DNB Working Paper

No. 674 / March 2020

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EUROSYSTEEM

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* Views expressed are those of the authors and do not necessarily reflect official positions of De Nederlandsche Bank.

Working Paper No. 674

March 2020

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Demand Shocks for Public Debt in the Eurozone*

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March 2020

Abstract

In this paper we use high-frequency (intraday) government bond futures price changes around German and Italian Treasury auctions to identify unexpected shifts in the demand for public debt. Estimates show that positive demand shocks lead to large and persistent negative movements in Treasury yields. There is also evidence of significant spillover effects into Treasury bond, equity and corporate bond markets of other euro area countries. We find interesting differences in the effects of demands shocks between the two countries, which are consistent with the "safe-haven" status of German bonds versus the "high-debt" status of Italian Treasuries. Results also suggest that these effects are stronger during periods of high financial stress.

Keywords: Sovereign bonds; Primary market; High-frequency identification; Yield curve

JEL Classification: F4, E43, G15

*The authors would like to thank Roel Beetsma, Raffaele Corvino, Robin Döttling, Gabriele Galati, Jakob de Haan, Kostas Mavromatis, Julia Schaumburg, Sweder van Wijnbergen and seminar participants at 2nd Lancaster Summer School on Applied Macroeconometrics (September 24-25, 2019), Erasmus Universiteit Rotterdam (December 4, 2019), De Nederlandsche Bank (December 5, 2019), Universiteit van Amsterdam (December 11, 2019) and the 12th PhD Workshop at Collegio Carlo Alberto (December 12, 2019) for their useful comments and suggestions. Andras Lengyel would like to acknowledge the hospitality of the De Nederlandsche Bank where part of this research was conducted during April-June 2019. The Online Appendix is available at: https://www.uva.nl/en/profile/l/e/a.lengyel/a.lengyel.html

1. Introduction

Government bonds of developed countries are usually considered the safest and most liquid assets. They have a key role in savers' portfolio decisions, investors' risk-management activities and banks' repo operations. Consequently, private sector demand for the largest European economies sovereign bonds was initially stable, following the introduction of the single currency. Volatility was low, with yields exhibiting strong co-movements, up until the Global Financial Crisis (Figure 1). The crisis broke this pattern and credit risk became an increasing problem in many euro area countries. Countries on the periphery of the euro area have seen private sector demand for their bonds drying up. The European Central Bank (ECB) took up an active role and entered the buy side of the market, in order to first facilitate liquidity with the Securities Markets Programme (SMP), and later to influence prices with the Public Sector Purchase Programme (PSPP). The aim of this latter program was to decrease long-term interest rates, by purchasing large quantities of long-term euro area public debt securities.

These shifts in the demand for public debt provide the motivation for our study. Our goal, in a broader sense, is to identify unexpected demand shocks for German and Italian government bonds and analyze how financial markets react to these shocks. The choice of these two countries stems from the fact that a shift in the demand for German and Italian debt is associated with markedly different sentiments in financial markets. German government bonds are some of the safest traded securities, experiencing large inflows during times of high financial stress. Consequently, investors attach large "safety" and "liquidity" premiums to them (Ejsing and Sihvonen (2009) and Klingler and Sundaseran (2019)). Investors' attitude towards Italian bonds, on the other hand, is substantially different. Italy has one of the highest public debt-to-GDP ratios in the euro area. Its sustainability is a topic of ongoing debate and investors require a substantial risk premium for holding Italian bonds.

The first contribution of our paper is to identify unexpected shifts in the demand for public debt in these two countries, by exploiting the institutional setup of government bond auctions. The identification strategy follows Gorodnichenko and Ray (2017), who proposed it in the context of US auctions. These auctions are important events where institutional investors can accommodate part of their security needs. Therefore, auction results can give hints about changes in market demand for these securities.[1] Furthermore, the prevailing demand at an auction shows investors' perception of the health of a country's economy

[1] News agency Bloomberg wrote on the 27th December 2018: *"The Treasury in Rome plans to auction as much as 5 billion euros of debt Friday, including benchmark five-year and 10-year securities. (. . .) The results will provide an indication of the underlying demand for Italian bonds next year."*

and creditworthiness of its government.[2] Importantly, the timing and the setup of these events are such that they allow to capture price movements that can mainly be attributed to demand-side factors. Debt management agencies disclose information about the supplied securities and its quantity well in advance of an auction. On the auction day, therefore, investors are already well informed of the supply side of the market. The demand side is, however, unknown up until the agency releases the results of the auction. Hence, when these results are published, investors receive new information solely on the demand conditions. By looking at high-frequency price movements of government bond futures contracts around the first releases of the results, we can isolate price variations that are mainly attributed to the strength of the demand side.

The second contribution of the paper is on the estimation of the effects of the identified Treasury demand shocks on domestic Treasury yields and the yield curve. Our estimates show that a one-standard-deviation demand shock in Germany decreases home yields by around 1.6 basis points. In Italy a similar shock has an effect of 3.3 basis points. These effects are found to be long lasting and persistent. Using our estimated effects of the private demand for Treasuries, we provide back-of-the-envelope calculations of the effects of the PSPP on German and Italian yields which are in line with the findings of the existing literature (Altavilla, Carboni, and Motto (2015) and De Santis (2019)). We also investigate the effects of a location-specific demand shock on the Treasury yield curve, distinguishing between short-term and long-term Treasury demand shocks. We find that in Germany the shocks have local effect in the sense that nearby (i.e. similar maturity) yields respond stronger. Our findings for Germany are in line with the results of Gorodnichenko and Ray (2017) who find local effects of demand shocks for the US Treasury yield curve. It is also consistent with studies bringing evidence of bond market segmentation, such as Boermans and Vermeulen (2018). In Italy, on the other hand, a positive demand shock always decreases short-term interest rates more, regardless of the shock's location.

The third contribution of the paper is to estimate the spillover effects on Treasury bond, equity and corporate bond markets of the main euro area countries. We find that German and Italian demand shocks have spillover effects on the Treasury bond yields of other euro area countries. While the German shocks have more sizable effects on France and the Netherlands, the responses to the Italian demand shocks are mostly centered on the Spanish Treasury yields. We also find that Treasury demand shocks lead to reactions of the corporate bond and equity markets. More specifically, our estimates show that euro area corporate bond yields

[2] As news agency Reuters wrote on the 30th July 2018: *"Italy's scheduled bond auctions, which included the sale of a new 10-year benchmark, was seen as a test of investor risk appetite amid political tensions in the euro zone's third largest economy."*

drop in response to German demand shocks, whereas they are rather unaffected by Italian demand shocks. Interestingly, we find that the main euro area stock indices drop following German demand shocks, whereas Italian Treasury demand shocks lead to positive responses of equity prices. We reconcile these results as follows. A sudden increase for German bonds is associated with financial markets turning to a flight-to-safety mode. Willingness to take risk decreases and investors re-balance their portfolios from equities to bonds. On the other hand, the market movements associated with the Italian demand shock are the result of a higher risk appetite and a better outlook for the Italian economy leading to positive effects on the Italian stock market.

Finally, our last contribution is to test for the presence of state dependence. We show that during times of high financial stress the estimated responses documented above tend to be larger relative to periods of low financial stress. We also study if positive and negative demand shocks for Treasury bonds have asymmetric effects. We find that German responses are rather symmetric, while in the case of Italy the baseline results on Treasury markets seem to be mainly driven by positive demand shocks. This is particularly the case for the Treasury spillover effects to other euro area countries. Similarly, we find that that both the equity and corporate bond indices react significantly only to positive Italian demand shocks.

The remainder of the paper is organized as follows. Section 2 summarizes the literature related to our study. Section 3 provides more details on the institutional setup of Treasury auctions in Germany and Italy. Section 4 describes the data used in the analysis. The high-frequency identification and the construction of the demand shocks are explained in Section 5. The main empirical results are shown in Section 6, which also contains an extensive robustness analysis. Section 7 examines the presence of state dependency and asymmetries in the effects. Finally, Section 8 concludes.

2. Literature Review

This paper is related to several lines of existing research. On the one hand, it is connected to the literature that analyses high-frequency price movements around specific events, where disproportionately large amount of information is released to the public. Such events include monetary policy decisions, financial and macroeconomic data releases, and Treasury auctions. The underlying assumption in these studies is that prior to the event, all relevant information is already incorporated in market prices. Then, in a short event window, nothing other than the announcement could affect the price (see Gürkaynak and Wright (2013) for a discussion). The method is widely used in the empirical monetary policy literature and was introduced by Gürkaynak, Sack, and Swanson (2005) who isolated monetary surprises using federal fund futures prices on FOMC decision days. This approach was also applied by Campbell, Evans, Fisher, and Justiniano (2012) and Gertler and Karadi (2015). Other authors extended this analysis to high-frequency price movements of other financial instruments on FOMC days. These included stock prices and exchange rates as in Gorodnichenko and Weber (2016), Jarociński and Karadi (2019) and Altavilla, Brugnolini, Gürkaynak, Motto, and Ragusa (2019). Analyzing high-frequency price movements are also widely used in the literature tracing markets' responses to financial and macroeconomic data releases. The reaction of exchange rates, stock and bond prices to these releases are studied by Fleming and Remolona (1997), Fleming and Remolona (1999), Andersen, Bollerslev, Diebold, and Vega (2003), Balduzzi, Elton, and Green (2001) and Faust, Rogers, Wang, and Wright (2007), among others. Very few papers study intraday price movements around Treasury auctions. Fleming and Liu (2016) show that prices follow a V-shaped pattern on the day of the auctions, due to participants limited risk-bearing capacity. Gorodnichenko and Ray (2017) identifies demand shocks for US Treasuries by analyzing high-frequency price movements around the release of the auction results. Our paper extends their analysis to the European context and studies the effects of German and Italian Treasury demand shocks on the sovereign bond, equity and corporate bond markets in the euro area countries. The focus on Germany and Italy is of particular interest, because these two countries differ substantially in terms of their risk perception. Whereas Germany Treasuries have a "safe-haven" status, Italian sovereign bonds contain a substantial country-risk premium. To the best of our knowledge, this paper is the first attempt in quantifying the effects of demand shocks for public debt in the euro area.

The paper also relates to the literature studying Treasury market segmentation, particularly in relation to large scale asset purchases by central banks. Interest in the topic stems from these institutions' desire to lower interest rates on longer maturities through these purchases. The standard no-arbitrage term structure asset pricing theory predicts that supply and demand shifts, which are unrelated to economic fundamentals, do not affect bond yields. However, if segmentation is present, the interest rate at a given maturity is strongly influenced by the supply and demand conditions of bonds with such a maturity. The theoretical term structure model with these features was first developed by Vayanos and Vila (2009) and Greenwood and Vayanos (2014). Empirical investigations include Krishnamurthy and Vissing-Jorgensen (2011), Li and Wei (2013) and Gorodnichenko and Ray (2017) in the US, and Boermans and Vermeulen (2018) and Bubeck, Habib, and Manganelli (2018) in the euro area. This paper complements these findings by bringing further evidence of market segmentation in eurozone Treasury markets. Unlike most pre-existing studies, however, we do not estimate the effects using central bank announcements or data on their actual purchases.

Instead, we use primary market auctions, which are held frequently in a timely manner, to identify unexpected Treasury demand shocks.

There is only a limited amount of empirical papers examining the effects of government bond auctions on financial markets. One line of research documents predictable price patterns in the secondary market during the day before and after auctions (see Lou, Yan, and Zhang (2013), Beetsma, Giuliodori, de Jong, and Widijanto (2016), Beetsma, Giuliodori, Hanson, and de Jong (2018), Eisl, Ochs, Osadchiy, and Subrahmanyam (2019)). Gorodnichenko and Ray (2017) studies how US Treasury demand shocks, identified on auction days, affect the yield curve and how this is transmitted to other domestic financial markets. Two closely related papers, Klingler and Sundaseran (2019) and Dobrev (2019), identify demand shocks by looking at bid-to-cover ratios of Treasury auctions. Klingler and Sundaseran (2019) analyzes how this shock affects the liquidity premium on US and German government bonds. Their results suggest that a demand shock for German public debt significantly increases the liquidity premium on these bonds. Moreover, while the "safe-haven" status of US Treasuries decreased after the crisis, the German securities still enjoy it. Dobrev (2019) documents a demand shift from longer to shorter-duration Treasuries after the crisis. Another recent study is Fuhrer and Giese (2019). They identify demand shocks for UK Treasury bonds as deviations of the bid-to-cover ratio from its long-term mean. Their results show large and localized effects of the demand shock on the yield curve, in particular during volatile market conditions.

To summarize, although public debt auctions convey substantial amount of information to financial markets, it is still an under-researched area, especially within the euro area. While in most eurozone countries the institutional setup of auctions provides an ideal environment for an event study style high-frequency analysis, this has not been implemented yet. The aim of this paper is to bridge this gap by employing the methodology of Gorodnichenko and Ray (2017) to identify demand shocks for German and Italian public debt and tracing their effects on financial markets in the euro area. There is an important motive behind our country selection. Gorodnichenko and Ray (2017) focuses on the US Treasury market, that is highly safe and liquid. Italian and German bonds are also considerably liquid, but they are traded with substantial differences in terms of risk level. German Treasuries are considered "safe-haven" assets, whereas Italian Treasuries are perceived to be riskier assets. As a result, this study contributes to our understanding of the role of demand shocks in Treasury markets, in particular in relation to issuers with different risk characteristics. The paper also documents the transmission of the demand shock to other assets, namely corporate bonds and equities. Additionally, we look at spillovers of German and Italian Treasury demand shocks to other major euro area countries. Here we document large differences in the effect of the demand shock, depending on the risk perception of the country issuing the debt. The spillover effects show different patterns following investors' demand shifts for safe Germany Treasury bonds, compared to demand changes for riskier Italian securities. The paper also contributes to the literature by studying the role of state-dependence (e.g. high versus low financial stress) and sign-dependence (positive versus negative demand shocks) of the results we document above.

3. Institutional Setup of Government Bond Auctions

In this section we briefly discuss the institutional setup of German and Italian government bond auctions, also known as the primary markets. For more details, we refer to AFME (2017). The German Finance Agency is responsible for all public debt management functions in Germany. In Italy the government bond auctions are carried out by the Bank of Italy in collaboration with the Treasury of the Ministry of Economy and Finance. Only a specific group of investors is allowed to participate in the auction process. In Germany this group is the "Bund Issues Auction Group" and in Italy they are the "Authorized Dealers." These so-called primary dealers have to meet specific requirements such as a minimum amount of successfully submitted bids within a year.[3] The German Treasury uses a multi-price auction process where the winning bids are allotted at the price specified in the bid. For the maturities we consider, the Italian Treasury employs a uniform price auction where the Treasury discretionarily sets the clearing price of the auction and the quantity issued within a range previously announced.

Both governments publish a yearly issuance calendar at the end of every year to inform investors about the auction dates in the upcoming year. Then, at the end of every quarter they publish an issuance schedule with information on the types of bonds and the volume to be issued. A few days (e.g. 6 working days in Germany and 3 working days in Italy) prior to the auction, the agencies post the exact maturity and volume of the bonds, specify the coupon rate and provide additional details. The Online Appendix shows a press release of an auction announcement of a 10-year German bond and a 10-year Italian bond (Figures A1 and A2). Both documents clearly communicate the issuance volumes, coupon payments, the time frame when bids are accepted and the settlement date among other pieces of information. Finally, the German agency posts an invitation to bid the weekday prior to the tender, to inform about the timing of the auction.

On the day of German auctions, bidding starts at 8:00 am Central European Time (CET).

[3] In 2017 the number of primary dealers was 36 in Germany and 18 in Italy. For the complete list of members and the membership requirements see AFME (2017).

Primary dealers can place their bids until 11:30 a.m., but before 2012 this was 11:00 a.m. The timeline of the German tender process is shown in Figure 2. Multiple bids at different prices can be placed, but bids must be of par value of no less than one million EUR. Bidders may also choose to issue non-competitive bids with no upper limit on the demanded amount. The price that these bidders must pay is the weighted average of the winning competitive bids. Whether these bids will be filled completely or not will be decided by the agency. Non-competitive bids accounts for around 30% of all bids. At 11:30 a.m. CET the agency collates the bids and decides on the allotment. The decision is made within roughly 5 minutes, after which bidders are notified and the results are published. This document contains information on the amount of competitive and non-competitive bids received, the allotted volume, the resulting bid-to-cover ratio and the lowest and the average price of the allotted bonds (see Figure A3 in the Online Appendix). In each auction, the German Treasury sets aside a part of the initially announced issuance volume for future secondary market operations. This amount is communicated in the same document.

The Italian auctions are organized in a very similar fashion.[4] On the day of the auction, all authorized dealers are allowed to submit their bids through the Italian electronic interbank network. These bids are accepted until 11.00 a.m. and automatically rejected afterwards. The bids can be continuously adjusted until the closing time, after which all bids are sent out to the Treasury Officer who sets the results, publishes the outcome and communicates it to the Bank of Italy. According to the Treasury, this process can take up to 15 minutes. A press statement is then uploaded to the agency's website. An example of these press releases is shown in the Online Appendix (Figure A4). The document contains the amount of bids received, the amount allotted, the resulting bid-to-cover ratio, the market clearing price the agency chooses and much more. The settlement of the securities is two working days following the auction. After posting the press release with the issuance volume, the Italian Treasury did not have any discretion regarding the allotment volume prior to 2008. It issued 100% of the quantity announced. After 2008 the Treasury allowed itself some flexibility, and now only announces a minimum and maximum amount to be allotted at the auctions. Nonetheless it rarely exercises this option, and most cases the maximum amount is allotted.

4. Data

In this section we describe government bond futures contracts and provide the main reasons for using them in the high-frequency identification of Treasury demand shocks. Afterwards, we introduce all other time series we use in the paper.

[4] For details see Dipartimento Del Tresoro (2017).

Government bond futures contracts

Treasury futures are legal agreements that oblige the party taking a short position to deliver the underlying security at the specified delivery date to the party taking a long position. The predetermined price is called the *futures price*. Futures for European Government Bonds are traded on the EUREX exchange. Currently there are four types of contracts for Germany: The Euro-Schatz, the Euro-Bobl, the Euro-Bund and the Euro-Buxl. A short position arising from these contracts must be fulfilled by a German government bond with remaining maturity of 1.75 to 2.25, 4.5 to 5.5, 8.5 to 10.5 and 24 to 35 years, respectively.

Prior to the financial crisis, the strong correlation among euro area sovereign yields made the existence of distinct futures contracts for the member countries unnecessary. Investors simply used the German contracts for their daily operations. The crisis broke this strong co-movement (Figure 1) and euro futures contracts for Italy, France and Spain were gradually introduced from 2009 onward. From these four countries, currently the contracts of Germany and Italy are traded in the largest volumes. Liquidity of the Italian contracts was initially extremely low, but later picked up to similar levels of other European countries (see Bank of Italy (2010) and Bank of Italy (2015)). The first contract was the Long-Term Euro-BTP Futures, followed by the Short-Term Euro-BTP Futures and the Mid-Term Euro-BTP Futures in the coming years. These contracts can be settled by Italian government bonds with remaining maturities of 8.5 to 11.0, 2.0 to 3.25 and 4.5 to 6.0 years respectively.

For each futures contract, there are four cycles in a year, implying that there only exist contracts ending in March, June, September and December. The contract that naturally emerges as the most liquid is the one with the closest expiration. The others are traded very infrequently. Data provider Refinitiv publishes long series displaying the details of the contract with the closest expiry, which is what we use in our analysis.[5]

There are three main reasons for using futures prices when constructing the high-frequency surprises around the auctions. First of all, as we are looking at contracts with the closest maturity, these futures can be considered close substitute of the underlying cash security. However, futures contracts trade on centralized exchanges, while the underlying bonds are traded over the counter with certain financial institutions acting as market makers. For this reason, the availability and reliability of high-frequency (intraday) futures price data is substantially better. Secondly, the way these contracts are traded leads to several differences in the two products market micro-structure, which in turn make futures much more attractive for traders. Indeed, the futures markets tend to be substantially more active than their bond counterparts. Its relative size is 13 times as large in Germany and 2.5 times in Italy

[5] These series are called continuation RICs. For example, the identifier for the euro-bund futures contract with the closest expiry is FGBLc1, while the contract that expires three months after this is FGBLc2.

(see Table A1 of the Online Appendix). Lastly, in markets where substitution is present, new information tends to be incorporated first in the more liquid market. Early studies by Garbade and Silber (1979) and Garbade and Silber (1983) show empirically that futures markets lead the price discovery ahead of the spot. Upper and Werner (2007) shows that 70-100% of price discovery happens in futures prices for German bonds.

Other data

Besides intraday Treasury futures prices, our dataset consists of daily secondary market government bond yields, primary market auction data, daily stock market indices, daily corporate bond indices, daily credit default swap (CDS) premiums on Treasuries and a monthly country level financial stress index. The sample starts on the 1st of January 1999 and ends on the 29th of December 2017. Demand shocks are identified only for Germany and Italy, but the other largest euro area countries (namely France, Spain and the Netherlands) are considered in the spillover analysis.

Information on Treasury auction results is taken from the national debt management agency websites.[6] Our analysis covers 2, 5, 10 and 30-year bond auctions. For Germany, we use 536 auctions, while for Italy the number is 247. This is due to the fact that Italian futures contracts were introduced after 2009 and sufficient market depth was reached only in 2010. All daily financial markets data was taken from Datastream with the exception of the corporate bond indices, which are sourced from FactSet. Government bond yields include $2, 3, 5, 7, 10, 20$ and 30-year maturities for both Germany and Italy, with the exception of 15 years instead of 20 for Italy. Figure 1 shows the Treasury bond yields of the five countries for the 2, 5, 10 and 30-year maturities over the full sample period. The series display strong co-movement prior to 2010 and the divergence of Spanish and Italian yields thereafter. The country-level corporate bond indices are the corporate sub-indices of the Bloomberg Barclays Euro Aggregate Index. We use the five largest euro are countries' stock market indices: the German DAX, the French CAC40, the Italian FTSEMIB, the Spanish IBEX35 and the Dutch AEX. These are displayed in Figure 3. The series show two major corrections, one after the dot-com bubble in the early 2000s and the other during the global financial crisis in 2009. CDS spreads are based on euro dominated government bonds with maturities of 2 and 10 years and are available from 2007 onward. Figure 4 shows the premium for the 10-year maturity for Germany and Italy. It displays a large and positive difference between the two series, peaking during the Eurocrisis. Finally, the Country Level Index of Financial Stress (CLIFS) was obtained from the ECB and it is based on Duprey, Klaus, and Peltonen

[6] See `https://www.deutsche-finanzagentur.de` for Germany and `http://www.dt.tesoro.it` for Italy.

(2017). The index is constructed to identify regimes with financial stress that is associated with substantial negative impact on the real economy. The dummy variable we created from this index takes the value one when the index is above its historical 70th percentile, a threshold the authors mention for systemic financial stress events. The German and Italian CLIFS series within our sample period are displayed in Figure 5. The German index peaks in the 2009 market turmoil, with relatively high values also after the burst of the dot-com bubble in the early 2000s. The Italian index is relatively low prior to 2008, but fairly volatile thereafter, peaking during the euro area sovereign debt crisis.

5. Identification

In this section we describe how we identify unexpected demand shocks for public debt. As shown in Figures A3 and A4, debt management agencies publish a number of pieces of information related to the outcome of an auction. One of them is the bid-to-cover ratio, which is the total amount of bids submitted by participants divided by the allotted volume. The bid-to-cover ratio is one of the measures investors and the press follow the closest to assess demand conditions and the overall success of a given auction. Hence, it would seem natural to use it to directly quantify demand shocks, as done in Klingler and Sundaseran (2019) and Fuhrer and Giese (2019). There are, however, some issues that make the headline bid-to-cover ratio problematic to identify unexpected changes in the demand for Treasuries.

First of all, differently from the US, German and Italian debt management agencies can adjust the final allotment volume during the auction.[7] An unsuccessful auction can question the credibility of the fiscal authority and cause market turbulence. Therefore, when the agencies judge that the demand conditions are weak and that the bids are at an unacceptable discount to the prevailing market levels, they do not allot all the bonds on offer. For example, the German Treasury typically withholds around 14-23% of the issuance, to set aside for future secondary market operations.[8] Italy introduced discretion in the issued quantity after 2008 to have the option to exclude bids not in line with market conditions. The agency, however, rarely resorts to this measure. In general, agencies base their decision of retention and allotted volume on the prevailing demand conditions, and the resulting retained volume, which is communicated in the same document as the auction results, provides investors with additional information about the market demand. The above

[7] Also the UK debt management office reserves the right to withhold part of the gilts on offer, although this option is only considered in "exceptional circumstances."

[8] It is important to note that the total volume of securities initially announced by the German Treasury is issued within days after the auction. In fact, the withheld securities enter the secondary market gradually in the days following the auction through operations of the agency.

arguments suggest that for Germany and Italy the headline bid-to-cover ratios do not provide a fully informative summary of demand conditions prevailing in an auction. Partly because it does not directly reveal the quality of the individual bids and partly because the allotted volume is adjusted by the debt management agencies in response to demand conditions.[9] In other words, the same headline bid-to-cover ratio could be the outcome of different demand conditions. An additional complication in using bid-to-cover ratios is related to the fact that there is no easy and uncontroversial way to isolate its unexpected component, which is the main focus of this paper.

A second issue to consider is that, when assessing the strength of the demand at an auction, market participants also closely follow pricing data. An important price statistic in auctions is the average (or accepted) yield. Investors compare these with secondary market yields of comparable securities. When the demand is strong, auction participants tend to bid up prices, and offer lower yields. The difference between the secondary and the primary market yields, which we call "yield gap" is another indicator of the strength of the demand for public debt.[10] However, similarly to the bid-to-cover ratio, interpreting the size and isolating the predictable and unpredictable components of the yield gap is again a difficult task.

To overcome these potential shortcomings, we employ the high-frequency identification proposed by Gorodnichenko and Ray (2017). It relies on the idea that on the day of an auction, the debt management agencies have already disclosed all relevant information about the supply side of the market, such as the issuance volume and security characteristics. Therefore, the press release with the auction results only contains new information about the demand side of the market. Within a short event window around the release of the results, all price movements can be attributed to unexpected changes in market beliefs about the demand for Treasury bonds. As such, this shock does not rely on a specific headline measure of the auction results, nor it requires specific assumptions to identify the unexpected variation of the demand conditions.

[9] To bring empirical support to this, for Germany we regressed the retained amount (over the target volume) on the total volume of bids (over the target volume) submitted at each auctioned maturity. Results displayed in Table A2 of the Online Appendix show that the amount of bids is significantly and negatively associated with the volume withheld by the agency. This shows that the higher the amount of bids submitted by the primary dealers, the smaller the amount retained by the German agency.

[10] More specifically, market participants focus on the "price gap", also called "concession", which is the difference between the secondary market price and the primary market accepted price. But given the relationship between prices and yields of coupon bonds, the yield gap offers the same amount of information. See ITC Markets (2017) for more details on how market participants assess results of Treasury auctions.

High-frequency surprises

In order to capture these unexpected shifts in demand conditions, we use the price movements of Treasury futures contracts. Investors' reaction to the new information could potentially involve purchases of securities throughout the entire maturity spectrum. Ideally, we would like to have time series that track these shifts in demand at every maturity point. However, we can only proxy the shifts by price movements at the points where future contracts are available.

The demand shock $D_t^{(m)}$ at an auction on day t for maturity m is measured as the difference between the (log) price after and before the release of the auction results. More explicitly:

$$D_t^{(m)} = \left(ln(P_{t,post}^{(m)}) - ln(P_{t,pre}^{(m)}) \right) \times 100 \qquad\qquad m \in \{2, 5, 10, 30\} \tag{1}$$

where $P_{t,pre}^{(m)}$ and $P_{t,post}^{(m)}$ are the prices observed before and after the close of the auction. $D_t^{(m)}$ is calculated for all $m \in \{2, 5, 10, 30\}$ each day when an auction takes place, regardless of the maturity being auctioned. The series $D_t^{(2Y)}$ for Germany provides therefore surprise movements in the 2-year Treasury futures prices on days when German government bonds are auctioned.

The frequency of the futures prices is at one minute i.e. it displays the last traded price within a given minute. For some less liquid contracts there might not be a trade in every minute, therefore we use the 5-minute moving average of the observed traded prices. In case of the Italian contracts, there are periods of very infrequent trading. For those minutes when trading did not take place, we proxy the price with the average of the highest ask and the lowest bid price within the minute.

For Germany $P_{t,pre}$ is chosen to be 30-minutes before the closing of the tender and $P_{t,post}$ to be 30 minutes after, as the German Finance Agency releases the auction results within 5 minutes of the closing. The Italian agency indicated that their process might take up to 15 minutes, therefore we consider a window of 20 minutes before and 40 minutes after the closing of the tender. We experiment with alternative windows in both countries. The correlation coefficient among the resulting shock series is usually very high and the results of the analysis are qualitatively and quantitatively robust to alternative window sizes. In the Online Appendix we show results with two different choices for the event window. First, we set $P_{t,pre}$ to be the start of the bidding process, 8:00 a.m., and $P_{t,post}$ to be 30 minutes after the release of the results. This specification allows to rule out any effect of participants' collusion during the bidding process. The Online Appendix also includes results when we use a 30-minute event window.

As an illustration, Figure 6 shows the price movements of the four German futures contracts within the one-hour event window on the 23rd of November 2011. In this auction the German government was targeting to sell 6 billion euros of bonds with a maturity of 10 years, but primary dealers submitted bids for the total amount of around 3.9 billion. Facing this low demand, the Finanzagentur cut back on the supply and only sold 3.6 billion, resulting in the official bid-to-cover ratio of 1.1. The futures price movements during this specific auction are displayed in Figure 6. It shows a large drop at the time the auction result was published (i.e. when investors learned how low market demand was). News agency Reuters commented on this auction as *"A "disastrous" sale of German benchmark bonds"*. As an illustration of a successful auction, we consider the 10-year bund tender on the 17th of April 2013. The 4 billion intended issuance volume met 5.2 billion of bids, resulting in a bid-to-cover ratio of 1.3. Figure 7 display sharp futures price increases following the release of the auction results. The Financial Times reported the following reaction by Rabobank analysts: *"Given the backdrop of a* [Euro Area] *peripheral rally and the very low yield available, this is a solid auction result."* While the bid-to-cover ratio statistic in the two auctions do not differ substantially, the corresponding price movements and market commentaries reveals large differences in the success of the tenders. This example illustrates the potential benefits of our identification methodology.

The time series of the identified high-frequency demand shocks are displayed in Figures 8 and 9. Due to limited availability of futures prices, for Italy the sample is constraint to the post-October-2010 period. The summary statistics of the shocks are displayed in Table 1. The means are close to zero (albeit all slightly negative) and the distribution is relatively symmetric, with standard deviations increasing with the maturity. The correlation coefficients among the shocks are generally very high (0.5-0.9) and even higher for shocks with a closer maturity.

The main assumption of our identification strategy is that $D_t^{(m)}$ captures unexpected changes in the demand for public debt. It is the equilibrium price change arising from the shift in the demand, which is unobservable by nature. Hence, it is important to verify if $D_t^{(m)}$ is linked to observable movements in the demand. As discussed above, two indicators that market participants look at when assessing demand conditions at auctions are the bid-to-cover ratio and the yield gap. We check if the identified demand shocks are related to these two indicators by means of linear regressions. Panel A of Tables 2 and 3 shows the regression results of the bid-to-cover ratios and the yield gaps on the demand shocks. The estimates, which are mainly statistically significant in the case of Germany, show that higher bid-to-cover ratios and lower yield gaps are associated with higher futures price shocks. Panel

B shows that this is mostly coming from their unexpected or surprise components. The decomposition of the bid-to-cover and the yield gap series between expected and surprise components are based on the fitted (expected) and residual (surprise) values of AR(4) models. These findings show that our identified demand shocks are correlated with observed outcome-based indicators of auctions offering additional confidence on the reliability of our identification strategy. In the robustness section below, we will also show that our results are robust when these two indicators are used as instruments for our demand shocks.

6. Empirical analysis

We now use a regression analysis to study how financial markets react to the demand shocks identified above. The dependent variables in the regressions are daily price changes of different financial assets. By moving from intra-day to daily frequency, we intend to capture responses that might take longer to materialize then the one-hour length of the event window.

As shown in Table 1 and Figures 6 and 7, the demand shocks $D_t^{(m)}$ at different maturities are highly correlated. Following Gorodnichenko and Ray (2017), we compress these series into a single variable by taking the first principal component, denoted with D_t, which explains over 94% of the variation in the four shock series for Germany. In case of Italy the principal component is constructed from $D_t^{(2Y)}$ and $D_t^{(10Y)}$, due to the limited availability of $D_t^{(5Y)}$. The resulting series explains 98% of their variation. The interpretation of the shock D_t is an unexpected and non-maturity-specific shift in the demand for public debt.

Furthermore, we construct two addition series of shocks to give the analysis more granularity. A long-term shock series $D_t^{(long)}$ is constructed by taking the values of the 10- and 30-year surprise series on the days when 10- or 30-year maturity bonds were auctioned, and extracting the first principal component. It is meant to capture shocks that increase demand for longer maturity government debt. A short-term shock $D_t^{(short)}$ is constructed in a similar way, but with 2- and 5-year auctions, and then rotated to be uncorrelated with the 30-year series $D_t^{(30Y)}$.[11] This series is meant to capture shocks that increase demand only for short maturities. The availability of the German $D_t^{(long)}$ and D_t are from March 1999 onward, while $D_t^{(short)}$ is available from October 2005.[12] The futures contract on 30-year bonds does not exist for Italy and the 5-year contract is not liquid enough to be used in the analysis. Therefore short-term Italian demand shocks are proxied by the 2-year series $D_t^{(2Y)}$,

[11] More precisely, it was projected onto the space that is orthogonal to the space spanned by the 30-year shock: $D^{(short)} = \left[I - D^{30}\left((D^{30})'D^{30}\right)^{-1}(D^{30})'\right]D^{2,5}$, where $D^{2,5}$ is the first principal component of $D^{(2Y)}$ and $D^{(5Y)}$ on auction days, i.e. the non-rotated short-term shock.

[12] $D_t^{(short)}$ was constructed to be uncorrelated with 30-year futures, that is available from October 2005 onward

while long-term demand shocks are based on the 10-year series $D_t^{(10Y)}$. All shock measures were then normalized to have zero mean and unit variance. Table 1 displays the summary statistics of these series. $D_t^{(short)}$ and $D_t^{(long)}$ are more correlated with shocks in their own maturity segment, while D_t shows a strong correlation with all maturities. D_t has means very close to zero in both countries, with similar standard deviation (0.26 in Germany and 0.22 in Italy).

Effects on the secondary Treasury market

How does a demand shock for public debt affect domestic Treasury yields? In order to answer this question, we estimate local projection (Jordà (2005)) specifications of following form:

$$\Delta^h R_{t+h}^{(m)} = \alpha_h + \beta_h D_t + \varepsilon_{t+h}. \qquad h = 0, 1, 2 \ldots 30 \tag{2}$$

Here $\Delta^h R_{t+h}^{(m)} = R_{t+h}^{(m)} - R_{t-1}^{(m)}$ is the difference between the yield of a bond with maturity $m \in \{2, 5, 10, 30\}$, h days after the auction relative to the day before the auction. D_t is the non-maturity specific demand shock. The responses of secondary Treasury yields to the demand shock D_t are displayed in Figure 10. The effects are strongest on impact, with bond yields decreasing by 1-2 basis points in Germany. In Italy the magnitude is larger and yields drop by 3-4 basis points. The effects gradually turns insignificant after around 15 days. The figures show that German long-term yields are more responsive to the shock, while in Italy 2- and 5-year bond yields decrease more.

A back-of-the-envelope application of these estimates is to assess the effects of the ECB government bond purchases, the Public Sector Purchase Programme (PSPP), on sovereign yields. On 22 January 2015 the ECB Governing Council announced the launch of its asset purchase program, that entailed the monthly purchases of €60 billion. Starting in March 2015 and carried out until (at least) September 2016, the announcement summed up to €1140 billion. This amount was to be allocated on the basis of the ECB's capital key, which was at the time 18% for Germany and 12.46% for Italy resulting in a share of €205.2 and €142.04 billion respectively. The average volume of submitted bids and the target in German (Italian) auctions has been €7.9 billion and €5.2 billion (€9 and €5.7). An unexpected increase of €205.2 and €142.04 billion in the submitted bids at a single auction would correspond to a bid-to-cover ratio of 35.8 in Germany and 50.7 in Italy. To translate this into futures price shocks, we scale these numbers by using the estimated coefficient of the regression of the surprise bid-to-cover ratios on the high-frequency futures price shocks (Table 2 and 3). According to this, an unexpected increase in the demand for the Treasuries would be a 19 (Germany) and a 42.7 (Italy) standard-deviation event in terms of futures price shocks. Based on our estimated impact effects (Figure 10), this would decrease 10-year bond yields by 33.4 basis points in Germany and 141.2 in Italy.

There are two major caveats with the above back-of-the-envelope calculations. Firstly, the size of the shock makes it an enormous out-of-sample exercise. Secondly, the source of the demand shocks we identify is the change in *private* investors demand (as opposed to the *public* demand increase due to the PSPP program). Nevertheless, the effects we find are comparable to the findings of Altavilla et al. (2015) and De Santis (2019). According to the event study of Altavilla et al. (2015), the asset purchase announcements decreased 10-year government bond yields by 17 basis points in Germany and 75 basis points in Italy on 22 January, the day of the announcement. De Santis (2019) calculated the effect of all news related to the ECB's asset purchases from September 2014 to February 2015, a period that includes the program announcement itself, as well as speculations about the possibility of asset purchases prior to the official announcement. De Santis (2019) estimates that these amounted to a decrease of 43 basis points in Germany and 80 basis points in Italy in the 10-year yields. The actual decrease in the secondary market yield on the day of the announcement was 56 basis points in Germany and 108 in Italy.

Impact responses of the yield curve

Up to now we looked at the effects of the demand shock over time and found that the strongest responses are mostly on impact. We now restrict our attention to the contemporaneous effects on the entire yield curve. In particular, we study whether demand shocks at a specific location move different parts of the yield curve. The standard no-arbitrage term structure asset pricing theory predicts that a demand shift, that is unrelated to economic fundamentals, would not affect yields at all. On the other hand, when bond markets are perfectly segmented, interest rates are disconnected at different maturities and affected by local demand (and supply) conditions.

As discussed above and shown in Table 1, the demand shocks $D_t^{(2Y)}$, $D_t^{(5Y)}$, $D_t^{(10Y)}$ and $D_t^{(30Y)}$ are highly correlated. Therefore, we compressed them into two distinct series, $D_t^{(short)}$ and $D_t^{(long)}$ to capture demand shocks at specific locations in the maturity space. Below we regress these series on elements of the Treasury yield curve:

$$\Delta R_t^{(m)} = \alpha^{(m)} + \beta^{(m)} D_t^{(m')} + \varepsilon_t^{(m)} \tag{3}$$

where $R_t^{(m)}$ is the yield of a bond with maturity $m \in \{2, 3, 5, 7, 10, 20, 30\}$ and $D_t^{(m')}$ is the demand shock for $m' \in \{short, long\}$.[13] Figure 11 displays the estimated $\beta^{(m)}$ coefficients from Equation 3. Panel A shows that a one-standard-deviation increase in the demand for short-term German bonds decreases 2-year yields by 0.8 basis points, while 30-year yields drop by only 0.5. The demand shock for long-term maturities shows more local effects. Specifically, a positive one-standard-deviation long-term demand shock decreases 30-year bond yields by 2.2 basis points, whereas at the same time the 2-year yield only drops by 0.7 basis points. In the case of Italy, the responses show more disparity (see Panel B of Figure 11). A positive one-standard-deviation short-term demand shock decreases 2-year yields by 4.1 basis points and 30-year yields by around 1.4 basis points. Interestingly, the long-term demand shock has larger effects on the short end of the yield curve, then on the long end. While 3-year bond yields drop by 3.9 basis points, interest rates on 30-year bonds drop by only 2.2 basis points after a positive demand shock.

Our findings for Germany are in line with the results of Gorodnichenko and Ray (2017) and Fuhrer and Giese (2019) who find local effects of demand shocks for the US and the UK yield curve. It is also consistent with studies bringing evidence of bond market segmentation in the euro area, such as Boermans and Vermeulen (2018). The estimates for Italy are more puzzling. The strong reaction of short-maturity bonds to the long-term demand shock cannot be reconciled with neither the no-arbitrage term structure asset pricing theory nor with market segmentation.

Spillover effects into other financial markets

In this section we study the spillover effects on Treasury bond, corporate bond and equity markets of Germany, Italy, France, Spain and the Netherlands. We intend to uncover how different assets react to a general increase in the demand for public debt. For the analysis we use the demand shock D_t, that captures shifts in the demand for government bonds at various maturities. We regress this series on daily asset price changes:

$$\Delta Y_t = \mu + \delta D_t + \varsigma_t \tag{4}$$

where $\Delta Y_t = Y_t - Y_{t-1}$ is the change in the price of a financial asset on auction day t. Table 4 displays the estimated δ coefficients on German and Italian Treasury yields and the Treasury credit default swap rates of both countries, while Table 5 displays the spillover effects on the Treasury markets of France, Spain and the Netherlands.

The results indicate that regardless of the origin of the shock, bond yields tend to decrease in all the other countries and maturities following a positive demand shock. Nevertheless,

[13] Due to data availability in the case of Italy we use the 15-year instead of the 20-year maturity.

some interesting differences are worth noticing. Increased demand for German debt is followed by an increase in the Italian-German sovereign spread. Increased demand for Italian debt, on the other hand, decreases this spread. Furthermore, a change in the demand for German debt has stronger effect on French and Dutch yields (especially at longer maturities) whereas the Italian demand shock affects mainly Spanish bonds (particularly at short maturities). These results can be explained by the fact that bond price movements are more correlated for securities with similar risk characteristics. The strong co-movement between Italian and Spanish bonds has been also documented by Ehrmann and Fratzscher (2017) who show large contagion effects after 2010 between these two countries. Moreover, Conefrey and Cronin (2016) find that these two countries have the strongest bilateral bond market interactions among the ten largest euro area members.

Table 4 also shows the responses of CDS spreads of German and Italian Treasuries. CDS contracts transfer the default risks of the bond from the buyer to the seller of the contract. According to a no-arbitrage argument, the CDS spread should match the yield spread of the corresponding bond with the risk-free rate (Duffie (1999)). The CDS spread can be interpreted as an insurance premium payed to insure against the default of the bond issuing entity. The premium is widely used as a proxy for the credit risk of this entity. Results show interesting differences in the reaction of CDS spreads to demand shocks in Germany and Italy. As investors demand more Italian bonds, the credit risk priced in CDS spreads decrease in both countries. On the other hand, a positive German demand shock increases CDS spreads in both countries. To see rising credit risks priced by investors after an increase in the demand for bonds seems counter-intuitive at first. But it is consistent with the fact that a sudden increase in the (private) demand for German bonds is a reflection of a higher demand for "safe-haven" assets. This corresponds to a decrease in investors' risk appetite and, in turn, higher insurance premiums, i.e. CDS spreads.

Table 6 shows the responses of equity and corporate bond markets to the German and Italian demand shocks. We find that corporate bond yields decrease, although these reactions are only statistically significant when German demand shocks occur. The reaction of German corporate bond yields to a positive German Treasury demand shock is comparable in size to its effect on the sovereign bond yields. These domestic responses of corporate bond markets are consistent with the findings of Gorodnichenko and Ray (2017) who focus on the US over the period 1995-2015. Interestingly, we find that the corporate bond yields of the other euro countries also drop between 1.1 and 1.4 basis points, with French corporate bonds being the most responsive. The effect of the Italian shock is also negative although largely insignificant. Altavilla et al. (2015) also find that the ECB's purchases had large spillover effects to corporate bonds, with movements comparable in size to the reaction of French sovereign yields.

Turning to equity markets, we document large and significant responses of the major euro area stock indices. This is in contrast with Gorodnichenko and Ray (2017), who found no response of the US equity market to Treasury demand shocks. The German shock decreases equity prices in all the major euro area economies. A one-standard-deviation increase in demand for German Treasuries is associated with a 0.26-0.30% drop of the stock prices, whereas a higher demand for Italian bonds leads to positive responses of the stock indices. These latter reactions are statistically significant only for the Italian and Spanish equity indices (0.25 and 0.13% respectively). These stock price movements are consistent with the responses of the CDS spreads. A sudden increase in the demand for German bonds is a signal of investors' lower risk appetite and lower willingness to hold risky assets in their portfolios, leading to a re-balancing from risky equities towards risk-free German public bonds. On the other hand, higher demand for Italian debt is a sign of investors' trust in the Italian economy and fiscal position, which leads to a higher willingness to hold riskier assets.

To bring some narrative evidence in support of this mechanism we refer to the 10-year Italian auction on the 30th of May 2018. During this auction the Italian Treasury allotted 1.8 billion euros, for which it received bids for over 2.7 billion euros, resulting in a bid-to-cover ratio of 1.48. This was considered an improvement relative to the previous auctions, where this measure ranged between 1.25 and 1.38. As documented in the news site Investment Week, a global investment strategist at Principal Global Investors commented the outcome of the auction saying that this *"clearly indicates that investors still have faith in the Italian economy, if not the government (. . .) putting aside the political turmoil, Italy is enjoying a much improved economic and fiscal position"*. Commenting on the same auction, Investment Week also summarized consequent market movements as: *"Following the auction, Italy's FTSE MIB, which slumped by 2.65% on Tuesday, is up 1.97% as at 12.30pm, and yields on the two-year government bond had fallen to 1.648% from Tuesday's high of 2.805%. Similarly, the five-year bond's yield has fallen to 2.246% from Tuesday's high of 3.074%"*. A German example is for the 10-year auction on the 4th of June 2019, when Deutsche Welle wrote: *"German 10-year government bond yields have fallen to an all-time low as investors scrambled to buy the safe haven asset amid worsening global economic outlook"*.

Summarizing, we find that German and Italian demand shocks for Treasury bonds have spillover effects on the Treasury bond yields of other euro area countries. While the German shocks have more sizable effects on France and the Netherlands, the responses to the Italian demand shocks are mostly centered on the Spanish Treasury yields. We also find that Treasury demand shocks lead to reactions of the corporate bond and equity markets. Namely, our estimates show that euro area corporate bond yields drop in response to German Treasury demand shocks, whereas they are rather unaffected by Italian demand shocks. Interestingly, we find that the main euro area stock indices drop following German demand shocks, whereas Italian Treasury demand shocks lead to positive responses of equity prices.

Robustness analysis

Before we extend our analysis, we briefly discuss a number of robustness checks which are available in the Online Appendix. First, we test if the asymmetries we find between Germany and Italy depend on the different samples we use for the two countries. More specifically, the demand shock D_t is available from March 1999 onward for Germany, while for Italy only from September 2009. Tables A3-A5 show our baseline results for Germany based on the full sample in comparison with the results obtained when imposing the same restricted sample available for Italy. We find that restricting the estimation sample of Germany to match the Italian one does not have major effects on the results.

In the second robustness exercise, we instrument the demand shocks $D_t^{(m)}$ with observable measures related to the strength of demand in the auctions. As discussed in Section 5, two such measures are the bid-to-cover ratio and the yield gap. Figure A5 and Tables A6-A8 show the results when the high-frequency demand shocks are instrumented with the expected and the surprise components of the bid-to-cover ratios and the yield gaps.[14] In case of Germany, the estimates are both qualitatively and quantitatively close to the baseline. For Italy the main results are qualitatively robust, but the estimates tend to be less statistically significant, which can be attributed to the weakness of the instruments (see the last column of Table 3).

Finally, we test if our results are robust to the inclusion of control variables. More specifically, we control for the lagged dependent variable, lagged changes in the domestic and the euro stock indices, lagged changes of the domestic 10-year government bond yield and the euro area government bond index and the lagged change of the domestic corporate bond index. The coefficients associated to these controls are found to be statistically insignificant in most cases and, not surprisingly, our baseline results are hardly affected (see Tables A9-A11).

7. State dependence and asymmetries

During the sample period under examination, euro area countries went through times of high and low financial stress that may have affected the risk appetite of investors.[15] The

[14] Notice that the results of the first stage regressions were reported in the last column of Tables 2 and 3.

[15] He and Krishnamurthy (2013) show that risk aversion and risk premium rise during a financial crisis.

theoretical model of Vayanos and Vila (2009) predicts that if investors risk aversion is high, the demand shock has more localized effects. On the other hand, if risk aversion is low, the shock will rather shift the entire yield curve. In order to proxy the risk appetite in markets, we use the monthly CLIFS indicator by Duprey et al. (2017) (see Section 4) and construct a dummy variable C_t, taking the value of one when the CLIFS index is over its 70th percentile and zero otherwise.[16] We then estimate the following extension of Equation 3:

$$\Delta R_t^{(m)} = C_t\big(\alpha^{(m,H)} + \beta^{(m,H)} D_t^{(m')}\big) + (1 - C_t)\big(\alpha^{(m,L)} + \beta^{(m,L)} D_t^{(m')}\big) + \eta_t^{(m)} \tag{5}$$

for $m' \in \{short, long\}$ and for $m \in \{2, 3, 5, 7, 10, 20, 30\}$. The coefficients $\beta^{(m,H)}$ capture the impact of the demand shock $D^{(m')}$ at the maturity segment m' on Treasury yields at maturity m, during periods of high financial stress. Similarly, $\beta^{(m,L)}$ captures the effects of demand shocks during times of low financial stress. Figure 12 shows the main results. The contemporaneous response of the yield curve is strong and statistically significant in both countries. In the case of Germany (Panel A) the results seem to be supportive of the prediction of the theoretical model and consistent with the findings of Gorodnichenko and Ray (2017) and Fuhrer and Giese (2019). Under the regime of no stress (or lower risk aversion), the responses are flatter than under the regime of high stress (or higher risk aversion). When markets are under stress, domestic yields have stronger reactions, and the location of the demand shock bears importance. Figure 12 shows that under such market conditions, a one-standard-deviation demand increase for long-term German debt decreases 30-year bond yields by 3 basis points, while 2-year bonds are unaffected.

Panel B of Figure 12 shows the state-dependent effects of Italian yields to Treasury demand shocks. The reaction at the short end is very similar in both regimes. The results for the long-term shock, however, present some interesting features. At maturities longer then 10 years, the effects are quite similar. On the other hand, shorter maturity Treasuries react very strongly in the high stress state. A one-standard-deviation demand shock decreases 2-year bond yields by 5.3 basis points during times of high financial stress, which is more than three times as large as the reaction under the low stress regime.[17]

[16] Slight modifications of this cutoff value do not affect our results. These estimates are shown in the Online Appendix.

[17] It is important to notice that the Italian sample runs from 2010 to 2017, a period generally classified as turbulent. The financial stress indicator is on a monthly frequency and can therefore identify stressful periods with some granularity (see Figure 5) and there is a sufficient number of months that fall below our threshold. Nevertheless, the limited number of available observations under each regime reduced the precision of the estimated coefficients.

In Table 7 we show estimates of the state-dependent variant of Equation 4, that is:

$$\Delta Y_t = C_t\big(\mu^{(H)} + \delta^{(H)} D_t\big) + (1 - C_t)\big(\mu^{(L)} + \delta^{(L)} D_t\big) + \xi_t. \tag{6}$$

The coefficient $\delta^{(H)}$ captures the impact of the demand shock D_t, during periods of high financial stress, while $\delta^{(L)}$ captures its effect when financial stress is low. In general, we find higher responses during times of higher financial stress. However, in most cases this difference is not statistically significant. While the German results seem fairly similar in the two states, the Italian results show larger differences. Increased demand for Italian debt is associated with large reductions in the credit risk priced in CDS spreads in both Germany and Italy. At the same time, if the sudden shift in the demand occurs during calm periods, CDS spreads remain unaffected. The Italian and the Spanish equity indices display a similar behaviour: unaffected during low stress periods, but strong and positive responses during market stress episodes (see Table 7).

So far, we have assumed that positive and negative demand shocks have symmetric effects. However, the behavioral finance literature and anecdotal evidence also suggest that markets might respond differently to positive and negative news.[18] In order to test the asymmetry of our results, we estimate variants of Equations 5 and 6 where we replace C_t with S_t, a dummy variable taking the value one when the identified demand shock is negative and a value zero when the demand shock is positive. The resulting estimated equations are:

$$\Delta R_t^{(m)} = S_t\big(\alpha^{(m,N)} + \beta^{(m,N)} D_t^{(m')}\big) + (1 - S_t)\big(\alpha^{(m,P)} + \beta^{(m,P)} D_t^{(m')}\big) + \nu_t^{(m)} \tag{7}$$

and

$$\Delta Y_t = S_t\big(\mu^{(N)} + \delta^{(N)} D_t\big) + (1 - S_t)\big(\mu^{(P)} + \delta^{(P)} D_t\big) + \zeta_t. \tag{8}$$

Here, $\beta^{(m,P)}$ and $\delta^{(P)}$ capture the effects of positive demand shocks, while $\beta^{(m,N)}$ and $\delta^{(N)}$ estimate the effects of negative demand shocks. The responses of the yield curve to short and long-term demand shocks are displayed in Figure 13. When German demand shocks are negative, the localized effect on interest rates are stronger relative to the effects of positive demand shocks. The Italian yield curve, on the other hand, responds in a rather symmetric way. The results of the sign-dependent Equation 8 are shown in Table 8. Here, the German responses seem to be rather symmetric, while in the case of Italy the baseline results on Treasury markets appear to be mainly driven by positive demand shocks. This is particularly the case for the Treasury spillover effects to other euro area countries. Similarly,

[18] See Veronesi (1999) for an early reference.

we find that that both the equity and corporate bond indices react significantly only to positive Italian demand shocks.

An interesting question is whether these sign-dependent effects are more or less pronounced during periods of high and low financial stress. In order to address this, we classified our shocks by their sign (positive versus negative) and by the level of financial stress when they occur. This exercise has the shortcoming that the number of observations for each of the four scenarios is limited.[19] Tables 9 and 10 show some interesting findings, in particular with respect to the response of equity indices to demand shocks. We find that during high stress periods, German positive demand shocks lead to larger reduction of stock prices. Whereas in Italy the stock markets' reaction seem to be driven by positive demand shocks for Italian bonds during financial turmoil periods. When markets are under stress, investors react more positively to stronger demand conditions in the Treasury market. Seeing increased demand for Italian bonds assures markets about the soundness of public finances and the economic prospects, leading to higher stock prices. This is also apparent in CDS spreads. During high financial stress, a positive Italian demand shock decreases CDS spreads in both countries. The same shock in normal times, however, does not have significant effect.

8. Conclusions

In this paper we use high-frequency government bond futures price changes around German and Italian Treasury auctions to identify unexpected shifts in the demand for public debt. We first study their effects on secondary market yields of Treasury bonds. Our findings show that positive demand shocks for public debt lead to large and persistent negative movements in Treasury yields. We test whether a location-specific demand shock moves interest rates at closer maturities. Our results show that shocks at a specific point of the German yield curve have stronger effects on nearby maturities. In Italy, on the other hand, a positive demand shock always decreases short-term interest rates more, regardless of the shock's location.

We also document spillover effects into other euro area Treasury bond, corporate debt and equity markets. We find that German demand shocks have larger spillover effects on public debt yields in France and the Netherlands, whereas the Italian spillovers are mostly on Spain. Further interesting differences are found in the responses of equity markets and CDS spreads. An increase in the demand for German bonds is associated with drops in the stock prices and increase in the credit risk priced in CDS spreads. This is in contrast

[19] The number of negative shocks in high stress, positive shocks in high stress, negative shocks in low stress and positive shocks in low stress is 59, 77, 187, 229 respectively in Germany, and 37, 45, 63 and 102 in Italy.

with Italy, where a sudden increase of demand for its bonds is followed by stock price increases and decreases in CDS spreads. We believe that the divergent responses to the two countries demand shock is related to the difference in the perceived riskiness of each country's Treasury bonds. German Treasuries enjoy a "safe-haven" status, meaning investors hoard them in financial turmoil. Higher demand for German Treasuries is associated with investors flight-to-safety and a re-balancing from riskier to safer assets. Italy, on the other hand, with its "high-debt" status, has been facing substantial credit risk, above all since the start of the euro area crisis. Higher demand for Italian Treasuries is perceived as a positive signal about its economy, eliminating fears of debt rollover issues. This improvement in markets sentiment increases investors willingness to take more risk. Most of these effects seem to be amplified when markets experience high financial stress. Furthermore, we document that for both countries, stock prices are more responsive to a sudden increase in the demand for Treasuries compared to a decrease, especially during market stress.

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Appendix

Fig. 1. Government bond yields of the five largest euro area member country

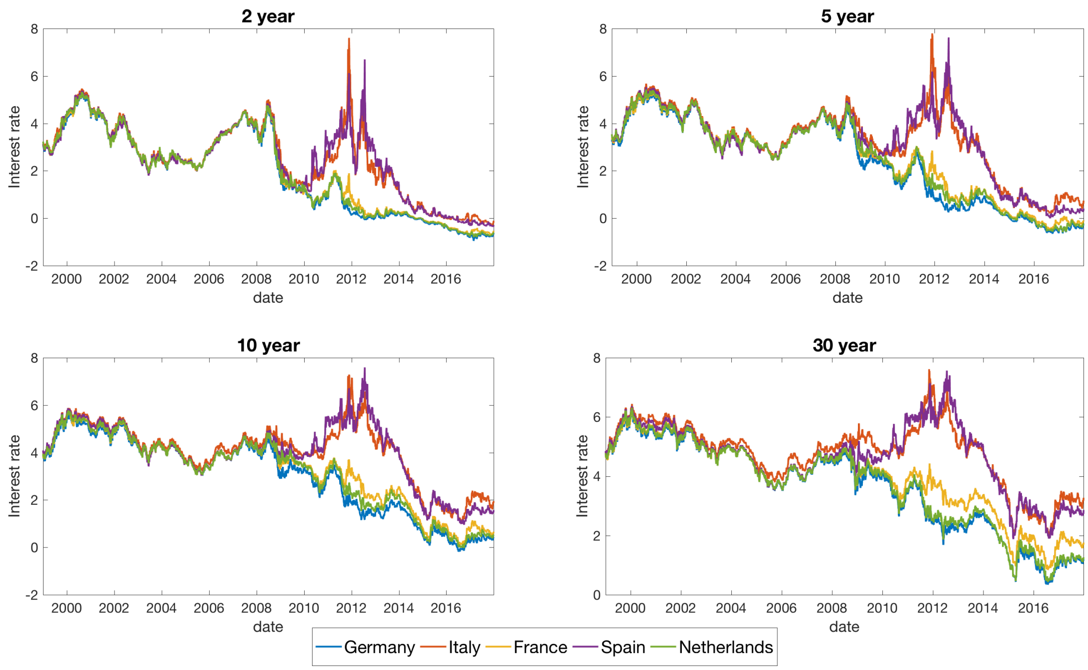


Fig. 2. Timeline of the Germany tender process on day t (after 2012)

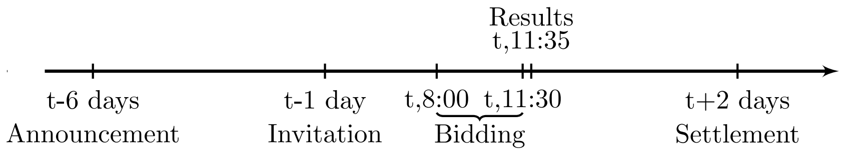
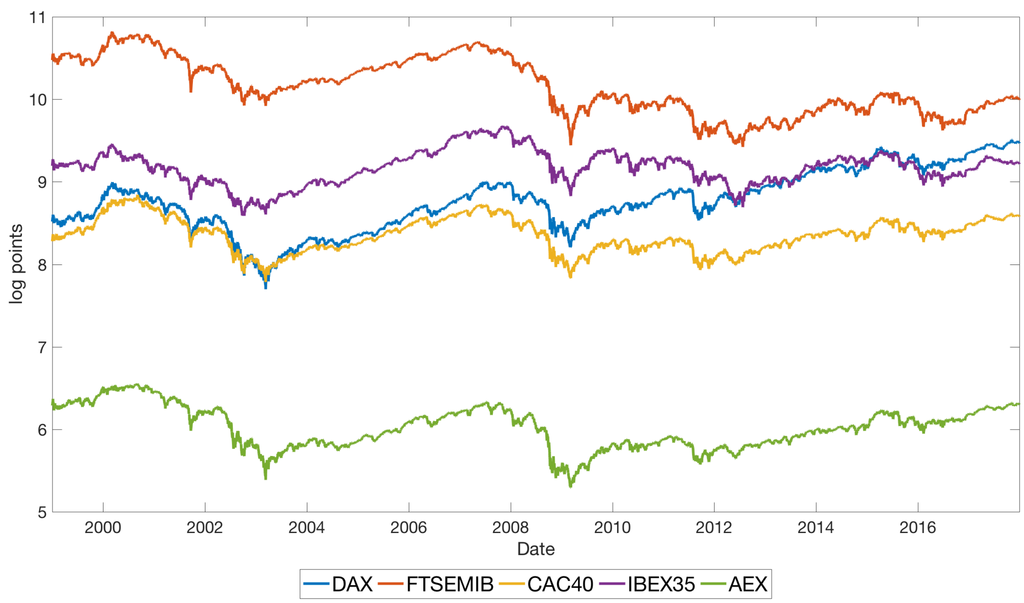


Fig. 3. Stock indices of the five largest euro area member country



Note: Germany: DAX, Italy: FTSEMIB, France: CAC40. Spain: IBEX35, Netherlands: AEX. Values in logarithm

Fig. 4. CDS spread on German and Italian 10-year government bond

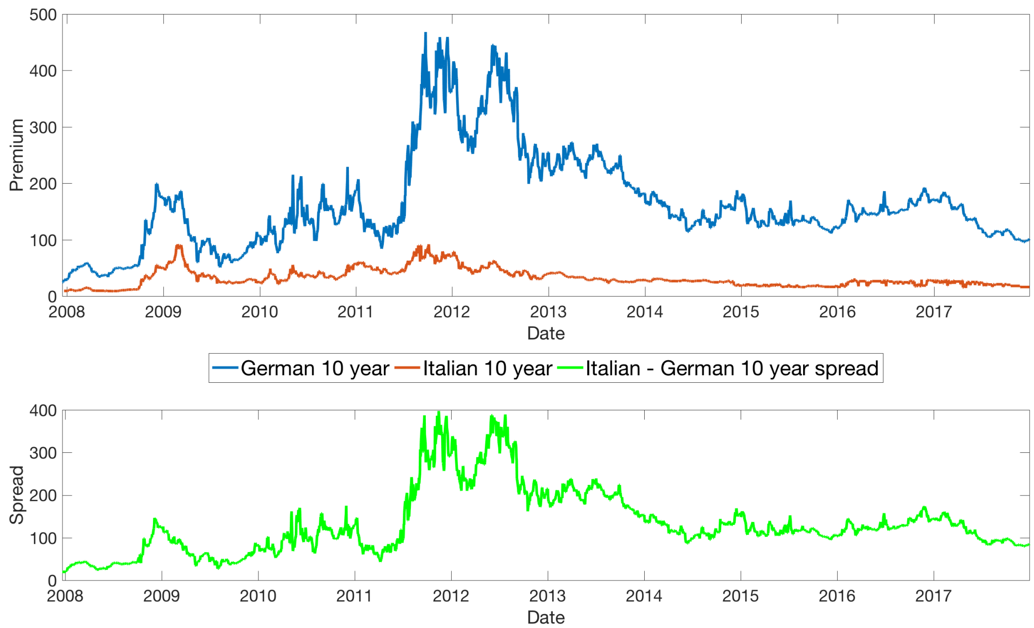


Fig. 5. Country Level Index of Financial Stress (CLIFS) and its historical 70th percentile in Germany and Italy

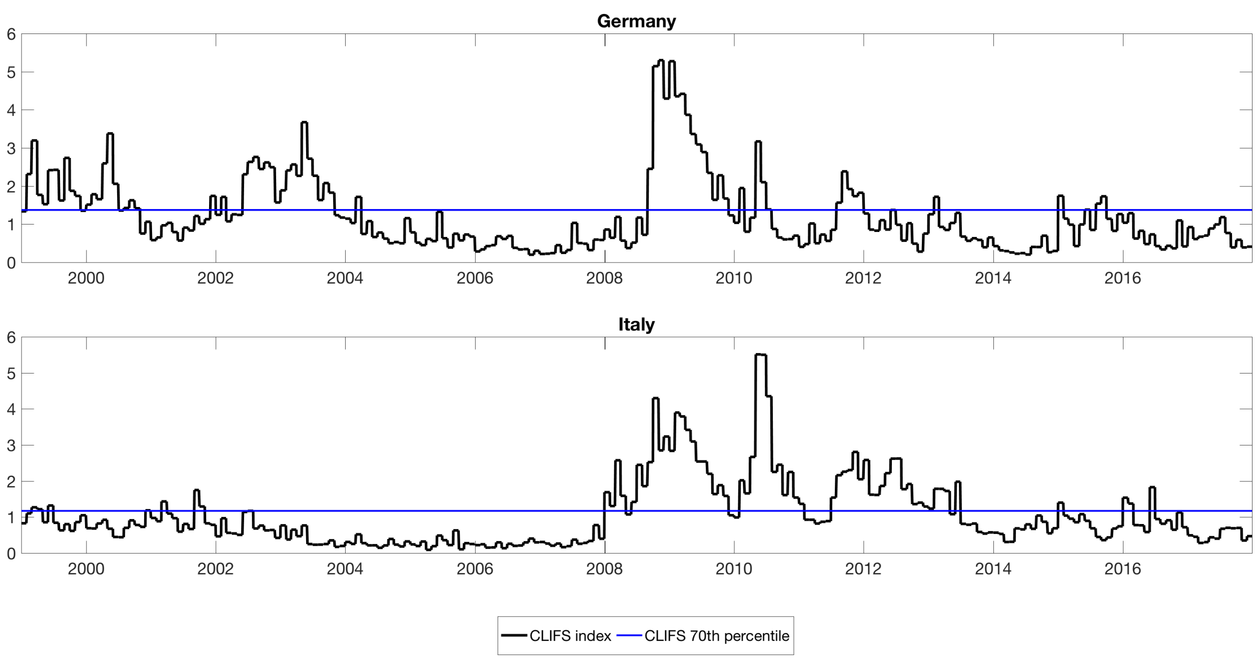
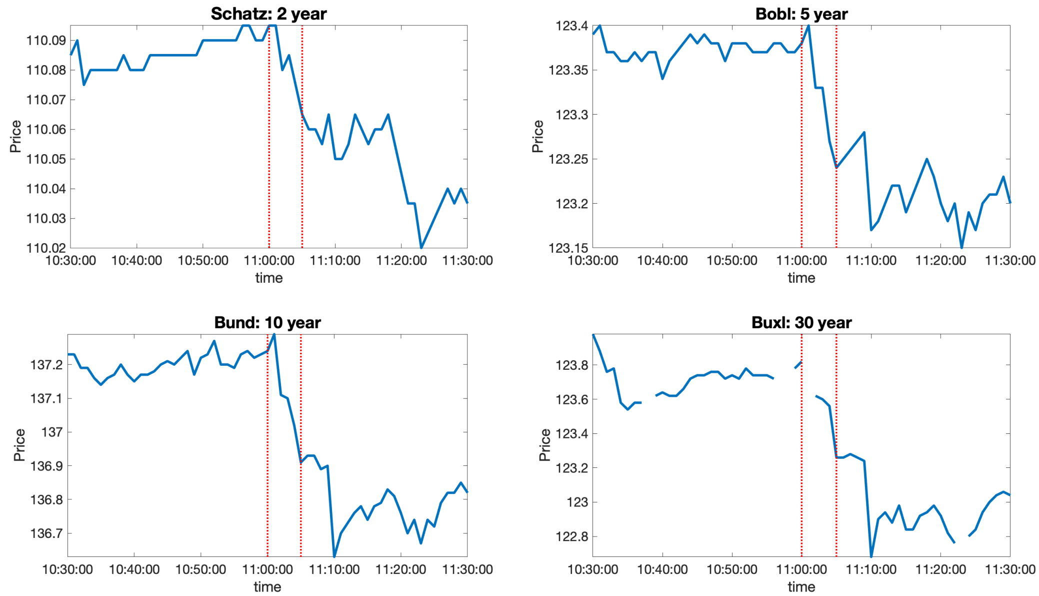
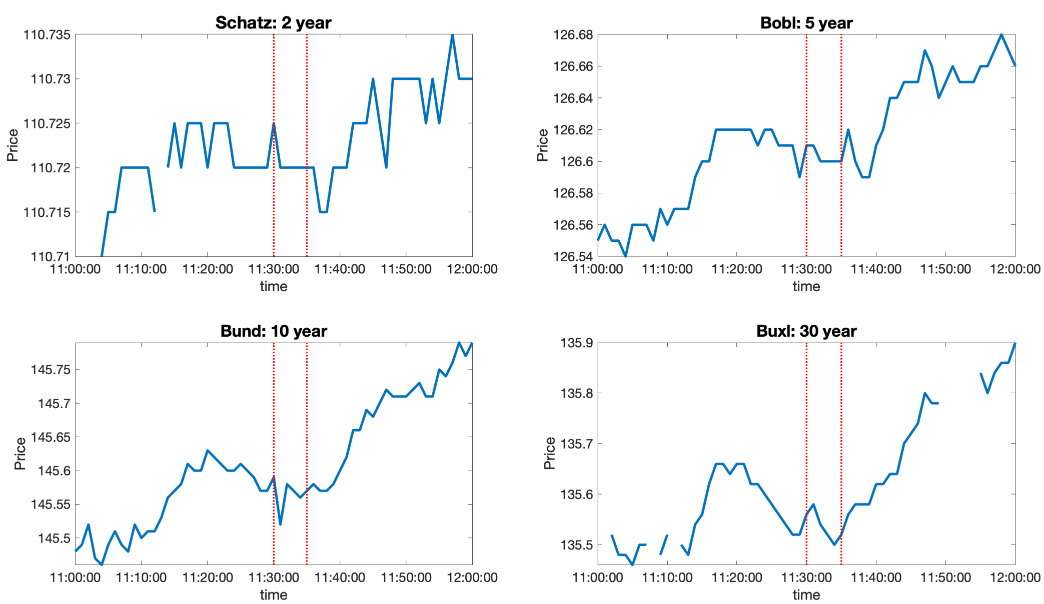


Fig. 6. German futures price movements in the event window on the 23rd of November 2011



Note: Auction results are published between 11:00 and 11:05, indicated by the dotted red lines.

Fig. 7. German futures price movements in the event window on the 17th of April 2013



Note: Auction results are published between 11:30 and 11:35, indicated by the dotted red lines.

Fig. 8. Time series of the German demand shock

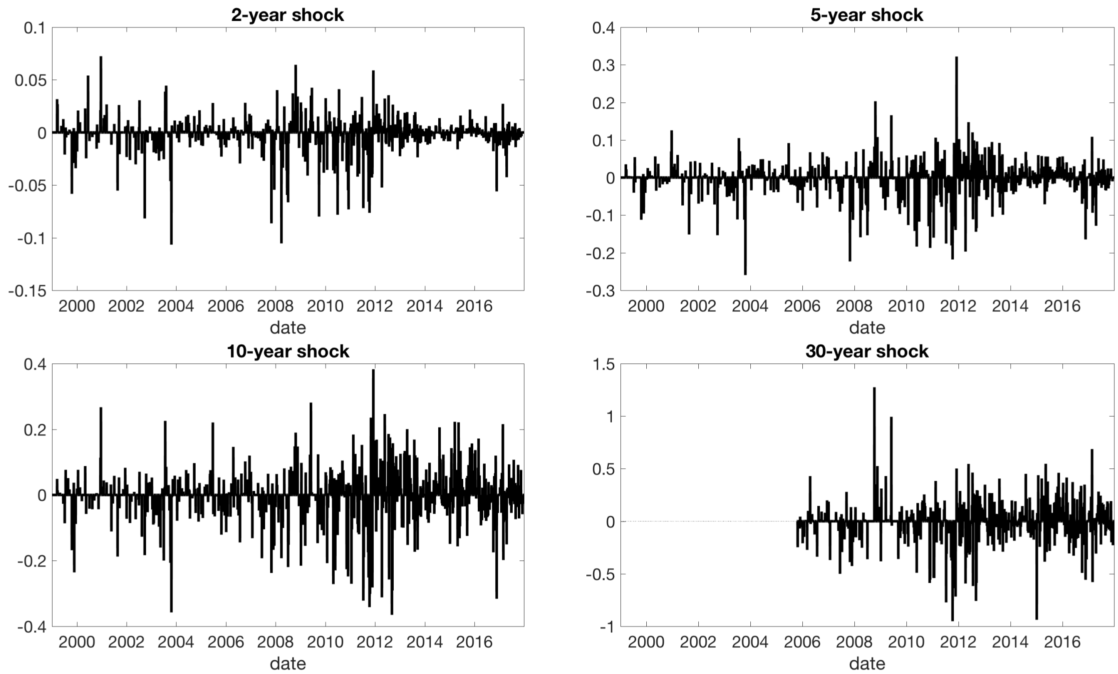


Fig. 9. Time series of the Italian demand shock

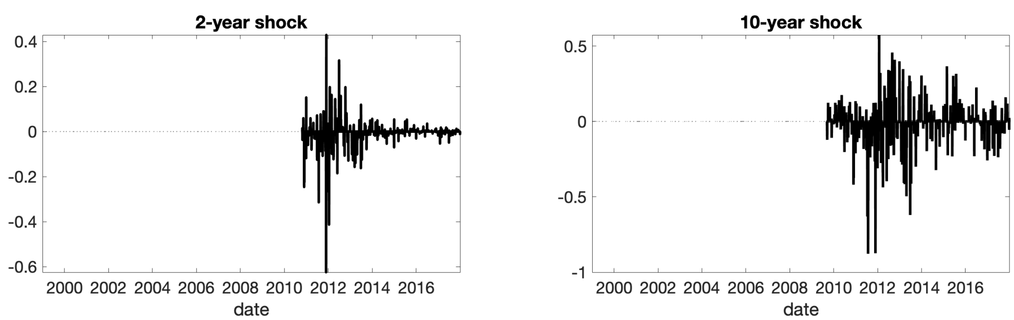
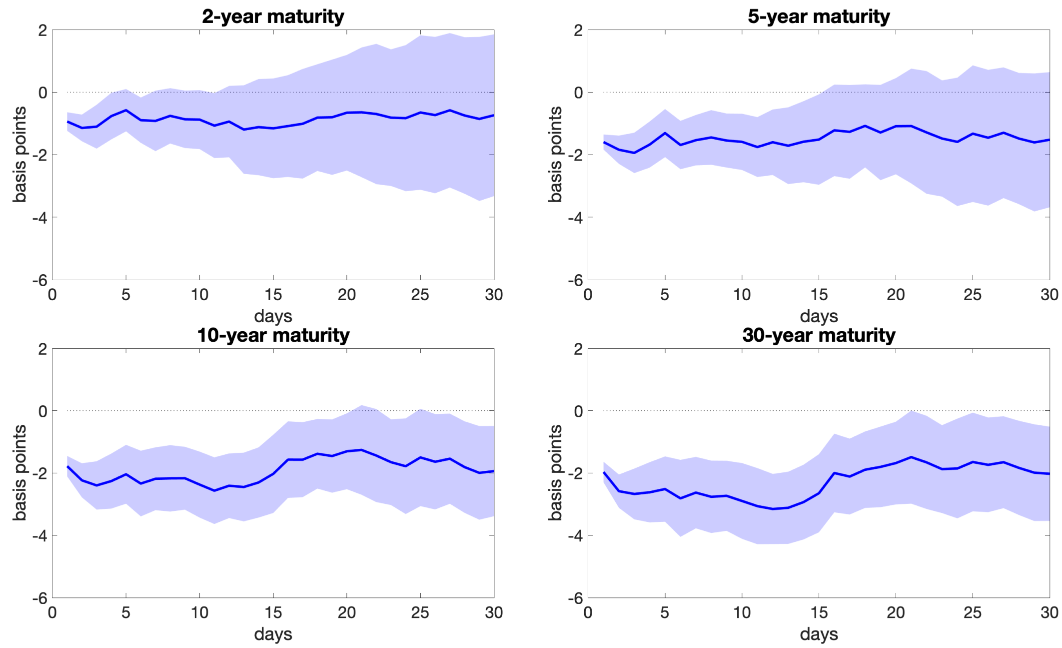
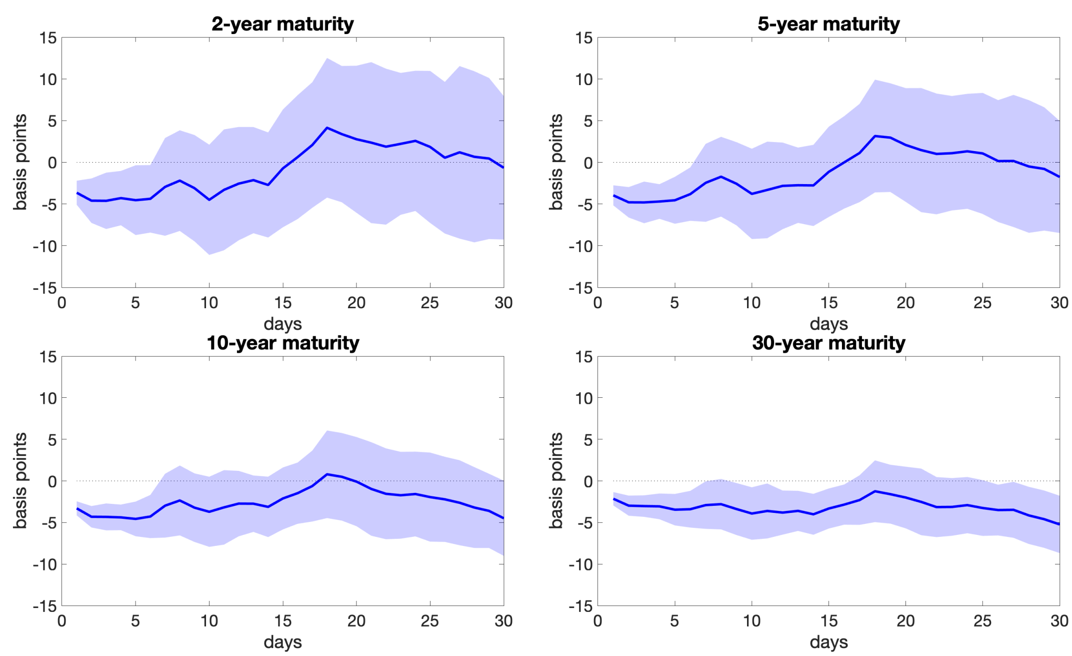


Fig. 10. Impulse responses of secondary market yields to the Treasury demand shock

Panel A: Germany



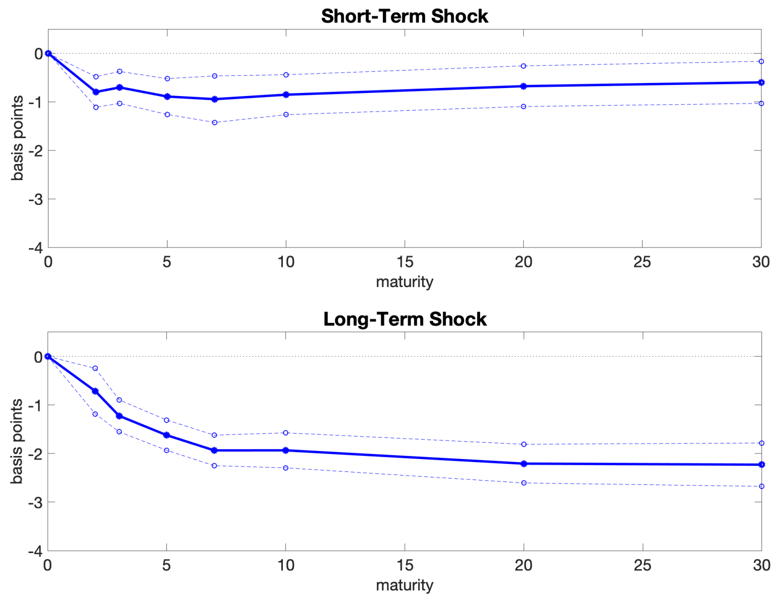
Panel B: Italy



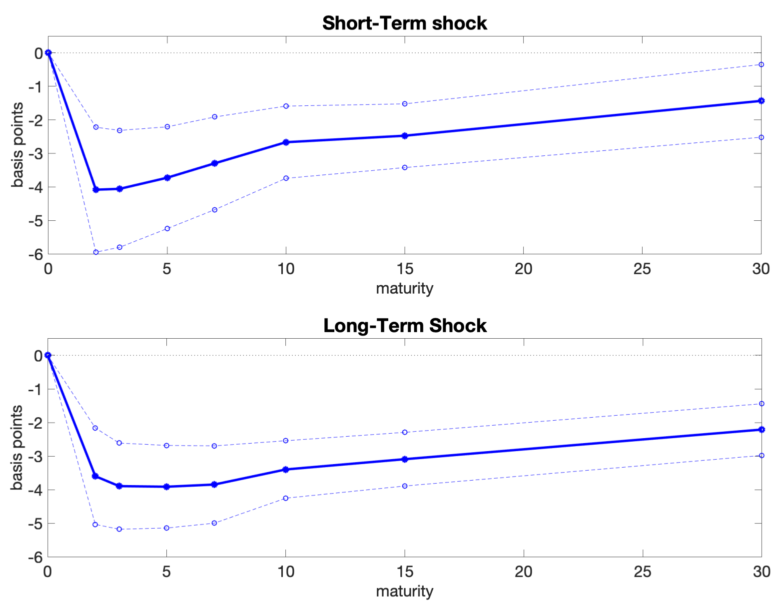
Note: Estimated β_h coefficients from $\Delta^h R_{t+h}^{(m)} = \alpha_h + \beta_h D_t + resid$. Panel (A) shows the impulse responses of 2, 5, 10 and 30-year benchmark German government bonds to the non-maturity specific German Treasury demand shock. Panel (B) shows the impulse responses of 2, 5, 10 and 30-year benchmark Italian government bonds to the non-maturity specific Italian Treasury demand shock. Shaded areas are 90% Newey-West confidence intervals.

Fig. 11. On impact response of the Treasury yield curve

Panel A: Germany



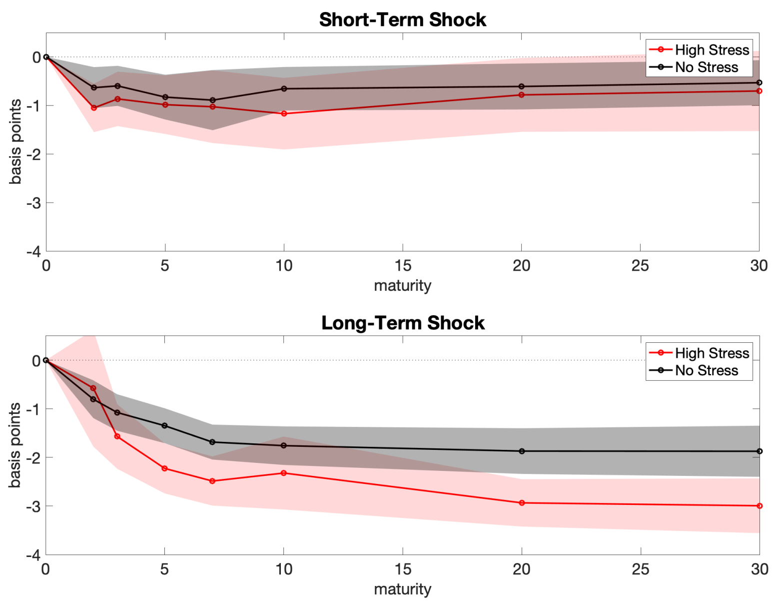
Panel B: Italy



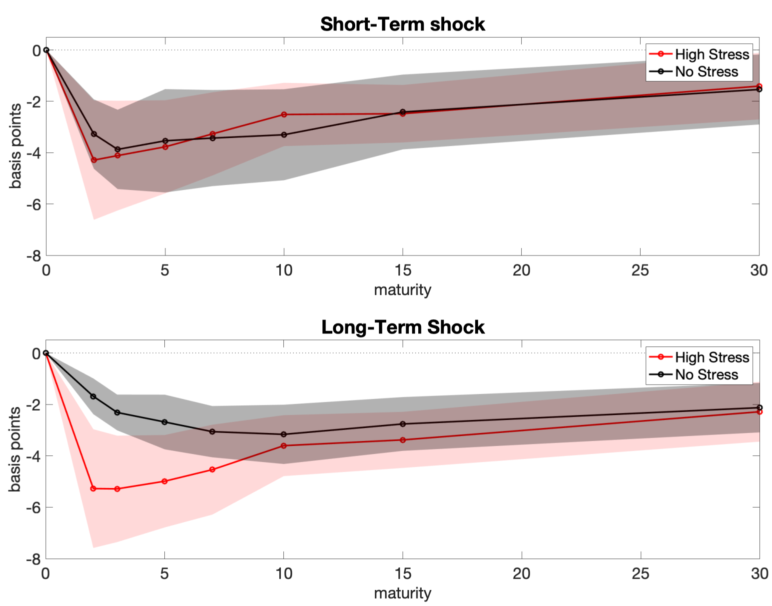
Note: Estimated β coefficients from the equation $\Delta R_t = \alpha + \beta D_t^{(m)} + \epsilon_t^{(m)}$, for $m \in \{short, long\}$. $D_t^{(long)}$ is the first principal component of the 10 and 30 year shock, $D_t^{(short)}$ is the first principal component of the 2 and 5 year shock, rotated to be uncorrelated with the 30 year series. For Italy $D_t^{(short)} = D_t^{(2Y)}$ and $D^{(long)} = D^{(10Y)}$ due to data limitations. Dashed lines are 90% Newey-West confidence intervals.

Fig. 12. On impact response of the Treasury yield curve in periods of high and low financial stress

Panel A: Germany



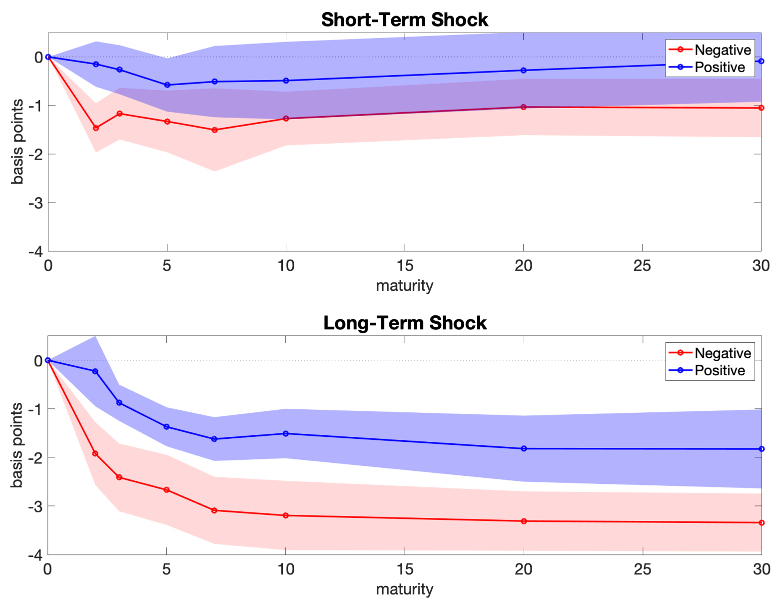
Panel B: Italy



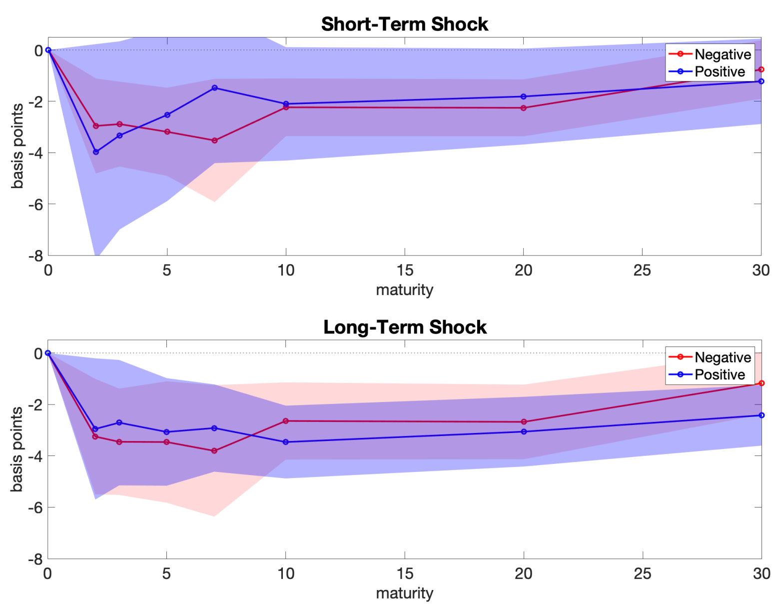
Note: Estimated $\beta^{(m,L)}$ and $\beta^{(m,H)}$ coefficients from the equation $\Delta R_t^{(m)} = C_t\big(\alpha^{(m,H)} + \beta^{(m,H)} D_t^{(m')}\big) + (1 - C_t)\big(\alpha^{(m,L)} + \beta^{(m,L)} D_t^{(m')}\big) + \eta_t^{(m)}$, for $m' \in \{short, long\}$. $D_t^{(long)}$ is the first principal component of the 10 and 30 year shock, $D_t^{(short)}$ is the first principal component of the 2 and 5 year shock, rotated to be uncorrelated with the 30 year series. For Italy $D^{(short)} = D_t^{(2Y)}$ and $D^{(long)} = D_t^{(10Y)}$, due to data limitations. C_t is a high financial stress dummy, indicating a CLIFS index higher than its historical 70th percentile value. Shaded areas are 90% Newey-West confidence intervals.

Fig. 13. On impact response of the Treasury yield curve to negative vs. positive demand shock

Panel A: Germany



Panel B: Italy



Note: Estimated $\beta^{(m,N)}$ and $\beta^{(m,P)}$ coefficients from the equation $\Delta R_t^{(m)} = S_t\big(\alpha^{(m,N)} + \beta^{(m,N)} D_t^{(m')}{}_t\big) + (1 - S_t)\big(\alpha^{(m,P)} + \beta^{(m,P)} D_t^{(m')}{}_t\big) + \nu_t^{(m)}$, for $m' \in \{short, long\}$. $D_t^{(long)}$ is the first principal component of the 10 and 30 year shock. $D_t^{(short)}$ is the first principal component of the 2 and 5 year shock, rotated to be uncorrelated with the 30 year series. S_t is a dummy variable taking one when $D_t^{(m')} < 0$. For Italy due to data limitations $D_t^{(short)} = D_t^{(2Y)}$ and $D_t^{(long)} = D_t^{(10Y)}$. Shaded areas are 90% Newey-West confidence intervals.

Table 1: Summary statistics of the high-frequency demand shock

Germany	Sample	N	Mean	Med.	Std. dev.	Correlations						
						$D_t^{(2Y)}$	$D_t^{(5Y)}$	$D_t^{(10Y)}$	$D_t^{(30Y)}$	D_t	$D_t^{(short)}$	$D_t^{(long)}$
$D_t^{(2Y)}$	03.1999-12.2017	536	-0.003	0.000	0.020	1.000						
$D_t^{(5Y)}$	03.1999-12.2017	536	-0.004	0.002	0.057	0.837	1.000					
$D_t^{(10Y)}$	03.1999-12.2017	536	-0.005	0.001	0.099	0.674	0.915	1.000				
$D_t^{(30Y)}$	10.2005-12.2017	414	-0.008	0.000	0.238	0.512	0.742	0.858	1.000			
D_t	03.1999-12.2017	536	0.000	0.016	0.251	0.564	0.797	0.903	0.995	1.000		
$D_t^{(short)}$	10.2005-12.2017	414	0.001	0.002	0.042	0.513	0.485	0.257	0.001	0.059	1.000	
$D_t^{(long)}$	03.1999-12.2017	536	0.000	0.000	0.185	0.386	0.550	0.678	0.726	0.731	-0.366	1.000
Italy	Sample	N	Mean	Med.	Std. dev.	Correlations						
						$D_t^{(2Y)}$	$D_t^{(5Y)}$	$D_t^{(10Y)}$	D_t			
$D_t^{(2Y)}$	10.2010-12.2017	208	-0.011	-0.002	0.092	1.000						
$D_t^{(5Y)}$	09.2011-02.2013	47	-0.037	0.000	0.197	0.815	1.000					
$D_t^{(10Y)}$	09.2009-12.2017	247	-0.022	-0.003	0.193	0.760	0.859	1.000				
D_t	10.2010-12.2017	247	0.000	0.020	0.203	0.832	0.883	0.993	1.000			

Note: Shocks are the recorded high-frequency futures price movements in the event window. $D_t^{(short)}$ is the first principal component of the 2 and 5 year shock, recorded on days of auctions of 2 and 5-year bonds, rotated to be uncorrelated with the 30 year series $D_t^{(30Y)}$. $D_t^{(long)}$ is the first principal component of the 10 and 30 year shock recorded on days of auctions of 10 and 30-year bonds. D_t is the first principal component of the surprise series at all maturities.

Table 2: Auction results and high-frequency surprises: Germany

Panel (A): Total bid-to-cover ratio and yield gap					
	(1)	(2)	(3)	(4)	(5)
	$D_t^{(2Y)}$	$D_t^{(5Y)}$	$D_t^{(10Y)}$	$D_t^{(30Y)}$	D_t
Bid-to-Cover	0.007**	0.045***	0.106***	0.141	0.059***
	(0.003)	(0.013)	(0.020)	(0.124)	(0.021)
Yield gap	-0.063**	-0.192*	-0.608***	-2.946**	-0.033***
	(0.031)	(0.099)	(0.215)	(1.376)	(0.005)
Observations	170	140	163	48	536
R^2	0.099	0.146	0.252	0.165	0.085
Panel (B): Expected and surprise components					
	(1)	(2)	(3)	(4)	(5)
	$D_t^{(2Y)}$	$D_t^{(5Y)}$	$D_t^{(10Y)}$	$D_t^{(30Y)}$	D_t
Bid-to-cover (exp.)	-0.003	0.019	0.123**	0.007	0.045
	(0.010)	(0.033)	(0.056)	(0.282)	(0.029)
Bid-to-cover (surp.)	0.010**	0.057***	0.106***	0.185	0.113***
	(0.004)	(0.015)	(0.024)	(0.141)	(0.031)
Yield gap (exp.)	0.171	0.261**	-1.410	29.381	-0.341
	(0.107)	(0.457)	(2.320)	(20.819)	(0.600)
Yield gap (surp.)	-0.096***	-0.224	-0.605***	-3.346**	-1.387***
	(0.033)	(0.104)	(0.226)	(1.370)	(0.248)
Observations	168	138	163	48	524
R^2	0.127	0.176	0.252	0.230	0.092

Note: Panel (A) shows the estimated coefficient of the regression of the bid-to-cover ratio (total bids over targeted volume) and the yield gap (yield at the action minus the secondary market yield the previous day) series on the high frequency demand shocks. Panel (B) shows the estimated coefficient when the expected and the surprise component of the bid-to-cover and the yield gap series enter separately. The expected component is defined as the fitted values, while the surprise is the residual series from an AR(4) model. All regressions include two lagged values of the total ratio, omitted from the tables. Column (1) restricts the sample to include only auctions of 2-year bonds, Column (2) restricts the sample to include only auctions of 5-year bonds, Column (3) restricts the sample to include only auctions of 10-year bonds, Column (4) restricts the sample to include only auctions of 30-year bonds. Column (5) pools auction with all maturities. Standard errors in parentheses. (*), (**) and (***) denote statistical significance at 10, 5 and 1% respectively.

Table 3: Auction results and high-frequency surprises: Italy

Panel (A): Total bid-to-cover ratio and yield gap				
	(1)	(2)	(3)	(4)
	$D_t^{(2Y)}$	$D_t^{(5Y)}$	$D_t^{(10Y)}$	D_t
Bid-to-cover	0.023	0.093	0.184*	0.022
	(0.024)	(0.126)	(0.093)	(0.036)
Yield gap	0.085*	-0.390*	-0.079	-0.018*
	(0.045)	(0.199)	(0.065)	(0.010)
Observations	80	20	102	247
R^2	0.148	0.309	0.104	0.025

Panel (B): Expected and surprise components				
	(1)	(2)	(3)	(4)
	$D_t^{(2Y)}$	$D_t^{(5Y)}$	$D_t^{(10Y)}$	D_t
Bid-to-cover (exp.)	-0.013	0.046	0.243	0.011
	(0.063)	(0.321)	(0.228)	(0.050)
Bid-to-cover (surp.)	0.026	0.155	0.160	0.034
	(0.026)	(0.151)	(0.106)	(0.043)
Yield gap (exp.)	-0.238	-1.344	-1.453	-0.106**
	(0.428)	(0.933)	(1.085)	(0.043)
Yield gap (surp.)	0.088*	-0.379*	-0.073	-0.046
	(0.046)	(0.200)	(0.066)	(0.053)
Observations	80	20	102	247
R^2	0.155	0.405	0.121	0.042

Note: Table 2

Table 4: Reaction of German and Italian Treasury yields and CDS spreads

	Germany	**Italy**
Treasuries		
German 2 year	-0.941***	-0.004
	(0.181)	(0.148)
German 5 year	-1.596***	-0.256
	(0.146)	(0.232)
German 10 year	-1.780***	-0.373*
	(0.200)	(0.252)
German 30 year	-1.968***	-0.276
	(0.200)	(0.256)
Italian 2 year	-0.549*	-3.650***
	(0.376)	(0.876)
Italian 5 year	-0.616**	-3.962***
	(0.348)	(0.731)
Italian 10 year	-0.596**	-3.304***
	(0.307)	(0.513)
Italian 30 year	-0.569**	-2.151***
	(0.264)	(0.489)
Treasury credit default swaps		
German 2 year	0.211*	-0.295***
	(0.135)	(0.122)
German 10 year	0.207*	-0.505***
	(0.143)	(0.170)
Italian 2 year	1.313***	-1.565***
	(0.479)	(0.632)
Italian 10 year	1.175***	-1.377***
	(0.461)	(0.586)

Note: Estimated δ coefficients from $\Delta Y_t = \mu + \delta D_t + \varsigma_t$. The left column displays the estimates of the German demand shock, the right column displays the estimates of the Italian shock. D_t is the first principal component of the shock measures, normalized to zero mean and unit variance. Newey-West standard errors in parenthesis. (*), (**) and (***) denote statistical significance at 10, 5 and 1% respectively.

Table 5: Spillover to other euro area members Treasury yields

	Germany	**Italy**
Treasuries		
French 2 year	-0.921***	-0.409**
	(0.171)	(0.182)
French 5 year	-1.388***	-0.519**
	(0.174)	(0.236)
French 10 year	-1.508***	-0.734***
	(0.195)	(0.245)
French 30 year	-1.655***	-0.651***
	(0.190)	(0.245)
Spanish 2 year	-0.289	-3.297***
	(0.418)	(0.759)
Spanish 5 year	-0.354	-3.209***
	(0.391)	(0.618)
Spanish 10 year	-0.392	-2.491***
	(0.342)	(0.552)
Spanish 30 year	-0.541**	-1.811***
	(0.313)	(0.479)
Dutch 2 year	-0.964***	-0.174
	(0.144)	(0.160)
Dutch 5 year	-1.445***	-0.559***
	(0.391)	(0.618)
Dutch 10 year	-1.594***	-0.682***
	(0.180)	(0.237)
Dutch 30 year	-1.877***	-0.307
	(0.184)	(0.252)

Note: Estimated δ coefficients from $\Delta Y_t = \mu + \delta D_t + \varsigma_t$. The left column displays the estimates of the German demand shock, the right column displays the estimates of the Italian shock. D_t is the first principal component of the shock measures, normalized to zero mean and unit variance. Newey-West standard errors in parenthesis. (*), (**) and (***) denote statistical significance at 10, 5 and 1% respectively.

Table 6: Reaction of stock indices and corporate bond indices

	Germany	Italy
Equity indices		
German	-0.260***	0.039
	(0.078)	(0.073)
Italian	-0.300***	0.245***
	(0.075)	(0.085)
French	-0.246***	0.074
	(0.077)	(0.080)
Spanish	-0.291***	0.128*
	(0.075)	(0.084)
Dutch	-0.257***	0.037
	(0.086)	(0.057)
Euro Area	-0.266***	0.076
	(0.079)	(0.076)
Corporate bond indices		
German	-1.129***	-0.206
	(0.209)	(0.219)
Italian	-1.177***	-0.342
	(0.310)	(0.400)
French	-1.355***	-0.149
	(0.205)	(0.348)
Spanish	-1.091***	-0.226
	(0.326)	(0.533)
Dutch	-1.106***	-0.335**
	(0.269)	(0.183)
Euro Area	-1.254***	-0.221
	(0.214)	(0.284)

Note: Estimated δ coefficients from $\Delta Y_t = \mu + \delta D_t + \varsigma_t$. D_t is the first principal component of the high-frequency shock series, normalized to zero mean unit variance. Left column displays reactions to the German shock, right column displays the reaction to the Italian shock. Equity indices are the DAX, FTSEMIB, CAC40, IBEX35, AEX, EUROSTOXX in logarithm. Corporate bond indices are the Corporate sub-index of the country level Bloomberg Barclays Euro Aggregate Index. Newey-West standard errors in parenthesis. (*), (**) and (***) denote statistical significance at 10, 5 and 1% respectively.

Table 7: Asset price responses in low and high financial stress

	Germany			Italy		
	Low Stress	**High Stress**	**Test**	**Low Stress**	**High Stress**	**Test**
10-year Treasury yields						
German	-1.870***	1.640***		-0.618*	-0.201	
	(0.194)	(0.418)		(0.567)	(0.315)	
Italian	-0.270	-1.148***		-3.097***	-3.461***	
	(0.385)	(0.489)		(0.731)	(0.681)	
French	-1.517***	1.499***		-0.644*	-0.811***	
	(0.199)	(0.406)		(0.429)	(0.273)	
Spanish	-0.134	-0.834*		-1.886***	-2.942***	
	(0.412)	(0.582)		(0.574)	(0.793)	
Dutch	-1.636***	-1.538***		-0.805**	-0.600**	
	(0.184)	(0.373)		(0.419)	(0.292)	
CDS on 10-year Treasuries						
German	0.145*	0.330		-0.084	-0.823***	† † †
	(0.112)	(0.349)		(0.102)	(0.247)	
Italian	1.673***	0.202		-0.206	-2.246***	†
	(0.473)	(0.894)		(0.542)	(0.904)	
Equity indices						
German	-0.163***	-0.430***		0.033	0.042	
	(0.065)	(0.171)		(0.076)	(0.112)	
Italian	-0.266***	-0.361**		0.113	0.339***	
	(0.072)	(0.157)		(0.099)	(0.130)	
French	-0.143***	-0.425***		0.056	0.085	
	(0.061)	(0.170)		(0.087)	(0.128)	
Spanish	-0.242***	-0.379***		0.053	0.181*	
	(0.076)	(0.154)		(0.086)	(0.136)	
Dutch	-0.115**	-0.505***	†	0.041	0.033	
	(0.055)	(0.196)		(0.064)	(0.088)	
Corporate bond indices						
German	-1.258***	-0.918**		-0.490**	-0.003	
	(0.175)	(0.469)		(0.263)	(0.330)	
Italian	-1.164***	-1.186**		-0.836***	0.033	
	(0.263)	(0.712)		(0.221)	(0.648)	
French	-1.344***	-1.380***		-0.645***	0.217	
	(0.165)	(0.485)		(0.221)	(0.551)	
Spanish	-1.154***	-0.995*		-0.403*	-0.083	
	(0.340)	(0.667)		(0.314)	(0.898)	
Dutch	-1.387***	-0.634		-0.660***	-0.098	
	(0.156)	(0.645)		(0.241)	(0.265)	

Note: Estimated $\delta^{(L)}$ and $\delta^{(H)}$ coefficients from $\Delta Y_t = C_t(\mu^{(H)} + \delta^{(H)} D_t) + (1 - C_t)(\mu^{(L)} + \delta^{(L)} D_t) + \xi_t$. D_t is the first principal component of the shock measures normalized to zero mean, unit variance. C_t is a financial stress dummy, indicating a CLIFS index value higher than its historical 70th percentile value. Newey-West standard errors in parenthesis. (*), (**) and (***) denote statistical significance at the 10, 5 and 1% level. (†), (††) and († † †) in the test columns indicate statistically different estimates in the two regimes at the 10, 5 and 1% level.

Table 8: Asset price responses to positive and negative demand shock

	Germany			Italy		
	Negative	**Positive**	**Test**	**Negative**	**Positive**	**Test**
10-year Treasury yields						
German	-1.997***	-1.498***		0.060	-1.295***	††
	(0.363)	(0.313)		(0.447)	(0.308)	
Italian	-0.486	-0.634*		-2.611***	-3.445***	
	(0.659)	(0.395)		(0.852)	(0.890)	
French	-1.627***	-1.357***		-0.220	-1.365***	††
	(0.368)	(0.295)		(0.356)	(0.384)	
Spanish	-0.220	-0.178		-1.866**	-2.773**	
	(0.679)	(0.493)		(0.842)	(1.095)	
Dutch	-1.702***	-1.519***		-0.344	-1.629***	††
	(0.337)	(0.284)		(0.404)	(0.291)	
CDS on 10-year Treasuries						
German	0.244	0.197		-0.264	-0.566**	
	(0.224)	(0.248)		(0.283)	(0.312)	
Italian	1.125	0.835*		-1.383*	-1.070	
	(0.977)	(0.601)		(1.053)	(0.924)	
Equity indices						
German	-0.215**	-0.393***		-0.019	0.172*	
	(0.122)	(0.128)		(0.115)	(0.116)	
Italian	-0.269**	-0.365***		0.144	0.418***	
	(0.126)	(0.123)		(0.130)	(0.138)	
French	-0.152*	-0.408***		0.007	0.254**	
	(0.106)	(0.131)		(0.135)	(0.123)	
Spanish	-0.203**	-0.443***		0.056	0.294**	
	(0.107)	(0.126)		(0.116)	(0.162)	
Dutch	-0.138	-0.462***	†	0.004	0.135*	
	(0.113)	(0.148)		(0.103)	(0.086)	
Corporate bond indices						
German	-1.165***	-0.929***		0.222	-0.999**	† † †
	(0.387)	(0.313)		(0.267)	(0.311)	
Italian	-1.303**	-1.067***		0.006	-1.033**	
	(0.695)	(0.362)		(0.663)	(0.594)	
French	-1.393***	-1.215***		0.584	-1.180***	††
	(0.418)	(0.293)		(0.581)	(0.395)	
Spanish	-1.285**	-0.816***		0.056	-0.712	
	(0.711)	(0.337)		(1.064)	(0.771)	
Dutch	-1.442***	-0.646*		-0.024	-0.939***	††
	(0.323)	(0.496)		(0.251)	(0.270)	

Note: Estimated $\delta^{(N)}$ and $\delta^{(P)}$ coefficients from $\Delta Y_t = S_t(\mu^{(N)} + \delta^{(N)} D_t) + (1 - S_t)(\mu^{(P)} + \delta^{(P)} D_t) + \zeta_t$. D_t is the first principal component of the shock measures normalized to zero mean, unit variance. S_t is a dummy variable, taking the value 1 when $D_t < 0$. Newey-West standard errors in parenthesis. (*), (**) and (***) denote statistical significance at the 10, 5 and 1% level. (†), (††) and († † †) in the test columns indicate statistically different estimates in the two regimes at the 10, 5 and 1% level.

Table 9: Positive and negative shock estimates in high and low financial stress - Germany

	Low stress			High stress				
	Negative	**Positive**	**Test(1)**	**Negative**	**Positive**	**Test(1)**	**Test(2)**	**Test(3)**
10-year Treasury yields								
German	-2.232***	-1.543***		-1.765***	-1.423**			
	(0.375)	(0.277)		(0.702)	(0.738)			
Italian	0.949	-0.811**	†	-2.369***	-0.284	††	- - -	
	(0.852)	(0.425)		-0.740	(0.760)			
French	-1.642***	-1.454***		-1.534**	-1.175**			
	(0.439)	(0.244)		(0.669)	(0.698)			
Spanish	0.952	-0.322		-1.759***	0.101		- -	
	(0.955)	(0.439)		(0.668)	(1.157)			
Dutch	-1.772***	-1.552***		-1.695***	-1.469**			
	(0.412)	(0.224)		(0.601)	(0.709)			
CDS on 10-year Treasuries								
German	0.424*	-0.006		-0.123	0.564			
	(0.267)	(0.125)		(0.375)	(0.566)			
Italian	3.242***	0.687*	††	-2.729**	1.104	†	- - -	
	(1.086)	(0.482)		(1.319)	(1.467)			
Equity indices								
German	-0.303***	-0.099		-0.143	-0.964***	††		+++
	(0.111)	(0.108)		(0.247)	(0.222)			
Italian	-0.437***	-0.143	†	-0.106	-0.797***	††	-	+++
	(0.128)	(0.118)		(0.238)	(0.191)			
French	-0.223**	-0.111		-0.094	-0.987***	† † †		+++
	(0.100)	(0.104)		(0.218)	(0.223)			
Spanish	-0.391***	-0.194*		0.015	-0.929***	† † †	-	+++
	(0.127)	(0.125)		(0.186)	(0.219)			
Dutch	-0.158*	-0.122*		-0.144	-1.124***	† † †		+++
	(0.103)	(0.833)		(0.236)	(0.279)			
Corporate bond indices								
German	-1.380***	-1.083***		-0.900*	-0.640			
	(0.423)	(0.193)		(0.687)	(0.796)			
Italian	-1.293**	-1.091***		-1.230	-1.009			
	(0.596)	(0.350)		(1.404)	(0.812)			
French	-1.579***	-1.157***		-1.067	-1.336**			
	(0.355)	(0.218)		(0.848)	(0.776)			
Spanish	-1.215*	-1.045***		-1.380	-0.385			
	(0.596)	(0.239)		(1.213)	(0.804)			
Dutch	-1.596***	-1.182***		-1.272**	0.396			
	(0.862)	(0.224)		(0.642)	(1.202)			

Note: Estimated $\delta^{\cdot}$ coefficients from $\Delta Y_t = C_t S_t(\mu^{(H,N)} + \delta^{(H,N)} D_t) + (1 - C_t) S_t(\mu^{(L,N)} + \delta^{(L,N)} D_t) + C_t(1 - S_t)(\mu^{(H,P)} + \delta^{(H,P)} D_t) + (1 - C_t)(1 - S_t)(\mu^{(L,P)} + \delta^{(L,P)} D_t) + \zeta_t$. D_t is the first principal component of the shock measures normalized to zero mean, unit variance. C_t is a high financial stress indicator, S_t is a negative shock indicator. Newey-West standard errors in parenthesis. (*), (**) and (***) denote statistical significance, (†), (††) and († † †) indicate statistically different estimates within high and low stress states, (-), (–) and (—) indicates statistically different estimates of negative shocks between high and low stress regimes, (+), (++) and (+++) indicate statistically different estimates of positive shocks between high and low stress regimes, at the 10, 5 and 1% level.

Table 10: Positive and negative shock estimates in high and low financial stress - Italy

	Low stress			**High stress**				
	Negative	**Positive**	**Test(1)**	**Negative**	**Positive**	**Test(1)**	**Test(2)**	**Test(3)**
10-year Treasury yields								
German	0.218	-1.675***	† † †	-0.424	-0.911**			
	(0.556)	(0.473)		(0.676)	(0.425)			
Italian	-1.684*	-4.383***	††	-2.737***	-2.636**			
	(1.037)	(0.729)		(1.021)	(1.563)			
French	0.237	-1.667***	† † †	-0.495	-1.056**			
	(0.415)	(0.560)		(0.539)	(0.539)			
Spanish	-1.044*	-2.850***		-1.707*	-2.725*			
	(0.783)	(0.794)		(1.201)	(1.918)			
Dutch	-1.167	-1.717***	††	-0.859*	-1.503***			
	(0.521)	(0.504)		(0.609)	(0.345)			
CDS on 10-year Treasuries								
German	0.156	0.009		-0.480	-1.042**			++
	(0.162)	(0.227)		(0.436)	(0.468)			
Italian	-0.416	0.647		-1.786	-2.594**			+
	(0.908)	(0.922)		(1.899)	(1.437)			
Equity indices								
German	0.107	0.070		-0.161	0.270*	†		
	(0.105)	(0.124)		(0.180)	(0.190)			
Italian	0.063	0.191*		0.144	0.644***			+
	(0.145)	(0.135)		(0.239)	(0.226)			
French	0.178**	0.073		-0.173	0.427**	††		
	(0.108)	(0.148)		(0.220)	(0.188)			
Spanish	0.163*	0.062		-0.107	0.517**	†		
	(0.104)	(0.164)		(0.217)	(0.254)			
Dutch	0.100	0.042		-0.079	0.229**			
	(0.088)	(0.118)		(0.184)	(0.126)			
Corporate bond indices								
German	-0.210	-0.802**		0.135	-1.114**	†		
	(0.336)	(0.343)		(0.449)	(0.491)			
Italian	-1.114***	-0.695*		0.528	-1.358*			
	(0.336)	(0.440)		(0.968)	(1.001)			
French	-0.486*	-0.914***		1.080*	-1.378**	††	-	
	(0.335)	(0.325)		(0.815)	(0.647)			
Spanish	-0.600	-0.234		0.440	-1.193			
	(0.516)	(0.644)		(1.851)	(1.305)			
Dutch	-0.450	-0.805***		-0.145	-1.020***			
	(0.370)	(0.283)		(0.428)	(0.420)			

Note: See Table 9

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