Intraday Pricing and Liquidity of Italian and German Treasury Auctions

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ABSTRACT

This paper examines how the bond supply, via primary auctions of the Treasury, influences price and liquidity in the secondary market at the day of the auction. Using intraday data from the *Mercato Telematico dei titoli di Stato* (MTS), I find evidence of an intraday pronounced inverted V-Shape on the yield difference, which goes up with a maximum at the auction time, and then recovers more than two hours after. This "auction effect" is significant for the Italian bonds and for the 10Y German Bund. The analysis of intraday quotes shows that there is also a peculiar liquidity effect due to the bond supply event. Using as a proxy the presence of the dealers in the market, there is evidence of risk-aversion behavior due to capital constraints and information uncertainty. The sovereign bond crisis exacerbates the dry-up of liquidity for Italy and the price pressure for Germany. However, the ECB intervention through the Public Sector Purchase Program (PSPP) appears to restore the market makers confidence, especially for Italy.

JEL classification: G12, G14.

Key-words: Treasury Auctions, Sovereign Bonds, ECB Intervention.

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1 Introduction

The total amount of government debt for the Euro Area is about 10 trillions:[1] 70% of this amount (6.8 trillion) is composed of government securities, making the European sovereign bond market one of the largest in the world.[2] Among all the EU members, two Member State are particularly relevant, for different reasons. The first is Italy, that has one of the highest amount of public debt in the world and an historically very liquid secondary bond market. The second is Germany, one of the strongest country in Europe in terms of economic growth and industrial output. The amount of sovereign debt for these two countries is relevant: 2.3 trillion for Italy and about 2 trillion for Germany. Together, they account for roughly half of the total European sovereign debt outstanding.

The Treasury agencies issue a sizable part of this debt via auctions, which is the main funding source for the Treasury to borrow money from the market and to roll-over the maturing debt. The recent financial crises, the importance of a well functioning primary and secondary market for the sovereign bond and the size of the secondary market itself, motivates a careful analysis of the behavior of the market participants, especially during the auction days. Both the Italian and German sovereign markets are characterized by the presence of a pool of financial institutions (mostly investment banks) that have specific duties, called primary dealers. They are appointed by the Governments to provide liquidity in the secondary market, acting as market-makers, and are also required to participate to the primary auctions submitting meaningful bids actively.

The purpose of this paper is to analyze the influence of the bond supply on the behavior of the primary dealers (or market-makers), and the impact in terms of market quality. Consistent with the theoretical models of Duffie (2010) and Sigaux (2017), I show empirically the presence of an intraday price pressure together with liquidity patterns around the auction time. Further, I find that the liquidity, in terms of bid-ask spread, is better in the action days compared to non-auction days. The model of Bessembinder, Carrion, Tuttle, and Venkataraman (2016) motivates this finding, and predicts higher liquidity before a scheduled event. However, the uncertainty around the auction push market-makers to reduce the total

[1] See Eurostat http://ec.europa.eu/eurostat/web/euro-indicators/ for the EU 19 members.

[2] As a comparison, the US market is about 14 trillion, and the Japanese market 9.3 trillion as of 2017

amount quoted in the auction days, and most importantly to widen the bid-ask spread and withdrawn from the market. The sovereign bond crisis and the Public Sector Purchase Program (PSPP) have a different impact in the two countries. For Italy, the crisis amplifies the liquidity issues, while the PSPP beneficially affects the behavior of the market makers, that remains in the secondary market during the auctions and do not withdraw their quotes.

The existent empirical literature on European Treasury auctions shows that government security supply affects secondary market prices. These temporary price movements, that usually starts days before the auction and reabsorb few days after, identify an inverted V-shaped pattern of the yield. In other words, the bond yield rises before the auction and then fall in the following days. Since the calendar of Treasury auctions is published well in advance, together with the time of the auction and the amount auctioned, these price movements are clearly not related to unexpected events. While the general results are consistent with the existent evidence using daily data, I show that using intraday data it is possible to understand better the price dynamics and the behavior of market participants minutes before the auction take place.

The main contribution of this paper is to shed light on the intraday linkages between price movements, dry-up of liquidity, and market-makers' behavior in the auctions' days. To the best of my knowledge, no prior research investigates this issue in a high-frequency setting for the European Sovereign bond markets. Compared to the empirical works of Beetsma, Giuliodori, De Jong, and Widijanto (2016) with daily data for the European Bond market, and Fleming and Liu (2016) with intraday data on the U.S. Treasury, I am investigating the liquidity consequences of the behavior of the market-makers, in terms of bid-ask spread, participation, and total depth of the market. In a two-stage analysis, I show that the uncertainty around the auction push market-makers to reduce the amount quoted. Market-makers also widen the bid-ask spread very close to the auction time, to protect themselves from adverse selection costs. The explanation of this intraday behavior is due to the high risk-aversion of the market makers. Price and liquidity patterns are not observed on non-auction days, suggesting that auctions themselves influence the behavior of the market participants.

In the last years, many factors influenced the sovereign bond prices in the secondary market. The most important is the 2011 debt crisis and ECB interventions. Pelizzon,

Subrahmanyam, Tomio, and Uno (2016) analyze the dynamic relation between credit risk and liquidity in the Italian sovereign bond market during the 2011 crisis, finding that credit risk drives the liquidity. They also analyze the liquidity of the Italian sovereign bond market after the initial intervention by the ECB, showing that the increased liquidity available to the banks disconnect the link between credit risk and market liquidity. However, I show that there are peculiar intraday liquidity dynamics during the auction dates, that are exacerbated by the 2011 crisis and attenuated by the PSPP intervention.

One the one hand, cheaper funding is beneficial for both the market-makers, that could participate more effectively in the primary auction, and for the Treasury. On the other hand, the empirical evidence suggests that dealers also exploit the secondary market channel, short selling the auctioned bond (or a bond with similar characteristics, i.e., the previous on-the-run bond) before the auction, to push the price down. Moreover, in a high-frequency setting, the price pressure is present also the quoting activity and mainly driven by the liquidity channel. The Treasury potentially pays an additional cost for the issuance. This empirical analysis is aimed to address this concerns about liquidity and price movements. A better understanding of this relationship could improve the effectiveness of Treasury auctions, reduce the costs, and improve the liquidity in the secondary market.

The outline of the paper is as follows. Section 2 provides a literature review on the sovereign bond market, price pressures, and liquidity. Section 3 presents the hypothesis empirically that I verify empirically. Section 4 describes the details of the primary auctions for Italy and Germany and explains the institutional structure of trading on MTS and the data. The empirical evidence about price pressures, liquidity, sovereign bond crisis, and PSPP is presented in Section 5. Section 6 concludes.

2 Literature Review

The analysis of market-makers' behavior in the fixed income, especially in the treasury market outside the U.S., received attention only on recent years due to the availability of the data and the development of electronic trading platforms. Thus, understanding the mechanisms that governs their presence in the sovereign bond market is crucial, since the

securities auctioned by the Treasuries are underwritten by the same primary dealers that are the market makers in the secondary market.

The earliest literature focused on how public information drives the price movements in the treasury market. The work of Fleming and Remolona (1997) concludes that there is a significant impact of the macroeconomic announcement on bond prices. Together with Ederington and Lee (1993), albeit the latter in the derivative market, they pioneered the intraday analysis of price behavior in a market different than the stocks. In their work, Fleming and Remolona (1997) shows that the sharpest price movements of the five-year U.S. Treasury note are related to just-released macroeconomic announcements. This issue has been deeply investigated in Fleming and Remolona (1999), where they analyze the quotes of the market makers, rather than the trades only. They find an almost instantaneous price movement at the time of the macroeconomic release, relating this finding to the theoretical model of French and Roll (1986), i.e., the reaction to the public information is anticipated by the quotes, and do not require trading activity. Fleming and Remolona (1999) suggest that the effect on the bid-ask spread is related to the inventory management of the market makers, that withdrawn their quotes anticipating the price changes.

The issue of the market makers' inventories has been analyzed by Fleming and Rosenberg (2008). Using weekly net position of the primary dealers in government securities, they find that dealers include in their balance sheets a large part of the sovereign bond supply, maintaining it until the maturity. Most importantly, for the purpose of this paper, their analysis shows that dealers are compensated for the inventory risk they run in the week of the auction, suggesting that dealers buy sovereign bonds in the auction week when the prices are lower, and sell the securities late when the price is higher.

The recent empirical literature focuses on the secondary market movements mainly using daily data. Lou, Yan, and Zhang (2013) shows that the US treasury bond prices decrease significantly five days before the auctions and then shortly recover, linking their results to the limited risk-bearing capacity of the dealers and imperfect capital mobility of end users. A similar pattern is also detected by Beetsma et al. (2016). In their paper, they study the auction effect for Italy and Germany, in the context of the financial crisis. They find that the auction effect is stronger in Italy, and exacerbates during the crisis. They identify the

volatility as the main driving factor for Italy, and the limited risk-bearing capacity of the dealers for Germany.

In a broader sample composed of six European countries Beetsma, Giuliodori, De Jong, and Hanson (2016) finds evidence of spillover effects across countries in sovereign auctions' days. In contrast to this empirical evidences, Cafiso (2015) do not find evidence of auction cycles for Italy in a reduced sample of auctions, after comparing the result of the auction with the contemporaneous market quotes. However, all the European contributions on this topic use daily data. The only empirical contribution that analyzes the intraday movement around the US Treasury auctions, and close to this work, is by Fleming and Liu (2016). They do find evidence of price pressure effect, not present in non-auction days. They also show that the liquidity tends to deteriorate at the time of the auction and recover thereafter. They conclude that the price pressure could be explained by the limited risk-bearing capacity of the dealers.

Several theoretical papers attempt to explain the V-Shaped pattern and the price overshooting. Brunnermeier and Pedersen (2005) explain that the sharp price movements and subsequent recovery are due to predatory trading. In their model, the strategy consists of a predator that sell the asset before another trader, that has to liquidate a position, enter the market. The price thus will move down. Further, the predator will realize the profit reversing their position. This practice damages the market quality.

Duffie (2010) introduces a model of price impacts and reversal. He related his model not only to unanticipated shocks but also to anticipated shocks like the treasury auctions. The main empirical implications of this model are that, after a shock, the (slow) mobility of the capital, or additional searching costs, affect the price reversal. As soon as the investors have additional capital, the price shock is reabsorbed. This model is particularly designed for markets where the trading is infrequent, such as the bond market.

Boyarchenko, Lucca, and Veldkamp (2016) deal with information sharing, and how it affects primary dealer, customers, and the U.S. Treasury during the auctions. Besides the results related to the degree of informativeness, in their model the do allow post-auction appreciation due to private information of the bidders. Thus, the appreciation is the return awarded to the auction participants that submit competitive bids.

The model of Bessembinder et al. (2016) specifically deal with the liquidity around predictable trades, specifically the roll-over of crude oil future contracts. The model is close in spirit of the one by Brunnermeier and Pedersen (2005), but they allow transitory effects on the prices, rather than permanent. The framework is particularly suitable also for the Treasury auctions, where the date is known in advance. They find, both theoretically and empirically, that the liquidity is higher during the event day (the roll-days), and this effect is due to the liquidity provision role that the monopolistic trader assume. Under a set of assumptions, a strategic trader acts beneficially for the market given that the price impact is not too large and temporary.

Close to this paper are Beetsma et al. (2016) and Sigaux (2017). Beetsma et al. (2016) present a stylized model that relates the price effect to the inventory position of the dealers: the larger the amount issued in the auction, the larger the inventory risk and thus the price effect. They find that during the crisis, the volatility effect is prevailing with respect to the limited risk-bearing capacity of the dealer. Sigaux (2017) introduces a model aimed to explain the auction pattern, assuming that the price gradually decreases due to the uncertainty about the (net) size of the trade. The main implication of the model is that investors face the trade-off about speculating on the difference between the prices before and at the auction, or hedge the uncertainty regarding the supply, buying more bonds before the auction takes place. One additional corollary regards the trading activity and the short-selling of the issued notes that are usually higher and increase close to the auction. The author verify this prediction empirically in a broad sample that goes from 2000 to 2015, which includes the re-openings of the Italian sovereign bonds with a maturity between 2 and 30 years.[3] He also finds the inverted V-shaped pattern of the yield difference, but he shows that the meeting between dealers and the Treasury, and the auction announcement are able to explain 2.4 basis point of the yield increase. This work complements and extends these work in several ways. First, I use intraday quote data, which allow to explain the behavior of the primary dealers exactly around the auction time, rather than analyze it across several days. The use of intraday data also reduce substantially the potential confounding effect due to different events in the estimation window, or when primary auctions dates in different countries very

[3]The author uses daily data from Datastream and secondary trades and Repo from MTS.

close each other. Second, the MTS database is far richer than other common sources, and includes (albeit anonymized) all quotes from different primary dealers, a reliable bid-ask spread, market depth and the active presence of the primary dealers in the market, proxied by the number of proposals.

3 Hypotheses

The existence of an auction pattern in the Sovereign bond market has been demonstrate in several past studies, as discussed in the literature review. The explanation that previous authors give to this pattern are related to different aspects, which includes inventory constraints and limited risk-bearing capacity of the dealers, excess volatility especially during the crisis periods, uncertainty related to the final outcome of the auction, or price informativeness. One consolidated result is that the effect at price level is long-lasting, it starts days before the auction and persist for a considerable number of days after. However, as pointed out by Beetsma et al. (2016) among others, there might be confounding factors that can affect the estimation of the auction patterns. These confounding factors might be related to auctions of different maturities that might take place in dates around the main event, macroeconomic announcements, trading strategies that involve the use of other instruments (Futures or Repo contracts), or hedging strategies using bonds with similar maturities. These additional factors are mostly taken into account by previous works that use daily data, but are clearly less important when using intraday data.

Intraday data allows capturing almost "instantaneous" price dynamics, that are not affected by the specialness in the repo market of the new "on-the-run" bond, in case of a new issuance.[4] In addition, it is possible to have an estimation of the auction effect that is purely due to the auction itself, and would yield and estimation of the fraction of the total price pressure that occurs along several days. One peculiar features of the MTS data is that it allows also to investigate the behavior of single dealers in the time surrounding the auction.

[4]See Duffie (1996) and Corradin and Maddaloni (2020) for a detailed explanation of the effect of specialness in normal times and during the crisis.

With respect to Beetsma et al. (2016), which is close to this work for the sample of countries considered in the analysis, there are several aspects that complements their analysis. First of all, it is possible to include additional aspects that contributes to the price pressure, namely the intraday bid-ask spread and the market depth. In fact, the intense price revision that occur before and after the auction time has clearly an effect on the quoted bid-ask spread and the amount (in money term) of market depth available to the market. This leads to consider in the auction effect not only a price pattern, but also a liquidity pattern. Second, Beetsma et al. (2016) consider as a proxy of the risk aversion of the dealer an index composed by the CDS spread of all primary dealers for each country. However, there is a strong interlinkage between the sovereign CDS and the banks that belongs to the same country,[5], in addition to the well established link between Sovereign CDS and Sovereign bond prices (Pelizzon et al. (2016)). As a measure of the risk aversion of the dealers, to complement the liquidity measures cited above, I introduce also the actual presence in the market during the auction, proxied by the number of proposals to buy or sell a given auctioned bond. This measure is interesting because it gives a straightforward measure of the dealers' willingness to trade (or not to trade) the bond. In case of capital constraint, risk aversion or uncertainty, dealer might withdrawn their quotes temporarily, and then re-post the orders at a later stage, when the uncertainty is resolved.

More generally, dealers are required to participate in the auction, submitting bids and setting aside resources (capital). Since they have to incorporate the new issuance into their balance sheets, one would expect that their behavior surrounding the auction is very risk-averse. Theoretically, I should observe an effect on the general liquidity of the day, a reaction close to the auction time, and a recovery of the liquidity measures after some time. According to the model of Bessembinder et al. (2016), the best strategy for a strategic trader is to provide liquidity when some other traders have to liquidate their position. This implies that, generally, the liquidity during the event days should be higher compared to the non-event day. However, the shocks (the auctions in our case) affects the price and also the behavior of the dealers. In Duffie (2010), dealers have capital constraint and, after a shock, the slow mobility of the capital affect the speed of reversal.

[5]See Avino and Cotter (2014)

In view of these consideration, I formulate the following hypotheses:

Hypotesis 1: a significant part of the price pressure around the auctions dates occurs at the day of the auction;

Hypotesis 2: at the auction date, also liquidity is affected, creating liquidity pattern not present in non-auction dates;

Hypotesis 3: primary dealers (that participate to the auction) became risk averse and have capital constraint, thus they do not to expose themselves in the secondary market during the auction, and withdrawn their quotes temporarily.

In addition to the following hypotheses, I also verify empirically how the ECB intervention (with the PSPP program) affect the price pressures, the liquidity and the risk aversion of the dealers.

4 Auction data, descriptive statistics and methodology

4.1 Primary Market Auctions

The data for the primary auctions are collected directly from the official websites of the respective Debt Management offices: Banca d'Italia and the Deutsche Finanzagentur. The focus of the empirical analysis is only on the coupon-bearing Sovereign bonds, issued by the Italian and the German Treasuries. As described in Pelizzon et al. (2016), the majority of the Italian bonds exchanged in the MTS market are coupon-bearing Treasury bonds, or Buoni del Tesoro Poliennali (BTP). In line with previous works the maturity selected are the 3, 5 and 10 years BTP. For the German sovereign bond market, the sample consists of the 2 years Schatz, the 5 years Bobl and the 10 years Bund. Table 1 provides an overview of the auctions data, distinguishing between new issues (new on-the-run bonds), subsequent issues of the same on-the-run bond (On the run) and re-open specific bonds in order to improve the liquidity in the secondary market, or following specific requests from the primary dealers (re-opens). The strategy of reopening off-the-run bonds is applied only by the Italian Treasury, especially for the 10Y maturity. Starting from October 2012, the Italian Treasury auctioned only new on-the-run, or increase the quantity of the current on-the-run. For the

Italian sample, only the regular auctions are considered, excluding the supplemental auctions reserved for specialists, that take place one business day after the regular auctions.[6]

Table 1 shows that the number of auctions is quite similar between the two countries across maturities, as well as the average amount bid and allotted in particular for the 5 and 10 years maturities. The average yield is very different, reflecting the riskiness of the two countries: Germany displays a lower yield, on average negative for the shorter maturity. The difference of the yield in the two countries is around 2% across maturities. The total number of auctions is higher for Italy, that has a higher amount of re-openings compared to Germany and mostly concentrated in the 10 years maturity. The bid-to-cover ratio (the ratio between the total amount of bids and the maximum amount announced by the Treasuries) varies across auction types. In general, the value is higher for the auctions that follow the first issuance. For the on-the-run bonds, the values are on average from 1.36 to 1.53 for Italy, and from 1.41 to 1.91 for Germany. The re-opens for the Italian bonds displays the highest bid-to-cover ratio among maturities, indicating a high demand for these bonds. For the German auctions, the retention quote is higher for the new issues, around 10%-20% of the bid quantity.[7]

4.2 Secondary market data and variables definition

The dataset of secondary market data is composed of all quotes, orders, and trades for the MTS European sovereign bond market platform, from June 2011 to December 2016. Data have milliseconds timestamp and, from the beginning of 2013, the timestamp is at the microsecond level. The starting point of the sample coincide with the availability of tick-by-tick data.[8]

In the MTS market, two types of traders exist, primary dealers (market makers) and other dealers (market takers). The primary dealers have market-making obligations that

[6]For the supplemental auctions, the amount offered varies from 10% to 30% of the amount allotted at the auction, and only the specialists with at least one valid offer in the main auction can subscribe for an additional quantity, at the same marginal price fixed at the auction one day before.

[7]For every auction, the German Finance Agency retain a portion of the issuance for secondary market operation. (See https://www.deutsche-finanzagentur.de/en/institutional-investors/secondary-market/activities/) This practice is not carried out in Italy.

[8]For the period before June 2011, only the best bid and ask quotes are available from MTS

Table 1 Auctions' results: This table presents the summary statistics for the 2, 3, 5 and 10-year government bonds issued by Italy and Germany, from June 2011 to December 2016. The source of data is the website of the national Treasury Authorities (The Italian Treasury for Italy, and the Deutsche Finanzagentur for the German issues).

Panel A: Results of Italian Auctions (June 2011-December 2016)

	New issues	On the run	Re open	New issues	On the run	Re open	New issues	On the run	Re open
		3Y			5Y			10Y	
Number of Auctions	14	44	1	13	52	6	11	56	18
Amount bidded (average M. euro)	5613	4407	1773	5144	3729	1483	5650	3751	1594
Amount allotted (average M. euro)	3785	2916	779	3788	2590	653	4023	2687	918
Bid-to-cover ratio (average)	1.48	1.53	2.28	1.36	1.45	2.37	1.40	1.41	1.79
Average Yield (%)	2.25	1.81	4.29	2.62	2.30	4.11	3.43	3.45	5.54

Panel B: Result of German Auctions (June 2011-December 2016)

	2Y		5Y		10Y	
Number of Auctions	20	47	13	47	13	53
Amount bidded (average M. euro)	7252	7087	5726	5413	5369	4812
Amount allotted (average M. euro)	4213	3729	3926	3211	4040	3429
Retention Quote (average M. euro)	937	760	1074	725	1114	798
Bid-to-cover ratio (average)	1.74	1.91	1.47	1.70	1.32	1.41
Average Yield (%)	-0.06	0.00	0.47	0.32	1.29	1.10

require them to post on both sides of the market and to maintain a spread close to the average spread of the other primary dealers. The MTS also allows the use of iceberg orders, i.e. traders can display only a portion of the quantity that they are willing to trade. The trading hours goes from 8:00 a.m. to 5:30 p.m. Anonymity is preserved until the trade is executed; if the trade is centrally cleared, also the two counterparties of the trade are anonymous.

The bonds considered in the sample are only coupon bearing bonds, quoted in price per €100 of face value. The sample is restricted only to bonds that have been auctioned (or re-auctioned) during the sample period. The descriptive statistics of the sample, only for the auction dates, are provided in Table 2.

Several order book measures are calculated directly from the high-frequency quotes, extracting snapshots of the order book every minute. The *midprice* is calculated as a simple average of the best bid and best ask prices available. If one of the two prices (bid or ask) is not available, then the midprice is not calculated. Table 2, Panel A shows the average midprice for each Italian bonds is higher than the correspondent German bond for the same, or similar, maturity (Table 2, Panel B). The standard deviations and the two reported percentiles (P5 and P95) characterize a higher dispersion of the distribution. The *yield* of each bond is calculated directly from the quotes, taking into account the different rules for the coupon payments (semiannual for the Italian Bonds, annual for the German Bonds). The average yields numbers are in line with the values presented in Table 1 for the auction results. The average yield for the shortest maturity (2Y) for Germany is negative, reflecting the effects of the ECB quantitative easing and the low-interest rate environment in the aftermath of the financial crisis.

Following Fleming and Liu (2016), to analyze the impact of the Treasury auctions on the secondary market, I calculate the yield difference, i.e., the simple difference between the yield of the bond in a certain period after and before the auction, and the yield in the secondary market at the auction. The yield difference is calculated as:

$$Yield\ difference_{i,t,d} = Y_{i,d,TA-\epsilon} - Y_{i,d,TA} \tag{1}$$

Table 2 Descriptive statistics This table shows the summary statistics for the sample of Treasury coupon bonds included in the intraday analysis, only for the auction dates, for Italy (Panel A) and Germany (Panel B). The database is composed by fixed coupon sovereign bonds for Italy [Buoni del Tesoro Poliennali (BTP) with a maturity of 3, 5 and 10 years)] and Germany [2 years Schatz, 5 years Bobl and 10 years Bund], from June 2011 to December 2016. The source of data is the Mercato dei Titoli di Stato (MTS).

Panel A: ITALY

	3Y				**5Y**				**10Y**			
	Mean	STD	P5	P95	Mean	STD	P5	P95	Mean	STD	P5	P95
Midprice	101.82	2.52	97.88	106.00	104.36	4.20	96.84	110.26	107.17	9.29	91.76	122.11
Yield (%)	1.44	1.54	-0.04	4.80	1.54	1.63	-0.03	5.02	2.46	2.03	0.10	5.92
Yield Difference (bps)	-0.99	5.59	-9.30	3.90	-1.52	4.52	-9.10	3.00	-1.56	4.13	-8.50	3.40
Bid-Ask Spread	0.11	0.42	0.01	0.30	0.12	0.27	0.02	0.34	0.19	0.38	0.03	0.63
Depth (M €)	124.34	33.46	53.00	165.75	122.07	32.31	54.00	162.25	116.93	31.59	49.50	156.25
N. Proposals	19.99	5.32	8.00	27.00	20.14	5.40	8.00	27.00	20.05	5.46	8.00	27.00
Daily Volume Traded (M €)	542.57	141.86	309.50	822.50	499.76	226.78	84.50	961.50	289.57	206.23	54.50	673.00
Daily N. Trades	97.32	26.40	53.00	144.00	97.94	43.90	17.00	182.00	64.04	41.35	12.00	139.00
Bonds	15				15				18			
Days	58				68				77			

Panel B: GERMANY

	2Y				**5Y**				**10Y**			
	Mean	STD	P5	P95	Mean	STD	P5	P95	Mean	STD	P5	P95
Midprice	100.41	0.50	99.80	101.29	102.19	2.00	99.57	106.21	106.24	6.13	98.57	118.34
Yield (%)	-0.09	0.32	-0.68	0.27	0.02	0.42	-0.64	0.69	0.77	0.84	-0.54	1.91
Yield Difference (bps)	-0.11	0.87	-1.50	1.10	-0.07	1.23	-1.90	1.90	-0.36	1.94	-3.50	2.40
Bid-Ask Spread	0.05	0.21	0.02	0.08	0.06	0.09	0.03	0.10	0.08	0.52	0.03	0.13
Depth (M €)	69.42	27.18	22.00	110.00	69.58	22.44	25.00	100.00	71.38	23.23	25.00	105.00
N. Proposals	7.91	2.63	3.00	12.00	8.32	2.59	3.00	12.00	9.21	2.88	3.00	13.00
Daily Volume Traded (M €)	50.75	57.29	5.00	155.00	41.40	40.20	5.00	110.00	35.65	34.56	2.50	120.00
Daily N. Trades	4.45	5.89	0.00	16.00	3.38	4.93	0.00	15.50	4.67	6.01	0.00	21.00
Bonds	15				15				15			
Days	60				60				65			

Where $Y_{i,d,TA-\epsilon}$ is the yield measured in one-minute increments ϵ minutes away from the auctions time, for bond i and day d, and $Y_{i,d,TA}$ is the yield measured at the time of the auction. The auction time are 11:00 a.m. and 11:30 a.m for Italy and Germany, respectively. The time series evolution of the yield difference is presented in Section 5.

Table 2, Panel A and B show the average yield difference (in basis points) for the entire day. The values across countries reflect the different yields of the underlying bonds. On average, the value is negative, and Italy displays higher values of these differences. To measure the liquidity of the bonds, I consider two different liquidity measures. The First liquidity measure is the *Bid-Ask Spread*, calculated as the difference between the best ask price and the best bid price available in a given minute. Table 2 Panel A shows that the Bid-Ask Spread for the Italian bonds ranges, on average, from 0.11 euros (maturity of 3 years) to 0.19 (maturity of 10 years). These figures are almost halved for the German Bid-Ask spread, reflecting the lower risk and the high liquidity of the German bonds (Panel B). The second is the total *depth* of the market, calculated for each one-minute interval as the average quantity at the bid and ask, quoted in the entire order book and measured in millions of euros (par value). Table 2, Panel A shows that the depth across maturities for Italy is comparable and, on average, around 120 millions euros. Panel B shows that the average depth for the German market is roughly one half compared to Italy, around 70 millions of euros across maturities.

As a proxy for the risk aversion of the dealers, I use the number of proposals (*N. Proposals*) available for trading, for each minute. Every quote, or "proposal" in the database can be tracked throughout the trading day and is representative of one single dealer. A high number of proposals indicates that the dealers are available to trade, and the market is therefore liquid. Table 2 shows that the average number of proposals is higher for Italy (20) compared to Germany (8), mainly for two reasons. The first is that the number of participants is smaller for MTS Germany. The second is that other competing venues have a considerable market share for the German Sovereign bonds. On top of this, a substantial number of trades for the German bonds is conducted over-the-counter. According to MTS, there are 56 participants for MTS Italy, and 36 for MTS Germany as of end 2017.[9] Crossing

[9]The List of market participants, for both Market Makers and Takers, is available on the MTS website for Italy and Germany

the two lists, there are 22 dealers that operate as market makers in both markets. Among them, three are Italians (Banca IMI, Banca Sella, and Monte dei Paschi) and one is German (Deutsche Bank). One interesting difference between Italy and Germany is that the Bank of Italy is recognized as a dealer only for the Italian market, while the Finanzagentur is not present in both lists.

Table 2 also provides an overview of the trading activity during the auction days. The daily volume traded for the Italian bonds (Panel A) is higher for the shortest maturities: the 3 years BTP display an average of 542 millions of euros, while for the 10 years, the average value is 289 million. On average, the number of daily trades is around 97 for the 3 and 5 years maturity, and 64 for the 10 years maturity. Panel B shows that the volume traded and the number of trades for the German bonds is more than an order of magnitude smaller. Finally, the number of bonds and auction days considered in the analysis are similar for the two countries.

In the MTS market, there is also the possibility to trade a bond that has been announced by the Treasury, but not yet issued. This is usually referred as "grey market" or "when-issued market". Sovereign bonds traded on the grey market will be settled following the settlement conditions of the issued bond. The grey market activity in the sample is particularly relevant for the newly issued bonds, which will be the new on-the-run after the auction. There is evidence of quoting activity for both Italy and Germany in the grey market. However, trading activity is present only for the Italian Sovereign bonds. Figure 1 plot the time-series evolution of the traded volume, for the 3, 5 and 10 years Italian notes and represent the traded volume of the current on-the-run bond, i.e., each bar corresponds to the total quantity traded for the current on-the-run bond. The red bars represent the volume traded in the grey market before a new on-the-run bond is issued. The trading activity in the grey market usually appears around three days before the auction, since the Treasury has to announce the full details of the auctioned bond (ISIN Code, maturity, and coupon). For the US Treasury market, Fabozzi and Fleming (2000) document that the volume traded in the grey market accounts for around six percent of the total volume of Treasury securities traded electronically. Figure 1 shows that there is a non-negligible volume traded before the auction for all the maturities.

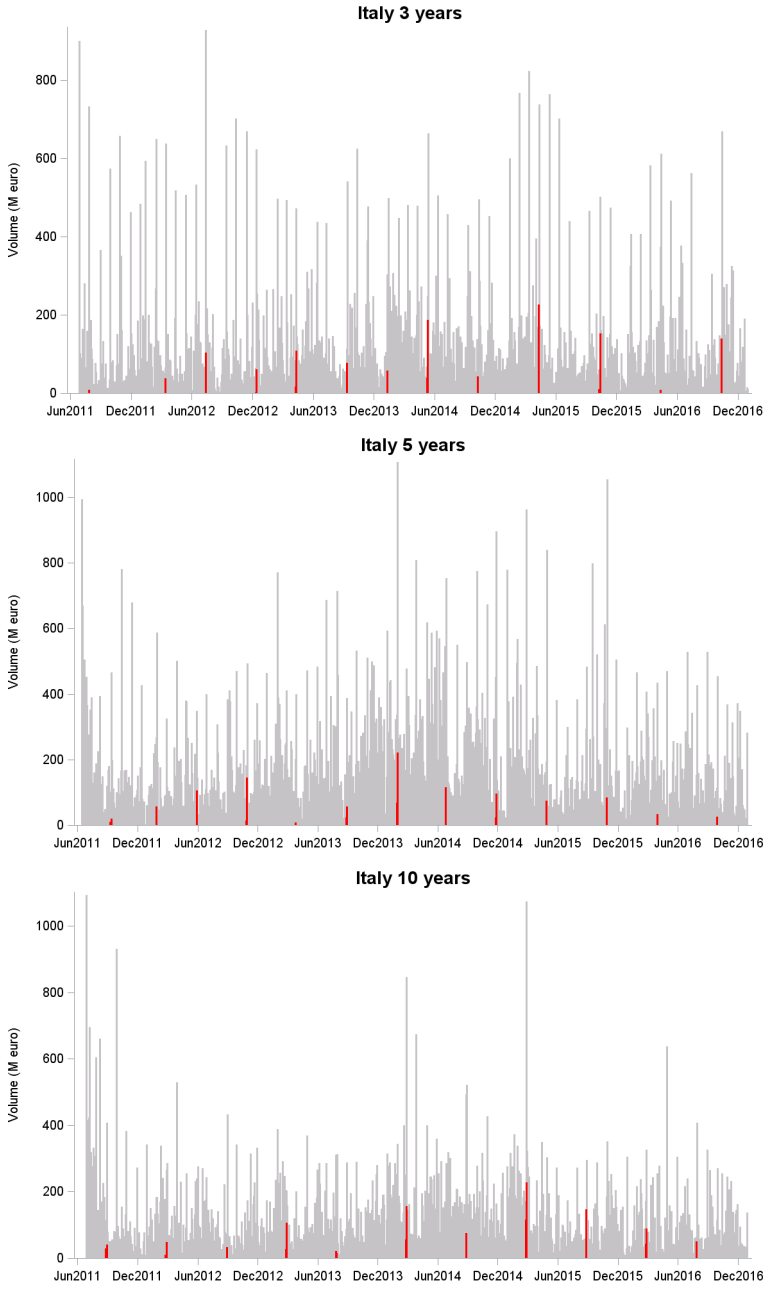

Figure 1. Trading volume and Grey Market for the Italian Sovereign Bonds
This figure shows the total trading activity only for the respective on-the-run bond in the sample period. The red bars represent the quantity traded in the grey market, before the official issuance of the new on-the-run bond. The database is composed by fixed coupon sovereign bonds for Italy [Buoni del Tesoro Poliennali (BTP) with a maturity of 3, 5 and 10 years)], from June 2011 to December 2016. The source of data is the Mercato dei Titoli di Stato (MTS).

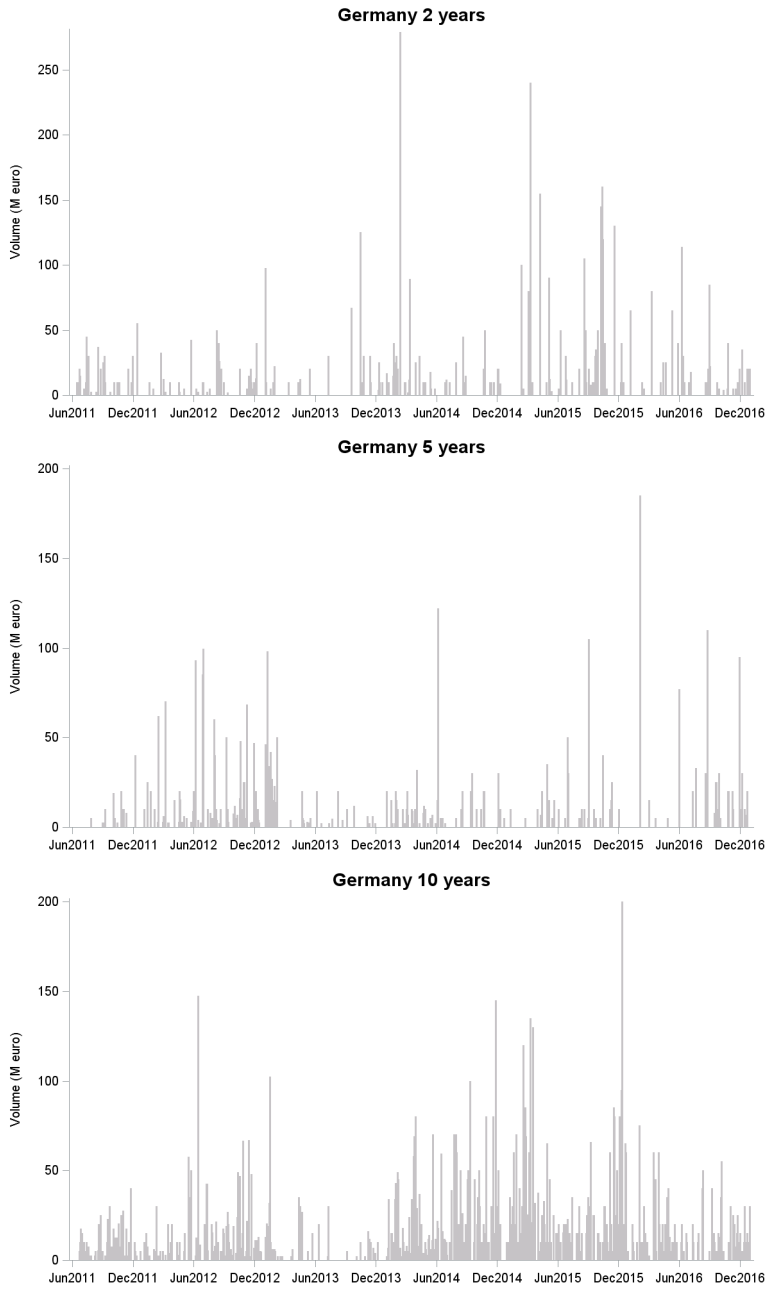

Figure 2. Trading volume for the German Sovereign Bonds

This figure shows the total trading activity only for the respective on-the-run bond in the sample period. The database is composed by fixed coupon sovereign bonds for Germany [2 years Schatz, 5 years Bobl and 10 years Bund], from June 2011 to December 2016. The source of data is the Mercato dei Titoli di Stato (MTS).

Figure 2 shows that the overall trading activity for the German bonds is lower. Especially during 2013 and across maturities, there is a sharp reduction of the trading volume, which increase afterward starting from January 2014, particularly for the 10 years Bund. As pointed out before, there is no trading activity in the grey market for the German bonds.

5 Empirical Results

5.1 Auctions' days and Price Pressure

The aim of this section is to verify whether the first hypothesis is verified, i.e. there is empirical evidence that the Treasury auctions are a source of temporary price movements in the secondary market during the auction day. To do so, I calculate the Yield difference as defined in Equation 1, for each auctioned bond, for Italy and Germany. The yield difference is measured in the window from two hours before the auction to two hours after the auction, in a way that the value of ϵ of Equation 1 ranges from -120 to +120 minutes.[10] Thus, the time of the auction is always zero.

The main analysis considers only the auction days of the on-the-run bonds, excluding the days where the new on-the-run is issued.[11] Table 3 reports the average yield difference for Italy and Germany, only for the on-the-run bonds, for different intervals ranging from 2 hours before to 2 hours after the auction.

A negative yield difference implies that the yield at the time of the auction is higher compared to the yield before and after the issuance time. Panel A of Table 3 shows the results for the Italian bonds where, for almost all the intervals considered in the analysis, the difference is negative for all the maturities, especially for the 5Y and 10Y notes. For the 3Y bonds, the yield difference is statistically significantly different from zero starting from 100 minutes before the auction, but twenty minutes after the auction, it is no longer

[10] Fleming and Liu (2016) use a larger time window, that goes from minus four hours to plus for hours of the auction time. There are two reasons to choose a smaller window. The first is related to the auction time of Italy and Germany (11 a.m. and 11:30 a.m.). The second is related to the high price volatility and bid-ask spread at the beginning of the day. This effect is due to the fact that not all the dealers' quotes are present immediately after market opening.

[11] As a robustness check, I repeat the same analysis also for the auctions of the newly issued bonds, which includes the quotes in the grey market and, for Italy only, the re-openings of off-the-run bonds. The analysis is presented in Appendix.

significant. For the 5Y and 10Y Italian bonds, the yield difference is always negative and significant in the entire estimation window.

The effect is almost symmetric for the 5Y notes: two hours before the auction, the yield difference is around 1.6 basis points. Two hours after, the same difference is around 1.77, indicating that the price of the bond return to the initial value before the auction. The pattern is similar also for the 10Y bonds. This symmetric pattern is not present for the 3Y bonds, where, after a significant movement in the 10 minutes after the auction, the yield remains statistically the same in the following two hours.

Panel B of Table 3 reports the same analysis for the German bonds. In this case, the shortest maturity (2Y) does not display a consistent significant pattern around the auction, albeit the yield difference is negative for almost all the time intervals. The yield difference for the 5Y German bonds is statistically different from zero starting from twenty minutes before the auction and remains significantly different up to one hour after. The 10Y Bund display the strongest auction effect in the pool of German bonds. The yield difference is negative and statistically significant starting from 100 minutes before the auction and remains different from zero for the rest of the time window. The effect is, also in this case, almost symmetric. A graphical evidence of the inverted V-shaped pattern for Italy and Germany is provided in Figure 3. The solid line represents the average yield difference (in basis points), the shaded area displays the 95% confidence intervals, and the dashed line shows the yield difference calculated, for the same set of bonds, when there are no auctions. The figure shows that the auction effect is particularly pronounced for the Italian 5 and 10Y bonds, and for the 10Y German Bund, and confirm the Hypothesis 1 for the presence of a significant price pressure at the day of the auction. Since the pattern is not present in non-auction days (dashed line in Figure 3), this effect is peculiar and can be attribute to the event itself.

The work of Beetsma et al. (2016) reports for Italy, a yield daily movement up to 3.5 basis points for the 5Y and 10Y Italian bond, while the intraday quote movement I evaluate is up to 2 basis points across maturities. Albeit a direct comparison cannot be done, since in most cases the intraday yield almost completely revert back to the initial value, the estimation suggests that more than one-half of the total price pressure (that occurs along several days) can be tracked intraday. For Germany, the average yield differences across maturities are

Table 3 Yield Difference On the run This table shows the average yield difference, or the yield change from t minutes before the auction to the time of auction ($t = 0$), for the re-opening of on-the-run bonds. The auction times are 11:00 a.m. for Italy, and 11:30 a.m. for Germany. The midpoint is converted into yields using the respective conventions. The number of observations corresponds to the number of auctions for each country and maturity (Panel A for Italy, and Panel B for Germany). *, **, and *** denote significance at the 10, 5, and 1% levels using a t-test to verify if the values are statistically different from zero. The database is composed by fixed coupon sovereign bonds for Italy [Buoni del Tesoro Poliennali (BTP) with a maturity of 3, 5 and 10 years)] and Germany [2 years Schatz, 5 years Bobl and 10 years Bund], from June 2011 to December 2016. The source of data is the Mercato dei Titoli di Stato (MTS).

Panel A: Italy On-the-run bonds

	3Y		**5Y**		**10Y**	
t	Avg. Yield Diff.	Tstat	Avg. Yield Diff.	Tstat	Avg. Yield Diff.	Tstat
-120	-1.530	-1.594	-0.958	-1.314	-1.550**	-2.408
-100	-2.011**	-2.337	-1.609**	-2.289	-2.016***	-3.275
-80	-2.104***	-2.980	-2.105***	-3.389	-2.015***	-3.754
-60	-1.888***	-3.061	-2.18***	-4.306	-1.856***	-4.168
-30	-1.497***	-3.829	-1.483***	-4.062	-1.071***	-3.492
-20	-1.020***	-3.480	-1.276***	-3.716	-0.861***	-3.223
-10	-0.5**	-2.519	-0.570**	-2.469	-0.293*	-1.711
10	-0.675***	-2.993	-0.701***	-2.982	-0.877***	-3.838
20	-0.172	-0.403	-1.116***	-3.347	-1.051***	-2.704
30	0.147	0.274	-1.389***	-3.609	-1.018**	-2.528
60	-0.065	-0.112	-1.041**	-2.463	-1.101***	-3.237
80	0.238	0.324	-1.172**	-2.512	-0.936**	-2.264
100	0.136	0.166	-1.583***	-3.475	-0.980**	-2.302
120	-0.236	-0.311	-1.770***	-3.420	-1.322***	-3.190
Obs	44		52		56	

Panel B: Germany On-the-run bonds

	2Y		**5Y**		**10Y**	
t	Avg. Yield Diff.	Tstat	Avg. Yield Diff.	Tstat	Avg. Yield Diff.	Tstat
-120	-0.111	-0.796	-0.102	-0.445	-0.303	-1.302
-100	-0.132	-1.168	-0.112	-0.534	-0.486**	-2.057
-80	-0.247**	-2.443	0.034	0.164	-0.401*	-1.897
-60	-0.173*	-1.785	0.058	0.277	-0.363*	-1.871
-30	0.085	1.067	-0.121	-0.648	-0.336***	-2.770
-20	-0.046	-0.822	-0.270***	-2.745	-0.286***	-2.764
-10	-0.059	-1.113	-0.142**	-2.169	-0.278***	-4.018
10	-0.210***	-2.928	-0.287***	-3.241	-0.338***	-2.983
20	-0.185*	-1.856	-0.389***	-3.062	-0.369***	-2.903
30	-0.146	-1.499	-0.365***	-2.983	-0.5***	-3.440
60	-0.202*	-1.731	-0.421**	-2.410	-0.530***	-2.911
80	-0.178	-1.306	-0.314	-1.595	-0.461**	-2.332
100	-0.234	-1.585	-0.295	-1.286	-0.501**	-2.316
120	-0.331**	-2.301	-0.291	-1.219	-0.575**	-2.602
Obs	47		47		53	

smaller and comparable with the intraday data on the US treasury notes reported in Fleming and Liu (2016). The maximum average intraday yield difference is about 0.5 basis points, while Beetsma et al. (2016) reports a maximum yield increase around 2.5 basis point for the five year bonds.

The bottom of Figure 3 also reports for each panel the evolution of the average total depth. There is a remarkable difference between Italy and Germany. For Italy, the quoted depth sharply decrease few minutes before the auction and then takes several minutes to recover. For Germany, the average depth mildly changes only for the 10Y bond. The evolution of the depth, toghether with the bid-ask spread, will be analyzed explicitly in Section 5.2.

Following Lou et al. (2013) and Fleming and Liu (2016), I introduce an additional measure that integrate the impact before and after the auction and is more robust to detect and measure the auction effect with respect to the yield differences, the Δ *return* for bond i, day d, and time ϵ, defined as follows:

$$\Delta \ return_{\ i,d,\epsilon} = \left(\frac{Midquote_{\epsilon} - Midquote_{TA}}{Midquote_{TA}} \right) - \left(\frac{Midquote_{TA} - Midquote_{-\epsilon}}{Midquote_{-\epsilon}} \right) \quad (2)$$

where $Midquote$ represents the average of the bid and ask quote for each minute snapshot, and ϵ represents the time (in minutes) before and after the auction where the return is calculated. The first ratio of Equation 2 represent the return after the auction, while the second fraction is the return before the auction.

As shown in Panel A of Table 4, the cumulative return for an Italian 10Y on-the-run bond thirty minutes after the auction is, on average 12.41 bps higher than the return of the same bond thirty minutes before the auction, statistically significant at the 1% level. The Δ *return* for the 5Y bond displays a slightly lower value (11.63 bps). For the 3Y bonds, the difference between return is always positive, but significant only up to 80 minutes before and after the auction. Panel B of Table 4 shows the value of Δ *return* for the German bonds. The results are mixed for the 2Y and 5Y bonds, and does not allows to drawn conclusions.

For the 10Y bond, the difference between the two return is always positive and significant at the 1% level, with values halved compared to the Italian bonds. Thirty minutes after the

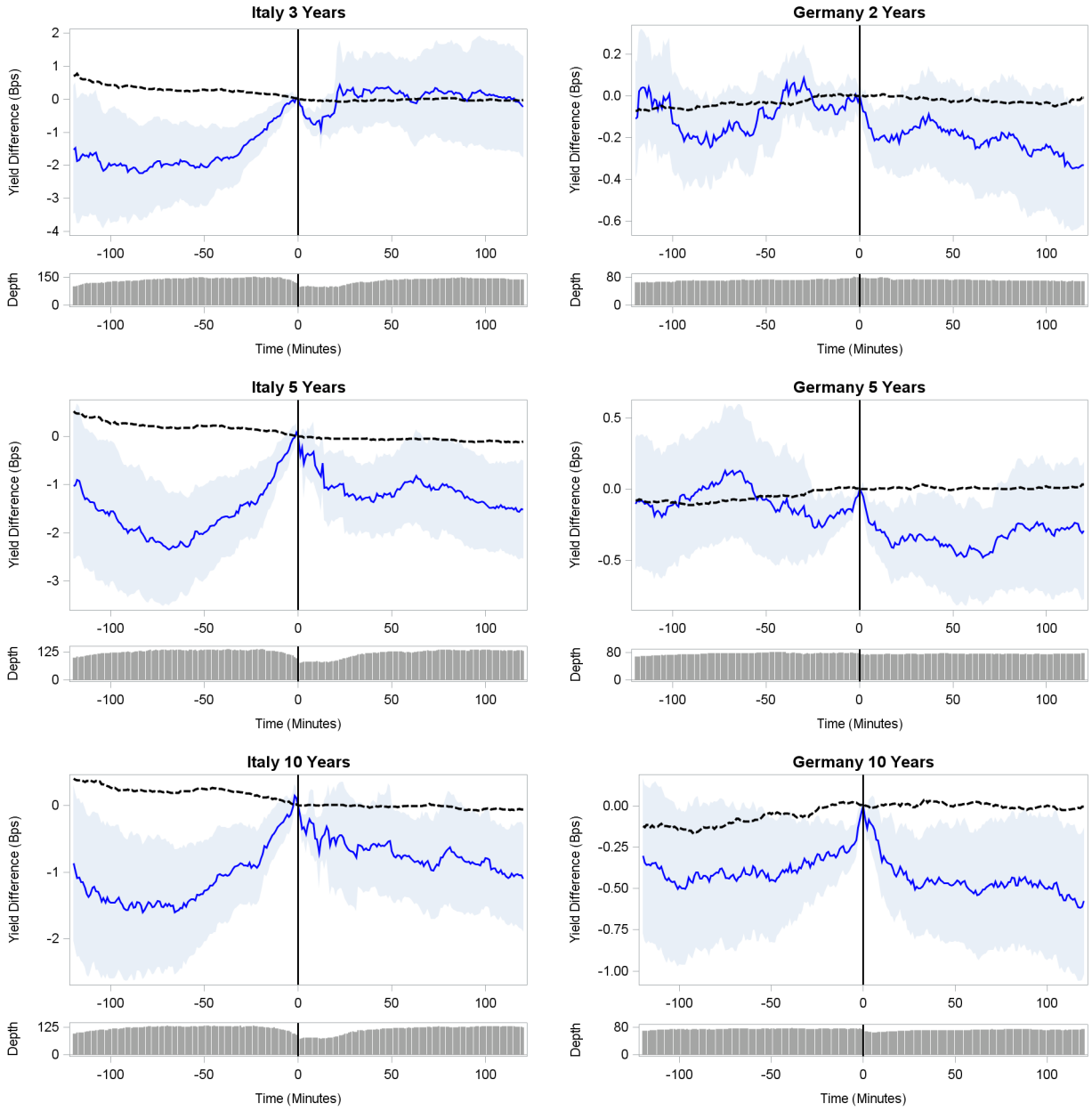

Figure 3. Yield difference for the On-the-run bonds

This figure plot the average yield difference (top panel) and the total depth available in the market (bottom panel, in Millions of €), for the re-opening of on-the-run bonds during the auction dates. The shaded area represents the 95% confidence interval around the sample mean, and the black dashed line represents the average yield difference on non-auction dates. The database is composed by fixed coupon sovereign bonds for Italy [Buoni del Tesoro Poliennali (BTP) with a maturity of 3, 5 and 10 years)] and Germany [2 years Schatz, 5 years Bobl and 10 years Bund], from June 2011 to December 2016. The source of data is the Mercato dei Titoli di Stato (MTS).

Table 4 Return for the on-the-run Bonds This table shows the Average Δ Return, or the cumulative return before and after the auction as defined in Equation 2, during the auction dates for the re-opening of on-the-run bonds. The number of observations corresponds to the number of auctions for each country and maturity (Panel A for Italy, and Panel B for Germany). *, **, and *** denote significance at the 10, 5, and 1% levels using a t-test to verify if the values are statistically different from zero. The database is composed by fixed coupon sovereign bonds for Italy [Buoni del Tesoro Poliennali (BTP) with a maturity of 3, 5 and 10 years)] and Germany [2 years Schatz, 5 years Bobl and 10 years Bund], from June 2011 to December 2016. The source of data is the Mercato dei Titoli di Stato (MTS).

Panel A: Italy On-the-run bonds

	3Y		**5Y**		**10Y**	
Time (minutes)	Avg. Δ Return	Tstat	Avg. Δ Return	Tstat	Avg. Δ Return	Tstat
10	3.050***	3.918	5.187***	3.465	6.201***	3.308
20	3.177**	2.524	9.783***	4.445	10.686***	2.796
30	3.561**	2.229	11.638***	4.492	12.416***	3.249
60	5.164**	2.367	14.196***	4.413	18.004***	4.209
80	5.027*	1.853	14.337***	4.011	16.523***	3.188
100	5.092	1.560	13.117***	3.268	17.372***	3.232
120	4.749	1.372	11.406**	2.597	15.329***	2.754
Obs	44		52		56	

Panel B: Germany On-the-run bonds

	2Y		**5Y**		**10Y**	
Time (minutes)	Avg. Δ Return	Tstat	Avg. Δ Return	Tstat	Avg. Δ Return	Tstat
10	0.530**	2.665	2.085***	3.498	5.621***	4.321
20	0.461*	1.828	3.227***	4.081	5.957***	3.946
30	0.139	0.471	2.383**	2.269	7.712***	4.643
60	0.738**	2.475	1.890	1.404	8.123***	3.437
80	0.873***	2.750	1.444	0.972	7.681***	3.022
100	0.711*	1.837	2.002	1.448	8.799***	3.055
120	0.953**	2.375	1.979	1.249	8.231***	2.782
Obs	47		47		53	

auction, the return is, on average 7.71 bps higher than the return thirty minutes before the auction. Figure 4 plot the values of Δ *return* for the entire estimation window, for both Italy and Germany, depicting the summary results presented on Table 4. Further, the pattern of the Δ *return* is specific for the auction days: the dashed line in Figure 4 shows that the return is close to zero or negative during non-auction days.

5.2 Liquidity and Risk Aversion

The statistics presented in Table 2 shows that, especially for the German sovereign bonds, the daily number of trades is quite low. Thus, one has to rely on different measures of liquidity, as described in Schneider, Lillo, and Pelizzon (2016). According to the model of French and Roll (1986), the reaction of the market does not require trades but is anticipated and followed by the quoting activity.

Given the particular microstructure of the MTS market, I consider two measures of liquidity, described in Section 4: the *Bid-ask spread* and the total *depth* of the market, plus a third measure, the number of proposals (*N. Proposals*) available in the market, as a proxy for the risk aversion of the dealers. These three measures are closely related to each other: the higher the number of proposals available in the market, the higher is usually the depth, and the lower is the bid-ask spread.[12]

The graphical representation of these measures, presented in Figure 5 for a subset of bonds-country, allows outlining an initial assessment of the liquidity effect induced by the Treasury auctions. In almost all the considered panels, and for at least one measure, there is a significantly different behavior of the market participants. For a straightforward comparison, the black dashed line represents the average values of the metrics in non-auction days. Non-auction days are defined as days where there are no auctions for both the Italian and the German Treasury, for any maturity and any bonds. In most of the cases, there is a sharp adjustment very close to the auction time (time 0 in the plots), with a subsequent adjustment that could last, when present, one hour. For this reason, I introduce a two-stage analysis

[12] Pelizzon, Subrahmanyam, Tomio, and Uno (2014) and Schneider et al. (2016) consider three measures of liquidity, the bid-ask spread, the total quoted volume (or total depth) and the inverse depth, that reflects the cost of immediacy. I include only the first two measures in my analysis, since I am interested in the liquidity shocks due to the auction, rather than due to potential trading activity.

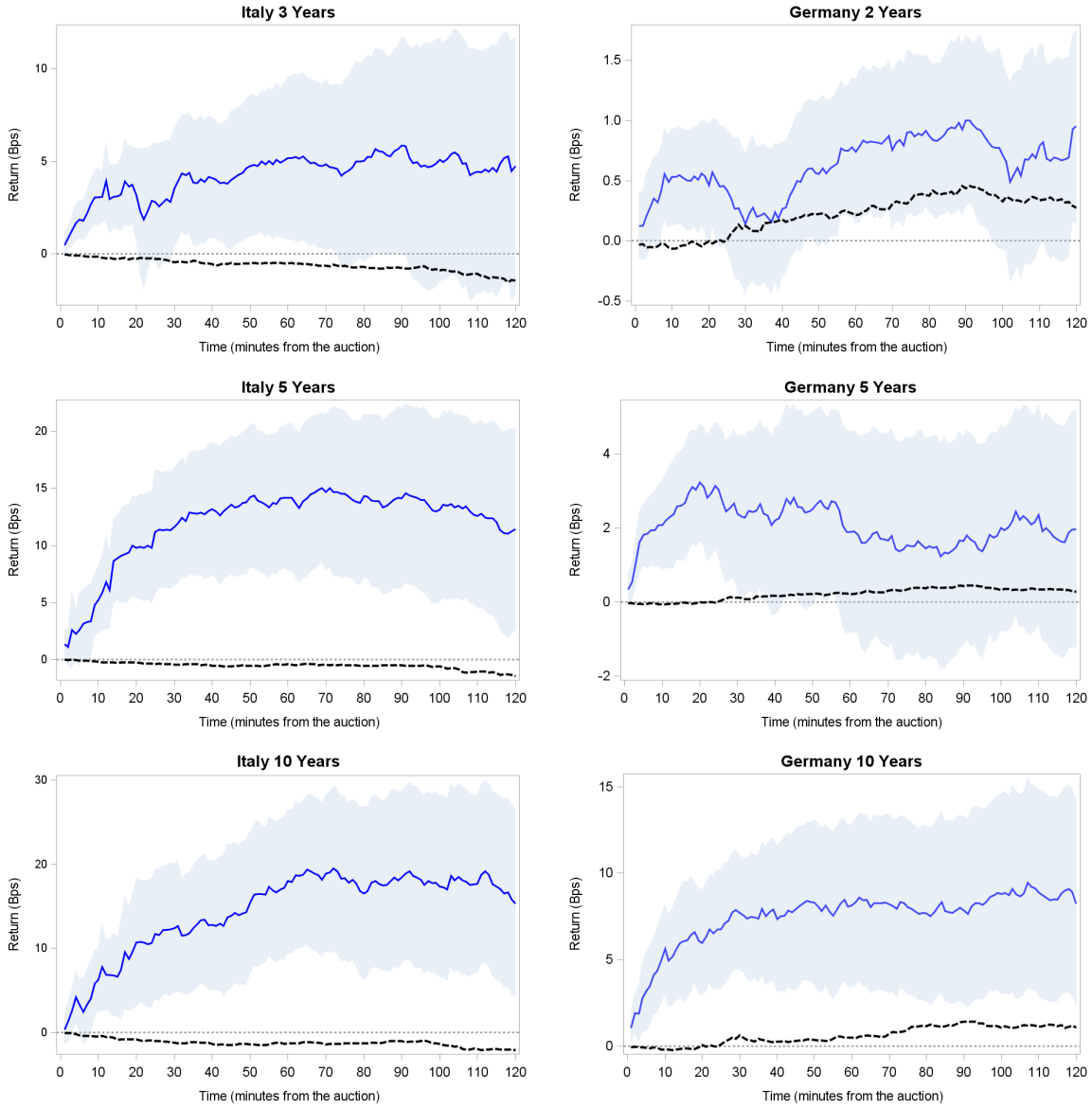

Figure 4. Cumulative Return for the On-the-run bonds

This figures plot the cumulative average Δ return, or the cumulative return before and after the auction as defined in Equation 2, during the auction dates for the re-opening of on-the-run bonds. The shaded area represents the 95% confidence interval around the sample mean, and the black dashed line represents the average cumulative return on non-auction dates. The database is composed by fixed coupon sovereign bonds for Italy [Buoni del Tesoro Poliennali (BTP) with a maturity of 3, 5 and 10 years)] and Germany [2 years Schatz, 5 years Bobl and 10 years Bund], from June 2011 to December 2016. The source of data is the Mercato dei Titoli di Stato (MTS).

in the spirit of Fleming and Remolona (1999). The first stage uses minute-by-minute time interval from five minutes before the auction, to five minutes after the auction, in order to analyze the response of the liquidity measures to in the time immediately surrounding the auction. Since the auction, like the macroeconomic news in Fleming and Remolona (1999), are announced well in advance, I expect a comparable reaction in a very short time frame. The second stage takes into account the subsequent adjustments that occur after the announcement of the auction results. Graphically, figure 5 shows that the adjustment could take a significant amount of time. For this reason, I use ten-minutes intervals from one hour before to one hour after the auction.

5.2.1 First stage analysis

The minute-by-minute analysis allows evaluating the short-term impact of the auction. Table 5 presents the bid-ask spread, the number of proposals and the total depth, for every minute from 10:55 to 11:05 for the Italian bonds, and from 11:25 to 11:35 for the German bonds. A common result across bonds is that the bid-ask spread is lower in the five minutes prior to the auction compared to non-auction days. Panel A of Table 5 examine the liquidity measures for the 3Y Italian BTP. The bid-ask spread is significantly lower in auction days, but this gap closes quickly five minutes after the auction time, where the spread is statistically equal to the non-auction days. The number of proposals in the market significantly drop exactly at the time of the auction and remains at a lower level for the entire time window. On average, from 1 to 3 dealers are withdrawing their quotes. In terms of total depth, the quantity available starts dropping by around 10 millions two minutes before the auction and reaches the lowest peak three minutes after. Panel B of Table 5 examine the liquidity measures for the 2Y German bond. In this case, the only significant effect is related to the bid-ask spread, that is significantly lower for the entire time window. No significant effects are present for the number of proposals and the depth: both remains comparable to the non-auction days.

Panel C of Table 5 shows the results for the 5Y Italian bond. In this case, the bid-ask spread before the auction is lower than usually, but exactly at the time of the auction, it starts increasing sharply, becoming six basis point higher than usual three minutes after the

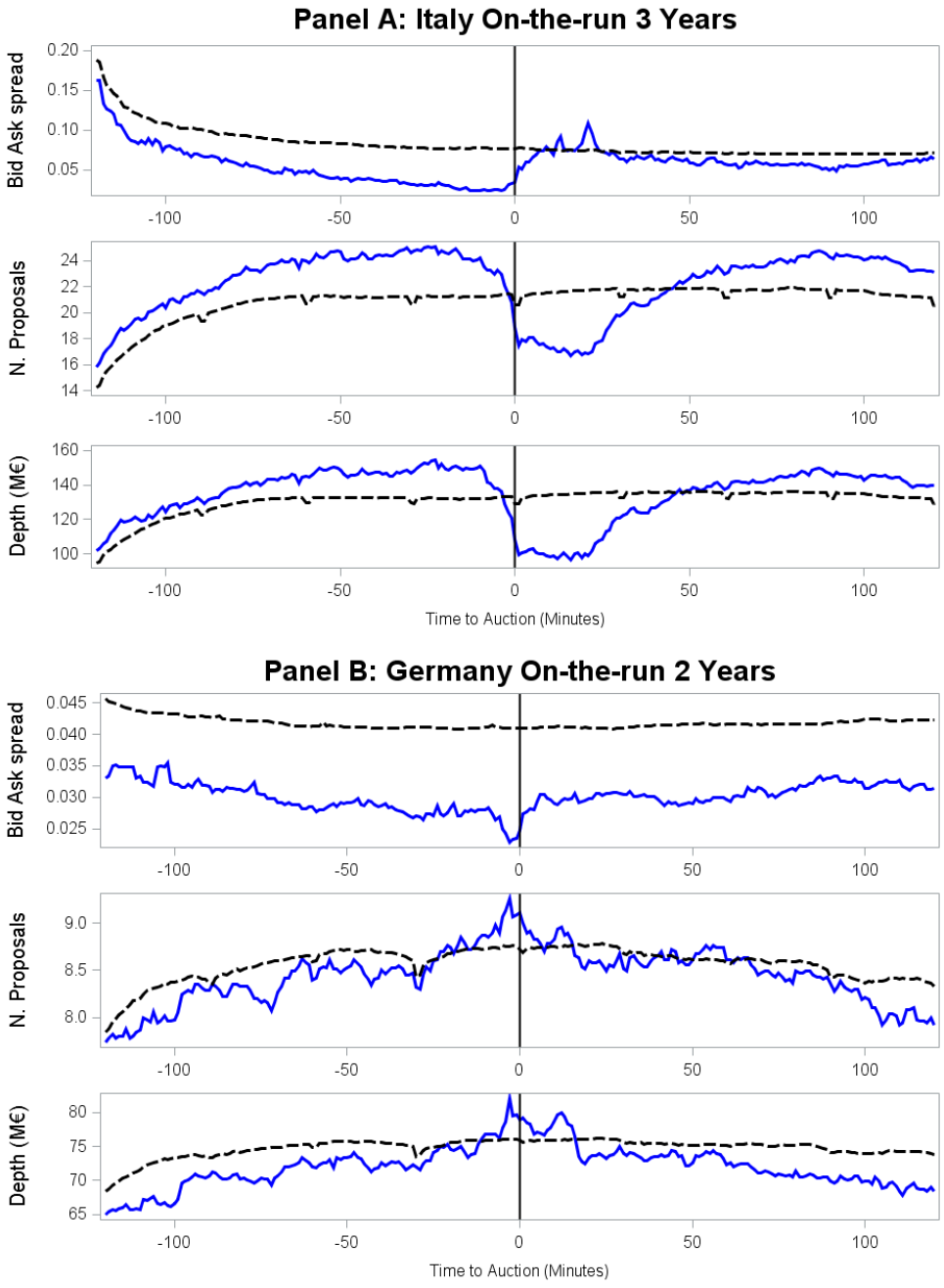

Figure 5. Liquidity and Risk-aversion measures

This figures plot the average Bid-Ask spread, the number of proposals and the total depth (in Millions of €) as defined in Section 4.2, for each one-minute interval for a sample of bonds. The black dashed line represents the average value of the measures on non-auction dates. The database is composed by fixed coupon sovereign bonds for Italy and Germany, from June 2011 to December 2016. The source of data is the Mercato dei Titoli di Stato (MTS).

auction. The number of dealers that exit from the market is six: on average, only around 15 traders are quoting during the auction, compared to 22 in non-auction days. The same effect is present also in the total depth, that is systematically lower than usual for the entire time window. The results for the 5Y German bonds, presented in Panel D of Table 5, show that the bid-ask spread is around one basis point lower than non-auction days, significant only up to one minute after the auction.

The 10Y tenor presents very clear results in terms of liquidity, for both countries. Panel E of Table 5 shows that the bid-ask spread is lower before the auction, but exactly in the minute of the auction, it raises at the usual level. The behavior of the dealer is comparable to the one presented for the 5Y Italian tenor. Dealers start to withdrawn their quotes four minutes before the auction, and one minute after at least six dealers are no longer quoting. This clearly influences the total depth of the market, that is generally lower but sharply decrease at the time of the auction. For Germany, Panel F of Table 5 shows that for the 10Y maturity the behavior of the bid-ask spread is comparable to Italy, albeit the order of magnitude is smaller. Immediately after the auction, the bid-ask spread comes back to the normal values. At least one dealer withdrawn from the market, and the total depth steadily decreases during the entire time window.

In summary, the higher liquidity of the bonds in terms of bid-ask spread reflects the willingness of the traders to provide liquidity before the auctions take place. This very small time frame allows to detect liquidity patterns very close to the auction time, that in most case revert very quickly. For what concerns the risk aversion of the dealers, there are some clear indications that at least a portion of them are withdrawing their quotes from the market minutes before the auction time. Even if these bonds are among the most liquid in the sovereign bond market, the total quantity available for trading in auction days is statistically lower compared to the non-auction days, reflecting the higher risk aversion and the capital constraints due to the auction participation.

Table 5 Liquidity measures by One-minute Intervals This table shows the average values of the Bid-Ask spread, the Number of Proposals, and the total Depth, as defined in Section 4.2, for each one-minute interval for the re-opening of on-the-run bonds. The bid-ask spread is the difference between ask price and bid price. The Depth is reported in millions of Euros. Column (a) represents the average values, t minutes from the auction for non-auction days, while column (b) for the auction days only. Column (a-b) represents the difference between non-auction and auction days, for each country and maturity (Panel A, C, and E for Italy, and Panel B, D and F for Germany). *, **, and *** denote significance at the 10, 5, and 1% levels using a t-statistic comparing means for non-auction and auction days assuming unequal variances. The database is composed by fixed coupon sovereign bonds for Italy [Buoni del Tesoro Poliennali (BTP) with a maturity of 3, 5 and 10 years)] and Germany [2 years Schatz, 5 years Bobl and 10 years Bund], from June 2011 to December 2016. The source of data is the Mercato dei Titoli di Stato (MTS).

Panel A: Italy 3Y On-the-run

	Bid-Ask Spread			N. Proposals			Depth		
Minutes to auction	(a)	(b)	(a-b)	(a)	(b)	(a-b)	(a)	(b)	(a-b)
-5	0.08	0.02	0.05***	21.33	23.32	-1.99**	132.55	138.19	-5.64
-4	0.08	0.02	0.05***	21.41	23.00	-1.59**	133.21	136.39	-3.17
-3	0.08	0.03	0.05***	21.41	22.11	-0.70	133.20	128.87	4.32
-2	0.08	0.03	0.04***	21.44	21.41	0.03	133.45	123.66	9.78**
-1	0.08	0.03	0.04***	21.39	20.75	0.63	133.04	120.59	12.45***
0	0.08	0.03	0.04***	20.63	18.89	1.74**	128.86	108.06	20.80***
1	0.08	0.05	0.02***	20.63	17.48	3.15***	128.91	99.19	29.71***
2	0.08	0.05	0.02***	21.30	17.95	3.34***	132.51	100.78	31.72***
3	0.08	0.06	0.01**	21.34	17.80	3.54***	132.85	101.16	31.68***
4	0.08	0.06	0.01**	21.39	18.11	3.27***	133.04	102.65	30.39***
5	0.08	0.07	0.00	21.49	18.11	3.37***	133.73	102.96	30.77***

Panel B: Germany 2Y On-the-run

	Bid-Ask Spread			N. Proposals			Depth		
	(a)	(b)	(a-b)	(a)	(b)	(a-b)	(a)	(b)	(a-b)
-5	0.04	0.03	0.01***	8.76	9.06	-0.30	76.12	77.69	-1.56
-4	0.04	0.02	0.01***	8.75	9.13	-0.37	76.02	78.59	-2.57
-3	0.04	0.02	0.01***	8.75	9.26	-0.51	76.04	82.06	-6.01
-2	0.04	0.02	0.01***	8.76	9.06	-0.30	76.11	79.55	-3.43
-1	0.04	0.02	0.01***	8.76	9.09	-0.32	76.09	79.60	-3.50
0	0.04	0.02	0.01***	8.72	9.11	-0.38	75.86	78.89	-3.02
1	0.04	0.03	0.01***	8.69	9.00	-0.31	75.61	79.22	-3.61
2	0.04	0.03	0.01***	8.73	8.89	-0.16	75.82	78.40	-2.57
3	0.04	0.03	0.01***	8.74	8.91	-0.17	75.88	78.36	-2.47
4	0.04	0.03	0.01***	8.73	8.83	-0.09	75.82	76.81	-0.99
5	0.04	0.03	0.01***	8.75	8.83	-0.08	75.96	77.10	-1.13

Table 5 Liquidity measures by One-minute Intervals (cont.)

Panel C: Italy 5Y On-the-run									
	Bid-Ask Spread			N. Proposals			Depth		
Minutes to auction	(a)	(b)	(a-b)	(a)	(b)	(a-b)	(a)	(b)	(a-b)
-5	0.09	0.04	0.05***	22.17	21.77	0.40	133.73	116.57	17.16***
-4	0.09	0.04	0.04***	22.26	20.98	1.27*	134.39	111.81	22.58***
-3	0.09	0.04	0.04***	22.30	20.42	1.88**	134.59	109.42	25.17***
-2	0.09	0.04	0.04***	22.33	19.60	2.73***	134.83	103.19	31.64***
-1	0.09	0.04	0.04***	22.24	18.85	3.39***	134.23	96.61	37.61***
0	0.09	0.07	0.02	21.41	17.08	4.32***	129.79	88.06	41.72***
1	0.09	0.11	-0.01	21.43	15.17	6.25***	129.89	77.53	52.35***
2	0.09	0.13	-0.04**	22.17	15.48	6.69***	133.78	80.21	53.56***
3	0.09	0.15	-0.06**	22.22	15.90	6.31***	134.05	81.98	52.06***
4	0.09	0.14	-0.05**	22.28	16.02	6.26***	134.39	81.74	52.65***
5	0.08	0.14	-0.05**	22.41	15.81	6.60***	135.22	81.02	54.20***
Panel D: Germany 5Y On-the-run									
	Bid-Ask Spread			N. Proposals			Depth		
	(a)	(b)	(a-b)	(a)	(b)	(a-b)	(a)	(b)	(a-b)
-5	0.06	0.05	0.01**	9.25	9.66	-0.41	77.30	78.79	-1.49
-4	0.06	0.05	0.01**	9.23	9.68	-0.44	77.16	79.18	-2.01
-3	0.06	0.05	0.01**	9.25	9.62	-0.36	77.33	78.15	-0.82
-2	0.06	0.05	0.01**	9.26	9.64	-0.37	77.38	78.25	-0.86
-1	0.06	0.05	0.01	9.27	9.47	-0.19	77.49	77.29	0.19
0	0.06	0.04	0.01***	9.24	9.32	-0.08	77.35	75.79	1.56
1	0.06	0.05	0.01*	9.24	9.04	0.19	77.37	74.61	2.75
2	0.06	0.05	0.00	9.28	9.04	0.23	77.60	74.69	2.91
3	0.06	0.05	0.00	9.29	8.94	0.35	77.69	73.47	4.21
4	0.06	0.06	0.00	9.30	8.89	0.41	77.80	74.13	3.66
5	0.06	0.06	0.00	9.31	8.85	0.46	77.86	73.56	4.30

Table 5 Liquidity measures by One-minute Intervals (cont.)

Panel E: Italy 10Y On-the-run									
	Bid-Ask Spread			N. Proposals			Depth		
Minutes to auction	(a)	(b)	(a-b)	(a)	(b)	(a-b)	(a)	(b)	(a-b)
-5	0.13	0.05	0.07***	22.13	22.09	0.04	127.99	108.38	19.60***
-4	0.13	0.06	0.06***	22.21	20.89	1.31**	128.58	102.45	26.13***
-3	0.13	0.05	0.07***	22.29	20.16	2.13***	129.03	96.81	32.22***
-2	0.13	0.06	0.06***	22.31	19.96	2.34***	129.14	96.63	32.51***
-1	0.13	0.07	0.06***	22.23	19.25	2.97***	128.59	91.04	37.55***
0	0.13	0.09	0.04***	21.35	17.21	4.13***	124.04	80.71	43.33***
1	0.13	0.13	0.00	21.40	15.50	5.89***	124.24	71.60	52.64***
2	0.13	0.14	-0.01	22.10	16.13	5.97***	127.92	75.09	52.83***
3	0.13	0.14	-0.01	22.16	16.50	5.66***	128.22	76.89	51.33***
4	0.13	0.15	-0.02	22.21	16.46	5.74***	128.46	76.76	51.69***
5	0.13	0.15	-0.02	22.32	16.41	5.90***	129.07	76.67	52.39***
Panel F: Germany 10Y On-the-run									
	Bid-Ask Spread			N. Proposals			Depth		
	(a)	(b)	(a-b)	(a)	(b)	(a-b)	(a)	(b)	(a-b)
-5	0.07	0.05	0.01***	10.48	10.75	-0.27	80.89	76.21	4.68*
-4	0.07	0.05	0.01***	10.45	10.69	-0.24	80.58	75.90	4.68*
-3	0.07	0.05	0.01***	10.46	10.63	-0.17	80.72	74.76	5.95**
-2	0.07	0.05	0.01***	10.45	10.75	-0.29	80.69	75.73	4.96**
-1	0.07	0.05	0.01***	10.45	10.62	-0.16	80.72	74.65	6.07***
0	0.07	0.05	0.01***	10.41	10.17	0.24	80.55	71.48	9.07***
1	0.07	0.06	0.00	10.41	9.62	0.79***	80.59	68.11	12.48***
2	0.07	0.06	0.00	10.46	9.60	0.86***	80.85	67.66	13.18***
3	0.07	0.07	0.00	10.45	9.40	1.05***	80.84	66.73	14.11***
4	0.07	0.07	-0.00	10.47	9.29	1.17***	80.90	65.65	15.24***
5	0.07	0.07	-0.00	10.48	9.12	1.36***	80.99	64.98	16.01***

5.2.2 Second stage analysis

According to Duffie (2010), Bessembinder et al. (2016), and Sigaux (2017), the price pressure is temporary and should revert at least partially as soon as the information about the auction has been assimilated by the market participants. In this second stage, I analyze the subsequent adjustment, examining the behavior of the market at a higher interval, every ten minutes, and covering the time window that goes from one hour before, to one hour after the auction time. The results follow the same format of Table 5 and are presented in Table 6 for all the maturities and the two countries considered.

For the shortest maturity, Table 6 Panel A shows that the bid-ask spread is initially lower with respect to the non-auction days, and remains lower until the auction time. In terms of risk aversion, the number of proposals shows that the dealer that withdrawn from the market re-join at least thirty minutes before. Roughly in the same amount of time, the total depth returns to the average value of non-auction days. For Germany, Panel B of Table 6 shows that the bid-ask spread is consistently lower in the auction days, with the same magnitude presented in Panel B of Table 5. Other variables are not significant.

For the 5Y maturities, Table 6 Panel C and D mirror the results of the 3Y bonds for the bid-ask spread and the risk aversion of the dealers. The only difference is related to the total depth for the Italian 5Y bond: the depth available starts to decrease around ten minutes before the auction and does not completely recover after one hour, also indicating, in this case, most likely a higher risk aversion and capital constraint for the market participants.

Finally, Panel E and F of Table 6 show the results for the 10Y bonds for Italy and Germany, respectively. For Italy, the significance of the bid-ask spread display that the liquidity is better until ten minutes minutes after the auction, compared to non-auction days. In the following fifty minutes, the bid-ask spread is statistically not different from the other days. The dealers that withdrawn from the market wait at least thirty minutes to start quoting again. The peak is reached after sixty minutes, where 24 members are, on average, joining the market simultaneously. Regarding market depth, it starts to decrease well before the auction, at least twenty minutes. It almost fully recovers after one hour.

Regarding Germany, in terms of bid-ask spread the market is slightly more liquid only

Table 6 Liquidity measures by Ten-minute Intervals This table reports the average values of the Bid-Ask spread, the Number of Proposals, and the total Depth, as defined in Section 4.2 for the re-openings of on-the-run bonds, for each ten-minute interval from one hour before to one hour after the auction. The bid-ask spread is the difference between ask price and bid price. The Depth is reported in millions of Euros. Column (a) represents the average values, t minutes from the auction for non-auction days, while column (b) for the auction days only. Column (a-b) represents the difference between non-auction and auction days, for each country and maturity (Panel A, C and E for Italy, and Panel B, D and F for Germany). *, **, and *** denote significance at the 10, 5, and 1% levels using a t-statistic comparing means for non-auction and auction days assuming unequal variances. The database is composed by fixed coupon sovereign bonds for Italy [Buoni del Tesoro Poliennali (BTP) with maturity of 3, 5 and 10 years)] and Germany [2 years Schatz, 5 years Bobl and 10 years Bund], from June 2011 to December 2016. The source of data is the Mercato dei Titoli di Stato (MTS).

Panel A: Italy 3Y On-the-run

	Bid-Ask Spread			N. Proposals			Depth		
Minutes to auction	(a)	(b)	(a-b)	(a)	(b)	(a-b)	(a)	(b)	(a-b)
-60	0.08	0.04	0.04***	21.16	24.32	-3.16***	132.01	148.16	-16.14***
-50	0.08	0.04	0.04***	21.20	24.26	-3.05***	132.70	146.78	-14.08***
-40	0.08	0.03	0.04***	21.22	24.52	-3.29***	132.58	147.00	-14.42***
-30	0.08	0.03	0.04***	21.13	24.83	-3.69***	131.61	151.31	-19.69***
-20	0.08	0.03	0.05***	21.23	24.39	-3.15***	131.91	149.94	-18.02***
-10	0.08	0.03	0.05***	21.33	22.79	-1.46**	132.62	136.73	-4.10
0	0.08	0.06	0.01*	21.27	17.86	3.40***	132.48	101.46	31.02***
10	0.07	0.08	-0.00	21.64	17.11	4.53***	134.69	99.24	35.44***
20	0.07	0.08	-0.00	21.79	18.10	3.69***	135.51	108.90	26.60***
30	0.07	0.06	0.00	21.65	20.48	1.17**	134.80	124.22	10.57**
40	0.07	0.06	0.00	21.83	21.82	0.01	135.76	132.50	3.26
50	0.07	0.06	0.01	21.86	23.05	-1.18**	135.99	138.82	-2.83
60	0.07	0.06	0.01**	21.63	23.38	-1.74***	134.67	140.68	-6.01

Panel B: Germany 2Y On-the-run

	Bid-Ask Spread			N. Proposals			Depth		
	(a)	(b)	(a-b)	(a)	(b)	(a-b)	(a)	(b)	(a-b)
-60	0.04	0.03	0.01***	8.67	8.43	0.23	75.41	71.96	3.44
-50	0.04	0.03	0.01***	8.71	8.40	0.30	75.71	71.79	3.91
-40	0.04	0.03	0.01***	8.66	8.49	0.16	75.26	72.26	2.99
-30	0.04	0.03	0.01***	8.57	8.55	0.02	74.60	73.52	1.08
-20	0.04	0.03	0.01***	8.71	8.77	-0.05	75.68	74.45	1.22
-10	0.04	0.03	0.01***	8.74	9.00	-0.26	75.95	78.00	-2.04
0	0.04	0.03	0.01***	8.73	8.85	-0.12	75.83	77.58	-1.75
10	0.04	0.03	0.01***	8.75	8.72	0.03	75.94	76.36	-0.41
20	0.04	0.03	0.01***	8.76	8.56	0.19	76.04	73.73	2.31
30	0.04	0.03	0.01***	8.66	8.57	0.08	75.38	73.53	1.85
40	0.04	0.03	0.01***	8.62	8.61	0.01	75.20	73.29	1.90
50	0.04	0.03	0.01***	8.61	8.71	-0.10	75.19	73.60	1.59
60	0.04	0.03	0.01***	8.60	8.59	0.01	75.27	72.11	3.16

Table 6 Liquidity measures by Ten-minute Intervals (cont.)

Panel C: Italy 5Y On-the-run

	Bid-Ask Spread			N. Proposals			Depth		
Minutes to auction	(a)	(b)	(a-b)	(a)	(b)	(a-b)	(a)	(b)	(a-b)
-60	0.09	0.07	0.02***	22.15	23.79	-1.64***	134.37	134.05	0.31
-50	0.09	0.06	0.02***	22.18	23.95	-1.76***	135.09	135.81	-0.71
-40	0.09	0.06	0.03***	22.17	23.96	-1.79***	134.62	135.89	-1.26
-30	0.09	0.05	0.03***	22.03	24.11	-2.08***	133.34	135.09	-1.75
-20	0.09	0.05	0.04***	22.15	24.04	-1.88***	133.77	133.08	0.68
-10	0.09	0.04	0.04***	22.21	21.46	0.75	134.04	115.25	18.78***
0	0.09	0.13	-0.04**	22.15	15.86	6.28***	133.82	82.09	51.72***
10	0.08	0.16	-0.07***	22.60	15.73	6.87***	136.43	81.85	54.57***
20	0.08	0.12	-0.04**	22.74	17.89	4.85***	137.24	96.38	40.85***
30	0.08	0.10	-0.01*	22.63	20.91	1.71***	136.66	116.74	19.92***
40	0.08	0.10	-0.01	22.83	22.30	0.53	137.72	124.88	12.83***
50	0.08	0.10	-0.02*	22.80	22.65	0.15	137.58	127.07	10.51***
60	0.08	0.10	-0.02	22.57	23.04	-0.47	136.09	128.10	7.99**

Panel D: Germany 5Y On-the-run

	Bid-Ask Spread			N. Proposals			Depth		
	(a)	(b)	(a-b)	(a)	(b)	(a-b)	(a)	(b)	(a-b)
-60	0.06	0.05	0.01***	9.19	9.53	-0.34	76.95	78.67	-1.71
-50	0.06	0.05	0.01***	9.26	9.73	-0.47*	77.45	80.60	-3.14
-40	0.06	0.05	0.01***	9.13	9.62	-0.48*	76.27	79.58	-3.30
-30	0.06	0.05	0.01***	8.94	9.35	-0.41	74.69	76.88	-2.18
-20	0.06	0.05	0.01***	9.16	9.56	-0.39	76.51	78.53	-2.02
-10	0.06	0.05	0.01**	9.22	9.63	-0.40	77.11	78.47	-1.36
0	0.06	0.05	0.00	9.28	8.98	0.30	77.64	74.48	3.15
10	0.06	0.06	0.00*	9.32	9.00	0.32	77.91	75.14	2.76
20	0.06	0.06	0.00	9.33	9.08	0.25	77.98	75.17	2.80
30	0.06	0.05	0.00**	9.21	9.14	0.06	77.16	75.75	1.41
40	0.06	0.05	0.00**	9.17	9.23	-0.06	76.96	76.91	0.05
50	0.06	0.06	0.00**	9.10	9.03	0.06	76.65	75.74	0.91
60	0.06	0.06	0.00*	9.07	9.09	-0.02	76.60	76.00	0.59

Table 6 Liquidity measures by Ten-minute Intervals (cont.)

Panel E: Italy 10Y On-the-run									
	Bid-Ask Spread			N. Proposals			Depth		
Minutes to auction	(a)	(b)	(a-b)	(a)	(b)	(a-b)	(a)	(b)	(a-b)
-60	0.14	0.09	0.04***	22.13	24.62	-2.49***	128.73	128.50	0.22
-50	0.13	0.09	0.04***	22.28	24.98	-2.69***	129.66	130.30	-0.64
-40	0.13	0.09	0.04***	22.21	24.95	-2.73***	128.98	129.80	-0.81
-30	0.13	0.08	0.05***	21.99	24.83	-2.83***	127.44	128.57	-1.12
-20	0.13	0.07	0.05***	22.09	24.38	-2.29***	127.79	123.03	4.76**
-10	0.13	0.06	0.07***	22.15	21.60	0.55	128.17	106.00	22.16***
0	0.13	0.15	-0.02	22.09	16.46	5.62***	127.92	76.88	51.04***
10	0.12	0.18	-0.05**	22.55	16.21	6.33***	130.52	76.14	54.37***
20	0.12	0.14	-0.01	22.65	19.08	3.57***	130.99	94.06	36.92***
30	0.12	0.14	-0.02	22.53	21.66	0.86	130.30	110.67	19.63***
40	0.12	0.13	-0.01	22.73	22.81	-0.08	131.48	116.82	14.65***
50	0.12	0.13	-0.00	22.69	23.55	-0.85	131.40	121.43	9.97***
60	0.12	0.13	-0.00	22.45	24.00	-1.55***	129.93	123.97	5.96*

Panel F: Germany 10Y On-the-run									
	Bid-Ask Spread			N. Proposals			Depth		
	(a)	(b)	(a-b)	(a)	(b)	(a-b)	(a)	(b)	(a-b)
-60	0.07	0.06	0.01***	10.42	10.62	-0.19	80.49	75.41	5.07**
-50	0.07	0.05	0.01***	10.48	10.79	-0.31	80.87	76.40	4.46*
-40	0.07	0.05	0.01***	10.33	10.74	-0.40	79.71	76.67	3.03
-30	0.07	0.06	0.01***	10.07	10.50	-0.43	77.58	75.20	2.38
-20	0.07	0.06	0.01***	10.33	10.64	-0.31	79.56	75.89	3.67
-10	0.07	0.05	0.01***	10.43	10.65	-0.21	80.49	75.53	4.95**
0	0.07	0.07	0.00	10.46	9.42	1.04***	80.85	66.58	14.27***
10	0.07	0.07	0.00	10.50	9.50	1.00***	81.10	67.75	13.35***
20	0.07	0.06	0.00	10.51	9.88	0.63*	81.28	70.55	10.73***
30	0.07	0.06	0.00	10.35	10.15	0.19	80.38	73.03	7.35***
40	0.07	0.06	0.00	10.30	10.14	0.16	80.22	72.96	7.26***
50	0.07	0.06	0.00	10.27	10.13	0.14	80.06	73.02	7.03***
60	0.07	0.06	0.00	10.24	10.16	0.07	79.93	73.26	6.66**

before the auction, and then it is indistinguishable from non-auction days. The single dealer that withdrawn from the market is probably responsible for the lower depth available in the market. However, for the 10Y German bonds, the quantity displayed is usually smaller starting from ten minutes before the auction, and do not recover completely thereafter.

The overall empirical evidence presented in these section allows to drawn some conclusions with respect to the hypotheses formulated. In addition to the price pressure, there is also a statistically significant liquidity pattern around the auction time, for both countries and for all maturities. In particular, both the analysis (at the finest one minute interval and at ten minutes interval) show that the bid-ask spread is lower before the auction, consistent with the theory of Bessembinder et al. (2016), that postulate a strategic decision from a set of traders that are willing to provide liquidity knowing that some other has to unwind their position. This result is also in line with the empirical intraday evidence of Fleming and Liu (2016) for the US market. However, this theoretical higher liquidity does not translate into a higher quantity available for trading, expressed in terms of market depth. In fact, market depth is usually indistinguishable for auction vs. non-auction before the auction time. After the auction time, the situation is quite different. Especially for Italian bonds and the German 10Y bond, market depth is systematically lower after the auction time and it might takes more than 60 minutes to recover to the usual level. This result signal that a considerable portion of dealers reduce their quantity displayed compared to non-auction days. In other words, they are less willing to trade, despite the supposed better market conditions.

In addition to the liquidity pattern, there is also empirical evidence of an increase of risk aversion, proxied with the number of proposals. The effects of dealers' risk aversion are present for Italy (across maturities) and only for the 10Y German bond. The phenomenon of quotes withdrawn very close to the auction seems not to be related only to specific years in the sample period, but appears consistently across all the sample. Figure 6 and 7, that plot the average value of the *N. Proposals* for each minute per year, shows that this behavior is quite common, and has been exacerbated during the crisis of 2011-12. For the most affected auctions, around 25% of dealers disappear momentarily from the market; information uncertainty and limited available capital might be a realistic interpretation of this behavior. However, the information uncertainty resolves around ten to twenty minutes later, when

the results of the auction are fully incorporated not only in the prices but also in terms of liquidity in the market. After that moment, the situation starts to come back to the usual levels.

5.2.3 The Sovereign Bond Crisis and the PSPP Program

The previous sections presented empirical evidence of price pressure and liquidity pattern around the auction time. This section aims to verify if the price pressure, the liquidity, and the risk aversion are influenced by the Sovereign Bond Crisis of 2011-12 and the European Central Bank (ECB) intervention through its Public Sector Purchase Program (PSPP) during the auctions. Specifically, under the PSPP program that began in March 2015, the ECB purchases a significant amount of public and private sector securities every month (around 60 billion monthly). The sovereign bond crisis and the extraordinary quantitative easing intervention by the ECB are very likely to have an impact on prices and also on the behavior of the dealers during the auctions. In fact, one of the objective of the ECB intervention is to restore confidence in the sovereign bond markets. For what concern the sovereign bond crisis, the work of Pelizzon, Subrahmanyam, Tomio, and Uno (2013) find that a considerable fraction of dealers withdraws their quotes from the market, regardless the presence of an auction. Further, frequent update of quotes does not reflect into a higher level of liquidity.

This analysis is motivated by the graphical evidence presented in Figures 6 and 7. The number of dealers that withdraw their quotes from the market in different years varies substantially through time, suggesting that both the crisis and the PSPP have an impact on the behavior of the market makers, especially for Italy.

To assess both the effects of the financial crisis and the PSPP, I estimate a set of daily time-series regressions, where the dependent variables represents the price pressure, the dealers' risk aversion and the liquidity in the market. Specifically, these variables are the daily cumulative Δ *return* as a measure of price pressure; the *N. of Withdraw* represents the difference between the maximum amount of dealers present in the two hours surrounding the auction, minus the minimum at the time of the auction. Intuitively, this variable represents the number of dealers that are more risk adverse. The *Bid to Cover Ratio* represents how "successful" has been the primary auction, and it is calculated as the ratio between the total

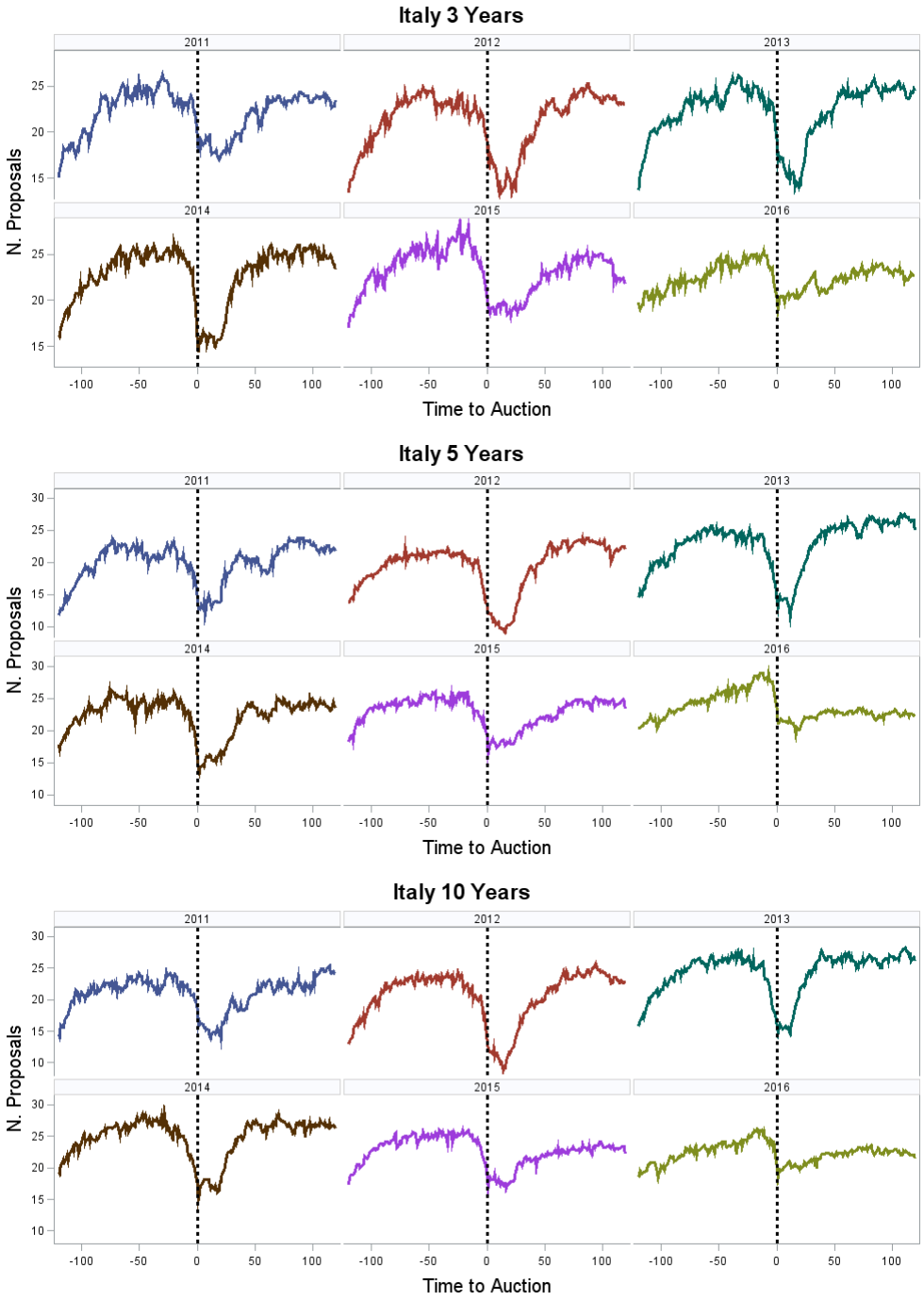

Figure 6. Number of Proposals by year for Italy

This figures plot the average number of proposals by year, as defined in Section 4.2, for each one-minute interval and for the re-openings dates of on-the-run bonds only. The database is composed by fixed coupon sovereign bonds for Italy [Buoni del Tesoro Poliennali (BTP) with maturity of 3, 5 and 10 years)], from June 2011 to December 2016. The source of data is the Mercato dei Titoli di Stato (MTS).

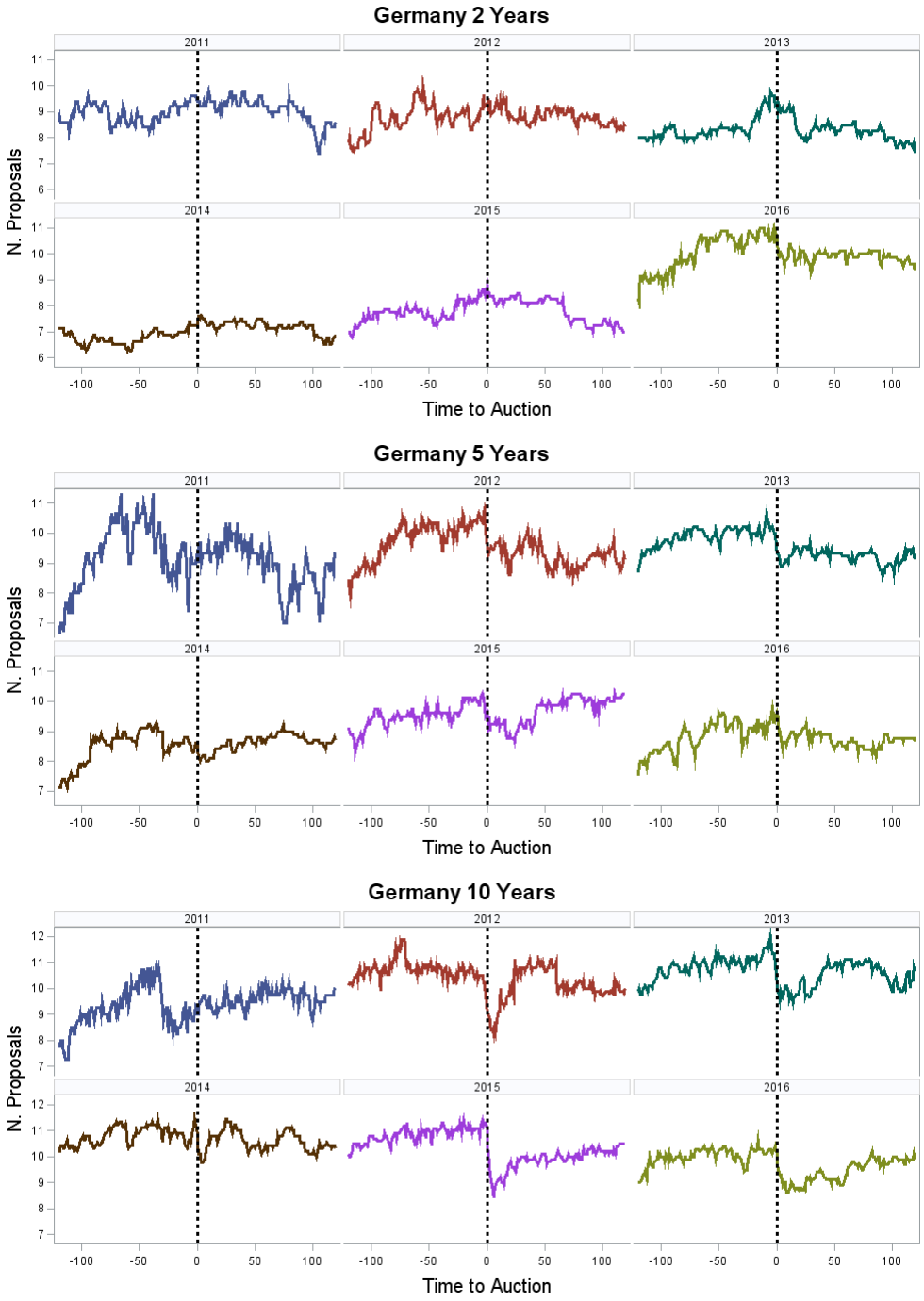

Figure 7. Number of Proposals by year for Germany

This figures plot the average number of proposals by year, as defined in Section 4.2, for each one-minute interval and for the re-openings dates of on-the-run bonds only. The database is composed by fixed coupon sovereign bonds for Germany [2 years Schatz, 5 years Bobl and 10 years Bund], from June 2011 to December 2016. The source of data is the Mercato dei Titoli di Stato (MTS).

amount of quantity bid by the primary auction participant divided by the amount allocated at the auction. The higher the ratio, the more successful the auction. Finally, the average *Bid-ask spread* and the average *depth* are calculated only during the two hours surrounding the auction.

Formally, for Italy and Germany, I estimate the following model:

$$y_t = \alpha_t + \beta_1 Crisis_t + \beta_2 PSPP_t + \beta_3 VIX + \epsilon_t \tag{3}$$

where y is one of the variables defined before, $Crisis$ is a dummy that is equal to one during the sovereign bond crisis (from November 9, 2011 to July 26, 2012, date of the "whatever it takes" speech of Mario Draghi), $PSPP$ a dummy that is equal to one for the period of the asset purchase (from March 2015 until the end of the sample period), VIX is the well-know volatility index as a control variable for the general risk-aversion in the financial markets. Standard errors are robust for heteroscedasticity and clustered at bond level. The results of the regressions, which consider only the on-the-run bonds for the two countries, are reported in Table 7. Panel A of Table 7 show that the cumulative Δ *return* is unaffected by the financial crisis, and is negatively affected by the PSPP program only for the 5Y bonds, showing that at least for this maturity the ECB program reduces the price pressures around the auction. About the behavior of the dealer, the analysis shows that for the 3Y and 5Y maturity the number of dealers that withdraw from the market increase significantly. However, the PSPP program appears to reduce the perception of risk for the dealers, since the number of withdrawn reduces considerably for all the maturities. The results of the auction are positively affected by the PSPP since the bid to cover ratio has positive and significant sign across maturities. Finally, the two measures of liquidity, the average *Bid-ask spread* and the average *depth* are significant for the 3Y and 5Y maturities, and show that during the crisis the spread increase and the depth decrease, while the ECB intervention leads to a reduction of the spreads and an increase of the total depth available during the auction.

About Germany, Panel B of Table 7 shows that there is a significant stronger price pressure for the 2 and 10 years bonds during the crisis. Surprisingly, the coefficient of the cumulative Δ *return* is also positive for the 2 years bonds during the PSPP, indicating

Table 7 The Sovereign Bond Crisis and the PSPP This table reports the results of the linear regression presented in Section 5.2.3, for Italy (Panel A) and Germany (Panel B). All variables are aggregated at daily level, considering only the two hours surrounding the auction. Standard error are robust for heteroschedasticity and clustered at bond level. *, **, and *** denote significance at the 10, 5, and 1% levels. The database is composed by fixed coupon sovereign bonds for Italy [Buoni del Tesoro Poliennali (BTP) with maturity of 3, 5 and 10 years)] and Germany [2 years Schatz, 5 years Bobl and 10 years Bund], from June 2011 to December 2016. The source of data is the Mercato dei Titoli di Stato (MTS).

Panel A: Italy

		Cum. ΔReturn	N. of Withdraw	Bid to Cover Ratio	Avg. Bid-ask Spread	Avg. Depth
3Y	Sov. Bond Crisis	15.72	2.206*	-0.0431	0.0943**	-22.43***
	PSPP	3.757	-4.000***	0.197**	-0.0402***	6.916
	VIX	0.253	-0.203	-0.00338	0.00165***	1.234**
	Constant	-3.059	17.14***	1.536***	0.0388**	96.39***
	Observations	43	43	43	43	43
	R-squared	0.066	0.341	0.323	0.613	0.186
5Y	Sov. Bond Crisis	-29.21	2.886***	0.0412	0.120***	5.169
	PSPP	-15.69**	-6.023***	0.0696*	-0.0591**	12.12**
	VIX	0.206	-0.151*	0.000910	0.00305	-0.640
	Constant	16.81**	17.80***	1.411***	0.0753**	110.9***
	Observations	52	52	52	52	52
	R-squared	0.104	0.461	0.064	0.385	0.091
10Y	Sov. Bond Crisis	34.70	-0.265	0.0679*	0.224	-27.28***
	PSPP	-8.359	-6.438***	0.0612*	-0.0208	-3.035
	VIX	0.484	-0.0709	-0.00490**	0.00694**	-0.556***
	Constant	6.172	16.91***	1.454***	0.0243	112.7***
	Observations	56	56	56	56	56
	R-squared	0.122	0.458	0.160	0.415	0.311

Table 7 The Sovereign Bond Crisis and the PSPP (cont.)

Panel B: Germany						
		Cum. ΔReturn	N. of Withdraw	Bid to Cover Ratio	Avg. Bid-ask Spread	Avg. Depth
2Y	Sov. Bond Crisis	3.661***	-0.194	-0.100*	0.00384	18.36*
	PSPP	1.400**	0.309	-0.106	0.00105	28.83***
	VIX	-0.0406	-0.0571**	-0.0131*	0.000836*	-0.598
	Constant	0.695	3.279***	2.204***	0.0145*	73.73***
	Observations	45	45	45	45	45
	R-squared	0.218	0.080	0.096	0.107	0.304
5Y	Sov. Bond Crisis	4.954	0.143	0.243*	0.0356**	-9.469
	PSPP	0.473	0.402	-0.245*	0.00665	10.33**
	VIX	-0.353	0.0442*	-0.0158	0.00213*	0.0634
	Constant	6.777	1.921***	1.994***	0.0145	72.44***
	Observations	47	47	47	47	47
	R-squared	0.042	0.044	0.210	0.447	0.140
10Y	Sov. Bond Crisis	15.35***	1.857	0.0544	0.0261**	-0.257
	PSPP	-3.284	0.386	-0.0276	0.0159*	3.687
	VIX	1.322**	-0.0369	-0.0107*	0.000249	-0.321
	Constant	-14.05	3.720***	1.595***	0.0513***	75.24***
	Observations	51	51	51	51	51
	R-squared	0.215	0.104	0.047	0.176	0.032

only for this maturity that the ECB program does not reduce the price pressure during the auction with respect to other periods. However, it worth noting that the price pressure for this note was not particularly strong (see Table 4). The primary dealers do not behave differently during the crisis or during the PSPP period, as they do not significantly withdraw quotes in general during the auctions, as seen in the previous section. The bid to cover ratio is only mildly significant. The liquidity measures display interesting results. During the sovereign bond crisis, the bid-ask spread statistically increases for the 5 and 10 years maturity. However, for the 10 Y bond, the spread increases also during the PSPP program, showing some potential scarcity problems for the bonds auctioned. About the depth available in the market, the coefficients of the dummies are significant and positive for the 2 years bond for the crisis and the PSPP, and only for the PSPP program for the 5 years bonds.

To summarize, the analysis shows that the crisis and the PSPP have a different impact on the two countries. For Italy, the crisis strongly affected the behavior of the dealers, that withdraw from the market and become more risk-averse. This results in a wider bid-ask spread and a lower quantity quoted in the market. The PSPP program seems to restore the confidence of the dealer, as all the measures improve substantially. The results for Germany are mixed, most likely given the fact that the sovereign bond crisis mostly affected the peripheral countries. In this context, Germany is viewed as a "safe heaven", the dealers' behavior is thus not strongly influenced by this event. For the same reason, the PSPP do not affect both the price pressures and liquidity measures.

6 Conclusion

This paper provides intraday empirical evidence of the impact of Treasury auctions in the secondary market of sovereign bonds. Using data from the Mercato dei Titoli di Stato (MTS), I find price and liquidity patterns around auction dates, showing that these patterns are present not only in the days surrounding the auctions, as demonstrated in previous studies in the European Market, but also in the hours and minutes around the auctions' times.

The main contribution of this work is to shed light on the intraday linkages between price

movements, dry-up of liquidity, and market-makers' behavior in the auctions' days. To the best of my knowledge, no prior research investigates this issue in a high-frequency setting for the European Sovereign bond markets. The analysis show that there is a statistically significant price pressure for the Italian coupon bonds with a maturity of 5 and 10 years and for the German 10 years Bund, together with a peculiar liquidity pattern the day of the auction and around the auction time.

Using the presence of the dealers in the market during the auction as a proxy for risk aversion, I find that dealers tend to become risk-averse around the auction time. A significant portion of them withdraw their quotes minutes before the auction time. In a two-stage analysis, I show that the uncertainty around the auction push dealers to reduce the amount quoted, reducing the total depth of the market. Information uncertainty and limited risk-bearing capacity of the dealers motivates this behavior. In addition, dealers that remains in the market widen the bid-ask spread very close to the auction time, to protect themselves from adverse selection costs. These patterns are not observed on non-auction days, suggesting that the bond supply through primary auctions influence the behavior of the market participants in the secondary market.

These findings complement the work of Beetsma et al. (2016) with daily data, and includes more direct measures of the risk aversion, together with intraday liquidity patterns that cannot be shown using daily data. A specific analysis show that the Sovereign Crisis of 2011-12 exacerbate the liquidity patterns and the risk aversion of the dealers. The ECB intervention of 2015, through the PSPP, contributes substantially to reduce the "auction-cycle effect" especially for Italy.

Finally, the findings suggest some policy implications. The "auction-cycle effect" identify a potential mispricing between the bond in the primary market and the same bond on the secondary market. This mispricing might result in a potential additional cost of issuance for the Treasury, and also some opportunistic behavior of the dealers that participate to the auction, that might submit aggressive bids to increase the mispricing and make profits on that. The analysis shows that the timing of the auction is important, and dealers are acting very close to the auction time. Albeit Treasury cannot force primary dealers to quote in a different way surrounding the auction, they might provide incentives to dealers to not

deviate their behavior from normal during the auction. Since the auction cycle is particularly pronounced for Italy and less important for Germany (excluding the 10Y Bund), there might be some peculiar characteristics of the auction design itself that could be exploited to reduce such anomalies.

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Appendix

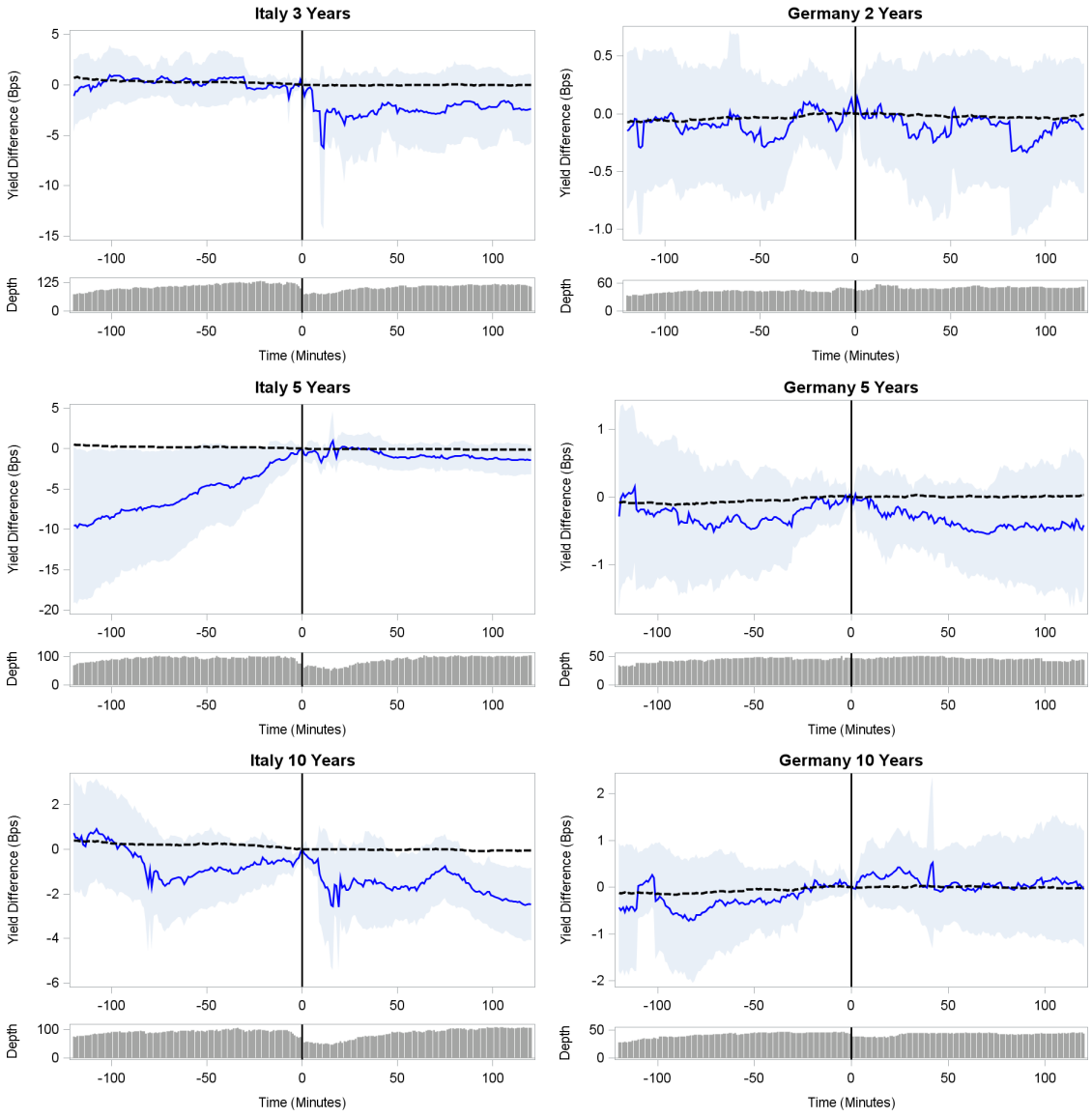

Figure 8. Yield difference for the Newly issued bonds

This figure plot the average yield difference (top panel) and the total depth available in the market (bottom panel, in Millions of €), only for the new-issued bonds. The quotes are in the grey market before the issuance. The shaded area represents the 95% confidence interval around the sample mean, and the black dashed line represents the average yield difference on non-auction dates. The database is composed by fixed coupon sovereign bonds for Italy [Buoni del Tesoro Poliennali (BTP) with maturity of 3, 5 and 10 years)] and Germany [2 years Schatz, 5 years Bobl and 10 years Bund], from June 2011 to December 2016. The source of data is the Mercato dei Titoli di Stato (MTS).

Table 8 Yield Difference for the Newly Issued Bonds

This table shows the average yield difference, or the yield change from t minutes before the auction to the time of auction ($t = 0$), only for the newly issued bonds. The quotes are in the grey market before the issuance. The midpoint is converted into yields using the respective conventions. The number of observations corresponds to the number of auctions for each country and maturity (Panel A for Italy, and Panel B for Germany). *, **, and *** denote significance at the 10, 5, and 1% levels using a t-test to verify if the values are statistically different from zero. The database is composed by fixed coupon sovereign bonds for Italy [Buoni del Tesoro Poliennali (BTP) with maturity of 3, 5 and 10 years)] and Germany [2 years Schatz, 5 years Bobl and 10 years Bund], from June 2011 to December 2016. The source of data is the Mercato dei Titoli di Stato (MTS).

Panel A: Italy New Issues

	3Y		**5Y**		**10Y**	
t	Avg. Yield Diff.	Tstat	Avg. Yield Diff.	Tstat	Avg. Yield Diff.	Tstat
-120	-1.085	-0.647	-9.515*	-2.163	0.718	0.635
-100	0.821	0.634	-8.453**	-2.251	0.445	0.447
-80	0.357	0.455	-7.253**	-2.300	-0.945	-0.998
-60	0.55	0.458	-5.861*	-2.156	-1.218	-1.527
-30	0.228	0.323	-3.776*	-2.010	-0.854	-1.627
-20	-0.342	-0.689	-2.753*	-2.136	-0.472	-0.930
-10	-0.085	-0.237	-1.4	-1.556	-0.427	-1.482
10	-5.971	-1.648	-1.676**	-2.286	-1.354	-1.454
20	-3.092*	-1.789	1.065	1.437	-1.29	-1.630
30	-2.978	-1.685	-0.061	-0.075	-1.545*	-1.901
60	-2.407	-1.514	-0.976	-1.345	-1.845**	-2.571
80	-1.828	-0.949	-0.876	-1.063	-1.081	-1.658
100	-2.228	-1.239	-1.246	-1.505	-2.072**	-3.126
120	-2.357	-1.519	-1.446	-1.751	-2.463***	-3.390
Obs	14		13		11	

Panel B: Germany New Issues

	2Y		**5Y**		**10Y**	
t	Avg. Yield Diff.	Tstat	Avg. Yield Diff.	Tstat	Avg. Yield Diff.	Tstat
-120	-0.15	-0.468	-0.290	-0.476	-0.430	-0.684
-100	-0.027	-0.100	-0.218	-0.504	-0.253	-0.465
-80	-0.088	-0.356	-0.345	-0.798	-0.6	-1.003
-60	-0.129	-0.513	-0.272	-0.744	-0.261	-0.567
-30	0.026	0.166	-0.272	-1.342	-0.130	-0.427
-20	0.078	0.499	-0.1	-0.519	-0.023	-0.183
-10	-0.147	-0.884	-0.118	-0.860	0.030	0.304
10	0.022	0.108	-0.027	-0.124	0.276	0.833
20	-0.055	-0.248	-0.281	-0.987	0.269	0.809
30	-0.184	-0.703	-0.309	-1.417	0.338	0.838
60	-0.035	-0.126	-0.490	-1.563	-0.023	-0.056
80	-0.088	-0.339	-0.454	-1.119	-0.007	-0.015
100	-0.142	-0.449	-0.5	-1.154	0.123	0.230
120	-0.126	-0.473	-0.418	-0.973	-0.046	-0.080
Obs	20		13		13	

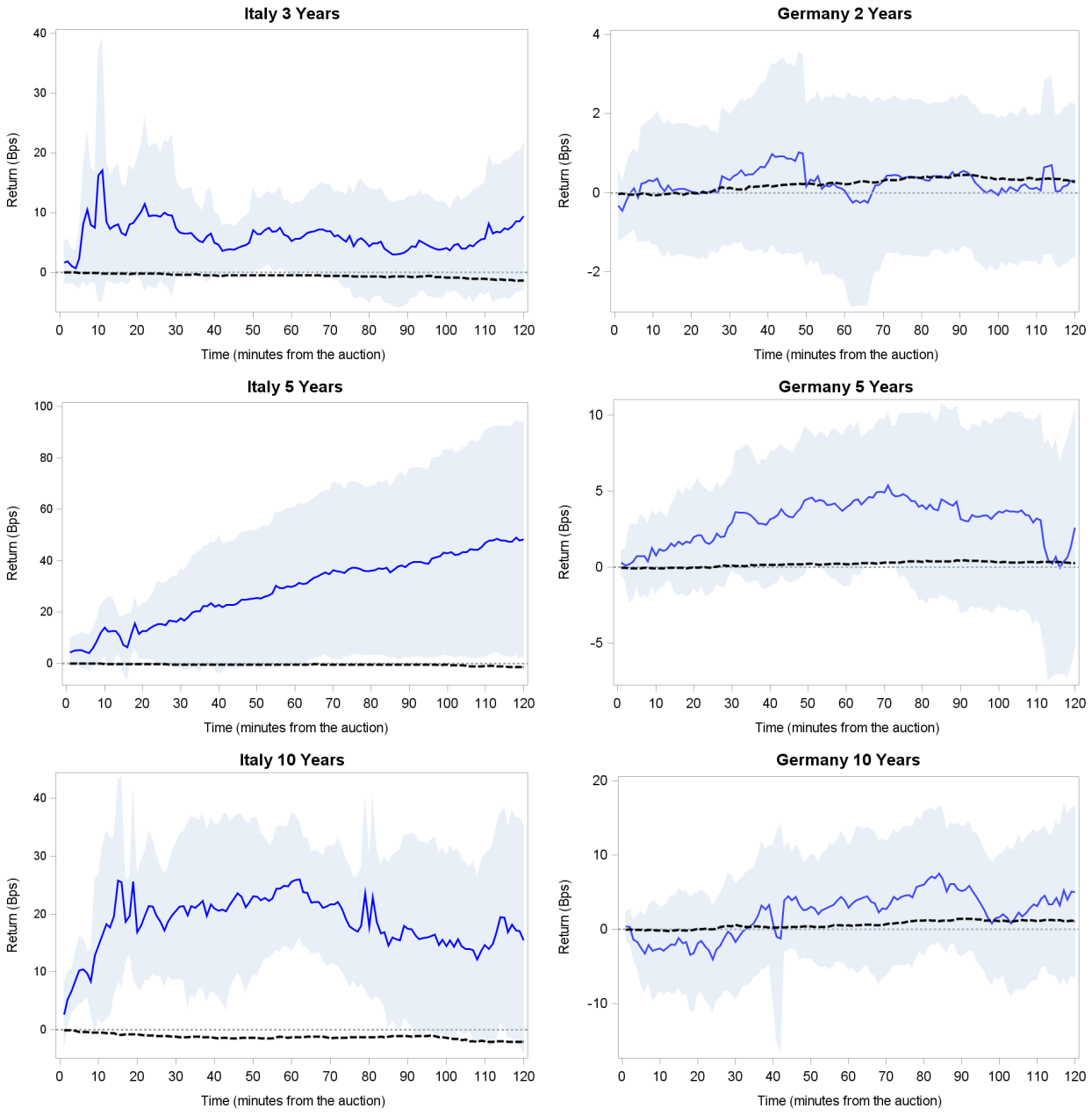

Figure 9. Cumulative Return for the Newly Issued bonds

This figures plot the cumulative average Δ return, or the cumulative return before and after the auction as defined in Equation 2, during the auction dates only for the newly issued bonds. The quotes are in the grey market before the issuance. The shaded area represents the 95% confidence interval around the sample mean, and the black dashed line represents the average cumulative return on non-auction dates. The database is composed by fixed coupon sovereign bonds for Italy [Buoni del Tesoro Poliennali (BTP) with maturity of 3, 5 and 10 years)] and Germany [2 years Schatz, 5 years Bobl and 10 years Bund], from June 2011 to December 2016. The source of data is the Mercato dei Titoli di Stato (MTS).

Table 9 Return for the Newly Issued Bonds

This table shows the Average Δ Return, or the cumulative return before and after the auction as defined in Equation 2, during the auction dates during the auction dates only for the newly issued bonds. The quotes are in the grey market before the issuance. The number of observations corresponds to the number of auctions for each country and maturity (Panel A for Italy, and Panel B for Germany). *, **, and *** denote significance at the 10, 5, and 1% levels using a t-test to verify if the values are statistically different from zero. The database is composed by fixed coupon sovereign bonds for Italy [Buoni del Tesoro Poliennali (BTP) with maturity of 3, 5 and 10 years)] and Germany [2 years Schatz, 5 years Bobl and 10 years Bund], from June 2011 to December 2016. The source of data is the Mercato dei Titoli di Stato (MTS).

Panel A: Italy New Issues bonds

	3Y		**5Y**		**10Y**	
t	Avg. ΔReturn	Tstat	Avg. ΔReturn	Tstat	Avg. ΔReturn	Tstat
10	16.157	1.647	13.853**	2.845	14.456**	2.585
20	9.194*	1.998	12.685**	2.544	16.897***	3.959
30	7.351*	1.913	17.497*	1.958	20.515***	3.898
60	5.234*	1.868	30.257*	2.147	25.550***	4.779
80	4.348	0.980	36.141**	2.400	17.768***	3.253
100	4.069	1.189	42.916**	2.330	14.449*	2.066
120	9.372	1.626	48.389**	2.297	15.497	1.753
Obs	14		13		11	

Panel B: Germany New Issues bonds

	2Y		**5Y**		**10Y**	
t	Avg. ΔReturn	Tstat	Avg. ΔReturn	Tstat	Avg. ΔReturn	Tstat
10	0.002	0.380	0.007	0.670	-0.025	-0.997
20	0.000	0.033	0.020	1.330	-0.019	-0.604
30	0.003	0.399	0.029*	2.079	-0.016	-0.473
60	0.000	0.055	0.039	1.684	0.028	0.741
80	0.003	0.380	0.040	1.471	0.060	1.338
100	-0.000	-0.064	0.036	1.341	0.016	0.418
120	0.003	0.329	0.026	0.754	0.049	0.936
Obs	20		13		13	

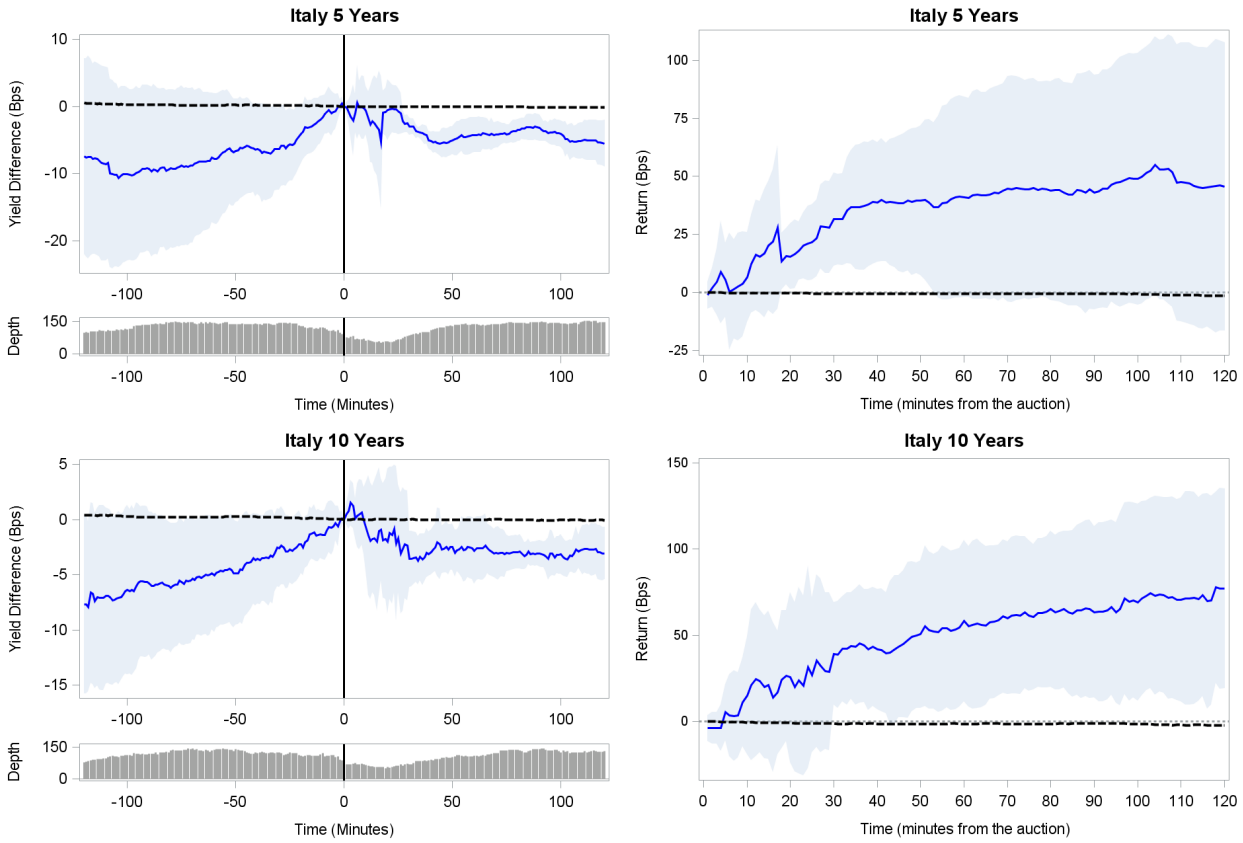

Figure 10. Yield Difference and Return for the off-the-run bonds

This figure show the average yield difference (top panel), the total depth available in the market (bottom panel, in Millions of €), and the cumulative average Δ return (right side), only for the re-openings of off-the-run bonds. The shaded area represents the 95% confidence interval around the sample mean, and the black dashed line represents the average yield difference on non-auction dates. The database is composed by fixed coupon sovereign bonds for Italy [Buoni del Tesoro Poliennali (BTP) with maturity of 3, 5 and 10 years)], from June 2011 to December 2016. The source of data is the Mercato dei Titoli di Stato (MTS).

Table 10 Yield Difference and Return for the off-the-run bonds

This table shows the average yield difference and the average Δ Return, during the auction datesonly for the re-openings of off-the-run bonds. The number of observations corresponds to the number of auctions for each country and maturity (Panel A for Italy, and Panel B for Germany). *, **, and *** denote significance at the 10, 5, and 1% levels using a t-test to verify if the values are statistically different from zero. The database is composed by fixed coupon sovereign bonds for Italy [Buoni del Tesoro Poliennali (BTP) with maturity of 5 and 10 years)], from June 2011 to December 2016. The source of data is the Mercato dei Titoli di Stato (MTS).

Panel A: Italy Yield change

	5Y		**10Y**	
t	Avg. Yield Diff.	Tstat	Avg. Yield Diff.	Tstat
-120	-7.416	-1.310	-7.712*	-2.262
-100	-10.066	-2.004	-6.362*	-1.964
-80	-9.2	-2.009	-6.2**	-2.507
-60	-7.783*	-2.066	-5.037*	-2.301
-30	-6.316**	-2.655	-2.6	-1.754
-20	-4.016*	-2.326	-2.225*	-1.992
-10	-1.566	-1.272	-1.425	-1.531
10	-0.6	-0.431	-0.662	-0.392
20	-0.5	-0.284	-2.000	-0.747
30	-2.966***	-6.033	-3.587**	-3.355
60	-4.216***	-4.104	-2.862*	-2.294
80	-3.516***	-5.446	-2.975***	-4.749
100	-4.066***	-5.322	-3.137***	-4.126
120	-5.5**	-4.018	-3.075**	-3.075
Obs	6		8	

Panel B: Italy Returns

	5Y		**10Y**	
t	Avg. ΔReturn	Tstat	Avg. ΔReturn	Tstat
10	6.664	0.882	15.144	1.052
20	15.541**	2.847	25.675	1.275
30	31.518***	4.034	39.362**	3.116
60	41.157*	2.455	58.245**	2.942
80	43.840*	2.395	65.395**	3.416
100	48.873*	2.320	68.970**	2.855
120	45.599	1.892	77.279**	3.155
Obs	6		8	