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Systemic risk in clearing houses: Evidence from the European repo market☆

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ABSTRACT

We study how crises affect Central Clearing Counterparties (CCPs). We focus on a large and safe segment of the CCP-cleared repo market during the Eurozone sovereign debt crisis. We develop a simple model to infer CCP stress, which is measured as repo rates' sensitivity to sovereign credit default swaps (CDS) spreads and jointly captures (1) the effectiveness of haircut policies, (2) CCP-member default risk (conditional on sovereign default), and (3) CCP default risk (conditional on both sovereign and CCP-member default). During 2011, repo rates strongly respond to sovereign risk, particularly for Greece, Italy, Ireland, Portugal and Spain (GIIPS): Repo investors behaved as if the conditional probability of CCP default was substantial.

1. Introduction

Central clearing counterparties (CCPs) are a fundamental component of the infrastructure of modern financial markets. In normal times, CCPs eliminate counterparty risk by inserting themselves between the buyer and the seller of an agreed-upon trade. They do so in exchange of imposing a collateral-specific haircut to member institutions, a contribution to their "default fund," and concentration limits (Duffie, 2015). As such, CCPs can help increase financial stability. But they are no panacea: While CCPs mutualize idiosyncratic counterparty risk in many ways, they remain vulnerable to financial crises. Given their size and centrality in the functioning of financial markets, their ability to withstand extreme financial shocks has become a first-order concern for all regulators around the world (e.g., Bank of International Settlement (BIS), 2012; International Swaps and Derivatives Association (ISDA), 2013; Coeuré, 2014; DTCC, 2015). There is, however, little empirical

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evidence on how CCPs actually behave in times of crisis, and this study is an attempt to fill this gap.

In this paper, we examine how the CCPs backing the European repurchase agreement (repo) market were affected by the Eurozone crisis of 2008–2012. In this market, sovereign bonds are used as collateral by banks to borrow overnight. This collateralized interbank lending market, which has become very large in recent years, with a daily volume of about €220bn that corresponds to 55% of total secured lending in the Eurozone (European Central Bank (ECB) Money Market Study, 2012), is crucial for the mutualization of liquidity shocks across banks. When sovereign crises arise, government bonds become worse collateral. This can affect the borrowing conditions on the repo market, which may in turn reduce interbank liquidity and weaken the banking system, as in Martin, Skeie and Von Thadden (2014). To mitigate such contagion, regulators have recently pushed market participants to systematically use CCP-cleared transactions.

To examine whether the European sovereign debt crisis led to the build-up of stress in a major CCP, we focus on one large segment of repo transactions called "General Collateral" (henceforth GC). In this segment cash lenders commit to accept as collateral any bond from a given sovereign (e.g., "Italian GC").[1] The focus on GC ensures that market participants in our data are banks conducting transactions for cash management purposes. Our data cover the 2008–2012 period, and come from two trading platforms that match repo transactions anonymously. These trades are then cleared via CCPs. Our sample covers a sizable part of the European GC repo market: In our data, the daily volume is close to €50bn on average, compared to a total volume of CCP-cleared European interbank repos of about €120bn (Fig. 1).[2]

Our null hypothesis is that the CCP offers perfect protection against risk fluctuations of the underlying collateral. To test it, we measure the extent to which shocks to sovereign collateral affect the repo rate. In a nutshell, our findings are consistent with the CCP-cleared repo market being immune against moderate sovereign stress. In times of extreme sovereign stress, however, repo market participants appear to factor-in into their repo pricing the higher probability of CCP default conditional on sovereign default. Interestingly, increases in collateral-specific haircuts imposed by the CCP have no impact on the repo market, possibly because the instituted haircut changes are not sufficiently large.

To structure our empirical tests, we first develop a simple theoretical framework, in which cash lenders in a repo transaction have some exposure to collateral (sovereign bonds in our case). We use this model to formalize the relation between sovereign CDS spreads and repo rates, making the simplifying assumption that the cash lender expects to own the sovereign collateral if the CCP default. The model shows that this relation is stronger when (1) the default risk of CCP member financial institutions conditional on sovereign default increases, (2) CCP risk conditional on CCP member and sovereign defaults increases, and (3) haircuts are not high enough to eliminate these increases in risk. When, however, investors do not expect the CCP to default at all, the framework shows that the repo rate should not be sensitive to the sovereign CDS spread: This is our null hypothesis.

We then go to the data. In times of "moderate sovereign stress" (2009–2010), we are indeed unable to reject our null hypothesis: Repo rates are uncorrelated with the CDS spread of the underlying sovereign. In "high sovereign stress" times (2011), however, repo rates become strongly correlated with CDS spreads. This relation is concentrated in the countries that were affected the most by the crisis, namely, Greece, Ireland, Italy, Portugal, and Spain (hereafter, GIIPS countries). The same relation does not exist for the other Eurozone countries. We also find a similar negative connection, albeit weaker, between repo volume and CDS spreads. All in all, our findings suggest that in 2011, the repo market participants priced CCP default. This ceased to be the case in the first half of 2012.

Next, we use our simple framework to decompose the 2011 stress of the repo market into the contributions of (1) haircuts, (2) CCP members' default risk, and (3) CCP default risk. Our decomposition suggests that investors perceived CCP protection to be fully effective in 2009–2010, but highly ineffective at the peak of the sovereign crisis in 2011. First, we look at the effect of haircuts, which in our model should reduce the connection between repo rates and CDS spreads. To evaluate the effectiveness of haircut policies, we run event studies around large changes in haircuts. We find that in 2011, haircut changes have no effect on the relation between sovereign CDS spreads and repo rates. We infer that changes in haircuts put in place by the CCP were not effective (i.e., not large enough) to stem the adverse movements in repo rates for GIIPS countries. Second, we look at changes in CCP member default risk *conditional* on sovereign default risk. We estimate this parameter by regressing bank CDS spreads on sovereign CDS spreads. We find that the risk of CCP member failure, controlling for the effect of sovereign default risk, does not increase between 2010 and 2011. Hence, if the repo market appears more stressed in 2011, this does not seem to come from the fact that CCP-member banks became riskier. Thus, it must be the case that investors perceived the conditional probability of CCP failure as being higher in 2011 than in earlier years. To confirm that the CCP was seen as offering little protection in 2011, we estimate the repo rate-to-sovereign CDS spread relation separately for a sample of bilateral trades that go through the same trading platform but are not cleared by the CCP. We find that in 2011, repo rates in CCP-based trades were not less sensitive to sovereign CDS spreads than repo rates in bilateral trades. This suggests that, at that time, investors estimated the probability of CCP failure to be similar to counterparty risk in bilateral transactions.

We provide several robustness tests and examine alternative explanations for our findings. In particular, we show that the haircut policy of the ECB, which uses the repo

[1] Albeit with CCP-imposed haircuts that vary by the sovereign and the maturity of the underlying collateral.

[2] The interbank market is mostly constituted of secured (i.e., bilateral or trilateral repo) transactions. By comparison, the average daily volume on the unsecured interbank market is about €60bn (ECB Money Market Study, 2012).

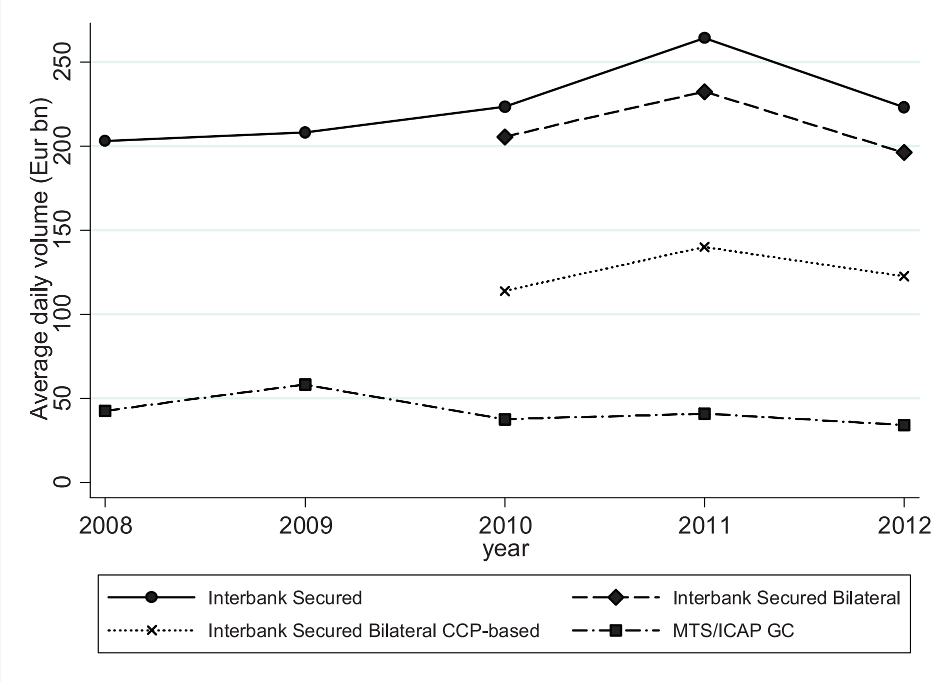


Fig. 1. Average daily trading volume in the Eurozone interbank repo market. This figure presents the evolution of different segments of the Eurozone interbank repo market between 2008 and 2012. Volumes for the Interbank Secured market, the Interbank Secured Bilateral market, and the Interbank Secured Bilateral CCP-based market are estimated from the 2012 European Central Bank Money Market Study. To avoid-double counting, we take the sum of estimated lending and borrowing volumes in a given year and divide it by two. MTS/ICAP GC is the sum of one-day GC repo trades in our data set. All numbers are in €bn of average daily volume.

market to conduct its monetary policy operations, does not explain our findings. We also explore a monopoly power explanation, in which concentrated lenders facing cash-short borrowers with collateral from GIIPS countries, can impose high borrowing rates on the repo market in 2011. The evolution of supply and demand on the repo market suggests that this is unlikely to be the main driver of our results. Additional tests also rule out liquidity funding risk as the main driver of our results: Our main finding remains unaffected when we add proxies for liquidity crunch (e.g., outstanding Certificate of Deposit (CD) volume) in our main regressions.

Our paper contributes to the nascent literature on the role of CCPs, which focuses exclusively on derivatives clearing. New regulatory frameworks, such as Dodd–Frank in the US and European Market Infrastructure Regulation (EMIR) in the EU, require that more Over The Counter (OTC) trading go through CCPs as the latter provide insurance against counterparty default at lower collateral cost. This is because CCPs are multilateral, and thus allow internalizing default externalities (Koeppl, Monnet and Temzelides, 2012; Acharya and Bisin, 2014) and efficient use of collateral (Duffie and Zhu, 2011; Duffie, Scheicher and Vuillemey, 2015). But while CCPs provide efficient protection against idiosyncratic counterparty risk, they offer no intrinsic protection against aggregate risk and may even encourage risk-shifting (Biais, Heider and Hoerova, 2012). Due to their size and connections, they are likely to be systemically important and thus need to be monitored. Although recent papers have proposed econometric methods to estimate CCP risk, these have focused on derivative trading (Jones and Pérignon, 2013; Menkveld, 2015). Our paper develops an alternative approach to estimate the extent of CCP stress in the data, in the context of repo transactions. Our method relies on the idea that market participants expect, in case of CCP default, that they will be exposed to the sovereign collateral. This is admittedly a strong assumption about the liquidation process, as the sharing of losses among CCP members in case of default was not very well defined during the period studied (Bank of England, 2011; Duffie, 2015; DTCC, 2015). It is however consistent with Variation Margin Gains Haircuts (VMGHs) advocated by many experts in recent years.

This paper also belongs to the larger literature on the repo market, in particular, repo transactions motivated by cash lending or borrowing (as opposed to shorting of particular securities). Most recent work in this area has focused on the evolution of the US repo market during the 2008–2009 crisis (Gorton and Metrick, 2012; Copeland, Martin and Walker, 2014; Krishnamurthy, Nagel and Orlov, 2014). The European repo market is different in two dimensions. First, while the US market is dominated by triparty repo (in which settlement, but not counterparty risk, is managed by a third party), transactions conducted on electronic platforms and cleared via a CCP predominate in Europe. However, both markets are similar in that they resisted well the financial crisis, with no significant decline in volume (see our Fig. 1 and Copeland, Martin and Walker, 2014). Second and most importantly, the European repo market is the main segment of the European interbank market, unlike in the US where the unsecured Fed Funds market dominates (Afonso, Kovner and Schoar, 2011). The European repo market is a key part of the interbank market where the ECB conducts its conventional and non-conventional monetary operations.[3] While several papers study its stability via the network structure (see, for instance, Gai, Haldane and Kapadi, 2011), our focus is different. In Europe, because public debt is the most common source of collateral on the repo market, sovereign crises have an additional power to contaminate the banking system.[4] The recent regulatory push towards centrally cleared transactions is an attempt to break the doom loop between sovereigns and their banks. Our paper is a tentative evaluation of the possibility that CCPs may be a focal point of stress rather than a source of stability for the European interbank market, at least in extreme circumstances (see also Mancini, Ranaldo and Wrampelmeyer, 2015, on this topic).

The paper proceeds as follows. Section 2 describes the European repo market, data sources, and variables used in the analysis. Section 3 presents our conceptual framework. Main results are in Section 4. In Section 5, we propose and test several explanations for the link between sovereign CDS spreads and repo rates. Section 6 discusses alternative explanations for our findings and Section 7 concludes.

2. Institutional background and data

2.1. The repo market

We focus on the role of CCPs in managing GC repo transactions that are electronically and anonymously matched. We start with a brief description of this market.

A repo is a loan collateralized with a security. Both parties (the cash lender and the security owner) agree on an interest rate, a maturity, and a haircut. The maturity is typically short (in our data, one day). The haircut is the percentage difference between the value of the security and the loan size (it is positive, i.e., the loan is over-collateralized). Hence, the interest rate is close to the safe rate of return. It may, however, fluctuate as a function of collateral risk, bank risk, and insufficient haircut adjustments (see below).

We restrict our analysis to GC repos. Repo transactions are typically classified into "general collateral" and "special." The latter are loans against a specific collateral (e.g., "Italian fixed-rate bond maturing in 2017"). Specials are often motivated by the desire to sell short a specific security in order to arbitrage the yield curve or manage dealer inventory (Duffie, 1996). In contrast, the GC repos are loans, typically short-term, whose collateral belongs to a certain predetermined list (e.g., "Italian government bonds"). The cash lender agrees to take any security from this list as collateral and is thus not looking to sell short a particular one.

[3] Several papers examine the microstructure of the ECB's main refinancing operations in normal vs. crisis times (Bindseil, Nyborg, and Strebulaev, 2009; Cassola, Hortaçsu, and Kastl, 2013; Dunne, Fleming, and Zholos, 2011, 2013).

[4] This mechanism can contribute to the link between banks and sovereigns as more broadly discussed in several recent papers (Acharya, Dreschler, and Schnabl, 2014; Gennaioli, Marin, and Rossi, 2014), which focus on other transmission mechanisms.

Not all repo transactions use a CCP. The repo market has several segments (Copeland, Martin and Walker, 2014): OTC bilateral, tri-party repos, and CCP-cleared. On the OTC market, both parties bear the counterparty risk and set the haircuts. Tri-party repos are transactions in which a private bank organizes the settlement of the operations, but does not bear the counterparty risk. CCP-cleared repos are transactions in which—besides offering settlement services—a clearinghouse bears the counterparty risk and therefore sets the haircut centrally. The CCP inserts itself between the two counterparties: It borrows the security (and lends cash against it) from the cash-borrower, and lends the security to the cash-lender (and borrows cash in exchange). CCP clearing often comes with electronic trading services. Historically, the repo market was an OTC market intermediated by broker-dealers. Over time, electronic trading platforms that match lenders and borrowers anonymously came to dominate the market in the Eurozone. The use of these platforms often comes with attached CCP services. Our data come from such platforms.[5]

2.2. Data

2.2.1. Transaction data

Our data come from two large electronic platforms (ICAP BrokerTec and MTS Repo) and cover the period from January 1, 2008 to June 30, 2012. ICAP BrokerTec provides us with the bulk of the data, but these do not cover repos based on Italian government collateral. For Italian GC, we rely on data from MTS Repo, which is that country's main electronic repo platform. For both platforms, our raw data contain all repo transactions. For each transaction, data contain (1) whether the transaction is GC or special, (2) the nature of the underlying collateral (say, German government debt), (3) whether the transaction is CCP-cleared or not, (4) the date of the repo transaction and its maturity, and (5) the interest rate and the amount.

We restrict our analysis to GC repo transactions that use sovereign bonds from Eurozone countries as collateral. In these transactions, the lender is allowed to provide any collateral from the GC list, which is considered to be safe enough to warrant cash lending at the repo rate. The GC list is country-specific. As shown in Fig. 1, MTS and ICAP GC repos represent a daily volume of about €50bn during the period, vs. a total daily repo volume of roughly €220bn.

[5] The segmentation and motivation for repos are not the same in the US and Europe. The two markets are of similar size, although it is difficult to make accurate comparisons due to the presence of bilateral and tri-party segments. As of May 2012, the US repo market is estimated to be $3.04 trillion (Copeland et al., 2012), while the Eurozone repo market is estimated to be €5.6 trillion as of June 2012 based on a survey of 62 large banks by the International Capital Market Association (2013). These measures are subject to double-counting but they suggest comparable sizes. However, the US is dominated by tri-party repos, which account for 53% of the market as of May 2012. In contrast in the EU, CCP-cleared repos account for 55% of the total in 2012 (ECB Money Market Study, 2012). Another important difference is that European banks (which hold more government bonds) are very active in European repo markets (Mancini, Ranaldo, and Wrampelmeyer, 2015), while the US repo market is mostly used to finance the shadow banking system (Krishnamurthy, Nagel, and Orlov, 2014). The European repo market is also where the ECB tends to conduct its routine monetary policy operations (see, for instance, Cassola, Hortaçsu and Kastl, 2013).

Since our focus is on the role of CCPs, we restrict the sample to CCP-cleared transactions for the most part. Sometimes counterparties sign bilateral contracts rather than going through CCPs, but this is not the norm. Most of the time, electronic transactions are CCP-cleared. Counterparties trading through ICAP need to clear transactions through LCH.Clearnet Ltd.[6] Counterparties trading Italian GC through MTS have to use Cassa di Compensazione e Garanzia SpA (CC&G). The fact that Italian GC is cleared via a different CCP in our data does not have a bearing on our findings: Our main results are not affected when we exclude Italy. We can distinguish CCP-based vs. bilateral transactions in the ICAP database. We can do the same in the MTS data but only in 2010–2012 (MTS does not allow this distinction in 2008–2009). Assuming that all pre-2010 Italian repo transactions are CCP-based, we find that 85% (80%) of the transactions turn out to be CCP-cleared in our data over the entire period (in the post-2009 period).[7] We focus on these transactions for our main results (in Section 4), but we return to the CCP/bilateral distinction in additional tests (in Section 5).

In terms of maturity, we restrict our analysis to one-day repo transactions, which represent about 97% of total volume in our data.[8] These one-day transactions are denoted as “overnight,” “tomorrow next,” and “spot next” depending on the day of delivery.

We collapse these repo trade data into daily observations of GC rates per sovereign collateral. We have GC trades for 11 countries: Five GIIPS countries (Greece, Ireland, Italy, Portugal, and Spain), and six non-GIIPS countries (Austria, Belgium, Finland, France, Germany, and the Netherlands). For each day and each country, we compute two variables. The daily country-level repo rate is the volume-weighted average interest rate on one-day, CCP-cleared, repo transactions. The GC volume is the total value of all transactions for a given country. We ignore daily observations with missing repo rates, except in the tests of Section 4.3, in which we analyze repo volume after assigning a volume of zero to days with missing repo rates. Table 1 reports summary statistics for repo rates and volume for the entire sample period (January 2008–June 2012) and for the four subperiods that we consider in our tests: “Normal times” (January 2008 to Lehman Brothers’ bankruptcy on September 15, 2008); “Sovereign stress times” (January 2009–December 2010); “Sovereign crisis times” (January 2011 to the day before the 36-month Long Term Refinancing Operations (LTRO) on December 20, 2011); and “post-LTRO period” (January–June 2012).

Fig. 2 presents the evolution of total daily volumes (averaged by month) of repo transactions broken down by GIIPS and non-GIIPS countries. The average daily volumes have the same order of magnitude, but the volume of GIIPS repos goes down from about €35bn in 2008–2009 to about €20bn in June 2012. Non-GIIPS repo volumes are stable at around €20bn.[9] For Greece, Ireland, and Portugal, which enter a bailout program during our sample period, we exclude all observations in and after the month of the bailout program.

2.2.2. Sovereign and bank risk data

We match our repo data with each country’s daily credit default swap (CDS) rates from Datastream using the five-year senior CDS series (*Sovereign CDS* in our tables). We also estimate default risk for banks in a given country using the simple average of (five-year) individual bank senior CDS rates to the extent they are available in Datastream. We report summary statistics on bank and sovereign CDS spreads per subperiod in Table 1.

2.3. The unfolding of the Euro crisis in our sample

This section provides a short description of the data and preliminary evidence that the repo market was affected by the developments of the European sovereign crisis, despite the fact that the segment we consider is backed by a CCP that is supposed to insulate market participants from default risks. This observation, further refined later, constitutes our main finding.

We report in Fig. 3 the repo rates of GIIPS and non-GIIPS transactions over the period that we study (2008–mid 2012), as well as the ECB rate corridor (the deposit rate, which is the lower bound, and the lending facility rate, which is the upper bound). In normal times, the repo rate follows the main ECB policy rate.[10] After October 2008, the ECB greatly expands the size of its interventions (auctions change from partial to full allotment), so that the repo rate converges quickly to the ECB deposit rate. In mid-2010, the Greek sovereign crisis becomes more acute, and all repo rates increase again, up to 50 basis points (bp) above the central bank’s 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 repo market separates into two: GIIPS repos remain about 50 bp higher than the deposit rate, while non-GIIPS repos fall. This situation lasts for about half a year, until the two rates become realigned with the lower bound of the corridor at the end of 2011 (we argue in Section 4 that

[6] One exception is French GC that is cleared via LCH.Clearnet SA, which is an affiliate of LCH.Clearnet Ltd.

[7] This assumption seems reasonable given the increasing predominance of CCP-based transactions over bilateral ones, but it inevitably makes our data noisier. To ensure that this does not affect our results, we present our main results excluding Italy in a robustness test (in Appendix Table A1, Panel B). Doing so does not affect our conclusions.

[8] There are no maintenance margins for one-day repos, for which only the initial haircuts matter. Moreover, in one-day repos the uncertainty regarding default premium of the underlying sovereign bond is also reduced to a minimum (compared to, say, one- or three-month repos).

[9] Appendix Fig. A1 provides a more detailed breakdown by country. Note that each panel uses a different scale. Panel A of Appendix Fig. A1 reports trading volume for Italy, France, and Germany, whose total repo trading volume is about €30bn per day. In Panel B, which reports numbers for Austria, Belgium, Spain, Finland, and the Netherlands, the trading volume is smaller but never zero (approximately €1bn per day on average, with peaks at about €4bn to €6bn for Belgium, Spain, and the Netherlands). Panel C shows volume for the three countries that eventually went through a bailout program (Greece in March 2010, Ireland in November 2010, and Portugal in April 2011), and whose repo markets shut down entirely once their banks obtained financial assistance.

[10] This is because the ECB’s interventions (called Main Refinancing Operations, or MROs for short) are auctions with partial allotment whose goal was to align the repo rate with the main policy rate (see Cassola, Hortaçsu, and Kastl, 2013, for a description).

Table 1
Summary statistics.
This table reports summary statistics over the entire sample period, and over each of the four subperiods we consider in subsequent tests. *Repo rate-ECB deposit rate* is the annualized country-level average daily general collateral (GC) repo rate for one-day repo contracts minus the ECB deposit facility rate. *Daily volume* is the country-level total daily trading volume of such repo contracts. *Sovereign CDS spread* is the country-level daily five-year sovereign credit default swap rate. *CCP members CDS spread* is the average daily five-year CDS spread of all financial institutions that are members of the CCPs in the sample. *Local banks' CDS* is the daily country-level average of five-year CDS spreads of local banks. *CD volume* is the daily country-level amount outstanding of Certificates of Deposit of local banks.

	Number of observations	Mean	Median	Std. Dev.	Min.	Max.
Jan. 2008–June 2012						
Repo Rate-ECB Deposit Rate (pct)	8,814	0.31	0.14	0.40	−0.65	1.88
Daily volume (€bn)	8,814	5.80	1.65	9.44	0.03	61.77
Sovereign CDS spread (pct)	8,471	1.04	0.68	0.95	0.05	5.22
CCP members CDS spread (pct)	8,814	1.78	1.53	0.89	0.46	4.52
Local banks' CDS (pct)	7,872	1.96	1.53	1.26	0.35	9.24
CD volume (billions)	7,667	52.74	9.28	104.37	0.00	373.34
Jan. 2008–Lehman's bankruptcy						
Repo rate-ECB deposit rate (pct)	1,218	1.06	1.06	0.06	0.74	1.46
Daily volume (€bn)	1,218	6.17	1.05	11.62	0.03	53.27
Sovereign CDS spread (pct)	989	0.24	0.20	0.15	0.05	0.64
CCP members CDS spread (pct)	1,218	0.89	0.90	0.24	0.46	1.68
Local banks' CDS (pct)	913	0.82	0.76	0.26	0.35	2.07
CD volume (billions)	1,021	63.07	7.85	120.79	0.17	346.09
Jan. 2009–Dec. 2010						
Repo rate-ECB deposit rate (pct)	4,190	0.19	0.10	0.21	−0.45	1.63
Daily volume (€bn)	4,190	5.92	1.17	10.35	0.03	61.77
Sovereign CDS spread (pct)	4,134	0.97	0.68	0.76	0.17	4.81
CCP members CDS spread (pct)	4,190	1.41	1.41	0.35	0.83	2.32
Local banks' CDS (pct)	3,837	1.73	1.40	1.06	0.56	8.88
CD volume (billions)	3,562	49.45	11.12	99.37	0.01	373.34
Jan. 2011–Dec. 2011 LTRO						
Repo rate-ECB deposit rate (pct)	1,857	0.30	0.29	0.33	−0.43	1.88
Daily volume (€bn)	1,857	5.80	3.10	6.78	0.03	38.51
Sovereign CDS spread (pct)	1,857	1.36	1.00	1.13	0.23	5.22
CCP members CDS spread (pct)	1,857	2.60	2.19	0.84	1.53	4.52
Local banks' CDS (pct)	1,753	2.61	2.22	1.39	1.09	9.24
CD volume (billions)	1,692	50.39	8.90	96.99	0.00	323.30
Jan. 2012–June 2012						
Repo rate-ECB deposit rate (pct)	882	−0.05	−0.07	0.08	−0.21	0.22
Daily volume (€bn)	882	4.85	2.30	5.80	0.03	27.18
Sovereign CDS spread (pct)	882	1.77	1.22	1.20	0.28	4.73
CCP members CDS spread (pct)	882	3.25	3.26	0.42	2.55	3.93
Local banks' CDS (pct)	837	3.23	3.03	0.94	1.83	5.67
CD volume (billions)	837	54.78	8.55	104.16	0.20	326.90

the timing coincides with the implementation of the 36-month LTRO of December 2011).

Over the entire period, the average repo rate is not stationary (the Dickey-Fuller test fails to reject the unit root hypothesis at 89%). We deal with the non-stationary series using two approaches. First, our focus on four separate subperiods (2008-Lehman, 2009–2010, 2011, 2012 first semester) helps. During each of these subperiods except the first one (which is not the focus of our paper), Dickey-Fuller statistics clearly reject the unit root hypothesis, and the time series show no statistically significant trend. Second, in all our specifications we use the difference between the repo rate and the ECB deposit rate. This difference is theoretically motivated (see the next section), and is stationary both within each subperiod and over the entire period.

Fig. 4 displays the evolution of average sovereign CDS spreads of GIIPS and non-GIIPS countries. Similar to repo rates' evolution, CDS spreads for the two groups of countries move very closely until the Greek crisis erupts in early 2010. The two groups start to drift apart but the difference remains moderate until the spring of 2011 (when Portugal officially requires EU assistance to fund its sovereign borrowing). Between mid-2011 and the end of 2011, GIIPS CDS spreads increase from 5% to 25%, while non-GIIPS CDS remain essentially flat. The divergence in CDS rates coincides with the divergence in repo rates during this period.

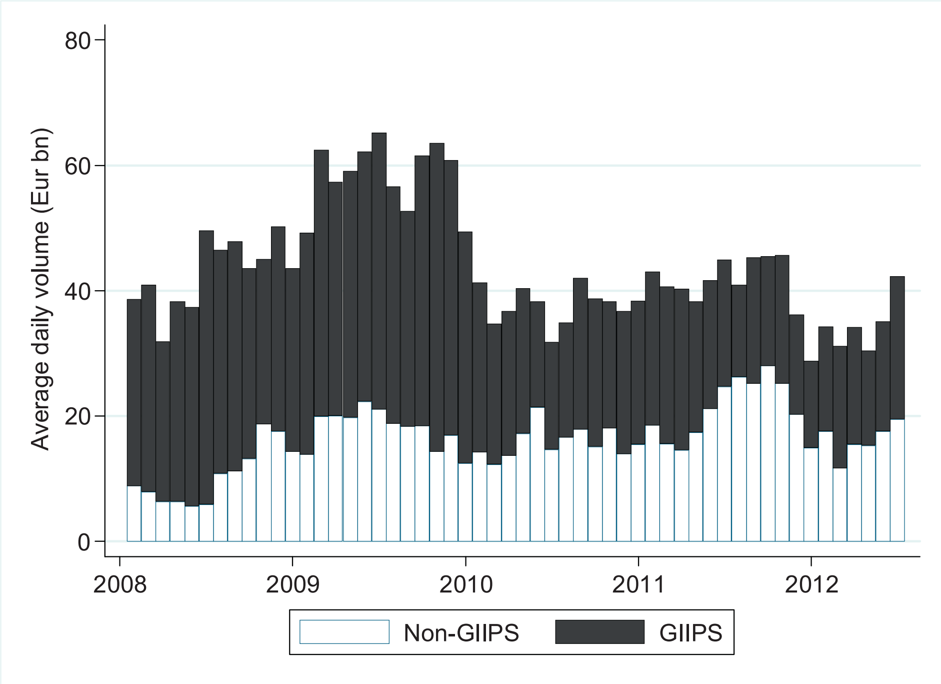


Fig. 2. Evolution of the volume of repo transactions in the Eurozone, GIIPS vs. non-GIIPS, 2008–2012 S1.This figure presents the monthly evolution of the average daily total volume of general collateral (GC) repo in the Eurozone between January 2008 and June 2012, for GIIPS countries (Greece, Ireland, Italy, Portugal, and Spain) and the six non-GIIPS countries combined together. The scale of the *y*-axis is in €bn.

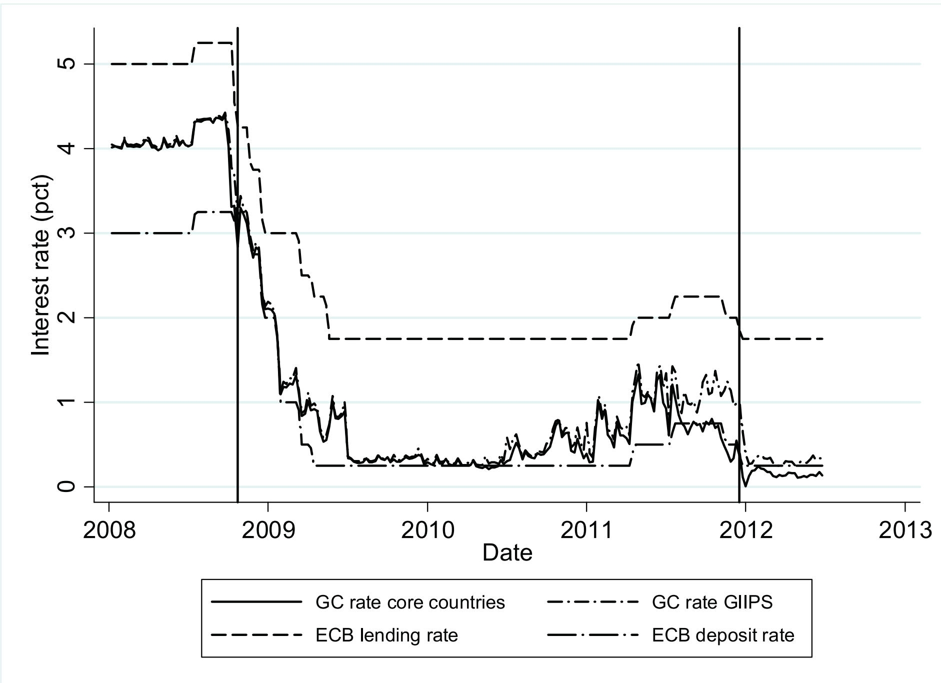


Fig. 3. Interest rates, 2008–2012 S1. This figure presents the evolution of the ECB marginal lending and deposit rates, as well as the average general collateral (GC) repo rate for GIIPS (Greece, Ireland, Italy, Portugal, and Spain) and non-GIIPS Eurozone countries between January 2008 and June 2012. Interest rates are expressed in percent. The vertical line on the left corresponds to the Lehman bankruptcy of September 15, 2008, whereas the vertical line on the right corresponds to ECB's 36-month LTRO announcement of December 20, 2011.

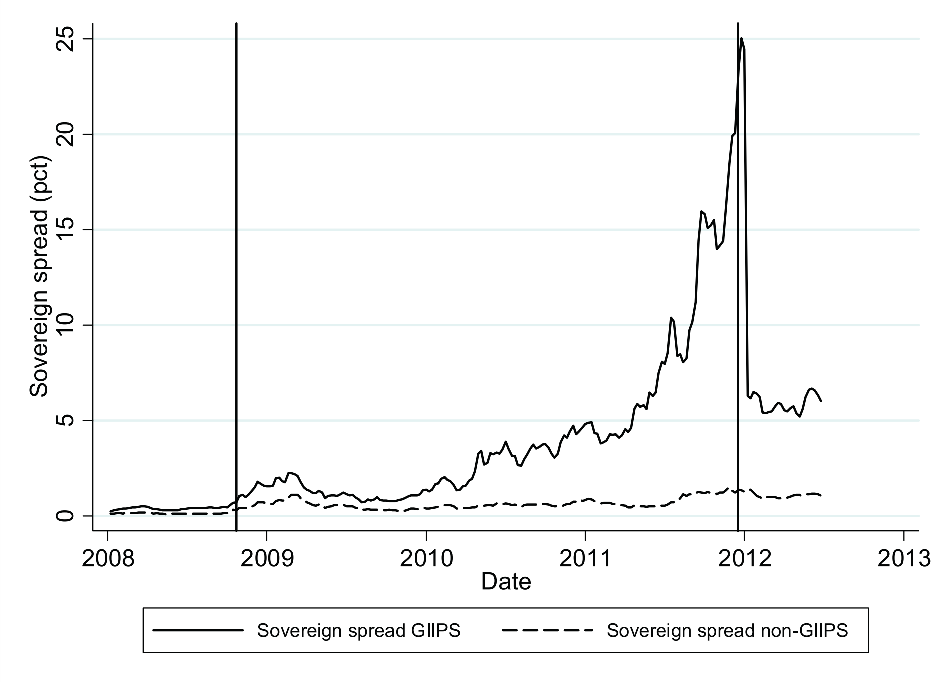


Fig. 4. Sovereign CDS spreads, 2008–2012 S1. This figure presents the evolution of weekly average sovereign CDS spreads for GIIPS (Greece, Ireland, Italy, Portugal, and Spain) and non-GIIPS Eurozone countries between January 2008 and June 2012. CDS spreads are in percent. The vertical line on the left corresponds to the Lehman bankruptcy of September 15, 2008, whereas the vertical line on the right corresponds to ECB's 36-month LTRO announcement of December 20, 2011.

The above observations suggest a correlation between CDS spreads and repo rates, at least in GIIPS countries. This is surprising, given that all transactions that we consider are CCP-cleared and therefore in principle insulated from default risks. Before we investigate this more deeply, we note that this finding is not present in the aggregate data, which justifies our analysis at the country-level. The time-series relationship between repo rates and sovereign risk is actually negative and statistically significant (in particular in 2009 and 2011).[11] Hence, aggregate repo rates do not seem to react to sovereign stress. If anything, they react negatively, i.e., repo borrowing becomes cheaper in times of stress. This happens because the aggregate repo rate in our data mixes GC rates on GIIPS and non-GIIPS countries.

Subsequently, we exploit the country-by-country variation to refine our tests. In fact, we find a sharp contrast between the reactions of repo markets to the Eurozone sovereign crisis in GIIPS vs. non-GIIPS countries. Our conceptual framework suggests a channel that is consistent with these results: During periods of significant sovereign stress, the probability of CCP insolvency (conditional on sovereign and member banks defaults) increases.

[11] Appendix Fig. A2 shows how the average repo rate and the average CDS spread correlate. First, we take the difference between the repo rate and the ECB deposit rate to make the series stationary. Then, we compute the average sovereign CDS spread and the average adjusted repo rate, each day, across all 11 countries in our sample. We obtain a time series of 1,149 daily observations, which we plot in Appendix Fig. A2.

3. Explaining repo rates: a conceptual framework

3.1. Assumptions

To analyze the pricing of repo loans, we start from a stylized risk-neutral no-arbitrage model. Assume that cash lenders arbitrage between overnight lending on the repo market at r^{REPO} and lending with no risk to the ECB at the deposit rate r^{ECB}. Repo lending of $P(1-h)$€ is collateralized with P€ of sovereign bonds, where h is the haircut and P the price of the bond. The sovereign bond defaults with probability π, in which case the bondholder incurs a loss given default (LGD) of x, which is a random variable with conditional distribution function (c.d.f.) $F()$.

In the data, repo rates and collateral risk are strongly related in times of crisis. For such a link to arise, we need to assume that the cash lender is exposed to the collateral in some states of nature, which necessarily happen when the CCP defaults. To see this, imagine that the CCP never defaults. In this case, repo lending is always safe and at equilibrium $r^{\text{REPO}} = r^{\text{ECB}}$. Such a model cannot explain the repo rate-to-sovereign CDS spread sensitivity that we document in Section 4. By contrast, if the cash lender becomes exposed to the collateral upon CCP default, then she will price this exposure and the repo rate will be sensitive to collateral risk.

To rationalize the results, we thus need to make the following assumption:

Assumption 1. In case of CCP failure, the lender owns the collateral.

During the period of our study (2008–2012S1) liquidation in case of CCP failure is not very well defined, but the practitioner literature as well as informal interviews with CCP employees, suggest that this is a credible assumption. We defer the discussion on the plausibility of this assumption to Section 3.3.

3.2. Set-up

In the absence of sovereign default, the lender is made whole as long as daily fluctuations of the bond price are below the haircut. We assume, accordingly, that the haircut policy is set conservatively enough to absorb such price movements. However, in the alternative scenario, conditional on sovereign default, the expected LGD on $1/(1-h)$ € of bond is thus $\int_h^1 (x-h)dF(x)/(1-h) = G(h)$. $G(.)$ is a decreasing function of h: Bigger haircuts allow to minimize the loss in case of default.

Denote p the probability of CCP member default *conditional* on sovereign default. "CCP member default" is a general term that means the default of one or several banks that trade through the CCP and that are big enough to require a large-scale intervention by the CCP to settle their transactions, which can ultimately cause the failure of the CCP itself.[12] This probability p can be estimated for instance by regressing bank CDS spreads on sovereign CDS spreads as in Acharya, Dreschler and Schnabl, (2014), something we also do in Table 7. Finally, we denote λ the probability that the CCP defaults, *conditional* on both CCP members and sovereign defaults. As in Krishnamurthy, Nagel and Vissing-Jorgensen (2013), we rely on risk-neutral probabilities rather than the true physical probabilities of default.

Because lenders always have the choice to lend to the ECB at the deposit rate, a no-arbitrage condition implies:

$$r^{ECB} = (1 - p\lambda\pi)\, r^{REPO} - p\lambda\pi\, G(h) \tag{1}$$

which, after straightforward manipulation and first-order approximation, leads to:

$$r^{REPO} = r^{ECB} + (p\lambda G(h)/G(0)).(\pi G(0)). \tag{2}$$

This simple framework allows us to interpret the results of our regressions, in which we regress the repo rate on sovereign CDS spread. The sovereign CDS spread measures $\pi G(0)$, i.e., the probability of default π times the expected loss given default $\int_0^1 x dF(x) = G(0)$ for €1 of bond. As a result, our regressions allow us to obtain an estimate of $p\lambda G(h)/G(0)$, which measures the conditional probabilities of default of the CCP and its member banks, as well as the LGD given the haircut. This will be our main empirical strategy.

[12] Modeling the conditional failure of member banks is not necessary since these do not directly affect the cash lender, as counterparty failure would in a bilateral transaction. However, considering the failure of CCP members permits us to describe more realistically the chain of events leading to the failure of the CCP—from sovereign default to member defaults to CCP default. Moreover, it also allows us to motivate the tests of Section 5, in which we consider separately the change in bank risk and the change in perceived CCP risk as possible factors driving the strong link between sovereign CDS spreads and repo rates in 2011.

Finally, note that our framework only allows us to measure the market's perception. The repo rate-to-CDS sensitivity may increase because market participants become more risk averse. It may also increase because traders hold excessive beliefs that the CCP may fail. Thus, we cannot discard "behavioral" explanations, although we cannot prove them either. It is important to bear in mind, however, that λ is a *conditional* probability. It is closer to a correlation (between CCP failure and sovereign default) than to the unconditional belief that the CCP will fail.

3.3. What happens in case of CCP failure?

We discuss here our Assumption 1 that, in case of CCP default, the lender becomes the owner of the collateral. First, notice that CCP failure is a plausible event. When one or several members default, CCPs typically have buffers that consist of default funds and capital reserves (equity). As long as these buffers are sufficient, non-defaulting members face no loss on their margin accounts. Such events correspond to CCP "non-failure" in the model, since lenders get repaid fully. But in case of a major crisis, these buffers quickly become too small. For instance, as of December 2011, LCH.Clearnet (which clears all non-Italian repos in our data) only had a single default fund, of approximately €680 m, for all its clearinghouse activities (both repo and derivatives) (LCH.Clearnet, 2011). This is to be compared with an average daily volume of €17bn on the repo market in our data, excluding Italy. Default on 8% of these transactions with a 50% loss given default would be sufficient to wipe out the entire default fund.[13] Given European banks' active reliance on repo funding, the default of two medium-sized members concurrent with the default of their related sovereign is a shock big enough to exhaust the default fund of LCH.Clearnet.[14]

Second, in case of CCP default, lenders get a fraction of the value of their collateral. This is called "end-of-waterfall loss sharing." This procedure was not precisely defined in 2011. The Bank of England in 2011 acknowledged that "CCPs do not generally have formal arrangements for allocating losses that exceed their default resources [...] If a CCP were to fail, residual losses would

[13] A similar order of magnitude is valid for CC&G, the CCP clearing Italian repos in our data. At the end of 2011, CC&G had a default fund for bonds of €1.1bn. With an average daily volume of Italian repo of €26bn, defaults on about 9% of the transactions along with 50% haircuts on collateral would be enough to exhaust the default fund.

[14] The recent stress tests conducted by the European Securities Market Association (ESMA) for 17 European CCPs (including LCH.Clearnet Ltd. and CC&G) indicate that "... the prefunded resources of CCPs would be sufficient for the reporting dates to cover the losses resulting from the considered historical/hypothetical market stress scenarios after the default of the top-2 EU-wide groups, selected either on the basis of the largest aggregate exposure or also after weighting by their probability of default" (ESMA, 2016, p. 57). However, these stress tests, based on 2014 data and prefunded resource-levels of CCPs, are unlikely to be representative of the weaker conditions of CCPs prior to 2012. In fact, upon request of their regulators, many CCPs had to strengthen their abilities to absorb potential losses. For example, "... in August [2012], LCH.Clearnet Ltd (LCH) established a new ring-fenced default fund of approximately £500 million in respect of its clearing of repo transactions" and introduced new waterfall arrangement for repo clearing (Bank of England, 2012, pp. 13–14).

fall on participants (as creditors) and it is likely any allocation would occur in a way that was difficult to predict with certainty and could take a considerable period of time." (Bank of England, 2011, p. 53). After 2011, however, end-of-waterfall loss sharing was codified more explicitly. When default funds are insufficient to absorb all losses, the remaining contracts are "torn up" (see, for instance, Elliott, 2013, Table A1). Then, a haircut is applied to all positions. This haircut reflects the mismatch between positive and negative positions due to the default of some members. It is also a function of the value of the underlying collateral of each lender. Lenders with worse collateral receive a smaller fraction of their claim, which is the spirit of VMGH for derivatives (see Elliott, 2013; Duffie, 2015). This makes the payoff of lenders sensitive to the value of the collateral in case of default. This allocation rule was confirmed to us by a risk manager at LCH.Clearnet.

Finally, our assumption that the cash lender becomes exposed to collateral in the event of CCP default can be understood as representing the *beliefs* of market participants about the resolution procedure, rather than the procedure itself. Although end-of-waterfall loss sharing rules were not precisely codified in 2011, it seems reasonable to assume that market participants were behaving as if lenders would be exposed to the collateral in case of CCP default, as it is the case today. In several informal conversations that we had, repo traders indicated that they were subject to sovereign exposure limits set by their institutions' risk management departments (for instance, "not more than €500 m of Italian paper"). Such anecdotal evidence suggests that risk managers of, at least, several large repo dealers, thought that lending cash against a particular sovereign collateral exposed the bank to this country's debt, which is consistent with our Assumption 1.

4. Main results

4.1. Sovereign default risk and repo rates

We estimate Eq. (2) by running the following regression, for country c, at date t:

$$r^{\text{Repo}}{}_{c,t} - r^{\text{ECB}}{}_{t} = \beta.SovereignCDS_{c,t} + \delta_c + \delta_t + \varepsilon_{c,t}, \qquad (3)$$

where the dependent variable is the spread between the repo rate of country c and the ECB deposit rate, which is our measure of the safe rate of return. The coefficient of interest is β, the sensitivity of the repo rate to the sovereign CDS spread. Our null hypothesis is that $\beta = 0$, i.e., that haircuts are conservative enough, and/or that the CCP and its members are resilient enough. In our baseline specification, the regression also includes country fixed effects (δ_c) and time fixed effects (δ_t) to account for movements in the common factors affecting the European repo market. We cluster error terms $\varepsilon_{c,t}$ at the daily level across countries. Finally, note that the average excess repo rate (the average of $r^{\text{Repo}\circ}{}_{c,t}$ – $r^{\text{ECB}}{}_{t}$ across countries) is a stationary variable, in particular if we focus on the post-Lehman period. The Dickey-Fuller (DF) statistic over the entire period is −2.9, which allows us to reject the unit root hypothesis at the 4%-level.[15]

Estimates of Eq. (3) appear in Panels A and B of Table 2, for various subperiods. In Panel B, we report regressions in which δ_c is replaced with country-month fixed effects $\delta_{c,m}$. This forces identification on daily variations within the month. We split our sample into the four subperiods described in Section 2.3: "Normal times," "sovereign stress times," "sovereign crisis times," and "post-LTRO period." The only period in which β is significantly positive in both Panels A and B is "sovereign stress times". Before 2011, markets did not seem to price a risk of CCP and member bank default. In 2012, the stress that had built up in the repo market abated. But in 2011, the coefficient estimate is positive and statistically significant, although weaker when we control for country-month fixed effects. Using estimates from Panel B, we see that during these "sovereign crisis times," a one-standard deviation increase in the CDS spread leads to an average increase of almost 9 basis points ($= 0.076 \times 113$ bp) for all one-day Eurozone GC-repo rates combined across countries. The effect is thus moderate and, in our most saturated specification, only significant at 5%. However, this finding conceals a large heterogeneity between GIIPS and non-GIIPS countries, to which we now turn.

4.2. Sovereign default risk and repo rates in GIIPS vs. non-GIIPS countries

In our framework, the coefficient β corresponds to $p\lambda G(h)/G(0)$, which contains the joint conditional default of the CCP and member banks, as well as the effect of the haircut. In this section, we investigate whether β is the same in GIIPS and non-GIIPS countries. A difference may arise because haircuts are too low in transactions using riskier GIIPS collateral, i.e., because $G(h)/G(0)$ is larger in GIIPS countries. To test whether the sensitivity of repo rates to sovereign risk differs between GIIPS and non-GIIPS countries, we create an indicator variable named *GIIPS*, which is equal to one for GIIPS countries, and zero otherwise. Then, we add an interaction term *GIIPS* × *Sovereign CDS* to the version of Eq. (3) that includes country-month fixed effects ($\delta_{c,m}$). The coefficient on this interaction term measures the extent to which repo rates are differentially sensitive to sovereign CDS spreads across the two country groups.

We report these results in Table 2, Panel C. They suggest that GIIPS countries mostly drive the positive sensitivity of repo rates to CDS spreads. This relation is statistically significantly *negative* for non-GIIPS countries: In column 1 the coefficient on *Sovereign CDS* (the non-interacted term) is equal to −0.051 (significant at the 1%-level), which we understand as evidence of flight to quality. An increase

[15] If we focus on 2009–2012S1, the DF statistic becomes −4.8, which rejects the unit root hypothesis at less than 0.01%. As we discussed in Section 2.3, the monetary policy of the ECB in normal times implies a large difference between the repo rate and the ECB deposit rate, which explains the relative weakness of the DF test over the entire period. This large difference disappears, and the results of the DF test improve, in the period following Lehman's bankruptcy, which is the period the paper mostly focuses on.

Table 2
GC repo rates and sovereign CDS spreads.
This table reports estimates of fixed-effect panel regressions in which the dependent variable is the daily country-level average general collateral (GC) repurchase agreement rate minus the ECB deposit facility rate (*Repo rate – ECB deposit rate).* The explanatory variables are the daily country-level five-year sovereign credit default swap rate (*Sovereign CDS*) in Panels A and B, and its interaction with an indicator variable equal to one for Greece, Ireland, Italy, Portugal, and Spain (*GIIPS*), and zero otherwise in Panel C. All regressions include day fixed effects. Moreover, Panel A regressions include country fixed effects, and regressions in Panels B and C include country-month fixed effects. *t*-statistics are presented in parentheses. Standard errors are clustered at the daily level. *, **, and *** denote statistical significance at the 10%-, 5%-, and 1%-level, respectively.

Panel A: Fixed-effect regressions

	(1) 2008–2012 S1	(2) 2008-Lehman	(3) 2009–2010	(4) 2011	(5) 2012 S1
Sovereign CDS	0.065***	−0.023	0.016***	0.192***	0.033***
	(14.54)	(−0.58)	(6.34)	(16.53)	(6.78)
Day FE	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes
Country-month FE	No	No	No	No	No
Number of observations	8,471	989	4,174	1,817	882
R^2	0.959	0.739	0.941	0.922	0.850

Panel B: Fixed-effect regressions with country-month fixed effects

	(1) 2008–2012 S1	(2) 2008-Lehman	(3) 2009–2010	(4) 2011	(5) 2012 S1
Sovereign CDS	0.015	−0.010	0.002	0.076**	0.007
	(1.19)	(−1.30)	(0.21)	(2.28)	(0.57)
Day FE	Yes	Yes	Yes	Yes	Yes
Country FE	No	No	No	No	No
Country-month FE	Yes	Yes	Yes	Yes	Yes
Number of observations	8,471	989	4,174	1,817	882
R^2	0.980	0.785	0.950	0.949	0.946

Panel C: GIIPS vs. *non-GIIPS countries*

	(1) 2008–2012 S1	(2) 2008-Lehman	(3) 2009–2010	(4) 2011	(5) 2012 S1
Sovereign CDS	−0.051***	−0.130	−0.030	−0.108***	0.016
	(−2.87)	(−0.58)	(−1.23)	(−3.36)	(1.13)
GIIPS × *Sovereign CDS*	0.066***	0.028	0.030	0.208***	−0.009
	(3.43)	(0.15)	(1.32)	(5.24)	(−0.48)
Day FE	Yes	Yes	Yes	Yes	Yes
Country FE	No	No	No	No	No
Country-month FE	Yes	Yes	Yes	Yes	Yes
Number of observations	8,471	989	4,174	1,817	882
R^2	0.981	0.785	0.950	0.950	0.946

in non-GIIPS CDS spreads indicates general stress in bond markets.[16] In this instance, the CDS spreads of GIIPS countries go up even more, which increases the relative attractiveness of safe haven sovereign debt as collateral. Consistent with this and as expected, the coefficient estimates for the interacted variables *GIIPS* × *Sovereign CDS* are *positive* and statistically significant at 1% in column 1: The statistically significant estimate of 0.066 in column 1 indicates that a one-standard deviation (120 bp) increase in sovereign CDS spreads for GIIPS countries raises the related repo rates by some 8 bp on average. Consistent with results from Panels A and B, this relation becomes more pronounced at the peak of the sovereign crisis, as does the divergence between GIIPS and non-GIIPS countries. In Panel C of Table 2, the coefficients on the two variables *Sovereign CDS* and *GIIPS* × *Sovereign CDS* are insignificant until 2010 (columns 2 and 3). They become strongly significant at the peak of the crisis (in 2011, column 4). Using the estimate of 0.208 for the interaction term in 2011, a one-standard deviation increase in the sovereign CDS spread of GIIPS countries (120 bp) is associated with a $0.208 \times 120 = 25$ bp relative increase in the GC repo rate of these countries. And consistent with our previous findings, this relation between underlying sovereign-debt risk and GC repo rates decreases after the introduction of the first 36-month LTRO in December 2011: In column 5 of Panel C the coefficient for the interaction is statistically insignificant.

We implement here two robustness checks. First, we rule out the possibility that our results are somehow linked to the maturity mismatch between overnight repo

[16] This is apparent from Fig. 4. Average CDS spreads of GIIPS and non-GIIPS countries co-move strongly. Over the entire period that we study, the correlation between the two series is 0.77. In 2011, the peak of the sovereign crisis, it reaches 0.85.

Table 3
GC repo volume and sovereign CDS spreads.

This table reports the estimates of fixed-effect panel regressions in which the dependent variable is the logarithm of the daily country-level general collateral (GC) repurchase agreement volume in €bn (*ln(Daily volume* + 1*)*). The explanatory variables are the daily country-level five-year sovereign credit default swap rate (*Sovereign CDS*) in Panels A and B, and its interaction with an indicator variable equal to one for Greece, Ireland, Italy, Portugal, and Spain (*GIIPS*), and zero otherwise, in Panel C. All regressions include day fixed effects. Moreover, Panel A regressions include country fixed effects, and regressions in Panels B and C include country-month fixed effects. *t*-statistics are presented in parentheses. Standard errors are clustered at the daily level. *, **, and *** denote statistical significance at the 10%-, 5%-, and 1%-level, respectively.

Panel A: Fixed-effect regressions

	(1) 2008–2012 S1	(2) 2008-Lehman	(3) 2009–2010	(4) 2011	(5) 2012 S1
Sovereign CDS	−0.368***	−0.160	−0.900***	−0.413***	−0.412***
	(−8.27)	(−0.10)	(−17.42)	(−4.77)	(−3.94)
Day FE	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes
Country-month FE	No	No	No	No	No
Number of observations	10,135	1,263	5,053	2,117	989
R^2	0.174	0.207	0.198	0.180	0.320

Panel B: Fixed-effect regressions with country-month fixed effects

	(1) 2008–2012 S1	(2) 2008-Lehman	(3) 2009–2010	(4) 2011	(5) 2012 S1
Sovereign CDS	−0.183	4.088	−0.107	−0.302	−0.443
	(−1.23)	(1.12)	(−0.59)	(−0.98)	(−1.39)
Day FE	Yes	Yes	Yes	Yes	Yes
Country FE	No	No	No	No	No
Country-month FE	Yes	Yes	Yes	Yes	Yes
Number of observations	10,135	1,263	5,053	2,117	989
R^2	0.811	0.851	0.791	0.828	0.849

Panel C: GIIPS vs. *non-GIIPS countries*

	(1) 2008–2012 S1	(2) 2008-Lehman	(3) 2009–2010	(4) 2011	(5) 2012 S1
Sovereign CDS	0.345	−0.645	1.433**	0.128	−0.533
	(1.10)	(−0.09)	(2.34)	(0.31)	(−1.03)
GIIPS × *Sovereign CDS*	−0.523*	4.396	−1.489**	−0.471	0.098
	(−1.73)	(0.78)	(−2.53)	(−1.08)	(0.20)
Day FE	Yes	Yes	Yes	Yes	Yes
Country FE	No	No	No	No	No
Country-month FE	Yes	Yes	Yes	Yes	Yes
Number of observations	10,135	1,263	5,053	2,117	989
R^2	0.811	0.851	0.791	0.828	0.849

rates and the five-year sovereign CDS.[17] When we replace the latter with the one-year sovereign CDS rates (the shortest sovereign CDS maturity available to us), we obtain very similar results (which we report in Appendix Table A1, Panel A). Second, we explore whether our results are CCP-dependent, and find that they are not. As we explain above, Italian GC repo transactions are cleared by CC&G, while all other repos are traded via ICAP and cleared via LCH.Clearnet. To investigate the possibility that only CC&G, and not LCH.Clearnet, is considered at risk by the market, we repeat the same regressions excluding Italian transactions and report them in Appendix Table A1, Panel B. We find that our results are not materially affected.

4.3. Repo volume and sovereign risk

In this section, we ask whether sovereign risk affects trading volume on the repo market. To do this, we run variants of Eq. (3), in which the dependent variable is now the daily volume traded instead of the repo rate. We take the logarithm of 1 + volume, and we attribute a volume of zero to days with no transactions. Our results are not sensitive to this convention, and carry through when we exclude days with missing observations instead. Regression results are reported in Table 3, which is structured exactly like Table 2 (country and month fixed effects in Panel A, country-month fixed effects in Panel B, GIIPS/non-GIIPS interaction in Panel C).

Table 3 shows that the effects we observed for repo rates become somewhat weaker when we look at volume. Panel A shows a strong negative relationship between CDS spreads and repo volume over the entire period, but also

[17] See Augustin (2013) on the term structure of CDS spreads.

in most subperiods and not just the "sovereign crisis time" period. Panel B shows that all these effects are driven by low (monthly) frequency movements in country-level factors. Once we include country-month dummies, the average effect becomes statistically insignificant in all periods, including 2011. We notice, however, that the coefficient is not driven to zero, it only becomes more noisily estimated. Panel C does not show strong evidence that the sensitivity of repo volume to sovereign CDS spreads is stronger for GIIPS countries, as it was very strongly the case for repo rates.

5. The transmission channel between sovereign CDS spreads and repo rates

Our next objective is to understand how shocks to GIIPS CDS spreads are transmitted to repo rates. To do this, we use the model of Section 3. If we take Eq. (2) literally, the sensitivity of repo rates to CDS spreads should be equal to $p\lambda G(h)/G(0)$. It means that sovereign stress transmits to repo rates more when (1) haircuts are set less conservatively, (2) the conditional probability of CCP member failure increases or, (3) the conditional probability of CCP failure increases. Here, we investigate the relative importance of these determinants one by one.

5.1. Haircuts

A conservative haircut policy has the potential to eliminate, or at least attenuate, the effect of stress on repo rates. However big the increase in default probabilities of the CCP or some of its members, a high enough haircut h leads to a negligible conditional loss given default $G(h)$, thereby breaking the link between sovereign CDS spreads and repo rates. The findings above show that this link is present in 2011, indicating that haircuts were not generally high enough at that time. To investigate the effect of haircuts on repo rates, we focus on three instances in which haircuts were increased sharply, and ask whether the repo rate-to-CDS sensitivity was affected by these changes in haircuts. Clearly, haircut modifications are themselves endogenous and are adjusted in response to heightened sovereign stress. To deal with this concern, we focus on short periods around haircut changes, but we acknowledge this method is imperfect.

From the website of LCH.Clearnet we could find haircut changes for France, Spain, and Italy. These are plotted in Fig. 5. These haircuts are averaged across maturity groups (below and above seven years). We focus on three episodes in which LCH.Clearnet raises haircuts by more than 100 bp. The first two haircut changes occurred for Spain (December 16, 2010 and September 21, 2011), the last one for Italy (November 10, 2011). For the two Spanish haircut changes, we focus on a three-month window around the haircut change, because the change follows a relatively neat "step function." These two "experiments" correspond to relatively modest haircut rises (slightly above 100 bp). The Italian shock of 2011 is bigger: The haircut goes up from approximately 6% to 10%. The problem with this change is that it only lasted a month, after which the haircut went back to 7%. As a result, for the Italian test we thus restrict ourselves to a one-month window around November 10, 2011.

The results are reported in Table 4. For each shock, we run a variant of Eq. (3) in which we interact all terms with a *POST* dummy variable equal to one after the haircut change, and zero before. We report the results of these regressions in columns 1, 3, and 5. In this case, the coefficient of interest is the interaction term *POST* × *Sovereign CDS*. We then extend the sample to all other countries and add to the specification the *HC Country* dummy variable, which is equal to one if the country experiences a haircut change (the "treatment" country), and zero otherwise. These regressions are in the spirit of difference-in-difference tests: They allow us to compare the change in repo-to-CDS spread sensitivity in treated countries relative to other Eurozone countries around the haircut change. The coefficient of interest in these regressions is the triple interaction *POST* × *HC Country* × *Sovereign CDS*. These regressions appear in columns 2, 4, and 6 of Table 4.

Overall, the results are consistent with haircuts being effective in "normal times," but not in the second half of 2011, the peak of the sovereign crisis in Europe. The first Spanish haircut seems to have been effective at reducing stress on the Spanish repo market. In Table 4, column 2, the excess sensitivity of Spanish repo rates to CDS spreads goes down from a statistically positive 0.209 before the haircut change to −0.027 (= 0.209 – 0.236), i.e., close to zero, after the change. By contrast, for the changes occurring in 2011, the sensitivity increases strongly after the haircut increase, which we interpret as evidence that the haircut increase was not large enough to insulate the repo market from sovereign stress. In both the Italian and the Spanish cases, the repo rate-to-CDS spread sensitivity actually increased after the haircut increase (columns 3–6).

5.2. CCP members risk

When CCP member risk (p in our model) goes up, we also expect the repo-to-CDS sensitivity $p\lambda G(h)/G(0)$ to increase. In this section, we propose a measure of p and investigate how it changes over time. We show that, if anything, p decreased in 2011, a result coherent with the fact that banks in the Eurozone decreased their exposure to their own sovereigns in 2011 as Angeloni and Wolff (2012) and Acharya and Steffen (2015) show.

To measure p, we regress the average CDS spread of CCP members on the CDS spread of GIIPS countries. Note that p is the probability of default of the average member *conditional* on sovereign default. As such, it may differ substantially from an unconditional default probability. To estimate it, we exploit Bayes' law and assumptions about stationarity. Let P_t be the unconditional probability that the average CCP member defaults at date t; π_t is the sovereign default probability; ρ is the probability of member default conditional on GIIPS non-default. According to Bayes' law:

$$P_t = p\pi_t + \rho(1 - \pi_t) = (p - \rho)\pi_t + \rho, \tag{4}$$

where we assume that both conditional member default probabilities p and ρ are stationary. By regressing P_t on π_t, we obtain an estimate of the difference between the

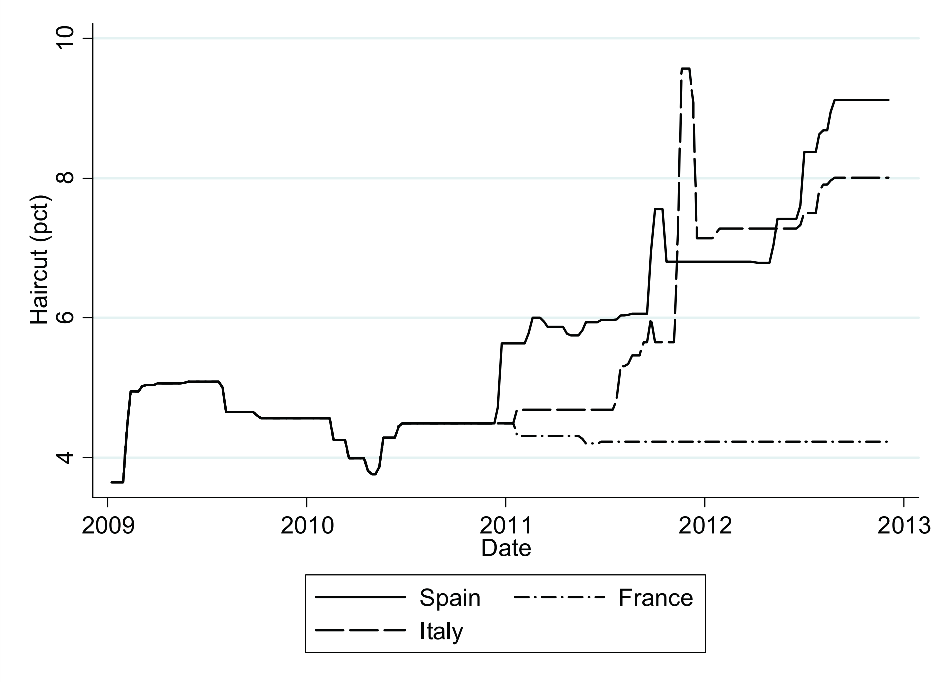


Fig. 5. The evolution of haircuts. This figure presents the evolution of haircuts applied to general collateral (GC) repo transactions by ICAP BrokerTec in France, Italy, and Spain between 2008 and June 2012. Haircuts are averaged across maturity groups (below and above seven years) and are expressed in percent.

two default probabilities ($p-\rho$), which is a lower bound for p.

Relying on this insight, we estimate ($p-\rho$) using data on CDS spreads to measure CCP member and sovereign default conditional probabilities. In principle, we could estimate one regression Eq. (4) per sovereign, but reporting results would be cumbersome. To simplify presentation, we only run one regression with π_t measuring average GIIPS sovereign default risk.[18] We use the following first-difference version of Eq. (4):

$$\Delta \mathrm{CDS}_t^{\mathrm{members}} = \alpha + \beta.\Delta \mathrm{CDS}_t^{\mathrm{GIIPS\,sov.}} + \gamma.F_t + \varepsilon_t \qquad (5)$$

where Δ represents daily differences. We use first-difference because DF tests cannot reject the possibility that the (undifferenced) series have unit roots, even within the various subperiods that we analyze, while first-differenced variables are stationary. $\mathrm{CDS}_t^{\mathrm{GIIPS\,sov}}$ corresponds to the average change in five-year CDS on all available GIIPS sovereigns on day t. $\mathrm{CDS}_t^{\mathrm{members}}$ is the average CDS spread of CCP members on day t. We look at three groups of members separately: Members of both LCH.Clearnet and CC&G, members of LCH.Clearnet only, and members of CC&G. We obtain the current list of members from LCH.Clearnet and CC&G from their websites.[19] Finally, F_t is a risk factor for the CDS market, designed to capture fluctuations in spreads that do not come from Eq. (4). To construct this factor, we follow Pan and Singleton (2008) and compute the first principal component of CDS changes of five large European sovereigns (Belgium, France, Germany, Italy, and Spain) that are chosen because their CDS spreads are continuously available over the entire period. The resulting factor loads positively on all five sovereigns. We experimented with alternative measures of the risk factor, without a material change in our results.[20]

Table 5 reports the results. In Panel A, the dependent variable is the average CDS spread of members of CC&G and LCH.Clearnet, the two CCPs clearing trades on the MTS and ICAP platforms, respectively. In Panels B and C, we estimate the average default probabilities of LCH.Clearnet and CC&G members separately. This split is warranted by the fact that members of CC&G are mostly Italian banks and therefore particularly vulnerable to their sovereign CDS. Looking at all panels, we reach the same conclusion: During the sovereign crisis, the probability of member default conditional on GIIPS default does not seem to increase much. If anything, it decreases. This evolution is

[18] As we have seen earlier, repo rates respond more to the CDS spreads of sovereign bonds from GIIPS countries, therefore we focus on CDS spreads of these sovereigns only. Considering average CDS spreads of all countries in the sample yields the same results.

[19] The full list of CC&G's members is available at: http://www.lseg.com/post-trade-services/ccp-services/ccg/membership/members. The list of LCH.Clearnet's members is available at: http://www.lchclearnet.com/fr/members-clients/members/current-membership. Pulling this information from the current website may expose us to some form of look-ahead bias, although it is not entirely clear how it affects our results.

[20] For instance, we have added the second principal component as an additional control, but it was most of the time insignificant, consistent with the findings of Pan and Singleton (2008). We have also used the average sovereign CDS spread, and a change in the VSTOXX index, which measures the implicit volatility on the EUROSTOXX 50. None of these alternative approaches yield materially different results.

Table 4
The impact of haircuts on the repo rate-to-CDS spread sensitivity.

This table reports the estimates of OLS regressions explaining the daily country-level general collateral (GC) repo rate minus the ECB deposit facility rate (*Repo rate-ECB deposit rate)* around the haircut changes on Spanish repos of December 16, 2010 and September 21, 2011 and around the haircut change on Italian repos of November 10, 2011. The explanatory variables are the daily country-level five-year sovereign credit default swap rate (*Sovereign CDS*), an indicator variable equal to one after the haircut change (*POST*), an indicator variable equal to one for Spain or Italy (*HC Country*), and interactions between these variables. Columns 1 and 3 present the results for Spanish repo rates only in a six-month window around the haircut change, respectively for the December 2010 and the September 2011 increases. Column 5 presents the results for Italian repo rates only in a two-month window around the haircut change of November 2011. Columns 2 and 4 present the results for Spanish repo using a difference-in-differences estimation using repo rates from all Eurozone countries as the control group in a six-month window around the two Spanish haircut changes. Column 6 presents the results for Italian repo using a difference-in-differences estimation using repo rates from all Eurozone countries as the control group in a two-month window around the November 2011 haircut change. In columns 1, 3, and 5, standard errors are corrected using the Newey-West procedure with a five-day lag. In columns 2, 4, and 6, standard errors are clustered at the daily level. *t*-statistics are in parentheses. *, **, and *** denote statistical significance at the 10%-, 5%-, and 1%-level, respectively.

	Spain December 2010 haircut change		Spain September 2011 haircut change		Italy November 2011 haircut change	
	(1)	(2)	(3)	(4)	(5)	(6)
	Spain only	Spain and others	Spain only	Spain and others	Italy only	Italy and others
Sovereign CDS	−0.082	−0.291***	−0.385***	−0.245***	−0.095	−0.111
	(−1.47)	(−5.98)	(−3.51)	(−6.24)	(−1.01)	(−1.53)
POST	0.586***	0.068*	−1.501***	−0.340***	−1.289***	−0.095**
	(2.79)	(1.70)	(−3.73)	(−8.48)	(−3.00)	(−2.04)
POST × Sovereign CDS	−0.209**	0.027**	0.524***	0.203***	0.357***	0.059***
	(−2.26)	(2.07)	(4.01)	(9.88)	(3.30)	(2.76)
HC Country × Sovereign CDS		0.209***		−0.140		0.017
		(4.24)		(−1.05)		(0.16)
POST × HC Country		0.518***		−1.161**		−1.172**
		(2.68)		(−2.32)		(−2.21)
POST × HC Country × Sovereign CDS		−0.236**		0.320**		0.291**
		(−2.58)		(2.06)		(2.22)
Constant	0.524***	0.644***	1.498***	0.580***	0.851**	0.272**
	(4.19)	(11.25)	(4.52)	(6.12)	(2.36)	(2.27)
Country FE	No	Yes	No	Yes	No	Yes
Number of obs.	88	997	111	951	44	333
R^2		0.148		0.571		0.803

consistent with the findings of earlier papers, which show that banks in GIIPS countries reduced exposure to their own sovereigns in 2011 (Angeloni and Wolff, 2012; Acharya and Steffen, 2015).[21]

Overall, the evolution of our estimates of CCP member risk p during the crisis does not match the evolution of the repo rate-to-sovereign CDS spread found in earlier tables: Repo stress is the highest in 2011, but this is precisely the moment when member risk p is decreasing. There are two potential explanations for this: (1) Market participants' perception that CCP failure risk increased (i.e., λ increased), or (2) haircuts did not increase enough to compensate increased sovereign bond risk (i.e., $G(h)$ increased). Note that in both cases, the probability of CCP failure *conditional* on sovereign default (λ) has to be nonzero. While it is impossible to discard explanation (2) due to lack of data, we offer below evidence supporting explanation (1).

5.3. CCP default pricing

This section discusses the possibility that the increase in repo rates-to-CDS spread sensitivity in 2011 may be explained by an increase in (real or perceived) risk of CCP failure. There is anecdotal evidence that financial regulators and market participants were worried about a large CCP default. For example, Paul Tucker, deputy governor at the Bank of England warned in June 2011 that: "Central counterparties need to adopt prudent collateral policies, but also to monitor the robustness of their clearing members and risks from the business that they are bringing to the CCP. I am not convinced that that is sufficiently recognized by clearing houses or by standard setters" (Stafford, 2011). A few months later, he further stated that "There is a big gap in the regimes for CCPs – what happens if they go bust?" (Grant and Masters, 2011). The market participants whom we spoke with also indicated that the amount of GIIPS collateral that they could take was severely limited by their risk management, in spite of the risk-protection of the CCP. This is consistent with the view that this protection was considered imperfect at that time.

Note also that the key parameter λ in our model is the probability of CCP default *conditional* on sovereign default, which is a priori much higher than the unconditional probability. One possible reason is that sovereigns are themselves a possible backstop liquidity provider for CCPs. As discussed in Section 3.3, for instance, the default fund of LCH.Clearnet was not large enough to accommodate the default of more than two average size members in a situation where their collateral would take a 50% haircut. This

[21] In fact, this reduction in exposure to GIIPS sovereign debt in 2011 is observed for nearly all Eurozone banks (Popov and Van Horen, 2015).

Table 5
GIIPS sovereign CDS spreads and the CDS spreads of CCP members.
This table reports OLS regressions of changes in CCP members' CDS spreads on changes in GIIPS sovereign CDS spreads, controlling for a CDS risk factor. *Change in GIIPS sovereign CDS* is the average daily change in the spread of the five-year sovereign CDS across all five GIIPS countries. *CDS common risk factor* is the first principal component of the vector of CDS changes of all sovereign CDS. In Panel A, the dependent variable is the average change of CDS of LCH.Clearnet and CC&G members. In Panel B, we use the average CDS change of LCH.Clearnet members only. In Panel C, we use the average CDS change of CC&G members only. GIIPS countries are Greece, Ireland, Italy, Portugal, and Spain. Standard errors are robust to heteroskedasticity. *t*-statistics are in parentheses. *, **, and *** denote statistical significance at the 10%-, 5%-, and 1%-level, respectively.

Panel A: ΔCDS of all CCP members

	(1) 2008–2012 S1	(2) 2008-Lehman	(3) 2009–2010	(4) 2011	(5) 2012 S1
ΔGIIPS sovereign CDS	0.001	0.796**	0.033**	0.004	0.0002
	(0.80)	(2.39)	(2.33)	(0.76)	(0.57)
CDS common risk factor	0.025***	0.083***	0.023***	0.022***	0.028***
	(24.88)	(4.01)	(14.10)	(17.35)	(12.08)
Number of observations	1,075	136	486	243	125
R^2	0.482	0.241	0.597	0.689	0.612

Panel B: ΔCDS of members of LCH.Clearnet

	(1) 2008–2012 S1	(2) 2008-Lehman	(3) 2009–2010	(4) 2011	(5) 2012 S1
ΔGIIPS sovereign CDS	0.001	0.815**	0.034**	0.004	0.0002
	(0.79)	(2.37)	(2.21)	(0.79)	(0.47)
CDS common risk factor	0.023***	0.085***	0.022***	0.021***	0.027***
	(23.11)	(4.10)	(14.01)	(16.29)	(11.69)
Number of observations	1,075	136	486	243	125
R^2	0.461	0.237	0.596	0.682	0.612

Panel C: ΔCDS of members of CC&G

	(1) 2008–2012 S1	(2) 2008-Lehman	(3) 2009–2010	(4) 2011	(5) 2012 S1
ΔGIIPS sovereign CDS	0.0005	0.781*	0.020	0.002	0.0005
	(0.35)	(1.98)	(1.29)	(0.26)	(0.89)
CDS common risk factor	0.027***	0.091***	0.023***	0.026***	0.033***
	(28.61)	(3.50)	(12.74)	(19.79)	(13.74)
Number of observations	1,075	136	486	243	125
R^2	0.481	0.219	0.536	0.733	0.621

in itself is an unlikely event, but not necessarily so *conditional* on sovereign default.

To test whether market participants perceived CCP risk to be high, we exploit the fact that a non-negligible fraction of the trades on our two platforms are bilateral and therefore not CCP-cleared. Following our Eq. (3), we ask whether the repo-to-CDS sensitivity is lower among CCP-cleared trades. We use data on GC repo bilateral transactions between January 2011 and June 2012 on all non-GIIPS markets plus Italy, Portugal, and Spain.[22] Bilateral transactions are similar to CCP-based ones in that they use the same GC lists and haircuts, but they are not anonymous. Thus, bilateral transactions that go through trading platforms are very similar to OTC transactions. They represent smaller volumes than the CCP-cleared transactions that we focused on previously, but they are still large enough to help us implement our test. In non-GIIPS countries, bilateral trades represent about 15% of CCP-cleared trades and are quite stable over time. In Portugal and Spain, they represent much smaller volumes, in particular in the last four months of 2011, when they virtually disappear.

Because bilateral trades are less frequent than CCP-cleared ones, many days have no transaction data, and therefore no bilateral repo rate. To get around this data limitation, we aggregate the rates at the monthly level, taking the average monthly rate for the two series needed to create the dependent variable, and replacing country-month fixed effects by separate country fixed effects and month fixed-effects.[23] We then repeat the tests of Table 2 separately for CCP-based and bilateral repo rates.

Table 6 reports the results. In column 1 of Panel A, in which the dependent variable is the CCP-cleared repo spread (over and above ECB deposit rate) in year 2011, the coefficient on *Sovereign CDS* is negative but statistically insignificant. The coefficient on *GIIPS* × *Sovereign CDS* is statistically significant and, reassuringly, of the same order of magnitude as the corresponding coefficient that we

[22] Appendix Fig. A3 presents the monthly trading volumes of CCP-based vs. bilateral transactions in our sample. These data exclude Greece and Ireland, as their repo markets shut down before January 2011.

[23] Our results are the same if we use daily rates and keep only days with nonzero bilateral trade volume.

Table 6
Repo-to-CDS spread sensitivity in CCP-cleared vs. bilateral transactions.
This table reports the estimates of fixed-effect panel regressions in which the dependent variable is the monthly country-level volume-weighted average general collateral (GC) repo rate minus the ECB deposit facility rate (*Repo rate – ECB deposit rate*) in column 1 and the monthly country-level volume-weighted average bilateral repo rate minus the ECB deposit facility rate in column 2. The explanatory variables are the volume-weighted average monthly country-level five-year sovereign credit default swap rate (*Sovereign CDS*), and its interaction with an indicator variable that is equal to one for Portugal, Italy, and Spain (*GIIPS*), and zero otherwise. Observations are limited to countries for which both bilateral and GC repo transactions are observed in a given month. The regressions include month fixed effects and country fixed effects. *t*-statistics are presented in parentheses. Standard errors are clustered at the monthly level. *, **, and *** denote statistical significance at the 10%-, 5%-, and 1%-level, respectively.

Panel A: 2011

	(1) CCP	(2) Bilaterall
Sovereign CDS	−0.018	−0.003
	(−0.31)	(−0.05)
GIIPS × Sovereign CDS	0.186***	0.141**
	(4.57)	(2.66)
Month FE	Yes	Yes
Country FE	Yes	Yes
Number of observations	84	84
R^2	0.942	0.882

Panel B: 2012

	(1) CCP	(2) Bilateral
Sovereign CDS	0.038**	0.019
	(2.86)	(0.50)
GIIPS × Sovereign CDS	−0.016	0.018
	(−1.12)	(0.54)
Month FE	Yes	Yes
Country FE	Yes	Yes
Number of observations	38	38
R^2	0.985	0.944

obtain on the same interaction variable in Table 2, Panel C. In column 2, a similar result holds for bilateral rates but the coefficient on *GIIPS × Sovereign CDS* is smaller than in column 1. This suggests that in 2011, repo rates are not less sensitive to sovereign stress in the CCP-based segment of the market (if anything, the contrary happens). They are, however, in 2012 (Panel B), when the coefficient on *GIIPS × Sovereign CDS* becomes smaller for CCP-based repo than for bilateral repo, although both coefficients are statistically insignificant. These results have to be interpreted with care because when sovereign stress rises, the pool of banks that have access to the bilateral market may shrink to only the safest ones. Thus, the test on bilateral repo rates probably underestimates their sensitivity to sovereign stress.

6. Alternative hypotheses

6.1. Market power of lenders

An alternative explanation of our findings is that the second half of 2011 was a period of increased market power of investors willing to lend cash against stressed sovereign collateral. The intuition is that during this phase of intense sovereign stress, most cash-rich banks refused to increase their exposure to GIIPS sovereign risk. At the same time, banks in the periphery had few alternative sources of funding and were thus ready to accept higher rates to be able to continue borrowing from the repo market. As a result, the increase in the repo rates-to-CDS spreads sensitivity that we document could come from a handful of cash-rich banks willing to lend against bonds that few wanted as collateral.

The demand and supply for repo transactions are hard to estimate, but a few elements suggest that shifts in the demand and supply curves on the repo market cannot fully explain our main finding. On the borrowing side, July-December 2011 is a period during which the supply of GIIPS collateral from potentially risky counterparties was going *down*, not up. Angeloni and Wolff (2012) show that between July and December 2011, holdings of their own sovereign bonds by Italian, Spanish, Irish, and Portuguese banks went down in absolute terms. Acharya and Steffen (2015) document that, over 2011, own-sovereign holdings of GIIPS banks went down by about 3%. If anything, it looks like GIIPS banks had less GIIPS collateral to supply, not more, in the second half of 2011.

On the lending side, we could not find evidence of weaker competition between lenders in 2011S2. Our transactions data do not contain counterparty IDs. As a result, we cannot measure lender concentration directly. But some aggregate data are available, and these do not show evidence of increased concentration on the repo market. We show this evidence in Fig. A4. First, the ECB Euro Money Market Surveys from 2009 to 2014 report annually the percentage of reverse repos accounted for by the top five, ten, and 20 largest European banks in this market. Over time, the market share of the largest banks did not increase but instead *decreased* (Appendix Fig. A4, Panel A). Second, we use Bankscope and pull data on reverse-repos from the balance sheets of banks. The evolution of the Herfindahl-Hirschman Index based on this variable suggests that over time, the lending side of the repo market becomes *less*, not more, concentrated, with no breakdown of this trend in 2011 (Appendix Fig. A4, Panel B). Unfortunately, we cannot observe this concentration separately for each type of sovereign collateral, so we cannot rule out the possibility that the lending side of the repo market became more competitive on some bonds and less competitive on others. However, increased overall competition in this market suggests that arising opportunities should have been arbitraged away more easily in 2011 than in the earlier years in our study.

A way to account for the possibility that banks from GIIPS countries suffered from a liquidity crunch is to add country-level variables that capture this phenomenon in our main specification. This liquidity shortage story posits that banks from GIIPS countries would have difficulty accessing the unsecured interbank market because of higher risk associated with their sovereign or themselves. Thus, their only way to obtain funding is to borrow on the repo market against collateral that cash-rich banks are reluctant to accept, which leads to an increased cost of borrowing.

Table 7
GC repo rates and banks' funding liquidity risk.
This table report estimates of fixed-effect panel regressions in which the dependent variable is the daily country-level average general collateral (GC) repurchase agreement rate minus the ECB deposit facility rate (*Repo rate – ECB deposit rate).* The explanatory variables are the daily country-level five-year sovereign credit default swap rate (*Sovereign CDS*), the GIIPS indicator variable equal to one for Greece, Ireland, Italy, Portugal, and Spain (*GIIPS*), and zero otherwise and a country-level proxy funding liquidity risk, which is equal to the daily country-level volume of outstanding Certificates of Deposit (*CD volume*) in Panel A and the daily country-level average of five-year CDS spreads of local banks (*Local banks' CDS*) in Panel B. All regressions include day fixed effects and country-month fixed effects. *t*-statistics are presented in parentheses. Standard errors are clustered at the daily level. *, **, and *** denote statistical significance at the 10%-, 5%-, and 1%-level, respectively.

Panel A: Funding liquidity risk proxied by outstanding CD volume

	(1) 2008–2012 S1	(2) 2008-Lehman	(3) 2009–2010	(4) 2011	(5) 2012 S1
Sovereign CDS	−0.056***	−0.200	−0.045	−0.096***	0.022
	(−3.06)	(−0.87)	(−1.64)	(−3.09)	(1.65)
CD volume	0.0004	0.002**	0.0002	−0.0005	−0.0004*
	(0.92)	(2.00)	(0.30)	(−0.47)	(−1.77)
GIIPS × *Sovereign CDS*	0.073***	0.143	0.038	0.178***	−0.013
	(3.77)	(0.74)	(1.52)	(4.50)	(−0.71)
GIIPS × *CD volume*	−0.018***	−0.002	−0.003	−0.039***	−0.002
	(−4.44)	(−0.27)	(−0.76)	(−4.43)	(−0.19)
Day FE	Yes	Yes	Yes	Yes	Yes
Country-month FE	Yes	Yes	Yes	Yes	Yes
Number of observations	7,362	815	3,555	1,658	837
R^2	0.980	0.777	0.950	0.949	0.947

Panel B: Funding liquidity risk proxied by CDS spreads

	(1) 2008–2012 S1	(2) 2008-Lehman	(3) 2009–2010	(4) 2011	(5) 2012 S1
Sovereign CDS	−0.038**	−0.173	−0.019	−0.073**	0.019
	(−2.30)	(−0.69)	(−0.74)	(−2.58)	(1.60)
Local banks' CDS	−0.017	−0.077	−0.025*	−0.004	0.018
	(−1.44)	(−1.09)	(−1.84)	(−0.21)	(1.46)
GIIPS × *Sovereign CDS*	0.040**	0.023	0.005	0.134***	−0.034
	(2.08)	(0.12)	(0.21)	(3.37)	(−1.31)
GIIPS × *Local banks' CDS*	0.039**	0.027	0.034**	0.080**	0.012
	(2.50)	(0.79)	(2.52)	(2.41)	(0.50)
Day FE	Yes	Yes	Yes	Yes	Yes
Country-month FE	Yes	Yes	Yes	Yes	Yes
Number of observations	7,683	815	3,821	1,713	837
R^2	0.980	0.771	0.952	0.949	0.947

To measure the access of local banks to the unsecured interbank market, we collect data on daily outstanding volume of Certificates of Deposit (CD) at the level of each country in our sample. This variable should take low values when a country's banks have difficulty accessing the unsecured funding market. As an alternative proxy for the liquidity crunch facing European banks we use daily country-level bank CDS spread. This measure should peak when banks are under severe liquidity stress. It is a less precise measure of funding difficulties of banks than the outstanding CD volume, but it allows us to capture more generally situations in which changes in GIIPS repo rates are driven by difficulties, including liquidity funding problems, faced by of GIIPS banks.

In Table 7, we repeat our main tests of Table 2 adding one control variable at a time. In Panel A, column 4 the coefficient estimate for the *GIIPS* × *Sovereign CDS* interaction is negative (and statistically significant) as expected: As country-level outstanding *CD volume* increases, repo spread decreases in 2011. In Panel B, column 4 the coefficient estimate for the *GIIPS* × *Sovereign CDS* interaction is positive (and statistically significant) as expected: As country-level average bank CDS spread increases, repo spread increases in 2011. Importantly for us, adding these variables does not eliminate the strong relation between sovereign CDS spreads and repo rates in 2011, suggesting that this latter finding is not mostly due to liquidity stress of GIIPS banks.

6.2. Haircut policy of the ECB

In this section, we explore the possibility that the ECB's haircut policy may drive our results. The ECB does most of its monetary policy interventions on the repo market, so it has the power to affect repo rates. Conventional monetary policy operations are not country- specific, so they should be absorbed in the day fixed effects of our regressions. But since the crisis, the ECB has started to intervene through its collateral list, by changing the haircuts that it takes on specific collateral.[24] It could be the case that the ECB responds to increased sovereign risk by differentially increasing the haircuts it demands on riskier sovereigns. If the CCPs in our data fail to react by aligning their haircuts on the ECB, lending cash against stressed collateral through the CCP becomes less attractive to investors, and rates should increase. Thus, if the ECB increases haircuts on stressed sovereigns, our estimates would be biased upward. If, on the contrary, the ECB reduces haircuts on stressed sovereigns, they are biased downward.

To implement this test, we add the ECB's haircut as an additional control to Eq. (3) and we estimate the following equation:

$$r^{\text{Repo}}{}_{c,t} - r^{\text{ECB}}{}_{t} = \beta . Sovereign\, CDS_{c,t} + \gamma . ECB\, HC_{c,t} + \delta_{c,m} + \delta_t + \varepsilon_{c,t} \tag{6}$$

where $ECB\ HC_{c,t}$ is the average haircut taken by ECB on sovereign bonds of country c at date t. We compute this measure using the publicly available collateral list of the ECB.[25] A natural hypothesis is that $\gamma > 0$: When the ECB increases its haircut on country c, lending to the ECB becomes relatively more attractive (safer), and lending through the platform requires a higher risk premium. If however, $ECB\ HC_{c,t}$ and $CDS_{c,t}$ are positively correlated, and the haircut is omitted from the equation, the Ordinary Least Squares (OLS) estimate of β is biased upward.

We report estimates of Eq. (6) in Appendix Table A2. We only report results including country-month fixed effects though results without them deliver the same message. In both specifications (with sovereign CDS, or sovereign CDS interacted with the GIIPS dummy), controlling for the haircut of the ECB does not change our results.

6.3. Accounting for country-specific risk exposure

In Eq. (3), we control for common factors on the repo market through the inclusion of a day fixed effect. The limitation of this approach is that it assumes that all repo rates have the same exposure to the risk factors. However, it is reasonable to think that some countries have different exposures to the same risk factor. Our main specification partially deals with this issue with country-month fixed effects, but these can only capture slow-moving factors. Given the data available to us, we cannot identify the effect of the sovereign CDS if we introduce country-level day-fixed effects as well. In this section, we adopt a different approach: We focus on a specific risk factor (the VIX), and allow for different country-specific exposures across country-level repo rates. We do this by estimating the following version of our basic Eq. (3):

$$r^{\text{Repo}}{}_{c,t} - r^{\text{ECB}}{}_{t} = \beta . Sovereign\ CDS_{c,t} + \gamma_c . Vix_t + \delta_{c,m} + \delta_t + \varepsilon_{c,t} \tag{7}$$

where Vix_t is the VIX obtained at the daily frequency from Datastream. γ_c captures the country-specific exposure to volatility risk. While there is no clear consensus in the literature about the factor structure of repo rates, we take the VIX as a first-pass measure of "risk aversion" like Mancini, Ranaldo and Wrampelmeyer, (2015).

We run Eq. (7) and report the results in Table A3. We only report results including country-month fixed effects though results without them deliver the same message. In both specifications (with sovereign CDS, or sovereign CDS interacted with the GIIPS dummy), controlling for differential country exposures to VIX does not change our results.

7. Conclusion

We analyze the sensitivity of repo market rates to sovereign default risk during the Eurozone crisis. This sensitivity is very high, even for CCP-cleared repos, in which lenders are in principle protected against default risks. We propose a simple framework that allows us to decompose this sensitivity into (1) CCP default risk, (2) CCP members default risk, and (3) haircut policy effectiveness. In 2009–2010, the sensitivity is low, in spite of significant bank risk. The evidence from a haircut increase experiment in 2010 suggests that CCP haircut policies appear to have been effective at reducing repo stress. Overall, markets behave as if the CCP was able to insulate the repo market from stress in 2009–2010. In 2011, however, attempts at raising haircuts prove ineffective. The repo-to-sovereign risk sensitivity increases strongly, despite the fact that bank default risk decreases somewhat during that period.

Our results are consistent with CCP failure being perceived as a reality and being priced in repo rates. Given how crucial the repo market is for banks, such failure needs to be dealt with through ex ante regulation. Until 2011, explicit resolution frameworks (especially end-of-waterfall loss-sharing rules) were lacking because CCPs were perceived as solid and unlikely to fail. However, 2011 has proved that this was not the case and central banks began to push much harder for explicit CCP resolution frameworks.

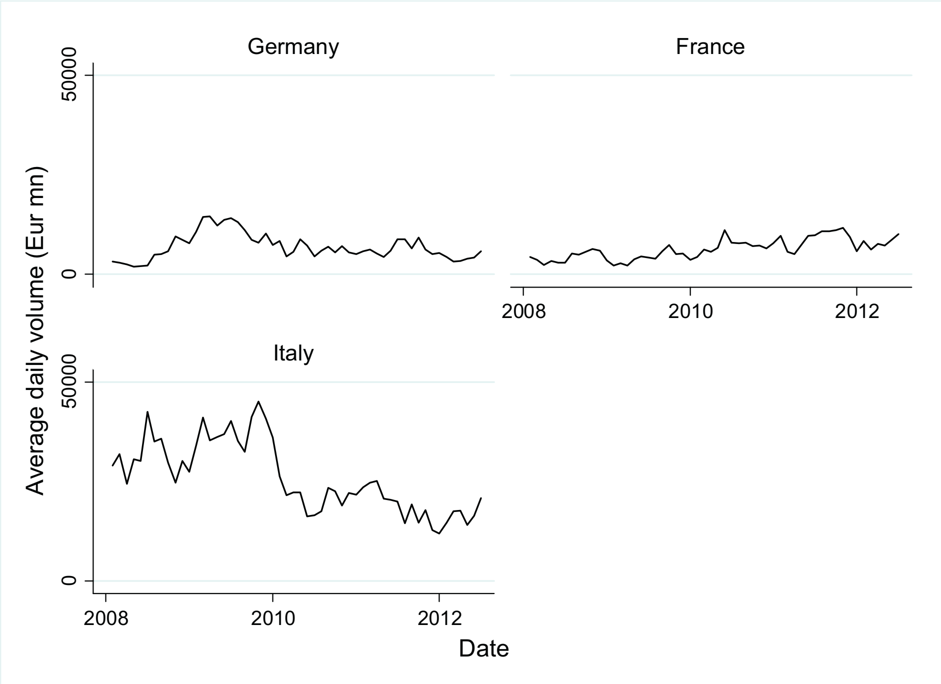
Our analysis may also suggest that central banks have the power to alleviate stress on CCPs through massive intervention. After the December 2011 LTRO announcement by the ECB, repo rates-to-CDS spreads sensitivity went down dramatically, indicating that market participants have stopped pricing CCP default risk. There are many possible channels through which this may be the case. For instance, by making large long-term loans to borrowers, the ECB may have made it much less risky for lenders to lend through private CCP-cleared platforms, but this is only one of the channels.

Appendix A: Supplementary tables and figures

[24] Nyborg (2016) suggests that differential ECB haircuts have effectively subsidized certain sovereigns.

[25] We are grateful to Guillaume Vuillemey for sharing these data with us.

Panel A: Germany, France, Italy



Panel B: Austria, Belgium, Spain, Finland, the Netherlands

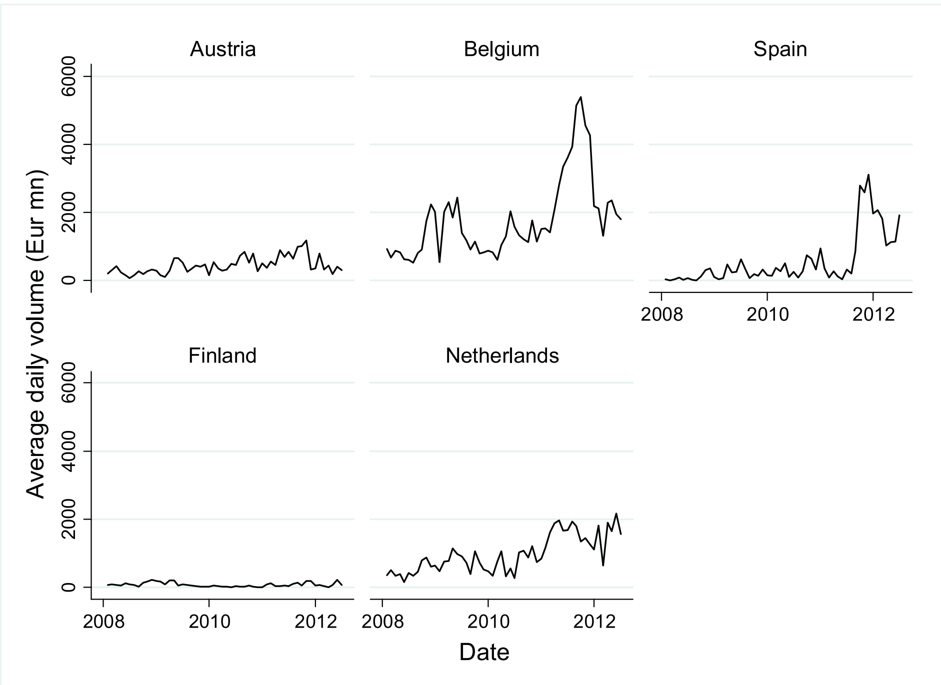


Fig. A1. Evolution of the volume of repo transactions in the Eurozone by country, 2008–2012 S1.
This figure presents the evolution of the average daily volume of general collateral (GC) repo in the Eurozone over our sample period, between January 2008 and June 2012, by country. All amounts are in €m, but each panel uses a different scale. Panel A is restricted to Germany, Italy, and France. Panel B presents all other countries that did not seek foreign assistance through a bailout program. Panel C is restricted to countries that entered assistance programs (Ireland, Portugal, and Greece). The start dates of bailout programs are indicated by vertical lines.

Panel C: Greece, Ireland, Portugal

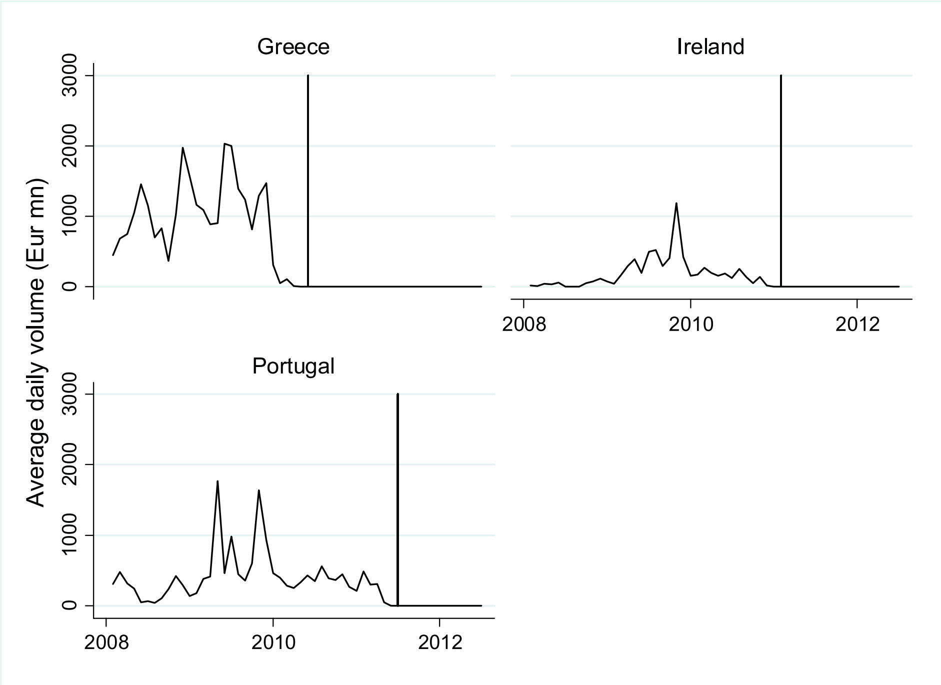


Fig. A1. Continued

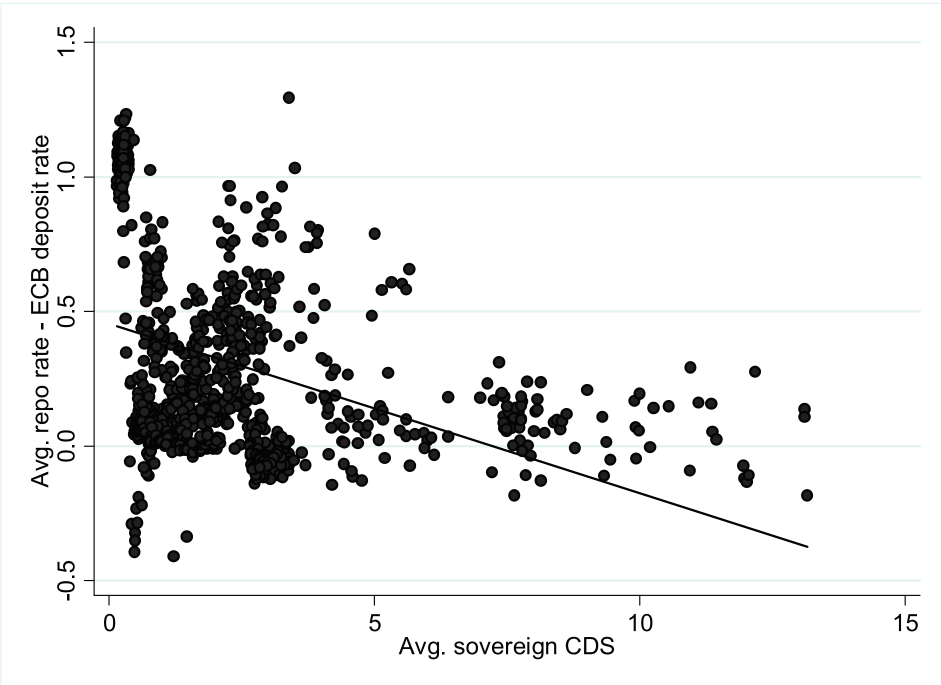
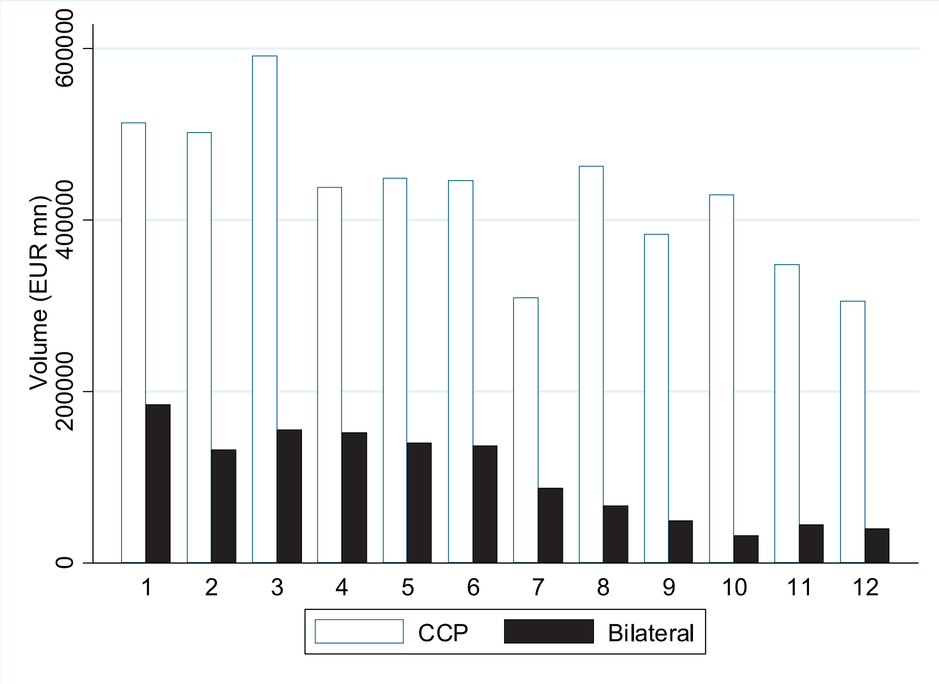


Fig. A2. Relationship between repo rates and sovereign CDS spreads.
This figure presents a scatter plot of the relationship between the average daily repo rate and the average daily sovereign CDS spread, across the 11 repo markets in our data. Each dot corresponds to one day. On the *x*-axis, we report the average sovereign CDS spread across the 11 countries. On the *y*-axis, we report the average difference between the repo rate and the ECB deposit rate across the same 11 countries. Our data include 1,149 observations, corresponding to all days between January 1, 2008 and June 30, 2012. The coefficient of the regression of repo rates on CDS spreads is −0.06, with a heteroskedacity-adjusted *t*-statistic of −14.01.

Panel A: Italy, Portugal, and Spain



Panel B: Non-GIIPS countries

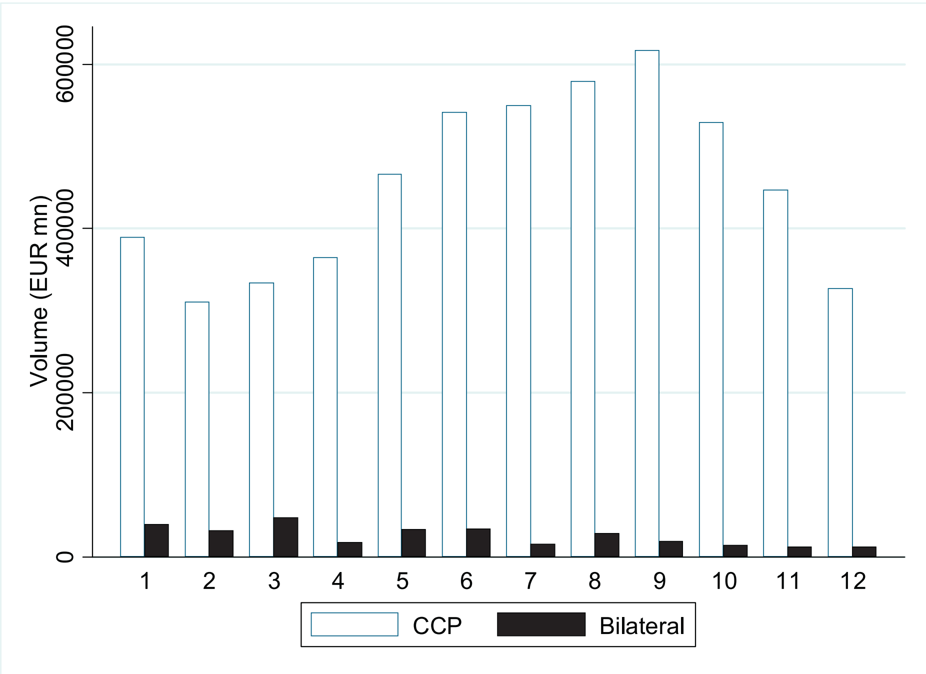
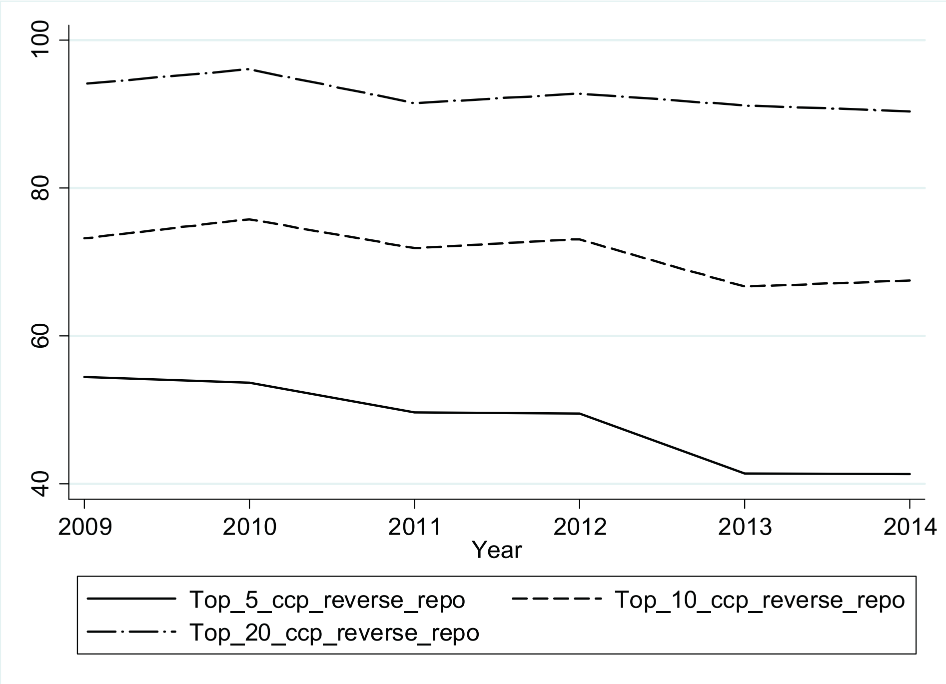


Fig. A3. Monthly volumes of CCP-cleared versus bilateral repo transactions in 2011.
This figure presents volumes of CCP-based and bilateral GC repo transactions in the Eurozone for each month of 2011. Panel A presents volume for GIIPS countries for which data are available (Italy, Portugal, and Spain). Panel B presents volume for all non-GIIPS countries in our data set. All amounts are in €m.

Panel A: Share of largest participants to CCP-cleared repo



Panel B: Herfindahl-Hirschman Index of reverse repo market concentration

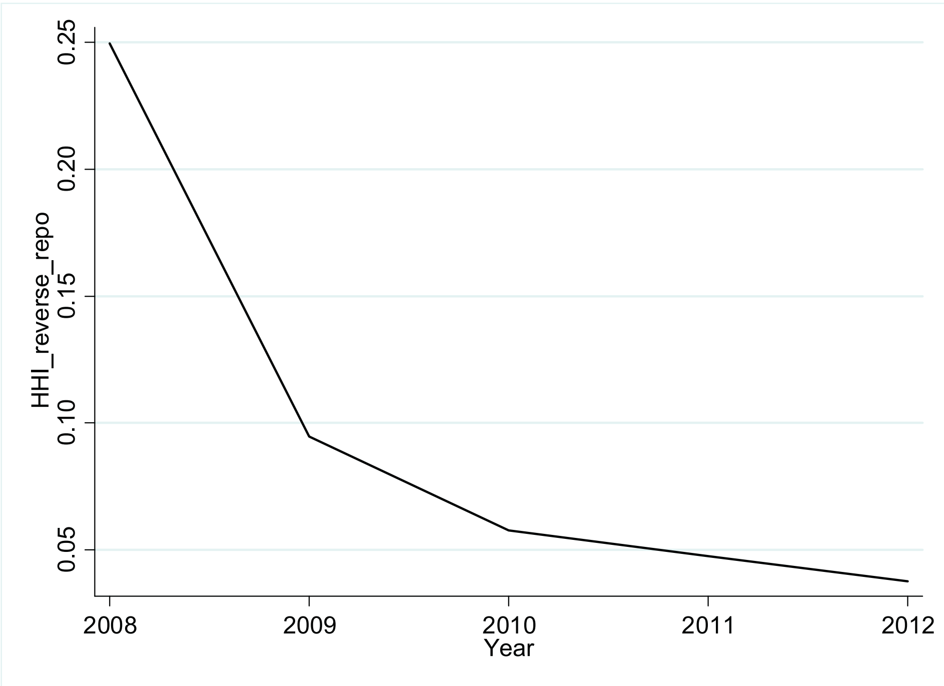


Fig. A4. Concentration on the CCP-cleared repo market.
Panel A presents the annual percentage share of reverse repos by the top five, ten, and 20 largest European banks as reported in the ECB Money Market Surveys published annually from 2009 to 2014. Panel B presents the evolution of the Herfindahl-Hirschman Index, which is calculated based on reverse repo data from Bankscope.

Table A1
GC repo rates and sovereign CDS spreads – Robustness checks.

This table reports the estimates of fixed-effect panel regressions in which the dependent variable is the country-level average daily general collateral (GC) repurchase agreement rate minus the ECB deposit facility rate (*Repo rate-ECB deposit rate).* In Panel A, the explanatory variable is the daily country-level one-year sovereign credit default swap rate (*Sovereign CDS*) and its interaction with an indicator variable that is equal to one for Greece, Ireland, Italy, Portugal, and Spain (*GIIPS*), and zero otherwise. In Panel B, we run the same regression with the five-year sovereign CDS rate (as in Table 3, Panel B) excluding Italy from the sample. All regressions include day and country-month fixed effects. *t*-statistics are presented in parentheses. Standard errors are clustered at the daily level. *, **, and *** denote statistical significance at the 10%-, 5%-, and 1%-level, respectively.

Panel A: Repo-to-CDS spread sensitivity with one-year sovereign CDS

	(1) 2008–2012 S1	(2) 2008-Lehman	(3) 2009–2010	(4) 2011	(5) 2012 S1
Sovereign CDS	−0.032**	−0.350	−0.017	−0.064**	0.005
	(−2.10)	(−1.41)	(−0.72)	(−2.30)	(0.45)
GIIPS × Sovereign CDS	0.055***	0.122	0.022	0.180***	−0.012
	(3.20)	(0.52)	(1.02)	(5.40)	(−0.79)
Day FE	Yes	Yes	Yes	Yes	Yes
Country-month FE	Yes	Yes	Yes	Yes	Yes
Number of observations	7,151	846	3,653	1,460	716
R^2	0.979	0.793	0.947	0.944	0.945

Panel B: Fixed-effect regressions with country-month fixed effects excluding Italy

	(1) 2008–2012 S1	(2) 2008-Lehman	(3) 2009–2010	(4) 2011	(5) 2012 S1
Sovereign CDS	−0.037**	−0.108	−0.033	−0.089***	0.009
	(−2.52)	(−0.44)	(−1.26)	(−3.49)	(0.68)
GIIPS × Sovereign CDS	0.032*	0.007	0.034	0.129***	−0.009
	(1.93)	(0.03)	(1.39)	(3.03)	(−0.46)
Day FE	Yes	Yes	Yes	Yes	Yes
Country-month FE	Yes	Yes	Yes	Yes	Yes
Number of observations	7324	813	3918	1564	760
R^2	0.983	0.766	0.948	0.960	0.950

Table A2
Controlling for ECB haircut policy.

This table reports the estimates of Eq. (6). All regressions include day and country-month fixed effects. The average ECB haircut (*ECB HC*) is computed as the average prevailing haircut on all sovereigns of the country. *t*-statistics are presented in parentheses. Standard errors are clustered at the daily level. *, **, and *** denote statistical significance at the 10%-, 5%-, and 1%-level, respectively.

Panel A: Sensitivity of repo rates to sovereign CDS spreads

	(1) 2010–2012 S1	(2) 2010	(3) 2011	(4) 2012 S1
Sovereign CDS	0.033**	0.00123	0.076**	0.007
	(2.31)	(0.13)	(2.28)	(0.56)
ECB HC	−0.0003	−0.013	−0.009	0.002
	(−0.05)	(−0.34)	(−0.39)	(0.51)
Day FE	Yes	Yes	Yes	Yes
Country-month FE	Yes	Yes	Yes	Yes
Number of observations	4,173	1,462	1,809	875
R^2	0.957	0.923	0.949	0.946

Panel B: Sensitivity of repo rates to sovereign CDS spreads – GIIPS vs. *non-GIIPS*

	(1) 2010–2012 S1	(2) 2010	(3) 2011	(4) 2012 S1
Sovereign CDS	−0.090***	−0.138***	−0.108***	0.016
	(−4.34)	(−4.10)	(−3.35)	(1.18)
GIIPS × Sovereign CDS	0.128***	0.135***	0.208***	−0.010
	(5.57)	(4.18)	(5.23)	(−0.52)
ECB HC	−0.004	−0.005	−0.008	0.003
	(−0.51)	(−0.14)	(−0.29)	(0.61)
Day FE	Yes	Yes	Yes	Yes
Country-month FE	Yes	Yes	Yes	Yes
Number of observations	4,173	1,462	1,809	875
R^2	0.957	0.924	0.950	0.946

Table A3
Controlling for country-level exposure to risk.
This table reports the estimates of Eq. (7). All regressions include day fixed effects and country-month fixed effects. We also include the VIX interacted with country fixed effects. *t*-statistics are presented in parentheses. Standard errors are clustered at the daily level. *, **, and *** denote statistical significance at the 10%-, 5%-, and 1%-level, respectively.

Panel A: Sensitivity of repo rates to sovereign CDS spreads

	(1) 2008–2012 S1	(2) 2008-Lehman	(3) 2009–2010	(4) 2011	(5) 2012 S1
Sovereign CDS	0.016	−0.149*	−0.001	0.073**	0.012
	(1.32)	(−1.69)	(−0.16)	(2.09)	(0.85)
Day FE	Yes	Yes	Yes	Yes	Yes
Country-Month FE	Yes	Yes	Yes	Yes	Yes
Country FE × VIX	Yes	Yes	Yes	Yes	Yes
Number of obs.	8,437	989	4,156	1,817	882
R^2	0.981	0.786	0.951	0.949	0.946

Panel B: Sensitivity of repo rates to sovereign CDS spreads – GIIPS vs. *non-GIIPS*

	(1) 2008–2012 S1	(2) 2008-Lehman	(3) 2009–2010	(4) 2011	(5) 2012 S1
Sovereign CDS	−0.060***	−0.089	−0.028	−0.121***	0.023
	(−3.30)	(−0.28)	(−1.01)	(−3.81)	(1.61)
GIIPS × Sovereign CDS	0.079***	−0.056	0.026	0.225***	−0.014
	(4.05)	(−0.21)	(0.96)	(5.60)	(−0.63)
Day FE	Yes	Yes	Yes	Yes	Yes
Country-Month FE	Yes	Yes	Yes	Yes	Yes
Country FE × VIX	Yes	Yes	Yes	Yes	Yes
Number of obs.	8,437	989	4,156	1,817	882
R^2	0.981	0.786	0.951	0.951	0.946

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