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In this paper we use 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 negative movements in Treasury yields. Evidence shows significant spillover effects into Treasury bond, equity, and corporate bond markets of other eurozone countries. We find interesting differences in the effects of demand shocks between the two countries, consistent with the "safe-haven" status of German bonds versus the "high-debt" status of Italian Treasuries. Results suggest that these effects are stronger during periods of high financial stress.

JEL codes: E43, F4, G15
Keywords: high-frequency identification, primary market, sovereign bonds, yield curve

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 comovements, up until the Global Financial

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Crisis.[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, Klingler and Sundaresan 2020). Investors' attitude toward 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 U.S. 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.[2] Furthermore, the prevailing demand at an auction shows investors' perception of the health of a country's economy and creditworthiness of its government.[3] 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

1. See Figure A1 in the Online Appendix.

2. News agency Bloomberg wrote on December 27, 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."*

3. As news agency Reuters wrote on July 30, 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."*

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 bonds 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 last up to 30 trading days. Using our estimates 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 et al. 2015, De Santis 2020). 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 show that in Germany the shocks have local effects, in the sense that nearby (i.e., similar maturity) yields respond stronger. Our findings for Germany are in line with Gorodnichenko and Ray (2017), who find local effects of demand shocks for the U.S. Treasury yield curve. Our results are 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 location. 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 show that Treasury demand shocks lead to reactions of the corporate bond markets. More specifically, euro area corporate bond yields drop in response to German demand shocks, whereas they are rather unaffected by Italian demand shocks.

Of particular interest are the results of the spillover effects of demand shocks on equity markets and Treasury credit default swap (CDS) spreads. The seemingly similar information (increased demand for government debt) has vastly different effects between the two countries. More specifically the main euro area stock indices drop following German demand shocks, while Treasury CDS spreads increase. On the other hand, Italian demand shocks lead to positive responses of equity prices and decreases in CDS spreads. We reconcile these results as follows. The information about increased demand for bonds alters investors' risk preferences and expectations in two different ways. A sudden demand increase for German bonds is associated with financial markets turning to a "flight-to-safety" mode. Willingness to take risk decreases and investors rebalance their portfolios from equities to bonds. On the other hand, the market movements associated with a positive 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 and decreases in Treasury CDS spreads.

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 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 1 summarizes the literature related to our study. Section 2 provides more details on the institutional setup of Treasury auctions in Germany and Italy. Section 3 describes the data used in the analysis. The high-frequency identification and the construction of the demand shocks are explained in Section 4. The main empirical results are shown in Section 5, which also contains an extensive robustness analysis. Section 6 examines the presence of state dependency and asymmetries in the effects. Finally, Section 7 concludes. An Online Appendix (not for publication) is available in the authors' personal webpages.

1. LITERATURE REVIEW

This paper is related to several lines of existing research. On the one hand, it is connected to the literature that analyzes Treasury market behavior in response to news. Macro-economic announcements are typically found to cause large intraday movements in prices, traded volumes, and bid-ask spreads in Treasury and foreign exchange futures markets (Ederington and Lee 1993, Fleming and Remolona 1999). Balduzzi et al. (2001) show that some releases do not affect the Treasury yield curve uniformly but have stronger effects on specific maturity segments. Fleming and Remolona (1997) find that not only macro-economic announcements, but also monetary policy announcements and Treasury auction results are important drivers of bond prices. In line with these results, Huang et al. (2002) also find that following the release of auction results, trading activity increases in U.S. government bond markets. This leads to the second line of research our paper relates to, that is, the literature examining market behavior around Treasury auctions.

Although Treasury auctions convey a substantial amount of information to financial markets, it is still an underresearched area. There is a long-standing literature documenting systematic price differential between the primary and the secondary Treasury markets. It suggests that the secondary market learns from the outcome of the auctions (see Bikhchandani and Huang 1989, Cammack 1991, Goldreich 2007). Others document predictable price and liquidity patterns in the secondary market around auctions (see Lou et al. 2013, Beetsma et al. 2016, Fleming and Liu 2016). Other papers show that auction effects have spillover effects internationally, for example, Beetsma et al. (2018) and Eisl et al. (2019). Some recent papers look at auction results to identify changes in the demand for Treasuries. Klingler and Sundaresan (2020) analyze the liquidity premium and "safe-haven" status of Treasuries, Dobrev (2019) investigates how demand for U.S. Treasuries has changed in recent years, and Fuhrer and Giese (2021) study how demand shifts transmit across the yield curve in the United Kingdom. Gorodnichenko and Ray (2017) identify demand shocks by looking at high-frequency price changes around U.S. auctions and analyze the effects on the yield curve and transmission into other markets.

Our paper also relates to the literature studying Treasury market segmentation in the maturity space, particularly in relation to large-scale asset purchases by central banks. This is closely connected to the preferred-habitat view of interest rates, proposed by Culbertson (1957) and Modigliani and Sutch (1966) and recently picked up by Vayanos and Vila (2021). Empirical support for the theory has been provided by Krishnamurthy and Vissing-Jorgensen (2011) and Li and Wei (2013) in the United States and Boermans and Vermeulen (2018) in Europe among others. Our study complements these findings by bringing further evidence of market segmentation in eurozone Treasury markets with a methodology that has not been used for this purpose.

To summarize, although public debt auctions convey a substantial amount of information to financial markets, it is still an underresearched area, especially within the euro area. 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. There is an important motive behind our country selection. Gorodnichenko and Ray (2017) focus on the U.S. Treasury market, which 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. 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. 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).

2. DATA

The data set we use in this study is collected from various sources. The sample starts on January 1, 1999, and ends on December 29, 2017. In case of Italy a shorter sample was used, starting in September 2009. We use front contract intraday government bond futures prices data compiled by Refinitiv. There are four types of contracts for Germany, connected to four maturity segments. A short position arising from one of 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. The longest contract was introduced in 2005, while the other three in 1999. The first day with sufficient data to construct the surprise measure is March 17, 1999, and October 26, 2005, for the longest contract. There are three types of Italian contracts, settled by Italian government bonds with remaining maturities of 2.0 to 3.25, 4.5 to 6.0, and 8.5 to 11.0 years. These were introduced to markets in 2010, 2011, and 2009, respectively. As the middle contract exhibits almost no trading activity, we omitted it from our analysis. The first date market depth allowed us to construct the high-frequency surprise is October 26, 2010, for the 2.0 to 3.25 maturity and September 14, 2009, for the 8.5- to 11.0-year maturity.

Besides intraday Treasury futures prices, our data set consists of daily secondary market government bond yields, primary market auction data, daily stock market indices, daily corporate bond indices, daily CDS premiums on Treasuries, and a monthly country-level financial stress index. These are displayed in Figures A1– A4 in the Online Appendix. 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.[4] Our analysis covers all 2-, 5-, 10-, and 30-year bond auctions available in the sample period. For Germany, there are 536 auctions, while for Italy the number is 247. 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. The country-level corporate bond indices are the corporate subindices of the Bloomberg Barclays Euro Aggregate Index. We use the five largest euro area countries' stock market indices: the German DAX, the French CAC40, the Italian FTSEMIB, the Spanish IBEX35, and the Dutch AEX. Finally, the Country Level Index of Financial Stress (CLIFS) was obtained from the ECB and it is based on Duprey et al. (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 A4 of the Online Appendix. 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.

3. IDENTIFICATION

In this section, we briefly describe the institutional setup of German and Italian Treasury auctions. We then explain how we exploit it to capture unexpected demand shocks for public debt. A more detailed description of the auction procedures is available in the Online Appendix.

The Debt Management Office (DMO) of both countries publishes 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 at each auction

4. See https://www.deutsche-finanzagentur.defor Germany and http://www.dt.tesoro.itfor Italy.

day. A few days (e.g., six working days in Germany and three 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.[5]

On the day of German (Italian) auctions, bidding starts at 8:00 a.m. Central European Time (CET). Primary dealers can place their bids until 11:30 a.m. (11.00 a.m.). At 11:30 a.m. (11.00 a.m.) the DMO collates the bids and decides on the allotment. The decision is made within roughly 5 (15) minutes, after which bidders are notified and the results are published. The published document contains information on the amount of bids received, the amount allotted, the resulting bid-to-cover ratio, the winning price(s) the agency chooses, and much more.[6]

The information in auction results can be utilized in multiple ways to quantify demand shocks. The bid-to-cover ratio is the total amount of bids submitted by participants divided by the allotted volume. This measure has been used by Klingler and Sundaresan (2020), Dobrev (2019), and Fuhrer and Giese (2021). 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, there is no easy and uncontroversial way to isolate its unexpected component, which is the main focus of this paper. Second, differently from the United States, German and Italian debt management agencies can adjust the final allotment volume during the auction, based on the prevailing demand conditions.[7] When the agencies judge that the demand conditions are weak, they do not allot all the bonds on offer.[8] Hence, the same headline bid-to-cover ratio could be the outcome of different demand conditions. For example, the German Treasury typically withholds around 14%–23% of the issuance, to set aside for secondary market operations in the days following the auction.[9] The Italian agency also has this option, however, it 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.

5. Figures A5 and A6 in the Online Appendix display two auction announcement documents for Germany and Italy.

6. As an example Figures A7 and A8 in the Online Appendix display two auction result documents published by the German and Italian agencies.

7. Also the UK DMO reserves the right to withhold part of the gilts on offer, although this option is only considered in “exceptional circumstances.”

8. 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 A1 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.

9. 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.

To assess demand in an auction, market participants follow closely pricing data (see ITC Markets 2017). 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 a high-frequency identification. Nevertheless, as later described, we also utilize the above measures in an instrumental variable framework. We use the identification proposed by Gorodnichenko and Ray (2017). This relies on the idea that on the day of an auction, the debt management agencies have already disclosed virtually 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 contains new information almost exclusively about the demand side of the market. Within a short event window around the release of the results, nearly 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 does it require specific assumptions to identify the unexpected variation of the demand conditions.

As it is standard in the high-frequency identification literature, we follow futures price movements in the event window. Futures contracts have many advantages compared to spot or when-issued prices, such as substantially higher liquidity and better data availability. Furthermore, futures markets tend to lead price discovery ahead of the spot (see Garbade and Silber 1979, 1983, Upper and Werner 2007).

Investors' reaction to the new information could potentially involve purchasing and selling 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, using futures data, we can only proxy the shifts by price movements at the points where futures 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:

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

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,

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.

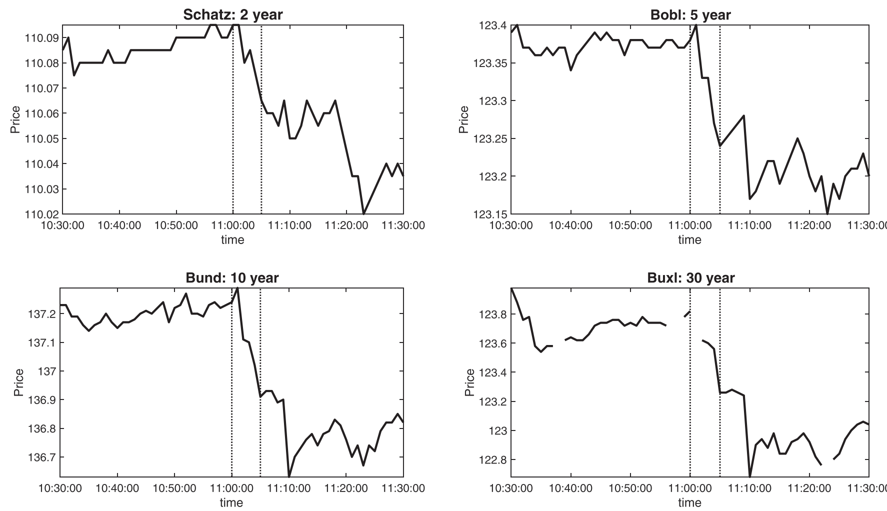

Fig 1. German Futures Price Movements in the Event Window on November 23, 2011.

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

regardless of the maturity being auctioned. Therefore, on each auction day we record four data points in case of Germany and two in case of Italy. For example, the series $D_t^{(2Y)}$ is equal to the price difference from equation (1) on auction days, and zero on nonauction days.

The frequency of the futures prices is at 1 minute, that is, 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.[11]

As an illustration, Figure 1 shows the price movements of the four German futures contracts within the 1-hour event window on November 23, 2011. In this auction the German government was targeting to sell 6 billion euros of bonds with a maturity

11. These results are available upon request.

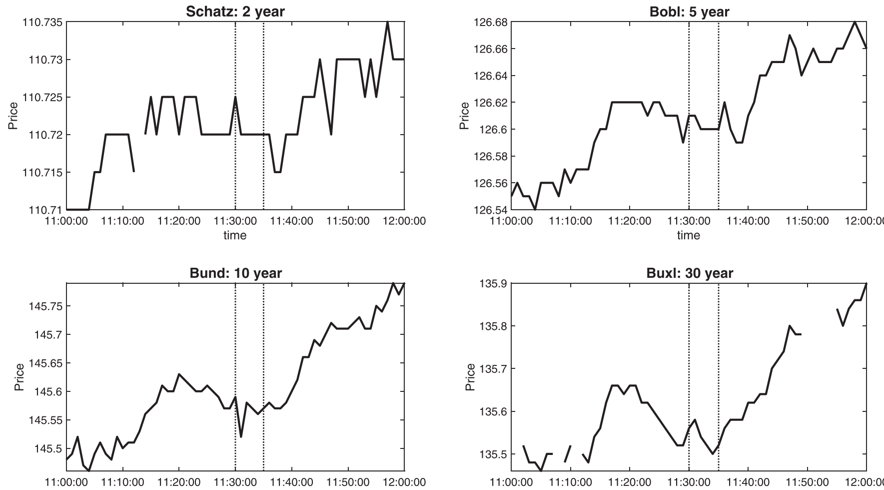

Fig 2. German Futures Price Movements in the Event Window on the April 17, 2013.

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

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. Futures price movements during this specific auction show 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 April 17, 2013. The 4 billion intended issuance volume met 5.2 billion of bids, resulting in a bid-to-cover ratio of 1.3. Figure 2 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."*

The time series of the identified high-frequency demand shocks are displayed in Figures 3 and 4. Due to limited availability of futures prices, for Italy the sample is constrained 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.

There are two issues to consider regarding our identification. First, unexpected changes in the demand for public debt are unobservable by nature. $D_t^{(m)}$ captures the equilibrium price change arising from the shift in the demand. Hence, it is reassuring to verify if $D_t^{(m)}$ is linked to observable movements in the demand. In the Online

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	536	0.000	0.000	0.046	0.703	0.772	0.627	0.450	0.543	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	0.000	1.000

Italy	Sample	N	Mean	Med.	Std. dev.	Correlations $D_t^{(2Y)}$	$D_t^{(10Y)}$	D_t
$D_t^{(2Y)}$	10.2010–12.2017	208	−0.011	−0.002	0.092	1.000		
$D_t^{(10Y)}$	09.2009–12.2017	247	−0.022	−0.003	0.193	0.760	1.000	
D_t	10.2010–12.2017	247	0.000	0.020	0.203	0.832	0.993	1.000

Notes: Shocks are the recorded high-frequency futures price movements in the event window on auction days. $D_t^{(short)}$ is the first principal component of the 2 and 5 year shock, recorded on days of auctions of 2 and 5-year bonds. $D_t^{(long)}$ is the first principal component of the 10 and 30 year shock recorded on days of auctions of 10 and 30-year bonds. In case of Italy $D_t^{(short)} = D_t^{(2Y)}$ and $D_t^{(long)} = D_t^{(10Y)}$ due to data limitations. D_t is the first principal component of the surprise series at all maturities.

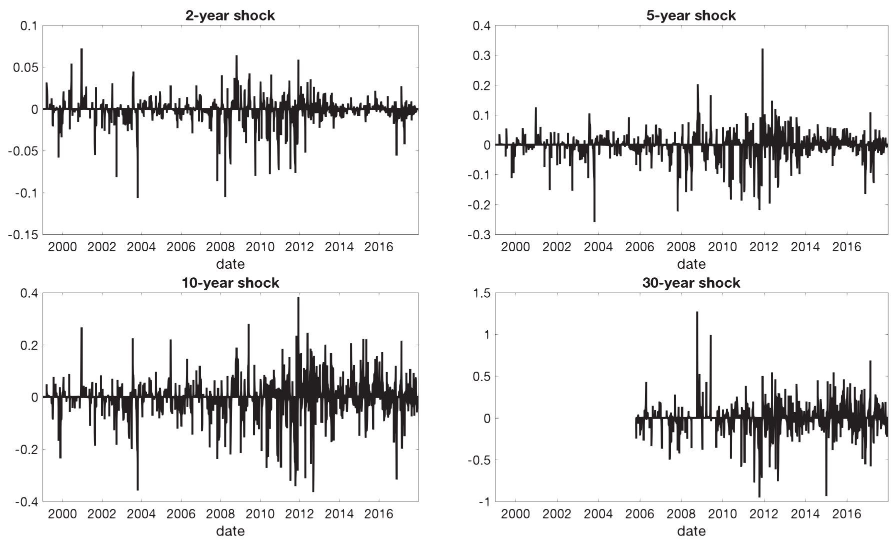

Fig 3. Time Series of the German Demand Shock.

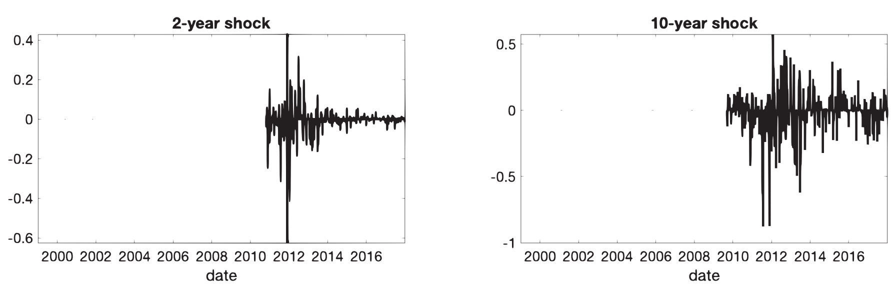

Fig 4. Time Series of the Italian Demand Shock.

Appendix (Tables A2 and A3), we show that our demand shock is closely associated with the bid-to-cover ratio and the yield gap (and their unexpected component). In the robustness section below, we also show that our results are robust when these two indicators are used as instruments for our demand shocks.

Second, our high-frequency surprises might be contaminated if other relevant events happen within our event window or earlier events have not yet been fully incorporated into asset prices at the start of the event window. Nonetheless, narrowing our event window or excluding days with relevant Eurostat data releases or ECB announcements yields qualitatively and quantitatively similar results.[12]

12. These results are available in the Online Appendix and/or upon request.

4. 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 intraday to daily frequency, we intend to capture responses that might take longer to materialize then the 1-hour length of the event window.

As shown in Table 1 and Figures 1 and 2, 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. As futures contracts were introduced at different points in time, we use probabilistic principal component analysis to deal with missing observations. D_t 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 additional 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. This series is meant to capture shocks that increase demand only for short maturities. The availability of the German shocks are from March 17, 1999, onward. 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 $D_t^{(2Y)}$, while long-term demand shocks are based on the 10-year series $D_t^{(10Y)}$. The availability of these are from October 26, 2010, and September 14, 2009, onward, respectively. 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).

4.1 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 the following form:

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

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. β_h are the coefficients of interest, while α_h can pick up any pattern in yields independent of the shock around the auction, for example, documented by Lou et al. (2013). The responses of Treasury yields to the demand shock D_t are displayed in Figure 5, with Newey-West standard errors in parenthesis.[13] Not surprisingly, the shock (defined as a change in the futures price) and the bond yields move in opposite direction. What is more interesting is that a price movement in a very narrow intraday window has a large effect that even persists in the following days. The effects are strongest on impact, with bond yields decreasing by 1–2 basis points in Germany and gradually turning insignificant after around 15 days. In Italy the magnitude is larger, and yields drop by 3–4 basis points. The effect turns insignificant quicker, in about 7 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 PSPP, on sovereign yields. On January 22, 2015, the ECB Governing Council announced the launch of its asset purchase program, which 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, 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 (Tables A2 and A3). 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 5), 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. First, the size of the shock makes it an enormous out-of-sample exercise. Second, 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 (2020). According to the event study of Altavilla et al. (2015), the asset purchase announcements decreased 10-year government bond yields by 17 basis points

13. To address the serial correlation induced by the overlapping structure of the data, we set a lag truncation parameter of $2H$ throughout the paper. $H = 30$ is the max length of the local projection exercise. Our results, however, are robust to a wide spectrum of parameter values.

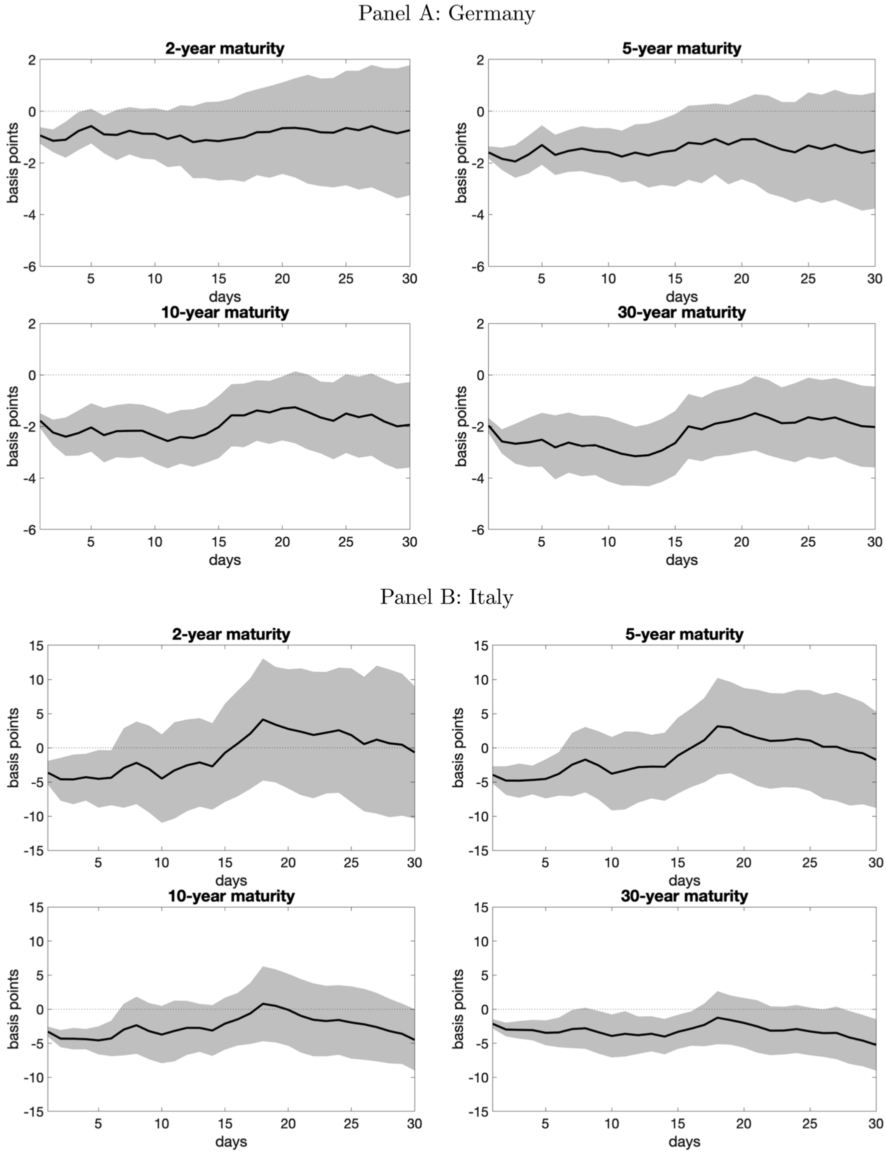

Fig 5. Impulse Responses of Secondary Market Yields to the Treasury Demand Shock.

Notes: 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.

in Germany and 75 basis points in Italy on the day of the announcement. De Santis (2020) 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 (2020) 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.

4.2 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 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.

To assess these predictions, we regress $D_t^{(short)}$ and $D_t^{(long)}$ 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 $m' \in \{short, long\}$.[14] Figure 6 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 1.3 basis points, while 30-year yields drop by 1.6. 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 6). 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, than 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 (2021) who find local effects of demand shocks in the United States and the United Kingdom. It is also consistent with studies bringing

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

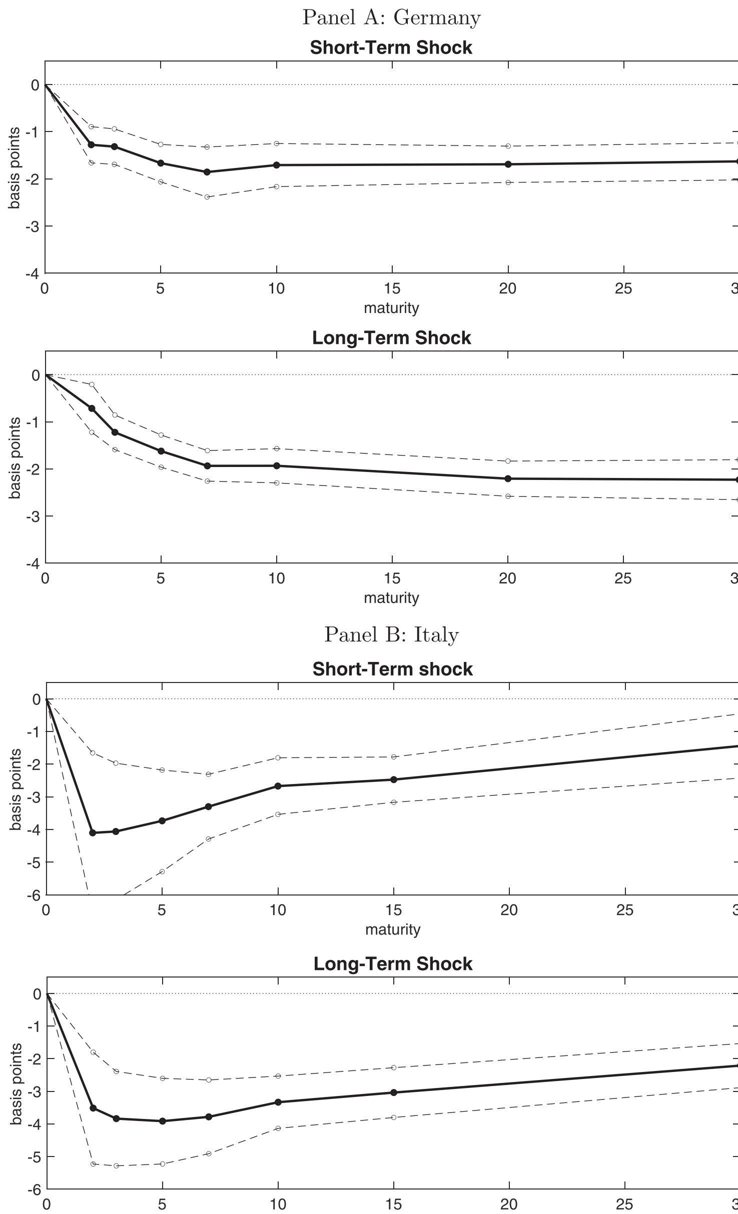

Fig 6. On Impact Response of the Treasury Yield Curve.

NOTES: Nodes are the 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. In case of Italy $D_t^{(short)} = D_t^{(2Y)}$ and $D^{(long)} = D^{(10Y)}$ due to data limitations. Dashed lines are 90% Newey-West confidence intervals.

evidence of bond market segmentation in the euro area, such as Boermans and Vermeulen (2018).

The strong reaction of short-maturity bonds to the long-term demand shock seems puzzling at first. One possible explanation is through a model where the government faces debt rollover risk and multiplicity of equilibria is present, such as Cole and Kehoe (2000). Here, one equilibrium is characterized by high interest rates and creditors not willing to roll over the debt inducing a default. The other equilibrium is with low interest rates and no default. The positive demand shock we identify might be taken by investors as a signal that Italy is heading toward the low-rate equilibrium. Debt rollover risks will not materialize in the near future, which drives short-term interest rates down.

4.3 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 2 displays the reaction of Treasury yields and CDS spreads. Panel A (Panel B) shows the reactions to the German (Italian) demand shock.

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, 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. Strong comovements between Italian and Spanish bonds after 2010 have been documented by many studies (e.g., Ehrmann and Fratzscher 2017).[15]

Table 2 also shows the responses of CDS spreads. CDS contracts transfer the default risks of the bond from the buyer to the seller of the contract. According to a

15. As an additional result, we find that German demand shocks have spillover effects to the U.S. secondary Treasury yields, while the Italian demand shocks do not have any significant effect (see Table A4 in the Online Appendix). This seems to be consistent with the fact that German and U.S. yields are close substitutes and perceived as safe assets.

TABLE 2

Reaction of Treasuries Yields and CDS Spreads

Panel A: German demand shock

	DE	IT	FR	ES	NL
2 year	−0.941***	−0.549*	−0.921***	−0.289	−0.964***
	(0.194)	(0.382)	(0.190)	(0.449)	(0.155)
5 year	−1.596***	−0.616*	−1.388***	−0.354	−1.445***
	(0.145)	(0.385)	(0.167)	(0.457)	(0.146)
10 year	−1.780***	−0.596**	−1.508***	−0.392	−1.594***
	(0.177)	(0.322)	(0.176)	(0.374)	(0.163)
30 year	−1.968***	−0.569**	−1.655***	−0.541*	−1.877***
	(0.179)	(0.273)	(0.184)	(0.337)	(0.167)
2-year CDS	0.211*	1.313***	0.353***	1.933***	0.211**
	(0.129)	(0.497)	(0.135)	(0.487)	(0.096)
10-year CDS	0.207*	1.175***	0.386**	1.798***	0.202**
	(0.238)	(0.463)	(0.202)	(0.468)	(0.114)

Panel B: Italian demand shock

	DE	IT	FR	ES	NL
2 year	−0.004	−3.650***	−0.409**	−3.297***	−0.174
	(0.159)	(1.056)	(0.179)	(0.832)	(0.171)
5 year	−0.256	−3.962***	−0.519**	−3.209***	−0.559***
	(0.236)	(0.768)	(0.265)	(0.608)	(0.239)
10 year	−0.373*	−3.304***	−0.734***	−2.491***	−0.682***
	(0.252)	(0.454)	(0.264)	(0.519)	(0.246)
30 year	−0.276	−2.151***	−0.651***	−1.811***	−0.307
	(0.255)	(0.418)	(0.253)	(0.422)	(0.241)
2-year CDS	−0.295***	−1.565***	−0.119	−1.109**	−0.406***
	(0.116)	(0.651)	(0.186)	(0.519)	(0.155)
10-year CDS	−0.505***	−1.377**	−0.384**	−0.980***	−0.434***
	(0.176)	(0.650)	(0.170)	(0.411)	(0.155)

Notes: Estimated δ coefficients from $\Delta Y_t = \mu + \delta D_t + \varsigma_t$. 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. Panel A displays the estimates of the German demand shock, Panel B displays the estimates of the Italian shock. The columns correspond to German (DE), Italian (IT), French (FR), Spanish (ES), and Dutch (NL) assets. The rows correspond to 2-year, 5-year, 10-year, and 30-year Treasuries and credit defaults swaps (CDS) written on 2- and 10-year Treasuries.

no-arbitrage argument, the CDS spread should match the yield spread of the corresponding bond with the risk-free rate (Duffie, Darrell 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 counterintuitive 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, that is, CDS spreads.

Table 3 shows the responses of equity and corporate bond markets to the German and Italian demand shocks. We find that corporate bond yields decrease, although

TABLE 3

Reaction of Equity Indices and Corporate Bond Indices

	Germany		Italy	
	Equities	Corp. bonds	Equities	Corp. bonds
Germany	−0.260***	−1.129***	0.039	−0.206
	(0.090)	(0.185)	(0.066)	(0.205)
Italy	−0.300***	−1.177***	0.245***	−0.342
	(0.082)	(0.187)	(0.093)	(0.343)
France	−0.246***	−1.355***	0.074	−0.149
	(0.091)	(0.285)	(0.083)	(0.347)
Spain	−0.291***	−1.091***	0.128*	−0.226
	(0.092)	(0.320)	(0.087)	(0.490)
Netherlands	−0.257***	−1.106***	0.037	−0.335**
	(0.104)	(0.285)	(0.055)	(0.176)
Euro area	−0.266***	−1.254***	0.076	−0.221
	(0.093)	(0.192)	(0.076)	(0.269)

Notes: Estimated δ coefficients from $\Delta Y_t = \mu + \delta D_t + \varsigma_t$. The left two columns display the estimates of the German demand shock, the right two columns display the estimates of the Italian shock. D_t is the first principal component of the shock measures, normalized to zero mean and unit variance. Equity indices are the DAX, FTSEMIB, CAC40, IBEX35, AEX, EUROSTOXX in logarithm. Corporate bond indices are the corporate subindex 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.

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 United States 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 U.S. 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 rebalancing from risky equities toward 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 May 30, 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. 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 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 June 4, 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.

4.4 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 A5– A6 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 4, two such measures are the bid-to-cover ratio and the yield gap. Figure A9 and Tables A7 and 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.[16] 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 A3).

In the third robustness exercise, we follow Gorodnichenko and Ray (2017) and rotate the German $D^{(short)}$ to be uncorrelated with the 30-year series $D_t^{(30Y)}$.[17] This exercise allows to better separate the shocks in the maturity space. Figure A10 shows that are main results are not affected.

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 and A10).

5. 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.[18] The theoretical model of Vayanos and Vila (2021) 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 2—and construct a dummy variable C_t, taking the value of one when the CLIFS index is over its 70th percentile and zero otherwise.[19] We then estimate the following extension of equation (3):

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

16. Notice that the results of the first-stage regressions were reported in the last column of Tables A2 and A3.

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

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

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

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 7 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 for long-term shocks 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 (2021). Under the regime of no stress (or lower risk aversion), the responses to long-term shocks 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 7 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 7 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.[20]

In Table 4 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 stronger 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 behavior: unaffected during low stress periods, but strong and positive responses during market stress episodes (see Table 4).

20. 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 A4) 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.

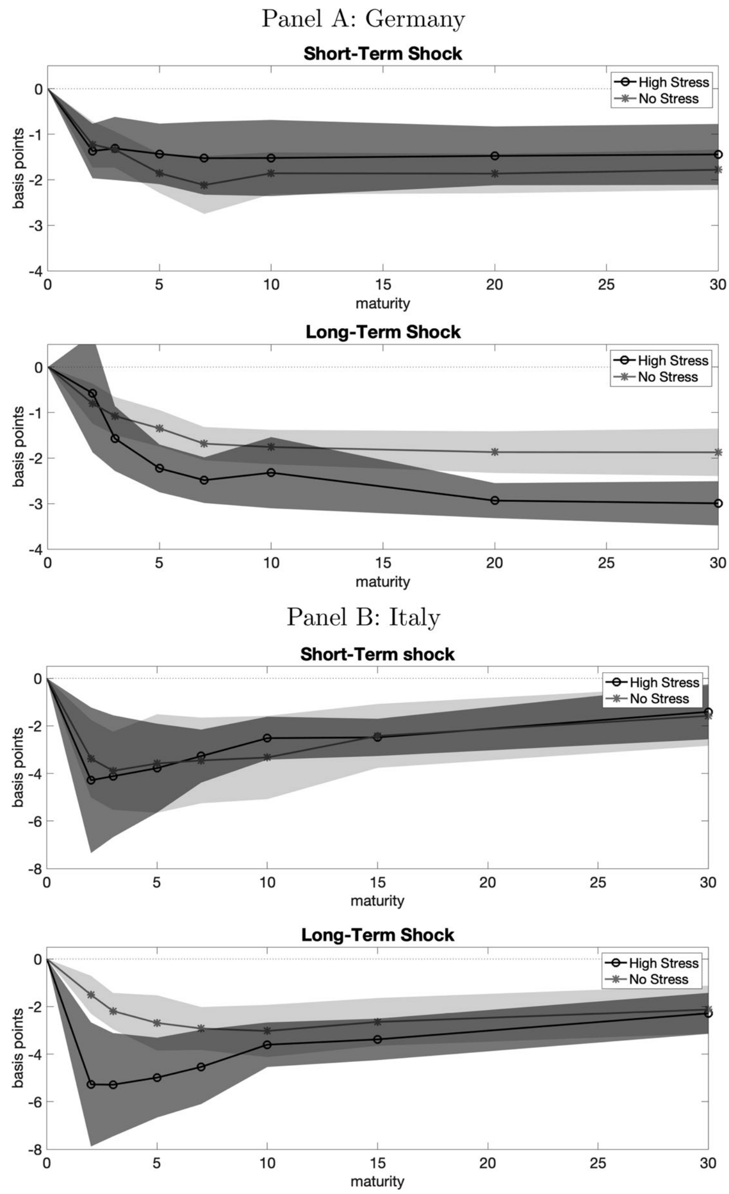

Fig 7. On Impact Response of the Treasury Yield Curve in Periods of High and Low Financial Stress.

NOTES: Nodes are the estimated $\beta^{(m,L)}$ and $\beta^{(m,H)}$ coefficients from the equation $\Delta R_t^{(m)} = C_t(\alpha^{(m,H)} + \beta^{(m,H)} D_t^{(m')}) + (1 - C_t)(\alpha^{(m,L)} + \beta^{(m,L)} D_t^{(m')}) + \eta_t^{(m)}$, 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. In case of 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.

TABLE 4

Asset Price Reaction 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	
	(0.161)	(0.390)		(0.516)	(0.257)	
Italian	−0.270	−1.148***		−3.097***	−3.461***	
	(0.425)	(0.365)		(0.720)	(0.486)	
French	−1.517***	−1.499***		−0.644*	−0.811***	
	(0.188)	(0.357)		(0.481)	(0.236)	
Spanish	−0.134	−0.834**		−1.886***	−2.942***	
	(0.491)	(0.504)		(0.630)	(0.627)	
Dutch	−1.636***	−1.538***		−0.805**	−0.600**	
	(0.172)	(0.330)		(0.470)	(0.264)	
CDS on 10-year Treasuries						
German	0.145*	0.330		−0.084	−0.823***	† † †
	(0.104)	(0.347)		(0.096)	(0.239)	
Italian	1.673***	0.202	†	−0.206	−2.246***	† †
	(0.532)	(0.631)		(0.486)	(0.876)	
Equity indices						
German	−0.163***	−0.430**		0.033	0.042	
	(0.069)	(0.205)		(0.070)	(0.107)	
Italian	−0.266***	−0.361**		0.113	0.339***	
	(0.082)	(0.169)		(0.092)	(0.142)	
French	−0.143**	−0.425**		0.056	0.085	
	(0.068)	(0.204)		(0.088)	(0.139)	
Spanish	−0.242***	−0.379**		0.053	0.181	
	(0.085)	(0.199)		(0.083)	(0.142)	
Dutch	−0.115**	−0.505**		0.041	0.033	
	(0.059)	(0.243)		(0.064)	(0.089)	
Corporate bond indices						
German	−1.258***	−0.918**		−0.490**	−0.003	
	(0.165)	(0.403)		(0.288)	(0.270)	
Italian	−1.164***	−1.186**		−0.836***	0.033	
	(0.235)	(0.619)		(0.218)	(0.530)	
French	−1.344***	−1.380***		−0.645***	0.217	
	(0.146)	(0.440)		(0.243)	(0.526)	
Spanish	−1.154***	−0.995**		−0.403*	−0.083	
	(0.373)	(0.592)		(0.314)	(0.825)	
Dutch	−1.387***	−0.634		−0.660***	−0.098	
	(0.137)	(0.702)		(0.266)	(0.216)	

Notes: 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.

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.[21] 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:

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

and

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

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 8. When German long-term 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 5. 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, 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.[22] Tables A11 and A12 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

21. See Veronesi (1999) for an early reference.

22. 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.

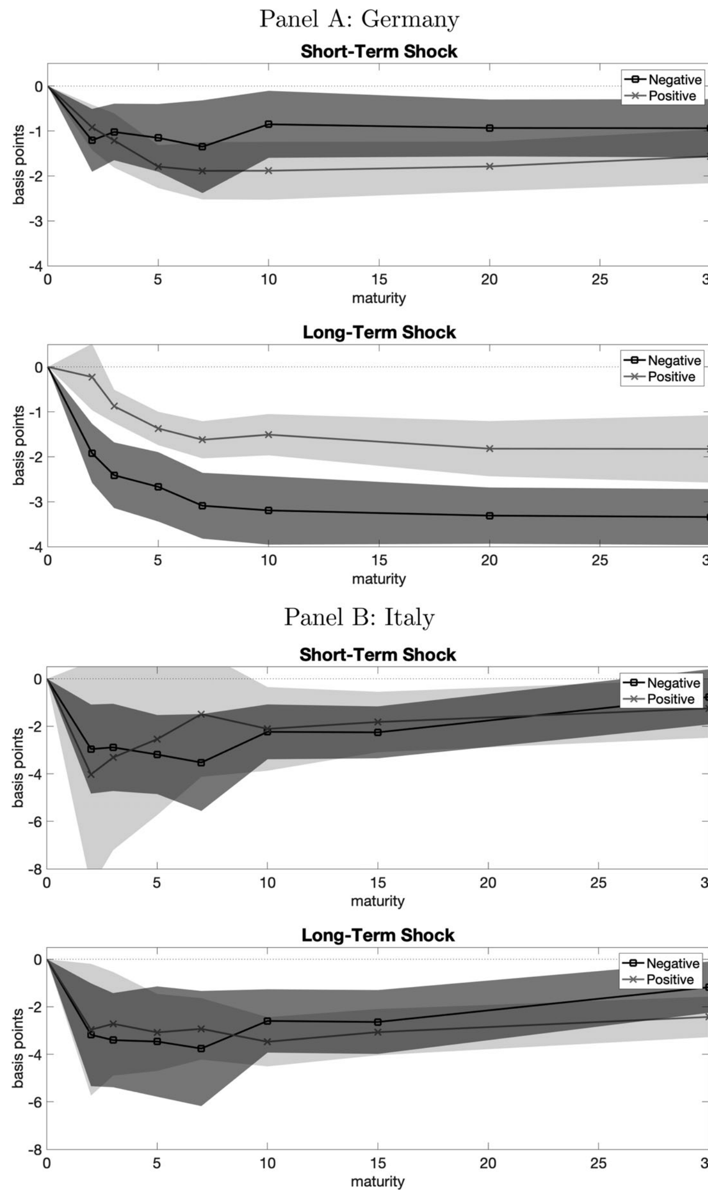

Fig 8. On Impact Response of the Treasury Yield Curve to Negative vs. Positive Demand Shock.

NOTES: Nodes are the estimated $\beta^{(m,N)}$ and $\beta^{(m,P)}$ coefficients from the equation $\Delta R_t^{(m)} = S_t(\alpha^{(m,N)} + \beta^{(m,N)} D_t^{(m')}) + (1 - S_t)(\alpha^{(m,P)} + \beta^{(m,P)} D_t^{(m')}) + \nu_t^{(m)}$, 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. S_t is a dummy variable taking one when $D_t^{(m')} < 0$. In case of Italy $D_t^{(short)} = D_t^{(2Y)}$ and $D_t^{(long)} = D_t^{(10Y)}$ due to data limitations. Shaded areas are 90% Newey-West confidence intervals.

TABLE 5

Asset Price Reaction 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***	† † †
	(0.369)	(0.245)		(0.391)	(0.322)	
Italian	−0.486	−0.634**		−2.611***	−3.445***	
	(0.794)	(0.365)		(0.755)	(0.645)	
French	−1.627***	−1.357***		−0.220	−1.365***	††
	(0.398)	(0.223)		(0.406)	(0.407)	
Spanish	−0.220	−0.178		−1.866***	−2.773***	
	(0.727)	(0.457)		(0.765)	(0.758)	
Dutch	−1.702***	−1.519***		−0.344	−1.629***	† † †
	(0.354)	(0.221)		(0.383)	(0.303)	
CDS on 10-year Treasuries						
German	0.244*	0.197		−0.264	−0.566**	
	(0.165)	(0.243)		(0.252)	(0.313)	
Italian	1.125	0.835*		−1.383**	−1.070*	
	(1.076)	(0.625)		(0.801)	(0.716)	
Equity indices						
German	−0.215**	−0.393***		−0.019	0.172**	
	(0.108)	(0.162)		(0.118)	(0.077)	
Italian	−0.269***	−0.365***		0.144*	0.418***	††
	(0.105)	(0.143)		(0.102)	(0.116)	
French	−0.152**	−0.408***		0.007	0.254***	
	(0.092)	(0.165)		(0.142)	(0.091)	
Spanish	−0.203**	−0.443***		0.056	0.294**	
	(0.100)	(0.162)		(0.102)	(0.129)	
Dutch	−0.138*	−0.462***	†	0.004	0.135**	
	(0.099)	(0.189)		(0.097)	(0.062)	
Corporate bond indices						
German	−1.165***	−0.929***		0.222	−0.999***	† † †
	(0.355)	(0.249)		(0.257)	(0.262)	
Italian	−1.303**	−1.067***		0.006	−1.033**	
	(0.583)	(0.310)		(0.689)	(0.480)	
French	−1.393***	−1.215***		0.584	−1.180***	††
	(0.348)	(0.258)		(0.623)	(0.380)	
Spanish	−1.285**	−0.816***		0.056	−0.712	
	(0.631)	(0.284)		(1.071)	(0.625)	
Dutch	−1.442***	−0.646		−0.024	−0.939***	† † †
	(0.320)	(0.514)		(0.244)	(0.236)	

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.

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.

6. 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 negative movements in Treasury yields that can last up to 30 trading days. 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, 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.

The most interesting differences we found are on 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 an increase in the credit risk priced in CDS spreads. This is in contrast 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 how investors perceive the seemingly similar information. Higher demand for German Treasuries is associated with a "flight-to-safety" behavior with investors rebalancing from riskier equities to safer bonds and increases in Treasury CDS spreads. 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. Increases of the stock market and decreases of Treasury CDS spreads indicate that investors are reassured and willing 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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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Figure A1. Government bond yields of the five largest euro area member country

Figure A2. Stock indices of the five largest euro area member country

Figure A3. CDS spread on German and Italian 10-year government bond

Figure A4. Country Level Index of Financial Stress (CLIFS) and its historical 70th percentile in Germany and Italy

Figure A5. Announcement of the 11 January 2017 10-year German bond auction

Figure A6. Announcement of the 30 January 2017 10-year Italian bond auction

Figure A7. Press release of the 11 January 2017 10-year German bond auction results

Figure A8. Press release of the 30 January 2017 10-year Italian bond auction results

Figure A9. On impact response of the Treasury yield curve (Bid-to-cover IV regression)

Figure A10. On impact response of the German Treasury yield curve to the rotated shortterm shock

Table A1: Retained volume in German auctions explained by demand

Table A2: Auction results and high-frequency surprises: Germany

Table A3: Auction results and high-frequency surprises: Italy

Table A4: Spillover effects into the US Treasury market

Table A5: Reaction of Treasury yields and CDS spreads - German sub-sample

Table A6: Reaction of equity indices and corporate bond indices - German sub-sample

Table A7: Reaction of Treasury yields and CDS spreads - IV regression

Table A8: Reaction of equity indices and corporate bond indices - IV regression

Table A9: Reaction of Treasury yields and CDS spreads - control variables

Table A10: Reaction of equity indices and corporate bond indices - control variables

Table A11: Positive and negative shock estimates in high and low financial stress - Germany

Table A12: Positive and negative shock estimates in high and low financial stress - Italy

Data S1