagged form to control for endogeneity. The remaining factors are summarized as follows.[105]

- **Proxy for sovereign credit risk:**

CDS $_{t-1}$: is the daily 5-year Euro-denominated Italian CDS mid-quote spread obtained from Bloomberg. The higher the CDS, the greater the use of CCPs (model (4.1)), and the greater the repo rate spread is expected to be (model (4.2)).

- **Proxy for counterparty risk:**

Excess Bank CDS $_{t-1}$: is the difference between the daily 5-year Euro-denominated CDS mid-quote for the Italian banking sector[106] and the Italian sovereign 5-year Euro-denominated CDS mid-quote.[107] Bank CDS are obtained from Bloomberg. The CDS-quote for the Italian banking sector is computed as the weighted average of CDS mid-quotes for Italian banks, where weights are computed as the relative average market capitalisation of Italian banks over the previous 22 trading day (rolling) window. We expect that the higher the Excess Bank CDS, the greater the use of CCPs (model (4.1)).

- **Proxies for repo riskiness:**

AT $_{CCP, t-1}$: is the daily volume-weighted average term (loan duration) of GC ON CCP repos. With high funding uncertainty, banks are more aggressive in trying to secure funds in the morning than in the afternoon. The higher the funding uncertainty, the greater the trading volumes of CCP repos with

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[104] We describe the main regulatory changes in Chapter 1 – i.e. Basel III, EMIR, Solvency II and the Dodd-Frank Act.

[105] We omit the lagged value of the *Repo Rate Spread* $_{BIL\text{-}CCP}$ from model (4.1) since it is not significant. For the same reason, we omit the lagged value of the *Repo Volume Spread* $_{CCP\text{-}BIL}$ from model (4.2). These findings are similar to the results in Mancini et al. (2016).

[106] Roughly 60% of the volume of GC ON Repo is traded by Italian banks. This fact has been confirmed by MTS repo market specialists.

[107] In model (4.1), Excess Bank CDS is orthogonalised with respect to CDS due to the high positive correlation with latter (see Boissel et al, 2017). We omit the Excess Bank CDs from model (4.2) since not significant once CDS is included in the model.

respect to BIL repos (model (4.1)), and the greater the spread between BIL and CCP repo rates are expected to be (model (4.2)).[108]

Amihud $_{\mathbf{BIL\text{-}CCP,\ t\text{-}1}}$: is the daily spread between the Amihud (2002) ratio of BIL and CCP repos. The Amihud (2002) ratio on day *t-1* is measured as the daily price range (in bps) divided by the daily transaction volume (in billions of Euros).[109] The daily price range is the difference between the maximum and minimum repo rate observed on day t-1. The Amihud ratio is measured as the daily maximum price change for a given volume of transactions, and averaged over a 22-day rolling window (see Abbassi et al., 2017).[110] We expect that the higher the Amihud spread between BIL and CCP repos, the greater the CCP trading activity (model (4.1)) and the higher the repo rate spread (model (4.2)).

EL $_{\mathbf{t\text{-}1}}$: is a proxy for the total daily excess liquidity which banks deposit at the ECB facility on day *t-1*. The excess liquidity is measured as credit institutions' current account holdings, plus funds in the ECB deposit facility minus reserve requirements. The greater the excess liquidity, the lower the funding uncertainty, the lower the use of CCP repos (model (4.1)), and the lower the spread between BIL and CCP repo rates (model (4.2)). We also include the square term $\mathbf{EL^2_{t-1}}$ in model (4.1) to account for possible non-linear effects (Mancini et al., 2016).[111]

[108] The findings by Baglioni and Monticini (2008, 2010, 2013) and Abbassi et al. (2017) support this hypothesis. However, longer average loan durations could be due to banks easily satisfying all liquidity needs in the morning with no additional funding requirements for later in the day. Shorter average loan duration could reflect high funding uncertainty and large competition amongst borrowers who are still trying to execute repo trades later in the day. A similar interpretation is found in Mancini el al. (2016), which explain how the average term can shorten if risk increases. To account for possible additional funding needs which are not satisfied later in the day, we have preliminarily included in both model (4.1) and (4.2) the average term of GC ON BIL repos. We omit this variable from the model since not significant. We interpret this result as a confirmation of the hypothesised positive relation between the average loan duration of GC CCP repos and funding uncertainty.

[109] See Abbassi et al. (2017) for a detailed description of alternative proxies for repo market illiquidity.

[110] To account for the reduction of the trading activity in BIL repos, we discard observations with less than 2 trades (for both CCP and BIL repos). The use of a 22-day rolling window allows to reduce the impact of possible underestimation of the illiquidity in the bilateral repo market.

[111] We omit $\mathbf{EL^2_{t-1}}$ in model (4.2) since not significant when all factors are included.

- **Proxy for regulatory changes:**

Margin Costs $_{t-1}$: is a proxy for the initial margin (measured in percentage points) required by the Italian CCPs for Italian sovereign bonds for a duration ranging from 3.25 to 4.75 years.[112] Since initial margins are usually increased when sovereign credit risk is higher or when the collateral is riskier, we expect that the higher the margins, the higher the sovereign credit risk and the greater the use of CCPs. **Margin Costs$^2_{t-1}$** is also included in model (4.2) to account for possible non-linear relationships with the repo volume spread and the repo rate spread. If margins are high, we expect that banks prefer BIL repos, and make less use of CCPs.

4.3 Results

4.3.1 The Determinants of the Use of CCP and Bilateral GC Repos

In this section we aim to establish which factors explain the variation of Repo Volume Spread $_{CCP-BIL}$. We expect a positive relation between Repo Volume Spread $_{CCP-BIL}$ and general aggregate risk or uncertainty. This positive relation would indicate that the *repo volume channel* is used by banks to mitigate respectively: (i) sovereign credit risk, (ii) repo riskiness, (iii) counterparty credit risk, and (iv) the impact of the margin costs required by the CCPs.

Table 4.3 and Figure 4.3 show the average statistics as well as the dynamics over time of the proxies for sovereign credit risk, counterparty credit risk, repo riskiness and regulatory changes. Table 4.4 presents the Pearson correlation matrix. Almost all correlations between the Repo Volume Spread $_{CCP-BIL}$ and the proxies of risk factors are significant at the 1% level except for EL.[113] As expected, the Repo Volume Spread $_{CCP-BIL}$ is positively correlated with the CDS (11.2%), the Excess Bank CDS (16.1%), the AT CCP (16.9%) and the Amihud Spread $_{BIL-CCP}$ (12.2%). Given the high positive

[112] The margin costs are chosen by matching the average duration of Italian sovereign bonds used as collateral in GC ON CCP repos in our dataset to the corresponding duration bucket set by the CCPs.

[113] We use the de-trended Repo Volume Spread $_{CCP-BIL}$ only for computing the correlation matrix (Mancini et al., 2016). This is done in order to remove the linear trend effect.

correlation between CDS and Excess Bank CDS (55.7%), we orthogonalise the latter with respect to the former (Boissel et al., 2017).

Table 4.5 reports the set of results on the link between risk proxies and the use of CCP and BIL repos. Model (4.1) – and modified versions of it - are estimated via OLS with Newey-West HAC standard errors.[114]

The columns headed (1) and (2), report the results for model (4.1), with factors regressed on the Repo Volume Spread $_{CCP\text{-}BIL,\ t}$.[115] In columns (3) and (4), the dependent variables are Repo Volume $_{CCP,\ t}$ and Repo Volume $_{BIL,\ t}$, respectively.

The explanatory power of model (4.1), as measured by the adjusted R^2, is 29.5%. As expected, the time trend is positive and highly significant when regressed on the Repo Volume Spread (columns (1) and (2)) and the CCP repo volume (column (3)), and negative for BIL repos, indicating the progressive use of CCPs over time.

The CDS is positive and highly significant, indicating that when the sovereign credit risk of Italy is higher, banks increase their CCP exposures (columns (1), (2) and (3)), and reduce their bilateral transactions (column (4)). This result differs from the finding of Mancini et al. (2016), which shows a negative relationship between proxies of risk and GC CCP repo volumes for the Italian repo market. Mancini el al. (2016) shows that the Italian GC CCP repo volumes are negatively impacted by risk, indicating a weaker resilience of repos with Italian collateral when compared to safer collateral – i.e. German or French sovereign bonds. However, we find a positive relation between the repo volume spread and CDS, suggesting that GC ON CCP repo volumes increases with sovereign credit risk.

[114] The Newey-West estimator includes three lags. The number of lags has been chosen by means of automatic lag selection procedure (see for instance Newey and West, 1994). Results are robust to the inclusion of a higher number of lags.
[115] For the sake of completeness, we show the results of model (4.1) with the addition of the average term of BIL repos. The lagged average loan duration of BIL repos (which I call AT $_{BIL,\ t-1}$) negatively relates to the Repo Volume Spread $_{CCP\text{-}BIL}$, but it is not significant. When higher volumes of BIL repos are executed towards the closure of the trading day, the Repo Volume Spread $_{CCP\text{-}BIL}$ is not affected.

Our findings show that CCC repos are resilient to sovereign credit risk, while BIL repos are not. This result suggests that when sovereign credit risk increases, banks do not really trust their counterparties and prefer to use CCP repos.

As we move to the remaining factors, the Excess Bank CDS has the expected positive sign, and it is significant at the 1% significance level, so that when the average counterparty risk of the Italian banks increases, CCPs are preferred (columns (1) to (3)), with respect to the bilateral alternative (column (4)).

We now investigate the effects of proxies for repo riskiness. The linear term of EL is negative and statistically significant for all columns, indicating that the excess liquidity provided by the ECB acts as substitute for repos. Column (1) shows that this effect is stronger for CCP repos. When we consider the quadratic term of EL, this proxy is positive and significant, suggesting that when the liquidity injected in the system via central banking operations is high, the substitution effect between central bank liquidity and CCP repos is still negative and significant but marginally decreasing with the size of the excess liquidity.

The coefficient of average loan duration for CCP repos is positive (columns (1) to (3)) and significant. When funding uncertainty is high –e.g. banks fear not meeting their daily liquidity obligations on time -, the demand for CCP repos executed earlier in the day increases, and so does the volume of CCP repos with respect to BIL repos (Abbassi et al., 2017). The Amihud Spread between BIL and CCP repos is also positive and significant. When BIL repos are more illiquid than CCP repos, banks prefer the latter to the former.

Overall, when analysing the t-statistics, both the linear time trend and the excess liquidity injected by the ECB have the greatest statistical significance.[116] This confirms that both regulatory pressures

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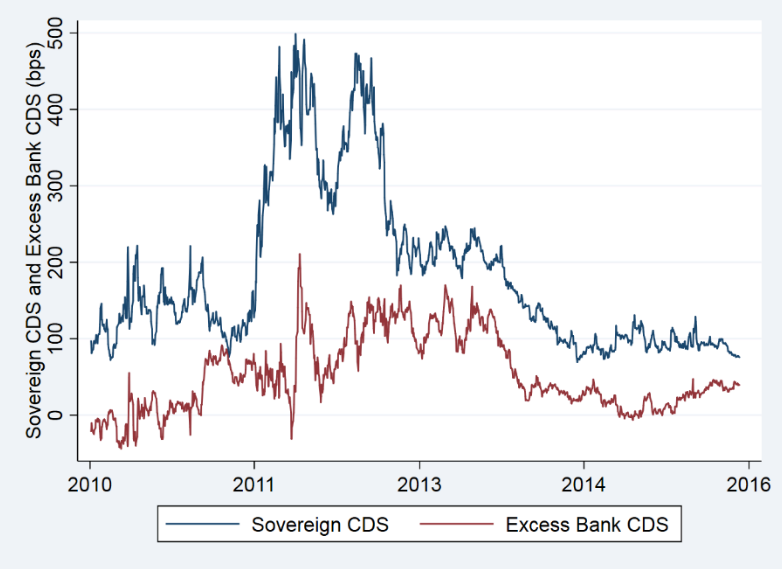
[116] In order to compare the relative importance of the factors in explaining the variation of the repo volume spread, we prefer to comment on the statistical power of the independent variables. We disregard the economic impact since it might not be informative in presence of a time-trend (Mancini et al., 2016).

towards the use of CCPs, and central banking polices highly influence the choice of trading via CCP repos. In general, the positive relationship between risk and the recourse to CCPs indicates the preference of banks for CCP repos when general market uncertainty is higher.

Figure 4.3: Explanatory variables

This figure shows the daily 5-year Italian Credit Default Swap (**CDS**) and the **Excess Bank CDS** (both measured in basis points) in Panel A, the **Excess Liquidity** (in billions of Euro) deposited at the ECB facility in Panel B, the average term of CCP repos (**AT** $_{CCP}$, measured in hours) in Panel C, and the **Amihud Spread** $_{BIL-CCP}$ in Panel D, over the period from January 4, 2010 to November 30, 2015. Detailed variable definitions are provided in Table 4.3.

Panel A: CDS and Excess Bank CDS



Panel B: Excess Liquidity

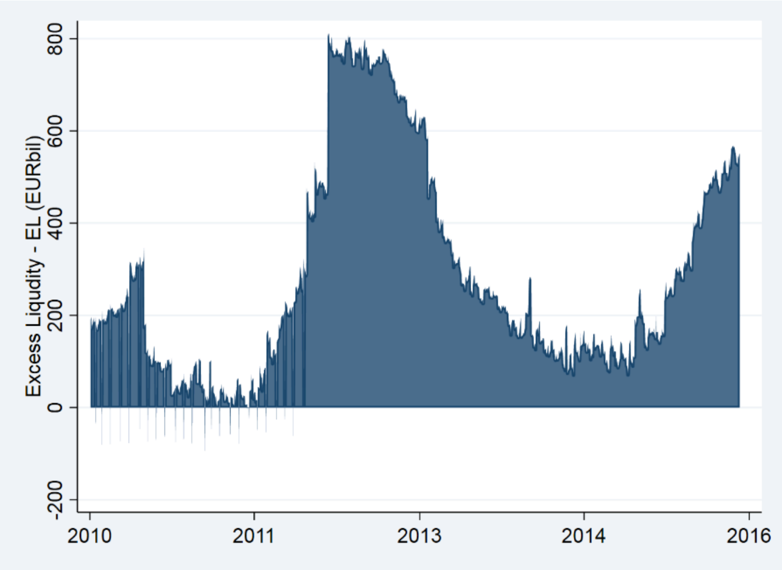
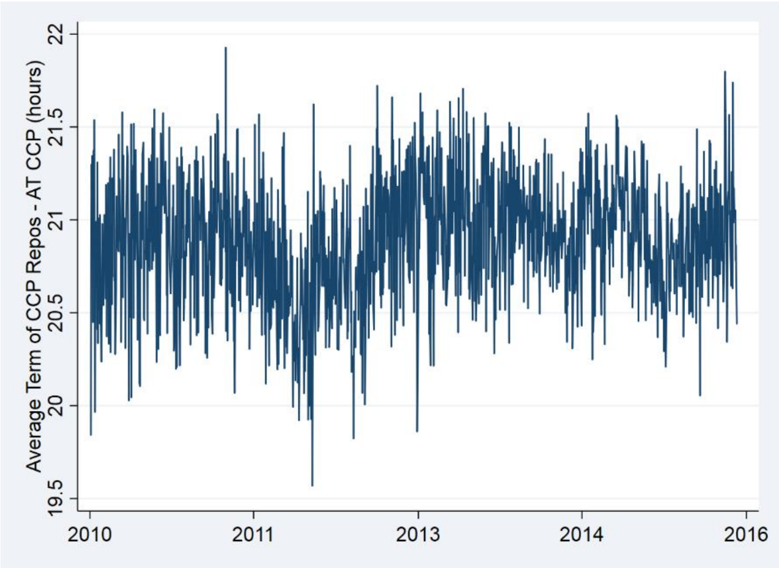


Figure 4.3: Explanatory variables – cont'd

Panel C: Average Term of CCP Repos (AT $_{CCP}$)



Panel D: Amihud Spread $_{BIL\text{-}CCP}$

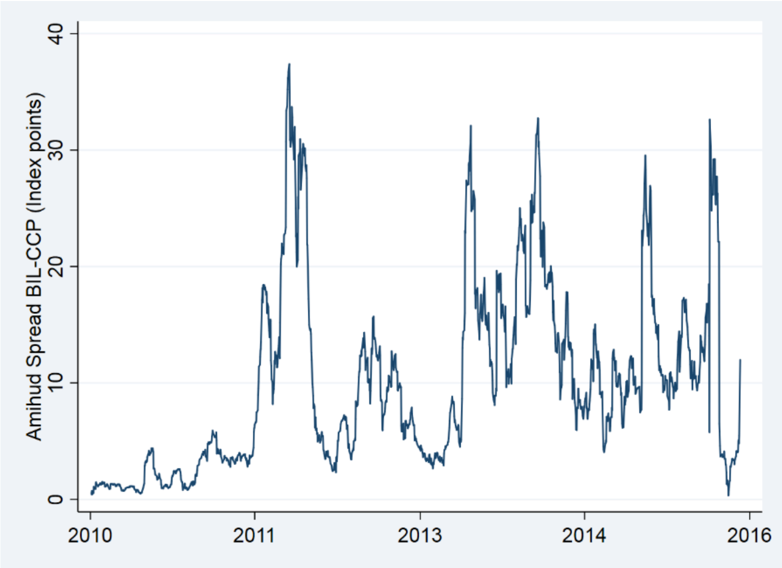


Table 4.3: Summary statistics for explanatory variables

The table presents the summary statistics for all independent variables over for the period January 4, 2010 to November, 30 2015. **CDS** is the 5-year Italian Credit Default Swap (Euro-denominated, measured in basis points). 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. **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). **AT $_{CCP}$** (measured in hours) is the average volume-weighted term (or loan duration) of GC ON CCP repos (weighted by the relative daily nominal transacted volumes). **Amihud Spread $_{BIL-CCP}$** (index points) is the difference between the Amihud (2002) ratio computed for BIL and CCP repos, averaged over a 22-day rolling window. The Amihud (2002) ratio is computed as the maximum daily price change in repo rates observed for a given transacted volume (Abbassi el al., 2017). **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**.** **Bank CDS Spread $_{SMALL-LARGE}$** is the difference between the Excess Small Bank CDS and Excess Large Bank CDS. **Margin Costs** (measured in percentage points) 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.

Variable	Summary Statistics Explanatory Variables							
	No. of Trading Days	Mean	STD	Min	25th Pct	Median	75th Pct	Max
Main Regressors								
CDS (bps)	1,501	184.54	106.84	69.25	99.29	143.92	226.26	498.66
Excess Bank CDS (bps)	1,501	53.57	49.34	-43.84	17.67	39.28	91.36	210.76
EL (EURbil)	1,501	286.09	231.24	-97.70	115.25	211.01	430.13	811.86
AT $_{CCP}$ (Hour)	1,501	20.89	0.33	19.57	20.68	20.89	21.13	21.93
Amihud $_{BIL-CCP}$	1,501	9.98	7.94	0.33	3.63	8.39	13.97	37.39
Additional Regressors								
Excess Large Bank CDS (bps)	1,501	39.68	43.98	-49.68	6.18	26.02	73.15	190.90
Excess Small Bank CDS (bps)	1,501	122.56	83.95	-46.12	61.21	105.66	178.30	332.93
Bank CDS Spread $_{SMALL-LARGE}$ (bps)	1,501	82.88	47.43	-51.58	52.45	75.27	110.04	219.85
Margin Costs (%)	1,501	5.08	2.04	1.50	2.65	4.90	7.25	8.70

Table 4.4: Pearson correlation matrix

Correlation matrix of dependent and independent variables over the period that goes from January 4, 2010 to November 30, 2015. Variables' definitions and measurements are explained in Table 4.4 *** indicates that the correlation is statistically significant at the 1% level (S.L.), ** 5% S.L.; and * 10% S.L., respectively.

Correlation Matrix									
Variables	De-Trended Repo Volume Spread $_{CCP - BIL}$	CDS	Excess Bank CDS	EL	AT $_{CCP}$	Amihud $_{BIL-CCP}$	Excess Large Bank CDS	Excess Small Bank CDS	Bank CDS Spread $_{SMALL - LARGE}$
Main Regressors									
CDS	0.112***								
Excess Bank CDS	0.161***	0.557***							
EL	0.001	0.509***	0.537***						
AT $_{CCP}$	0.169***	-0.243***	-0.010	-0.043*					
Amihud $_{BIL-CCP}$	0.122***	0.230**	0.177***	-0.032	-0.063*				
Additional Regressors									
Excess Large Bank CDS	0.150***	0.528***	0.993***	0.532***	-0.021	0.146***			
Excess Small Bank CDS	0.172***	0.562***	0.951***	0.499***	0.040	0.262***	0.912***		
Bank CDS Spread $_{SMALL - LARGE}$	0.165***	0.505***	0.762***	0.390***	0.091***	0.329***	0.687***	0.925***	
Margin Costs (%)	0.137***	0.393***	0.659***	0.530**	0.032	0.472***	0.630***	0.715***	0.681***

Table 4.5: The use of CCP repos - Regressions results for model (4.1)

This table reports results of OLS regressions estimated with HAC robust standard errors over the period January 4, 2010 to November 30, 2015. The dependent variable is the daily repo volume spread between GC ON CCP and Bilateral (BIL) repos on Italian Sovereign bonds in column (1), the daily repo volume for GC ON CCP repos in column (2) and the daily repo volume for GC ON BIL repos in column (3). Variables' definitions and measurements are explained at Table 4.3. **EL^2** is rescaled over 1,000. *** indicates 1% significance level (S.L.); ** 5% S.L.; and * 10% S.L., respectively.

Period	Full Sample 04/01/2010 - 30/11/2015			
Dep. Var.	Repo Volume Spread $_{CCP - BIL}$		Repo Volume $_{CCP}$	Repo Volume $_{BIL}$
	(1)	(2)	(3)	(4)
Constant	-7.3864**	-6.3317*	0.6816	2.6189***
	(-2.12)	(-1.78)	(0.22)	(6.25)
Trend	0.0026***	0.0026***	0.0008***	-0.0019***
	(13.73)	(13.06)	(4.88)	(-14.97)
Lag CDS	0.0030***	0.0029***	0.0019**	-0.0020***
	(3.18)	(3.06)	(2.01)	(-4.10)
Lag Excess Bank CDS	0.0060***	0.0057***	0.0037***	-0.0026***
	(4.06)	(3.84)	(2.76)	(-3.45)
Lag EL	-0.0082***	-0.0081***	-0.0098***	-0.0018***
	(-8.32)	(-8.19)	(-10.66)	(-3.05)
Lag EL^2	0.0091***	0.0090***	0.0098***	0.0013**
	(7.41)	(7.37)	(8.72)	(2.15)
Lag AT $_{CCP}$	0.4569***	0.4563***	0.2318	
	(2.77)	(2.77)	(1.58)	
Lag AT $_{BIL}$		-0.0591		0.0441**
		(-1.29)		(2.17)
Lag Amihud $_{BIL-CCP}$	0.0194**	0.0198**		
	(1.98)	(2.03)		
Lag Amihud $_{CCP}$			-0.0524	
			(-1.11)	
Lag Amihud $_{BIL}$				-0.0092**
				(-2.26)
Seasonal Controls	Y	Y	Y	Y
Time-of-Day Effects	Y	Y	Y	Y
Observations	1,500	1,500	1,500	1,500
Adj. R^2	0.295	0.295	0.122	0.598

4.3.1.1 Counterparty Credit Risk for Larger and Smaller Banks

An additional important facet of the link between counterparty credit risk and the choice to obtain funding via CCP or BIL repos, is the interaction between “safer” larger banks and less creditworthy smaller banks. We have observed in section 4.3.1 that the repo volume spread increases with counterparty risk. This could be interpreted as a negative externality to the financial system if riskier borrowers exploit the anonymity of CCP trading in order to avoid common market discipline (Cappelletti et al., 2012; Affinito and Piazza, 2015).

To test this hypothesis, we construct three additional proxies of counterparty risk: **Excess Small Bank CDS** for small and riskier banks, **Excess Large Bank CDS** which measures the excess CDS premium of larger and safer banks, and **Bank CDS Spread** $_{\textbf{SMALL – LARGE}}$ which is the difference between the two proxies (see Figure 4.4).[117] Excess Large Bank CDS and Excess Small Bank CDS (measured in bps) 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.

In columns (2) and (3) of Table 4.6, we control separately for the excess CDS premium of larger and smaller banks and drop the Excess Bank CDS due to the expected high correlation.[118] Both variables are positive and statistically significant.[119] The higher the counterparty risk, the more the banks trade via CCP repos, no matter the nature of such risk.

In column (4), Bank CDS Spread $_{\text{SMALL – LARGE}}$ is positive and significant. This suggests that the riskier smaller banks with respect to larger and safer counterparties, the greater the recourse to CCPs.

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[117] These measures are computed relative to the market capitalization of the Italian banks in the sample.

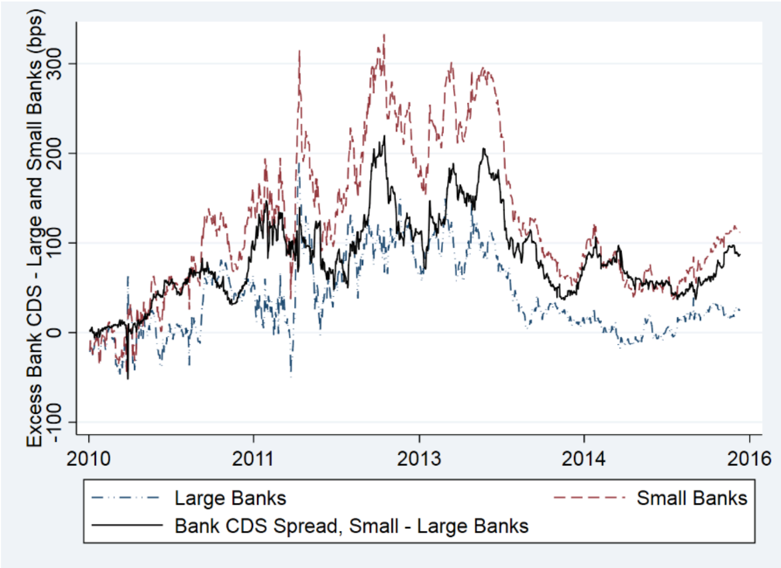
[118] Excess Large Bank CDS, Excess Small Bank CDS and Bank CDS Spread $_{\text{SMALL – LARGE}}$ are orthogonalised with respect to sovereign CDS (Boissel et al., 2017).

[119] Larger counterparties are usually more active than smaller banks in the repo markets. Thus the significance of the coefficient on the Excess Large Bank CDS is expected.

We interpret this result as a possible mechanism of “self-selection” of the riskier borrowers into the CCP repo market (Affinito and Piazza, 2015).[120] While the overall results of section 4.3.1 indicate that the repo volume channel is resilient to shocks, the self-selection of riskier banks into CCPs decreases such resilience.

Figure 4.4: The counterparty credit risk of larger and smaller banks

This figure shows the Excess Bank CDS (measured in EUR basis points) of large and smaller banks, and their difference (**Bank CDS Spread** $_{\text{SMALL - LARGE}}$) over the period from January 4, 2010 to November 30, 2015. Detailed variable definitions are provided in Table 4.3.



[120] Furthermore, larger banks could reduce the CCP repo exposures to avoid risk stemming from the mutualisation of losses in case of default (Arnsdorf, 2012; Heider et al., 2015). However, we cannot directly test this hypothesis.

Table 4.6: The use of CCP repos, and counterparty risk of larger and smaller banks - Regressions results for model (4.1)

This table reports results of OLS regressions estimated with HAC robust standard errors over the period January 4, 2010 to November 30, 2015. The dependent variable is the daily repo volume spread between GC ON CCP and BIL repos on Italian Sovereign bonds. Variables' definitions and measurements are explained at Table 4.3. **EL^2** is a rescaled over 1,000. *** indicates 1% significance level (S.L.); ** 5% S.L.; and * 10% S.L., respectively.

Period	Full Sample 04/01/2010 - 30/11/2015			
Dep. Var.	Repo Volume Spread $_{CCP - BIL}$			
	(1)	(2)	(3)	(4)
Constant	-7.3864**	-7.9421**	-6.0600*	-5.8547
	(-2.12)	(-2.29)	(-1.73)	(-1.64)
Trend	0.0026***	0.0027***	0.0025***	0.0025***
	(13.73)	(14.03)	(12.89)	(12.04)
Lag CDS	0.0030***	0.0031***	0.0026***	0.0023**
	(3.18)	(3.27)	(2.85)	(2.44)
Lag Excess Bank CDS	0.0060***			
	(4.06)			
Lag EL	-0.0082***	-0.0082***	-0.0081***	-0.0079***
	(-8.32)	(-8.36)	(-8.24)	(-8.03)
Lag EL^2	0.0091***	0.0091***	0.0092***	0.0093***
	(7.41)	(7.43)	(7.56)	(7.66)
Lag AT $_{CCP}$	0.4569***	0.4815***	0.3987**	0.3908**
	(2.77)	(2.93)	(2.41)	(2.33)
Lag Amihud $_{BIL-CCP}$	0.0194**	0.0191*	0.0198**	0.0211**
	(1.98)	(1.95)	(2.02)	(2.15)
Lag Excess Large Bank CDS		0.0062***		
		(3.82)		
Lag Excess Small Bank CDS			0.0036***	
			(4.03)	
Lag Bank CDS Spread $_{SMALL - LARGE}$				0.0052***
				(3.24)
Seasonal Controls	Y	Y	Y	Y
Time-of-Day Effects	Y	Y	Y	Y
Observations	1,500	1,500	1,500	1,500
Adj. R^2	0.295	0.294	0.294	0.291

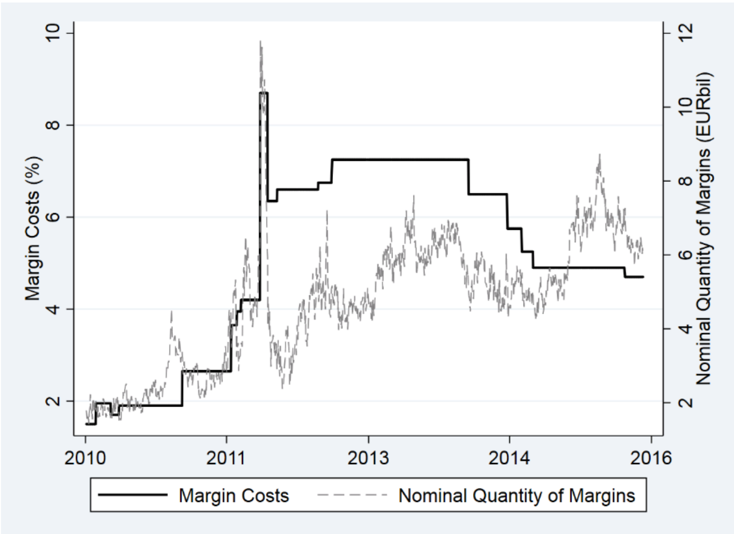
4.3.1.2 The Pro-Cyclicality of Margin Costs.

In this section, we examine the *pro-cyclical* impact of the CCP margin policies on the use of CCP and BIL repos. If margins' increases are pro-cyclical, CCP repo volumes should decrease in favour of BIL repos, since for the latter margins are not required.

The impact of counterparty risk in repos is mainly mitigated via the margins set by CCPs.[121] In our sample period, CCPs have significantly changed their margin policies, due to both the European sovereign crisis and the requests by regulatory bodies. On 8 November 2011, the risk management framework adopted by CCPs (*CC&G* and *LCH*), was made more responsive to the peaking sovereign credit risk of Italy than previously observed (Miglietta et al., 2015). As a result, the increase in initial margins ranges between 350 bps and 500 bps depending on the duration of the bond (Figure 4.5). In terms of the nominal amount of margins, the main CCP for Italian banks (*CC&G*) collected €11.81 billion on the same day, corresponding roughly to 78% more than the previous trading day.

Figure 4.5: Margin Costs

Initial margins (measured in percentage points) required by the Italian central counterparties (CC&G and LCH) for Italian sovereign bonds (duration buckets 3.25-4.75 years), 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.



[121] Among other tools, CCPs can also make use of "variation margins" to account for the changes of the mark-to-market valuation of counterparty risk. Additionally, a "default fund" is usually accumulated in case of extreme systemic risk.

The margin policies adopted during the European sovereign crisis have been criticized by regulatory authorities such as the International Monetary Fund and the Bank of Italy for their potential pro-cyclical effects.[122] When markets are already stressed and margins are set too high, safer banks have to allocate extra capital to compensate for the risk of smaller bank, since such risk is mutualised via the CCPs. This might act as a disincentive for the safer banks, which might trade less via CCPs than smaller and riskier banks (Pirrong, 2011).

Columns (3) to (5) of Table 4.7, report results for different model specifications with margin costs (both linear and non-linear terms). Margin costs are statistically significant and contribute to explaining the variations of the repo volume spread (adjusted R^2 equal to 31.2% in column (3)). While the linear term of Margin Costs positively relates to the dependent variable, the coefficient on the square term is negative. An increase in margin costs has a positive but marginally decreasing effect on CCP repo volumes. When margin costs increase, they simply reflect the higher sovereign credit risk and higher riskiness of the bonds used as collateral. However, when instead CCPs set margins at levels which are high, the banks marginally reduce their CCP exposure in order to save "capital" (pro-cyclical margin policies).

[122] Brunnermeier and Pedersen's (2009) model supports these policy assessments.

Table 4.7: The use of CCP repos and margin costs- Regressions results for model (4.1)

This table presents the results of OLS regressions estimated with HAC robust standard errors over the period from January 4, 2010 to November 30, 2015. The dependent variable is the daily repo volume spread between GC ON CCP and BIL repos on Italian Sovereign bonds. Variable definitions and measurements are explained in Table 4.3. **EL^2** is rescaled over 1,000. *** indicates 1% significance level (S.L.); ** 5% S.L.; and * 10% S.L

Period	Full Sample 04/01/2010 - 30/11/2015				
Dep. Var.	Repo Volume Spread $_{CCP - BIL}$				
	(1)	(2)	(3)	(4)	(5)
Constant	-7.3864**	-6.2226*	-9.9341***	-6.9687**	-8.2872**
	(-2.12)	(-1.82)	(-3.00)	(-2.00)	(-2.44)
Trend	0.0026***	0.0020***	0.0010***	0.0021***	0.0006
	(13.73)	(11.94)	(3.42)	(9.48)	(1.61)
Lag CDS	0.0030***			0.0007	-0.0013
	(3.18)			(0.70)	(-1.17)
Lag Excess Bank CDS	0.0060***				0.0029*
	(4.06)				(1.75)
Lag EL	-0.0082***	-0.0085***	-0.0074***	-0.0086***	-0.0070***
	(-8.32)	(-8.61)	(-7.03)	(-8.75)	(-6.66)
Lag EL^2	0.0091***	0.0097***	0.0079***	0.0096***	0.0076***
	(7.41)	(8.33)	(6.01)	(7.98)	(5.78)
Lag AT $_{CCP}$	0.4569***	0.3964**	0.4695***	0.4279***	0.3845**
	(2.77)	(2.42)	(2.97)	(2.59)	(2.35)
Lag Amihud $_{BIL-CCP}$	0.0194**	0.0184*	0.0091	0.0150	0.0171*
	(1.98)	(1.91)	(1.02)	(1.50)	(1.75)
Lag Margin Costs		0.2297***	1.5611***	0.2135***	1.8182***
		(5.31)	(4.62)	(4.41)	(5.19)
Lag Margin Costs^2			-0.1281***		-0.1539***
			(-4.01)		(-4.72)
Seasonal Controls	Y	Y	Y	Y	Y
Time-of-Day Effects	Y	Y	Y	Y	Y
Observations	1,500	1,500	1,500	1,500	1,500
Adj. R^2	0.295	0.297	0.312	0.297	0.315

4.3.1.3 The Use of CCP and Bilateral GC Repos: Robustness Checks

In this section, we conduct several robustness checks.[123]

First, we use the de-trended repo volume spread as an alternative dependent variable to assess the influence of the inclusion of a time-trend on our estimates. In Table 4.8, our results remain quantitatively and qualitatively similar.

Second, we evaluate the impact of each factor described in model (4.2) on the repo volume spread by estimating a series of parsimonious models. In Table 4.9, from columns (1) to (7), the signs of coefficients are stable and significant across all model specifications. In column (7), the model with only the time trend and the proxies of repo riskiness has the highest explanatory power among the parsimonious models, with the adjusted R^2 equal to 27.7%. This confirms that the riskiness in repos is an important risk factor which explains the use of CCP repos.

Third, we use an alternative measure of repo illiquidity (Abbassi et al., 2017). We construct a 22-day rolling spread between the daily volatility of BIL repos and CCP repos. We expect that the higher the repo volatility of BIL repos, the greater the CCP trading activity.[124] The repo volatility spread is positive and statistically significant, confirming that the more illiquid the BIL repo market, the lower the recourse to the latter and the higher the repo volume spread.

Finally, we investigate the impact of BIL and CCP repo rates.[125] We would expect that the higher BIL repo rates relative to CCP rates, the greater the repo volume spread. Surprisingly the repo rate spread between BIL and CCP repos is not significant.

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[123] In addition to the robustness checks presented in this section, we use alternative proxies which measure respectively: (i) the European financial systemic risk; (ii) the expectation about future changes in the monetary policy adopted by the ECB; (iii) the presence of possible substitution effects with Eonia volume (Mancini et al., 2016); (iv) funding uncertainty (as measured by the Euribor-OIS Spread). However, these factors do not explain the variation in the repo volume spread between CCP and BIL repos. See Mancini et al. (2016) and the literature therein, for a description and discussion of these factors. The corresponding tables are reported in the Appendix.

[124] See results in the Appendix.

[125] Tables are reported in the Appendix.

Table 4.8: Robustness checks - De-trended repo volume spread.

This table reports the results of 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 4.3. *** indicates 1% significance level (S.L.); ** 5% S.L.; and * 10% S.L., respectively.

Period	Full Sample 04/01/2010 - 30/11/2015	
Dep. Var.	Repo Volume Spread $_{CCP - BIL}$	De-Trended Repo Volume Spread $_{CCP - BIL}$
	(1)	(2)
Constant	-7.3864**	-9.2521***
	(-2.12)	(-2.64)
Trend	0.0026***	
	(13.73)	
Lag CDS	0.0030***	0.0019**
	(3.18)	(2.46)
Lag Excess Bank CDS	0.0060***	0.0062***
	(4.06)	(4.23)
Lag EL	-0.0082***	-0.0075***
	(-8.32)	(-7.76)
Lag EL^2	0.0091***	0.0087***
	(7.41)	(7.08)
Lag AT $_{CCP}$	0.4569***	0.4499***
	(2.77)	(2.71)
Lag Amihud $_{BIL-CCP}$	0.0194**	0.0310***
	(1.98)	(3.83)
Seasonal Controls	Y	Y
Time-of-Day Effects	Y	Y
Observations	1,500	1,500
Adj. R^2	0.295	0.0929

Table 4.9: Robustness checks - Rotation of independent variables – Model (4.1).

This table reports the results of 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 4.3 *** indicates 1% significance level (S.L.); ** 5% S.L.; and * 10% S.L., respectively.

Period	Full Sample 04/01/2010 - 30/11/2015							
Dep. Var.	Repo Volume Spread $_{CCP-BIL}$							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Constant	2.2155***	1.7008***	2.3171***	1.8411***	2.6446***	-5.6566	-6.9272**	-7.3864**
	(12.60)	(6.85)	(13.58)	(7.59)	(13.10)	(-1.53)	(-2.06)	(-2.12)
Trend	0.0022***	0.0024***	0.0021***	0.0023***	0.0026***	0.0020***	0.0023***	0.0026***
	(13.03)	(13.57)	(12.33)	(12.71)	(16.62)	(11.30)	(14.56)	(13.73)
Lag CDS		0.0021***		0.0019***				0.0030***
		(3.25)		(2.97)				(3.18)
Lag Excess Bank CDS			0.0058***	0.0054***				0.0060***
			(4.03)	(3.70)				(4.06)
Lag EL					-0.0070***		-0.0076***	-0.0082***
					(-6.62)		(-7.28)	(-8.32)
Lag EL^2					0.0089***		0.0098***	0.0091***
					(7.11)		(8.02)	(7.41)
Lag AT $_{CCP}$						0.3705**	0.4504***	0.4569***
						(2.09)	(2.81)	(2.77)
Lag Amihud $_{BIL-CCP}$						0.0307***	0.0398***	0.0194**
						(3.59)	(4.84)	(1.98)
Seasonal Controls	Y	Y	Y	Y	Y	Y	Y	Y
Time-of-Day Effects	Y	Y	Y	Y	Y	Y	Y	Y
Observations	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Adj. R^2	0.218	0.229	0.230	0.239	0.257	0.231	0.277	0.295

4.3.2 The Costs of the Use of CCP and Bilateral Repos.

The aim of this section is to provide an assessment of the *repo rate channel* as way for banks to mitigate risks – i.e. sovereign credit risk, counterparty credit risk and repo riskiness. We apply a similar framework to the one adopted for the assessment of the use of CCPs (repo volume channel), and described in section 4.3.1. In this section, we study the link between the BIL - CCP repo rate spread, and the factors described in model (4.2).[126] A positive relationship between the repo rate spread and the proxies for risk factors would further support the findings about the greater use of CCP repos with respect to BIL repos when risk increases. Due to the risk mitigation properties of CCPs, CCP repos should be perceived as safer than BIL repos if risk increases, and hence, can act as '*shock absorbers'*. As a consequence, during times of increased risk banks should demand a higher risk premium to trade via BIL repos instead of CCP repos.

In order to evaluate this, in Table 4.2 and Figure 4.2 we examine the difference between the daily volume-weighted average repo rates of BIL and CCP repos (**Repo Rate Spread $_{\text{BIL-CCP}}$**).[127] The average Repo Rate Spread $_{\text{BIL-CCP}}$ is positive and equal to 3.05 bps (Table 4.2, Panel A), and the difference between BIL and CCP repo rates is significantly greater than zero over time (Table 4.2, Panel B). However, as Figure 4.2 Panel B shows, the Repo Rate Spread $_{\textbf{BIL-CCP}}$ can take negative values (14.72% of the daily observations).

In model (4.2), we have included CDS, Margin Costs (linear and quadratic term), AT $_{\text{CCP}}$, Amihud Spread $_{\text{BIL-CCP}}$, and EL. Since CCP repos should be safer than BIL repos, we expect that the higher the sovereign credit risk, the higher the repo rate for BIL repos with respect to CCP repos (Boissel et al., 2017). Margin Costs are expected to be positively related to the repo rate spread, capturing

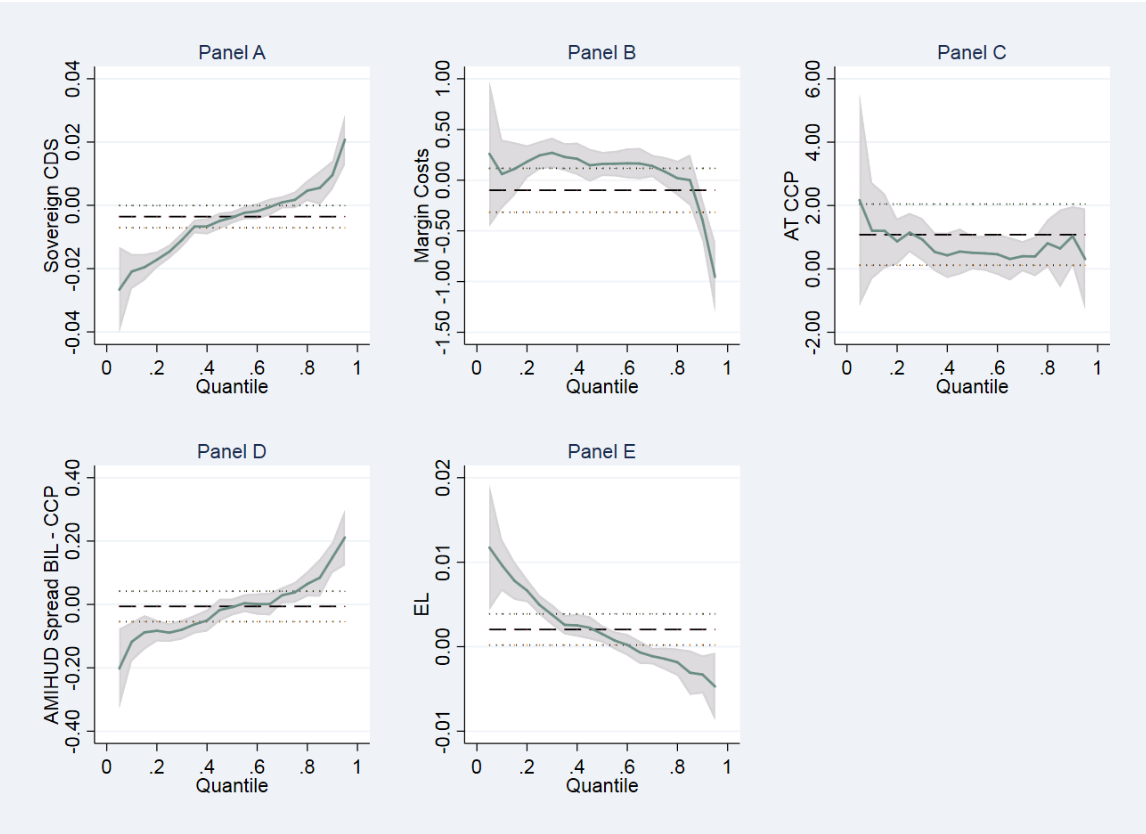
[126] In this section, model (4.2) and its variants are estimated via OLS with White-robust HC standard errors. Since we partition the sample into sub-sets with non-consecutive observations, the estimation via OLS with Newey-West HAC standard errors is not feasible.
[127] We use the last observed daily Repo Rate Spread CCP – BIL where the repo rate of bilateral transactions is not available (see Corradin and Maddaloni, 2017, for a similar assumption about missing GC repo rates).

both the general sovereign credit risk and collateral riskiness. Given the findings of section 4.3.1, we also include Margin Costs[2]. We expect that when margin costs increase, the higher the sovereign credit risk (and collateral riskiness), the higher the repo rate spread. However, we expect this effect to be positive but marginally decreasing with the level of margin costs set by the CCPs.

Moving to the proxies of repo riskiness, we expect that the higher the average loan term of CCP repos, the greater the funding uncertainty, the greater the demand for CCP repos and the smaller the repo rate spread. In terms of repo illiquidity, the more illiquid BIL repos are with respect to CCP repos, the higher the repo rate spread is expected to be (Abbassi et al., 2017). We also expect that the higher the excess liquidity injected by the ECB, the lower the funding uncertainty and the lower the repo spread (Mancini et al., 2016).

Figure 4.6: Estimated coefficients via quantile regressions - Model (4.2)

This figure plots the coefficients of the independent variables in model (4.2), estimated with quantile regressions. Period: January 4, 2010 to November 30, 2015



To understand how these factors relate to the repo rate spread, we preliminary compute the correlation matrix for the whole sample of observations (Table 4.10). Contrary to our expectations, only the correlation between AT $_{CCP}$ and the repo rate spread is significant, indicating the possibility of the existence of non-linear relationships among the proxies of risk and the dependent variable. To check this possibility, we estimate model (4.2) by means of quantile regressions and plot the estimated factor coefficients in Figure 4.6. Panel A, D and E reveals that CDS, Amihud BIL-CCP and EL are negative when the quantile is below the median, and positive otherwise. Panel B and C also illustrate the presence of non-linearity in the relationships between the Repo Rate Spread $_{BIL-CCP}$, margin costs and AT $_{CCP}$. When the repo rate spread is below the median value, the sensitivity to risk is greater for CCP repos than for BIL repos, and banks demand a higher risk premium for trading via CCPs than bilaterally.

Table 4.10: Pearson correlation matrix conditional on the value of Margin Costs

Correlations between dependent (Repo Rate Spread $_{CCP-BIL}$) and independent variables over the period that goes from January 4, 2010 to November 30, 2015 in Panel A, and conditional on the values of Margin Costs being below or above its median value (Panel B and C). Variables' definitions and measurements are explained at Table 4.4 *** indicates that the correlation is statistically significant at the 1% level (S.L.), ** 5% S.L.; and * 10% S.L

Correlation Matrix					
Panel A: Full Sample					
	Repo Rate Spread $_{BIL-CCP}$	CDS	Margin Costs	AT $_{CCP}$	Amihud $_{BIL-CCP}$
CDS	-0.021				
Margin Costs	-0.026	0.393***			
AT $_{CCP}$	0.098***	-0.243***	0.032		
Amihud $_{BIL-CCP}$	-0.013	0.230***	0.472***	-0.063**	
EL	0.036	0.509***	0.530***	-0.0430*	-0.032
Panel B: Margin Costs < Median					
	Repo Rate Spread $_{BIL-CCP}$	CDS	Margin Costs	AT $_{CCP}$	Amihud $_{BIL-CCP}$
CDS	0.235***				
Margin Costs	0.260***	0.406***			
AT $_{CCP}$	-0.019	-0.156***	-0.045		
Amihud $_{BIL-CCP}$	0.230***	0.399***	0.498***	-0.158***	
EL	0.041	-0.115***	0.490***	0.068	0.007
Panel C: Margin Costs >= Median					
	Repo Rate Spread $_{BIL-CCP}$	CDS	Margin Costs	AT $_{CCP}$	Amihud $_{BIL-CCP}$
CDS	-0.142***				
Margin Costs	-0.152***	0.578***			
AT $_{CCP}$	0.181***	-0.298***	0.012		
Amihud $_{BIL-CCP}$	-0.143***	-0.074**	0.007	-0.052	
EL	0.069**	0.665***	0.309***	-0.119***	-0.370***

Additionally, in section 4.3.2 we have provided evidence that the impact of margin costs set by CCPs on the trading volume of CCP repos with respect to BIL repos is positive and significant. However, this effect is marginally decreasing with the level of the margin costs, as indicated by the negative coefficient of the square term of Margin Costs. Given the preliminary results from the quantile regressions on the non-linear relationships between margin costs and Repo Rate Spread $_{BIL\text{-}CCP}$, and the findings on the pro-cyclicality of margin costs on repo volumes, we compute the correlation matrix for values of margin costs below their median (Table 4.10, Panel B) and for values equal or above their median (Table 4.10, Panel C). On the one hand, when the margin costs are below their median value, the correlations between CDS, Margin Costs, Amihud Spread $_{BIL\text{-}CCP}$, and Repo Rate Spread BIL-CCP confirm our original conjectures and the correlation coefficients are significant (Table5.10, Panel B). On the other hand, when margin costs are equal or above to their median value, the correlations between CDS, Margin Costs, AT $_{CCP}$, Amihud Spread $_{BIL\text{-}CCP}$, and Repo Rate Spread $_{BIL\text{-}CCP}$ are still significant, but change signs (Table 4.10, Panel C).

Table 4.11 reports the core results for the full sample, and the sub-samples conditional on the values of Margin Costs being below and equal / above the median value, in columns headed (1), (2) and (3), respectively. When considering the whole sample. the adjusted R^2 is 5.2% (column (1)), smaller than the adjusted R^2 of columns (1) and (2), equal to 10.1% and 8.51% respectively. In column (1), only Margin Costs, Margin Costs^2 and AT $_{CCP}$ are significant for the full sample results. The coefficient on Margin Costs^2 is negative, confirming that when initial margins are above their median value, the repo rate spread decreases. To compensate for the additional costs that banks face due to the increased margins, a risk premium is demanded on top of the CCP repo rate with respect to BIL repos.

The remaining factors are not significant when considering the full sample of observations (column (1)), confirming the preliminary findings of the quantile regressions and correlation matrix. Therefore, we interpret the results of columns (2) and (3) as the most relevant. When Margin Costs are below the median, our original expectations on the direction of the relationships of different risk factors to the repo rate spread are confirmed (column (2)) -i.e. the repo rate spread increases with sovereign credit risk and repo riskiness. On the other hand, when the Margin Costs are above their median, the repo rate spread decreases with the CDS and the proxies of riskiness of the repo market.

These results are confirmed in Table 4.12, where we interact the proxies of risk with a factor variable MC which takes the value of one when Margin Costs are above the median value of their distribution ($MC_{>=p50}$) and zero otherwise ($MC_{<p50}$). Again, our expectations are validated when Margin Costs are higher than the median, and reversed on the opposite case.

Table 4.11: The costs of the use of CCP repos - Regressions results for model (4.2)

This table shows the results of OLS regressions estimated with HC robust standard errors over the period January 4, 2010 to November 30, 2015. The dependent variable is the daily repo rate spread between GC ON BIL and CCP repos on Italian Sovereign bonds. Variable definitions and measurements are explained at Table 4.3. *** indicates 1% significance level (S.L.); ** 5% S.L.; and * 10% S.L., respectively.

Dep.Var. Repo Rate Spread $_{BIL-CCP}$	Margin Costs		
	Full Sample	Below Median (<p50)	Above Median (>=p50)
	(1)	(2)	(3)
Constant	-24.9902**	0.4774	-18.9546*
	(-2.43)	(0.03)	(-1.70)
Lag CDS	0.0025	0.0101*	-0.0094**
	(1.13)	(1.82)	(-2.44)
Lag Margin Costs	3.1775***	1.6751***	-0.4431**
	(4.72)	(3.83)	(-2.03)
Lag Margin Costs^2	-0.3510***		
	(-4.58)		
Lag AT $_{CCP}$	1.0637**	-0.1298	1.2391**
	(2.30)	(-0.18)	(2.22)
Lag Amihud $_{BIL-CCP}$	-0.0340	-0.0638	-0.0486**
	(-1.20)	(-0.53)	(-2.10)
Lag EL	0.0005	-0.0044*	0.0045***
	(0.61)	(-1.87)	(3.10)
Seasonal Controls	Y	Y	Y
Time-of-Day Effects	Y	Y	Y
Observations	1,500	523	977
Adj. R^2	0.0518	0.101	0.0851

Table 4.12: The costs of the use of CCP repos and Margin Costs- Regressions results for model (4.2)

This table reports the results of OLS regressions estimated with HC robust standard errors over the period January 4, 2010 to November 30, 2015. The dependent variable is the daily repo rate spread between GC ON BIL and CCP repos on Italian Sovereign bonds. Variable definitions and measurements are explained at Table 4.3. *** indicates 1% significance level (S.L.); ** 5% S.L.; and * 10% S.L

Dep.Var Repo Rate Spread $_{BIL\text{-}CCP}$	Full Sample
Constant	-11.4152
	(-1.26)
Lag CDS * MC $_{>= p50}$	0.0104*
	(1.87)
Lag CDS * MC $_{< p50}$	-0.0099**
	(-2.54)
Lag Margin Costs * MC $_{>= p50}$	1.6826***
	(3.87)
Lag Margin Costs * MC $_{< p50}$	-0.4207**
	(-1.98)
Lag AT $_{CCP}$ * MC $_{>= p50}$	0.4346
	(1.00)
Lag AT $_{CCP}$ * MC $_{< p50}$	0.8778*
	(1.93)
Lag Amihud BIL-CCP * MC $_{>= p50}$	-0.0628
	(-0.53)
Lag Amihud BIL-CCP * MC $_{< p50}$	-0.0497**
	(-2.14)
Lag EL * MC $_{>= p50}$	-0.0045*
	(-1.94)
Lag EL * MC $_{< p50}$	0.0046***
	(3.12)
Seasonal Controls	Y
Time-of-Day Effects	Y
Observations	1,500
Adj. R^2	0.0936

The repo rate spread BIL-CCP seems to capture the greater riskiness of CCP repos with respect to BIL repos when Margin Costs are above their median value. Under this scenario, banks demand a risk premium for trading via CCPs, a pricing anomaly, which represents a negative externality for the resilience of the interbank repo market.

4.3.2.1 The Costs of the Use of CCP and Bilateral Repos: Robustness Checks

We perform two main robustness checks.

First, we control whether the de-trended repo volume spread has an impact on the repo rate spread of BIL and CCP repos. Table 4.13 shows the regression results conditional on Margin Costs. The repo volume spread is significant in columns (1) only, showing the expected signs. However, once we adopt the basic model specification augmented by the repo volume spread, the de-trended repo volume spread is no more significant (column (2)) or only marginally significant (column (4)).

Second, we assess the impact of the counterparty risk proxies described in section 4.3.1 on the repo rate spread. Excess Bank CDS and the CDS Spread $_{\text{SMALL-LARGE}}$ are significant proxies. However, when we include CDS or Margin Costs in the model, Excess Bank CDS and the CDS Spread $_{\text{SMALL-LARGE}}$ are no longer significant.[128] When Margin Costs are above the median, our results suggest that the higher the counterparty risk of the riskier and smaller banks, the smaller the repo rate spread. These findings provide only partially support to the "self-selection" mechanism of riskier borrowers into CCP-base repo market that has been suggested by Affinito and Piazza (2015), and described in section 4.3.1. When the smaller banks are riskier than larger banks, and margin costs are above their median value, CCPs might attract smaller banks, which would not have otherwise access to BIL repos. In turn, this behaviour acts as disincentive for larger and safer banks to trade via CCP repos.

[128] See tables in the Appendix.

Table 4.13: Robustness checks - The costs of the use of CCP repos and Margin Costs- Model (4.2) with de-trended repo volume spread.

This table reports the results of OLS regressions estimated with HC robust standard errors over the period January 4, 2010 to November 30, 2015. The dependent variable is the daily repo rate spread between GC ON BIL and CCP repos on Italian Sovereign bonds. Variable definitions and measurements are explained at Table 4.3. *** indicates 1% significance level (S.L.); ** 5% S.L.; and * 10% S.L., respectively.

Dep.Var Repo Rate Spread $_{BIL\ -CCP}$	Margin Costs			
	Below Median (<p50)	Below Median (<p50)	Above Median (>=p50)	Above Median (>=p50)
	(1)	(2)	(3)	(4)
Constant	3.0289***	2.1797	3.3814***	-23.0335**
	(4.92)	(0.13)	(8.97)	(-2.14)
Lag CDS		0.0102*		-0.0091**
		(1.81)		(-2.36)
Lag Margin Costs		1.6463***		-0.4288*
		(3.62)		(-1.94)
Lag AT $_{CCP}$		-0.2088		1.4288***
		(-0.27)		(2.66)
Lag Amihud $_{BIL\text{-}CCP}$		-0.0677		-0.0485**
		(-0.57)		(-2.10)
Lag EL		-0.0041		0.0045***
		(-1.53)		(3.08)
Lag De-Trended Repo Volume Spread $_{CCP\ -\ BIL}$	0.2393**	0.0704	-0.1391	-0.1560*
	(2.13)	(0.54)	(-1.52)	(-1.66)
Seasonal Controls	Y	Y	Y	Y
Time-of-Day Effects	Y	Y	Y	Y
Observations	523	523	977	977
Adj. R^2	0.0246	0.100	0.00860	0.0867

4.4 Summary

This paper has conducted an extensive investigation into the use of ON GC CCP repos compared to that of BIL repos on Italian Government bonds, and of the factors affecting the difference between them. Using a novel dataset from MTS from January 2010 to November 2015, we are able to shed lights on the factors which explain the use of both CCP repos and BIL repos. We find that the trading activity of CCP repos increases with risk, while the opposite is true for BIL repos. When we allow for different proxies of risk, such as sovereign credit risk, counterparty risk, illiquidity in the repo market, and the excess liquidity injected by the ECB via unconventional interventions, we show that CCP repos act as *'shock absorber'* of these risks. This is different from the findings by Mancini et al. (2016) which show that the trading volumes of Italian GC CCP repos decreases with risk. In comparison, we find that BIL repos are not resilient and their trading activity negatively relates to risk. However, when CCPs set margin costs which are high, banks marginally reduce their exposures to CCP repos relative to BIL repos. We interpret these results as a confirmation of the pro-cyclicality of margins and the potential negative effects on the interbank funding liquidity, as theoretically modelled by Brunnermeir and Pedersen (2009).

Finally, we conduct an investigation of the difference of the rates between BIL and CCP repos, and of the determinants of the repo rate spread between the two. We find that, if the margin costs are high (above the median value), sovereign credit risk, repo riskiness and margin costs increase the risk premium demanded by banks for trading via CCP instead of bilaterally. This pricing anomaly highlights the existence of pro-cyclical effects of margin costs on the costs of funding via repos. Our results partially echoe the findings by Mancini et al. (2016), about a weaker resilience of the CCP repos when the collateral is less safe, as is the case for Italian sovereign bonds in our sample period when margin costs are high.

Our findings have important policy implications for regulatory bodies, banks and central clearing counterparties. In terms of regulation, the resilience of the repo market activity is not per se a sufficient fact to conclude that CCP repos are always a stable source of funding. The risk premium required by banks for lending via CCP repos with respect to BIL repos is a feature which signals anomalies in the pricing of these instruments, leading the former to be riskier than the latter. When margin costs are high, the additional risk premium required for trading via CCPs represents a negative externality for the interbank repo market. As an implication, banks are disincentivized to trade via CCPs and prefer to trade bilaterally. Additionally, by reducing their exposure to CCPs, banks limit the risk (albeit remote) of a default of the CCPs.

Secondly, the pro-cyclical effects of the margin policies implemented by CCPs on both repo rates and volumes, render the GC repo market less safe and resilient. Under this scenario, margins might impose excessive constraints to banks, and weaken market discipline by disincentivising the trading of the most active and safer banks in CCP repos.

Thirdly, the higher risk premium demanded by banks to trade via CCP repos with respect to BIL repos indicate that CCPs can be riskier than their alternative options. Regulators should monitor these pricing anomalies to determine when CCPs are perceived as too risky by the banking sector.

In conclusion, we argue that the current set of policy measures and features of the market design in CCP repos is sufficient to make the interbank market resilient only if more prudential margin policies are adopted by the CCPs.

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APPENDIX TO CHAPTER 4

Table A.4.1: Robustness checks - Rotation of explanatory variables– Model (4.1).

This table presents the results of 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 4.3. **Roll $_{\text{BIL-CCP}}$** is the difference between the bid-ask spread proxies proposed by Roll (1984) for BIL and CCP repos, and averaged over a 22-day rolling window. **Euribor-OIS Spread** is the difference between the Euro interbank offered rate (Euribor) and the overnight index swap (OIS) both with the maturity of one week. *** indicates 1% significance level (S.L.); ** 5% S.L.; and * 10% S.L., respectively.

Period	Full Sample 04/01/2010 - 30/11/2015					
Dep. Var.	Repo Volume Spread $_{\text{CCP - BIL}}$					
	(1)	(2)	(3)	(4)	(5)	(6)
Constant	1.9203***	2.1716***	2.2339***	-8.4313**	-6.4236*	-7.7784**
	(10.22)	(8.40)	(12.51)	(-2.42)	(-1.77)	(-2.22)
Trend	0.0022***	0.0023***	0.0022***	0.0027***	0.0024***	0.0026***
	(13.68)	(10.99)	(13.09)	(16.63)	(12.35)	(13.67)
Lag CDS				0.0027***		0.0030***
				(2.87)		(3.20)
Lag Excess Bank CDS				0.0058***	0.0065***	0.0059***
				(3.84)	(3.80)	(4.01)
Lag EL				-0.0079***	-0.0079***	-0.0082***
				(-8.01)	(-8.11)	(-8.32)
Lag EL^2				0.0089***	0.0097***	0.0091***
				(7.38)	(8.33)	(7.41)
Lag AT $_{\text{CCP}}$				0.5015***	0.4240**	0.4764***
				(3.03)	(2.48)	(2.87)
Lag Amihud $_{\text{BIL-CCP}}$					0.0334***	0.0190*
					(3.85)	(1.92)
Other Controls:						
Lag Roll $_{\text{BIL-CCP}}$	0.1890***			0.1457***		
	(3.72)			(2.60)		
Lag Euribor-OIS Spread		0.0009			0.0062	
		(0.24)			(1.27)	
Lag Repo Rate Spread $_{\text{BIL-CCP}}$			-0.0110			-0.0111
			(-1.04)			(-1.14)
Seasonal Controls	Y	Y	Y	Y	Y	Y
Time-of-Day Effects	Y	Y	Y	Y	Y	Y
Observations	1,500	1,500	1,500	1,500	1,500	1,500
Adj. R^2	0.236	0.218	0.219	0.299	0.288	0.295

Table A.4.2: Robustness checks -Alternative proxies as in Mancini et al. (2016) – Model (4.1).

This table presents the results of 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 4.3. **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). **Eonia Volume** (measured in Euro billions) is the total daily trading volume of the Euro Interbank Offered rate, and measures the unsecured overnight lending in the euro area. *** indicates 1% significance level (S.L.); ** 5% S.L.; and * 10% S.L., respectively.

Period	Full Sample 04/01/2010 - 30/11/2015				
Dep. Var.	Repo Volume Spread $_{CCP - BIL}$				
	(1)	(2)	(3)	(4)	(5)
Constant	2.1799***	-4.0158	-7.4853**	-7.1495**	-4.1225
	(5.23)	(-1.12)	(-2.16)	(-2.04)	(-1.15)
Trend	0.0022***	0.0021***	0.0026***	0.0026***	0.0021***
	(9.22)	(9.98)	(13.73)	(13.53)	(9.82)
Lag CDS			0.0030***	0.0030***	
			(3.17)	(3.19)	
Lag Excess Bank CDS		0.0048***	0.0060***	0.0059***	0.0048***
		(2.73)	(4.04)	(3.99)	(2.71)
Lag EL		-0.0076***	-0.0081***	-0.0085***	-0.0077***
		(-7.54)	(-8.21)	(-7.78)	(-6.79)
Lag EL^2		0.0096***	0.0090***	0.0094***	0.0097***
		(7.92)	(7.34)	(7.29)	(7.47)
Lag AT $_{CCP}$		0.3246*	0.4615***	0.4584***	0.3352**
		(1.94)	(2.81)	(2.78)	(2.01)
Lag Amihud $_{BIL-CCP}$		0.0424***	0.0194**	0.0191*	0.0420***
		(5.30)	(1.98)	(1.91)	(5.19)
<u>*Other Controls:*</u>					
Lag CISS	-0.6381	-0.5198			-0.4589
	(-1.06)	(-0.67)			(-0.58)
Lag EMC	-0.8477*		-0.1098		-0.1696
	(-1.68)		(-0.22)		(-0.34)
Lag Eonia Volume	0.0075			-0.0068	-0.0034
	(0.82)			(-0.71)	(-0.34)
Seasonal Controls	Y	Y	Y	Y	Y
Time-of-Day Effects	Y	Y	Y	Y	Y
Observations	1,500	1,500	1,500	1,500	1,500
Adj. R^2	0.221	0.287	0.294	0.295	0.286

Table A.4.3: Robustness checks - The costs of the use of CCP repos, and counterparty risk - Regressions results for model (4.2).

This table presents the results of OLS regressions estimated with HC robust standard errors over the period January 4, 2010 to November 30, 2015. The dependent variable is the daily repo rate spread between GC ON BIL and CCP repos on Italian Sovereign bonds. Variable definitions and measurements are explained in Table 4.3. Robustness checks for Excess Bank CDS and Bank CDS Spread $_{SMALL-LARGE}$ are in Panel A and B, respectively. *** indicates 1% significance level (S.L.); ** 5% S.L.; and * 10% S.L. respectively.

Panel A: Robustness checks - Excess Bank CDS

Dep.Var. Repo Rate Spread $_{BIL-CCP}$	Margin Costs			
	Below Median (<p50)	Below Median (<p50)	Above Median (>=p50)	Above Median (>=p50)
	(1)	(2)	(3)	(4)
Constant	2.5353***	5.0847	3.7850***	-36.6351***
	(4.34)	(0.33)	(8.39)	(-2.67)
Lag AT $_{CCP}$		-0.1555		1.9530***
		(-0.21)		(3.00)
Lag Amihud $_{BIL-CCP}$		0.1670**		-0.0717**
		(2.31)		(-2.52)
Lag EL		0.0007		0.0025***
		(0.57)		(2.93)
Lag Excess Bank CDS	0.0180**	0.0089	-0.0063*	-0.0137***
	(2.42)	(1.12)	(-1.78)	(-2.71)
Seasonal Controls	Y	Y	Y	Y
Time-of-Day Effects	Y	Y	Y	Y
Observations	523	523	977	977
Adj. R^2	0.0271	0.0618	0.0108	0.0526

Panel B: Robustness checks - Bank CDS Spread between smaller and larger Banks

Dep.Var Repo Rate Spread $_{BIL-CCP}$	Margin Costs			
	Below Median (<p50)	Below Median (<p50)	Above Median (>=p50)	Above Median (>=p50)
	(1)	(2)	(3)	(4)
Constant	0.9357	7.1531	4.0547***	-40.6495***
	(1.55)	(0.46)	(8.39)	(-2.94)
Lag AT $_{CCP}$		-0.2933		2.1769***
		(-0.39)		(3.29)
Lag Amihud $_{BIL-CCP}$		0.0790		-0.0758**
		(0.88)		(-2.50)
Lag EL		0.0002		0.0015***
		(0.12)		(2.67)
Lag Bank CDS Spread $_{SMALL-LARGE}$	0.0380***	0.0287***	-0.0072***	-0.0124***
	(5.51)	(2.78)	(-2.61)	(-4.03)
Seasonal Controls	Y	Y	Y	Y
Time-of-Day Effects	Y	Y	Y	Y
Observations	523	523	977	977
Adj. R^2	0.0810	0.0821	0.0109	0.0508

5 CONCLUSIONS

5.1 Summary of the Findings and Contributions of the Thesis

During the recent financial crisis of 2007-2008, a considerable number of banks has struggled to obtain liquidity at reasonable market conditions. The use of repos has instead seen a strong growth with banks heavily relying on these instruments to obtain secured short-term funding. Since banks borrow funds via repos typically in exchange for sovereign debt securities, this trend raises the question as to what extent the repo market and the sovereign bond market are interconnected. The aim of this thesis is to extend our knowledge regarding the determinants of the funding liquidity in the banking sector, and to investigate the interlinkages between the repo market and the sovereign bond market. Each of the three empirical chapters of the thesis focuses on a specific aspect of the repo market and attempts to shed light on the potential drivers of the funding conditions faced by banks.

In Chapter 2, I investigate which factors determine the degree of specialness, which is the risk premium demanded for procuring a specific collateral instrument via repos. Studying 1-day repo contracts on 130 Italian sovereign bonds over a 10-year sample period, I provide evidence that the dynamics of the degree of specialness are explained by collateral supply, repo liquidity, and speculative demand. I show that, during crisis periods, both the bond purchases undertaken by the ECB unconventional interventions as well as fire-sales of sovereign bonds affect the repo specialness. Interestingly, repo specialness shows recurrent patterns around bond auctions. First, specialness declines over successive reopening auctions and it varies according to the residual maturity of the collateral. Second, repo specialness increases from the auction announcement date until few days before the auction settlement date, while afterwards it decreases. This suggests a higher dealers' short-selling activity via reverse-repos ahead of auctions. Additionally, this pattern differs according to the specific timing of the collateral exchange of the short-term repo contract. Once a new auction is announced, primary treasury dealers hedge the risk of purchasing an excessive amount of the new bonds (winner's curse) by short-selling similar bonds which are already available in the secondary market. Dealers offer a lower special repo rate in order to obtain the temporary ownership of a collateral via reverse repos, and short-sell it. As a result, repo specialness tends to increase prior to the bond auction due to the demand for reverse repos.

Chapter 3 analyses the determinants of the variation of the spread between the intraday repo rate and the (risk-free) ECB deposit rate, using a large intraday dataset of GC CCP-based and bilaterally-traded repos on Italian government bonds. The intraday repo spread follows a downward sloping pattern and tends to decrease from the second hour of the trading day until market closure. When banks perceive a high risk of not meeting their end-of-day liquidity needs on time, they demand more funding earlier in the day, resulting in a greater interest rate paid by banks in the morning than in the afternoon. Furthermore, collateral supply, illiquidity and modified duration increase the riskiness of repos, and significantly explain the variation of the intraday repo spread. Moreover, repo riskiness as well as the excess liquidity provided by the ECB significantly impact the intraday repo spread. However, the intraday repo spread is much less influenced by collateral and repo riskiness during the post-crisis period, providing evidence for the impact of the ECB quantitative easing programmes on the repo market. Additionally, higher credit risk faced by banks-counterparties can increase the repo costs for both the CCP and bilateral segments. Furthermore, margin costs significantly affect the intraday repo spread during the European sovereign crisis. This result indicates that increasing margin costs during this period further deteriorate the funding conditions faced by banks (negative pro-cyclical effects) by increasing the intraday repo spread. Regarding the difference between CCP and bilateral repos, I find that the bilateral repo spread is on average higher than the CCP repo spread, reflecting the mitigation of counterparty risk via CCPs. Finally, I study the factors affecting the choice of a particular collateral in general collateral repo contract and find that bonds with greater collateral riskiness and lower specialness are more probable to be chosen as collaterals for GC repos. However, during the European sovereign crisis, repo buyers prefer bonds with lower duration and higher liquidity for CCP repos. Banks strategically choose which bond to use as collateral for the purpose of reducing the initial margins demanded by the CCPs, and thus the repo trading costs.

Finally, I evaluate the extent to which risk factors can explain the variation in the use of CCP repos with respect to bilaterally-traded repos. An important question in the literature on repos is whether the choice of trading via CCPs is (a) driven by general market uncertainty, (b) whether banks use this channel to elude market discipline, (c) whether it relates to regulatory changes. In Chapter 4, I address this question from a new angle by analysing and comparing trading activity (repo volume channel) and pricing (repo rate channel) for CCP and bilateral repos. The results show that sovereign credit risk, uncertainty in the funding conditions of the repo market, counterparty credit risk and margin costs explain the variation of the differences in traded volumes and rates between CCP and bilateral repos. Both sovereign credit risk and repo riskiness positively relate to the spread between the trading volumes of CCP and bilateral repos. However, the average counterparty credit risk of Italian banks as well as the difference between the counterparty credit risk of small and large banks, are also positively related to the spread between the trading volumes of CCP and bilateral repos. These findings suggest that banks do no really trust their counterparties. Furthermore, these results indicate the existence of incentives for riskier banks to use CCPs and elude market discipline. Additionally, banks reduce their use of CCP repos when margin costs are too high. A similar pro-cyclical effect of margins on the repo market is found when analysing the factors which explain the variation of the spread between bilateral and CCP repo rates. We find that when margin costs are above their median value, banks demand a risk premium for trading via CCPs. Overall, our results suggest that the margin policies adopted by the CCPs can discourage banks to trade via CCPs and induce them to demand a risk premium on top of the bilateral repo rate.

While the findings presented in this thesis make several contributions to the academic literature on repo markets, they also have important implications for (i) policymakers and regulators, (ii) for banks, as well as (iii) for Central Clearing Houses. I outline the main implications for these three groups of actors in the remainder of this section, and evaluate them by conducting a holistic review of the contributions of the three empirical chapters.

Regarding the implications for policymakers and regulators, the findings presented in this study reveal that repo markets are to a considerable extent driven by the unconventional central banking operations. However, these policies can have direct or indirect effects on the funding conditions of the repo market. Therefore, central banks should take care in choosing a strategy that at the same time best serves the general policy goals and that is not detrimental to the trading activity of the repo market. This thesis shows that appropriate central banking policies can be employed by regulators to restore the functioning of secured interbank repo markets without imposing additional funding costs to banks. In this sense, the findings in Chapters 2, 3 and 4 might help policymakers and regulators to evaluate the possible repercussions of their interventions on the repo market, and hence onto the funding costs for banks. Nevertheless, the results presented in Chapter 2, also imply that when central banks massively purchase government bonds as a way to inject liquidity into the interbank market, they reduce the availability of these bonds which are used as collateral for repo transactions. Thus, it becomes more difficult and more expensive to secure collaterals. While the design of better policy frameworks for collateral eligibility is crucial for the well-functioning of the secured money markets, the evaluation of the appropriateness of these requirements is left for future research since it goes beyond the scope of this thesis. Furthermore, the findings presented in Chapter 2 on the relationship between repo specialness and auction cycles are relevant to the national central bank. The results suggest that the Treasury influences the costs of procuring single bonds via repos by managing the reopening auctions of a particular type of security – e.g. bonds with the same residual maturity. Indeed, the general repo market is fundamental in ensuring liquidity to the primary dealers, by facilitating hedging and market making activities. As a consequence, a more efficient management of the auction cycles by the Treasury would reduce the costs faced by primary dealers due to their concern of the winners' curse.

The findings of this thesis also have important implications for banks. One of the main takeaways of Chapter 2 and 3, is that the riskiness of the sovereign bonds used as collaterals determines the costs of procuring funding via repos. This implies that banks should pay close attention to the choice of collaterals since this decision directly influences the efficiency of bank liquidity management, both at the daily and intraday levels. In particular, the results of Chapter 3 could help banks to understand the dynamics of their intraday liquidity positions and help to improve both intraday liquidity and collateral management as required by the Basel Committee. Additionally, the choice of bonds that are used as collaterals also depends on the margin costs set by the CCPs. This evidence suggests that banks already strategically manage collaterals by considering not only the characteristics of the underlying bonds, but also the costs derived from changes in the regulatory framework adopted by CCPs.

Finally, my findings are relevant for CCPs. The results presented in Chapter 4 suggest that the margin policies implemented by CCPs could destabilize the interbank repo markets. This links to the debate about whether CCPs could improve their risk frameworks in order to avoid pro-cyclical effects for banks. So far, the position of regulatory bodies is to encourage the CCPs to constantly monitor and improve both their margin methodologies and the implementation of policy changes, with the aim to reduce the potential adverse impacts on the allocation of funds among banks. The results of Chapter 4 reveal that trading via CCPs could actually be a riskier activity when margins are relatively higher than their median value. Thus, I argue that both CCPs and regulators should clarify whether the important role played by CCPs needs additional oversight. Indeed, CCPs are a risk pooling and sharing mechanism (Pirrong, 2011), which is susceptible to adverse selection by banks.

Implementing effective measures which address these risks would foster the well-functioning of the repo market as a resilient source of funding for banks.

5.2 Suggestions for Future Research

I believe that the findings of the thesis make significant contributions to the empirical research on the relation between the repo and the sovereign bond markets. Nevertheless, there are still many issues that could not be addressed in this study but would crucially expand our knowledge about repos. In the following, I outline several directions for future research.

As mentioned in the previous chapters, the interlinkages between repo markets and the riskiness of the sovereign collaterals differs depending on the regional market design and regulations - e.g. U.S. versus Europe -, and on the creditworthiness of the issuers of the debt instruments used as collateral - e.g. Italy versus Germany. It has been shown that the way in which repos are related to the Treasury bonds used as collaterals varies across borders and jurisdictions. Therefore, it would be interesting to extend the analysis of Chapters 2, 3 and 4 to other markets across Europe and to other developed countries in order to identify the main risk factors driving repo rates, i.e. sovereign bond riskiness versus funding uncertainty in the repo market, the margin policies adopted by the CCPs, and the central banking monetary interventions. In particular, given that the resilience of the European repo market depends on market design features (Mancini et al., 2016) which appear to be local (Euro area), it remains unclear whether these characteristics could be successfully replicated in countries with different market structures or which are rapidly changing – e.g. China[129] or African countries such as the Kenyan and Nigerian markets.[130]

[129] For a recent description of the Chinese interbank repo market, see Kendall and Lees (2017).
[130] See the fourth quarterly report issued by the International Capital Market Association (2016) at the following link: https://www.icmagroup.org/Regulatory-Policy-and-Market-Practice/Regulatory-Policy-Newsletter/Previous-versions/

Secondly, based on the findings of Chapter 4, it appears that under certain conditions, CCP repos may not be resilient to risks, in particular when CCPs set margin policies which are pro-cyclical and limit the allocation of funds and capital among banks in time of distress. However, the increased use of central clearing might give rise to other forms of systemic risk, since by nature CCPs concentrate the risk management of credit and liquidity risk in single entities. It would be interesting to more comprehensively analyse to what extent and in which ways the level of concentrations of such risks may affect market pricing and liquidity, and to explore these questions across different markets and products –e.g. equity, commodities, currencies and their derivatives.

Thirdly, the results presented in Chapters 3 and 4 imply that the unconventional monetary interventions implemented by the central banks could incentivise or disincentivise secured interbank lending, depending on the level of liquidity surplus in the European financial system. As a consequence, central bankers face uncertainty linked to future timing and potential exit strategies of these unconventional policies, and possible unintended consequences for the interbank repo market should be explicitly addressed. Thus it would be worthwhile to revisit the analysis undertaken in Chapter 3 and 4 in several years in order to investigate whether the interbank repo market would be affected under a regime where the expansionary monetary policies would come to an end. Such a re-examination would be an interesting effort for both policy-makers, and from an academic point of view, as to whether the interbank market conditions might be fully functioning without the support of the central banks.

Finally, a broad body of prior literature has examined repos on sovereign bonds, while relatively little is known about repos on other types of collateral – e.g. corporate bonds, also called the *credit repo market*[131]. Given the evidence presented in this thesis about the important role played by

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[131] See the report released by the International Capital Market Association about recent trends in the European credit repo market, which can be found at the following link: https://www.icmagroup.org/assets/documents/Regulatory/Secondary-markets/ICMA-European-Credit-Repo-Market-Report-22062017.pdf

collateral riskiness in explaining the variations in repo rates, it is a novel direction for future research to investigate whether the same interconnections could also determine the funding costs for repos which make use of non-sovereign collateral.

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