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The importance of being special: Repo markets during the crisis

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Stefano Corradin, Angela Maddaloni The importance of being special:
repo markets during the crisis

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Abstract

Specialness - the premium of procuring a specific security in the repo market - increased in the second half of 2011 for Italian government bonds. We assess the impact on specialness of the outright purchase program of the Eurosystem during the same period. Bonds bought by the Eurosystem had higher specialness. The impact was economically significant and persistent. Short-selling traders had to pay a net premium to close their positions and therefore may have decided to fail on their delivery. Indeed bonds that were bought under the program were more likely to be underlying a fail-to-deliver transaction.

JEL classification: E43, E51, G01, G12, G23

Keywords: Repo, Specialness, Central bank asset purchases, Short-selling

Non-technical summary

Temporary scarcity of securities may occur even in very liquid financial markets. Bonds that are scarce typically trade at a premium - reflected in their price - resulting from limited supply and high demand. Repo markets - where a short-term loan is guaranteed by the temporary transfer of collateral - are very relevant and liquid financing markets. They also provide a measure of the premium to be paid for a scarce security. Repo rates on loans collateralized by securities issued by the same sovereign pay the same rate - the general collateral (GC) rate - but a few securities are typically on special. The special rate associated with a security on special is typically less than the prevailing GC rate. As a result, the owner of a security that is on special is able to obtain a loan at a below-market refinancing rate via a repo. The specialness of a given security is defined as the difference between the GC rate and the special rate and it measures the premium to be paid for procuring that specific security.

How do changes in supply and demand affect the specialness of a security? How are shocks to supply and demand transmitted from the cash markets where securities are traded to the repo markets where they are used as collateral? What are the implications on market functioning? All these questions are relevant for researchers and policy makers with an interest in financial markets, not least because shocks to supply and demand of securities can result in episodes of market malfunctioning and can exacerbate stress in already volatile markets.

The Security Market Program (SMP) implemented by the Eurosystem in 2010 – 2012 provides a natural experiment to investigate these issues. The purchases were conducted on the bond cash market, but their impact was transmitted to the repo market. The SMP portfolio was strictly buy-to-hold and purchased securities were not lent out. Therefore, the purchases induced large shocks to the supply of these securities. This is a clear distinction between the SMP and the public sector purchase program (PSPP) implemented by the Eurosystem since March 2015 in the context of the expanded asset purchase programme. The holdings under the PSPP are made available for securities lending in order to “...*support bond and repo market liquidity without unduly curtailing normal repo market activity.*”¹

This study, based on repo trades with underlying Italian sovereign bonds, shows that indeed specialness is affected by the amount of a security that is effectively available for trading on the market. This results from the combined effect of the auction cycle, the amount of securities 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 and securities that are less available for trading tend to be more special.

¹See <https://www.ecb.europa.eu/mopo/implement/omt/lending/html/index.en.html>.

Bonds bought by the central bank through the SMP tended to have higher specialness and purchases likely affected also the distribution of specialness, inducing a larger right-hand tail. A purchase shock of 1% of outstanding amount of a security increased its specialness, on average, of 5 basis points. The peak impact was reached after around 5 trading days and persisted for two weeks. The impact of purchases was economically significant, accounting on average for around 25% of the recorded specialness.

The premium to be paid to procure a specific security results from the actions of the short-(speculative) sellers and the long position traders. The price at which a security is finally sold or bought to close the trade determines the gains or the losses of each position. During the period in which the central bank purchased securities through the SMP, short sellers ended up paying a positive premium to close their positions. They may have decided, therefore, to fail on the delivery of the bonds to limit their losses. Indeed, the probability of a transaction to end up with a delivery failure was higher for very special bonds and bonds that were bought by the central bank.

1 Introduction

In the bond market scarcity is an important phenomenon. Bonds may trade at a premium - reflected in their price - when they are scarce, resulting from limited supply and high demand. Repo markets allow to pin down a security-specific premium related to scarcity. Repo transactions with underlying securities issued by the same sovereign generally pay the same rate - the general collateral (GC) rate - but a few securities are typically on “special.” The associated special rate is typically less than the prevailing GC rate. As a result, the owner of a security that is on special is able to obtain a below-market refinancing rate via a repo. The specialness of a given security - defined as the difference between the GC rate and the special rate - measures the premium to be paid for procuring that specific security.

There is limited empirical evidence on how supply and demand affect specialness. How does specialness change in response to changes to the demand for and the available supply of a security? How are shocks to supply and demand transmitted from the cash market - where securities are traded - to the repo market - where they are used as collateral? and finally, what are the implications on market functioning? We address these questions guided by the seminal work of Duffie (1996), who examines the factors driving specialness. Normally, the supply curve for repo collateral would be sufficiently large relative to the demand curve to drive specialness close to zero. However, specialness increases when short-hedging and short-speculative demand in the cash market are high, particularly relative to the issued amount of the security. Specialness increases also when a large portion of investors buy-and-holds the security, thus taking collateral away from the repo market. These effects may be sizable and high levels of specialness may be triggered by temporary market squeezes.

But the effects of high level of specialness are not always confined to the repo market. If the premium to be paid to acquire a security is too high, investors may decide to fail to deliver when the cost of borrowing is larger than the cost of failing. Therefore, trades of that specific security are less likely to clear and hence a market participant is less likely to receive the security that has been purchased or borrowed adversely affecting the market functioning (Fleming and Garbade (2005)). More broadly, market liquidity can also be adversely affected. Market dealers, who rely on repo markets for financing and hedging their activities, can reduce their participation in the market due to the increasing cost of borrowing a specific security and/or to mitigate the costs associated with fails. In fact, specialness can be seen as a reflection of search frictions in the repo market and difficulties

in locating lenders of securities.^{2,3} This phenomenon can affect asset prices as well as shown by Duffie, Gârleanu, and Pedersen (2007).⁴

The Securities Market Programme (SMP) implemented by the Eurosystem provides a unique case study to test empirically on how supply and demand affect specialness. In the summer and fall of 2011, specialness of Italian government bonds strikingly increased. More Italian sovereign bonds became more special with dramatic changes in levels and persistency not previously observed in such liquid and large markets (see Figure 1).⁵ The average specialness computed on all underlying Italian sovereign securities increased from 12 to 30 basis points. But some bonds (for example the 10-year on-the-run bonds) became very special with specialness climbing from 20 basis points to an overall peak of 400 basis points resulting in a significant increase in the upper tail of the distribution. In August 2011 the Eurosystem started to actively intervene in the Italian sovereign bond market by purchasing government securities reactivating the SMP. The portfolio was strictly buy-to-hold and purchased securities were not lent out.

In the context of the outright purchases carried out by the central bank, we investigate the dynamic links between supply and demand shocks in the bond cash market and the premia paid in the repo market on certain bonds (the "specials"). Compared to the previous literature on special repos, which are generally traded over-the-counter, we have the advantage of investigating an exchange-traded repo and cash market, using a unique dataset obtained from the Mercato dei Titoli di Stato (MTS), one of largest electronic trading platform for sovereign bonds.

Our analysis poses a number of challenges, mainly related to endogeneity concerns. The decision to implement the SMP was in fact taken as a response to impairment in the monetary policy transmission amid market disruptions and rising yields in several euro area sovereign markets. A major concern is the possibility that the central bank might have reacted to

²Fleming and Garbade (2003) document how liquidity in US treasury markets improved by allowing alternative types of treasury securities to be deliverable in settlement of a given repurchase agreement, mitigating the costs of search for a particular issue.

³Kolasinski, Reed, and Ringgenberg (2013) examine how equity lending fees respond to demand shocks. They find that, at high demand levels, increases in demand lead to significantly higher fees and the extent to which demand shocks impact fees is also related to search frictions in the loan market. Moreover, consistent with search models, they find significant dispersion in loan fees, with this dispersion increasing in loan scarcity and search frictions.

⁴See Duffie, Gârleanu, and Pedersen (2005) and Duffie, Gârleanu, and Pedersen (2007) for models of over-the-counter markets where traders need to search for counter parties and incur opportunity cost or other costs while doing so.

⁵The figure plots the empirical distribution of specialness for the 50th, 70th and 90th percentile. Specialness is calculated as the difference between the general repo rate and the special repo rate on a specific security and day of trading. The rates refer to repo transactions with underlying Italian sovereign securities as traded on the MTS repo platform from 1 October 2009 to 7 July 2012. See Subsection 3.1 for a detailed description of the variables and the data sources.

developments in the cash and repo market targeting the bonds that were less liquid and were expected to face shorting pressure. We address this issue following several approaches. First, we analyze the holding portfolio of the Eurosystem by means of summary statistics. The Eurosystem disclosed only broad volumes of purchases, it did not communicate details on the portfolio of securities and it did not engage in securities lending. However, ex-post analysis of the portfolio suggests that purchases were concentrated in more liquid bonds with larger outstanding amounts. This notwithstanding, specialness of the purchased bonds rose significantly more than for the entire sample of bonds. This reflected also a positive demand for these same bonds in the repo market, a positive "repo imbalance". During the crisis, more traders in the repo market were offering cash in exchange for these bonds, presumably to cover short positions.

Then, we run exploratory panel regressions. Along the lines of the identification framework of Eser and Schwaab (2016), we assume that prices and quantities of purchased assets were not simultaneously determined. This is justified by the framework for the implementation of the SMP. Strong required coordination among the national central banks and the ECB implied that the purchase volumes were predetermined at a daily frequency (see Eser and Schwaab (2016) for details). In addition, Ghysels et al. (2016), using intraday data on purchases and yields during the same periods, find no evidence that the level of yields affected the volumes of SMP purchases. We show that specialness is affected by the amount of a security that is *effectively available* for trading on the market, resulting 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 consistent with previous literature (see Jegadeesh (1993), Sundaresan (1994), Keane (1995) and Jordan and Jordan (1997)). Securities that are less available for trading tend to be more special. Bonds bought by the Eurosystem through the SMP had higher specialness. Our OLS results are consistent with D'Amico, Fan, and Kitsul (2013), who analyze the impact of the Fed outright purchases on the US repo market during the recent quantitative easing programs. In addition to their results, we show also that purchases have an impact on the distribution of specialness, inducing a larger right-hand tail.

Our analysis departs from the current literature when we attempt to identify the economic factors behind specialness and assess the consequences of high levels of specialness. First, we estimate a structural panel VAR with the same set of variables used in the regressions. We show the impact of purchase shocks on specialness and repo imbalance by means of impulse responses. By estimating appropriate impulse responses we are able i) to disentangle the channels of transmission of the purchase shocks and assign a specific role to the demand in the repo market implied by the purchases and ii) analyze the persistence

of the effects. A purchase shock of 1% of the outstanding amount of a security increases its specialness, on average, of 5 basis points at the peak, which is reached after around 5 trading days. The impact on specialness is always significant and persistent up to 15 days, suggesting some long-lasting effect. A shock to the security-specific demand has a sizable impact on specialness as well. Conversely, we find that a shock to specialness does not have a statistically significant impact on outright purchases suggesting that higher specialness did not result in larger outright purchases. Therefore, we do not find evidence for the hypothesis that SMP purchases were targeted to securities with heightened specialness. The results are robust to different contemporaneous identification schemes and restrictions of the sample along different dimensions (restrictions to spot next transactions, trimming of the sample for outliers) and estimation of the variables in first differences to address possible stationarity concerns. We also perform a historical counterfactual decomposition and show that the effects of purchase shocks were economically significant. On average purchase shocks explained around 25% of specialness, but at times they accounted for up to 70%.

Second, we examine the relation between specialness and cash premium. By no-arbitrage a bond that trades “special” in the repo market should also trade at a premium in the cash market (Duffie (1996)). A number of papers have documented empirically a price premium paid for securities that trade on “special” (see Jordan and Jordan (1997), Krishnamurthy (2002), Buraschi and Menini (2002), Goldreich, Hanke, and Nath (2005), Banerjee and Graveline (2013) and D’Amico, Fan, and Kitsul (2013)).⁶ Banerjee and Graveline (2013) decompose the cash premium and show that short sellers and long investors have both a role in affecting the observed premium. In particular, they show that if short sellers pay a net premium, i.e. the cost of borrowing a bond is higher than the price premium they collect from selling it later, it must be that the long investors, in aggregate, are unwilling to lend out their holdings to provide the securities to the market. In addition, Banerjee and Graveline (2013) show that during financial crisis short sellers end up paying a net premium. We follow a similar approach and we link the short selling premium to the Eurosystem purchases. We show that during the SMP purchases short sellers largely paid the high security-specific premium, consistent with the argument that the long position (the Eurosystem indeed) forwent to cash in the large premium by not engaging in security lending.

Third, we document that the volume of failed transactions abnormally increased during the same period (see for example Banca d’Italia (2012)). Starting from this suggestive evidence, we look at how large purchases of securities and the related shocks to security-specific supply and demand may induce episodes of market malfunctioning. Fleming and

⁶D’Amico, Fan, and Kitsul (2013) find that this premium is significantly stronger on the days of the Fed operations and for securities eligible for the Fed purchases.

Garbade (2005) and more recently Fleming et al. (2014) provide suggestive evidence that traders may decide to strategically fail to deliver when the premium to get a specific security becomes high, even if they incur in penalties. However, current literature provides evidence only on the stock market (see Evans et al. (2009) and Fotak, Raman, and Yadav (2014)). We show, in fact, that the occurrence of fails-to-deliver is linked to specialness and central bank purchases in the bond market. We find that the probability of a fail-to-deliver increases with the specialness of the bond: a 1 basis point change in specialness increases the probability of a fail-to-deliver by 0.37%. Thus, the probability of a transaction to end with a delivery failure increases for bonds that were bought by the central bank.

The paper is organized as follows. Section 2 provides institutional details on repurchase markets and reviews the previous findings on the determinants of specialness. Section 3 describes the data. Section 4 provides an overview of our empirical strategy. Section 5 presents our explorative analysis, while we present the results of the dynamics of specialness around the SMP purchases in Section 6. Finally, we look at the link between specialness, central bank purchases and fails-to-deliver in Section 7. Section 8 concludes.

2 The repo: basic features

A repo transaction combines two financial transactions legs 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. Repo rates are implied by the difference between the two prices. The repurchase agreement may entail to buy back the next day (overnight repo) or at a later date, usually up to one year. The most common maturities for repos on electronic platforms are: *overnight*, when the repo settles on the trade date T and the bond is repurchased the next business day ($T + 1$); *tomorrow next*, when the repo settles at the trade date plus one business day ($T + 1$) and the bond is repurchased the following business day ($T + 2$); *spot next* when the repo settle at ($T + 2$) and the bond is repurchased at ($T + 3$) (see Miglietta et al. (2015) for an analysis of transactions on the MTS platform).

The party lending the security in the first transaction in exchange of liquidity (possibly to finance the original purchase of the bond) is entering a (financing) *repo* agreement, while the party that borrows the security and commits to deliver it at the agreed future date enters a *reverse repo*.⁷

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

⁷Since 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 example for transactions taking place on the electronic trading platform MTS repo.

ISIN code), while in general collateral repos (GC repos) he/she can choose among a basket of possible assets. We focus our study on special repos transactions because we are interested in the effect of changes to security-specific demand and supply.

Special repos imply the payment of a special rate. The special rate can be lower than the general repo rate, reflecting the convenience yield of the asset - how sought-after the asset is. Special rates can even become negative, in cases of extreme market squeezes, when the counter party lending liquidity is willing to pay a premium (and therefore forgo the return on the loan) in order to get a 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), bonds tend to become special when there are significant restrictions to the *available supply*, i.e. the quantity of the bond that can be effectively used for trading. Traders who are searching for a specific security and have difficulty in finding it (either by purchasing it or by borrowing it), are willing to pay a premium in the repo market to temporarily acquire that security. Jegadeesh (1993), Sundaresan (1994) and Keane (1995) for example relate these restrictions in supply to the tightness of the bids recorded at the auctions for on-the-run bonds. However, Dufour and Skinner (2005) point out that this may be less relevant when there are consecutive auctions for the same bond and when a long time has passed between the issuance of the first and the most recent tranche, for example (see Subsection 3.2 for details of the procedures followed by the Italian Treasury when issuing sovereign debt securities, which is most relevant for our studies).

The price of a special repo transaction tends to be related to short-selling activity, since the repo market is often 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 create and maintain short positions using the repo market. He also shows that specialness is increasing in the amount of short-selling activity in the cash market, also relative to the issue size.

We base our analysis on data on special repos traded on the MTS Repo electronic platform with Italian sovereign securities as collateral. The MTS Repo platform covers a significant percentage of the European market transactions and a leading share of the Italian repo market - repos backed by Italian government bonds. Miglietta et al. (2015) documents that

a large majority, up to 90%, of the current repo transactions on the MTS Repo platform is CCP-cleared. There are two CCPs involved in the clearing of the Italian repo market: LCH Clearnet SA and Cassa Compensazione and Garanzia (CCG). In centrally cleared repo transactions, CCPs require both parties to post initial margins with the CCP on the net of amount collateral due with the aim of providing the CCPs with sufficient resources to mitigate potential financial risks.⁸ Since transactions are CCP-cleared, the observed rates (prices) are not affected by counter party risk, but only by the risk of the underlying collateral.

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 our analysis comes from the MTS repo trading platform from 1 October 2009 to 7 July 2012. We have tick-by-tick transaction-level information on this market, including the type of repo contract (GC or 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, the maturity of the repo and the direction of the trading (reverse vs financing).⁹

We define the variable specialness as the difference between the general repo rate and the special repo rate on a specific security, repo maturity and day of trading

$$\text{Specialness}_{i,j,t} = \text{GCrate}_{j,t} - \text{Special rate}_{i,j,t}. \quad (1)$$

We calculate specialness of security i using all security-level transactions in the repo market on day t . Specifically, 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. To construct daily observations, we average this difference during day t for each bond i and repo maturity j . The average is weighted by the nominal

⁸In addition, both parties may be asked daily to post variation margins following mark-to-market valuation of individual positions vis-a-vis the CCP.

⁹See Adrian et al. (2012) for the important information needed to analyze the repo market. Differently from what happens in bilateral repos, there are no haircuts applied on the MTS electronic platform by the two trading parties.

amount of each special repo transaction. We select only transactions with one-day maturity (over night, tomorrow next and spot next). In the empirical analysis we further restrict the sample to tomorrow next and spot next transactions since we want to explore the links between the cash and the repo market. These transactions account for almost 98% of the total observed in our sample (see Table 6 in the Appendix). In particular, we focus on repo transactions where it is more likely that one of the counter party needs to hedge against a position previously acquired in the cash market. Settlement is two-day in the cash market trading on MTS, therefore the most relevant repo maturity are spot next and tomorrow next.

We also define a measure of security-specific demand in the repo market. Because we have information on the trading direction of the repo, we define the variable repo imbalance for security i and repo maturity j at time t as

$$\text{Repo imbalance}_{i,j,t} = \frac{\text{Reverse repo}_{i,j,t}}{\text{Outstanding amount}_{i,t}} - \frac{\text{Financing repo}_{i,j,t}}{\text{Outstanding amount}_{i,t}}, \quad (2)$$

where reverse (financing) repo is the aggregate reverse (financing) special repo transactions at security-repo maturity level on a daily basis. A positive value of the repo imbalance suggests the presence of market pressures from traders looking to borrow a security and lend liquidity. Outstanding amount is the volume of the security that has been issued until date t . Repo imbalance 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 Italian sovereign bonds market

We include information on the primary issuance of Italian sovereign bonds in the dataset. The daily amount outstanding of each bond (at the ISIN level) is reported using detailed issuance data from the Italian Treasury and the Bank of Italy. Given the large outstanding amount of the Italian government debt, bonds are issued by the Italian Treasury in (relatively small) tranches that however preserve the same maturity date and ISIN code. Normally, a new bond (with a new ISIN code) is issued in sequential tranches of about the same quantity.¹⁰ The currently issued bond is considered the *on the run* security for a certain maturity until a new bond (ISIN) is issued. 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 - a bond that it is currently off-the-run (see also Beetsma et al. (2014) for a detailed description of the Italian primary issuance market).

¹⁰An average number is for example six 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 debt management office.

The issuance mechanism may have an impact on the prices observed in the repo market. Therefore, we 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 total supply of that security. However, the amount of security that is actually available for trading is typically much lower, especially for securities that have been issued since long time. A sensible measure of the available supply of a security is 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 held in their portfolio to other market participants. The borrowers may use the securities to cover short positions and/or manage 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 define the variable cash imbalance as the difference between the sell volume and the buy volume of a single security on the MTS cash market. We have this information at a daily frequency from the MTS bond trading platform.¹¹ For each security i , we define

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

This measure reflects the *direction* of the cash market and the possible pressures stemming from short-selling activity. A positive value would suggest that the market is *short* on security i .

In the analysis we also use more traditional measures of market liquidity and security-specific liquidity as control variables. We consider the time-to-maturity of the bond as a proxy for the liquidity of that bond 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, but not coincident with an issue being on/off-the-run. We also include in the analysis the daily bid-ask spread, which should control for the liquidity pressures stemming from the cash market. Bid-ask spread is computed on BGN Bloomberg prices at or before 5pm.

¹¹MTS has two trading platforms where it is possible to trade Italian government bonds, an Italian and a European platform. Volumes are much larger on the domestic platform, but for completeness we have gathered data from both sources.

3.3 Fails-to-deliver

Trades taking place in both the repo and the cash market are typically agreed upon on a date T and settled on a successive date $T + x$. Transactions taking place on the MTS cash platform are settled after two days. However, there are also trades that fail to settle, when the relevant party fails to deliver the bond on the settlement date. While some episodes of high levels of fails arise from operational disruptions, other episodes are related to market participants' insufficient incentives to avoid fails (see for example Fleming and Garbade (2005)). This is the case when the price to acquire a specific security is so high that it is actually economically rational to bear the cost of failing, by paying penalty fees for example.

Fails-to-deliver in the Italian sovereign bond and repo markets have historically been very low, despite very low penalties.¹² Most likely this was related to the importance of maintaining credibility vis-a-vis other traders/financial institutions and also the CCPs. However, during the spring and summer of 2011, the number of fails notably increased (see Banca d'Italia (2012)). In order to minimize possible market disruptions arising from these fails, a new penalty system was introduced on 1 September 2011.¹³

To investigate how fails-to-deliver are linked to specialness, we have gathered data on fails-to-deliver involving transactions on Italian sovereign bonds from Monte Titoli, the relevant central securities depository for the Italian sovereign bonds. Data are reported at security level on a daily basis, but no distinction is available for fails taking place on different markets (for example for fails on the repo vis-a-vis the cash market). Settlement fails are reported on a cumulative basis, which implies that the volume of fails is equal to the number of days for which a transaction has not been settled times the volume of the failed transaction. Our measure of fails-to-deliver at security level is calculated as the nominal amount of fails over the total nominal amount of that security settled by Monte Titoli.

3.4 The Securities Market Programme (SMP)

The Eurosystem launched the securities market programme (SMP) in May 2010. This programme consisted of purchasing EUR-denominated bonds in the open market and retaining them on the balance sheet of the Eurosystem up to the payment of all the cash flows of the securities (hold-to-maturity strategy). The purchase programme had some distinctive features in terms of disclosure. The Eurosystem did not disclose the total amounts which

¹²Until 1 September 2011, there was a unitary penalty of 200 EUR charged for account and for security. However the penalty was triggered only when the combination of failed volumes and transactions reached a threshold of 90% and 95% respectively.

¹³After 1 September 2011, the penalty has been fixed at 0.001% of the failed volume and it is cumulated for the number of days during which the transaction remains on fail.

would be spent for the purchases, the time frame over which the program would be active, or the set of securities that would be targeted. Aggregate data on the outstanding value of the holding portfolio were only published weekly without any reference to the exact time during the week when the securities had been bought. Moreover, the Eurosystem did not provide a breakdown describing the composition of assets by national origin of issuance.¹⁴

Purchases were not evenly spread out over time. Figure 2 plots the accumulated book value over time. The largest purchases occurred after the introduction of the SMP on 10 May 2010, in the context of the central bank reactions to the Greek debt crisis, and after its reactivation on 8 August 2011, amid ongoing stress in the Italian and Spanish sovereign bond markets. In fact, there have been long periods in which no purchases took place. During the period from 25 March 2011 to 8 August 2011, the SMP was inactive for 19 weeks. Purchases stopped in January 2012.

To assess the impact of the SMP on specialness, we include data on the SMP bond purchases. $\text{SMP purchase}_{i,t}$ is the nominal amount bought by the Eurosystem of security i on day t and is standardized by the nominal outstanding amount of the security.

3.5 Summary evidence

Our dataset includes data on the MTS repo transactions on Italian government bonds from 1 October 2009 to 7 July 2012. During the summer of 2011, 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: the *pre-crisis*, *crisis* and *post-crisis* period. The first sub-period runs from 1 October 2009 to 7 August 2011, the date when the Eurosystem decided to reactivate the SMP and started open market purchases of Italian sovereign bonds. On 7 August 2011 an ECB press release stated '*The Governing Council of the European Central Bank (ECB) welcomes the announcements made by the governments of Italy and Spain concerning new measures and reforms in the areas of fiscal and structural policies. ... It is on the basis of the above assessments that the ECB will actively implement its Securities Markets Programme*'.

During the summer and fall of 2011, yields of Italian sovereign bonds remained very volatile. Figure 10 in the Appendix shows the yields of the on-the-run Italian government bonds with 5 and 10 years of maturity with the vertical lines separating the three periods

¹⁴On 21 February 2013, the Eurosystem provided details on securities holdings acquired under the programme revealing a country-by-country breakdown. Italian sovereign debt accounts for roughly half of the total: 103 billion Euros (\$136 billion) out of 218 billion Euros. Spain ranks second, with 44 billion euros of its debt purchased by the Euro area's central bank, followed by Greece (34 billion Euros), Portugal (23 billion Euros) and Ireland (14 billion Euros). These details on the SMP portfolio are updated yearly.

under consideration. Margins requested by CCPs on Italian sovereign bonds also went up, because the sharp rise in yields had reduced their collateral value (see Miglietta et al. (2015)). We end the *crisis* period on 21 December 2011, the day before the Eurosystem conducted the first 3-year Long Term Refinancing Operation (LTRO).¹⁵ 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.

During the crisis period specialness increased on average for all bonds and its distribution became more skewed with a fatter tail. Table 1 reports descriptive statistics for specialness for the overall period and the three sub-periods considered in the first row. During periods of market stress (from 8 August 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. Most notably, mean and standard deviation of specialness were higher for bonds purchased by the central bank (see figures in parenthesis). During the last period, specialness reverted back to the historical average and the standard deviation declined dramatically. One plausible explanation is the implementation of the first 3-year LTRO on 21 December 2012, which provided 489.2 euros billion to 523 credit institutions. Pelizzon et al. (2016) document that, following the Eurosystem intervention, the improved liquidity in the Italian government bond market strongly attenuated the dynamic relationship between credit risk and market liquidity.

Table 7 in the Appendix shows the distribution of specialness by 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. In Table 8 in the Appendix we also provide the main statistics for the GC and Special repo rates for the three sub-periods and show that special repo rates were negative in the tails of the distribution during crisis times.

Table 1 reports descriptive statistics for all the other explanatory variables. Looking at demand measures, it is noticeable that repo imbalance, the security-specific demand in the repo market, calculated for all the bonds traded on MTS Repo, substantially decreased in

¹⁵The Eurosystem engages in two types of market operations: main refinancing operations (MRO) and longer-term refinancing operations (LTRO). MROs are regular liquidity-providing transactions with a weekly frequency and a maturity that is one week. LTROs are liquidity-providing transactions offered every other week and usually have a maturity of one to three months. On two occasions during the time period that we consider, the Eurosystem decided to provide even longer maturities, a one-year LTRO (July 2009) and a three-year LTRO (December 2011 and February 2012). After October 2008, the Eurosystem has conducted fixed-rate auctions with full allotment.

the crisis period becoming negative. Indeed, more traders were willing to borrow liquidity offering as collateral specific securities to take advantage of very low special rates. We observe that indeed during the crisis period there was a significant increase in the volume of special transactions vis-a-vis GC transactions (see Figure 9 in the Appendix).¹⁶ However, when the statistics are computed only on the set of purchased securities, repo imbalance is positive, suggesting that these securities were instead in high demand.

At the same time, selling pressures in the cash market increased dramatically for the bonds in our sample, and much more for bonds that were purchased by the Eurosystem (see the statistics related to cash imbalance).

Turning to supply measures, the amount of securities available for lending declined already during the crisis, which may reflect worries from market participants that the securities would not be returned timely after lending, especially in periods of market stress. Available supply further declined in the post-crisis period, possibly linked to the effect of the very long term refinancing operations of the Eurosystem requiring more collateral posting (see Aggarwal, Bai, and Laeven (2015)).

We also consider two traditional liquidity measures. The average age of the bond used in repos - bond 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 average bid-ask spread increased over time pointing to some illiquidity in the cash market for sovereign bonds. Average bid-ask spread is significantly lower for the set of purchased securities, suggesting that the purchases were directed to generally more liquid assets.

Finally, turning to fail-to-deliver measure, the volume of fails over the exchanged amount doesn't vary dramatically across the three sub-periods, but it is about 20% higher than in the first period for the bonds purchased under the SMP.

4 Identification and empirical strategy

Our objective is to investigate the dynamic links between supply and demand shocks in the bond cash market and the premia paid on certain bonds (the "specials") in the repo market. In particular, we focus on the effects of outright purchases carried out by the Eurosystem in the bond cash market. The analysis of these links poses a number of challenges, mainly related to endogeneity concerns. The SMP implementation was decided amid high concerns for possible market disruptions. In fact, the decision of the Eurosystem to implement outright purchases was taken in reaction to rising yields in the sovereign bond markets of several

¹⁶One possible explanation is that parties looking for funds could get better rates in special operations, while, on the other hand, liquidity providers were very reluctant to accept any security in a period of high market stress.

euro area countries during the second half of 2011. A first issue to consider is therefore if this environment affects our analysis. Eser and Schwaab (2016) analyze the impact of the Eurosystem purchases on the yields of several euro area countries and control in their model for unobserved common factors, which capture the systematic co-movement across sovereign yields during the crisis. In our setting, we analyze only developments in two fixed income markets, with one sovereign as underlying, i.e. Italian sovereign securities. While the sovereign crisis most likely had different impacts on the financial markets across countries, it is sensible to assume that increasing sovereign credit risk would affect similarly yields in the cash market and GC rates in the repo market. Figure 3 shows the evolution of GC rates and special rates from July to December 2011. GC rates increased significantly during this period due to worsened funding conditions. Special rates increased as well on average, continued to mimic the patterns for GC rates but remained lower. We analyze specialness, the (weighted) difference between these two rates, with the assumption that the effect of the sovereign crisis would result in a similar rate increase. We control for all the variables that have been used in the related literature and are known to affect specialness and we try to isolate instead the effect that can be traced to the outright purchases. Indeed Figure 3 shows that special rates of purchased bonds recorded significantly lower rates, which suggests a distinct effect on specialness arising from the actions of the central bank.

An important related concern is also that purchases may not be exogenous to specialness since the Eurosystem might have reacted to developments in the cash repo market and targeted the bonds that were less liquid and were expected to face short-selling pressures. We approach this problem in several ways. First, we analyze the holding portfolio of the Eurosystem by means of summary statistics and run some exploratory panel regressions. The Eurosystem did not communicate details on the SMP and it did not engage in security lending. However, some important observations can be drawn by simply analyzing the summary statistics in Table 1. The average bid-ask spread for the bonds in the SMP portfolio is significantly lower than the average for the entire set of bonds. Thus, the Eurosystem did not consistently target less liquid bonds. At the same time, the average specialness of the securities in our sample increased significantly over the crisis period, but the increase was more pronounced (around 18% more) for the bonds that were purchased by the Eurosystem. Notably, at the same time, the average outstanding amount for the purchased bonds was around 25% higher than for the entire set of bonds in our sample. This is again consistent with the argument that the Eurosystem bought the most liquid bonds on the market. Most importantly, during crisis times, average repo imbalance was generally negative, i.e. there was a net balance of traders that were offering securities in exchange for cash, underlying the tight financing conditions in the money market. However, repo imbalance was positive

on average for the bonds purchased by the Eurosystem, which shows that demand for these bonds was indeed high in the repo market and that they were used in reverse repo transactions by traders looking to exchange cash for bonds.

Based on these observations, we run an exploratory analysis using panel regressions. First, we follow the identification framework of Eser and Schwaab (2016) assuming that prices and quantities of purchased bonds were not simultaneously determined. This is justified by the implementation framework for the SMP, which required strong coordination among the national central banks and the ECB. The purchase volumes were predetermined at a daily frequency (see Eser and Schwaab (2016) for details). In addition, Ghysels et al. (2016), using intraday data on purchases and yields, show that the level of yields did not affect SMP purchases. We explicitly include regressors that can be linked to demand and supply factors, and control for the most common factors used in the related literature. In fact our results are consistent with previous studies on determinants of specialness in the repo market. Next, we include in the analysis the purchases of the central bank and find statistically and economically significant impacts of the SMP purchases on specialness. These set of results is comparable with the results obtained by D'Amico, Fan, and Kitsul (2013) in the context of the Federal Reserve outright purchases. In addition to their results, we also show some evidence that purchases induced a fatter right-hand tail on the distribution of specialness.

Then, our main contribution compared to the related literature is to identify the economic factors behind specialness. First, we estimate a structural panel VAR with the same set of variables used in the regressions. We estimate impulse responses and show the impact of purchase shocks on specialness and repo imbalance. The results are robust to different contemporaneous identification schemes and restrictions of the sample along different dimensions (restrictions to spot next transactions, trimming of the sample for outliers). We also estimate the models using variables in first differences to address possible stationarity concerns. We also perform an historical counterfactual decomposition and show that the effects of purchase shocks were economically significant. By estimating appropriate impulse responses we are able i) to disentangle the channels of transmission of the purchase shocks and assign a specific role to the demand in the repo market implied by the purchases and ii) analyze the persistence of the effects.

Second, our analysis is devoted to the decomposition of the cash premium as in Banerjee and Graveline (2013). By calculating the returns of an appropriate arbitrage strategy between the repo and the cash market, we show that the Eurosystem purchases induced a very high short selling premium that was paid mainly by short sellers. The premium persisted because long positions (i.e. the central bank) were not constrained and did not make any action to cash in this premium, for example by lending the securities.

5 Explorative analysis of specialness

We estimate daily OLS panel regressions with bond and time fixed effects. Standards errors are clustered at the bond and time level.¹⁷ Our basic pooled fixed-effects panel regression specification is:

$$S_{i,t} = \beta_1 S_{i,t-1} + \beta_2 X_{i,t-1} + \beta_3 \tilde{X}_{i,t} + \alpha_i + \gamma_t + \theta + \varepsilon_{i,t}, \quad (4)$$

where $S_{i,t}$ is the specialness of bond i on day t . All the main explanatory variables are lagged by one period (day) to control for endogeneity effects. $X_{i,t-1}$ summarizes time-varying bond-specific controls that include: repo imbalance, cash imbalance, security lending supply and bid-ask spread. Instead, time-to-maturity and dummy variables for bond auction, $\tilde{X}_{i,t}$, are contemporaneous. Finally, the bond fixed effects, α_i , ensure that all bond-specific characteristics are accounted for, provided that they are invariant over time, while the time fixed effect, γ_t , captures time variation in the data. All the variables that we include in the regressions have little correlation with each other (see Table 9 in the Appendix). Thus, we test for unit roots across the panel using a Fisher-type Augmented Dickey-Fuller test and we reject the null hypothesis that our main variables are a unit root process (see Table 10 in the Appendix).

Table 2 shows the results of panel estimates with fixed effects as in Equation (4) for the full sample (Column (1)) and the three periods (Columns (2) – (4)). The estimation is carried out on the set of repo transactions *spot next* and *tomorrow next* because we want to pin down the channels of transmission between the cash and the repo market. Estimations based on the sample including separately spot next and tomorrow next transactions have similar results (see Table 11 and 12 in the Appendix).

The sign of the coefficient of repo imbalance is positive as expected, suggesting a role for security-specific demand linked to short-selling activities. Specialness is higher for bonds in high demand in the repo market - when more repo dealers are looking for initiating reverse repos on these bonds. This suggests a significant effect of short-selling activities on the specialness of specific bonds. The coefficient of repo imbalance is statistically significant for all the periods, except in the last one, but it is much larger during the crisis time. Thus, security-demand in the repo market affects specialness in normal times, but more so in times of stress, when short-sellers are willing to pay very high premiums to get hard-to-find

¹⁷As the descriptive statistics show, many values of the specialness are zero or very close to it (see in particular Table 7 in the Appendix). Thus, specialness is a truncated or limited dependent variable. To address this issue, we have run the analysis also using Tobit panel regressions. The results are very similar and available on request. We chose to report results obtained with OLS panel regressions to best compare with previous literature.

securities (see Banerjee and Graveline (2013)). During crisis, 1% increase in repo imbalance has an impact which is more than three times compared to the impact during pre-crisis period. At the same time, selling pressures in the cash market exert a negative impact on specialness.

Consistently with the previous literature (Duffie (1996) and Jordan and Jordan (1997)), we find also that specialness is related to variables reflecting the supply of a specific security. Securities available for lending, our proxy for the amount of a security available in the market, is negatively related to specialness. The coefficient is always significant at least at 10% except in the last period. Turning to the variables linked to the auction cycle, the occurrence of a new auction negatively affects specialness (Sundaresan (1994)). This effect is almost double than average during the crisis period, pointing to significant supply restrictions during market turbulences.¹⁸

The coefficient of the bond time-to-maturity variable is positive as expected and significant for all periods except in crisis times, suggesting that during market turbulences other determinants may become more relevant. The coefficient of the bid-ask spread variable is negative and statistically significant in all the periods suggesting that the more liquid securities tend to be on special.

So far, our results confirm that specialness is related to security-specific supply and demand. Security-specific supply depends on the auction cycle and on the supply available for trading. Demand is related to short-selling and trading for hedging purposes.

To investigate the impact on specialness of large purchases in the cash market, we explicitly include in the estimation the purchases of the central bank during the crisis. Table 3 reports the results of these panel regressions. We report the results for the *crisis* period (from 8 August to 21 December 2011) because SMP purchases were effectively carried out only during this period.¹⁹

The coefficients for the supply and demand variables are robust to the introduction of the new variable SMP purchase (see Column (1)). The values of the coefficients and the statistical significance are confirmed. Bonds purchased by the Eurosystem were more special. In terms of economic significance, a purchase of 1% of outstanding amount - on average around 200 millions (see Table 1) - results in 5 basis points of higher specialness. This value shows an important economic significance of the effect linked to the purchases,

¹⁸In non-reported regressions we have included the dummy in correspondence of the announcement of a new issuance, typically three days earlier. In this case, the coefficient for the dummy is significant and positive, consistent with the notion that traders take short positions in advance of the auction in order to exploit the liquidity of the on-the-run bonds (see Duffie (1996) and Sundaresan (1994)).

¹⁹Almost no purchases relevant for our analysis, i.e. involving Italian sovereign bonds, were carried out after 21 December 2011.

since the central bank acquired significant fractions of the outstanding amounts of several securities.

We also exclude the 10-year on-the-run bonds from our sample to verify whether our results are driven by the bonds who became very special - over 200 basis points - during the SMP implementation (see Section 6.2 for details). The results are not affected (see Column (2)).

As we have noticed already in Section 3, the crisis period was characterized by a significant increase in the dispersion of specialness. This suggests that the impact of determinants of specialness may not be constant across the distribution, but they vary across the quantiles. Therefore, we run quantile panel regressions with the same explanatory variables following the methodology proposed by Canay (2011).²⁰ Results are reported in the last three columns of Table 3 for the crisis period and for the highest quantiles (50th, 70th and 90th).²¹

The estimates from the quantile regressions suggest that demand and supply variables partly explain the differences across the quantiles of the distribution of specialness. In particular, the coefficients related to the Eurosystem outright purchases increase for the highest quantiles, suggesting a higher impact for the upper tail.

All in all our results suggest that large purchases in the cash market have an impact on the premium paid on these securities in the repo markets. The effect is economically significant (more than 5 basis points for a purchase of 1% of the outstanding amount). The increase in the dispersion of the specialness distribution points out to some heterogeneity in the effects across securities. On-the-run securities around the 10-year maturity seem to have a peculiar role. In the next sections we will try to pin down the role that a decrease in available supply and an increase in security-specific demand, possibly linked to short-selling may have had in affecting specialness.

6 Dynamics of specialness around the SMP purchases

6.1 Panel VAR

To examine more accurately the relation between SMP purchases, repo demand and specialness, we estimate a panel VAR with daily frequency using the entire portfolio of bonds that were purchased under the SMP. Following Ghysels et al. (2016), we rely on a VAR model for two main reasons. First, we can explicitly consider possible endogeneity between specialness

²⁰Canay (2011) proposes the following simple two-step estimator: (i) within estimation of the linear regression $Y_{it} = X_{it}\beta + \alpha_i + \varepsilon_{i,t}$, and from this estimation we can compute the individual fixed effects $\hat{\alpha}_i = (1/T) \sum_{t=1}^T (Y_{it} - X_{it}\beta)$; (ii) standard quantile regression of $\hat{Y}_{it} = Y_{it} - \hat{\alpha}_i$.

²¹We 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 estimated for the panel regressions.

and SMP interventions and estimate the related impulse response functions. Second, we can assess how the impact of SMP purchases fades over time.

We consider a 6-variable panel VAR with security-specific fixed effects represented by the following system of linear equations:

$$Y_{i,t} = A_1 Y_{i,t-1} + A_2 Y_{i,t-2} + \dots + A_p Y_{i,t-p} + B X_{i,t} + u_i + e_{i,t} \quad (5)$$

where $Y_{i,t}$ is the vector of dependent variables; $X_{i,t}$ is a vector of exogenous covariates; u_i and $e_{i,t}$ are vectors of security fixed effects and idiosyncratic errors, respectively. We consider the following dependent variables: (1) cash imbalance $_{i,t}$; (2) bid-ask spread $_{i,t}$; (3) SMP purchase $_{i,t}$; (4) repo imbalance $_{i,t}$; (5) specialness $_{i,t}$; and the (6) available lending $_{i,t}$. The estimation is based on GMM for dynamic panels with bond fixed effects as in Abrigo et al. (2016). All variables are in level. We restrict estimates to the crisis period, 8 August - 21 December 2011.

For all the specifications, we control for the auction date with dummy variables, as exogenous variable $X_{i,t}$. The lag length is set to one based on the usual information criteria (Schwarz SIC). This simple framework takes into account feedback loops between cash imbalance, bid-ask spread, SMP purchases, repo imbalance, specialness and available for lending. For identification we rely on a standard Choleski decomposition. In our baseline specification we order the variables as follows: cash imbalance, bid-ask spread, SMP purchases, repo imbalance, specialness and available for lending. We assume that shocks to SMP interventions have a contemporaneous impact on repo imbalance and specialness, but shocks to repo imbalance and specialness impact SMP purchases only with a lag. Shocks to cash imbalance and bid-ask spread affect contemporaneously SMP purchases, which explicitly takes into account that the Eurosystem may have reacted to developments in the cash market, although empirical evidence suggests that this was not the case (see also the discussion in Section 4). Shocks to repo imbalance have a contemporaneous impact on specialness, but shocks to specialness impact repo imbalance only with a lag.

We couch our main results in the form of impulse response functions (IRFs) and focus our discussion on significant responses. Bootstrapped 90% confidence intervals are based on 1,000 replications. Figure 4 shows selected IRFs, where each Panel corresponds to a different shock.²² Panel A shows the effect of a purchase shock of 1% of outstanding amount on repo imbalance and specialness. A purchase shock increases the level of specialness (right-hand plot) on average for all purchased bonds, of more than 5 basis points at the peak, after around 4 trading days. The size of the peak response is in line with the results of the panel

²²We report the complete set of IRFs in Figure 11 of the Appendix.

OLS regressions. The impact on specialness is always significant and persistent over 15 days, suggesting somewhat long-lasting effect.

The left-hand plot in Panel *A* shows the response of the security-specific demand in the repo market to a purchase shock of 1% of outstanding amount. The estimated response is positive. Purchases increase repo demand, but the estimated response is not statistically significant. Interestingly, the mean response peaks after around 2 days, consistent with traders trying to cover short positions, possibly because they have to deliver to the central bank, in time to settle transactions in the cash market.

As Panel *B* on the right-hand side shows, a positive shock of 1% to the repo imbalance has an immediate positive impact on specialness. The impact lasts for few days. The peak impact is around 5 basis points after 5 days, so it is economically significant also vis-à-vis the impact of purchases. Differently, SMP purchases do not clearly respond to repo imbalances and the impact is not statistically significant, which again supports our prior that the central bank did not react to developments in the repo market. Finally, Panel *C* shows that a shock to specialness does not have a significant impact on outright purchases and on security-specific demand. Overall, our main result is that SMP purchases have a medium-run statistically significant effect on specialness.

To test the robustness of our results, we perform three types of robustness checks: (1) consider alternative ordering of the variables where the SMP purchase variable is ordered last, thus allowing it to respond instantaneously also to repo imbalance and specialness shocks; (2) estimate the same panel VAR model with specialness in first-difference; and (3) exclude from the security portfolio the 10-year on-the-run bonds to verify whether our results are driven by the bonds who became very special, above 200 basis points, during the SMP implementation. Overall, we consistently find that SMP purchases increase specialness in a statistically and economically significant fashion. At the same time, the impact of specialness on SMP purchases is statistically insignificant. Results are confirmed when we change the order of the variables or exclude the 10-year on-the-run bonds from the sample (see Figures 12, 13 and 14 in the Appendix).

Finally, to better evaluate the economic significance of this impact, we construct a counterfactual series of average specialness based on the estimation of the structural panel VAR. Figure 5 plots the average specialness of bonds purchased under the SMP and the historical counterfactual of specialness.²³ The counterfactual shows how specialness for the bonds

²³Unlike structural impulse responses, historical decompositions are designed for stationary VAR variables. They cannot be applied to integrated or co-integrated variables in levels without modifications because they rely on the existence of a stationary moving average representation of the generating process. Therefore, the counterfactual historical exercise is based on the estimated VAR model with specialness in first-difference from 1 August 2011 to 21 December 2011.

bought under the SMP would have evolved replacing all realizations of the SMP structural shock with zero, while preserving the remaining structural shocks in the model. The historical counterfactual decomposition allows us to quantify how much of the specialness is due to the SMP purchases. The figure shows that the effects of purchase shocks were economically significant: on average purchase shocks explained around 25% of specialness, but at times they accounted for up to 70%.

Estimations of the impact of purchases on the entire portfolio suggest a sizable and persistent impact. The channel of transmission is related to the decrease in available supply, while the increase in demand is not significant. However, the increase in security-specific demand may have a short-lived but sizable impact on specialness. One major result that emerged from the panel regressions was the large heterogeneity of the effects (more dispersed distribution of specialness) and the importance of some specific benchmark bonds, in particular the 10-year issues. Thus, we run a case study based on the 10-year on-the-run bond, analyzing in detail the role of this benchmark issue and the determinants of its specialness.

6.2 Case study: 10-year on-the-run

In this section we focus the analysis on 10-year bonds and investigate the role that short-selling activities - usually concentrated on benchmark issues - have played.

During the time frame that we consider, two 10-year bonds issued successively were the benchmark (on-the-run) issues. Figure 6 shows all the important measures related to these 10-year on-the-run securities: specialness, repo imbalance and the SMP holdings (as percentage of the outstanding amounts).²⁴ The period covered is from 8 August 2011 to 21 December 2011. Each panel refers to a bond. The second bond was first issued on 1 September 2011 when the SMP was already active.²⁵

Panel A of Figure 6 shows that after the re-activation of the SMP on 8 August 2011 specialness of the on-the-run 10-year bond started to increase and it reached more than 400 basis points after few weeks, closely following the relative increase in SMP holdings and then it remained there for some time. The behavior of the second on-the-run bond is similar (see Panel B of Figure 6). The bond started trading on special few days after it was first auctioned consistent with the existent literature on premia of on-the-run bonds. As of mid-September, the repo rate on this issue fell below zero and as a result specialness reached 100 basis points and increased further up to 370 basis points until the bond was re-issued in the second regular auction on 3 October 2011. Following the second issuance, the specialness dropped almost to zero but after one week increased again. Afterwards, specialness decreased again

²⁴We don't report the SMP holding amounts given data confidentiality.

²⁵The ISINs codes of these two bonds are IT0004695075 and IT0004759673.

after the third auction.

The charts on the right side of Figure 6 show the patterns of repo imbalance for the two securities. During the first part of the sample, when the Eurosystem was purchasing securities at a sustained pace, repo imbalance was generally positive. Reverse repos were prevailing over financing repo transactions, possibly due to traders in need to cover short positions. These traders may have sold the securities to the central bank and needed to deliver. Alternatively, they might have had a short position in the futures market. Indeed, both benchmark securities were eligible for delivery to the future contracts expiring on 10 September and on 10 December 2011.

All in all, these developments are very much consistent with the predictions by Duffie (1996) concerning the impact of a large buy-to-hold investor. The Eurosystem became a large holder of the outstanding issue and did not supply again the security to the repo market by lending it out. This created a prolonged shortage of the issue for which possibly large short positions existed. As suggested by Duffie (1996) in his model, when the demand for an issue is unusually large, special repo rates tend to fall to entice the holders into supplying the bond to the market. In the next section we will investigate in detail this issue and try to identify the role played by short-sellers (possibly including brokers that had sold the securities short to the central bank).

6.2.1 A cash premium decomposition

Prices in the cash and in the repo market are linked by no-arbitrage arguments. Duffie (1996) shows that a bond that trades “special” in the repo market should also trade at a premium in the cash market. Jordan and Jordan (1997), Krishnamurthy (2002) and Buraschi and Menini (2002) empirically confirm this prediction. D’Amico, Fan, and Kitsul (2013) find that this relation is significant on the days of the Fed operations and for securities eligible for the Fed purchases, suggesting that specialness passes through to Treasury cash market prices, providing additional evidence in favor of the scarcity channel of quantitative easing (see for example Krishnamurthy and Vissing-Jorgensen (2011) and D’Amico and King (2013)). While these analysis find a statistically significant relationship between premia in the repo and in the cash market, the related economic significance is generally low as suggested by the estimated coefficients.²⁶

We follow a different approach to analyze the cash premium of bonds in our sample. Banerjee and Graveline (2013) provide a simple model which decomposes the cash premium

²⁶We perform a similar analysis as D’Amico, Fan, and Kitsul (2013) in our sample. Results are reported in Table 13 in the Appendix. While the coefficient of specialness is statistically significant only when the sample is restricted to the bonds purchased under the SMP, the value is low and therefore cannot fully justify the high value of specialness observed.

of a bond into the sum of two components, namely the net premium paid by the long and the short side of all the transactions involving that security. This decomposition allows us to quantify the fraction of the premium that it is due to the action of the central bank (the main holder of the long position) and to short-sellers. Consider two identical bonds, i and j , with respective price P_i and P_j that differ only by their liquidity, and therefore, by their shorting capability. Following Banerjee and Graveline (2013), let δ be the share of the liquid bond i that is sold short and let R be the premium to be paid to borrow that same security in the repo market (specialness).

The cash premium, C , can thus be decomposed in three components:

$$C = P_i - P_j = \underbrace{(1 + \delta) \times C}_{\substack{(1) \text{ Liquidity premium} \\ \text{paid by buyers} \\ \text{of the bond}}} - \underbrace{\delta \times R}_{\substack{(2) \text{ Financing premium} \\ \text{earned by buyers} \\ \text{of the bond}}} + \underbrace{\delta \times (R - C)}_{\substack{(3) \text{ Short-sellers pay} \\ \text{the financing premium} \\ \text{but sell at higher price}}} \quad (6)$$

where δ is the fraction of the outstanding supply of the bond that it is sold short.

The decomposition in Equation (6) emphasizes the importance of jointly analyzing the cash premium, the borrowing or financing premium, and the fraction of the outstanding supply of the liquid security that it is sold short. Indeed, a financing premium (i.e., $R > 0$) does not necessarily imply that short-sellers end up paying an overall net premium for positions in the liquid security, since it is possible that they recover completely these higher borrowing costs (i.e., if $C = R$). Similarly, a positive cash premium (i.e., $C > 0$) does not imply that long investors pay a net premium since they may be able to fully recover these costs by lending out their positions.²⁷ Banerjee and Graveline (2013) show that short-sellers pay a liquidity premium (i.e., $R - C > 0$) when there are very long-term investors (hold-to-maturity investors), like central banks, that forgo the special premia they can earn by lending out their bonds and recover almost none of the price premium they pay for taking long positions in on-the-run bonds.

We compute the short-selling premium as the returns from a trading strategy involving a short position in the on-the-run bond and a duration equivalent long position in the "more illiquid" bond. We roll over this position using observations from our sample during the crisis times. The on-the-run bonds are the two 10-year benchmark bonds that were on-the-run during the period of the outright purchases. The long position involves purchases in the second 10-year off-the-run bond, similarly to the procedure implemented by Banerjee and

²⁷Duffie (1996) and Krishnamurthy (2002) assume that there is an unconstrained arbitrageur who can hold arbitrarily large positions in the liquid security and lend out his entire position to short-sellers (while hedging the risk with an offsetting position in the illiquid security). This assumption ensures that short-sellers do not pay a liquidity premium (i.e., $R = C$), since otherwise the unconstrained long investor could make arbitrarily large profits by lending out all of his long positions in the liquid security at a premium and hedging with the illiquid security.

Graveline (2013) and along the lines of what proposed by Krishnamurthy (2002). Details of the procedure used to calculate this premium are outlined in the Appendix.

Figure 7 shows the short-selling premium for the two on-the-run bonds and plots also the difference between the SMP portfolio holdings of those bonds and the off-the-run bond. The average annual returns from the trading strategy are 2.10 and 7.24 basis points for the first and second 10-year on-the-run respectively. The short-selling premia are hovering around zero, but they reached high positive levels in two circumstances. The premium of the first on-the-run bond reached 100.84 basis points in the second week of September, when the SMP reached the highest level of holdings for that same bond (see Figure 6). It should be noted that this week coincides also with the delivery date of futures contract, 10 September 2011. Similarly, the premium of the second on-the-run bond reached 130 basis points in the second week of October 2011.

While the time-series plots are suggestive, we use regressions to formally test whether the variation on the cost of short-selling can be explained by the SMP purchases. Thus, we regress the daily estimate of $R - C$ on on-day lagged SMP purchases. We control for "flight to demand" using the one-day lagged yield spread between the Italian and the German GC rate.²⁸ The SMP purchases are included as the difference between the SMP daily purchases of the on-the-run and the off-the-run bond, $\widehat{\text{SMP}} \text{ purchase}_{ij,t}$, the supply that is likely to affect the prices paid by short-sellers. Table 4 reports separate estimates for the two bonds over the crisis period, from 8 August 2011 to 21 December 2011.

The empirical evidence supports our previous results. Table 4 shows that the SMP purchases are affecting the short-selling premium. Short sellers paid positive net premia. The long position held by the Eurosystem allowed this premium to be sustained in the market, since the central bank was not interested in cashing in the large premium by making the securities available again for trading.

This analysis raises the question of why some traders were willing to pay such high premia only to acquire some specific bonds. Bond dealers rely on the repo market to procure securities that they can sell to their clients when they don't have them already in inventory. This includes the case that we have already mentioned of dealers having to deliver securities to the Eurosystem. Another important observation is the close relationship between the cash, repo and futures market. The two securities that we have used for the decomposition, for example, were both eligible for delivery in the futures market. In particular, on 10 September 2011 and 10 December 2011 there were two delivery dates for the futures market with Italian bonds as underlying. This is likely to have fueled a strong security-specific demand for these

²⁸Banerjee and Graveline (2013) and Krishnamurthy (2002) instead use the yield spread between 3-month commercial paper and Treasury bills, CP-TBill spread.

two bonds. Pelizzon et al. (2014) provide a detailed evidence on this.

When the premium to be paid to acquire a security is extremely large, short sellers may also decide to strategically fail on delivering the securities. The volume of fails-to-deliver on the two benchmark securities increased dramatically during the period that we are considering suggesting the presence of strategic fails (see Figure 8). We analyze this issue in the next section.

7 Specialness and fails-to-deliver

To conclude the analysis we now look at how high specialness may induce episodes of market malfunctioning. We look in particular at the link between specialness, central bank purchases and fails-to-deliver. Fleming and Garbade (2005) and more recently Fleming et al. (2014) provide suggestive evidence that traders may decide to strategically fail-to-deliver when the premium to get a specific security becomes high, even if they incur in penalties. These phenomena are observed more often in periods of market stress.

During the spring and summer of 2011, the number of fails-to-deliver on transactions involving Italian sovereign bonds as underlying notably increased (see Banca d'Italia (2012)) and were not limited to the 10-year on-the-run bonds.

We estimate a Probit model of the probability of fail-to-deliver at time $t + 3$ and a OLS model on the nominal amount of fails over the nominal amount traded at time $t + 3$ with bond and time fixed effects. We estimate the following equation:

$$Y_{i,t+3} = \beta_{1,i}Z_{i,t} + \beta_{2,i}X_{i,t} + \alpha_i + \gamma_t + \theta + \varepsilon_{i,t}, \quad (7)$$

where $Y_{i,t+3}$ is either i) dummy variable equal to one when a fail-to-deliver of bond i at day $t + 3$ occurs (for the probit); ii) nominal amount of fail-to-deliver (over nominal amount traded) of bond i at day $t + 3$ (for the OLS). $Z_{i,t}$ is either i) the specialness of bond i at day t ; or ii) the SMP $_{i,t}$ purchase, over the outstanding amount, of bond i at date t . $X_{i,t}$ is a set of controls. We choose a lead of three days for our regressions to account for the possibility that a short-seller can fail-to-deliver the security at time $t + 3$ in a spot next repo contract.²⁹

Table 5 reports the results of this estimation over the crisis period. In the first three columns we report the results of the Probit model. Previous literature has shown that fails to deliver are associated to the premium to be paid to borrow the asset (see for example Evans et al. (2009) and Fotak, Raman, and Yadav (2014) for an analysis in the equity

²⁹Two 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 a lag ranging from 1 day to one week and found qualitatively similar results.

market). Therefore, we introduce specialness as explanatory variable and, as expected, the probability of a fail-to-deliver increases with the specialness of the bond. A 1 basis point change in specialness increases the probability of a fail-to-deliver by 0.37%.³⁰ Bonds that were issued since more time, therefore less liquid, have a higher probability not to be delivered at settlement. In Column (2) the sample is restricted to the bonds purchased under the SMP. To further disentangle the effect of outright purchases, we replace specialness with the SMP purchases (see Column (3)). The probability of fail-to-deliver is positively related to the amount of purchases, suggesting that the purchases have increased the cost of borrowing the bonds in the repo market and ultimately increased the value of the option to fail.

The results from the OLS estimation, reported in Columns (4) – (6), confirm the link between specialness, SMP purchases and fails-to-deliver. The dependent variable is the nominal amount of fails divided by the nominal amount outstanding at bond level.

In order to minimize possible market disruptions arising from these fails, an increase in fail-to-deliver penalties was introduced on 1 September 2011. However, we do not find a statistically significant evidence that the increase in the penalties was effective in mitigating the incidence or amount of fails when the SMP was active.

8 Concluding remarks

In this article we have analyzed how shocks to supply and demand in the cash market for sovereign bonds affect the scarcity premium - the specialness - recorded on the repo market where these bonds are used as collateral. 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.

The SMP - the outright purchase program conducted by the Eurosystem in 2011 - provides a unique case study to test how the actions of a large buy-and-hold investor in the cash market may affect developments in the repo market.

We analyze the channels of transmission of a shock to purchases to the repo market and find evidence of a clear role for SMP purchases in affecting specialness. The impact on specialness is sizable and persistent for around two weeks. The purchases affected also the premium paid by the long and the short positions by inducing a very low or negative returns on short sellers. Supported by this analysis we show that central bank purchases may have fostered strategic fails-to-deliver on fixed income markets.

³⁰The figure is based on the computation of the marginal effect of our Probit estimation.

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Figures

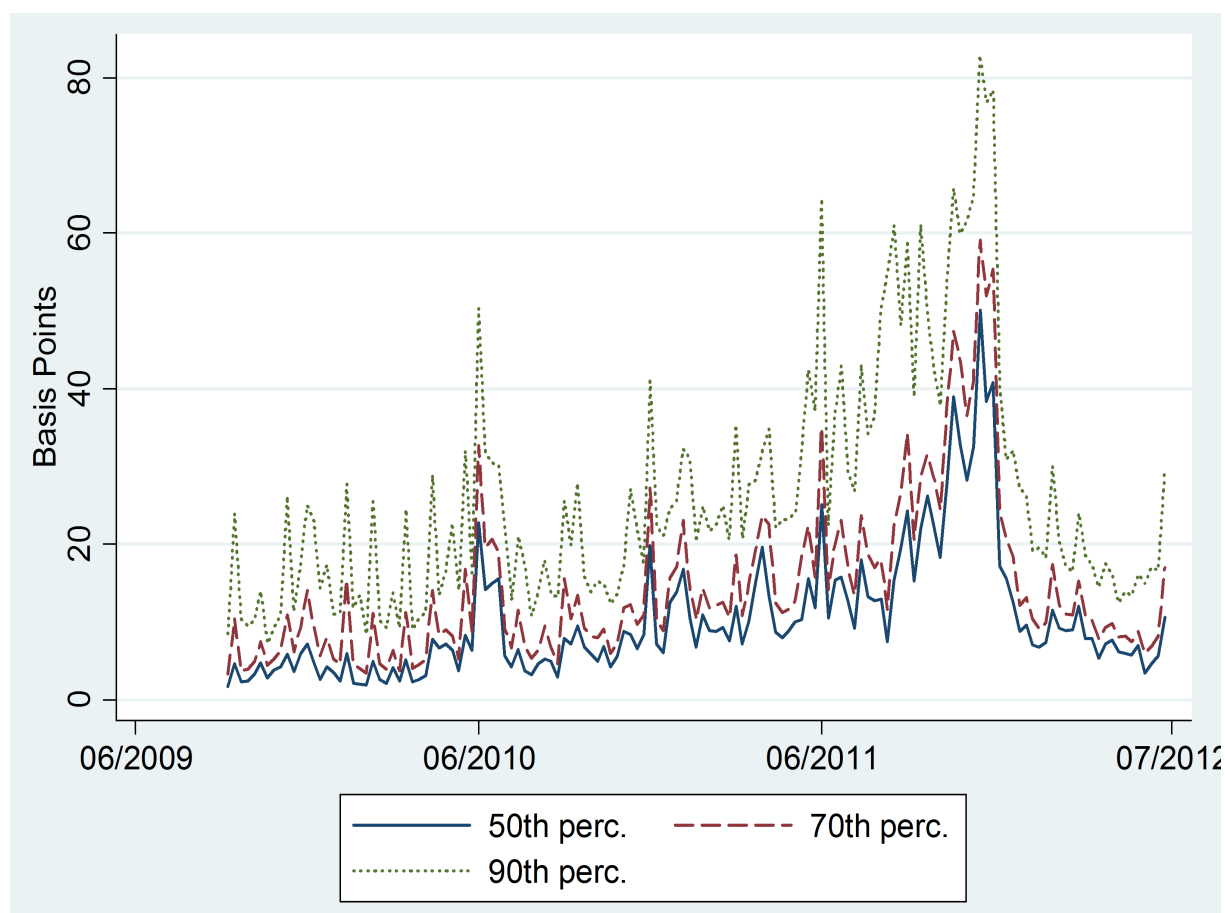


Figure 1: **The distribution of specialness** - The figure plots the empirical distribution of specialness for the 50th, 70th and 90th percentile. Specialness is calculated as the difference between the general collateral (GC) repo rate and the special repo rate on a specific security and day of trading. The rates refer to repo transactions on underlying Italian sovereign securities as traded on the MTS repo platform from 1 October 2009 to 7 July 2012. See Section 3.1 for a detailed description of the variables and the data sources.

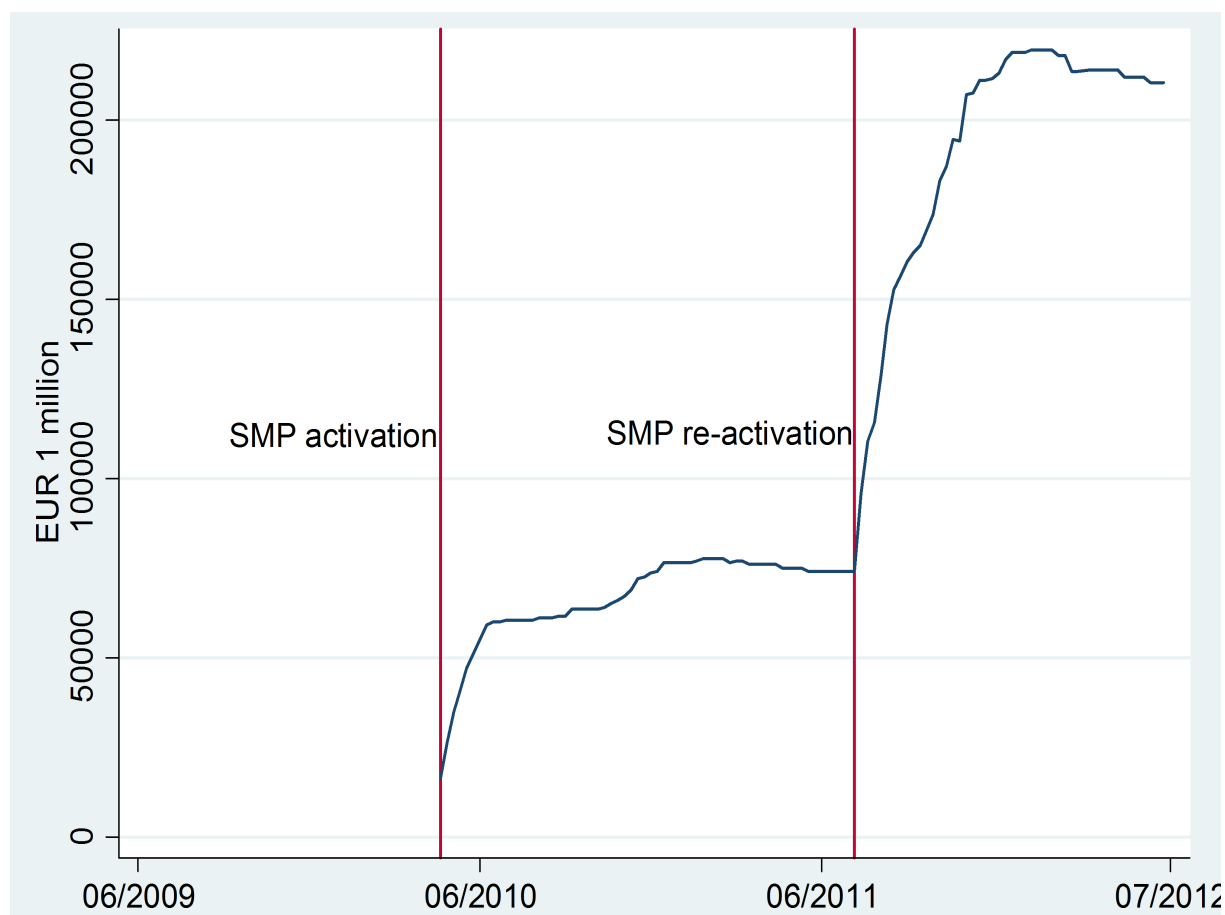


Figure 2: **The value of the Security Market Program (SMP) portfolio** - The figure plots the book value of the overall SMP portfolio held by the Eurosystem. The value of the portfolio is at amortized cost in EUR millions as published by the ECB. The vertical lines indicate the dates at which the SMP was first activated (decision of the ECB Governing Council on 10 May 2010) and then reactivated (8 August 2011). See Section 3.4 for details.

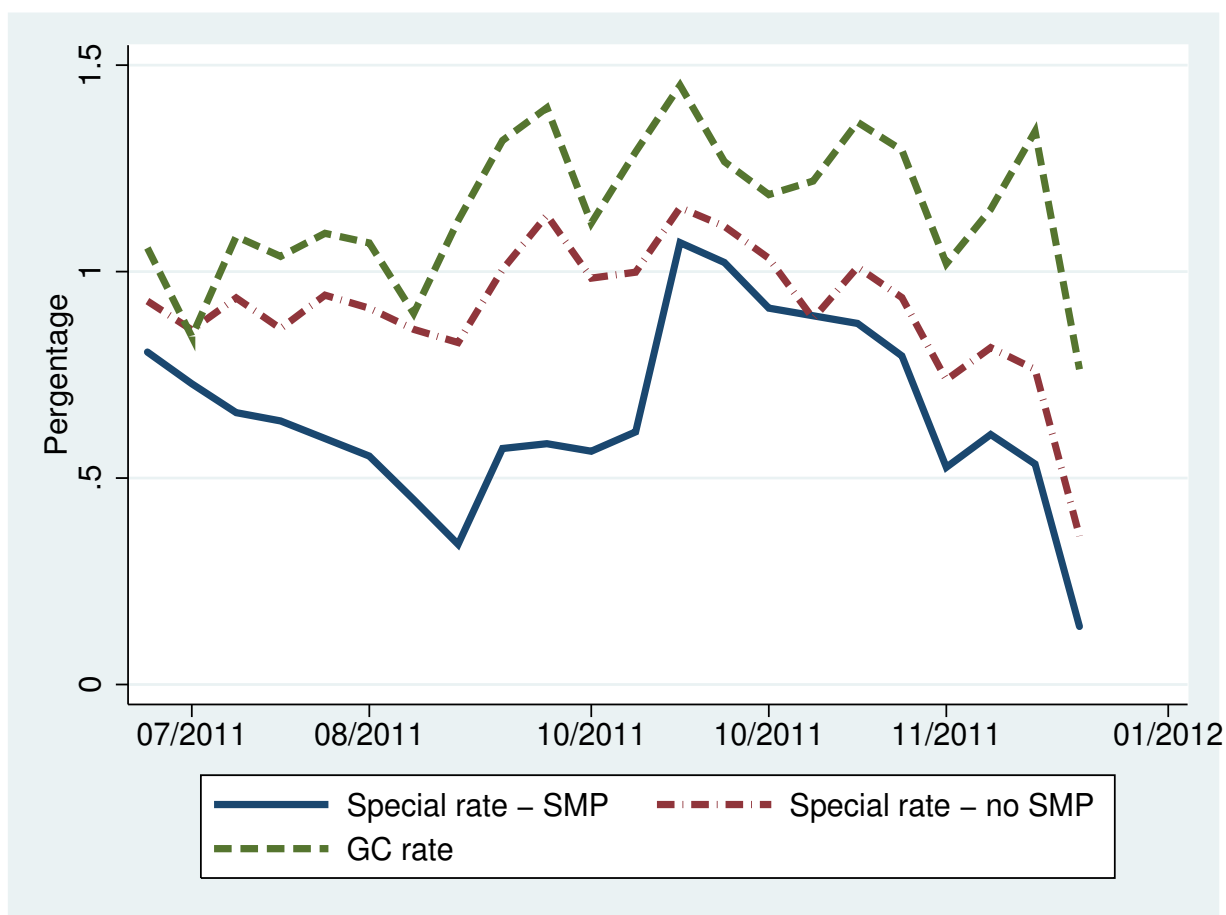


Figure 3: **General collateral (GC) and Special repo rates during the crisis** - The figure plots the evolution of average general collateral (GC) rates and special rates as traded on the MTS repo platform from January to December 2011. GC and special rates are based on over-night, tomorrow-next and spot-next repo transactions. The continuous line plots the average special rate of bonds purchased under the SMP. The dot-dashed line plots the average special rate of bonds not purchased under the SMP.

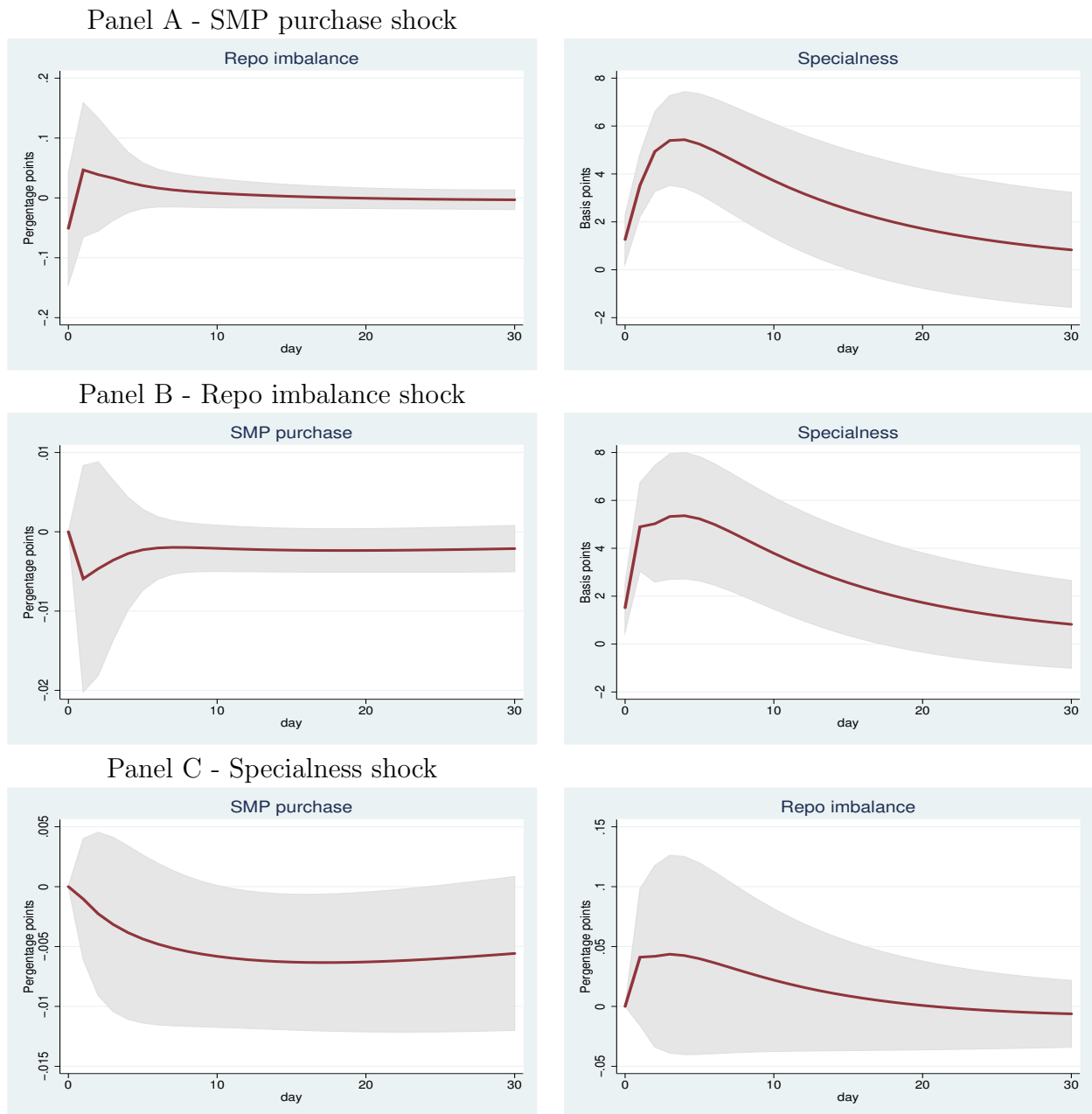


Figure 4: **Panel VAR - Impulse Response Functions** - The figure plots the impulse response functions of (1) repo imbalance and specialness to a SMP purchase shock of 1% of outstanding amount (Panel A); (2) SMP purchase and specialness to a repo imbalance shock of 1% of outstanding amount (Panel B); (3) SMP purchase and repo imbalance to a specialness shock of 1% (Panel C), and 90% bootstrapped confidence intervals (grey dashed lines) based on 1,000 replications. The impulse response functions are estimated from a structural panel VAR model including the following variables: cash imbalance, bid-ask spread, SMP purchase, repo imbalance, specialness and available for lending of the bonds purchased under the SMP from 8 August 2011 to 21 December 2011. See Section 6.1 for details.

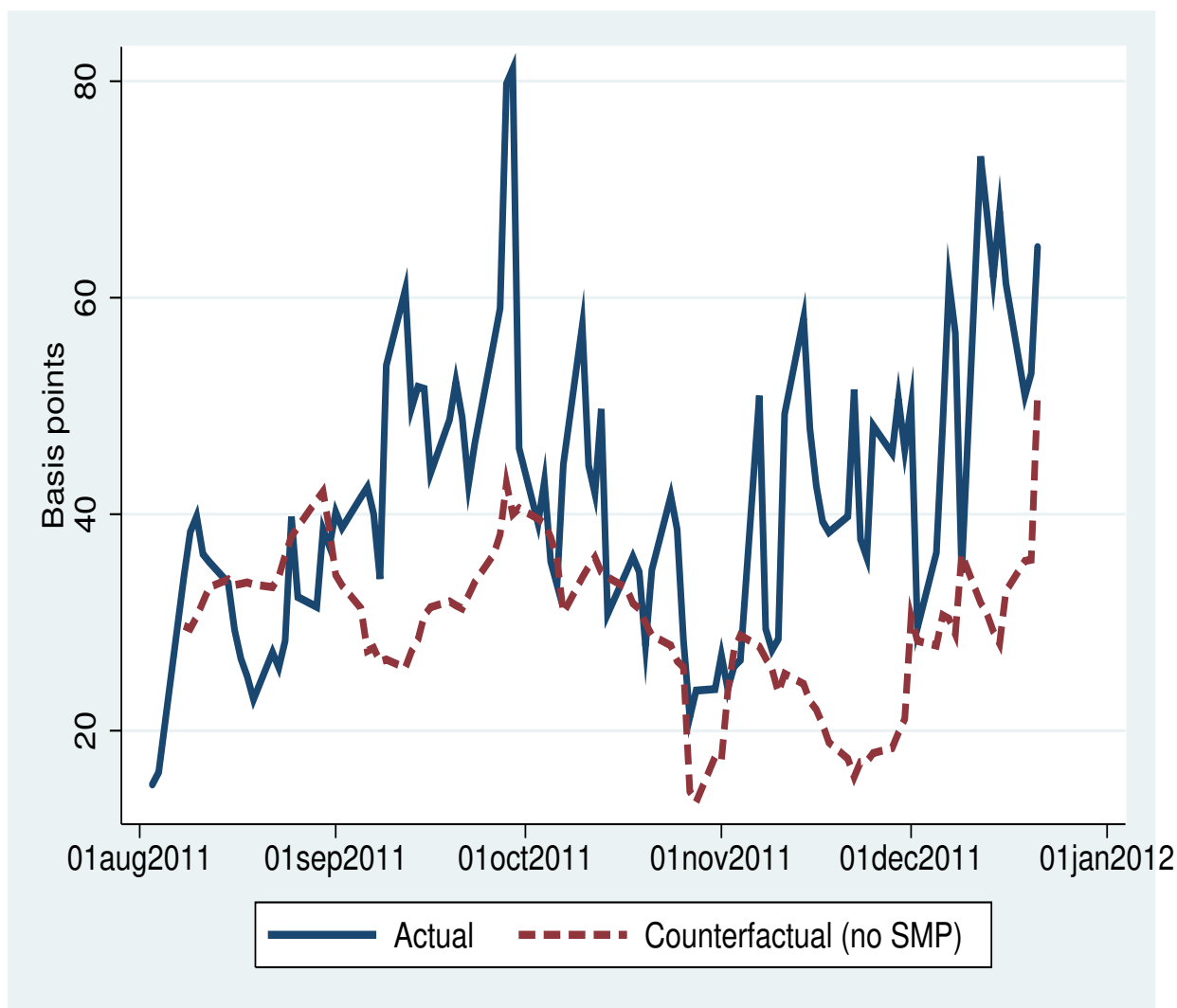


Figure 5: **Historical counterfactual of specialness** - This figure plots the average specialness of bonds purchased under the SMP and the historical counterfactual of specialness based on the estimation of a structural panel VAR model. The model includes the following variables: cash imbalance, bid-ask spread, SMP purchase, repo imbalance, specialness and available for lending of the bonds purchased under the SMP from 1 August 2011 to 21 December 2011. The counterfactual shows how specialness of the bonds bought under the SMP would have evolved replacing all realizations of the SMP structural shock by zero while preserving the remaining structural shocks in the model. See Section 6.1 for details.

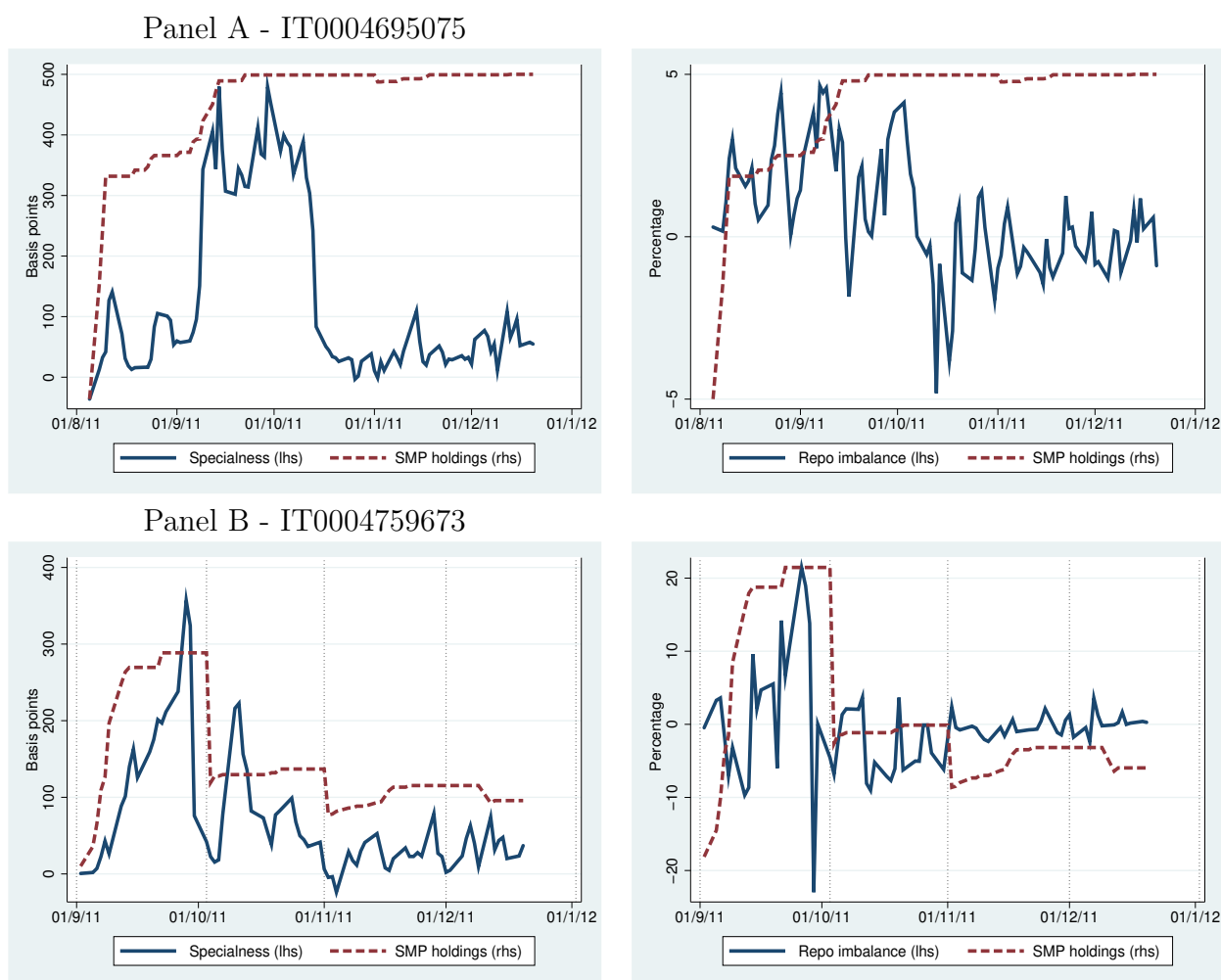


Figure 6: **Specialness and repo imbalance for the 10-year on-the-run bonds** - The figure shows the value of specialness (left-hand chart) and of repo imbalance (right-hand chart) calculated for the two Italian sovereign bonds with 10-year maturity that were on-the-run during the period of SMP purchases. Specialness is calculated as the difference between the general collateral (GC) repo rate and the special repo rate on these benchmark securities and it is reported in basis points (left-hand scale). Repo imbalance is the difference between the transactions initiated as special reverse repo and the transactions initiated as financing repo on the 10-year on-the-run security and it is reported in percentage points (left-hand scale). The dashed line reports the value of the on-the-run securities held in the SMP portfolio (no detailed amount is reported because of confidentiality).

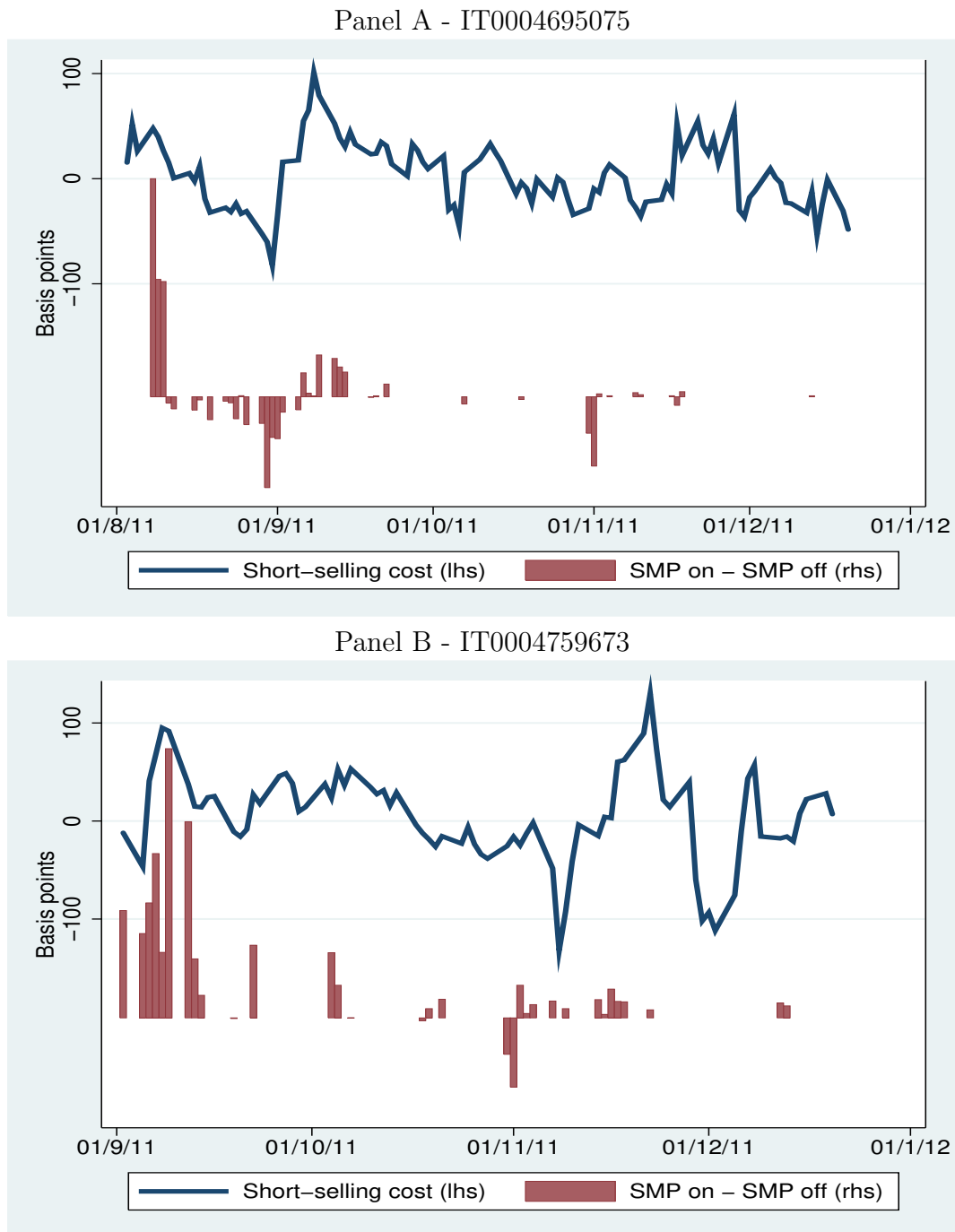


Figure 7: **Short-selling premium - 10-year on-the-run -** The figure plots the annualized cost of shorting a 10-year on-the-run bond at the daily frequency and taking a duration equivalent long position in the second off-the-run bond. See Section 6.2.1 for details. The bars show the difference between the SMP daily purchases of the on-the-run and the second off-the-run bond, which is the available supply relevant for the trading strategy.

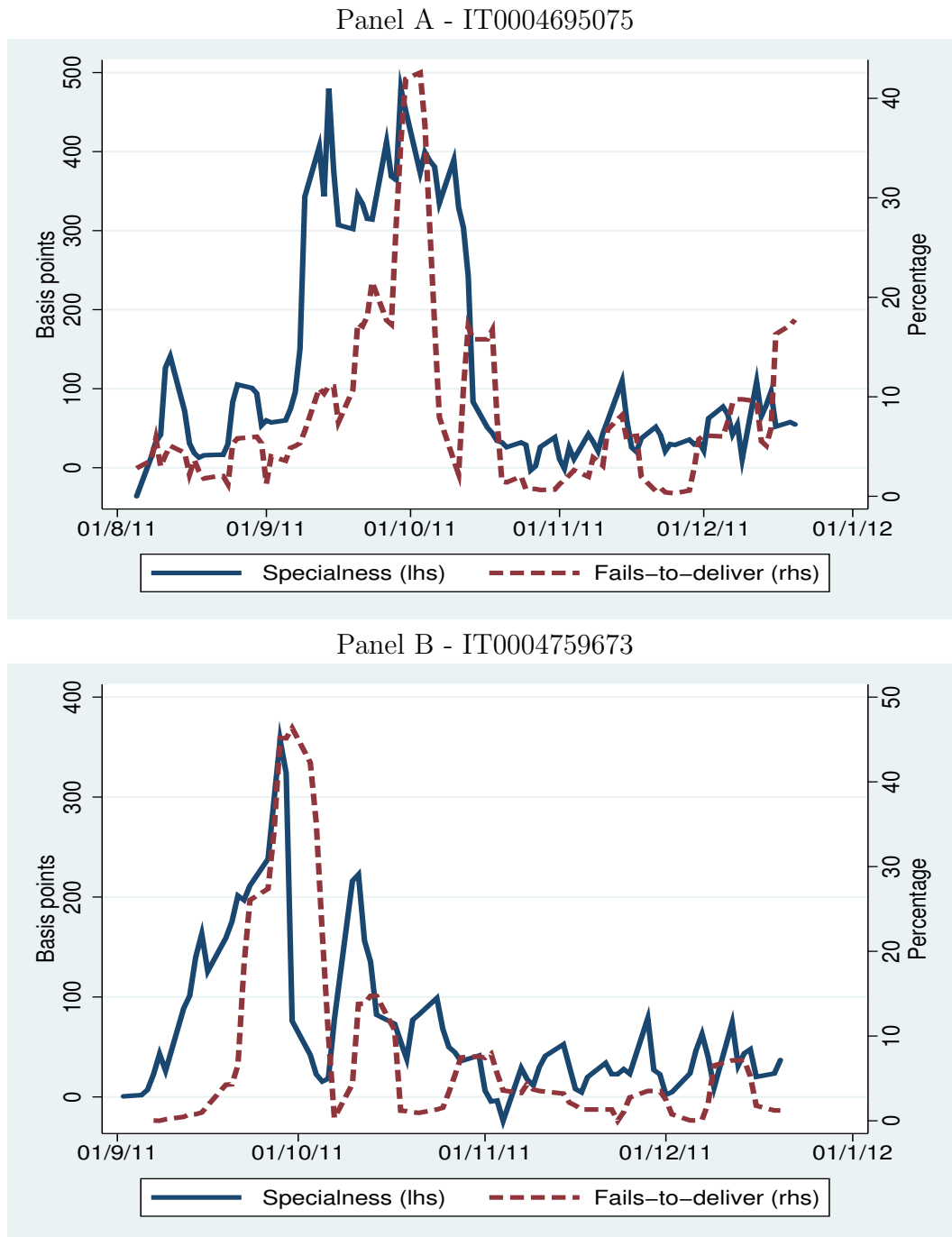


Figure 8: **Specialness and fails-to-deliver for the 10-year on-the-run** - The figure plots the value of specialness and of fails-to-deliver calculated for the two Italian sovereign bonds with 10-year maturity that were on-the-run during the SMP purchases. Specialness is calculated as the difference between the general collateral (GC) repo rate and the special repo rate on these benchmark securities and it is reported in basis points (left-hand scale). Fails-to-deliver is computed as the nominal value of failed transactions over the total nominal settled by Monte Titoli.

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 2011. Second period: from 8 August 2011 to 21 December 2011. Third period: from 22 December 2011 to 12 July 2012. Numbers in parenthesis report the same statistics calculated only on the days when the securities were bought under the Security Market Programme (SMP). Specialness denotes the difference between the general repo (GC) rate and the special repo rate on a specific security and day of trading and is expressed in basis points. Bond nominal outstanding denotes the nominal outstanding amount of a specific security underlying a special special repo transaction, at security level on a daily basis. Repo imbalance denotes the difference between the reverse initiated and the financing initiated special repo transactions, at security level on a daily basis. Cash imbalance denotes the difference between the aggregate sell and buy initiated volume, at security level on a daily basis. Available lending denotes the nominal amount available for lending, at security level on a daily basis. Bond time-to-maturity denotes the time to maturity of a specific security on a daily basis. Bid-ask spread denotes the bid-ask spread based on BGN Bloomberg prices at or before 5pm, at security level on a daily basis. Fail-to-deliver denotes the nominal amount of fails over the nominal amount settled by Monte Titoli, at security level on a daily basis. Specialness and repo imbalance are based on overnight, tomorrow next and spot next repo transactions. Repo imbalance, cash imbalance and available for lending are re-scaled by the nominal outstanding amount of the security and expressed in percentage terms. See Section 3.1, 3.2 and 3.3 for a detailed description of 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 (35.480)	31.762 (38.967)	12.902	15.953
Bond nominal outstanding	15284	6476	15151	6196	15632 (20792)	6803 (4785)	15467	7079
Repo imbalance	0.094	1.801	0.302	1.763	-0.226 (0.314)	1.802 (1.670)	-0.347	1.806
Cash imbalance	0.003	0.542	0.003	0.568	0.012 (0.037)	0.472 (0.185)	-0.005	0.474
Avail. lending	3.640	3.829	4.272	4.151	3.010 (2.615)	3.047 (1.468)	1.751	1.969
Bond time-to-mat.	6.010	7.477	6.096	7.648	6.025 (5.364)	7.272 (2.735)	5.727	7.048
Bid-ask spread	0.848	5.193	0.766	4.541	0.987 (0.522)	4.740 (0.450)	1.001	7.051
Fail-to-deliver	2.394	8.357	2.268	8.459	2.577 (2.729)	8.291 (6.518)	2.671	8.057

Table 2: **Specialness** - The table shows the results of OLS panel regressions with bond and time fixed effects with each observation defining a bond-day. Specialness is expressed in basis points and is based on spot next (SN) and tomorrow next (TN) transactions. The repo imbalance is based on spot next (SN) and tomorrow next (TN) transactions. The repo imbalance, cash imbalance and available for lending variables are rescaled by the nominal outstanding amount of the bond and expressed in percentage terms. Bond time-to-maturity denotes the time to maturity of a specific security. Bid-ask spread denotes the bid-ask spread based on BGN Bloomberg prices at or before 5pm. D. auction is a dummy variable to control for the date of a primary issuance of the security. Standard errors are in parenthesis and are clustered by bond and time identifier. The results are reported for the full period and for the three distinct sub-periods: 1 October 2009 - 7 August 2011, 8 August 2011 - 21 December 2011 and 22 December 2011 - 12 July 2012. Stars denote statistical significance at 10% (*), 5% (**) and 1% (***)).

	(1) Full	(2) 1st	(3) 2nd	(4) 3rd
Specialness (lag)	0.872*** (0.032)	0.892*** (0.026)	0.823*** (0.096)	0.814*** (0.043)
Repo imbalance (lag)	0.547*** (0.114)	0.452*** (0.097)	1.456*** (0.495)	0.080 (0.083)
Cash imbalance (lag)	-0.320** (0.148)	-0.147 (0.147)	-1.588*** (0.469)	0.005 (0.339)
Avail. lending (lag)	-0.134*** (0.039)	-0.106*** (0.030)	-0.327* (0.182)	-0.105 (0.078)
Bond time-to-mat.	0.032* (0.017)	0.027* (0.015)	0.021 (0.050)	0.063** (0.030)
D. auction	-3.950** (1.639)	-3.992* (2.164)	-6.120*** (1.846)	-2.090** (0.817)
Bid-ask spread (lag)	-0.045*** (0.012)	-0.045*** (0.016)	-0.062** (0.028)	-0.031** (0.014)
Constant	1.647*** (0.425)	-6.628*** (0.973)	11.124** (4.332)	6.418*** (0.961)
Time Fixed Effects	Yes	Yes	Yes	Yes
Bond Fixed Effects	Yes	Yes	Yes	Yes
R^2	0.823	0.829	0.803	0.696
Num. Obs.	38,222	27,585	4,880	5,757

Table 3: **Specialness and SMP purchases** - The table shows the results of OLS (Columns (1) – (2)) and quantile (Columns (3) – (5)) panel regressions with bond and time fixed effects with each observation defining a bond-day. Specialness is expressed in basis points and is based on spot next (SN) and tomorrow next (TN) transactions. The repo imbalance is based on spot next (SN) and tomorrow next (TN) transactions. The repo imbalance, cash imbalance, available for lending and SMP purchase variables are rescaled by the nominal outstanding amount of the bond and expressed in percentage terms. In Column (2) the observations on the 10– year on-the-run bonds are excluded from the sample. Standard errors are in parenthesis and are clustered by bond and time identifier (Columns (1) – (2))). The results are reported for the sub-period 8 August 2011 - 21 December 2011. Stars denote statistical significance at 10% (*), 5% (**) and 1% (***).

	(1)	(2)	(3)	(4)	(5)
	OLS	OLS	Q-50	Q-70	Q-90
Specialness (lag)	0.821*** (0.096)	0.821*** (0.105)			
Repo imbalance (lag)	1.430*** (0.524)	0.891** (0.377)	-0.473** (0.186)	0.842*** (0.251)	4.037*** (0.866)
Cash Imbalance (lag)	-1.707*** (0.546)	-1.107** (0.479)	-1.300* (0.719)	-3.552*** (0.838)	-5.883** (2.321)
Avail. Lending (lag)	-0.290 (0.178)	-0.290 (0.179)	-1.424*** (0.133)	-1.979*** (0.163)	-3.307*** (0.475)
Bond time-to-mat.	0.010 (0.046)	0.008 (0.043)	0.122** (0.055)	0.293*** (0.060)	0.702*** (0.121)
D. Auction	-5.718*** (1.847)	-5.374*** (1.837)	-5.064 (4.790)	-10.360* (5.433)	-18.502 (11.985)
Bid-ask spread (lag)	-0.057* (0.029)	-0.057* (0.032)	-0.061 (0.062)	-0.051 (0.050)	-0.169** (0.079)
SMP Purchase (lag)	5.061*** (0.816)	5.847*** (1.461)	4.817*** (1.034)	4.662*** (1.160)	14.672*** (2.204)
Constant	11.154*** (4.295)	3.662 (3.946)	25.553*** (0.580)	37.716*** (0.682)	66.687*** (1.782)
Time Fixed Effects	Yes	Yes	Yes	Yes	Yes
Bond Fixed Effects	Yes	Yes	Yes	Yes	Yes
R^2	0.805	0.803			
Num. Obs.	4,880	4,792	4,880	4,880	4,880

Table 4: **Cost of short-selling** - The table reports the results from predictive OLS regressions. The dependent variable is the cost of shorting one of the two 10-year on-the-run securities and hedging with a duration adjusted long position in the second 10-year off-the-run. The explanatory variables are: 1) the difference between the SMP daily purchases of the on-the-run and the second off-the-run bond and 2) the difference between the general collateral (GC) rates on repo transactions on Italian and German sovereign bonds. Observations are daily and the regressors are lagged by one day. Newey West standard errors with 5 lags are reported in parenthesis. Results are reported for the sub-period 8 August 2011 - 21 December 2011. Stars denote statistical significance at 10% (*), 5% (**) and 1% (***).

	IT0004695075		IT0004759673	
	(1)	(2)	(3)	(4)
$\widetilde{\text{SMP purchase}}_{ij,t-1}$	10.891** (4.518)	9.199* (5.455)	8.094*** (2.361)	7.964** (3.747)
GC Italy - GC Germany _{t-1}		-34.222 (39.703)		-2.265 (67.671)
Constant	1.113 (5.729)	16.944 (20.423)	0.669 (9.574)	1.852 (31.316)
Num. Obs.	97	97	78	78

Table 5: **Fails-to-deliver** - The table shows the results of Probit and OLS panel regressions with bond and time fixed effects with each observation defining a bond-day. The dependent variable for the Probit estimation is equal to one when at least a fail-to-deliver occurs at time $t + 3$ (see Columns (1) – (3)). In the OLS estimation the dependent variable corresponds to the nominal amount of settlement fails over the nominal amount traded at time $t + 3$ (see Columns (4) – (6)). In Column (2) and (5) the sample is restricted to the bonds purchased under the SMP. Specialness and repo imbalance is based on spot next (SN) and tomorrow next (TN) transactions. Standard errors are in parenthesis and are clustered by bond and time identifier. The results are reported for the sub-period 8 August 2011 - 21 December 2011. Stars denote statistical significance at 10% (*), 5% (**) and 1% (***)

	(1)	(2)	(3)	(4)	(5)	(6)
	Probit	Probit	Probit	OLS	OLS	OLS
Specialness	0.010*** (0.001)	0.007*** (0.001)		0.057*** (0.009)	0.042*** (0.006)	
SMP purchase			0.445*** (0.134)			0.624** (0.293)
Repo imbalance	0.020 (0.016)	0.019 (0.022)	0.046*** (0.016)	0.419*** (0.115)	0.644*** (0.179)	0.638*** (0.152)
Cash imbalance	-0.031 (0.051)	0.175 (0.150)	-0.049 (0.059)	-1.120* (0.636)	0.441 (0.467)	-1.149* (0.686)
Avail. lending	-0.021* (0.012)	0.020 (0.041)	-0.037** (0.015)	-0.081 (0.066)	-0.016 (0.147)	-0.196** (0.092)
Bond time-to-mat.	0.020*** (0.005)	0.036* (0.020)	0.022*** (0.006)	0.014 (0.029)	0.242** (0.108)	0.041 (0.038)
D. Auction	0.154 (0.166)	-0.321 (0.324)	0.035 (0.177)	-0.582 (0.707)	-1.365 (1.334)	-1.573* (0.864)
Bid-ask spread	-0.014 (0.013)	-0.165 (0.111)	-0.017 (0.014)	0.030 (0.039)	0.803* (0.488)	0.015 (0.037)
Constant	-0.214*** (0.076)	-0.463*** (0.079)	0.231*** (0.035)	2.373*** (0.279)	4.270 (.)	4.570*** (0.305)
Time Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Bond Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Num. Obs.	4,911	2,046	4,911	4,911	2,046	4,911

9 Appendix

9.1 Computation of the short-selling premium

To calculate the borrowing premium, we compute the ex-post cost of short-selling an Italian bond, taking into account that the cash market for Italian sovereign bonds is typically two days settlement. If a trader short-sells an Italian on-the-run bond i at time t , she receives the sale price $P_{i,t}$ at time $t+2$ and must borrow and deliver to the buyer the security on that date. To borrow the security at time $t+2$, the short-seller enters a spot-next repo transaction at time t , where the spot sale and forward repurchase prices are transacted simultaneously. She lends the spot sale price of the security $P_{i,t}^s$ to an owner of that security and receives the security as collateral at time $t+2$. The interest rate $r_{i,t}^{sn}$ on the loan is referred to as the special repo rate for security i from $t+2$ to $t+3$, the spot-next rate. Then, the short-seller repurchases the bond and at time $t+3$ she receives the Italian bond in exchange for the purchase price. She returns the Italian bond at the price $P_{i,t}^{s'}$ to the owner that she originally borrowed it from and receives $1 + r_{i,t}^{sn}$ for every euro that she has lent against the security. We assume that the difference, $P_{i,t+3} - P_{i,t}^{s'}$ which may be either positive or negative, is financed at the general collateral repo rate r^{gc} (the highest available interest rate for lending against Italian collateral). Thus, the cost of short-selling 1 euro of the 10-year on-the-run Italian bond is

$$\text{Short-selling cost}_{i,t} = \frac{P_{i,t}^s - P_{i,t}^{s'}(1 + r_{i,t}^{sn}) + (P_{i,t+3} - P_{i,t}^{s'})(1 + r_{t+3}^{gc})}{P_{i,t}}. \quad (8)$$

To isolate the price and borrowing premium, we compare the raw short-selling cost in Equation 8, to the cost of a short position with similar interest rate exposure in the off-the-run bond j . That is, we compare the cost of short-selling 1 euro of the on-the-run with the cost of short-selling $\text{DUR}_{i,t}/\text{DUR}_{j,t}$ euro in the off-the-run, where $\text{DUR}_{i,t}$ and $\text{DUR}_{j,t}$ are the duration of the on-the-run and off-the-run securities respectively.

The (liquidity) premium $R - C$ paid by short-sellers is then just the difference between the cost of short-selling the on-the-run bond and the cost of selling the duration adjusted position in the off-the-run which can be written as

$$(R - C)_{ij,t} = \text{Short-selling cost}_{i,t} - \frac{\text{DUR}_{i,t}}{\text{DUR}_{j,t}} \text{Short-selling cost}_{j,t}. \quad (9)$$

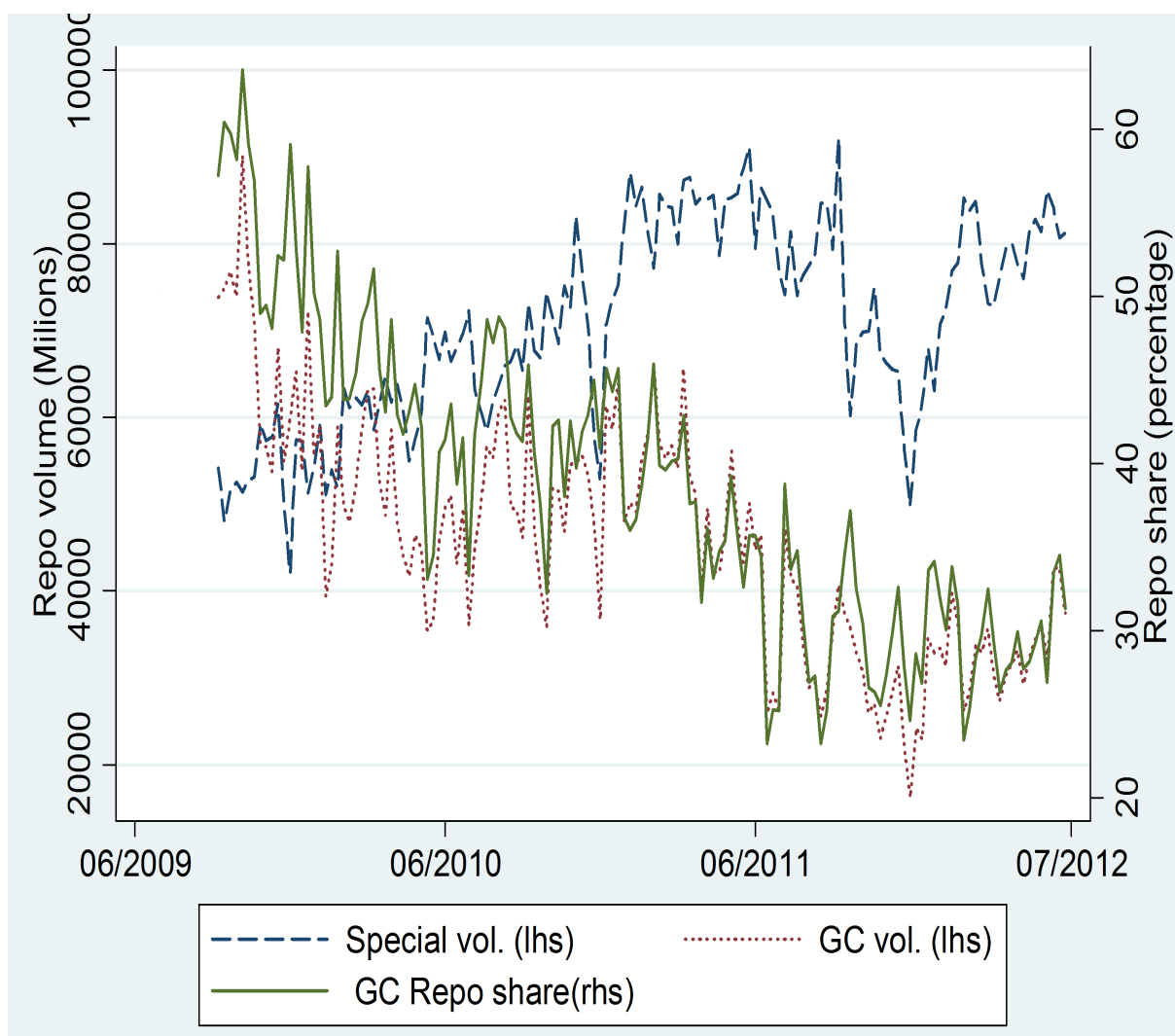


Figure 9: **Volume of general collateral (GC) and Special repos** - The figure plots the weekly volume of the general collateral (GC) and the Special repo transactions (left-hand scale, in EUR millions) and the share of GC repos over total repos (right-hand scale). The volumes refer to repo transactions with underlying Italian sovereign securities as traded on the MTS repo platform from 1 October 2009 to 7 July 2012. See Section 3.1 for a detailed description of the variables and the data sources.

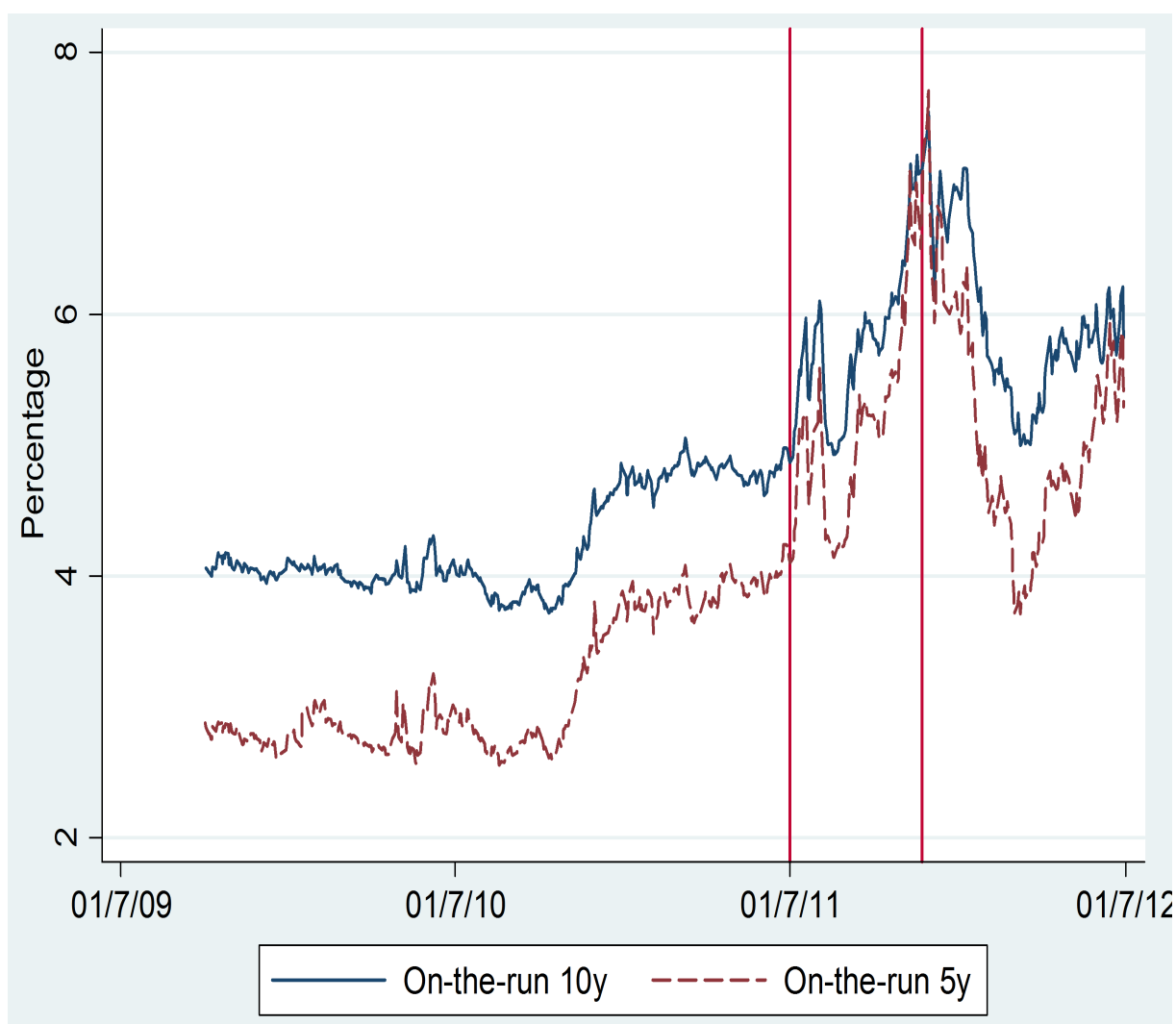
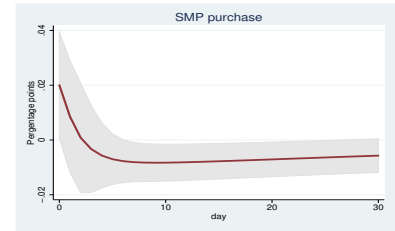
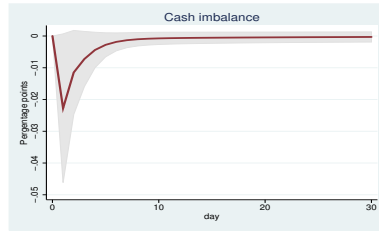
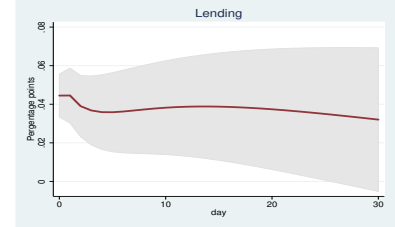
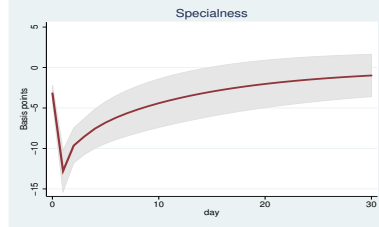
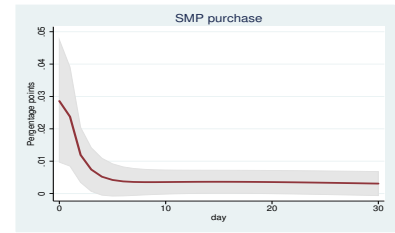
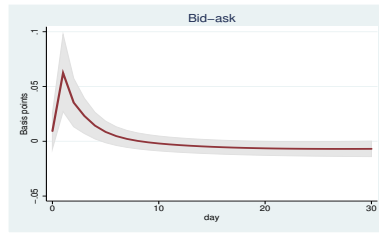
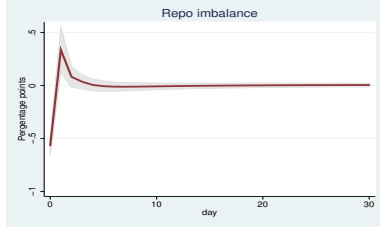
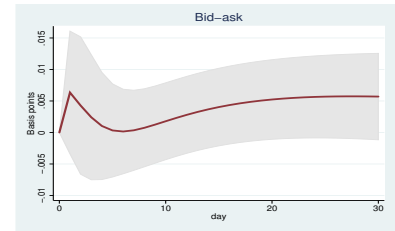
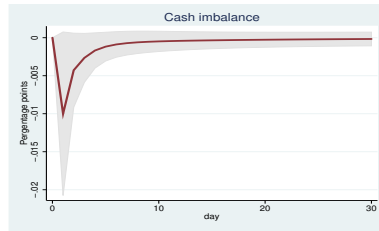
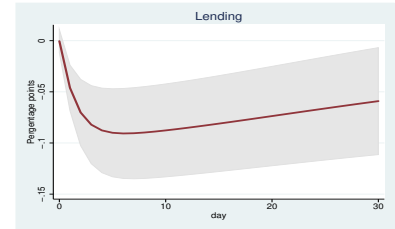
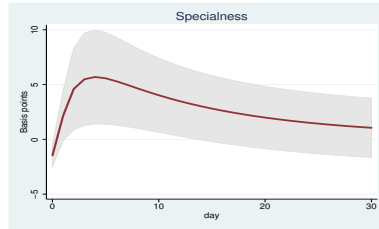
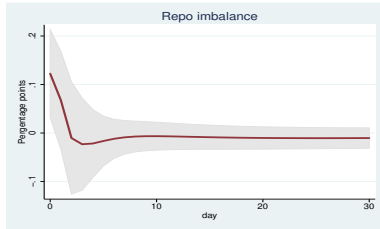


Figure 10: **Yields on the on-the-run Italian sovereign bonds** - This figure plots the yields on the on-the-run Italian sovereign bonds with 5 and 10 years of maturity. The vertical lines indicate the crisis period from 8 August 2011 to 21 December 2011. Data source: Bloomberg.

Panel A - Cash imbalance shock



Panel B - Bid-ask shock



Panel C - SMP shock

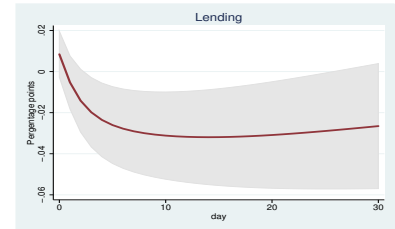
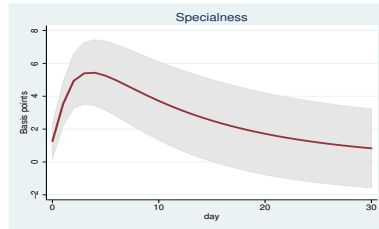
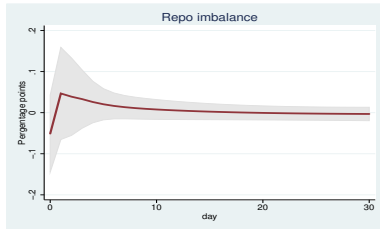
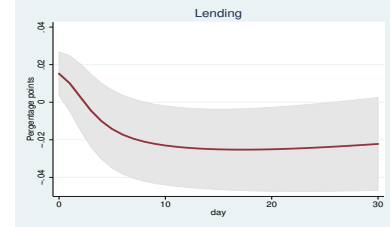
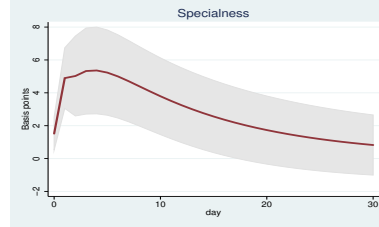
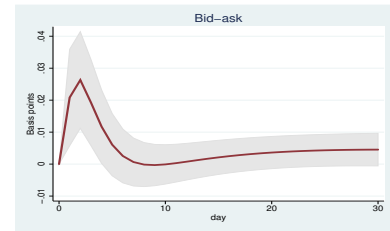
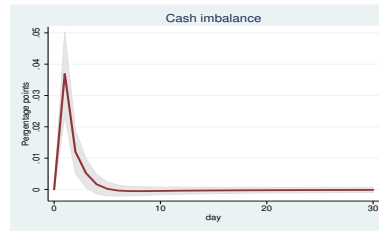
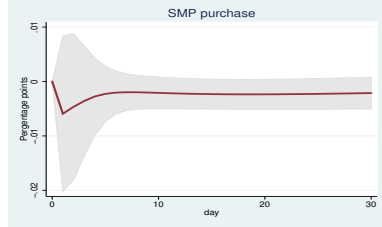
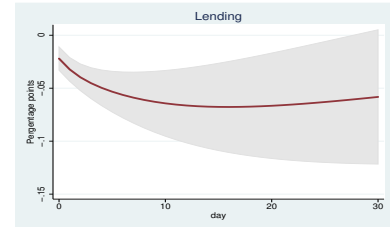
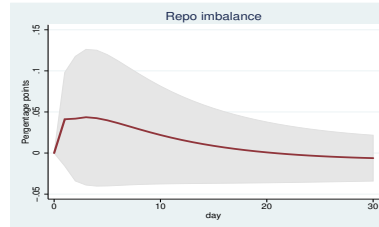
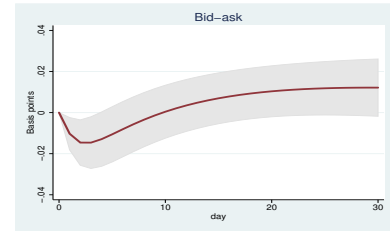
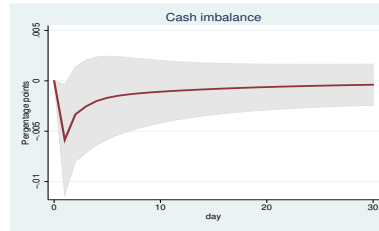
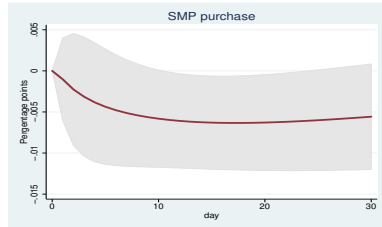


Figure 11: **Panel VAR Impulse Response Functions (IRF)** - The figure plots the impulse response functions to a cash imbalance shock (Panel A), a Bid-ask spread shock (Panel B) and an SMP purchase shock (Panel C). The IRF are shown with a 90% bootstrapped confidence intervals (grey dashed lines) based on 1,000 replications. The impulse response functions are estimated from a structural panel VAR model with the variables following the order: cash imbalance, bid-ask spread, SMP purchase, repo imbalance, specialness and available for lending of the bonds purchased under the SMP.

Panel D - Repo imbalance



Panel E - Specialness



Panel F - Lending

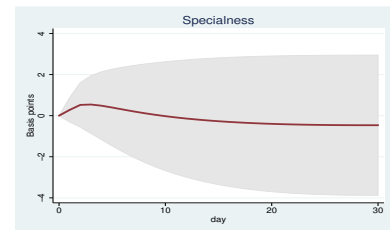
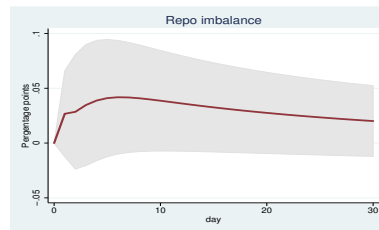
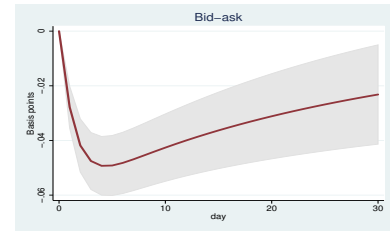
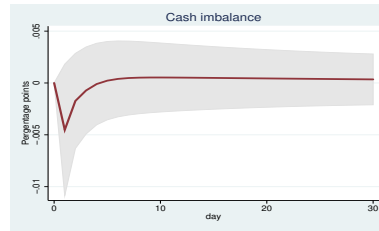
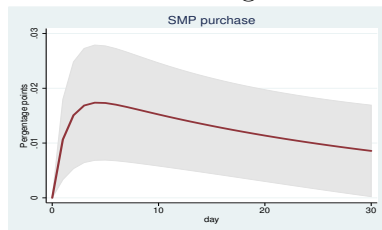
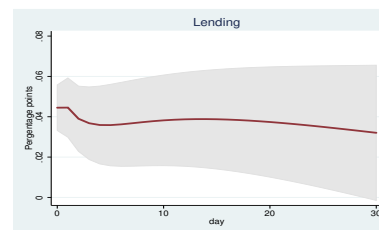
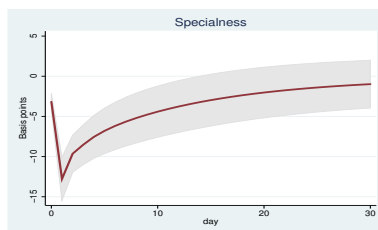
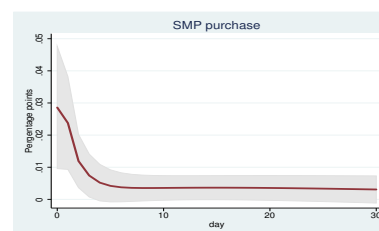
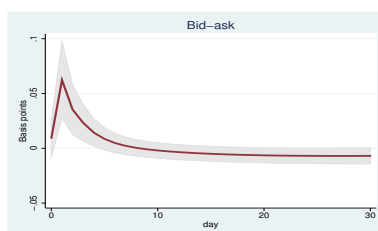
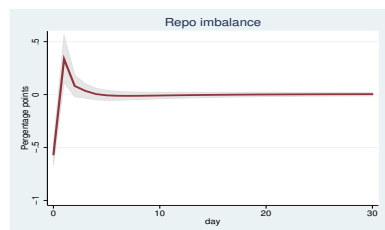
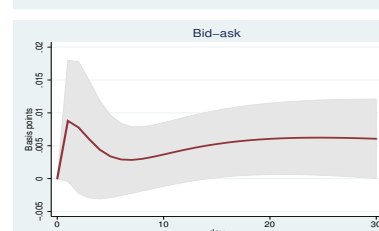
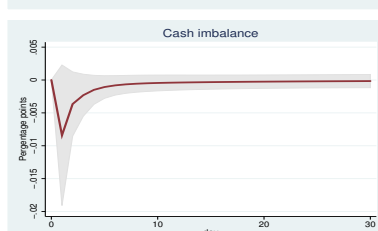
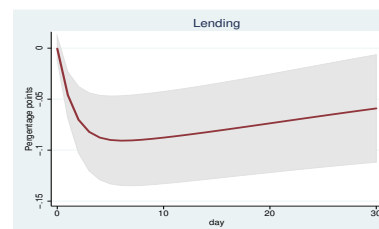
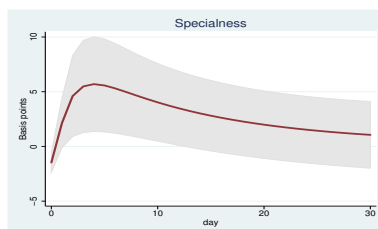
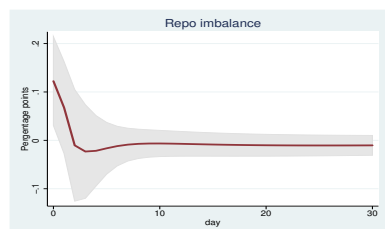


Figure 11: **Panel VAR Impulse Response Functions (IRF)** - The figure plots the impulse response functions to a Repo imbalance shock (Panel D), a Specialness shock (Panel E) and a Lending shock (Panel F). The IRF are shown with the 90% bootstrapped confidence intervals (grey dashed lines) based on 1,000 replications. The impulse response functions are estimated from a panel VAR model with the variables following the order: cash imbalance, bid-ask spread, SMP purchase, repo imbalance, specialness and available for lending of the bonds purchased under the SMP.

Panel A - Cash imbalance



Panel B - Bid-ask



Panel C - SMP purchase

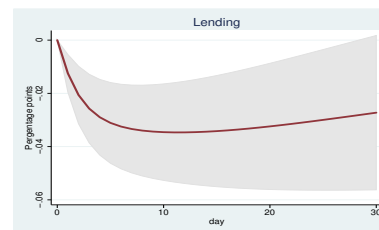
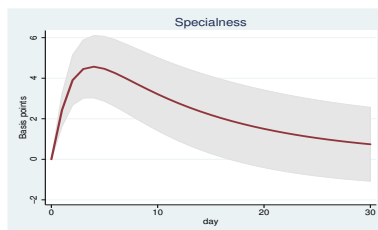
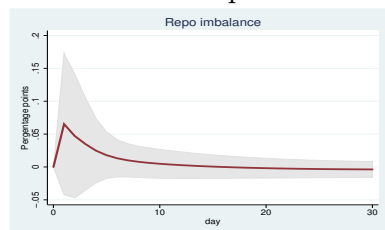
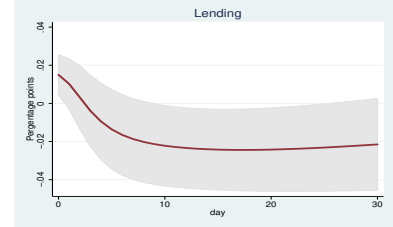
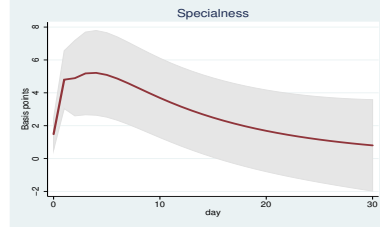
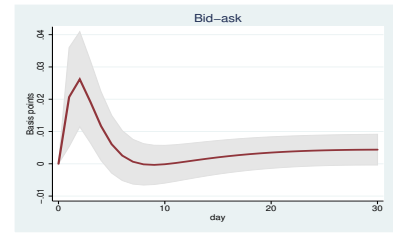
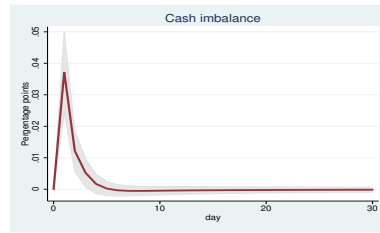
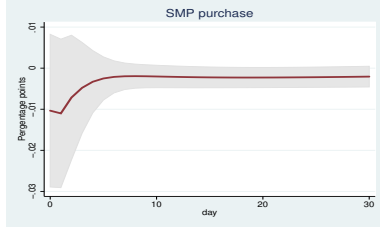
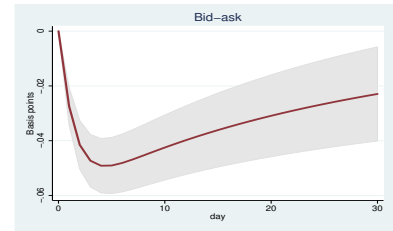
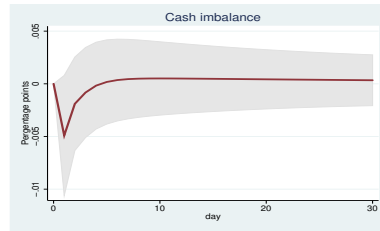
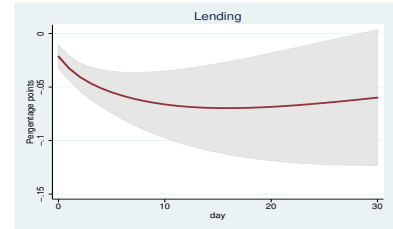
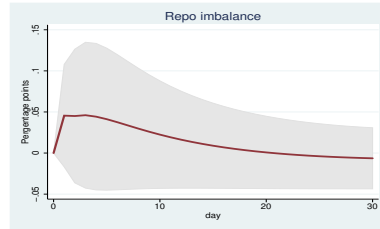
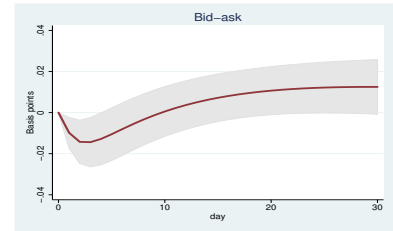
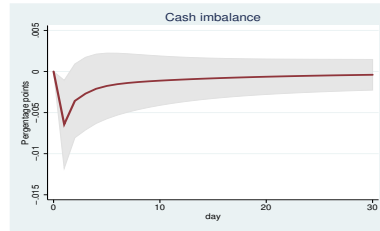
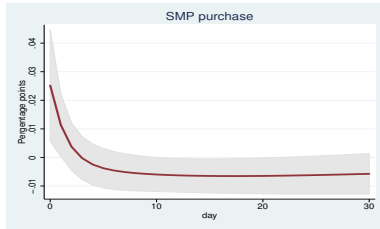


Figure 12: **Panel VAR IRFs - Change of order** - The figure plots the impulse response functions to a cash imbalance shock (Panel A), a Bid-ask spread shock (Panel B) and an SMP purchase shock (Panel C). The IRF are shown with the 90% bootstrapped confidence intervals (grey dashed lines) based on 1,000 replications. The impulse response functions are estimated from a panel VAR model with the following order: cash imbalance, bid-ask spread, repo imbalance, specialness, available for lending and SMP purchase of the bonds purchased under the SMP.

Panel D - Repo imbalance



Panel E - Specialness



Panel F - Available for lending

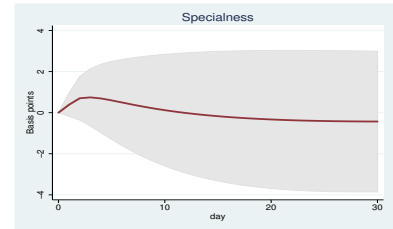
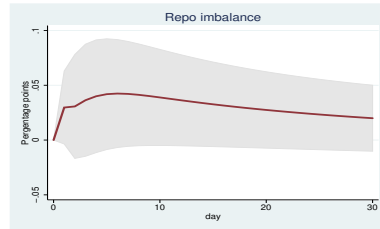
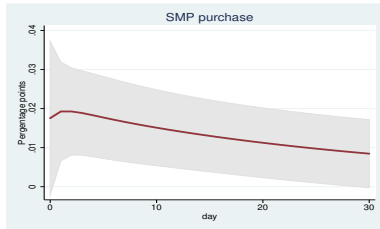
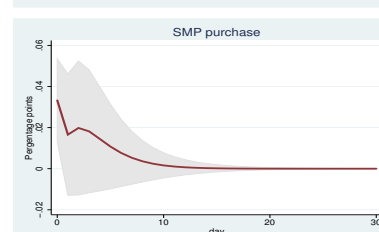
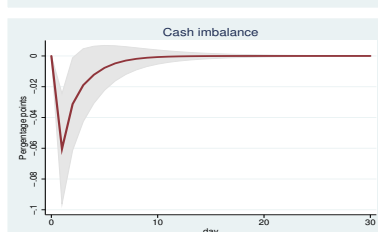
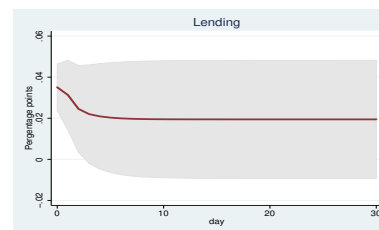
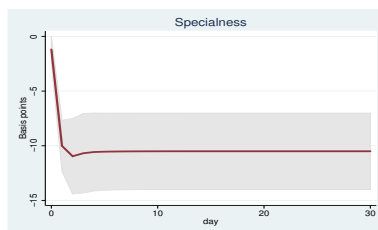
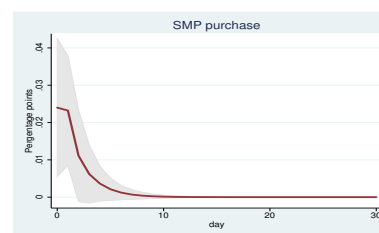
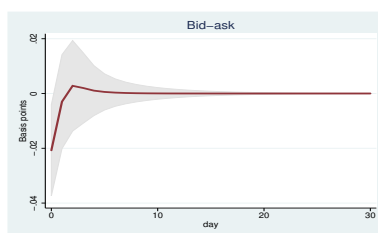
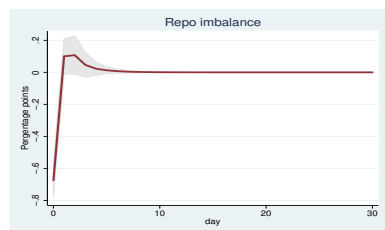
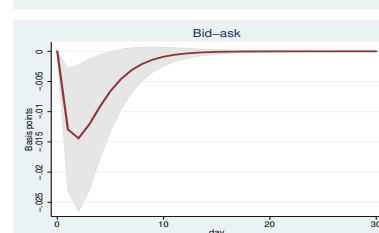
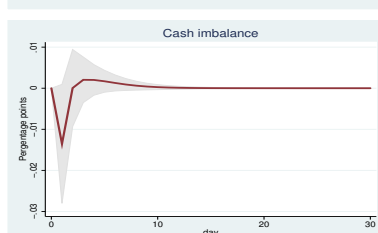
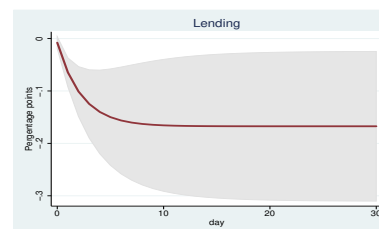
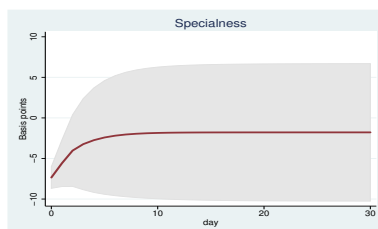
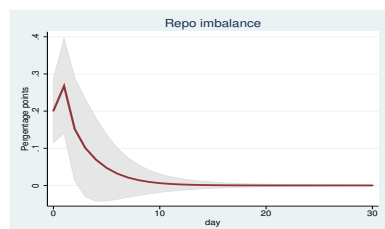


Figure 12: **Panel VAR IRFs - Change of order** - The figure plots the impulse response functions to a Repo imbalance shock (Panel D), a specialness shock (Panel E) and a Available for lending shock (Panel F). The IRF are shown with the 90% bootstrapped confidence intervals (grey dashed lines) based on 1,000 replications. The impulse response functions are estimated from a panel VAR model with the following order: cash imbalance, bid-ask spread, repo imbalance, specialness, available for lending and SMP purchase of the bonds purchased under the SMP.

Panel A - Cash imbalance



Panel B - Bid-ask



Panel C - SMP purchase

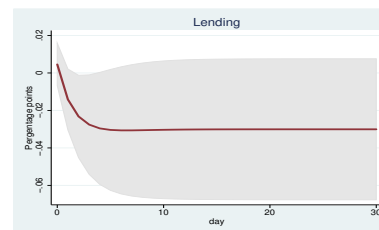
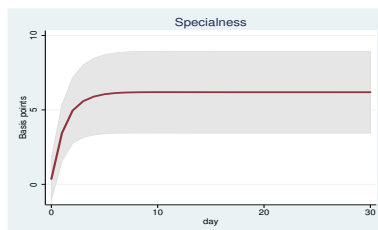
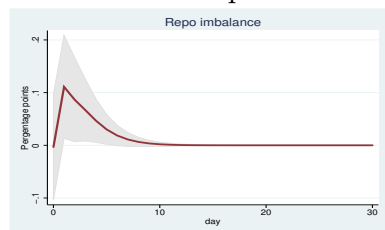
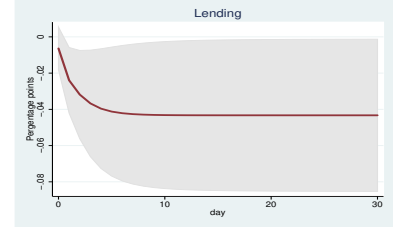
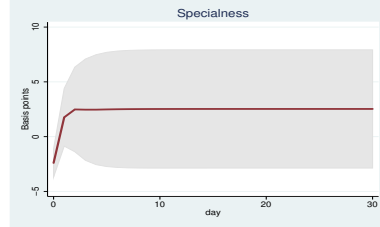
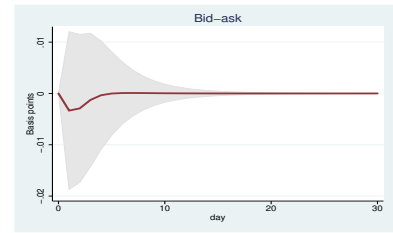
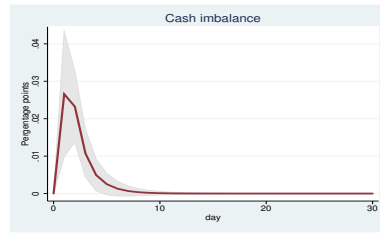
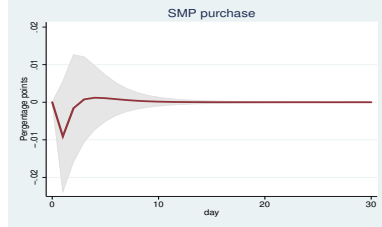
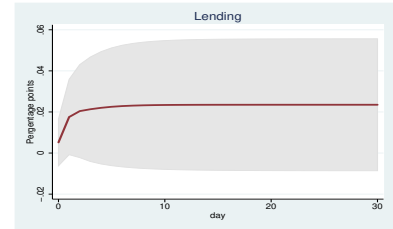
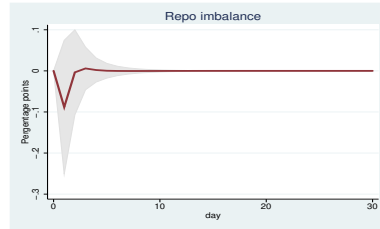
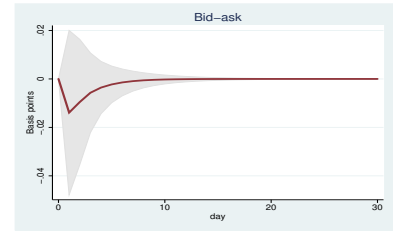
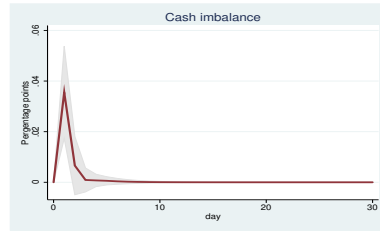
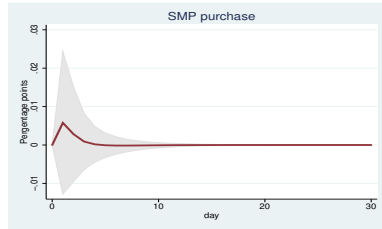


Figure 13: **Panel VAR IRFs - Δ specialness** - The figure plots the impulse response functions to a Cash imbalance shock (Panel A), a Bid-ask spread shock (Panel B) and an SMP purchase shock (Panel C). The IRFs are shown with the 90% bootstrapped confidence intervals (grey dashed lines) based on 1,000 replications. The impulse response functions are estimated from a panel VAR model with the following order: cash imbalance, bid-ask spread, repo imbalance, Δ specialness, Δ available for lending and SMP purchase of the bonds purchased under the SMP. For the variable Δ specialness and Δ available for lending the figure plots the cumulative impulse responses.

Panel D - Repo imbalance



Panel E - Specialness



Panel F - Available for lending

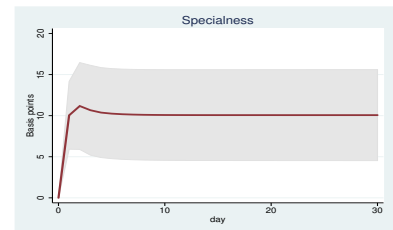
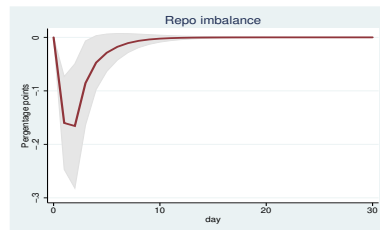
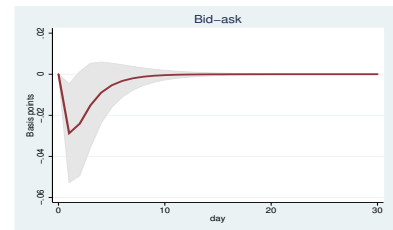
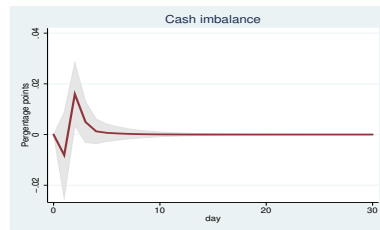
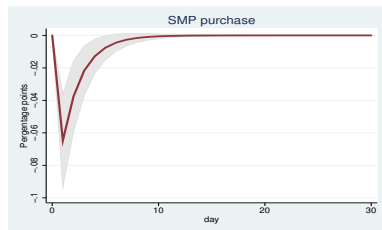
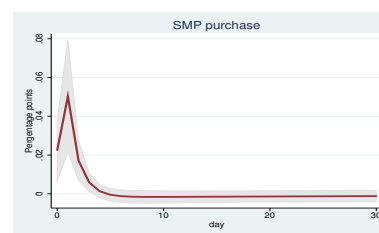
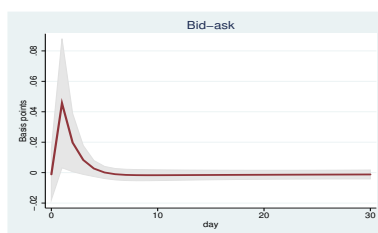
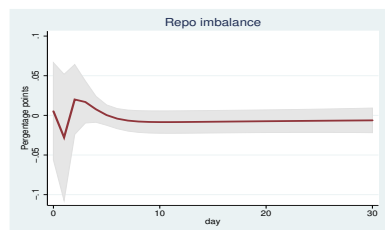
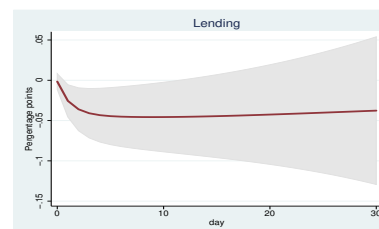
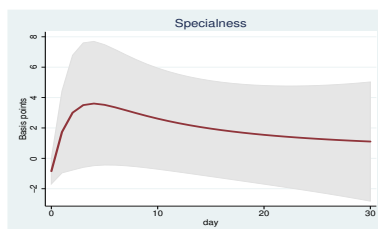
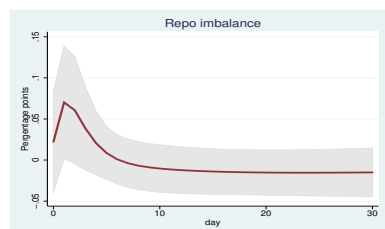


Figure 13: **Panel VAR IRFs - Δ specialness** - The figure plots the impulse response functions to a Repo imbalance shock (Panel D), a Specialness shock (Panel E) and an available for lending shock (Panel F). The IRFs are shown with the 90% bootstrapped confidence intervals (grey dashed lines) based on 1,000 replications. The impulse response functions are estimated from a panel VAR model with the following order: cash imbalance, bid-ask spread, repo imbalance, Δ specialness, Δ available for lending and SMP purchase of the bonds purchased under the SMP. For the variable Δ specialness and Δ available for lending the figure plots the cumulative impulse response.

Panel A - Cash imbalance



Panel B - Bid-ask



Panel C - SMP purchase

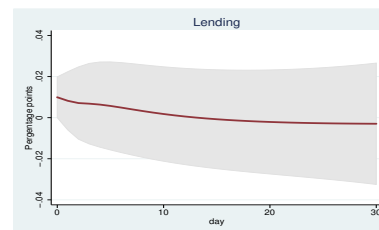
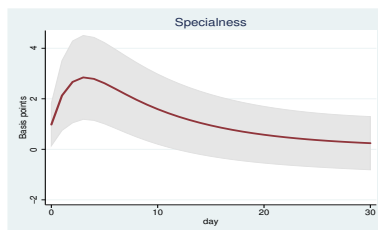
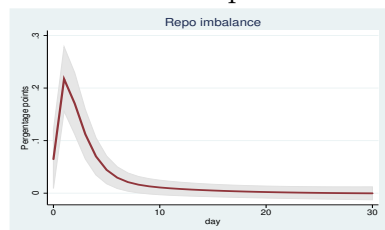
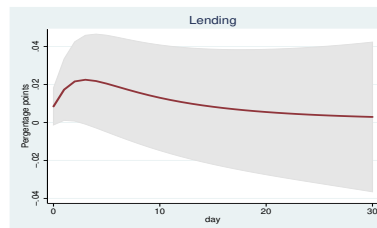
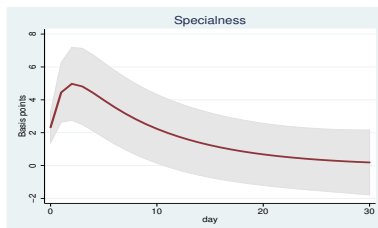
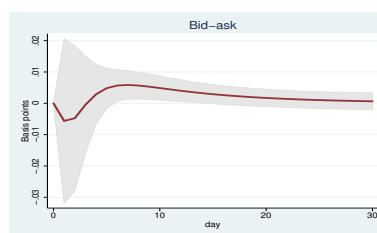
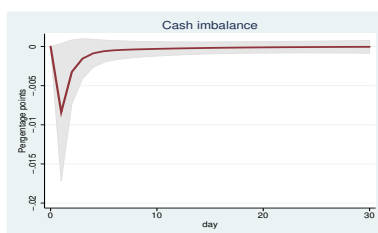
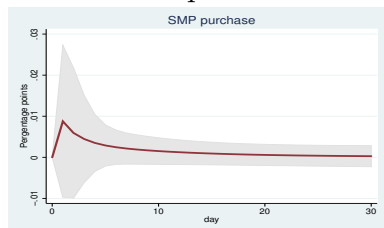
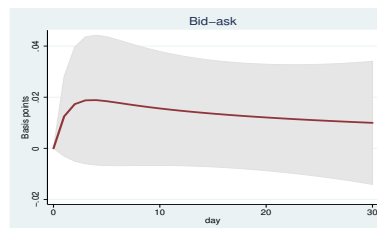
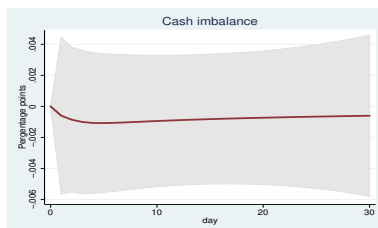
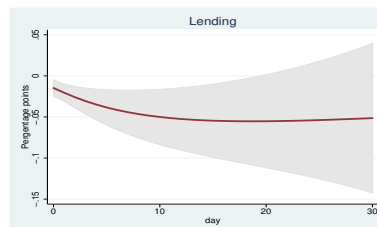
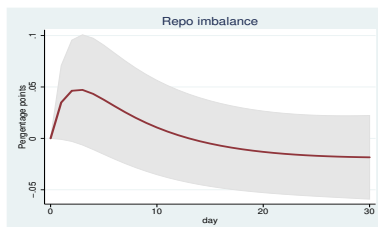
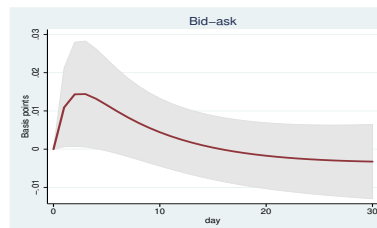
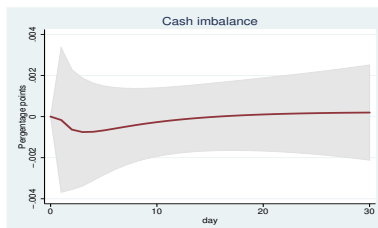
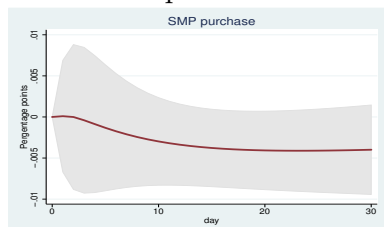


Figure 14: **Panel VAR IRFs - No 10-year on-the-run** - The figure plots the impulse response functions to a Cash imbalance shock (Panel A), a Bid-ask spread shock (Panel B) and an SMP purchase shock (Panel C). The IRFs are shown with the 90% bootstrapped confidence intervals (grey dashed lines) based on 1,000 replications. The impulse response functions are estimated from a panel VAR model with the following order: cash imbalance, bid-ask spread, SMP purchase, repo imbalance, specialness and available for lending of the bonds purchased under the SMP. The 10-year on-the-run bonds are excluded from the sample.

Panel D - Repo imbalance



Panel E - Specialness



Panel F - Available for lending

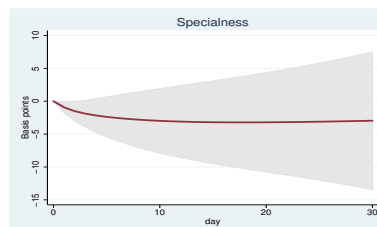
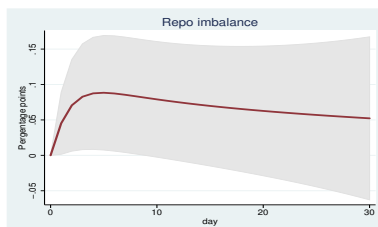
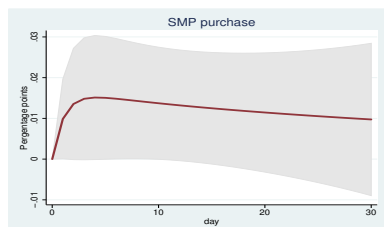


Figure 14: **Panel VAR IRFs - No 10-year on-the-run -** The figure plots the impulse response functions to a Repo imbalance shock (Panel D), a specialness shock (Panel E) and an available for lending shock (Panel F). The IRFs are shown with the 90% bootstrapped confidence intervals (grey dashed lines) based on 1,000 replications. The impulse response functions are estimated from a panel VAR model with the following order: cash imbalance, bid-ask spread, SMP purchase, repo imbalance, specialness and available for lending of the bonds purchased under the SMP. The 10-year on-the-run bonds are excluded from the sample.

Table 6: **Statistics on repo transactions for repo maturity** - This table reports the average and the standard deviation of the daily distribution of the special repo transactions for repo maturity. The statistics are reported for the full sample and for three distinct sub-periods. First period from 1 October 2009 to 7 August 2011. Second period: from 8 August 2011 to 21 December 2011. Third period: from 22 December 2011 to 12 July 2012.

	Spot next		Tomorrow next		Over night	
	Mean	St.dev	Mean	St.dev	Mean	St.dev
Full Sample	86.315	3.154	12.047	2.908	1.638	0.820
1st period	86.431	3.238	11.868	2.978	1.699	0.844
2nd period	84.869	2.425	13.620	2.285	1.509	0.622
3rd period	86.962	3.020	11.519	2.694	1.517	0.838

Table 7: **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. Specialness is in basis points and are based on spot next (SN), tomorrow next (TN) and overnight (ON) transactions. The statistics are reported for the full sample and for three distinct sub-periods. First period from 1 October 2009 to 7 August 2011. Second period: from 8 August 2011 to 21 December 2011. Third period: from 22 December 2011 to 12 July 2012.

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
1st period					
(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
2nd period					
(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
3rd period					
(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 8: **Statistics of GC and Special repo rates** - This table reports the average, the standard deviation, the 5th and 95th percentile of the daily distribution of the GC and special repo rates. Special and GC repo rates are based on spot next (SN), tomorrow next (TN) and overnight (ON) transactions. The statistics are reported for the full sample and for three distinct sub-periods. First period from 1 October 2009 to 7 August 2011. 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).

	GC repo rates				Special repo rates			
	Mean	St.dev	5 Perc.	95 Perc.	Mean	St.dev	5 Perc.	95 Perc.
Full Sample	0.618	0.377	0.246	1.590	0.491	0.390	-0.326	1.409
1st period	0.593	0.347	0.254	1.622	0.496	0.382	-0.231	1.462
2nd period	1.141	0.197	0.765	1.602	0.873	0.331	-0.372	1.310
3rd period	0.333	0.096	0.229	0.733	0.212	0.150	-0.396	0.397

Table 9: **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. Specialness and Repo imbalance are based on spot next (SN), tomorrow next (TN) and overnight (ON) transactions. The second period: from 8 August 2011 to 21 December 2011.

	Special.	Repo imbalance	Imbalance cash	Bid-ask spread	Lend.	SMP purchase	Fail-to-deliver
Full sample							
Specialness	1.000						
Repo imb.	0.091	1.000					
Cash imb.	-0.022	-0.011	1.000				
Bid-ask	-0.012	-0.008	0.027	1.000			
Lending	-0.138	0.044	0.013	-0.040	1.000		
SMP purch.	0.069	0.004	0.014	-0.006	-0.030	1.000	
Fail-to-deliver	0.434	0.122	-0.034	-0.017	-0.073	0.005	1.000
2nd period							
Specialness	1.000						
Repo imb.	0.155	1.000					
Cash imb.	-0.015	-0.054	1.000				
Bid-ask	-0.023	-0.006	0.010	1.000			
Lending	-0.181	-0.007	0.024	-0.033	1.000		
SMP purch.	0.050	0.048	0.040	-0.023	-0.032	1.000	
Fail-to-deliver	0.346	0.169	-0.061	-0.010	-0.051	0.016	1.000

Table 10: **Panel Stationary Test** - This table reports the results of the Fisher stationary test whose null hypothesis is that all the panels contain a unit root for the SMP purchase, repo imbalance, specialness, cash imbalance, bid-ask spread and available for lending variables over the sample 8 August 2011 - 21 December 2011.

	SMP purchase		Repo imbalance		Specialness	
	Statistic	P-value	Statistic	P-value	Statistic	P-value
Inverse chi-squared	393.26	0.00	305.43	0.00	187.92	0.00
Inverse normal	-15.36	0.00	-13.01	0.00	-8.30	0.00
Inverse logit t	-19.43	0.00	-15.02	0.00	-8.74	0.00
Modified inv. chi-squared	29.74	0.00	21.86	0.00	11.30	0.00
	Cash imbalance		Bid-ask spread		Lending	
	Statistic	P-value	Statistic	P-value	Statistic	P-value
Inverse chi-squared	70.26	0.00	300.23	0.00	305.89	0.00
Inverse normal	-4.42	0.00	-13.07	0.00	-12.77	0.00
Inverse logit t	-4.83	0.00	-15.07	0.00	-15.05	0.00
Modified inv. chi-squared	6.67	0.00	21.93	0.00	21.90	0.00

Table 11: **Specialness (Spot Next)** - The table shows the results of OLS panel regressions with bond and time fixed effects with each observation defining a bond-day. Specialness is expressed in basis points and is based on spot next (SN) and tomorrow next (TN) transactions. The repo imbalance is based on spot next (SN) transactions. The repo imbalance, cash imbalance and available for lending variables are rescaled by the nominal outstanding amount of the bond and expressed in percentage terms. Bond time-to-maturity denotes the time to maturity of a specific security. Bid-ask spread denotes the bid-ask spread based on BGN Bloomberg prices at or before 5pm. D. auction is a dummy variable to control for the date of a primary issuance of the security. Standard errors are in parenthesis and are clustered by bond and time identifier. The results are reported for the full period and for the three distinct sub-periods: 1 October 2009 - 7 August 2011, 8 August 2011 - 21 December 2011 and 22 December 2011 - 12 July 2012. Stars denote statistical significance at 10% (*), 5% (**) and 1% (***)).

	(1) Full	(2) 1st	(3) 2nd	(4) 3rd
Specialness (lag)	0.867*** (0.033)	0.886*** (0.028)	0.823*** (0.096)	0.802*** (0.049)
Repo imbalance (lag)	0.622*** (0.134)	0.516*** (0.111)	1.729*** (0.585)	0.101 (0.100)
Cash imbalance (lag)	-0.305** (0.155)	-0.153 (0.151)	-1.347** (0.648)	0.067 (0.274)
Avail. lending (lag)	-0.146*** (0.042)	-0.117*** (0.034)	-0.324* (0.166)	-0.148* (0.079)
Bond time-to-mat.	0.031* (0.017)	0.025* (0.015)	0.038 (0.048)	0.051* (0.028)
D. auction	-3.634*** (1.318)	-3.523** (1.785)	-6.581*** (1.273)	-1.679*** (0.499)
Bid-ask spread (lag)	-0.020* (0.011)	-0.033* (0.018)	-0.010 (0.020)	-0.011 (0.017)
Constant	1.775*** (0.429)	2.152*** (0.158)	3.026 (3.599)	8.982*** (1.055)
Time Fixed Effects	Yes	Yes	Yes	Yes
R^2	0.820	0.823	0.798	0.747
Num. Obs.	37,145	26,547	4,855	5,743

Table 12: **Specialness (Tomorrow Next)** - The table shows the results of OLS panel regressions with bond and time fixed effects with each observation defining a bond-day. Specialness is expressed in basis points and is based on spot next (SN) and tomorrow next (TN) transactions. The repo imbalance is based on tomorrow next (TN) transactions. The repo imbalance, cash imbalance and available for lending variables are rescaled by the nominal outstanding amount of the bond and expressed in percentage terms. Bond time-to-maturity denotes the time to maturity of a specific security. Bid-ask spread denotes the bid-ask spread based on BGN Bloomberg prices at or before 5pm. D. auction is a dummy variable to control for the date of a primary issuance of the security. Standard errors are in parenthesis and are clustered by bond and time identifier. The results are reported for the full period and for the three distinct sub-periods: 1 October 2009 - 7 August 2011, 8 August 2011 - 21 December 2011 and 22 December 2011 - 12 July 2012. Stars denote statistical significance at 10% (*), 5% (**) and 1% (***) .

	(1) Full	(2) 1st	(3) 2nd	(4) 3rd
Specialness (lag)	0.603*** (0.156)	0.576*** (0.197)	0.828*** (0.054)	0.338*** (0.087)
Repo imbalance (lag)	0.838 (0.591)	1.156 (0.781)	0.805* (0.463)	-1.243 (0.849)
Cash imbalance (lag)	-0.813 (0.544)	-0.566 (0.699)	-3.036 (1.915)	-0.346 (0.458)
Avail. lending (lag)	-0.763** (0.348)	-0.765** (0.383)	-0.412 (0.281)	-0.225 (0.421)
Bond time-to-mat.	0.361** (0.175)	0.348* (0.188)	0.174 (0.126)	0.633*** (0.199)
D. auction	-9.192** (4.025)	-8.105* (4.872)	-5.272 (5.448)	-15.700** (7.347)
Bid-ask spread (lag)	-0.127*** (0.034)	-0.173** (0.075)	-0.110*** (0.030)	-0.080* (0.045)
Constant	5.892*** (1.905)	11.109* (6.231)	16.299*** (4.202)	7.446*** (1.105)
Time Fixed Effects	Yes	Yes	Yes	Yes
R^2	0.445	0.392	0.699	0.255
Num. Obs.	22,060	15,972	2,999	3,089

Table 13: **Cash premium and specialness** - This table shows the relationship between bond and repo characteristics and the cash premium of the bond. The cash premium is expressed in basis points and is computed as the deviation of its observed yield from the Svensson zero coupon yield curve. The observed yield is computed using quoted prices (BGN) from Bloomberg. Specialness is based on spot next (SN) and tomorrow next (TN) transactions. In Column (1) the results are reported for the entire period, while in Columns (2) – (4) the results are reported for the period 8 August 2011 - 21 December 2011. In Column (3) the 10–year on-the-run bonds are excluded from the sample, while in Column (4) the sample is restricted to the bonds purchased under the SMP. The table shows the results of OLS panel regressions with bond and time fixed effects with each observation defining a bond-day. All the variables are contemporaneous. OLS Standard errors are in parenthesis and are clustered by bond and time identifier. The results are reported for the sub-period 8 August 2011 - 21 December 2011. Stars denote significance at 10% (*), 5% (**) and 1% (***).

	(1)	(1)	(3)	(4)
Specialness	0.027 (0.018)	0.008 (0.035)	0.015 (0.037)	0.075*** (0.027)
Bond time-to-mat.	-0.971*** (0.279)	-0.917* (0.547)	-0.899* (0.544)	-0.690 (0.675)
D. auction	-2.829 (2.532)	-14.665** (6.204)	-12.231** (6.006)	-13.418** (5.651)
Bid-ask spread	-0.207 (0.205)	-0.292 (2.180)	-0.343 (2.184)	8.595** (3.620)
Constant	12.091*** (1.169)	30.805*** (4.172)	30.801*** (4.178)	-21.577*** (4.714)
Time Fixed Effects	Yes	Yes	Yes	Yes
R^2	0.107	0.061	0.059	0.195
Num. Obs.	49,746	7,281	7,185	3,123

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