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Price Effects of Sovereign Debt Auctions in the Euro-zone: The Role of the Crisis[*]

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ABSTRACT

We show that new public debt issues cause an auction cycle for Italian secondary-market debt, but not for German debt. The cycle is mainly observed for the crisis period since mid-2007 and is larger when the crisis, as measured by yield volatility and CDS spreads of primary dealers, is more intense. Volatility seems to be the main driving factor. The cycle is also present in secondary-market series with maturities close to the auctioned series. Our findings are consistent with the theory of primary dealers' limited risk-bearing capacity. There is also weak evidence of spill-overs from foreign auctions to domestic markets.

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1. Introduction

Auctions are important events in the treasury bond market. As their timing and size are typically known several days in advance, in an efficient market one would expect no predictable bond price or yield movements around auctions.[1] Nevertheless, recent empirical research documents the existence of an 'auction cycle' in the U.S. treasury bond market, in which bond yields show an inverted V-shaped pattern around the auction dates.[2] That is, bond yields rise in the run-up to the auction and fall back to their original level after the auction.

In this paper, we offer new evidence on the existence of an auction cycle in secondary markets for public debt and explore specifically the impact of the economic and financial crisis on the magnitude of the auction cycle. We focus on two countries, Germany and Italy, with large economies and substantial amounts of public debt outstanding.[3] Hence, these countries have public debt markets that are among the most liquid and active of the euro-zone. However, they have been affected in substantially different ways by the crisis, with German yields falling to unprecedentedly low levels and Italian yields rising to dangerously high levels. Moreover, the two countries generally feature different auctioning mechanisms and auctioning policies. We compare the auction cycle for the two countries during periods of different intensity of the crisis and find that the crisis has a strong effect on the Italian auction cycle, but essentially no effect on the German auction cycle.[4]

We focus on a particular theoretical explanation for the existence of the auction cycle, namely the inventory management operations of the primary dealers. This theory has a number of testable predictions specifically related to the crisis. A first prediction is that if the crisis intensifies as evidenced by higher market volatility, primary dealers will charge higher markups and we expect the auction cycle to be larger. A second prediction is that the auction cycle also becomes larger if, as a result of the crisis becoming more intense, the risk-bearing capacity of the primary dealers shrinks. Since primary dealers make the market in bonds of various maturities, a third prediction of the theory is that an auction also puts pressure on the yields of bonds with maturities close to the auctioned maturity.

[1] Of course, the announcement of the auction outcome may move the market in so far as it is unexpected, see Fleming and Remolona (1997).
[2] See Fleming and Rosenberg (2007) and Lou, Yan and Zhang (2013).
[3] At the end of December 2012 the total Italian public debt was €1,990 billion (of which €1,640 billion of outstanding bonds), while the German public debt was €1,139 billion.
[4] However, German public debt markets are affected by the crisis in other ways, in particular by flight-to-safety effects (e.g., see De Santis, 2014).

Our results are strongly in line with these predictions. Secondary-market yields on Italian public debt increase in anticipation of a new debt auction and decrease after the auction, while there is little evidence of such an auction cycle for German public debt. Importantly, this difference in the behaviour of Italian and German secondary-market yields is only present between in the period of the crisis since mid-2007, which is in line with the strong adverse tensions in the Italian debt markets during the crisis, while no such tensions were observed for the German debt markets. We provide further testing of the crisis-related predictions of the theory by linking the size of the auction cycle to the yield volatility and the risk-bearing capacity of the primary dealers, as captured by an index of CDS spreads, in the relevant market. While for Germany we are unable to detect any link between an auction cycle and any of the two measures, for Italy we do find that an increase in market volatility or a reduction in risk-bearing capacity has a strong positive effect on the size of the auction cycle. While the Italian auction cycle ranges over an average of 13 – 17 basis points since mid-2007, depending on the maturity of the issued debt, there are moments when the auction cycle is far larger with estimated peaks of up to 80 – 130 basis points around the end of 2011.

Alternative explanations of predictable price patterns around auctions have been put forward, such as the on/off-the-run effect, price effects of repo specialness and supply effects (see Section 2). All these theories predict price effects in anticipation of the auction, but little or no effect after the auction. Instead, we do find predictable patterns after auctions. We also find that the secondary-market behaviour of series for which there is *no* auction, but with a maturity close to that of the auctioned series, is very similar to the secondary-market behaviour of the auctioned series. This particular finding supports our theory of yield movements being driven by the behaviour of primary dealers with limited risk-bearing capacity over the other possible explanations.

We present two practical applications of our analysis. First, for the issue of an Italian five-year bond we calculate for the sub-period since mid-2007 an auction-induced additional issuance cost of almost 11 million euros, while the additional annual cost associated with a complete roll-over of the outstanding debt amounts to almost 1.3 billion euros. This is a more-than-10-fold increase of the corresponding numbers for the pre-crisis period. In a second application, we assess the profit opportunities of duration-hedged trading strategies in the debt whose maturity is auctioned. However, the negative Sharpe ratios suggest that it is not possible to profitably exploit Italy's auction cycles, the reason being that Italian transaction costs having increased substantially during the crisis. Even so, there may be timing opportunities for parties that for exogenous reasons have to trade.

There exists only a limited literature on how public debt auctions affect secondary-market yields. Fleming and Rosenberg (2007) document positive yield changes before U.S. treasury auctions and negative yield changes after the auctions. Closest to this paper is Lou, Yan and Zhang (2013), who document the existence of an auction cycle in the U.S. treasury bond market. Our paper complements and extends their work in several ways. First, we explore auction cycles for countries other than the U.S. Second, and most importantly, based on our theoretical framework we explicitly link the auction cycle to the influence and the intensity of the crisis. We do this by contrasting the evidence for Italy, which experienced severe debt-market tensions during the crisis, with that for Germany, as a flight-to-safety country; by contrasting for Italy the pre-crisis period and the crisis period; and by exploring how the auction cycle is affected by variations in market volatility and primary dealer risk-bearing capacity. The results suggest that the change in market volatility is the main driving force in this regard. How the crisis affects the auction cycle is important, because it may inform policymakers about the costs associated with debt issuance during periods of heightened financial-market tensions and how they could limit these. Third, the fact that we have auctions data for two major European countries allows us to explore spill-overs from foreign auctions to domestic secondary debt markets. Motivated by general perceptions that contagion among financial markets intensifies during crises, we interact dummies of foreign auctions with indicators of crisis intensity. However, only limited evidence of spill-overs from foreign auction activity is found. Finally, we document differences in the German and Italian auction cycles, even after controlling for our indicators of the crisis intensity. We explore various policy and design implications of our analysis for debt auctions. In particular, we address the discretion to regulate the eventual supply at the auction.

The remainder of this article is structured as follows. Section 2 contains a description of the auction processes, after which it provides a brief literature review and sets out the conceptual framework for our empirical analysis. Section 3 discusses the dataset, while Section 4 presents the results of an event study in the vein of Lou *et al.* (2013). Section 5 contains the basic regression analysis and provides further testing of our theoretical framework, by linking the auction cycle to market volatility and the risk-bearing capacity of the primary dealers and exploring potential cross-border spill-overs of auctions. Section 6 contains the applications to trading strategies and issuance costs, and discusses the potential policy and design implications of our analysis. Finally, Section 7 concludes the main body of the paper.

2. Auction mechanisms, conceptual framework and model

2.1. Auction procedures for German and Italian public debt

Detailed descriptions of the auction procedures for Germany and Italy can be found in AFME (2013). Here, we describe them briefly, while we provide more information in Appendix A. Both governments report the days on which public debt auctions take place in an annual issuance calendar, implying that auction dates are precisely known for quite some time in advance. The terms and conditions of each specific auction, including its size, are announced about a week before it actually takes place. Hence, generally they are in the information set for the event window we consider.

Acting for the Federal Government, the German Finance Agency (GFA) auctions federal securities via the Bundesbank. Only members of the "Bund Issues Auction Group" (37 members, according to AFME, 2013), which includes both domestic and foreign banks, can participate directly. For the maturities under consideration, Germany uses discriminatory-price auctions, in which bids above the lowest accepted price are allotted in full at the submitted price, while bids below this lowest accepted price will not be considered. However, non-competitive bids are also possible and are allotted at the weighted average price of the accepted competitive bids. The auction results are published on the auction day, while the financial settlement and transfer of ownership of the allotted securities typically take place two days after the auction.

The terms and conditions of auctions of Italian public debt, which are carried out by the Italian central bank, are published roughly one week before the auction. Only specific agents, the so-called "Authorized Dealers" (twenty, according to AFME, 2013, and almost a subset of Germany's primary dealers), can submit bids. For the maturities we consider the Italian Treasury uses marginal-price auctions, also referred to as uniform-price auctions, in which all bidders pay the same price, the so-called marginal price. In order to compensate them for having collected bids from the public, the dealers in these auctions are awarded a commission of 0.20% to 0.40% of the amount allotted. The settlement takes place two working days after the auction.[5]

A potentially important difference between the German and Italian auctions is that the supply in German auctions after their announcement is variable, while that in Italian auctions was fixed until not too long ago. Concretely, the German Treasury reserves the right to reject all bids, to scale down bids quoting the lowest accepted price, and/or to scale down non-competitive bids. Hence, a certain amount of the instrument may be retained for secondary market operations after the auction. Only since October 2008 for our 5- and 10-year series and since December 2011 for our 2-year series has Italy allowed itself discretion regarding the eventual supply (Italian Treasury, 2014a).

2.2. Potential sources of yield effects of auctions

As discussed above, most of the bonds in treasury auctions are bought by a relatively small number of primary dealers. Those primary dealers have limited risk-bearing capacity, for example because they are risk averse or their capital is costly. Consequently, they need to be compensated for their large position in the asset and the price risk they take on their inventory in the auction. This compensation comes in the form of higher auction yields from which the dealers generate trading profits (see Fleming and Rosenberg, 2007). If the dealers' risk aversion or the price risk is larger, one may expect them to charge a higher yield at the auction. Due to hedging pressures, other bond series, and in particular those for which the returns are highly correlated with the return on the new series, will also see an increase in the yield. For equity markets, empirical evidence in support of the inventory theory has been found by Hansch *et al.* (1998) and Hendershott and Menkveld (2014). These papers detect significant price pressures from dealers' inventories. They also document that inventories are mean reverting with a half-life of one to two-and-a-half days, so that the price pressures are temporary.

In the bond market, several studies document price pressures around auctions. Fleming and Rosenberg (2007) study the price returns of U.S. treasury bonds on days surrounding the auctions, and relate these to the position changes of primary dealers, decomposed into a part

[5] A fixed proportion (between 10% and 35%, depending on the type of bond) of the amount offered in each auction is reserved for non-competitive supplementary re-openings taking place on the business day after the auction. Only "Specialists", who are dealers selected, and evaluated year-by-year, by the Treasury are allowed to participate in the re-openings. Settlement is at the marginal price of the auction.

related to auctions and a residual part. They document positive yield changes before auctions (1 to 1.5 basis points), and negative yield changes after auctions (1 to 2.5 basis points), as a result of the auction-driven position changes. They also show that the larger the position change, the larger the yield effects. Lou *et al.* (2013) empirically document that yields in the U.S. secondary market increase before auction days and decline again in the days after the auction. The effect is quite large and roughly the same for 2, 5 and 10-year maturities, namely around 2.5 basis points in a five-day window around the auction. They also document spillovers from 10-year bond auctions to the 5-year yield (and less so to the 2-year yield) and stronger effects in volatile periods. Forest (2012) adds to this literature by investigating the effect of bid-to-cover ratios on U.S. Treasury interest rates during the 1990s. He finds that a higher-than-expected bid-to-cover ratio, which indicates strong auction demand, tends to push the yield of 5 and 10-year Treasury notes down. Conversely, a lower ratio, indicating a weak auction demand, is associated with increased interest rates.

All this evidence is consistent with the inventory management explanation. Nevertheless, there are possible alternative explanations for yield effects around auctions. These yield effects could pertain to the primary market, to the secondary market, or both. First, auctions may change the supply of treasury bonds. As such, there could be an effect of auctions on the interest rates on both outstanding and new debt issues. Moreover, the effect should remain for as long as the change in the supply lasts. Krishnamurty and Vissing-Jorgensen (2012) find a negative effect of the U.S. Treasury bond supply on the difference between corporate bond yields and treasury yields.[6] Second, with the auction of a new series of a given maturity the previous issue of the same maturity goes “off-the-run”, while the new series becomes the “on-the-run” series.[7] The liquidity of the on-the-run issue is generally higher, for example because it is better collateral for repo transactions, and therefore the on-the-run issue may have a higher price, see Sundaresan (1994). Prices of Treasury securities in the cash market may also reflect future specialness in the repo market (Duffie, 1996, and Corradin and Maddaloni, 2013). Of course, the two effects are closely related because a part of the on-the-run premium is in fact due to the specialness of the on-the-run security (Jordan

[6] Further evidence on the yield effects of the supply of treasury securities is provided by Joyce et al. (2011), Krishnamurty and Vissing-Jorgensen (2011), and d’Amico and King (2013).

[7] The switch to the new on-the-run bond does not necessarily occur on the auction day. For instance, Bloomberg, our data source, reports the yield of “bonds and bills selected on the closest current nominal maturity to the indicated term”. Whereas for Germany the change in the benchmark bond typically happens on the auction day, for Italy it is not standardized and tends to occur a few days after the auction.

and Jordan, 1997).[8] After the auction announcement, the previous issue loses its "on-the-run" status and its yield goes up (see Keane, 1996). Third, the new on-the-run series has a longer maturity than the series that goes off-the-run, implying that, with an upward-sloping term structure, this pushes up the yield on the new on-the-run series compared to the previous on-the-run series.

A key difference between these theories and the inventory theory is that the alternative theories all predict persistent or permanent changes in yields after the auction, whereas the inventory theory predicts temporary yield effects that are reversed after a few days (an 'auction cycle'). We will show strong evidence supporting the reversal.

2.3. A simple model of primary dealer behavior

We present a simple theoretical framework that models the behaviour of primary dealers with limited risk-bearing capacity. The model is relevant for the primary market, as suggested by the description of the auction processes in the previous subsection. It is also relevant for the secondary market, as the group of secondary-market dealers in public debt to a large extent coincides with the group of primary dealers. We derive specific predictions about the role of volatility and risk aversion and about spill-overs of auctions to secondary-market yields on bonds of other maturities.

Starting point is the model by Ho and Stoll (1983) of oligopolistic dealers who make the market in several correlated assets. Assuming a mean-variance utility function, in a one-period setting the dealers will quote a price P_j (mid-point of bid and ask prices) based on the equilibrium ("fundamental") value F_j of the asset, corrected for the current inventories in all correlated assets ($i,j \in \{1,..,N\}$):

$$P_j = F_j - A\sum_{i=1}^{N} Cov\left(R_j, R_i\right)I_i,$$

[8] Krishnamurthy (2002) shows that the on-the-run premium is highest right after an auction and declines slowly towards the new auction. This pattern is precisely what one expects if the on-the-run premium is driven by the specialness of the bond, because just before the auction, only a few days of being special remain for the previous bond issue before the market switches to the newly-issued bond as the benchmark.

where $Cov\left(R_j, R_i\right)$ is the covariance between the returns on the assets *i* and *j*, *A* is the coefficient of absolute risk aversion and I_i is the inventory in asset *i*. Hence, the effect of an increase in the inventory of asset *i* on the price of asset *j* is given by:

$$\frac{\partial P_j}{\partial I_i} = -ACov\left(R_i, R_j\right) = -A\beta_{ji}\sigma_i^2,$$

where $\sigma_i^2 = Var\left(R_i\right)$ is the variance of the return on asset *i* and β_{ji} is the exposure of the return on asset *j* to the return on asset *i*, $\beta_{ji} = \frac{Cov\left(R_j, R_i\right)}{\sigma_i^2}$. The own price effect of a change in the inventory of asset *i* simplifies to

$$\frac{\partial P_i}{\partial I_i} = -A\sigma_i^2,$$

and, hence, is proportional to the variance of asset *i*.

This model yields several useful predictions for our ensuing analysis of the bond auctions. First, an upcoming auction of a new bond *i* will lead to a positive inventory position in this asset. This will have a negative effect on the price (and, hence, a positive effect on the yield) at which the bond can be issued. Second, the larger the issuance size of the auction, the larger the inventory and, hence, the larger this price effect, which is equal to $\left(\partial P_i / \partial I_i\right)\left(\Delta I_i\right) = -A\sigma_i^2 \Delta I_i$. Third, in the run-up to the auction, the yield on the latest issue of the same headline maturity or on a close maturity, which we denote by bond *j*, will increase, as the correlation of the returns on bonds *i* and *j* tends to be high, at least at the daily frequency. Fourth, the price effect on this bond *j* will be larger if the amount issued of bond *i* is larger. This effect equals $\left(\partial P_j / \partial I_i\right)\left(\Delta I_i\right) = -A\beta_{ji}\sigma_i^2 \Delta I_i = \beta_{ji}\left(\partial P_i / \partial I_i\right)\Delta I_i$. That is, the cross-price effect of an auction in bond *i* on the price of bond *j* is equal to the own price effect on bond *i* multiplied by the return exposure of bond *j* to the return on bond *i*.

The crisis manifests itself in two possible specific ways in the effect of an auction on the price of the bond. We will explicitly test for these channels. First, when the crisis is more severe, the variance of the return on bond *i* is likely higher and, hence, the effect of a given auction of bond *i* on its price and on closely substitutable bonds will be larger. Second, during a more severe crisis, primary dealers behave in a more risk-averse way, as captured by a higher value of *A*, and, hence, an auction of a given size also has larger price effects for this reason.

3. Data description and key statistics

Our dataset consists of secondary-market daily yields of various maturities, bid-ask spreads, futures yields, CDS spreads, repo rates, the Euro OverNight Index Average (EONIA) rate, and information on auctions of Treasury bonds for Germany and Italy over (at most) the period from 1 January 1999 until 12th February 2013. The information on the auctions is collected both from Bloomberg and directly from the countries' debt agencies. It consists of the specific maturity of the new issue, the auction date, the total amount bid, the total amount allotted and the average accepted yield at which the debt is sold. The remaining data are all from Bloomberg. For secondary-market yields Bloomberg has agreements with a set of brokers who report their daily bid prices to Bloomberg, which then publishes an average of these prices for their customers.

Table 1 reports summary statistics for the bond yields on our baseline maturities of 2, 5 and 10 years. It does so for the full sample period, the "pre-crisis" sub-period up to June 30, 2007, and the "crisis" sub-period as of July 1, 2007. Over the latter sub-period we observe a slight downward trend in the yields on German and Italian debt, although the Italian yields occasionally exhibit sharp peaks during this sub-period (not shown). Indeed, the yields have become significantly more volatile since mid-2007.

Table 2 reports some key statistics for the auctions data. The frequency of the Italian auctions is higher than that for Germany. Moreover, for Italy the frequency of the 2 and 5-year auctions is higher during the first than during the second sub-period, while for Germany for all three maturities the frequency is higher during the second crisis period. Over the entire sample period, the number of auctions of specific maturities ranges from 90 for 5-year German debt to 189 for 2-year Italian debt. For the sub-periods, these numbers range from 43 for 5-year German debt during the first sub-period to 122 for 2-year Italian debt during the first sub-period. The total number of Italian auctions exceeds the number of German auctions, while Italian auctions are on average smaller, both in terms of the total amounts bid and in terms of the amounts allotted. However, part of the difference in issuance size is accounted for by Bloomberg not publishing the non-competitive bids for Italy on the business day after the auction.[9] As reported by Bloomberg, average total bids in Italian auctions lie in the range of 4 – 5 billion and in German auctions in the range of 6 – 15 billion, while average allotted amounts lie in the range of 1.8 – 3 billion for Italy and in the range of 5 – 7.5 billion for Germany. The average accepted yields at the auctions for Germany lie uniformly below those for Italy for any given maturity, although the differences are small during the first sub-period. These differences are substantially larger during the second sub-period, with the average accepted yield ranging between 1.40% and 2.80% for German debt and between 2.98% and 4.82% for Italian debt. Finally, Table 2 reports average bid-to-cover ratios, which for the full sample period are in the range of 1.5 – 1.8 for Germany and 1.6 – 2.1 for Italy. However, for each of the two countries and for all maturities considered, the average bid-to-cover ratios have gone down. During the first sub-period, the bid-to-cover ratios are in the ranges of 1.7 – 2.2 for Germany and 1.8 – 2.4 for Italy, whereas during the second sub-period they are in ranges 1.2 – 1.5 for Germany and 1.3 – 1.7 for Italy.

4. Event study analysis

This section presents the results of an event study in which we report the average difference between the on-the-run yields during the 5 trading days before and after the auction and the yield on the auction day.[10] Specifically, following Lou *et al.* (2013) we report the average of $y_t - y_0$, where y_t is the end-of-day yield of the on-the-run Treasury bond on day *t*, and y_0 is the end-of-day yield of the same headline maturity (2, 5 and 10-years) bond on the auction day.[11] We report 90% confidence bands (based on Newey-West adjusted standard errors) around these yield differences. Figure 1a shows these movements in basis points for both countries for the full sample period. Consistent with Lou *et al.* (2013) who focus on the U.S. Treasury bond market, we find an inverted-V shaped pattern. That is, there is a tendency for

[9] For Germany, Bloomberg reports the sum of the competitive and non-competitive bids, whereas for Italy only the competitive bids are published. However, the non-competitive supplementary bids are limited to a fixed proportion – see Footnote 4.

[10] We limit ourselves to a 10-day window around each auction, because by far most of the movement in the yields is concentrated on these days. During the entire window or almost the entire window, the terms and conditions of the auction are known. Moreover, by focusing on a relatively narrow window we reduce the risk of contamination due to the presence of auctions of other bonds. These potential effects will be controlled for in the regression analysis below.

[11] As discussed above, Bloomberg reports the yield on the bond with maturity closest to the headline maturity. As a result, the underlying benchmark bond will generally switch within the remaining part of the window after the auction date.

yields to increase in the run-up to the auction and to fall once the auction has taken place. For Italy these movements are both larger and tend to reach a higher degree of significance than for Germany. In the run-up to the auction yields increase by up to 3.5 basis points for five- and ten-year debt and by up to almost 3 basis points for two-year debt. For German debt, the maximum yield increase is around 2.5 basis points for the five-year debt. Next, we split the sample into our two sub-periods. Comparing the before-crisis (Figure 1b) and crisis periods (Figure 1c) we observe that for Germany the differences in the movements of the yields between the two sub-periods are relatively limited when compared with Italy. For Italy yield movements before the crisis are very small and only occasionally significant, while during the crisis they are substantially larger and in many instances highly significant. The magnitude of the movements ranges from around 6 basis points to around 10 basis points at the limits of the window we consider.

A potential complication is that usually in the days before the auction of a maturity *m* debt instrument Bloomberg reports the yields on the latest issue of this headline maturity, while after the auction Bloomberg switches to reporting the yield on the new issue of this headline maturity. In other words, for most auctions we are comparing yield movements in two different instruments (although usually with maturities very close to each other) around the time of the auction. To assess the relevance of this switch of the benchmark bond, for each of the headline maturities we explore the yield movements of an instrument with a maturity close to the relevant headline maturity. Specifically, we study the yields on the 3-year (6-year, 9-year) instrument around the issuance dates of the 2-year (5-year, 10-year) instrument. The advantage of this approach is that we can explore the yields movements on instruments that are kept unchanged as much as possible around the auction dates. Figure 2 shows the results of this variation. Both qualitatively and quantitatively, the results are very similar to those shown in Figure 1. In particular, by far most of the action is for Italy during the second sub-period. These findings suggest that the switch after the auction in the instrument for which yields are reported has no bearing on our results.

The combined set of results reported so far casts an interesting perspective on the various theoretical explanations for yield movements around auction dates. First, the fact that yield movements during the run-up of auctions tend to be fully reversed after the auction suggests that the auction cycle is not driven by long-term supply effects. Second, our finding of a full auction cycle for close-maturity instruments suggests that both the liquidity effect associated with changes in the benchmark security as well as the specialness effect associated with the repo market are unimportant. Since the close-maturity instrument is not subject to a change in benchmark status, the aforementioned liquidity effect cannot be the source of its auction cycle. Moreover, a permanent reduction in liquidity would be associated with a permanent increase in the yield. Similarly, if the close-maturity bond were to become less attractive as collateral, its yield would not revert to its original level. However, our results are fully consistent with the above theory of limited risk-bearing capacity of dealers. According to this theory the price effects of close-maturity assets, hence assets with similar risk profiles, should be similar.

To further corroborate these results, we also study the effects of auctions on the prices of Treasury bond futures. There is an extremely active market for futures on German bonds of 2, 5 and 10-year maturity. Since 2009, there is also an active market in futures on the 10-year Italian bond (there are also more recent markets in 2 and 5 year bond futures, but these are less active). Futures contracts are a very efficient hedging vehicle for bond traders. According to our inventory model, auctions should therefore also exert price pressure on the futures market, but alternative explanations like liquidity and on-the-run effects have no immediate predictions for the futures market. Figure 3 shows the price pattern of the Italian and German 10-year bond futures around the auctions of the Italian and German 10-year bond for the period September 15, 2009, the starting date of the futures series on the 10-year Italian debt, to February 12, 2013. There is a clear and statistically significant downward price pressure for Italy, but no significant effect for Germany. This price pressure is temporary: after the auction prices revert to their original levels. These effects are very similar to the effects on the bond yields. In terms of magnitude, the auction cycle is around 1% of the price, i.e. a 50 basis points downward price movement before the auction and a 50 basis points upwards movement after the auction. The futures contracts are written on a notional bond with a 6% coupon. This bond’s duration is 7.8 years. Hence, this auction cycle translates into a 13 basis point auction cycle in the yield of this notional bond. This is almost exactly the same as the auction cycle in the yield of the Italian 10-year bond during the crisis period, shown in Table 3.

5. Regression analysis and interpretation of results

5.1. Regressions with auction dummies

The drawback of an event study analysis is the potential presence of confounding factors occurring during the event window. In particular, debt auctions of different maturities sometimes take place at the same or a nearby moment. With a regression we can control for the role of other relevant variables. For maturity *m* of country *i*, we estimate the following equation:

$$\Delta y_t^{i,m} = c_0^{i,m} + \sum_{l=4}^{-5} \alpha_l AUC_{t+l}^{i,m} + \sum_{l=4}^{-5} \beta_l AUC_{t+l}^{i,n} + \varepsilon_t^{i,m},\ n \neq m, \tag{1}$$

where c_0 is a constant, *AUC* is a dummy that takes a value of 1 (0) when there is an (no) auction of the specified country-maturity combination on the indicated date, ε is a disturbance term and $n \neq m$ denotes the maturity of another series. Hence, equation (1) links daily yield changes to upcoming ($l > 0$) or past ($l < 0$) auctions of the same and other (i.e., $n \neq m$) maturities. We estimate this equation for Germany and Italy and for the maturities of 2, 5 and 10 years, either setting the β coefficients to zero or allowing them to be free. We use an *F*-test to test the hypotheses:

$$\begin{aligned} H_0^{\alpha}&:\ \left(\sum_{l=4}^{0} \alpha_l\right) - \left(\sum_{l=-1}^{-5} \alpha_l\right) = 0, \\ H_0^{\beta}&:\ \left(\sum_{l=4}^{0} \beta_l\right) - \left(\sum_{l=-1}^{-5} \beta_l\right) = 0. \end{aligned} \tag{2}$$

Similar to the event study of the previous section, we expect that $\sum_{l=4}^{0} \alpha_l > 0$ and $\sum_{l=-1}^{-5} \alpha_l < 0$. In other words, we test the presence of a full cycle of temporary up and down movements in yields as a result of a given auction.

Table 3 reports the OLS estimates of the magnitude of the auction cycle, $\left(\sum_{l=4}^{0} \alpha_l\right) - \left(\sum_{l=-1}^{-5} \alpha_l\right)$. The standard errors are Newey-West adjusted. The regression results are in line with the results of the event study. For the full sample period and with only the own maturity included on the right-hand side of the regression equation, we see that for

Germany the auction cycle is significant only for the 5 and 10-year maturity,[12] while for Italy at all maturities the level of significance is higher and the sum of the coefficients is about double the size of that for Germany. Turning to the sub-periods, we see that the action is essentially confined to Italy during the crisis period. In the first sub-period, the only instance of significance concerns the German 10-year auction. In the second sub-period, for Germany only the 5-year maturity is significant, while for Italy all maturities are (highly) significant. In addition, the sizes of the Italian coefficient sums are more than double those for the full sample period. For example, for the 2-year maturity the auction cycle is 17 basis points over a period of 10 trading days.

We also test formally whether the magnitudes of the auction cycles differ between Germany and Italy. To this end, we estimate (1) as a system simultaneously for the two countries and use a Wald test for the null hypothesis that the auction cycles are equally large. For the full sample and for the first sub-sample, except in the case of 10-year debt, the hypothesis can never be rejected. However, for the second sub-period the hypothesis is rejected for all maturities with a p-value of 0.076 for 5-year debt and with a p-value of 0.004 for 2 and 10-year debt.

Inclusion of another headline maturity of the same country i (the β coefficients) tends to have only a limited effect on the size of the own-maturity coefficients when they are significant and does not affect the statistical significance at our standard confidence levels. Specifically, the sums of the own-maturity coefficients for Italy during the second sub-period remain highly significant and, in fact, this sum even increases substantially for the 2-year maturity regression with the 10-year alternative maturity. Except in one instance for Italy during the second sub-period, the auction cycle associated with the alternative maturity is significant as well as rather substantial in size.

We have also tested the symmetry of the auction cycle, i.e. the hypothesis that $\sum_{l=-1}^{-5} \alpha_l = \sum_{l=4}^{0} \alpha_l$. As already discussed above, this test can be used to discriminate the hypothesis that the effects of debt auctions are driven by the behaviour of primary dealers against the alternative theories we reviewed above, which all predict a permanent effect of auctions on secondary market yields. We do not find instances in which the symmetry of the auction cycle is rejected, which casts doubt about the relevance of these alternative theories for the observed movements in the secondary market yields.

[12] We term a statistic "significant" when it is statistically significant at the 10% confidence level.

5.2. Regressions with issue size of the auctions

According to our theoretical model, a larger issue implies that primary dealers have to hold a larger inventory of the new debt series and, hence, the price movement around the auction date will be larger. Hence, we refine baseline regression (1) by replacing the auction dummies with the issuance size of the auctions:

$$\Delta y_t^{i,m} = c_0^{i,m} + \sum_{l=4}^{-5} \alpha_l \; SIZE_{t+l}^{i,m} + \sum_{l=4}^{-5} \beta_l \; SIZE_{t+l}^{i,n(\neq m)} + \varepsilon_t^{i,m}, \qquad (3)$$

where *SIZE* is the announced (maximum) amount to be issued in billions when there is an auction of the specified country-maturity combination on the indicated date. Otherwise, *SIZE* is zero. It is important to recall that the size of the auction is announced well before the auction, so that any potential feedback effects of yield movements onto the (maximum) amount to be issued are absent. We expect that, if there is any effect of the auction size, the effect is positive, because the larger the size of the auction, the more difficult it will be for the primary dealers to sell their inventory of the acquired new issue. This is borne out by the estimates of $\left(\sum_{l=4}^{0} \alpha_l\right) - \left(\sum_{l=-1}^{-5} \alpha_l\right)$ shown in Table 4. Whenever this coefficient sum is significant, it is positive. For the full sample regression, for Germany only the 10-year maturity yields significance now, while for Italy the coefficient sums are highly significant at all maturities and, moreover, they are much larger than in the case of Germany.

Again, most of the action is in the Italian debt in the second sub-period. To give an idea about the magnitude of the effects, for the 2-year maturity an increase by one billion in the (maximum) issuance size produces an additional up and down movement in the yield of almost 6 basis points. These estimated yield impacts are larger than the estimates for the U.S. auctions documented by Fleming and Rosenberg (2007), who report a 0.3 to 0.5 basis point yield increase per billion dollars auctioned for the five year U.S. Treasury note. The yield impacts can also be compared with the effects of the recent large-scale bond purchases by the ECB. Eser and Schwaab (2013) find a yield decrease for Italy of 1.5 basis points per billion euros of bond purchases.

For the regressions with the other maturity included, we see that the coefficient sums on the own maturity generally become somewhat smaller, except in the case of the 2-year own maturity combined with the 10-year other maturity, where an increase in the size by one billion produces an almost 10 basis points additional yield.

5.3. Probing deeper into the role of the crisis: volatility and risk aversion

The results for Italy in the previous subsections suggest that during the crisis period the auction cycle is larger than when there is no crisis. In this subsection we provide additional evidence for the effect of the crisis on the auction cycle.

The crisis manifests itself in increased uncertainty about the yields and/or more risk aversion. In line with the theoretical model, we expect the auction cycle to be larger for both reasons. As our measure of uncertainty for date *t*, we construct a volatility measure $VOL_t^{i,m}$ as a moving window over the period (*t*-30, .., *t*-1, 0) of the standard deviation of the daily yield changes for the maturity *m* instrument of country *i*, where past observations are weighed along a scheme that declines linearly with the number of days passed. As our measure CDS_t^i of risk aversion, we construct an index of the CDS spreads of all primary dealers for country *i*.[13] The CDS spread is mainly determined by the product of the probability of default and the loss in case of default. One may expect the probability of default to increase with the intensity of the crisis, which makes primary dealers more reluctant to take a given position in a new debt issue. Hence, they would require a larger return on a position of a given size, so that we would expect the auction cycle to be positively correlated with our index of CDS spreads.[14]

To investigate the roles of volatility and risk aversion, we estimate:

$$\Delta y_t^{i,m} = c_0^{i,m} + \sum\nolimits_{l=4}^{-5} \left(\alpha_l + \beta_l INT_{t+l}^{i,m} \right) AUC_{t+l}^{i,m} + \varepsilon_t^{i,m}, \tag{4}$$

where $INT_{t+l}^{i,m}$ is a variable or vector of variables to be interacted with the auction dummies. For $INT_{t+l}^{i,m} = VOL_{t+l}^{i,m} - \overline{VOL}^{i,m}$ we can use our full sample period, while for $INT_{t+l}^{i,m} = CDS_{t+l}^{i} - \overline{CDS}^{i}$ the sample period runs from March 8, 2001 until February 12, 2013.

[13] Estimates for an index of the top-5 primary dealers turn out to be very similar and will not be separately reported. In fact, for Germany the list of top-5 dealers is only available for 2013, so for Germany we have to keep the composition of top-5 index constant, while for Italy it may vary from year-to-year as it is available for all our sample years.

[14] In a previous version of this paper, we used the KfW-Bund spread constructed by De Santis (2014) as an indicator of the severity of the crisis. This gave similar results. However, as *VOL* and *CDS* are more directly related to our theory of primary dealer inventory control we report only those results.

Here, $\overline{VOL}^{i,m}$ and $\overline{CDS}^{i}$ are the averages over the auction days of our volatility and CDS index. The formulation of the interaction variables in deviations from their averages keeps the estimates of the dummy coefficients essentially unaffected. Table 5 presents the estimates. When we interact the auction dummies with the volatility index, we see that coefficient sum of the interaction term is never significant for Germany, while it is always (highly) significant and positive for Italy. This may not be surprising because the variation in volatility is substantially smaller for Germany than for Italy during our second sub-sample (see the graph in Appendix B.1 – not for publication). The findings indicate that an increase in volatility (relative to its average) in the secondary market magnifies the auction cycle for Italy. Figure 4 depicts for the three maturities under consideration the "total auction cycle", calculated as $\left(\sum_{l=4}^{0}\hat{\alpha}_l\right)-\left(\sum_{l=-1}^{-5}\hat{\alpha}_l\right)+\left[\sum_{l=4}^{0}\hat{\beta}_l\left(VOL_{t+l}^{i,m}-\overline{VOL}^{i,m}\right)-\sum_{l=-1}^{-5}\hat{\beta}_l\left(VOL_{t+l}^{i,m}-\overline{VOL}^{i,m}\right)\right]$. In particular, for the two- and five-year maturities we see at times sharp positive peaks in the size of the auction cycle during our second sub-sample, the highest peak occurring around the end of 2011 when it reaches about 130 basis points for two-year debt. No such peaks are observed during our first sub-period.

Table 5 also reports the estimates when we interact the auction dummies with the CDS index, so as to assess the effect of fluctuations in risk-aversion on the auction cycle. Again, the effects of including the interaction term are insignificant for Germany, but highly significant and positive for Italy for all three maturities, indicating that the Italian auction cycle increases when the perceived riskiness of the primary dealers increases. To preserve space, we do not depict the total auction cycle. However, in all cases it is similar to that shown in Figure 4, though with somewhat smaller peaks.

Finally, we report in Table 5 also the estimates of the regression when we simultaneously include the interactions of the auction dummies with our volatility index and the CDS index. Not surprisingly, because the two variables are highly correlated the coefficient sums on both of them become insignificant at regular confidence levels. This begs the question which variable is the more important one driving the auction cycle. The economically more plausible transmission channel is that from market volatility to dealers' CDS spreads, rather than the other way round. Therefore, in order to orthogonalise these two factors we regress our CDS index on a constant and our volatility index and include the residuals $RES_{t+l}^{i,m}$ from this regression simultaneously with the volatility index in equation (4). The estimates show (for Italy) that the coefficient sums on the interaction term with the volatility index regain their original significance, while the coefficient sum associated with the interaction term with the residuals is always insignificant. These results suggest that it is changes in market volatility that are driving the effects of the crisis fluctuations, while changes in risk-averse behaviour do not have any distinct additional effect.

5.4. Cross-border spill-overs of auctions

The availability of auction data for two European countries provides us with the possibility to investigate whether secondary market yields in one country are affected by auctions in the other country and whether these potential spill-overs may be different when the effects of the crisis manifest themselves in a more intense way. One hypothesis is that foreign auctions have a direct positive effect on domestic secondary market yields, because primary dealers need to create room to buy the newly-issued foreign debt, but that this positive effect is mitigated when the crisis intensifies, because in that case the primary dealers are less inclined to free up space for the new foreign debt issue. Hence, we extend the regression model in the previous section to:

$$\Delta y_t^{i,m} = c_0^{i,m} + \sum_{l=4}^{-5} \left(\alpha_l + \beta_l INT_{t+l}^{i,m} \right) AUC_{t+l}^{i,m} + \sum_{l=4}^{-5} \left(\gamma_l + \delta_l INT_{t+l}^{j,m} \right) AUC_{t+l}^{j,m} + \varepsilon_t^{i,m},\ j \neq i, \qquad (5)$$

where $AUC_{t+l}^{j,m}$ is the auction dummy for the other country $j \neq i$ for the same maturity and $INT_{t+l}^{j,m}$ is again an interaction variable. In line with the previous section we consider for $INT_{t+l}^{j,m}$ the volatility and CDS indices $VOL_{t+l}^{j,m} - \overline{VOL}^{j,m}$, respectively $CDS_{t+l}^{j} - \overline{CDS}^{j}$. Table 6 reports the estimates for the maximum available sample period. Extending (4) in the absence of a foreign interaction term (i.e., $\delta_l = 0$ for all l) has no effect on the original coefficient estimates that were reported in Table 5 both in terms of significance and in terms of magnitude. Interestingly, there is evidence of an auction cycle in 10-year Italian secondary market yields associated with auctions of 10-year German debt, while the magnitude of this auction cycle is about two-thirds of the auction cycle associated with domestic debt issues. Allowing in addition for a foreign interaction term does not affect this finding. In the case of 5-year Italian debt the foreign interaction term based on the CDS index has a significantly negative coefficient, in line with the above hypothesis. However, this finding has to be interpreted with care, because the foreign interaction term $VOL_{t+l}^{j,m} - \overline{VOL}^{j,m}$ for German 2-year loans has a significant positive sign. Overall, the evidence of foreign auction spill-overs is rather weak, possibly because we have data only for one foreign country rather than all countries serviced by the same primary dealers.

5.5. The role of (foreign) end investors

The discussion of the theoretical model in Subsection 2.3 suggests that auction cycles will be smaller when it is easier for primary dealers to unload their inventory of the newly issued asset. This would be the case when the base of end investors willing to buy the asset is broader. Lou *et al*. (2013) conclude that a large fraction of potential end-investors in U.S. public debt are passive investors that do not stand ready to absorb new debt issues, thereby contributing to the auction cycle. Data constructed by Arslanalp and Tsuda (2012) indicate that the share of foreign holdings of Italian public debt fell from 41% in 2007Q2 to 36% in 2013Q1, while the share of holdings by foreign banks fell from 14% to 7%. By contrast, over the same period the share of German public debt held by foreigners rose from 44% to 56%, while the share held by foreign banks fell slightly from 10% to 9%. Appendix B.2 (not for publication) graphs these shares.

The question arises whether the shrinking base of foreign end investors, and in particular those of the banking sector, which likely reacts faster to market tensions, helps to explain the difference in the auction cycles between Germany and Italy. We extend the baseline regression equation (1) with the share of foreign holdings and estimate it over the period since 2004Q1 (the period for which the debt data have been constructed). The results of these regressions are reported in Appendix B.2 (not for publication). We find that the share of foreign holdings enters with a significantly negative coefficient in the case of Italian 2 and 5-year debt, while the share of foreign bank holdings has a significantly negative coefficient for all maturities. By contrast, foreign (bank) holdings of German public debt are never significant. However, the negative effect of the foreign (bank) holdings on the size of the Italian auction cycle disappears in almost all instances when we extend the more appropriate specification (4), which also includes an indicator of volatility or primary dealer default risk.

6. Implications

6.1 Do yield movements around auctions constitute excess profit opportunities?

Market participants could try to exploit the secondary-market yield movements around auction dates. However, whether these constitute an opportunity to make excess profits depends on the transaction costs that need to be overcome and on the volatility of the returns on the trading strategy, which is potentially higher around auction dates than during other periods.

Following Lou *et al.* (2013) we calculate Sharpe ratios for trading strategies involving two-, five- and ten-year German and Italian debt around their auction dates. As a concrete example, consider the auction of a German five-year bond at date *t*. Our trader sells a five-year German bond five days prior to the auction and invests the proceeds in the repo market.[15] On the day of the auction he reverses both transactions. Moreover, he buys a German five-year bond, while going short on the repo market. Both these latter transactions are reversed five days after the auction. We also consider duration-hedged strategies. The duration hedge is performed by buying the appropriate amount of ten-year German debt five days prior to the auction and by selling sufficient ten-year German debt on auction day. Similarly, for the case of a two-year or ten-year debt auction we use domestic five-year debt to hedge the duration.

Table 7 reports the outcomes of these trading strategies over the full sample period. For both countries, the unhedged trading profits are positive for the five-year and ten-year bonds, and negative but very close to zero for the two-year bond. The profits are also fairly volatile and the annualized Sharpe ratio (assuming one auction per month) of the unhedged auction trading strategy for the five-year bond is 0.49. This is smaller than the Sharpe ratio of 0.84 reported by Lou *et al.* (2013) for the two-year note in U.S. Treasury auctions (they do not

[15] We do not have data on bond prices, but only on bond yields. Therefore, we approximate the change in a bond price by (minus) the change in the yield times the duration of the bond. However, we do have bid and ask yields, hence we can take account of transaction costs for all transactions, including the duration hedge involved in the strategy. That is, we assume that bonds are sold against their bid price and bought against their ask price on the relevant date when the transaction takes place. We take account of the financing costs as follows. A long position in a particular bond receives the accrued interest, which we assume to be equal to the bond yield, and is financed by a repo loan, on which the (country-specific) general collateral repo rate is paid. For a short position in a particular bond it is the other way around: accrued interest is paid and the general collateral repo rate is received. Bloomberg reports the general collateral repo rates for Italy and Germany from 2006 onward. For the earlier years, we use the EONIA rate instead. For all the years from 2006 to 2010, the general collateral repo rates for Germany and Italy were very close to EONIA, and most likely these were also very close in the early sample period from 1999 to 2005, as there were no major financial crises in the Eurozone in that period.

report results for other maturities). The duration-hedged trading profits are smaller than the unhedged profits, but also less volatile. For Germany, the duration-hedged average profits are slightly positive, but for Italy they are negative. The main reason for the negative duration-hedged trading profits for Italy is the strong correlation between the yields across maturities. Due to this correlation, the duration hedge takes away a large fraction of the auction cycle profits. At the same time, the duration-hedged trading strategy incurs transaction costs twice, both on the auctioned maturity and the bond used to hedge the duration.

We also compare the trading profits across the two sub-periods, before and during the crisis. The duration-hedged profits are negative before the crisis for both Germany and Italy, whereas during the crisis period they become positive for Germany (see Appendix B.3 – not for publication). The profits remain negative for Italy over the crisis period despite its much stronger auction cycle during that period. The differences between Germany and Italy can be explained by the transaction costs: in the case of Italy, transaction costs have increased substantially during the crisis, unlike for Germany where transaction costs went down during the crisis (see Appendix B.3 – not for publication).

6.2 *Debt issuance cost*

The observed yield movements surrounding auctions can be exploited to provide an estimate of the issuance costs borne by the government. Lou *et al.* (2013) split the issuance cost into a component related to the auction cycle and a component related to the difference between the auction yield and the secondary market yield on auction day. Here, we focus only on the first component, the additional debt issuance costs that arise purely because of the auction cycle. There are two reasons for doing so. The first is that the specific focus of this paper is on the auction cycle, while the other reason is that it will be difficult to obtain an accurate estimate of the second component, because the Italian Treasury pays the dealers commissions that get reflected in the auction yield. In line with Lou *et al.* (2013) who use the difference between the average secondary market yield *t* periods before and after the auction and the secondary market yield on auction day, we use the estimated size of the auction cycle, i.e. the estimate of $\left(\sum_{l=4}^{0}\alpha_l\right)-\left(\sum_{l=-1}^{-5}\alpha_l\right)$ in equation (1) reported in Table 3, divided by two.

As an example, we focus on 5-year Italian debt to provide a rough calculation of the cycle-induced additional issuance costs for both our full sample and our two subsamples. The estimated average yield movements are 3.40 basis points for the full sample and 0.75 and 7.74 basis points for the first and second subsample, respectively. Hence, using the auction data from Table 2 we compute for the full sample the average additional issuance cost as an additional annual interest payment of 2,546 million (the average amount allotted) times 3.40 basis points, which is approximately 866,000 euro's per year. To obtain the cost for the full length of the issue we need to multiply this number by the duration of a typical 5-year bond. The duration can be calculated as a function of the length of the period between settlement date and maturity date, the coupon rate, the frequency of coupon payments and the average accepted yield at the auction date. We randomly take three five-year bonds issued in 2006, which have an average duration of 4.36 years, and three five-year bonds issued in 2012. These have an average duration of 4.52 years. Hence, for the full sample we use an average duration of (4.36+4.52)/2 = 4.44 years, implying a total additional cost of almost 3.8 million euros for an issue. Assuming that all the currently outstanding debt issued by the Italian Treasury has been subject to the same additional issuance cost of 3.40 basis points, the additional *annual* cost to the Treasury is almost 560 million euros (1,640 billion euros times 3.40 basis points).

Similar calculations for the first subsample yield an additional cost of an issue of about 710,000 euros, while the additional annual cost associated with a roll-over of the complete stock of debt is about 120 million euros. The corresponding figures for the second sub-period are 11 million euros, respectively almost 1.3 billion euros. In other words, the additional cycle-induced issuance cost increases more than 10-fold going from the pre-crisis to the crisis period.

6.3 Auction design

The findings of this paper may also provide some useful, though tentative, leads for (sovereign) debt auctioning policies and the design of the underlying auctioning mechanisms. First, our evidence regarding the link between the actual crisis intensity and the auction cycle suggests that a treasury may want to keep sufficient flexibility regarding the timing of auctions so as to limit issuance costs.[16] More, and larger, auctions may be scheduled during calm periods in the financial markets, and vice versa for turbulent periods in these markets. Obviously, funding needs could prevent governments from shifting auction activity over long

[16] See the literature on underpricing in auctions by Simon (1994), Damianov *et al.* (1996), Nyborg and Sundaresan (1996), and Goldreich (2007).

periods, but shifts over shorter periods might be possible if the government has arranged for access to temporary funding such as credit lines with banks. The data suggest that the crisis intensity is sufficiently variable to benefit from a suitable timing of the auctions.

Second, a related planning problem concerns the size of the new debt issue. Our earlier estimates already indicated that for Italy during the crisis period the auction cycle was positively related to the issuance size. This means that smaller, but more frequent, auctions are likely to reduce total issuance costs. Turning back to Table 2, it is remarkable that going from the first to the second sub-period, Germany has rather drastically increased the average monthly frequency of its auctions, while at the same time having reduced the average issuance size. By contrast, Italy has even slightly reduced the frequency of its auctions, while at the same time having rather drastically increased the average issuance size. It may well be that the increase in the issuance size at times when the demand for periphery debt was under pressure has contributed to Italy's auction cycle. To investigate the matter further, we estimate the specification in (4) with the interaction variable $INT_{t+l}^{i,m} = BC_{t+l}^{i,m} - \overline{BC}^{i,m}$, where BC denotes the bid-to-cover ratio when there is an auction of the specified country-maturity combination on the indicated date. Further, $\overline{BC}$ is the average bid-to-cover ratio in our sample. The results reported in Table 8 show that the coefficient sum on the bid-to-cover ratio tends to be significantly negative. This indicates that, while an upcoming auction leads to a rise in the yield, a larger bid-to-cover ratio reduces the effect on the yield. Obviously, a government does not have perfect control over the bid-to-cover ratio, because it has little direct control over the demand for its debt, while the supply is to a large extent determined by immediate financing needs. Nevertheless, a government may still want to create some flexibility regarding the latter, so that, when it picks up signals that the demand for a new debt issue might be low, it can shift some of the new supply to a moment in the future when demand is likely to be higher.

Third, the virtual absence of an auction cycle for Germany even during the crisis period suggests that other differences in auctioning policies as well as differences in the design of the auctions may play a role in explaining the differences in the auction cycle between the two countries. To investigate whether this may indeed be the case, we simultaneously re-estimate equation (4) with $INT_{t+l}^{i,m} = VOL_{t+l}^{i,m} - \overline{VOL}^{i,m}$ as a system for Germany and Italy and formally test whether the relevant coefficient sums are equal for the two countries. We do this for the full sample period. The joint hypothesis

$\sum_{l=4}^{0}\hat{\alpha}_l^G - \sum_{l=-1}^{-5}\hat{\alpha}_l^G = \sum_{l=4}^{0}\hat{\alpha}_l^I - \sum_{l=-1}^{-5}\hat{\alpha}_l^I$ and $\sum_{l=4}^{0}\hat{\beta}_l^G - \sum_{l=-1}^{-5}\hat{\beta}_l^G = \sum_{l=4}^{0}\hat{\beta}_l^I - \sum_{l=-1}^{-5}\hat{\beta}_l^I$, where superscript *G* (*I*) denotes Germany (Italy), is rejected for 2- and 5-year debt at the 1% significance level and for 10-year debt at the 5% level. Repeating the tests for $INT_{t+l}^{i,m} = CDS_{t+l}^{i} - \overline{CDS}^{i}$ for the maximum available sample period March 8, 2001 – February 12, 2013 yields rejections at the 1% level for all three maturities. Inspection of the tests of the individual restrictions shows that the rejections of the joint hypothesis are mainly driven by the differences between the two countries in their responses to our crisis intensity measures.

Differences in auction design and policy potentially contribute to these different responses. As documented in Section 2, an important difference between German and Italian auctions is that the supply in German auctions is variable, while in Italian auctions until not too long ago it was fixed before the auction. In contrast to Germany, even during the periods since it changed the design of its auctions Italy has made only very limited use of its discretion over the eventual supply. Table 9 shows that Germany has on average withheld between 18 and 20% of its announced maximum allotment, while Italy has on average withheld only between 1 and 3% of the announced maximum. A reason may be that during the crisis period the Italian Treasury was under such a financial pressure that it was effectively unable exert its discretion.

Back and Zender (2001) suggest that a uniform-price auction with fixed supply performs worse from the seller's perspective than one in which the supply may be restricted ex-post. Hence, in the current context a possible hypothesis is that a policy of exploiting a design that allows part of the new debt supply to be withheld depending on the success of the auction, may limit the fall in the new asset's price. Anticipating this, market participants may have a weaker incentive to bid down secondary market prices and the auction cycle may not come into existence. Exploiting this feature of the auction design may be particularly rewarding at times of stress in the financial markets. The hypothesis is consistent with the extensive use that the German Treasury has made of its discretion to regulate the supply at auctions and the absence of such discretion for the Italian Treasury during large parts of our sample period and its limited use of this discretion during the rest of the sample. It is also consistent with the fact that the U.S. features a clear auction cycle, as shown by Lou *et al.* (2013), while the supply of its new debt is fixed in advance.[17]

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[17] The website of the U.S. Treasury (2014) mentions "At the close of an auction, Treasury awards all noncompetitive bids that comply with the auction rules and then accepts competitive bids in ascending order of

Obviously, on the basis of the results so far one needs to be careful not to draw too strong conclusions about how auction design and policies affect the auction cycle, given that we have not been able to control at the same time for other factors, such as the much deeper and liquid futures markets for German (than for Italian) debt. These may allow primary dealers to hedge against the inventory risk, thereby also dampening yield movements in the cash market.

7. Concluding remarks

We have explored the relationship between public debt auctions and secondary-market yields and how this relationship is affected by the recent financial crisis. While secondary-market yields on Italian public debt increase in anticipation of an auction, no or a smaller such effect is found for German public debt. The yield movements on Italian debt are essentially confined to the period starting mid-2007. Further analysis shows that the auction cycle is positively related to volatility and risk-bearing capacity measures as proxies for the intensity of the crisis, with volatility likely being the more important measure. Overall, our results suggest a significant role for the crisis in determining this relationship. Moreover, they are consistent with our simple theoretical framework in which a small group of primary dealers require compensation for inventory risk, while this compensation needs to be higher when market uncertainty and risk aversion are larger. We also find that the secondary-market behaviour of debt for which there is *no* auction, but with a maturity close to that of the auctioned series, is very similar to the secondary-market behaviour of the auctioned maturity. This finding supports the primary-dealer model relative to other explanations based on liquidity effects.

Our results also allowed us to make a rough assessment of the additional issuance cost associated with the auction cycle. For an Italian five-year bond during the crisis period, we calculated these costs for an issue at almost 11 million euros and for a complete roll-over of the outstanding debt at almost 1.3 billion euros. Both figures constitute a more-than-10-fold increase relative to the pre-crisis period. Although secondary-market yields move appreciably around auctions, these movements seem insufficient to develop profitable trading strategies that overcome their associated transactions costs and the increase in market volatility during

their rate, yield, or discount margin (lowest to highest) until the quantity of awarded bids reaches the offering amount. All bidders will receive the same rate, yield, or discount margin at the highest accepted bid".

the run-up to an auction. Even so, there may be timing opportunities for parties that for exogenous reasons are forced to trade.

Finally, our findings suggest that specific choices regarding the design of the auction mechanism and the policies followed by the Treasury may matter for the auction cycle and the debt issuance costs. For example, even after controlling for our indicators of the crisis intensity, the German and Italian auction cycles differ significantly. Remarkably, Germany makes extensive use of the possibility to withhold part of the new debt issue if this is warranted, while Italy until recently did not have the discretion to do this and, once it allowed itself this discretion, it hardly made use of it. However, such observations remain only suggestive, as other differences, such as in the development of alternative hedging markets, may also contribute to explaining differences in auction cycles. Treasuries may benefit greatly from future research exploring in more detail which policies and design elements contribute to dampening the auction cycle.

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Table 1: Means and standard deviations of daily yield changes

	Germany			Italy		
	2-year	5-year	10-year	2-year	5-year	10-year
Mean (in basis points)						
Before crisis	0.06	0.05	0.03	0.06	0.06	0.04
Crisis	-0.29	-0.26	-0.20	-0.19	-0.09	-0.02
Equality test	0.02	0.06	0.13	0.36	0.55	0.76
Standard deviation (in basis points)						
Before crisis	4.09	4.37	3.85	4.10	4.36	3.90
Crisis	5.31	5.77	5.35	12.28	10.44	8.02
Equality test	0.00	0.00	0.00	0.00	0.00	0.00

Notes: This table reports the means and standard deviations of the 2, 5 and 10-year government bond yield changes of Germany and Italy. Data cover the period January 1, 1999 – February 12, 2013. "Before crisis" refers to the period January 1, 1999 – June 30, 2007, while "Crisis" refers to the period July 1, 2007 – February 12, 2013. The "Equality test" reports the *p*-value of the *F*-test of equality of means, respectively variances.

Table 2: Summary statistics for the auctions

	Germany			Italy		
	2-year	5-year	10-year	2-year	5-year	10-year
	Full sample period					
Number of auctions	114	90	104	189	168	166
Av. amount bid (mil.)	11,663	9,145	9,378	4,296	4,221	4,276
Av. amount allotted (mil.)	6,465	5,856	6,462	2,179	2,546	2,772
Av. bid-to-cover ratio	1.817	1.568	1.451	2.140	1.752	1.584
Av. accepted yield (%)	2.27	2.82	3.55	3.24	3.99	4.67
	January 1, 1999 – June 30, 2007					
Number of auctions	55	43	52	122	105	95
Av. amount bid (mil.)	14,747	11,461	12,164	4,100	4,096	4,326
Av. amount allotted (mil.)	6,927	6,535	7,500	1,826	2,183	2,489
Av. bid-to-cover ratio	2.188	1.772	1.674	2.403	1.949	1.767
Av. accepted yield (%)	3.20	3.74	4.31	3.38	4.03	4.55
	July 1, 2007 – February 12, 2013					
Number of auctions	59	47	52	67	63	71
Av. amount bid (mil.)	8,751	7,026	6,591	4,655	4,428	4,210
Av. amount allotted (mil.)	6,034	5,234	5,423	2,821	3,150	3,149
Av. bid-to-cover ratio	1.472	1.382	1.228	1.659	1.424	1.339
Av. accepted yield (%)	1.40	1.97	2.80	2.98	3.94	4.82

Notes: This table reports summary statistics for the auctions of 2, 5 and 10-year government bonds of Germany and Italy. Data cover the period January 1, 1999 – February 12, 2013. In the table, "Av." = "average", "mil." = "million". The average amount allotted refers to the announced (maximum) issue size, which in the case of Germany includes also the amount retained by the Treasury for secondary market operations. The bid-to-cover ratio is calculated as the ratio between the total amount bid and the announced (maximum) amount.

Table 3: Estimates of auction effects on yields

	Germany			Italy		
	2-year	5-year	10-year	2-year	5-year	10-year
	Full sample period					
Dummy own	2.11	3.34*	3.39***	5.64***	6.80***	6.12***
Dummy own		3.08*	2.99**		6.03***	5.66***
Dummy 2-year		-1.92	-1.87		4.34**	1.88
Dummy own	2.27		3.67***	4.97**		5.80***
Dummy 5-year	1.91		1.60	4.59**		3.63***
Dummy own	1.86	3.44*		3.92*	6.10***	
Dummy 10-year	-0.90	0.49		3.78	6.04***	
	January 1, 1999 – June 30, 2007					
Dummy own	2.27	-0.31	4.61***	-0.64	1.50	0.93
Dummy own		-0.29	4.55***		1.77	1.60
Dummy 2-year		0.15	-0.45		0.56	-0.34
Dummy own	2.42		4.48***	-0.39		1.21
Dummy 5-year	0.12		-0.71	1.19		1.33
Dummy own	2.31	-0.077		-0.93	1.75	
Dummy 10-year	0.44	1.56		0.39	0.60	
	July 1, 2007 – February 12, 2013					
Dummy own	1.95	6.75***	2.15	16.93***	15.48***	13.01***
Dummy own		6.44**	0.95		13.68***	11.11
Dummy 2-year		-3.40	-3.62		11.98***	15.42**
Dummy own	2.44		3.04	15.81***		11.66***
Dummy 5-year	4.13*		3.87*	10.99**		6.77**
Dummy own	1.11	6.79***		28.65***	12.57***	
Dummy 10-year	-2.70	-0.22		1.60	12.78***	

Notes: (i) This table reports estimates of equation (1), $\Delta y_t^{i,m} = c_0^{i,m} + \sum_{l=4}^{-5} \alpha_l AUC_{t+l}^{i,m} + \sum_{l=4}^{-5} \beta_l AUC_{t+l}^{i,n(\neq m)} + \varepsilon_t^{i,m}$, where *AUC* is the dummy for the day of the auction. The table reports, in basis points, the estimated sums of the coefficients $\sum_{l=4}^{0} \alpha_l - \sum_{l=-1}^{-5} \alpha_l$ for "Dummy own" (the maturity-country combination in the header) and $\sum_{l=4}^{0} \beta_l - \sum_{l=-1}^{-5} \beta_l$ for "Dummy 2-year", "Dummy 5-year" and "Dummy 10-year". (ii) Significance at the 10, 5 and 1% level is denoted by *, ** and ***, respectively. (iii) Estimation method is ordinary least squares (OLS) with Newey-West adjusted standard errors.

Table 4: Estimates of the effects of the issue size on the auction cycle

	Germany			Italy		
	2-year	5-year	10-year	2-year	5-year	10-year
	Full sample period					
Size own	0.30	0.52	0.60***	3.16***	2.66***	2.08***
Size own Size 2-year		0.48 -0.31	0.55*** -0.28		2.24*** 2.45***	1.38* 2.21***
Size own Size 5-year	0.33 0.29		0.62*** 0.21	2.97*** 1.78**		1.93*** 1.54***
Size own Size 10-year	0.28 -0.09	0.54* 0.16		3.62*** -0.18	2.40*** 2.10***	
	January 1, 1999 – June 30, 2007					
Size own	0.28	-0.16	0.64***	-0.018	0.78	0.32
Size own Size 2-year		-0.16 -0.03	0.64*** -0.07		0.83 0.50	0.34 0.35
Size own Size 5-year	0.29 -0.08		0.62*** -0.21	0.21 0.55		0.40 0.70
Size own Size 10-year	0.28 0.03	-0.13 0.22		0.028 -0.38	0.85 0.12	
	July 1, 2007 – February 12, 2013					
Size own	0.34	1.50***	0.50	5.73***	4.25***	3.59***
Size own Size 2-year		1.43*** -0.56	0.31 -0.58		3.46*** 4.03***	2.46 6.27***
Size own Size 5-year	0.45 0.94**		0.68* 0.89**	5.23*** 2.84**		3.24*** 2.10**
Size own Size 10-year	0.24 -0.36	1.58*** 0.14		10.64*** -1.78	3.52*** 3.74***	

Notes: (i) This table reports estimates of equation (3), $\Delta y_t^{i,m} = c_0^{i,m} + \sum_{l=4}^{-5} \alpha_l \; SIZE_{t+l}^{i,m} + \sum_{l=4}^{-5} \beta_l \; SIZE_{t+l}^{i,n(\neq m)} + \varepsilon_t^{i,m}$, where *SIZE* denotes the announced (maximum) issue size. The table reports, in basis points per billion euros, the estimated sums of the coefficients $\sum_{l=4}^{0} \alpha_l - \sum_{l=-1}^{-5} \alpha_l$ for "Size own" (the maturity-country combination in the header) and $\sum_{l=4}^{0} \beta_l - \sum_{l=-1}^{-5} \beta_l$ for "Size 2-year", "Size 5-year" and "Size 10-year", the announced (maximum) issue size of the relevant other maturity. (ii) Significance at the 10, 5 and 1% level is denoted by *, ** and ***, respectively. (iii) Estimation method is ordinary least squares (OLS) with Newey-West adjusted standard errors.

Table 5: Testing the role of volatility and risk aversion

	Germany			Italy		
	2-year	5-year	10-year	2-year	5-year	10-year
Dummy	2.09	3.35*	3.49**	5.65***	7.05***	6.17***
Dummy $*\left(VOL_{t+l}^{i,m} - \overline{VOL}^{i,m}\right)$	-0.30	-0.097	0.78	3.04**	2.75***	3.04**
Dummy	1.77	3.15	3.19**	7.66***	8.76***	7.22***
Dummy $*\left(CDS_{t+l}^{i} - \overline{CDS}^{i}\right)$	0.007	0.025	-0.021	0.17***	0.15***	0.089***
Dummy	1.77	3.22*	3.01**	6.36***	8.11***	6.52***
Dummy $*\left(VOL_{t+l}^{i,m} - \overline{VOL}^{i,m}\right)$	-0.41	-0.47	2.20	2.74	1.88	2.87
Dummy $*\left(CDS_{t+l}^{i} - \overline{CDS}^{i}\right)$	0.008	0.029	-0.047**	0.025	0.069	0.005
Dummy	1.77	3.19*	3.07**	6.25***	7.72***	6.50***
Dummy $*\left(VOL_{t+l}^{i,m} - \overline{VOL}^{i,m}\right)$	-0.36	0.21	0.49	3.00**	2.81***	2.96**
Dummy $* RES_{t+l}^{i,m}$	0.008	0.029	-0.047**	0.025	0.069	0.005

Notes: (i) This table reports estimates of equation (4), $\Delta y_t^{i,m} = c_0^{i,m} + \sum_{l=4}^{-5}\left(\alpha_l + \beta_l INT_{t+l}^{i,m}\right) AUC_{t+l}^{i,m} + \varepsilon_t^{i,m}$, where *AUC* denotes the dummy for the day of the auction and $INT_{t+l}^{i,m}$ denotes an interaction variable, which can be our volatility measure $VOL_{t+l}^{i,m} - \overline{VOL}^{i,m}$, our CDS index $CDS_{t+l}^{i} - \overline{CDS}^{i}$, or the residual $RES_{t+l}^{i,m}$ of the linear regression of our CDS index on our volatility measure. It reports, in basis points, the estimated sum of the coefficients $\sum_{l=4}^{0}\alpha_l - \sum_{l=-1}^{-5}\alpha_l$ for "Dummy", i.e. the auction dummy for the maturity-country combination in the header, and $\sum_{l=4}^{0}\beta_l - \sum_{l=-1}^{-5}\beta_l$ for the interaction term of the dummy and $INT_{t+l}^{i,m}$. (ii) Sample period is the full sample period January 1, 1999 – February 12, 2013 or March 8, 2001 – February 12, 2013, when $CDS_{t+l}^{i} - \overline{CDS}^{i}$ or $RES_{t+l}^{i,m}$ are used. (iii) Significance at the 10, 5 and 1% level is denoted by *, ** and ***, respectively. (iv) Estimation method is ordinary least squares (OLS) with Newey-West adjusted standard errors.

Table 6: Cross-border spill-overs of auctions

	Germany			Italy		
	2-year	5-year	10-year	2-year	5-year	10-year
Dummy own	2.19	3.07^{*}	3.50^{**}	5.70^{***}	7.23^{***}	6.29^{***}
Dummy own $*\left(VOL_{t+l}^{i,m} - \overline{VOL}^{i,m} \right)$	-0.32	-.001	0.77	3.02^{**}	2.72^{***}	3.02^{**}
Dummy foreign	0.93	0.94	0.94	-3.47	-4.18	4.13^{**}
Dummy own	2.28	2.92	3.34^{**}	5.75^{***}	7.00^{***}	6.16^{***}
Dummy own $*\left(VOL_{t+l}^{i,m} - \overline{VOL}^{i,m} \right)$	-0.28	-0.037	0.61	3.02^{**}	2.63^{**}	2.96^{**}
Dummy foreign	0.94	0.94	0.90	-3.42	-3.92	4.22^{**}
Dummy foreign $*\left(VOL_{t+l}^{j,m} - \overline{VOL}^{j,m} \right)$	0.33^{**}	-0.40	0.60	-0.48	-5.03	1.96
Dummy own	1.94	3.07	3.25^{**}	7.67^{***}	8.85^{***}	7.33^{***}
Dummy own $*\left(CDS_{t+l}^{i} - \overline{CDS}^{i} \right)$	0.008	0.024	-0.021	0.17^{***}	0.15^{***}	0.089^{***}
Dummy foreign	1.69	0.73	0.97	-3.66	-5.08	4.12^{**}
Dummy own	2.07	3.19^{*}	3.14^{**}	7.16^{***}	8.30^{***}	7.21^{***}
Dummy own $*\left(CDS_{t+l}^{i} - \overline{CDS}^{i} \right)$	0.007	0.024	-0.019	0.16^{**}	0.14^{***}	0.091^{***}
Dummy foreign	1.71	0.76	0.97	-3.81	-4.95	4.09^{**}
Dummy foreign $*\left(CDS_{t+l}^{j} - \overline{CDS}^{j} \right)$	0.020	-0.006	0.021	-0.083	-0.14^{*}	0.045

Notes: (i) This table reports estimates of equation (5), $\Delta y_t^{i,m} = c_0^{i,m} + \sum_{l=4}^{-5}\left(\alpha_l + \beta_l INT_{t+l}^{i,m}\right) AUC_{t+l}^{i,m} + \sum_{l=4}^{-5}\left(\gamma_l + \delta_l INT_{t+l}^{j,m}\right) AUC_{t+l}^{j,m} + \varepsilon_t^{i,m},\ j \neq i,$ where the variables are defined in the Notes to Table 5 and where superscript *j* denotes the foreign country. The table reports, in basis points, the estimated sums of the coefficients $\sum_{l=4}^{0}\alpha_l - \sum_{l=-1}^{-5}\alpha_l$, $\sum_{l=4}^{0}\beta_l - \sum_{l=-1}^{-5}\beta_l$, $\sum_{l=4}^{0}\gamma_l - \sum_{l=-1}^{-5}\gamma_l$ and $\sum_{l=4}^{0}\delta_l - \sum_{l=-1}^{-5}\delta_l$ associated with, respectively, the domestic auction dummy "Dummy own", its interaction with $INT_{t+l}^{i,m}$, the foreign auction dummy "Dummy foreign", and its interaction with $INT_{t+l}^{j,m}$. (ii) Sample period is the full sample period January 1, 1999 – February 12, 2013 or March 8, 2001 – February 12, 2013, when $CDS_{t+l}^{i} - \overline{CDS}^{i}$ is used. (iii) Significance at the 10, 5 and 1% level is denoted by *, ** and ***, respectively. (iv) Estimation method is ordinary least squares (OLS) with Newey-West adjusted standard errors. (v) "Dummy foreign" is the same-maturity Italian (German) dummy corresponding to "Dummy own" for Germany (Italy).

Table 7: Trading profits

	Germany			Italy		
	2-year	5-year	10-year	2-year	5-year	10-year
Unhedged						
Mean	-0.018	0.092	0.179	-0.016	0.150	0.264
Standard deviation	0.287	0.797	1.050	0.579	1.067	1.542
Annualized Sharpe ratio	-0.22	0.40	0.59	-0.10	0.49	0.59
Duration hedged						
Duration-hedged Mean	-0.001	0.012	0.094	-0.161	-0.127	-0.550
Standard deviation	0.169	0.329	0.516	0.294	0.445	1.045
Annualized Sharpe ratio	-0.02	0.13	0.63	-1.90	-0.99	-1.82

Notes: (i) The table reports means, standard deviations and annualized Sharpe ratios for the excess returns (in percent) after payment of transaction costs of our trading strategy around auctions of two-year debt (Columns “2-year”), five-year debt (Columns “5-year”) and ten-year debt (Columns “10-year”) over the full sample period. The first panel reports the results for the unhedged trading strategy, the second panel for the duration-hedged strategy. Transactions in five-year debt are hedged with domestic ten-year debt, and transactions in two-year and ten-year debt are hedged with domestic five-year debt. (ii) Sample period is the full sample period January 1, 1999 – February 12, 2013.

Table 8: Estimates of the effect of the bid-to-cover ratio on the auction cycle

	Germany			Italy		
	2-year	5-year	10-year	2-year	5-year	10-year
Dummy	2.11	3.34*	3.39**	5.64***	6.80***	6.12***
Dummy	2.11	3.34*	3.39**	5.65***	6.80***	6.14***
BC	-1.09	-0.99	-5.34**	-6.39***	-8.46**	-8.85**

Notes: (i) This table reports estimates of equation (4), $\Delta y_t^{i,m} = c_0^{i,m} + \sum_{l=4}^{-5}\left(\alpha_l + \beta_l INT_{t+l}^{i,m}\right) AUC_{t+l}^{i,m} + \varepsilon_t^{i,m}$, where *AUC* denotes the dummy for the day of the auction and $INT_{t+l}^{i,m} = BC_{t+l}^{i,m} - \overline{BC}^{i,m}$, where *BC* is the bid-to-cover ratio and $\overline{BC}$ is its sample average. It reports, in basis points, the estimated sum of the coefficients $\sum_{l=4}^{0}\alpha_l - \sum_{l=-1}^{-5}\alpha_l$ for "Dummy", i.e. the auction dummy for the country-maturity combination in the header, and $\sum_{l=4}^{0}\beta_l - \sum_{l=-1}^{-5}\beta_l$ for "BC", i.e. the bid-to-cover ratio for the country-maturity combination in the header. (ii) Sample period is the full sample period January 1, 1999 – February 12, 2013. (iii) Significance at the 10, 5 and 1% level is denoted by *, ** and ***, respectively. (iv) Estimation method is ordinary least squares (OLS) with Newey-West adjusted standard errors.

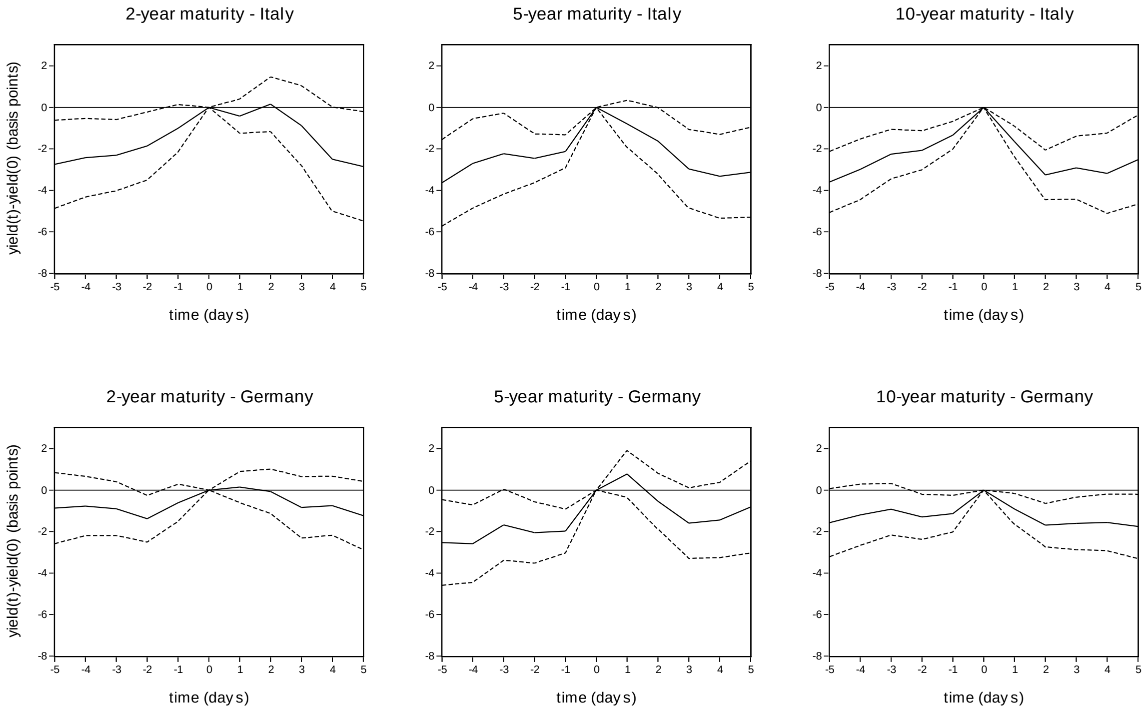
Table 9: Fraction of announced maximum supply withheld

Germany			Italy		
2-year	5-year	10-year	2-year	5-year	10-year
January 1, 1999 – June 30, 2007					
13.79	17.72	17.05	-	-	-
Germany: July 1, 2007 – February 12, 2013; Italy: December 1, 2011 - February 12, 2013 for 2-year maturity; October 1, 2008 - February 12, 2013 for 5- and 10-year maturity					
17.23	18.23	19.94	3.06	1.40	1.19

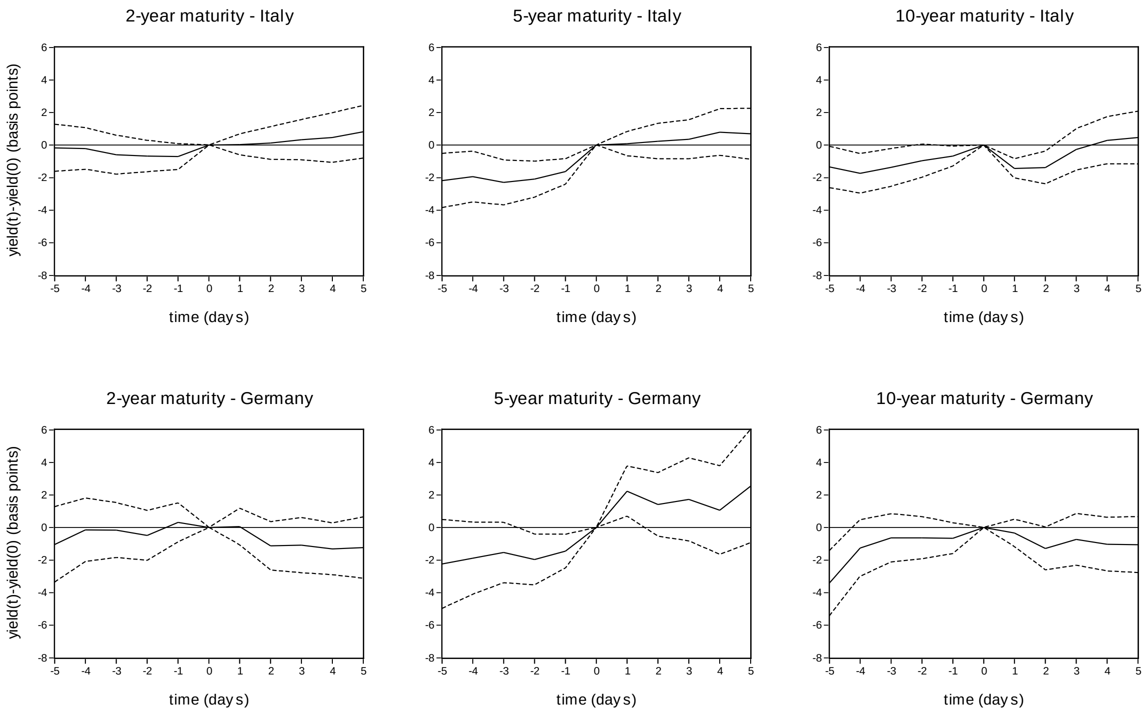
Note: The table reports, in percent, the fraction of the announced maximum supply that is withheld by the Treasury during the period when the Treasury had the discretion to do this. The German Treasury had this discretion over the full sample period. The Italian Treasury had this discretion only over the indicated sub-periods.

Figure 1: Yield movements before and after auctions

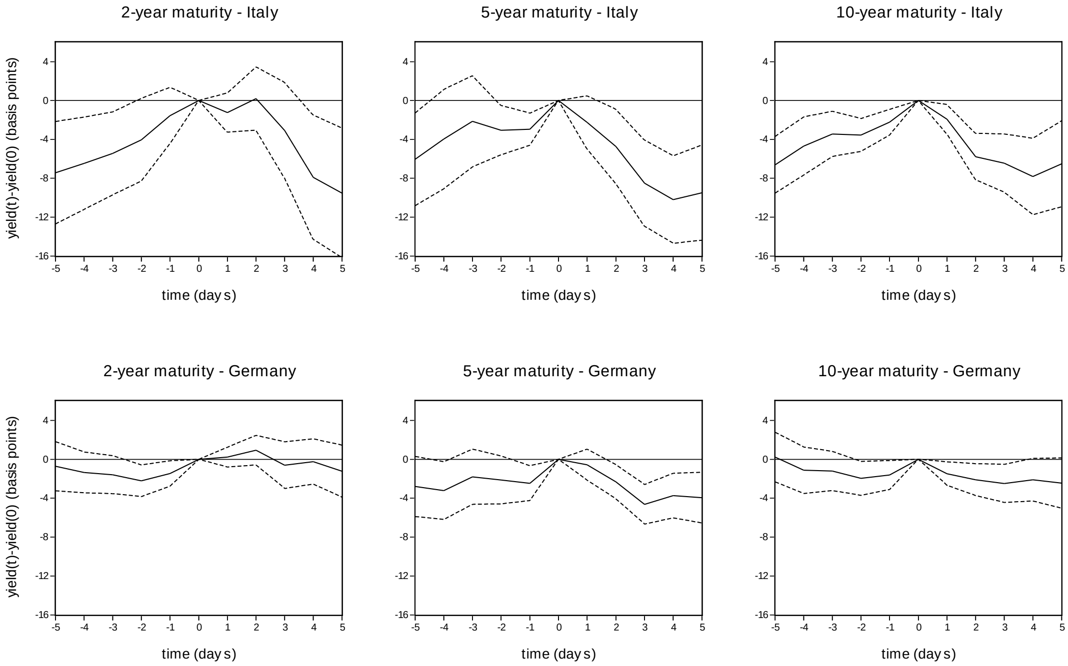
a. Full sample



b. Sub-period January 1, 1999 – June 30, 2007



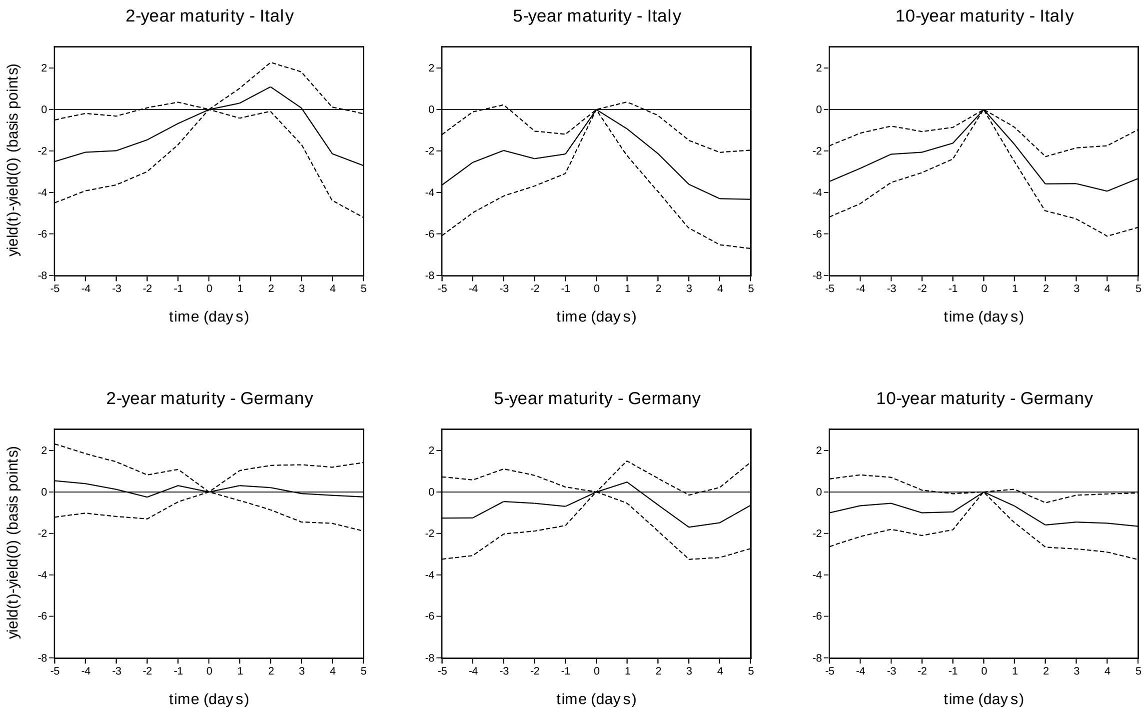
c. Subperiod July 1, 2007 – February 12, 2013



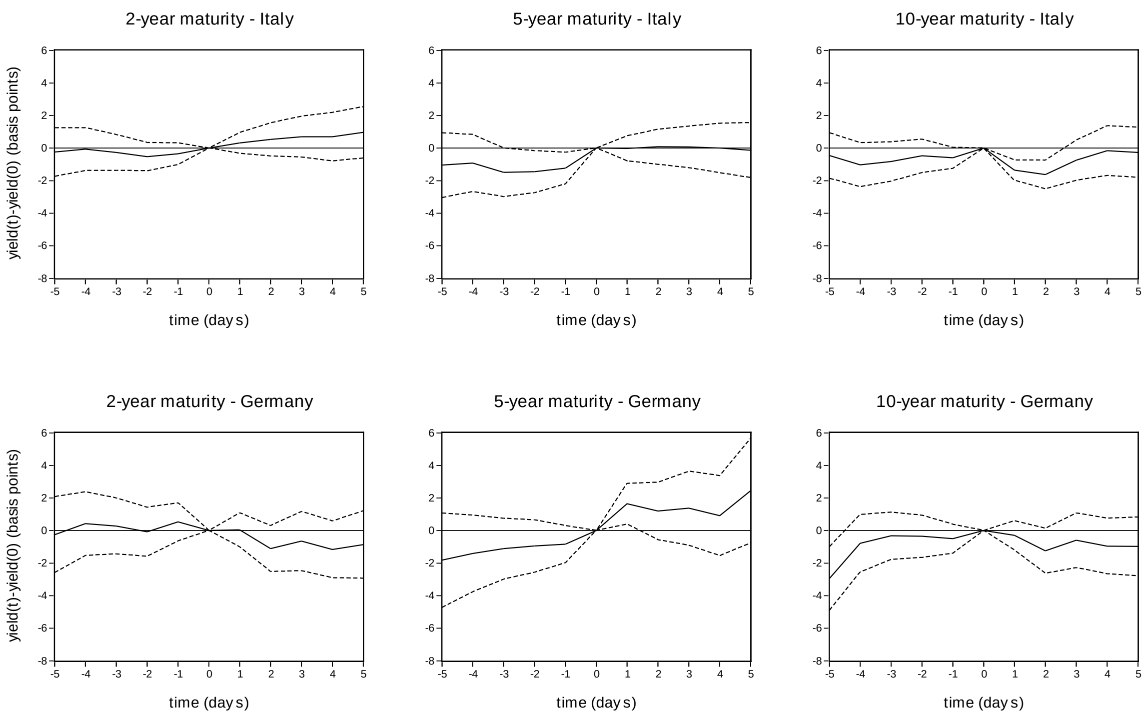
Notes: The figure reports the average of $y_t - y_0$, where y_t is the end-of-day yield of the Treasury bond on day *t*, and y_0 is the end-of-day yield on the same maturity bond on the auction day 0. All yields are expressed in basis points. The dotted lines are the 90% confidence intervals with Newey-West adjusted standard errors.

Figure 2: Yield movements around auctions – close maturities

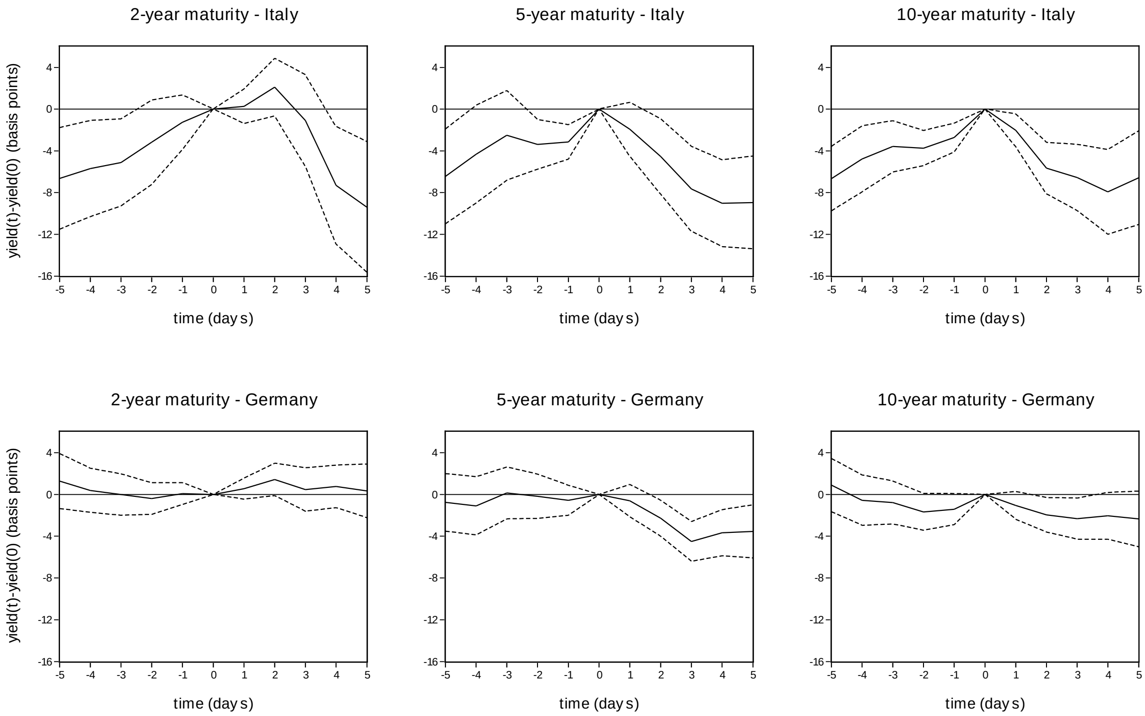
a. Full sample



b. Sub-period January 1, 1999 – June 30, 2007

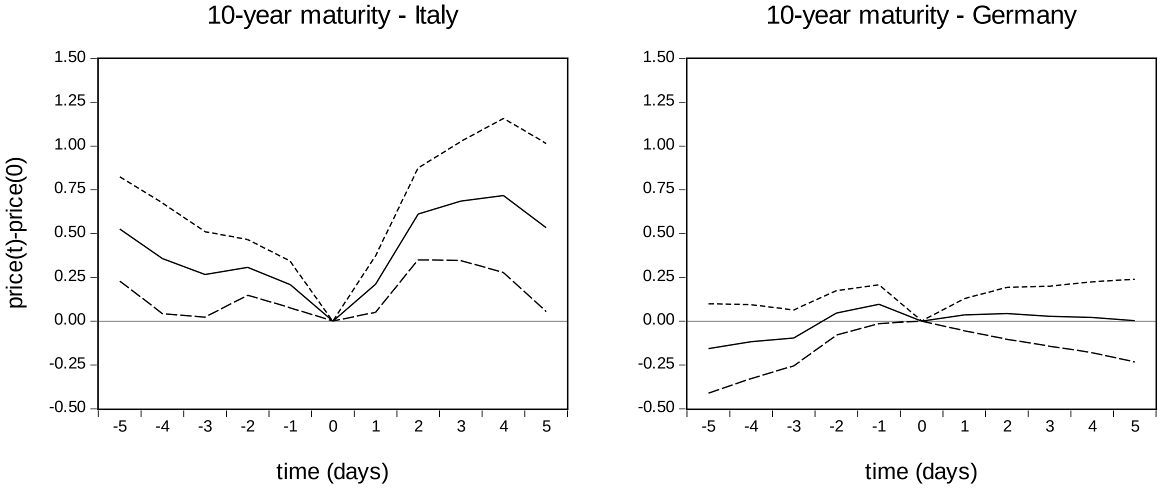


c. Sub-period July 1, 2007 – February 12, 2013



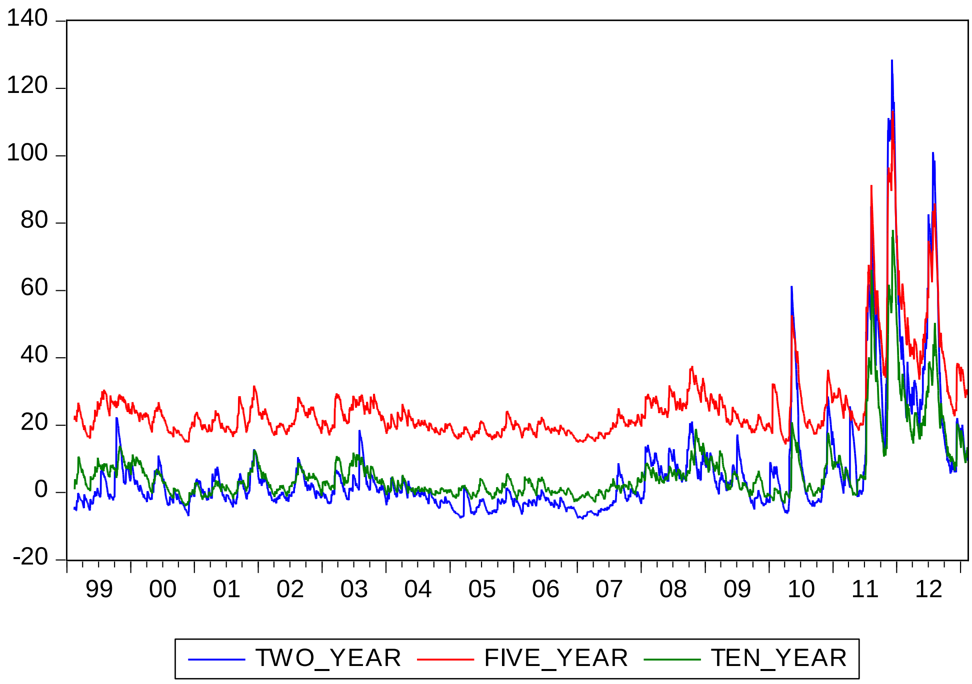
Notes: The figure reports the average yield movements of the 3-year bond around auctions of 2-year debt, of the 6-year bond around auctions of the 5-year debt and the 9-year bond around auctions of the 10-year debt. Further, see the *Notes* to Figure 1.

Figure 3: Price movements of futures on 10-year bonds before and after auctions



Notes: The figure reports the average movements of the (log of) prices of futures on 10-year bonds around auctions of 10-year debt. The sample period runs from September 15, 2009 to February 12, 2013. Further, see the *Notes* to Figure 1.

Figure 4: Full auction cycle based on interaction with volatility – Italy

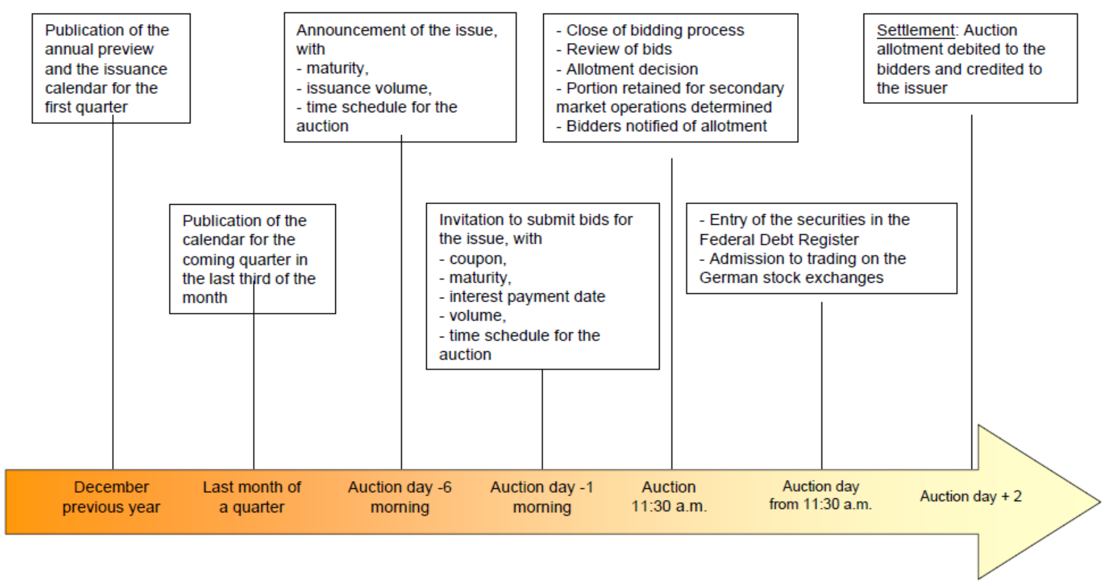


Appendix A: Background information on auction procedures

A.1. Germany

The GFA auctions Treasury discount paper (6 and 12-month maturity "Bubills"), Federal Treasury notes (2-year maturity "Schätze"), five-year Federal notes ("Bobls") and Federal bonds (10 and 30-year maturity "Bunds").[18] The procedure to place the individual issues in a year *t* is standardized as follows – see Figure A.1. Towards the end of the preceding year the annual preview and the issuance calendar are published. Further, towards the end of the month preceding a new quarter the new calendar for the coming quarter is published. Then, six trading days before each auction there is an announcement of the maturity, the issue size and time schedule of the auction, while a press release inviting the members of the Bund Issues Auction Group to submit their bids is sent out one working day before the auction.

Figure A.1: German Auction Procedure



Source: http://www.deutsche-finanzagentur.de/en/institutional/primary-market/auction-procedure/.

[18] Other financial instruments of the Federal Government include inflation-linked Federal notes (five-year Bobl/ei), inflation-linked Federal bonds (10-year Bund/ei), foreign currency bonds, special securitized loans ("Schuldscheindarlehen") and bonds issued in cooperation with the German Federal States.

A.2. Italy

The Italian Treasury issues, on the domestic market, four main categories of government bonds: Treasury bills (“BOTs” with a 3, 6, and 12-month maturity or with a flexible maturity between 1 and 12 months), zero-coupon Treasury bonds (24-month maturity “CTZs”), Treasury certificates (5 or 7-year maturity “CCTs”/”CCTs-eu” with a semi-annual floating coupon) and Treasury bonds (3, 5, 10, 15 and 30-year maturity “BTPs”).[19] Towards the end of each year, the Ministry publishes the auctions calendar for the following year. This is followed by the publication of a quarterly issuance programme. The terms and conditions of an auction are published roughly one week before the auction. The “Authorized Dealers” that are allowed to participate in the auction are Italian and foreign banks, financial brokers and EU and non-EU investment companies registered at the Bank of Italy (Italian Treasury, 2014b).[20]

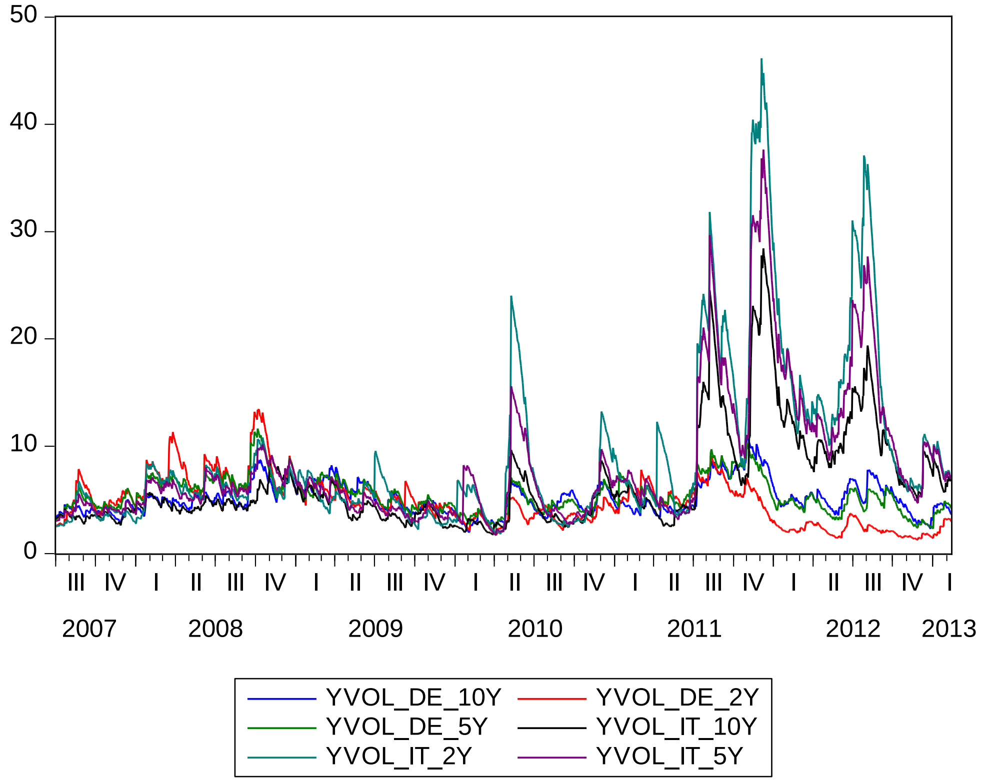
[19] The Ministry also issues Treasury bonds linked to euro-zone inflation (3, 5, 10, 15 and 30-year maturity “BTPs €i”) and to Italian inflation (“BTPs Italia”). Other instruments typically offered on international markets include medium/long-term securities or commercial paper in euros and in other currencies.

[20] Each dealer can submit a maximum of three bids. In order for the accepted yields to be in line with the market yields, a minimum acceptable yield, also called the safeguard yield, is calculated. Similarly, a maximum acceptable yield, or the exclusion yield, is calculated to avoid speculative behavior.

Appendix B: Further results
(NOT for publication – available upon request)

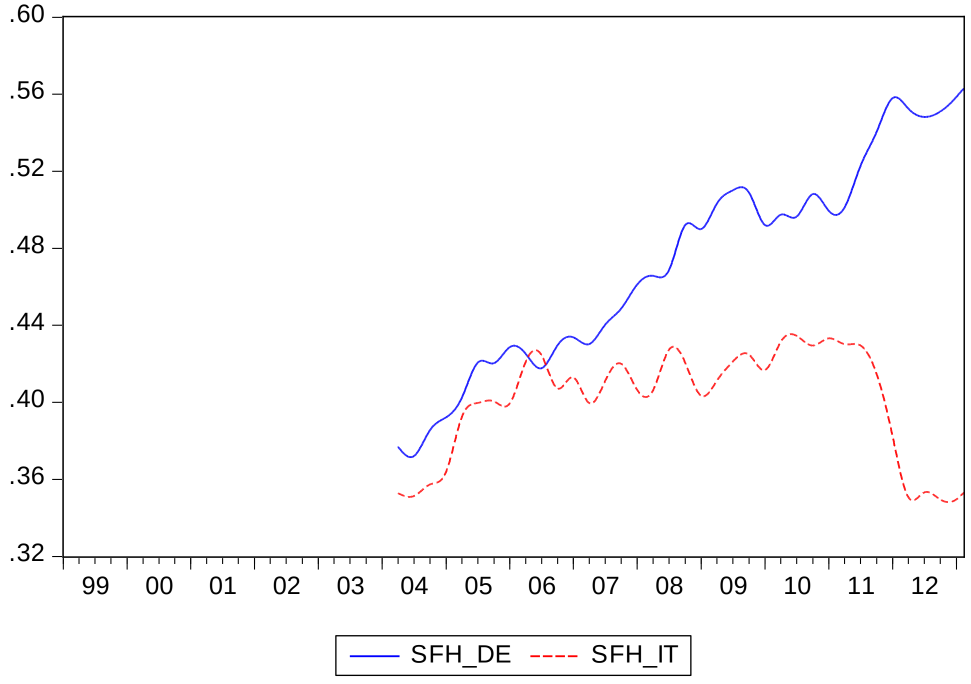
B.1. Plot of volatility measure

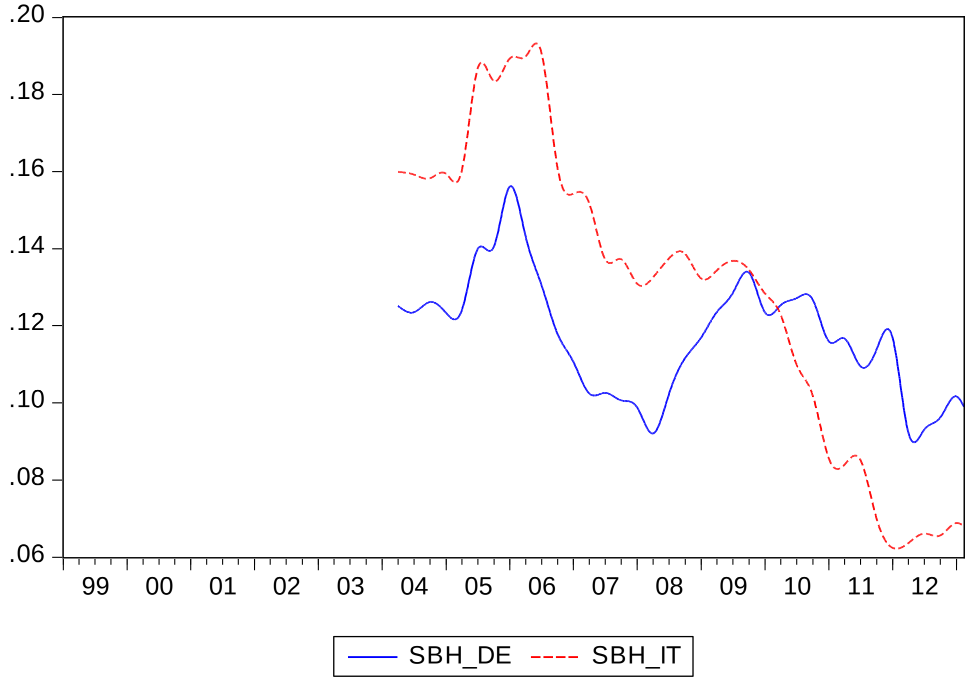
Below we depict our volatility measure for Germany and Italy for each of the maturities during the crisis period. The extreme peaks for Italy are absent for Germany.



B.2. Figures and results for regressions with (foreign) end investors.

The figures below show (total) foreign holdings of public debt, respectively foreign bank holdings of public debt as shares of total outstanding debt:





Notes: SFH_DE (SFH_IT) = total foreign holdings as a fraction of outstanding German (Italian) public debt, SBH_DE (SBH_IT) = foreign bank holdings as a fraction of outstanding German (Italian) public debt.

The first regression generalises model (1) to

$$\Delta y_t^{i,m} = c_0^{i,m} + \sum\nolimits_{l=4}^{-5} \left(\alpha_l + \beta_l INT_{t+l}^{i,m} \right) AUC_{t+l}^{i,m} + \varepsilon_t^{i,m},$$

where $INT_{t+l}^{i,m} = SFH_{t+l}^{i,m} - \overline{SFH}^{i,m}$ ($INT_{t+l}^{i,m} = SBH_{t+l}^{i,m} - \overline{SBH}^{i,m}$) is the share of foreign (foreign bank) holdings of Germany's or Italy's public debt of maturity *m* in deviation from its sample average. The estimates are over the period 2004Q1 – 2013Q1. The debt data are quarterly and we apply linear interpolation to obtain holdings shares at the daily frequency (substituting the same holdings number for each day of a quarter yields results that are practically identical). The second regression equation generalises model (4) to:

$$\Delta y_t^{i,m} = c_0^{i,m} + \sum\nolimits_{l=4}^{-5} \left(\alpha_l + \beta_l INT_{1,t+l}^{i,m} + \gamma_l INT_{2,t+l}^{i,m} \right) AUC_{t+l}^{i,m} + \varepsilon_t^{i,m},$$

where $INT_{1,t+l}^{i,m} = VOL_{t+l}^{i,m} - \overline{VOL}^{i,m}$ or $INT_{1,t+l}^{i,m} = CDS_{t+l}^{i} - \overline{CDS}^{i}$ and $INT_{2,t+l}^{j,m} = SFH_{t+l}^{i,m} - \overline{SFH}^{i,m}$ or $INT_{2,t+l}^{j,m} = SBH_{t+l}^{i,m} - \overline{SBH}^{i,m}$. The estimates of these regressions are in Table B.1, which has the same structure as Table 5. Hence, the notes to Table 5 apply.

Table B.1: Testing the role of foreign debt holdings

	Germany			Italy		
	2-year	5-year	10-year	2-year	5-year	10-year
Dummy	2.14	5.38***	2.61	11.28***	11.32***	9.07***
Dummy $*\left(SFH_{t+l}^{i,m} - \overline{SFH}^{i,m}\right)$	-0.001	-0.037	-0.29	-2.79*	-2.84**	-0.67
Dummy	2.14	5.37***	2.61	11.44***	11.32***	9.13***
Dummy $*\left(SBH_{t+l}^{i,m} - \overline{SBH}^{i,m}\right)$	-0.29	-0.58	1.44	-3.13**	-2.51***	-1.70**
Dummy	1.95	4.44**	2.42	7.73***	8.83***	7.76***
Dummy $*\left(VOL_{t+l}^{i,m} - \overline{VOL}^{i,m}\right)$	-0.22	1.50	0.88	2.90**	2.57**	3.15**
Dummy $*\left(SFH_{t+l}^{i,m} - \overline{SFH}^{i,m}\right)$	0.023	0.040	-0.40	-0.38	-1.08	0.62
Dummy	1.95	4.42**	2.43	7.19***	8.77***	7.73***
Dummy $*\left(VOL_{t+l}^{i,m} - \overline{VOL}^{i,m}\right)$	-0.23	1.51	0.24	3.30**	2.68*	3.18*
Dummy $*\left(SBH_{t+l}^{i,m} - \overline{SBH}^{i,m}\right)$	-0.36	-0.42	1.57	0.81	-0.17	0.37
Dummy	1.81	4.47**	2.98*	7.79***	8.76***	7.91***
Dummy $*\left(CDS_{t+l}^{i} - \overline{CDS}^{i}\right)$	0.014	0.019	-0.030	0.16**	0.13***	0.083**
Dummy $*\left(SFH_{t+l}^{i,m} - \overline{SFH}^{i,m}\right)$	-0.19	-0.062	0.23	-1.45	-1.85*	-0.22
Dummy	1.80	4.51**	2.61*	6.12**	7.88***	7.81***
Dummy $*\left(CDS_{t+l}^{i} - \overline{CDS}^{i}\right)$	0.001	0.012	-0.008	0.24**	0.20***	0.096*
Dummy $*\left(SBH_{t+l}^{i,m} - \overline{SBH}^{i,m}\right)$	-0.39	-0.35	1.26	1.77	1.26	0.32

B.3. Trading profits and bid-ask spreads over the sub-samples.

Table B.2 reports the profits of duration-hedged trading strategies for the two sub-periods. When perceived market uncertainty increases, bond dealers increase their bid-ask spreads to reduce the chances of a loss on their positions. Hence, in line with our theoretical model, enhanced bid-ask spreads should coincide with larger auction cycles. Table B.3 reports for five and ten-year public debt the average bid-ask spread, calculated using the approximation $(P^A - P^B)/P \approx D\ (y^B - y^A)$, where P^A and P^B are the ask and bid price, respectively, P is the average of the two, y^A and y^B are the ask and bid yields, respectively, and D is the duration. For each country, each maturity and each sub-period we calculate the average duration for three arbitrarily chosen bonds and use this to calculate the bid-ask spread. We see that for given maturity the average bid-ask spreads are always larger for Italy than for Germany. While for Germany the average bid-ask spread falls when going from the first to the second sub-period, exactly the opposite is seen for Italy, where the average bid-ask spread roughly doubles. This finding is consistent with the increase in the size of Italy's auction cycle when going from the first to the second sub-period. The estimates of the bid-ask spread for the Italian bonds are somewhat smaller than the estimates in Pelizzon et al. (2013), but their sample period covers the most volatile part of the crisis.

Table B.2: Average duration-hedged trading profits for sub-samples

	Germany			Italy		
January 1, 1999 – June 30, 2007						
	2-year	5-year	10-year	2-year	5-year	10-year
Mean	-0.090	-0.113	-0.046	-0.118	-0.121	-0.259
Standard deviation	0.095	0.267	0.404	0.189	0.251	0.400
Annualized Sharpe ratio	-3.28	-1.47	-0.39	-2.16	-1.67	-2.24
July 1, 2007 – February 12, 2013						
	2-year	5-year	10-year	2-year	5-year	10-year
Mean	0.080	0.109	0.162	-0.201	-0.126	-0.812
Standard deviation	0.182	0.334	0.568	0.384	0.646	1.454
Annualized Sharpe ratio	1.52	1.13	0.99	-1.81	-0.68	-1.93

Note: the table reports means, standard deviations and annualized Sharpe ratios for the excess returns (in percent) after transaction costs of our duration-hedged trading strategy around auctions of two-year debt (Columns "2-year"), five-year debt (Columns "5-year") and ten-year debt (Columns "10-year") over the two sub-sample periods. Transactions in the five-year bond are hedged with the domestic ten-year bond, and transactions in the two-year and ten-year bond are hedged with the domestic five-year bond.

Table B.3: Average bid-ask spreads

Germany			Italy		
2-year	5-year	10-year	2-year	5-year	10-year
January 1, 1999 – June 30, 2007					
0.055	0.053	0.073	0.063	0.058	0.078
July 1, 2007 – February 12, 2013					
0.012	0.014	0.036	0.106	0.125	0.142

Note: the table reports bid-ask spreads as an approximated percentage of the price of the bond.