The Importance of Being Special: Repo Markets During the Crisis *

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Abstract

Specialness is a measure of the scarcity premium of procuring a specific security. We analyze the impact of security-specific supply and demand on specialness. After controlling for the auction cycle on the supply of the bonds, we show that specialness is higher for highly demanded bonds - in the repo and in the cash market - and for bonds with lower available supply. The ECB outright purchases provide a natural experiment to analyze the impact on the scarcity premium of a big buy-to-hold investor on bonds. We find evidence of both a stock and a flow effect of the purchases. These effects are amplified when purchases involve bonds already in high demand. The impact of the purchases on specialness is conditional on the amount of the same security already bought. Very special bonds have a higher probability to be underlying a fail-to-deliver transaction.

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1 Introduction

The occurrence of the financial crisis has brought to the general attention the importance of "collateral rights" for the valuation of certain securities (see Bartolini et al., 2011). The value of a security does not arise solely from the cash flow that it provides but also from its ability to serve as collateral. This became particularly evident with the crisis when the impairment of the interbank unsecured market shifted a significant share of the funding of financial intermediaries to the secured repo market (see for example ECB, 2012).

In this paper we analyse the repo market for Italian sovereign collateral over a relatively long period of time, from October 2009 to July 2012. The time period that we consider includes episodes of significant market stress, the occurrence of the sovereign crisis in the euro area and consequent very volatile markets for government bonds. In the summer and fall of 2011, yields on the Italian government bonds increased dramatically both in levels and relative to the yields of other euro area countries, affecting also their collateral value.[1]

At the same time, specialness of Italian government bonds - a measure of how much a security is wanted - strikingly increased in the private repo market, both in terms of average (30-45 basis points) and dispersion of the distribution - the increase was more pronounced for extreme observations (see Figure 1). Specialness is defined as the difference between the rates of General Collateral (GC) repos and of special repos on similar bonds and it is a proxy for the scarcity premium to be paid for procuring a specific security (see Duffie, 2006). More Italian sovereign bonds became more special with dramatic changes in levels and persistency not previously observed in such liquid and large markets.

The European Central Bank (ECB) implemented a series of non-standard monetary policy measures, which often implied, both directly and indirectly, some form of intervention in the cash and repo markets. In particular, the ECB re-activated in August 2011 the Securities Market Programme (SMP), involving outright purchases of government securities and actively intervened on the Italian sovereign bond market.[2]

The purchases of the ECB provide a natural experiment to test the impact of a big buy-to-hold investor on bond markets and derivative markets. The purchases can be treated as large, unexpected, exogenous shocks to the available supply. The SMP was characterized by a high degree of opacity of the operations that were carried out by the central bank: there was no disclosure about amount, target and maturity structure of the purchases and the overall amounts were disclosed on an aggregate basis. Moreover, since the ECB did not engage in securities lending, its portfolio holdings effectively reduced the available supply of certain bonds.

The goal of this article is to analyse the time-series behavior of specialness in normal and crisis times. Specifically, we link specialness to security-specific measures of demand

[1] Notably, central counterpaty clearing increased significantly the margin requirements requested on Italian government bonds in the second half of 2011, likely exacerbating the abrupt changes in the bond yields, especially for shorter maturities.

[2] The SMP was formally introduced in May 2010 as an exceptional measure to sustain sovereign bond markets under pressure. Purchases of Italian bonds only took place starting in August 2011.

and supply in the repo and in the cash market. We show that specialness is affected by the amount of a security that is *effectively available* on the market. This results from the auction cycle, the amount that resides in the portfolios of buy-to-hold investors and security-specific demand, for example arising from short-sellers. Specialness drops after a new issuance takes place. It is higher for bonds that are highly demanded in the repo market, i.e. they are underlying special reverse repo, and in the cash market. Specialness is also related to demand for hedging interest rate risk (as in Graveline and McBrady, 2011). During periods of market stress these relationships tend to reinforce, as the estimated coefficients are economically more significant.

We also analyse specifically the distribution of specialness and show that very special bonds are particularly susceptible to changes in market demand, especially in periods of market stress. During crisis periods the distribution of specialness tend to become more dispersed and more bonds become more special. We analyse these effects by means of quantile panel regressions and show that the impact of security-specific supply and demand factors is higher for very special bonds - the upper tail of the distribution. This suggests that in periods of market stress short-sellers may face a very high cost to borrow the security through the reverse repo channel and end up paying a net liquidity premium, consistently with the analysis of Banerjee and Graveline (2011).

The actions of the central banks during the crisis, in particular the outright purchases of government bonds through the SMP had also an impact on the specialness recorded in the repo market. We find evidence of both a stock and flow effect, as in D 'Amico and King (2013). An increase in the SMP holdings of Italian government bonds is associated with higher specialness. Specialness of bonds purchased under the program is amplified when security-specific demand for these bonds was already high, in the repo and in the cash market, possible due to the demand of short-sellers.

We also study the dynamics of specialness around the SMP purchases and we follow a standard sorting approach looking at the relationship between realized and future specialness and SMP holdings. The analysis suggests that largest holding positions generally lead to higher levels of specialness. Similarly, we show that bonds that the ECB bought more aggressively tend to be more special. Overall, the impact of a big buy-to-hold investor is significant on the repo market and may last several days.

To model the dynamic of specialness, we estimate the responses of intraday specialness and security-specific demand in the repo market to a demand-shock in the cash market - the purchases of the ECB. We show that specialness react strongly but the effect disappears in around two days. The impact is conditional on the amount of the same security already bought by the ECB, suggesting that a demand shock increases specialness more when the holdings are relatively low.

Finally, we look at how these effects may induce episodes of market malfunctioning, linking fails-to-deliver with specialness and central banks purchases. We show that the probability of delivery failure increases for bonds that were bought by the central bank. However, our analysis suggests that this effect has been mitigated by the increase in the penalties for a fail-to-deliver.

1.1 Relevant literature and contribution

Our analysis focuses on how security-specific supply and demand affect specialness recorded in the repo market. Therefore, we contribute to the literature on the structure of the repo market and on the determinants of special rates. The seminal work of Duffie (1996) specifies a model describing the link between the repo and the cash market and showing that bonds trading on special should carry a price premium in the cash market. Jordan and Jordan (1997) tested empirically most of Duffie (1996) predictions and also shed light on the role played by the liquidity of the bonds (on-the-run issues) and by the holders of the security, introducing the concept of availability on-the-street of a specific security. Both Duffie (1996) and Jordan and Jordan (1997) use sample data from the US repo market – US Treasury securities are the collateral. Our analysis uses Italian repo market data from a standardized platform - MTS repo - and therefore complements the evidence provided in these papers. We highlight the importance of security-specific demand and introduce a novel measure of availability on the street, by using the amount of a security that it is available for trading, possibly linked to short-selling activity. We analyse the impact of security-specific supply and demand factors in normal times and in crisis times and study the related changes in the distribution of specialness, especially in periods of market stress. In particular, and differently from the previous literature, we analyze specifically the determinants of the quantiles of the distribution of specialness by means of quantile panel regressions and show that very special bonds are more sensitive to sizable changes in supply and demand.

We also provide empirical support to mechanisms related to limits to arbitrage and preferred-habitat theories (like in Vayanos and Vila, 2009), which provide an explicit role for demand and supply shocks. We ultimately show that a sizable scarcity premium is induced by the amount of a security that is privately held in portfolios. These effects may be particularly relevant in periods of market stress, as shown also in the recent study of Musto, Nini and Schwarz (2014). They relate price discrepancies among off-the-run Treasury securities to the liquidity characteristics of these securities and to the characteristics of the financial institutions trading them (most levered investors and investors trading more often). Consistently with their study, we find that the premium to be paid to hold a specific security - the specialness - is related to the effective available supply of that security, resulting from the auction cycle and from the fraction of issued amounts that is part of the portfolio of typical off-the-street investors (institutional investors and the central bank). This empirical result is also consistent with the outcome of the search model proposed by Vayanos and Weill (2007). They model endogenously liquidity and specialness through the role of short-sellers. In particular, they conclude that short-sellers would tend to concentrate in trading assets with the largest-supply and ultimately induce changes in their specialness premium.

Our paper fits within the literature studying the relations between sovereign securities prices and quantities, which include also the recent papers on the effects of the large purchases carried out by the central banks (see in particular Krishnamurthy and Vissing-Jorgensen, 2011, and D'Amico and King, 2013 for the impact of the FED quantitative easing, and Ghysel et al. 2014, and Eser and Schwaab 2014, for the effect of the outright purchases of the ECB through the SMP). Using security-level price and quantity data, we document a price impact that transmit from the bond cash market to the repo market through the collateral channel. We show how this local supply effect cumulates with other security-specific supply

and demand pressures.

We analyse the effect of the SMP purchases on a derivative market - the repo market where Treasury bonds are used as collateral. In the same spirit as in D'Amico and King (2013), we identify a stock and a flow effect of these purchases. We show that the stock effect tends to be more persistent, due also to the buy-and-hold portfolio strategy of the ECB. Flow effects are significant only in combination with other security-specific supply and demand factors - when purchases involve highly demanded bonds.

Because of the focus on the repo market, our analysis is more clearly related to the study of D'Amico, Fan and Kitsul (2014), which analyse the impact of the FED outright purchases on the US repo market. However, our approach is distinct and original in several dimensions. We introduce in the study a novel measure of security-specific available supply, proxied by the securities that are available for lending from institutional investors, a value that can be related also to short-selling activity, and show that specialness is higher for less available securities.

We also study the distribution of specialness and show that, especially in periods of market stress, bonds that are in the upper tail are more susceptible to changes in security-specific demand and supply. To address endogeneity issues surrounding the impact of central banks purchases, we perform the analysis using intraday, transaction-level observations, and show that specialness react momentarily to the purchases of the underlying bonds, but that this effect is not persistent and last only around two days. Moreover, the impact is conditional on the amount of the same security already in the central bank's portfolio.

We study the dynamic of specialness over a longer period of time and we find that the SMP purchases have a sizable effect on specialness over the following days only for bonds that are purchased in higher quantities. The impact of purchases on security-specific demand in the repo market is long lasting only for these bonds. Moreover, the effect lasts longer when purchases have been more aggressive.

Security-specific shocks to demand and supply can have also important externalities on market functioning. Very special bonds are in fact more likely to be underlying fail-to-deliver transactions as the value of failing is lower than the premium to be paid to acquire the security, in the same spirit as in Evans et al. (2009). Musto et al (2014) show that a decline in frequency of special trades is associated with an increase in fails volume. This evidence would suggest that in periods of market stress the premium to be paid to acquire a specific security is so high that there is less demand for specific security (in fact our measure of security-specific demand in the repo market drops during the crisis period) and this may even create incentive to fail to deliver. Local supply effects arising from the SMP purchases also had a similar impact, but their effect was mitigated by the introduction of penalties for fail-to-deliver.

Finally, we contribute on a growing and recent literature analyzing the functioning of repo markets in Europe. The few available studies have mainly concentrated on GC repos, looking at the role of the repo markets as a financing means for financial intermediaries. Dunne, Fleming and Zholos (2010) analyse how the crisis has affected the bidding behavior of the banks at the refinancing operations in the euro area. Mancini, Ranaldo and Wrampelmeyer (2013) performs a comprehensive study of the European repo markets and show that the importance of the central counterparty-based segment in this market makes it more resilient during crisis episodes and even acts as shock absorber. Instead, Boissel et al. (2014) argues

that CCPs provide some protection in periods of intermediate sovereign stress (2009-2010), but this protection became ineffective at the peak of the sovereign crisis (2011). We deviate somewhat from this literature and we concentrate on repo specials, that enable us to shed light on the effects of changes in the supply of bonds which cannot be substituted with other securities. Our study complements some of the results obtained by Dufour and Skinner (2006) and Buraschi and Menini (2002). Buraschi and Menini (2002) analyze more specifically the relationship between the current term structure of special repos and the future collateral values, using data on the German Government repo market. Dufour and Skinner (2006) analyze the Italian BTP repo market. Their sample however does not include periods of markets stress and they do not focus on the entire distribution of specialness – they argue that the distribution does not change over the sample.

2 The repo: basic features

A repo transaction combines two financial transactions taking place at different times. It involves the sale of a security at the spot price and a forward agreement to buy back the same security at a future specified date and price. The difference between the two prices defines the *repo rate*. The repurchase agreement may imply the buy back the next day (overnight repo) or at a later date, usually up to one year. Generally, repo transactions that are taking place on electronic trading platforms have a very short maturity date (up to one week), while bilateral repos agreed over the counter tend to have longer maturity.

In terms of definition, the party selling the security in the first transaction is entering a (financing) repo agreement, while the party that buys the security and it is committed to deliver it at the agreed future date enters a reverse repo. The party that sells the bond via the repo agreement is selling collateral (financing repo) in exchange of liquidity (possibly to finance the original purchase of the bond). The party that buys the bond via the repo is buying collateral (reverse repo) and it is lending liquidity.[3]

There are two types of repo transactions: *special repos* and *general collateral repos*. In special repos, the party delivering the security must deliver a specific asset (with a specific ISIN code), while in general collateral repos (GC repos) he/she can choose among a basket of possible assets.

Special repo implies the payment of a special rate. The special rate is generally lower than the general repo rate, reflecting the convenience yield of the specific asset - how sought after the asset is. Special rates can even become negative, in cases of extreme market squeezes, when the counterparty lending liquidity is willing to pay a premium (making a discount) in order to get the security on special.

A bond may trade on special for several reasons, like price segmentation resulting from structural characteristics of the market (see for example Boudoukh and Whitelaw (1993)). In practice, as suggested by Duffie (1996) and Jordan and Jordan (1997), all these factors may be linked to a restriction to the *available supply* of the bond. Traders who are searching for a specific security and have difficulty in finding it (either by purchasing it or by borrowing

[3]Since a repo transaction is composed by the two legs happening in sequence, the two parties are effectively borrowing and lending liquidity. Legally, however, all transactions may be treated as "true sales," which is the case for the MTS market for example.

it), are willing to pay a premium in the repo market to temporarily acquire that security. Jagadeesh (1993), Sundaresan (1994) and Keane (1995) relate these restrictions in supply to the tightness of the bids recorded at the auction of on-the-run bonds. However, as pointed out by Dufour and Skinner (2006), this measure may be less sensible in a context of consecutive auctions for the same bond, when a long time may have passed between the issuance of the first and the most recent tranche, for example (see Section 3.2 for details of the procedures followed by the Italian Treasury when issuing securities).

Duffie (1996) points out that specialness is increasing in the amount of short-selling activity in the cash market, also relative to the issue size. The price of a special repo transaction tends to be related to short-selling activity, since the repo market is often also a preferred vehicle to create short-selling positions in the cash market. If a trader short-sells a bond in the cash market, he/she can enter in a reverse repo with appropriate maturity and have the security delivered at the time needed to cover the short position. In this case, the trader will enter in a special reverse repo, since he/she needs a specific security. Thus, the relative price of special repos – the *specialness* – can give important information on short-selling pressures in the repo and cash market. Duffie (1996) describes in details the transactions involved to close the position.

An important feature of the European repo market, as reported also by Buraschi and Menini (2002), is the link between the private repo market and the implementation of monetary policy, specifically in the euro area. The ECB provides liquidity to the banking sector operating in the euro area - about 2500 counterparties - by means of repo loans. Banks participate to the refinancing operations of the Eurosystem and receive liquidity by pledging collateral. Over the last few years, the intermediation role of the ECB as liquidity provider has increased. Due to the changes in the liquidity provisions framework occurred because of the crisis, the ECB provides liquidity on demand through the full allotment policy.[4]

3 Data and summary evidence

In the following sections we describe in detail the data that we use in the analysis and how we have integrated different sources to compile an exhaustive database.

3.1 The market for special repos

The main dataset used in the analysis is constituted by the data of the MTS repo trading platform from 1 October 2009 to 7 July 2012. In Europe the repo market transactions are generally agreed on a bilateral basis. There are several electronic trading platforms where investors can trade more standardized repo contracts. The MTS repo platform covers a significant percentage of the European repo market transactions and a leading share of the

[4]Before October 2008, banks would bid for liquidity at the operations of the Eurosystem and the amount of liquidity to be allocated was fixed ex-ante. After the Lehman Brothers failure, the ECB decided to provide unlimited liquidity to the banks, in exchange of eligible collateral, at the monetary policy rate. While before 2007 repo transactions linked to monetary policy implementation were complementary to the private repo market, it can be said that over the years the Eurosystem became a market maker and has partly substituted the private market. Moreover, its decisions in terms of accepted collateral, maturity of the operations and haircuts have influenced also the activities in the private repo market.

Italian repo market - repo transactions backed by Italian collateral, typically government bonds. We have tick-by-tick transaction-level information on this market, including the type of repo contract (general collateral vs special), the ISIN of the underlying government bond, the repo interest rate paid on each transaction, the volume of the transaction, the spot and the end price of the underlying government bond and the maturity of the repo.[5]

We want to analyse how security-specific supply and demand factors affect the premium that investors are willing to pay to get a specific security. To this aim, we define the variable *Specialness* as the difference between the general repo rate and the special repo rate on a specific security and day of trading

$$\text{Specialness}_{i,t} = \text{GCrate}_t - \text{Special rate}_{i,t}. \tag{1}$$

We have data on repo transactions at intraday level, but we need to match the database with other variables from the cash market that are only available daily. In practice we calculate specialness of security i on day t in the following way. On day t, we take the first available GC rate for each repo maturity j (where j is overnight, spot next or tomorrow next) that we observe. Every time we observe a new transaction for each maturity j, we update the GC rate. Specialness is the difference between the most recent GC rate with the repo maturity j and the special rate of a security i with the same repo maturity. For the analysis based on daily data, we average this difference during the day t and across the repo maturity j. The average is weighted by the nominal amount of each repo transaction.

We also define a proxy for the security-specific demand in the repo market. Since we know the party that has initiated the transaction, we have information on the trading direction of the repo. Therefore we define the variable Repo flow for security i at time t as

$$\text{Repo flow}_{i,t} = \frac{\text{Reverse repo}_{i,t}}{\text{Outstanding amount}_{i,t}} - \frac{\text{Financing repo}_{i,t}}{\text{Outstanding amount}_{i,t}}. \tag{2}$$

Outstanding amount is the volume of the security that has been issued until date t. Repo flow tends to be quite persistent, suggesting that special bonds are demanded in the repo market over consecutive days (the autocorrelation is around 24% on average)

3.2 The market for Italian sovereign bonds

To investigate how the value of a security is affected by supply and demand factors, we define also other security-specific measures. First, we look at the information on the primary issuance of Italian sovereign bonds. The daily amount outstanding of each bond (at the ISIN level) is constructed using detailed issuance data from the Italian Treasury and the Bank of Italy (see also Beetsma et al., 2015). To understand better the possible impact of the outstanding amount on the prices and quantities traded in the repo market, it is important to explain how the issuance of government debt is managed in Italy. Given the large outstanding amount of the Italian government debt, bonds are issued in (relatively small) tranches which however preserve the same maturity date and ISIN code. Normally, a

[5]See Adrian et al. (2011) for the important information needed to analyse the repo market. Note also that no explicit haircuts are requested for trading in the MTS repo platform.

new bond (with a new ISIN code) is issued in sequential tranches of about the same quantity.[6] This bond is considered the *on the run* asset for a certain maturity until a new bond (ISIN) is issued. However, from time to time, to increase the liquidity of a specific security, the debt management agency may decide to reissue a tranche of an *old* bond - off the run. It is crucial when analyzing the repo market and especially the determinants of specialness, to take into account this mechanism and the possible influence that it can have on the effective supply of securities in the market. In order to control for these effects, we include in the analysis dummy variables indicating if a security is the 5 or the 10 years on-the-run benchmark. Consistently, we also include dummies to signal when these securities stop being the on-the-run benchmark and become off-the-run. We also include a time dummy in correspondence of a new issuance for each bond, to control for the increase in the amount outstanding.

The outstanding amount of a security is a proxy for the supply of that security. However, the amount of security that is actually available to trade is typically much lower, especially for securities that have been issued from longer time. A measure of the available supply of a security may be derived by the amount of that security that is *available for lending*. Institutional investors and other buy-and-hold financial intermediaries are typically willing to lend securities to other market participants. The borrowers may need to securities to cover short positions and/or managing their financial portfolio. These data are available from Data Explorers. We use the quantity of a certain security that is available for lending divided by the outstanding amount as a proxy for the available supply of that security.

We also consider the difference between the sell volume (the volume sold of each security every day) and the buy volume (the volume bought of each security every day), which gives an indication about the direction of the cash market and possible pressures stemming from short-selling activity. In particular for each security i, we define

$$\text{Cash imbalance}_{i,t} = \frac{\text{Sell volume}_{i,t}}{\text{Outstanding amount}_{i,t}} - \frac{\text{Buy volume}_{i,t}}{\text{Outstanding amount}_{i,t}}. \tag{3}$$

We have this information at a daily frequency from the MTS bond trading platform.[7] We follow also the approach of Graveline and McBrady (2011) and include in the analysis the option-implied volatility from 10-year interest rate caps, which also helps to capture the time variation in specialness. Implied volatility is related to hedging demand, since, especially in periods of high volatility, market intermediaries have great incentives to hedge the interest rate risk.

Finally, we use in the regressions also more traditional measures of market liquidity and control for the characteristics of the security. We consider the *time-to-maturity* of the bond as a proxy for the liquidity of that specific bonds stemming from its age. Usually bonds that have been issued earlier tend to have lower liquidity, partly because it is likely that significant holdings of these bonds are in the hands of buy-and-hold investors and are therefore not readily available for trading in the market. Note that this concept is related,

[6] An average number is for example 6 consecutive tranches for BOT, the securities with maturity up to one year. However, there are no fixed rules on the number of tranches that will be issued and/or on the amount issued each time, which preserves some flexibility for the management of the debt.

[7] MTS has two trading platform where it is possible to trade Italian government bonds, an Italian platform and a European platform. Volumes are much larger on the domestic platform, but for completeness we have gathered data from both sources.

but not coincident with an issue being on/off-the-run. The other liquidity measure that we include in the analysis is the daily *bid-ask spread*, which should control for the liquidity pressures stemming from the cash market.

3.3 The ECB Securities Market Programme (SMP)

Due to the exceptional circumstances prevailing in the Euro area sovereign bond markets at the beginning of 2010, the ECB launched the Securities Market Programme (SMP) on 10 May 2010 addressing the lack of depth and liquidity in some euro area government bonds markets. The SMP was first activated as a response to the run on Greek sovereign bonds, which triggered a crisis in the sovereign debt markets in the rest of the euro area, especially affecting countries with a weak fiscal position. The SMP was designed to conduct outright interventions in the euro area public and private debt securities market. Sovereign debt securities were bought on the secondary market and remained on the balance sheet of the ECB until expiration (hold-to-maturity strategy).

The implementation of the programme had some distinctive features. Differently from the LSAP program of the Federal Reserve, the ECB did not disclose the total or the maximum amount to be spent, did not indicate a time frame over which the program would be active, and the set of securities that would be targeted. Data on the outstanding value of the holding portfolio were only published weekly without any reference to the time during the week when the securities had been bought. Moreover, the ECB did not provide a breakdown describing the composition of assets, neither by asset class nor by geographical origin of issuance.

Thus, the analysis of the impact of the SMP provides an ideal testing for the theories related to the impact of a large investor entering in a market and in particular for an exogenous shock to available supply. In the context of the SMP, the ECB represented a typical *off-the-street* investor, purchasing large quantities of relatively similar assets and holding them to maturity (see also Eser and Schwaab, 2014, for a thorough discussion about the features of the SMP).

The ECB provided details on securities holdings acquired under the SMP program only on 21 February 2013, after the program had been officially terminated in September 2012.The SMP disclosure revealed the country-by-country breakdown of the purchases, with the Italian debt accounting for roughly half of the total (103 billion euros out of 218 billion euros).[8]

Figure 2 plots the accumulated book value over time. Clearly, purchases are not evenly spread over time. The largest purchases occurred after the introduction of the SMP on 10 May 2010 and after its reactivation on 8 August 2011. The chart also suggests that there have been long periods during which the SMP has been open but inactive. From the week ending in 25 March 2011 until 8 August 2011 the SMP was inactive for 19 weeks. The reactivation of the program was triggered by the tensions registered in the Spanish and Italian sovereign bond market in the summer of 2011. The purchases stopped on January 2012 when the uncertainty linked to the political climate in Italy and in Spain decreased.

To assess the impact of the SMP on specialness, we include data on the SMP bond purchases in the estimation. To isolate a stock and a flow effect, we define two different

[8]The ECB also purchased sovereign bonds from Spain (44 billion euros), Greece (34 billion euros), Portugal (23 billion euros) and Ireland (14 billion euros).

measures. SMP holdings is a standardized measure of the amount of a security already in the central bank portfolio at time t (stock effect). SMP purchases are the amount bought on day t or in each transaction in the intraday estimation (flow effect). SMP purchases are divided by the outstanding amount of the security.

3.4 Summary evidence

We have data on the MTS repo transactions on Italian government bonds from 1 October 2009 to 7 July 2012. Dufour and Skinner (2006) used the data from the same platform from 2003 to 2005 and showed that the volumes exchanged in GC and special repos were broadly similar over this period. Differently, in our sample we observe the fraction of total trades exchanged under special repos has significantly increased over time to reach 70%. This suggests that market participants, at least on the electronic trading platform, turned to the repo market more to satisfy security-specific demand than for financing purposes. This may be linked to an increase in short-selling activity.[9]

Looking at the developments of specialness, we note that, starting in the summer of 2011, its distribution became more dispersed, as specialness increased significantly both in average and dispersion. More bonds became more special resulting in a significant increase in the upper tail of the distribution (see Figure 1).

Starting from this observation, we divide the entire sample in three distinct sub-periods that we analyse separately. The first sub-period runs from 1 October 2009 to 8 August 2011, the date when the ECB decided to reactivate the SMP and started open market purchases of Italian sovereign bonds. Up to that moment, changes in the price of Italian government bonds were not dramatic, notwithstanding the impact of the sovereign crisis in the euro area that was already affecting the sovereign yields of other countries. We consider this period as a *pre-crisis* period.

During the summer and fall of 2011, the market for Italian sovereign bonds became very volatile and yields increased remarkably, especially compared with yields of bonds issued by other countries in the euro area with lower credit risk. Margins requested by market dealers and CCPs on Italian sovereign bonds also went up, because the sharp rise in yields had reduced their collateral value. The increase in margins had a feedback effect on the secondary market. As a result, the spread between the yields paid by Italian bonds and comparable German bonds widened significantly especially for shorter maturities. We end this *crisis* period on 21 December 2011, the day before the ECB conducted the first 3-year LTRO. The *post-crisis* period extends from 22 December 2011 to 12 July 2012 and it includes the second 3-year LTRO conducted on 1 March 2012.

Table 1 reports in the first row descriptive statistics for specialness for the three sub-periods considered. During periods of market stress (from 8 August July to 21 December 2011), average specialness of Italian government bonds increased significantly: the average was almost three times compared to the previous period. Standard deviation also increased. During the last period, specialness reverted back to historical average and the standard deviation declined dramatically.

[9]Some of the decline in the general repo transaction was also due to the increase in triparty repo (see Copeland et al. 2012, for the analysis of the triparty repo market in the US). However, this form of repo transaction still represents a small share in Europe (see for example ECB, 2012).

In addition, Table 1 reports descriptive statistics for all the other explanatory variables. Looking at demand measures, it is noticeable that Repo flow, security-specific demand in the repo market, almost halved in the crisis periods. This may suggest that, given the high level of specialness of certain bonds, market participants were more reluctant in demanding these securities. At the same time, selling pressures in the cash market increased dramatically for the bonds in our sample, possibly linked to short-selling pressures. Implied volatility also rose remarkably during the crisis period. This is consistent with an increasing demand for interest rate risk hedging during periods of market stress, when interest rates are more volatile and intermediaries have greater incentives to cap the payment on floating rate loans.

Turning to supply measures, the amount of securities available for lending declined steadily during the crisis and the post-crisis period, which may reflect worries that the security would not be returned timely after lending, especially in a period of market stress. Available supply further declined in the post-crisis period, probably linked to the effect of the very long term refinancing operations of the ECB.

We also consider two traditional liquidity measures. The average age of the bond used in repos - time to maturity - declines especially in the last period, consistent with the substantial decrease in the credit risk priced for the shorter maturities. Instead the mean Bid-ask spread increased over time pointing to some illiquidity in the cash market for sovereign bonds, possibly linked to the implementation of the LTROs of the ECB.

Table 2 shows the distribution of specialness for buckets. In the first part of the sample, most of the observations, around 85%, are concentrated in the first bucket, with specialness ranging between 0 and 25 basis points. Between August and December 2011, only 56% of the observations remained in that class, while about 30% of the securities had a specialness between 25 and 50 basis points. In the same period the frequencies of all the classes with very high specialness increased, with 3% of the bonds recording a specialness of more than 100 basis points.

4 Determinants of specialness: time series analysis

4.1 Empirical methodology

To analyse how specialness in the repo market is affected by changes to the relative supply of bonds available for trading, we run a series of regressions using variables that are linked to security-specific demand of investors (for hedging and/or short-selling purpose) and supply linked to the auction cycle. In particular, we relate specialness to three sets of explanatory variables. First, we include variables that are related to security-specific demand, arising from hedging demand and/or short-selling, in the repo and in the cash market. Repo flow is the demand for a specific bond in the repo market, while Cash imbalance proxy for the demand in the cash market. Implied volatility is a proxy for hedging demand. Second, we include variables measuring security-specific supply. These include the quantity of a security that is available for lending, SecLend, which proxy for the available supply. We also introduce a set of dummy variables which control for the auction cycle: the date of a new auction and the period during which a security is on-the-run/off-the-run.[10] Finally, we control for bond

[10]We do this for the benchmark securities with 5 and 10-year maturity.

characteristics, by including the time-to-maturity of the bond, and for market liquidity, using the bid-ask spread in the cash market.

All the variables that we consider in the regressions have little correlation with each other except the two measures of SMP purchases (see Table 3).

To investigate the determinants of specialness in the repo market, we estimate daily OLS panel regressions with standards errors that are clustered at the bond and time level.[11] Our basic pooled fixed-effects panel regression specification is:

$$\begin{aligned} S_{i,t} &= \alpha_i + \beta_1 \text{Repo flow}_{i,t-1} + \beta_2 \text{Cash imbalance}_{i,t-1} + \beta_3 \text{ Implied vol}_{t-1} + \beta_4 \text{Sec Lend} \\ &+ \beta_5 D\text{issuance}_{i,t-1} + \beta_6 D\text{on the run 5y}_{i,t-1} + \beta_7 D\text{on the run 10y}_{i,t-1} \\ &+ \beta_8 D\text{off the run 5y}_{i,t-1} + \beta_9 D\text{off the run 10y}_{i,t-1} + \beta_{10} \text{ Bid-ask}_{i,t-1} \\ &+ \beta_{11} \text{Time-to-maturity}_{i,t-1} + \varepsilon_{i,t}, \end{aligned} \tag{4}$$

where $S_{i,t}$ is the specialness of bond i at time (day) t. All the explanatory variables are lagged of one period (day) to control for endogeneity effects.

On 8 August 2011, the ECB reactivated the SMP, and started to purchase Italian sovereign bonds on the secondary market. We want to investigate the possible impact of these purchases on the specialness recorded in the repo markets. Therefore, we include in the panel regressions a flow variable accounting for the daily purchases, SMP purchases, and a variable accounting for the portfolio acquired up to time t, in order to capture a stock effect. D'Amico and King (2013) show that both effects are present in the cash market when studying the outright purchases of the Federal Reserve. The stock variable is standardized around its mean and over its standard deviation similar to the standardized inventory measure used by Hansch, Naik, and Viswanathan (1998). To investigate the channel through which the purchases affect specialness, we interact the SMP variables with the demand variables and obtain the following regressions:

$$\begin{aligned} S_{i,t} &= \alpha_i + \beta_1 \text{Repo flow}_{i,t-1} + \beta_2 \text{Cash imbalance}_{i,t-1} + \beta_3 \text{ Implied vol}_{t-1} + \beta_4 \text{Sec Lend} \\ &+ \beta_5 D\text{issuance}_{i,t-1} + \beta_6 D\text{on the run 5y}_{i,t-1} + \beta_7 D\text{on the run 10y}_{i,t-1} \\ &+ \beta_8 D\text{off the run 5y}_{i,t-1} + \beta_9 D\text{off the run 10y}_{i,t-1} \\ &+ \beta_{10} \text{ Bid-ask}_{i,t-1} + \beta_{11} \text{Time-to-maturity}_{i,t-1} \\ &+ \beta_{12} SMP\text{Purchases}_{i,t-1} + \beta_{13} SMP\text{Holdings}_{i,t-1} \\ &+ \beta_{14} (SMP\text{Purchases}_{i,t-1} \times \text{Cash imbalance}_{i,t-1}) \\ &+ \beta_{15} (SMP\text{Purchases}_{i,t-1} \times \text{Repo flow}_{i,t-1}) + \varepsilon_{i,t}, \end{aligned} \tag{5}$$

where SMP holdings$_{i,t}$ is the nominal SMP holdings at time t of bond i standardized around its mean and over its standard deviation over the period. SMP purchases$_{i,t}$ are the nominal amount of purchases of bond i at time t over the outstanding amount of the bond

[11] As the descriptive statistics show, many values of the specialness are zero or very close to it. Thus, specialness is a truncated or limited dependent variable. To address this issue, we run the analysis also using Tobit panel regressions. The results are very similar and therefore we chose to report results obtained with OLS panel regressions to best compare with previous literature and for a more intuitive explanation of the results.

at time t.

We first run panel regressions based on (4) and (5). The analysis is based on daily data and estimation is carried out for the entire period (1 October 2009-7 July 2012) and for the three distinct sub-periods that we have introduced earlier.

Then, we investigate how determinants of specialness and the SMP purchases have affected the distribution of specialness. As already observed in the previous section, the specialness during crisis periods tend to become more dispersed. More bonds become more special and investors pay very large premiums to acquire some specific security. In order to investigate these dynamics more in detail, we estimate quantile panel regressions with fixed effects. The specifications are the same as in (4) and (5) and we follow the methodology proposed by Canay (2011).

4.2 Results

In this section we illustrate the results obtained from the panel regressions. First, we analyze the determinants of specialness on average for the three subperiods identified (pre-crisis/crisis/post-crisis periods). The results are shown in Table 4 and 5. Second, we estimate the model using quantile panel regressions and show how the explanatory variables are related to the distribution of specialness (Table 6).

4.2.1 Demand, supply and specialness

Table 4 shows the results of panel estimates with fixed effects as in Equation (4). Both Repo flow and Cash imbalance have statistically significant coefficients throughout the sample, except for the last sub-period. The sign of the coefficients are as expected, implying that specialness is broadly related to security-specific demand. Specialness is higher for bonds in high demand in the repo market - more repo dealers are looking for initiating a reverse repos on these bonds. Selling pressures in the cash market is negatively related to specialness. Both these variables are related to short-selling activity in the cash market, therefore our results point to a significant effects of these activities on the specialness of specific bonds. These effects are present in normal times, but tend to be much larger in times of stress, when short-sellers are willing to pay very high premiums to get hard-to-find securities. During the crisis period, one standard deviation increase in Repo flow has an impact which is more than double a similar change in Cash imbalance (the overall effects are 3.80 and -1.62 basis points on the specialness). Interestingly, the coefficients of Repo flow and Cash imbalance are not significant when the analysis is run when the LTROs decided by the ECB are implemented. This could be related to the fact that banks took full advantage of the new liquidity facility, by limiting their financing activity in the repo market. At the same time, the buy-and-hold portfolio resulting from the SMP purchases of the ECB may have discouraged some traders to take short positions in securities included in that portfolio.[12]

The coefficient of the option-implied volatility is also always significant except for the last period. It is positive and very high in periods of crisis and negative afterwards. Following Graveline (2013), we interpret this result as an indication that during periods of market

[12]The details of the SMP portfolio have never been disclosed, however aneddoctical evidence suggests that some intermediaries were able to reconstruct the holdings by using market information.

stress there is a lot of demand for hedging interest rate exposure. While a priori we cannot expect a positive or negative coefficient for this variable, it may be inferred that the sign of the coefficient depends on whether agents are hedging inherently long or short exposures to interest rates.

Consistently with the previous literature, we find also that specialness is related to variables reflecting the supply of a specific security. Securities available for lending, our proxy for security available in the market, is negatively related to specialness. Turning to the variables linked to the auction cycle, the occurrence of a new auction negatively affect specialness. This effect is three times higher during the crisis period, pointing to significant supply restrictions during market turbulences.[13] The results also show the importance of the 10-year benchmark for the market, especially in periods of market stress. Specialness of both on-the-run and off-the-run 10-year securities is higher than average in crisis times, but the effect is threefold for the off-the-run bond. The off-the-run effect is present also for the 5-year benchmark, however with negative sign.

The coefficients of traditional liquidity and bond characteristic variables like Bond time-to-maturity and Bid-ask spread in the cash market have the expected sign - positive for the maturity of the bond and negative for the spread - but are generally not significant, suggesting that the liquidity effects are already captured by the other explanatory variables.

The results of the analysis so far are broadly consistent with previous studies on the repo market and confirm that specialness is related to security-specific supply and demand. The supply is linked to the auction cycle of the bonds, while demand is related to short-selling activity and hedging trading.

4.2.2 Specialness and the ECB purchases

Table 5 shows the results of the panel regressions where we include in the analysis the impact of the bond purchases made by the ECB through the SMP. To investigate the impact on specialness of a large off-the-street investor taking actions on the cash market, we explicitly include the purchases of the central bank during the crisis as in equation (5).

Coefficients for the supply and demand variable for all the periods considered are robust to the introduction of the new variables. The third and fourth column of Table 5 show the results of the analysis during the crisis period considering only on-the-run or off-the-run bonds.

The *stock* impact of the purchases is measured by the variable SMP holdings. Positive variation in the SMP holdings is associated with higher specialness throughout the sample and during all the considered subsamples. During the crisis period, the coefficient is significant. However, when we divide the sample of the bonds, it turns out that this effect is largely due to the off-the-run securities. When considering the interactions of the SMP holdings and the market demand variables, the coefficient are generally not significant, except for a negative coefficient of the interaction with Repo flow when considering only off-the-run

[13] In non-reported regressions we have included the dummy in correspondence of the announcement of an issuance, typically three days earlier. In this case, the coefficient for the dummy is significant and positive, consistent with traders taking short positions in advance of the auction trying to take advantage of the liquidity of the most on-the-run bonds (see Duffie 1996) and Sundaresan (1994).

bonds. Thus specialness is generally lower for off-the-run securities that have been bought by the ECB and that are sought in the repo market.

SMP purchases measures the *flow* effect of the purchases. For this variable the coefficient is significant only when considering the interactions, i.e. the impact of the ECB outright purchases on specialness is amplified when the ECB buys securities that are sought in the repo market but that are also on demand in the cash market. Also in this case the coefficients are generally higher when restricting the analysis only to off-the-run bonds. All effects disappear in the third period, when the purchases of the ECB where relatively more scattered and the LTROs were implemented.

4.2.3 Quantile regression analysis

As we have noticed already in Section 3, the crisis period was characterized by a significant increase in the dispersion of specialness. This observation suggests that the link between specialness and the variables that we are considering may not be constant across the distribution, but it may vary across the quantiles of the distribution. Therefore, we run quantile panel regressions where we explain the distribution corresponding to the 10th, 30th, 50th, 70th and 90th quantile, using all the explanatory variables as in Table 4 and 5. Results are reported in Table 6 for the crisis period and for the highest quantiles.[14]

Looking at the results, we note that the demand variables, Repo flow and Cash imbalances, always have significant coefficients, that are higher for the right-tail quantile, i.e. more special bonds. Therefore, bonds that are on demand in the cash market and that are underlying reverse repos tend to be more special. The impact of bond supply linked to the auction cycle is also consistent with the results from the OLS panel regressions, including the benchmark role of the 10-year issue and the amount of securities available for lending.

Looking at the impact of ECB interventions, the panel quantile regressions show both a stock and a flow effect, with coefficients that are significant and higher for the highest quantiles. Interactions are also generally significant with positive coefficients for the interaction with Repo Flow and negative coefficients for the interaction with Cash imbalance. These coefficients suggest significant amplification effects, in particular in the upper tail of the distribution. As already pointed out earlier, this relationship may result from an effect of the availability on-the-street as described in Jordan and Jordan (1997), since the ECB acted as a buy-and-hold investor. we first note that the coefficient of the bond time-to-maturity is generally positive and significant, consistently with the idea that "older" bonds tend to be more special. Similarly, the coefficient for the bid-ask spread is always negative and significant, suggesting that during crisis periods liquidity in the cash market plays a more important role on specialness.

Summing up, the estimates from the quantile regressions suggest that demand and supply variables partly explain the differences across the quantiles of the distribution of specialness. Similarly, ECB outright purchases are significantly related to some part of the distribution, particularly the upper tail.

[14] We are not aware of a procedure to cluster the standard errors when using quantile panel regressions. Therefore, the standard errors tend to be smaller than what observed for the panel regressions.

5 The dynamics of specialness around the SMP purchases

To study more in detail the dynamics of the specialness around the SMP purchases and to address endogeneity concerns, we follow a standard sorting approach (see D 'Avolio, 2002) looking at the relationship between *realized* and *future* specialness and SMP holdings. We limit our exercise to the bonds that were purchased under the SMP programme.

First, we filter the data by regressing the specialness on the same set of explanatory variables we use in the basic specification (see Equation (4)) and include time-fixed effects, which may absorb determinants of specialness other than the dynamic variation of the type featured by SMP purchases. Then, we consider the 10 days before and after the first date t a bond was purchased under the SMP programme. Finally, we sort the bonds in seven groups based on the percentiles of the SMP holdings over the outstanding amount of each bond i at date $t + 10$, i.e. the highest quantile correspond to the group of bonds that were bought in larger quantities in the ten days following the first purchase.

Figure 3 shows the cross-sectional average of this *realized* specialness (demeaned) at time $t - 10$ for each group. The specialness of the highest-holding group increases by around 40 basis points in the first four days after the first purchase. After that, the specialness declines by 30 basis points to increase again on days 6 through 10. The specialness of the next highest-holding group (labeled Perc.$70 - 90$) reaches lower levels of specialness on average, 20 basis points, but it is more persistent from days 2 to 10. The figure confirms our regression quantile results and show that the largest SMP positions lead to higher and persistent levels of specialness.

The second exercise consists in studying the impact of the SMP purchases on subsequent specialness. This approach is inspired by the backward looking version of the standardized inventory measure used by Hansch, Naik, and Viswanathan (1998). This time we sort bonds into percentile groups each day of our sample period based on our standardized SMP holdings measure.[15] We can then examine the pre- and post- formation specialness levels. Figure 4 shows the cross-sectional average of the *future* specialness (demeaned) at time $t - 5$ for each group. The highest-holding group is on top in Figure 4. The specialness increases by 20 basis points 4 days after the group formation and then reverses by 7 basis points reaching a level of average specialness of 13 basis points. This analysis shows that SMP purchases - how aggressive the ECB was in buying certain securities - have some predictive power on future specialness. Largest SMP purchases lead to higher and persistent level of specialness.

6 Intraday specialness

The previous analysis has shown that specialness is affected by security-specific demand and supply and by other liquidity and security-specific characteristics. We have shown that these results hold over time, with some changes occurring during periods of market stress.

[15] This measure uses deviations from target holdings standardized (divided) by holding volatility. The target holdings measure is a moving average computed over a 10-day horizon in the interval $[t - 15, t - 5]$, where t is the time of the group formation. The holding volatility is computed on the same horizon.

Especially during the crisis period specialness has changed dramatically also on a daily basis and may have reacted immediately to the actions of the ECB.

We have intraday, transaction-level data for the MTS repo market and for the SMP purchases. Both repo transactions and central bank purchases tend to be clustered around certain times of the day. Typically the majority of repo deals take place early in the morning and relatively late at night, when traders need to close their positions. To smooth the impact of this clustering, we have divided each trading day in three distinct periods (morning until 10, mid-day until 15 and evening until 19), therefore aggregating the transactions taking place in each period. To analyse the impact of the outright purchases on intraday specialness and repo flow we estimate a VAR. The analysis is carried out for the 10-year on-the-run bond.

The model has the following specification:

$$Y_{i,t} = A_i + B_i(L)\mathrm{Y}_{i,t} + \ \Gamma_i(L)\mathrm{X}_{i,t} + \varepsilon_{i,t} \tag{6}$$

where $\mathrm{Y}_{i,t}$ is a vector of endogenous variables including specialness and the repo flow in first-difference. $\mathrm{X}_{i,t}$ is a vector of exogenous variables including the SMP purchases and holdings. We include three lags for the SMP purchases after gauging the persistence of their impact from the value of alternative parameter estimates. We control for the SMP holdings introducing a dummy variable which takes value of one when the SMP holding (rescaled by the outstanding amount of the bond) is above its median. Then, we interact the dummy variable with the SMP purchase to allow for differential impact of a purchase on specialness and repo flow depending on the bond amount already held by the ECB. A_i is a vector of fixed effects at security level. $B_i(L)$ is a matrix polynomial of slopes in the lag operator L.

In Figure 5 we report the cumulative impact on specialness over five days of a 5% purchase over the outstanding amount of the bond considering the two possible scenarios of portfolio holdings, below and above the median. We see that the long run impact on specialness of a purchase of 5% of the outstanding amount of the bond, is different in the two scenarios. The SMP purchase has a larger direct effect of 6 basis points on specialness when the holding is below the median. The effect is not persistent and specialness reverts back to the level observed in absence of the purchase. The dynamics of specialness is similar when the SMP holdings are above the median but the impact is smaller suggesting that increases in specialness due to SMP purchases are larger after the first purchases of the bonds in the cash market. Figure 6 shows the long run impact on repo flow of a purchase of 5% of the outstanding amount of the bond. The SMP purchase leads immediately to a positive repo flow implying that the volume of reverse repos is higher than for financing repos, i.e. the bond is highly demanded in the repo market. Subsequently, the direction of the market reverses, suggesting that the higher level of specialness induces more financing than reverse repo. Repo flow reverts back to the level in absence of the interventions after two days.

7 Specialness and fails-to-deliver

In the previous sections we have shown how specialness of bonds in the repo market is affected by security-specific supply and demand factors. We have emphasized that these factors tend to reinforce their impact during periods of market stress, resulting in increased tails of the specialness distribution. We have also looked at the effect of large purchases in

the market for repo collateral - the bond cash market - on specialness and shown that this effect is sizable, it is amplified when purchases are directed towards bonds that are already in high demand, but it is generally not persistent.

To conclude the analysis we now look at how these effects may induce episodes of market malfunctioning. We look in particular at the link between specialness, central banks purchases and fails to deliver. Previous studies (see for example Fleming and Garbade, 2005) have shown that especially in periods of market stress, when the premium to be paid to get a specific security becomes relatively high, traders may decide to strategically fail to deliver, possibly incurring in penalties.

Fails to deliver in the bond markets we are considering in this study (the Italian sovereign bond market and the repo market) have historically been very limited, although almost no penalties were charged for the failure. Most likely this was related to the importance of maintaining credibility vis-a-vis other traders/financial institutions and also the CCPs, which are involved in a large part of these markets. However, during the spring and summer of 2011, the number of fails increased notably (see Bank of Italy, 2012). In order to minimize possible market disruptions arising from these fails, penalties were introduced on 1 September 2011 (see Figure 7).

In order to analyse how this phenomenon was linked in particular to the increase in specialness of certain bonds and to the outright purchases carried out by the central banks, we estimate a Probit model of the probability of fail-to-deliver at time $t + 2$ and a Tobit model on the volume of fails at time $t+2$.[16] Table 7 reports the results of this estimation. In the first two columns we report the results of the Probit model. We include as explanatory variables the specialness, a time dummy to control for the change in penalty regulation and the interaction between the two. We introduce specialness because previous literature has shown that fails to deliver are associated to high levels of specialness - the premium to be paid to borrow the bond (see for example Evans et al., 2009). As expected, the probability of a fail-to-deliver increases with the specialness of the bond. Bonds that have been issued since more time and that are less liquid have also a higher probability not to be delivered at settlement. At the same time, though, on-the-run bonds, typically chosen by short-sellers, are also more likely to be underlying a failure.

In the second column we replace specialness with the SMP purchases, since we have shown that in our sample high levels of specialness are associated with the central banks demand. The probability of failure increases for bonds that were bought by the central bank, suggesting that these purchases have increased the cost of borrowing the bonds in the repo market and ultimately increased the value of the option to fail. However, the analysis suggests that this effect has been mitigated by the increase in the penalties for a fail-to-deliver. The results from the Tobit estimation, reported in columns three and four, confirms the link between specialness, SMP purchases and fail-to-deliver.

[16]Two days is the standard settlement time for the MTS cash market. Settlement in the repo market depends on the repo contract. We have estimated the model with maturity ranging from 1 day to one week and found qualitatively similar results.

8 Concluding remarks

In this article we have used a very detailed dataset of the transactions in the repo market with Italian sovereign as collateral to analyze how security-specific demand and supply in the repo and in the cash market affect specialness. In particular, we show that specialness is related to the amount of a security that is effectively available on the market, resulting from the auction cycle and the amount that are in the portfolios of buy-to-hold investors. When a security is highly sought after and relatively scarce the premium to be paid by traders to get that specific security is higher. These effects tend to be stronger during periods of significant market stress.

The SMP, the outright purchase program conducted by the ECB in 2011 provides a natural experiment to test how the actions of a big buy-and-hold investor in the cash market may affect developments in a derivative (the repo) market. The impact is sizable on specialness and it is amplified when the central bank bought securities that were already in high demand.

Our results provide an empirical support to mechanisms related to limits to arbitrage in fixed income markets. We find that the available supply of a security determines its scarcity premium. Demand shocks, like the purchases of a big buy-to-hold investor, have sizable effects on this premium, also when measured in a derivative market, thus providing a clear role of collateral rights for the valuation of a security.

References

Adrian,T., B. Begalle, A. Copeland and A. Martin, 2011, "Repo and Securities Lending," Federal Reserve Bank of New York Staff Report 529, December.

Banerjee, S. and J. J. Graveline, 2013, "The Cost of Short-Selling Liquid Securities," *Journal of Finance*, March, 637-664.

Bank of Italy, 2011, *Financial Stability Review*, November.

Bank of Italy, 2012, *Financial Stability Review*, April.

Barclays Capital, 2012, "ECB SMP: Marking to Market," Interest Rates Research, January.

Bartolini, L., S. Hilton, S. Sundaresan and C. Tonetti, 2011, "Collateral Values by Asset Class: Evidence from Primary Securities Dealers," *Review of Financial Studies*, Vol. 24, No. 1, 248-278.

Beetsma, R.M.W.J., Giuliodori, M., Jong, F.C.J.M. de, and Widijanto, D., 2015, "Price effects of sovereign debt auctions in the Euro-zone: The role of the crisis." *Journal of Financial Intermediation*.

Boudoukh, J. and R. Whitelaw, 1993, "Liquidity as a Choice Variable: A Lesson From the Japanese Government Bond Market," *Review of Financial Studies*, Vol. 6, No. 2, 265-292.

Boissel, Charles, François Derrien, Evren Örs, and David Thesmar, 2014, "Systemic Risk in Clearing Houses: Evidence from the European Repo Market," HEC Paris, working paper.

Buraschi, A. and D. Menini, 2002, "Liquidity Risk and Specialness," *Journal of Financial Economics*, Vol. 64, 243-284.

Canay, I. A., 2011, "A simple approach to quantile regression for panel data," *Econometrics Journal*.

Copeland, A., D. Duffie, A. Martin, and Susan McLaughlin, 2012, "Key Mechanics of the U.S. Tri-Party Repo Market," Federal Reserve Bank of New York Economic Policy Review, Vol. 18, Number 3, November.

D'Amico, S. and T. B. King, 2013,"Flow and Stock Effects of Large-scale Treasury Purchases: Evidence on the Importance of Local Supply," *Journal of Financial Economics*, Vol. 108, 425-448.

D'Amico, Stefania, ROger Fan and Yuriy Kitsul, 2014, "The Scarcity Value of Treasury Collateral: Repo Market Effects of Security-specific Supply and Demand Factors, Federal Reserve Bank of Chicago, Working paper No. 2013-22.

D'Avolio, G., 2002,"The Market of Borrowing Stock," *Journal of Financial Economics,* 271-306.

Dufour A. and F. S. Skinner, "Degrees of Specialness: An Empirical Analysis of the Italian BTP Repo Market," unpublished manuscript.

Duffie, D., 1996, "Special Repo Rates," *Journal of Finance*, Vol. 51, Issue 2, 493-526.

Dunne, P., G., M. J. Fleming and A. Zholos, 2010, "Repo Market Microstructure in Unusual Monetary Policy Conditions," mimeo.

ECB, 2012, *Money Market Survey*, September.

Eser, Fabian and Bernd Schwaab, 2014, "Assessing asset purchases within the ECB's securities markets programme," *Journal of Financial Economics*, forthcoming.

Evans, R. B., C. G. Geczy, D. K. Musto and A. V. Reed, "Failure *is* an Option: Impediments to Short Selling and Options Prices," forthoming in *Review of Financial Studies*.

Fleming, M. J., and K. D. Garbade, 2005, "Explaining Settlements Fails," Current Issues in Economics and Finance, Federal Reserve Bank of New York.

FT Alphaville, 2011, "Why Italy is 'Oh, so special'," 10 November.

Fleming, M., J., W. B. Hung, and F. M. Keane, 2010, "Repo Market Effects of the Term Securities Lending Facility," *American Economic Review* 100, no. 2: 591-6.

Ghysels, Eric, Julien Idier, Simone Manganelli and Olivier Vergote, 2014, A high frequency assessment of the ECB securities markets programme, ECB Working Paper series No 1642.

Graveline, J. and M. R. McBrady, 2011, "Who Makes On-the-run Treasuries Special? " *Journal of Financial Intermediation*, Vol. 20 (4), 620-32.

Gorton, G. and A. Metrick, 2012, "Securitized Banking and the Run on Repo," *Journal of Financial Economics*, Vol. 104 (3), 425-51.

ICMA, 2013, *European repo market survey*, March.

Hansch, O., Narayan N. and S. Viswanathan, 1998, Do inventories matter in dealership markets? Evidence from the London Stock Exchange, *Journal of Finance* 53, 1623-1655.

Jegadeesh, N., 1993, "Treasury auction bids and the Salomon squeeze," *Journal of Finance* 48, 1403-1419.

Jordan, B., D. and S. D. Jordan, 1997, "Special Repo Rates: an Empirical Analysis," *Journal of Finance*, Vol. 52, Issue 5, 2051-2072.

Keane, F, 1995, "Expected Repo Specialness Costs and the Treasury Auction Cycle," Federal Reserve Bank of New York, Research Paper No 9504.

Koenker, R., 2004, "Quantile Regression for Longitudinal Data," *Journal of Multivariate Analysis*, 91(1):74–89

Krishnamurthy, A., S. Nagel, and D. Orlov, 2014, "Sizing Up Repo," *Journal of Finance*, 2381-2417.

Krishnamurthy, A. and A. Vissing-Jorgensen, 2011, "The Effects of Quantitative Easing on Interest Rates," Brookings Papers on Economic Activity.

Mancini, L., A. Ranaldo, J. Wrampelmeyer, 2013,"The Euro Interbank Repo Market", University of St. Gallen School of Finance Working Paper.

Musto, D., G. Nini, K. Schwarz, 2014, "Notes on Bonds: Liquidity at all Costs in the Great Recession," Working Paper

Sundaresan, S., 1994, "An Empirical Analysis of U.S. Treasury Auctions: Implications for Auction and Term Structure Theories," *Journal of Fixed Income*, 4 no 2, 35-50.

Vayanos, D. and J.-L. Vila, 2009, "A Preferred-Habitat Model of the Term Structure of Interest Rates," Working Paper.

Vayanos, D. and P.-O. Weill, 2008, "A Search-Based Theory of the On-the-Run Phenomenon," *Journal of Finance*, 63, 1361-1398.

Figures

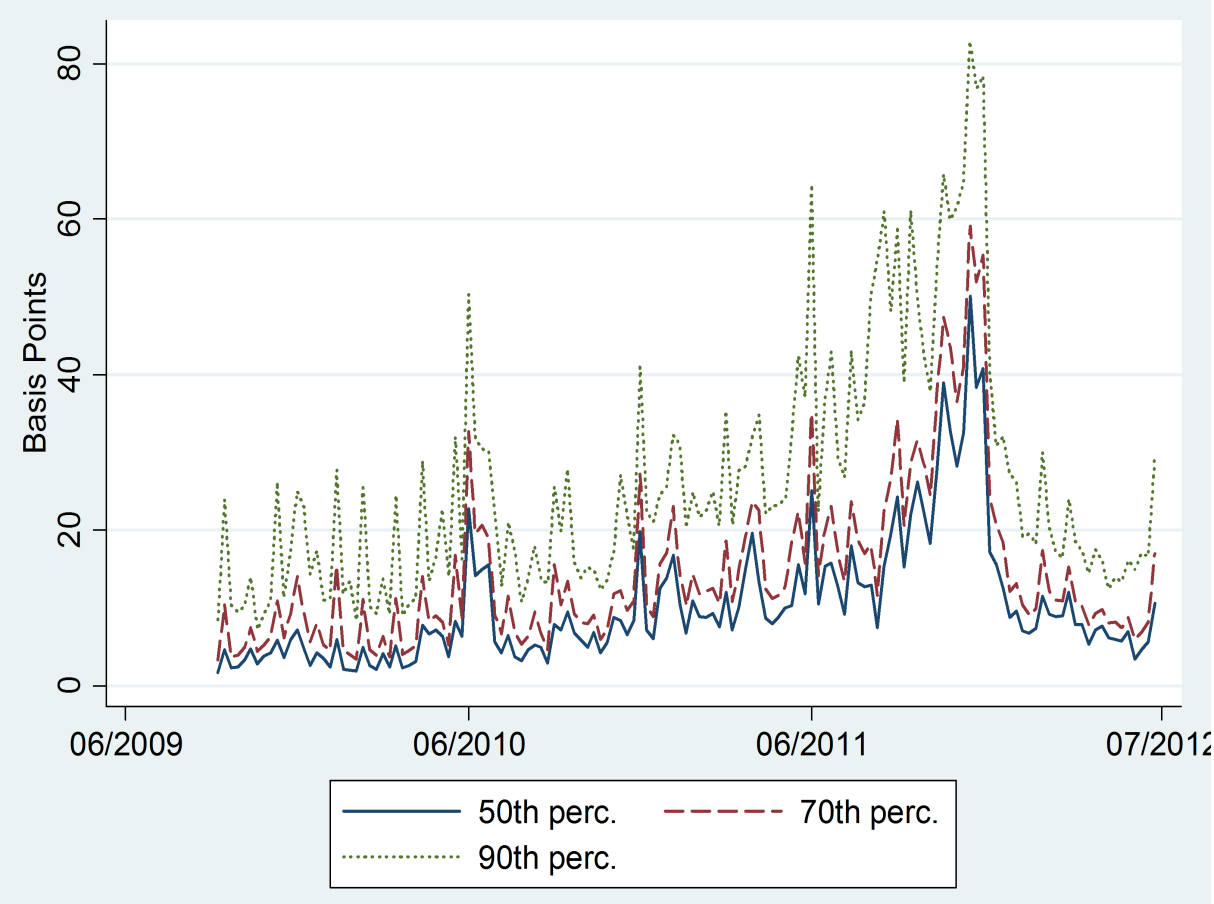

Figure 1: 50th, 70th and 90th percentile of weekly specialness.

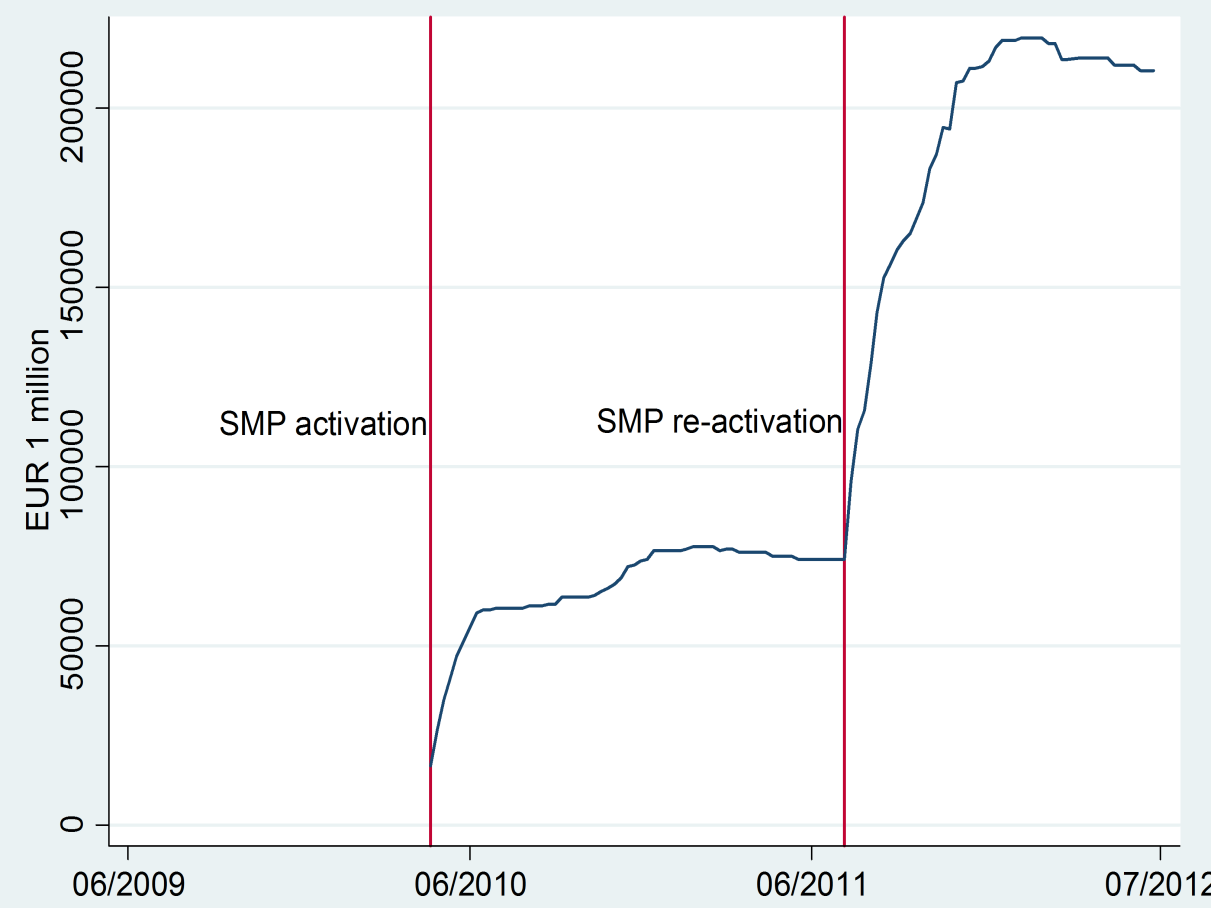

Figure 2: SMP portfolio (book value).

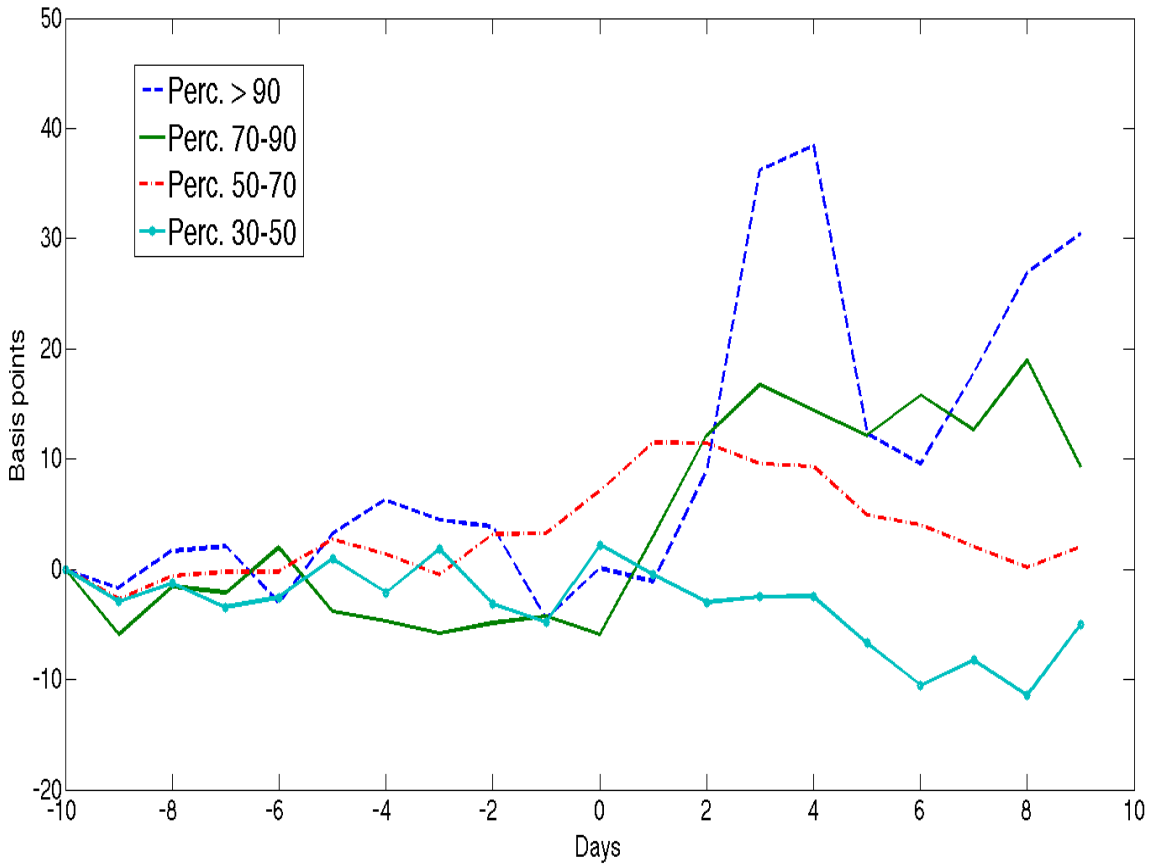

Figure 3: Realized specialness and SMP

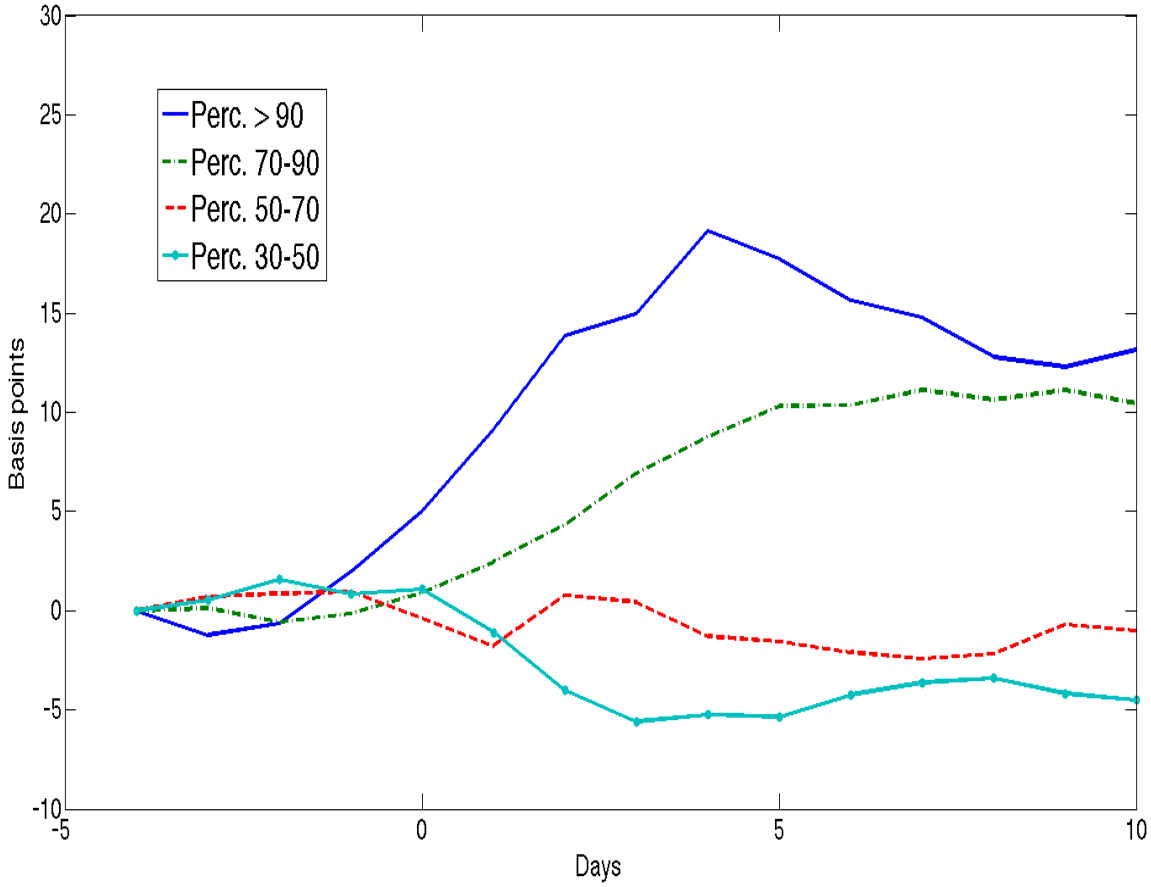

Figure 4: Future specialness and SMP

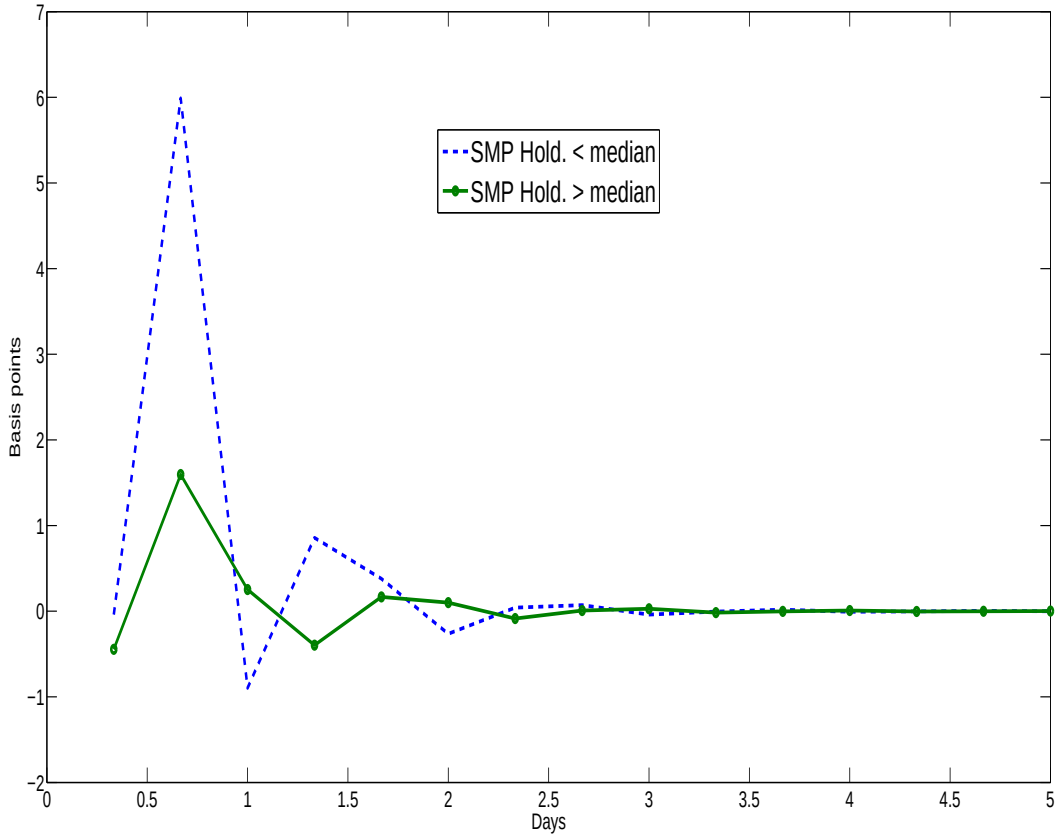

Figure 5: Impulse response functions for specialness of SMP interventions on 10-year on-the-run bond. Impact of 5% purchase over the outstanding amount.

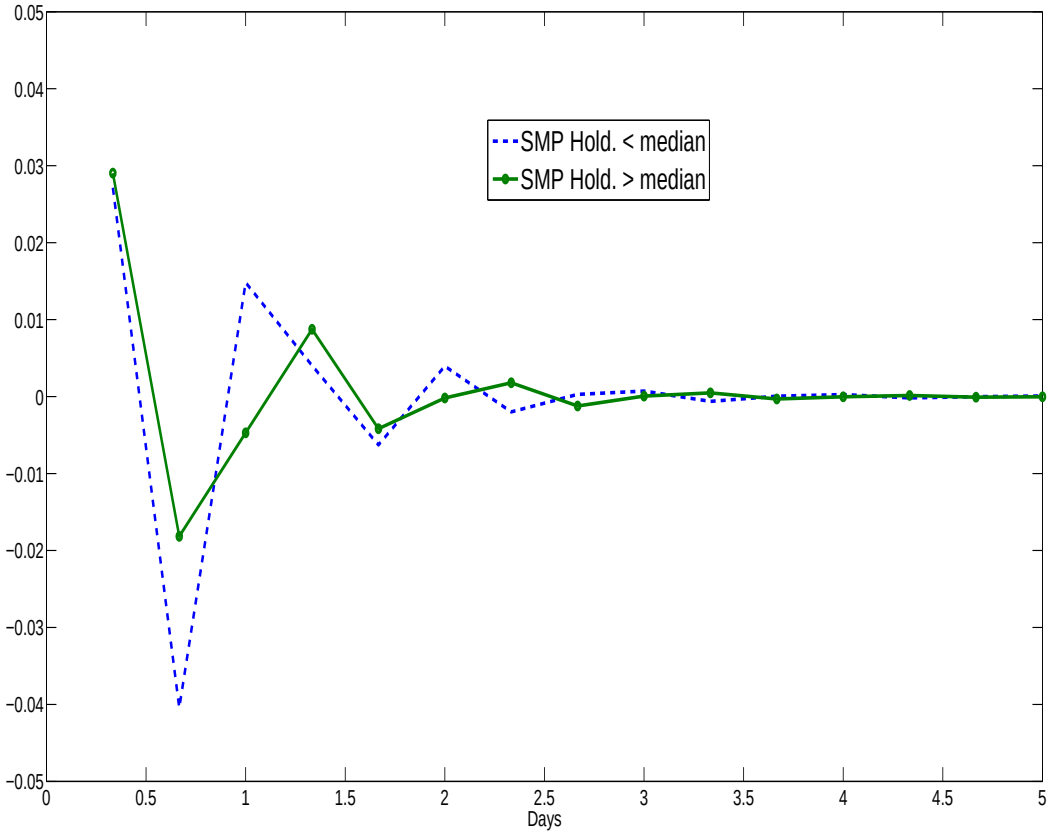

Figure 6: Impulse response functions for repo flow of SMP interventions on 10-year on-the-run bond. Impact of 5% purchase over the outstanding amount.

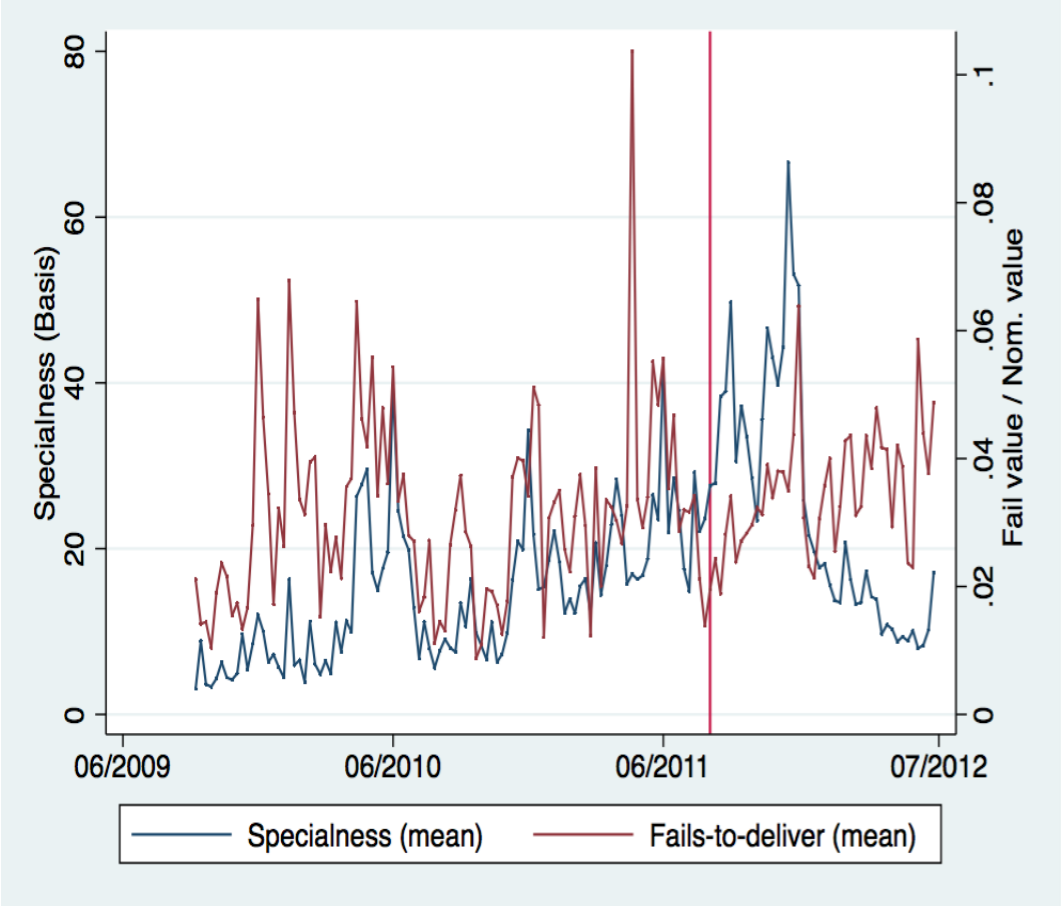

Figure 7: Specialness and fails

Tables

Table 1: **Descriptive statistics -** This table reports the mean and the standard deviation of all the main variables used in the analysis. The statistics are reported for the full sample and for three distinct sub-periods. First period from 1 October 2009 to 7 August 2001. Second period: from 8 August 2011 to 21 December 2011. Third period: from 22 December 2011 to 12 July 2012 (see section 3 for details about the variables).

	Mean	St.dev.	Mean	St.dev.	Mean	St.dev.	Mean	St.dev
	Full sample		1st period		2nd period		3rd period	
Specialness	14.708	24.525	11.967	23.734	29.965	31.762	12.902	15.953
Bond time-to-mat.	6.037	7.484	6.131	7.657	6.034	7.274	5.740	7.051
Repo flow	0.751	2.043	0.907	1.985	0.544	2.096	0.399	2.131
Cash imbalance	0.002	0.535	0.001	0.562	0.014	0.470	-0.005	0.463
Bid-ask spread	0.816	4.892	0.722	4.027	0.968	4.574	1.001	7.051
Impl. Vol. Floor 10y	29.774	6.279	25.848	3.176	36.295	1.958	37.745	3.916
Avail. Lending	3.640	3.829	4.272	4.151	3.010	3.047	1.751	1.969

Table 2: **Distribution of specialness -** This table reports the fractional distribution of specialness, the average, the standard deviation, the minimum and the maximum of the daily distribution. The statistics are reported for the full sample and for three distinct sub-periods. First period from 1 October 2009 to 7 August 2001. Second period: from 8 August 2011 to 21 December 2011. Third period: from 22 December 2011 to 12 July 2012 (see section 3 for details about the variables).

Specialness	Freq.	Mean	St.dev.	Min	Max
Full sample					
$(0, 25]$ bps	0.852	8.280	6.059	0.000	25.000
$(25, 50]$ bps	0.103	34.042	6.796	25.002	49.982
$(50, 75]$ bps	0.024	59.897	6.956	50.002	74.984
$(75, 100]$ bps	0.008	85.752	7.027	75.089	99.982
> 100 bps	0.011	173.981	96.899	100.002	1020.185
$10/09 - 08/11$					
$(0, 25]$ bps	0.904	7.472	5.853	0.000	25.000
$(25, 50]$ bps	0.069	33.534	6.679	25.002	49.974
$(50, 75]$ bps	0.012	59.967	6.959	50.002	74.702
$(75, 100]$ bps	0.004	85.402	7.225	75.110	99.763
> 100 bps	0.009	194.765	114.425	100.128	1020.185
$08/11 - 12/11$					
$(0, 25]$ bps	0.565	13.556	6.350	0.005	25.000
$(25, 50]$ bps	0.294	34.642	6.913	25.005	49.982
$(50, 75]$ bps	0.081	59.478	6.722	50.006	74.978
$(75, 100]$ bps	0.029	85.585	6.869	75.089	99.982
> 100 bps	0.031	156.093	71.190	100.002	458.099
$12/11 - 07/12$					
$(0, 25]$ bps	0.887	8.577	5.353	0.000	24.984
$(25, 50]$ bps	0.080	33.909	6.698	25.012	49.897
$(50, 75]$ bps	0.020	60.902	7.473	50.013	74.984
$(75, 100]$ bps	0.007	86.931	7.017	75.405	99.744
> 100 bps	0.005	133.025	37.885	100.875	282.754

Table 3: **Correlation matrix -** This table reports the correlation matrix of all the variables used in the analysis. The statistics are reported for the full sample and the second period. The second period: from 8 August 2011 to 21 December 2011.

	Special.	Repo flow	Imb. cash	Bid-ask	Impl. Vol.	Lend.	SMP Holding	SMP Purchase
Full sample								
Specialness	1.000							
Repo flow	0.057	1.000						
Imb. cash	-0.022	-0.011	1.000					
Bid-ask	-0.012	-0.019	0.027	1.000				
Impl. Vol.	0.166	-0.101	0.007	0.025	1.000			
Lending	-0.138	0.052	0.013	-0.040	-0.207	1.000		
SMP Hold.	0.162	-0.020	0.004	-0.019	0.351	-0.136	1.000	
SMP Purch.	0.069	0.032	0.014	-0.006	0.099	-0.030	0.355	1.000
08/11 - 12/11								
Specialness	1.000							
Repo flow	0.096	1.000						
Imb. cash	-0.015	- 0.047	1.000					
Bid-ask	-0.023	-0.012	0.010	1.000				
Impl. Vol.	0.130	-0.041	0.055	0.001	1.000			
Lending	-0.181	0.005	0.024	-0.033	-0.111	1.000		
SMP Hold.	0.118	0.085	0.006	-0.061	-0.150	-0.112	1.000	
SMP Purch.	0.050	0.105	0.040	-0.023	-0.054	-0.032	0.333	1.000

Table 4: The table shows the results of OLS panel regressions with bond fixed effects with each observation defining a bond-day. The dependent variable is Specialness (in basis points), defined as in section 3.1. Explanatory variables are lagged by one day. Standard errors are reported in parenthesis and are clustered by bond and time identifier. The results are reported for the full sample and for three distinct sub-periods. First period from 1 October 2009 to 7 August 2001. Second period: from 8 August 2011 to 21 December 2011. Third period: from 22 December 2011 to 12 July 2012 (see section 3 for details about the variables).

	(1)	(2)	(3)	(4)
	Full sample	1st period	2nd period	3rd period
Repo Flow	1.008***	0.877***	1.814**	0.193
	(0.259)	(0.261)	(0.734)	(0.150)
Cash Imbalance	-1.412***	-1.445***	-3.468**	-0.377
	(0.408)	(0.404)	(1.503)	(0.391)
Impl. Vol. Floor 10y (log)	21.871***	22.708***	75.739***	-2.396
	(3.895)	(4.080)	(21.618)	(7.273)
Avail. Lending	-1.011***	-1.121***	-1.812***	-0.361
	(0.338)	(0.412)	(0.518)	(0.329)
Bond time-to-mat.	0.256*	0.281*	0.204	0.177
	(0.146)	(0.162)	(0.152)	(0.130)
Dum. Auction	-7.938***	-6.342**	-18.700***	-7.820***
	(2.025)	(2.606)	(3.000)	(2.369)
Dum. on-the run 10y	20.704	21.253	33.759***	6.845***
	(17.744)	(25.218)	(3.331)	(1.724)
Dum. on-the run 5y	0.247	-0.475	8.082	-4.049
	(3.700)	(3.115)	(7.523)	(2.549)
Dum. first off-the run 10y	14.083	-3.776	100.425***	18.898***
	(14.500)	(2.351)	(22.132)	(1.932)
Dum. first off-the run 5y	-4.179**	-4.965***	-5.781***	-0.489
	(1.893)	(1.610)	(2.044)	(1.847)
Bid-ask spread	-0.064	-0.061	-0.112*	-0.055
	(0.043)	(0.055)	(0.062)	(0.065)
Constant	-56.567***	-58.486***	-239.255***	21.773
	(13.484)	(12.345)	(77.366)	(25.953)
R^2	0.067	0.052	0.205	0.035
Num. Obs.	37153	26609	4745	5747

Table 5: The table shows the results of OLS panel regressions with bond fixed effects with each observation defining a bond-day. The dependent variable is Specialness (in basis points), defined as in section 3.1. Explanatory variables are lagged by one day. Standard errors are reported in parenthesis and are clustered by bond and time identifier. The results are reported for the full sample and for two distinct sub-periods. Second period: from 8 August 2011 to 21 December 2011. Third period: from 22 December 2011 to 12 July 2012 (see section 3 for details about the variables). Column (3) and (4) shows the results for the "On-the-run" and "Off-the-run" bonds for the second period.

	(1)	(2)	(3)	(4)	(5)
	Full sample	2nd period	2nd period	2nd period	3rd period
			On-the-run	Off-the-run	
Repo Flow	0.923***	1.598**	2.734**	1.004	0.218
	(0.260)	(0.789)	(1.233)	(0.867)	(0.143)
Cash Imbalance	-1.396***	-3.144**	2.771	-3.910**	-0.752**
	(0.420)	(1.578)	(4.092)	(1.644)	(0.367)
Impl. Vol. Floor 10y (log)	16.374***	86.190***	163.539***	64.378***	-0.149
	(3.902)	(22.779)	(60.649)	(21.315)	(6.731)
Avail. Lending	-0.956***	-1.604***	-3.670	-1.668***	-0.406
	(0.329)	(0.482)	(2.807)	(0.520)	(0.339)
Bond time-to-mat.	0.259*	0.208	3.183	0.189	0.276**
	(0.143)	(0.139)	(1.963)	(0.128)	(0.124)
Dum. Auction	-7.686***	-19.121***	-5.042	-16.355***	-7.326***
	(2.075)	(3.155)	(6.926)	(4.574)	(2.524)
Dum. on-the run 10y	21.128	36.968***			10.910***
	(18.160)	(5.431)			(1.334)
Dum. on-the run 5y	0.231	8.893			-1.422
	(3.513)	(8.072)			(1.437)
Dum. first off-the run 10y	13.970	99.775***			21.453***
	(14.296)	(23.364)			(1.025)
Dum. first off-the run 5y	-4.544***	-6.530***			-0.410
	(1.570)	(2.023)			(1.530)
Bid-ask spread	-0.038	-0.065	-2.530	-0.079*	0.054
	(0.039)	(0.047)	(6.274)	(0.047)	(0.069)
SMP Holdings	1.993***	1.404**	0.756	1.663**	3.697***
	(0.636)	(0.579)	(1.223)	(0.695)	(0.920)
SMP Hold. x Repo Flow	0.088	-0.074	0.360	-0.349*	0.125
	(0.183)	(0.148)	(0.310)	(0.203)	(0.229)
SMP Hold. x Cash Imbalance	-0.440	-1.300	-0.177	-0.522	0.441
	(0.917)	(1.172)	(2.475)	(1.323)	(0.963)
SMP Purchase	1.527	-4.192	4.385	-8.201	8.797
	(3.320)	(3.454)	(3.341)	(5.163)	(15.796)
SMP Purch. x Cash Imbalance	-12.173***	-9.499***	-12.199***	-43.804***	-12.499
	(3.294)	(3.469)	(4.023)	(15.884)	(21.973)
SMP Purch. x Repo Flow	2.027***	1.958**	0.762	3.915**	-4.736
	(0.667)	(0.998)	(0.961)	(1.904)	(7.573)
Constant	-39.226***	-279.848***	-565.166***	-200.443***	9.530
	(13.648)	(81.363)	(216.353)	(76.160)	(24.097)
R^2	0.080	0.220	0.130	0.091	0.098
Num. Obs.	37153	4745	1112	3633	5747

Table 6: The table shows the results of quantile panel regressions with bond fixed effects with each observation defining a bond-day. The dependent variable is Specialness (in basis points), defined as in section 3.1. Explanatory variables are lagged by one day. Standard errors are in parenthesis. The results are reported for second sub-period. Second period: from 8 August 2011 to 21 December 2011 (see section 3 for details about the variables).

	(1)	(2)	(3)
	Q-50	Q-70	Q-90
Repo Flow	0.233***	0.354***	0.863***
	(0.033)	(0.042)	(0.150)
Cash Imbalance	-0.519***	-0.800***	-1.771***
	(0.130)	(0.154)	(0.474)
Impl. Vol. Floor 10y (log)	36.473***	48.611***	63.027***
	(0.401)	(0.437)	(1.112)
Avail. Lending	-0.780***	-0.966***	-1.260***
	(0.022)	(0.026)	(0.098)
Bond time-to-mat.	0.122***	0.143***	0.341***
	(0.010)	(0.011)	(0.028)
Dum. Auction	1.195	0.262	-6.197*
	(1.064)	(1.169)	(3.203)
Dum. on-the run 10y	37.188***	38.585***	86.121***
	(0.552)	(0.607)	(1.643)
Dum. on-the run 5y	9.813***	11.158***	12.313***
	(0.545)	(0.601)	(1.645)
Dum. first off-the run 10y	32.875***	37.436***	42.013***
	(0.554)	(0.609)	(1.649)
Dum. first off-the run 5y	4.906***	1.919***	-2.328
	(0.565)	(0.622)	(1.684)
Bid-ask spread	-0.222***	-0.151***	-0.153**
	(0.018)	(0.024)	(0.069)
SMP Holdings	0.034	0.996***	4.082***
	(0.064)	(0.073)	(0.192)
SMP Hold. x Repo Flow	0.248***	0.247***	0.022
	(0.030)	(0.038)	(0.113)
SMP Hold. x Cash Imbalance	-0.035	-0.774**	-3.897***
	(0.328)	(0.365)	(0.844)
SMP Purchase	13.456***	9.808***	10.746***
	(0.849)	(0.974)	(2.022)
SMP Purch. x Cash Imbalance	-4.566***	-5.658***	-15.828***
	(1.216)	(1.390)	(2.878)
SMP Purch. x Repo Flow	-0.340*	0.547*	1.367**
	(0.202)	(0.300)	(0.569)
Constant	-117.368***	-150.838***	-186.848***
	(1.353)	(1.471)	(3.789)
Num. Obs.	37153	37153	37153

Table 7: The table shows the results of probit and tobit panel regressions with bond fixed effects with each observation defining a bond-day. The dependent variable is equal to one when at least a fail-to-deliver occurs at time $t+2$ in Column (1) and (2) and corresponds to the volume of settlement fails at time $t+2$ in Column (3) and (4). Standard errors are in parenthesis. The results are reported for full sample (see section 3 for details about the variables).

	(1) Probit	(2) Probit	(3) Tobit	(4) Tobit
Dum. Penalties	0.292***	0.096	0.030**	0.015
	(0.068)	(0.064)	(0.013)	(0.012)
Specialness	0.023***		0.002***	
	(0.001)		(0.000)	
Specialness X Dum. Penalties	-0.012***		-0.001**	
	(0.002)		(0.000)	
SMP Purchase		0.333**		0.031***
		(0.140)		(0.010)
SMP Purchase X Dum. Penalties		-0.221		-0.031*
		(0.178)		(0.017)
Imply. vol. floor 10y (log)	-0.070	0.285**	-0.012	0.033
	(0.133)	(0.138)	(0.023)	(0.026)
Bond time-to-mat.	0.016***	0.018***	0.002***	0.003***
	(0.003)	(0.004)	(0.000)	(0.001)
Dum. Auction	0.145*	0.070	-0.004	-0.021*
	(0.078)	(0.078)	(0.010)	(0.012)
Dum. on-the run 10y	0.690***	0.767***	0.066***	0.130***
	(0.126)	(0.133)	(0.024)	(0.045)
Dum. on-the run 5y	0.683***	0.670***	0.087***	0.098***
	(0.118)	(0.138)	(0.024)	(0.029)
Dum. first off-the run 10y	0.895***	0.951***	0.094***	0.129***
	(0.101)	(0.120)	(0.020)	(0.024)
Dum. first off-the run 5y	0.464***	0.401***	0.047**	0.042**
	(0.137)	(0.138)	(0.019)	(0.021)
Num. Obs.	63598	62104	65377	63912