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**"THE INFORMATIVE LINKAGE BETWEEN PRIMARY AND
SECONDARY MARKETS OF ITALIAN GOVERNMENT BONDS"**

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Abstract

A key risk for the secondary market of government bonds is illiquidity because it affects the issuance strategy of the Treasury. Liquidity condition of the secondary market can be itself influenced by the primary market activity, as a loop. Our contribution is to develop a simple model that demonstrates how good treasury auctions affect liquidity when market makers are heterogeneously informed. With a panel of three lines of emission of BTPs, we explore empirically whether, and to what extent, primary market dynamics affect secondary market liquidity. Moreover, we infer whether auction's informativeness can be explained by an indicator different from the widely used bid-to-cover ratio, i.e. the overpricing.

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Introduction

The efficiency of the secondary market of a security is crucial for an efficient allocation of securities in the primary market, but on the same hand, liquidity of the secondary market itself depends on the decision taken by issuer which affects investors' portfolio choice and, consequently, the ease with which a security can trade.

Market liquidity is the ability to quickly trade large quantities of an asset at a low cost and it is thus the key for a good and efficient functioning of financial markets. Market participants and policymakers have always put a lot of attention on it.

When dealing with government securities, this link between primary and secondary markets is even more important. If the secondary market of government bonds is not liquid, primary dealers, that act as market makers on the secondary market, have more difficulty in trading the government securities. Consequently, when they participate at auction, they request a higher premium for the higher liquidity risk. This premium is reflected in lower prices, and, accordingly, higher yields. If the Treasury issues bonds with higher yields, it faces higher cost for the management of public debt.

The outcome of auctions, the main mean through which governments place their securities on the market¹, is very important for a sound management of government debt. This outcome communicates a lot about the securities, in terms of market sentiment and market participant behaviour, especially that of primary dealers, because it gives insight of the state of both the economy and the markets. It is a signal of trustworthiness that a government can give to the secondary market, in terms of demand received, price of emission and relative yield.

Indeed, it has been studied that primary market has an important effect on prices and yields movement around auctions, i.e. they exploit a cyclic pattern around the auction day.

However, we do not know how the performance of an auction of a government security impact on secondary market liquidity. By studying the informative power that auctions have on secondary market liquidity, we contribute to the strand of literature dealing with the interaction between primary and secondary market of government bonds.

To do this, we first develop a model in which we can find two market makers, that buy from the primary market and are active on the secondary one, and final investors, those that trade with market makers and have no power in determining prices. The novelty is that we assume market makers to be uninformed about the total demand bid of a specific security on auction day. The total demand can be inferred by the signal perceived by market makers through the

¹ Other ways of placing bonds in the market are syndicated loans or private placement.

performance of the auction. But these dealers, do not receive the same signal as it is linked to the respective individual demand, different for each market maker. The heterogeneity is another novelty introduced by our model, as, to my knowledge, no paper assumes market makers of government bonds to be privately and heterogeneously informed about the expected value of the bond, not perfectly known. Moreover, differently from previous works, we focus the attention on the demand received by the Treasury and not on the amount supplied, as it is how much the bond is requested that reflects the trust that dealers have on the issuer.

With this model, we theoretically find that the information coming from the primary market affects positively the liquidity condition of the secondary market on auction day, because it reduces uncertainty about the fundamental value of the bond. The more precise the information received, the tighter the bid-ask spread set by market makers and the bigger the quantity of traded bonds on the secondary market with final investors at the new price levels, i.e. larger depth.

Based on our theoretical predictions of our model, we empirically study how the development of liquidity on auction day is affected by auction's results. To this extent, we examine the results of Italy's government bonds' auctions and the MTS cash market of three selected lines of emission, i.e. 3-year, 7-year and 10-year BTPs, in the period from January 2016 to December 2019. The choice of Italy is linked to its huge stock of debt, whose management is crucial, and to MTS Italy, the secondary market of its government securities and the first electronic market of Europe. Because of its massive stock of debt, it is very important for the Public Debt Management to have a liquid secondary market. To be sure the secondary market of government security is efficient, primary dealers are encouraged to guarantee and maintain the market liquid. This incentive is satisfied by the ranking of the Public Debt Management of Italy where all Specialists (a subset of primary dealers meeting specific criteria²) are scored according to the points they gain conditional on their behaviour in both the primary and secondary markets. To analyse the impact of the primary market on the secondary one, we retrieved two feasible indicators to be used as measures of the performance of auctions from the auction's results. The first one is the bid-to-cover ratio. It is the ratio between aggregate demand of primary dealers and amount allotted by the issuer, and it is the metric that has been used the most to explain the

² To be classified as a Specialist, a primary dealer must meet several requirements as explained in the Decree no. 993039 of November the 11th 2011. Among all the criteria, they must participate efficiently at the auctions in terms of quality, quantity and continuity, with a minimum allocation higher, or equal, than 3% of the overall amount auctioned on a yearly basis, considering the characteristics of the subscribed securities.

performance of an auction. The second one, a novelty with respect to the literature, is the overbidding indicator. It is the difference between the allocation price and the midprice of the bond on the secondary market five minutes before the auction.

Our main contributions to the literature regarding the relationship between primary and secondary markets consist in demonstrating that liquidity conditions of the secondary market are influenced by the outcome of the auction. In fact, there is significant evidence that a good auction, in terms of bid-to-cover ratio or high overpricing, affects positively liquidity conditions on auctions day.

Moreover, we find empirical proof that these two measures used for the empirical analysis are complementary to each other as one is correlated only to price-related liquidity measures and the other one only to quantity-related ones. In addition, the overpricing indicator is more reliant than the bid-to-cover ratio during periods characterised by higher volatility. This is true also when analysing liquidity on the day after the auction, i.e. the overpricing remains significant for the liquidity metrics it affected the previous day.

Furthermore, market liquidity is studied through several liquidity metrics and not by a unique one because we want to emphasize its multidimensional nature and to have a more comprehensive approach with respect to previous work.

This work continues as follows. Section 2 reviews the literature related to the study. Section 3 introduces the model and the testable predictions. Section 4 deals with the institutional framework of how Italian government securities' markets work and the main descriptive statistics of the dataset used. Section 5 describes the empirical strategy, the main results and concludes.

Related Literature

Recently, treasury auctions have been acquiring more importance in the economic literature. First, because the bond market has often been analysed from a corporate point of view. Secondly, because auctions are the main method through which sovereign bonds are placed. Especially the Italian Treasury, which prefers public auctions when issuing on the domestic market (AFME, 2017).

Theoretically, auctions have been deeply studied through auction theory. According to this, Das et al. (1997) explain that the bidding behaviour of primary dealers³ is affected by the auction mechanism adopted by the seller. Auction theory distinguish several auction forms, but two of them are relevant for Italian sovereign debt issuance program: discriminatory price auction, the case of Italian BOTs, where winning bids are filled at the respective bid price, and the uniform-price auction, as for all other Italian sovereign bonds, where all winning bids are settled at the same price equal to the marginal price (the lowest winning price or stop-out price). Depending on the auction format, market imperfections can be stronger or weaker, and they may hamper the good functioning of the market. One of the most frequently assumed friction is information asymmetry between the issuer and the buyers in the primary market because buyers do not know the real value of the bond trading on the primary market.

Information asymmetry in common-value auction model⁴ takes the name of winner's curse. The rationality behind this is that every dealer bidding at auction, except from the winner, estimates the common value to be lower than the value estimated by the winner. According to auction theory (Das et al., 1997), the bidding behaviour of Primary Dealers is affected by the auction mechanism adopted by the seller. Depending on the auction format, the winner's curse effect can be stronger or weaker. It is stronger, in a discriminatory price auction (Das et al., 1997) and, thus, the expected bond yields are higher (Cole et al., 2018). While it is less significant when adopting a uniform-price auction protocol, since bidders have less bargaining power in pressuring the prices down. Buyers, in uniform-price auctions, are consequently less willing to acquire information (Cole et al., 2018).

³ Primary dealers are the counterparty that trades with the Government in the primary market. They are the link between primary and secondary markets for governments securities. In the last years, the number of primary dealers decreased in most European Countries.

⁴ Usually, the value model used in analysing treasury auctions is the common-value one, in which the value of the item for sale is assumed to be the same among bidders, but they have different information about it.

The good functioning of the primary market is closely related to the developments of the secondary market of government bonds. In the secondary market, market makers have often been seen as a homogenous group and liquidity traders, in our case final investors, as those that, trading with market makers, can be split between informed and uninformed (Copeland et al., 1983; Glosten et al., 1985). Market makers' status of informed traders with respect to other market makers has been theoretically studied especially in the field of stocks. Calcagno et al. (2006), for instance, study the behaviour of risk neutral market-makers that have private information about the fundamental value of the bond to trade and compete with market makers who are uninformed. Information in general can have an important role in market microstructure. Glosten and Milgrom (1985) predict that bid-ask spreads decrease as information about fundamental value is incorporated into prices. Ho and Stoll (1981) study the behaviour of the specialist in managing his inventory as a monopolist and the effect that its management has on the bid-ask spread.

Empirically, several studies have been conducted on the relationship between primary and secondary markets for both government and corporate bonds.

It has been shown that prices and yields on the secondary market exploits predictable patterns around auctions. Lou et al. (2013), Beetsma et al. (2016) and Cafiso (2019) demonstrate that this predictable patterns of yields and prices exist. Lou et al. (2013), Beetsma et al. (2016), find evidence that sovereign bond yields on the secondary market follow an auction cycle every time we are close to an auction, with an amplitude of the cycle in periods of turmoil. US Treasury yields of 2-, 5-, 10-year notes experience this pattern also intraday (Fleming et al., 2014).

Instead, Cafiso (2019), who focuses on the Italian sovereign bond wholesale market by analysing data provided by MTS, finds that the Italian sovereign bond yields have this pattern high-volatility periods.

The existence of these predictable patterns of both prices and yields can be explained by various factors.

First of all, the inventory management problem of primary dealers that makes them trading before and after auctions is affected by end-investors' portfolio stickiness (Cafiso, 2019), for profit-seeking purposes (Fleming et al., 2007), limited risk-bearing capacity (Lou et al., 2013; Beetsma et al., 2016), because of net supply risk, which is the uncertainty related to the fact that the Treasury may issue an amount smaller-than-expected, and the gradual disclosure of information prior to an auction (Sigaux, 2018), the gradual arrival of buyers in the market

(Duffie, 2010)⁵, the price impact of other traders who sell ahead the sale of the issuer (Bessembinder et al., 2016)⁶, the funding constraints of primary dealers, the characteristics of both the auctioned bond and those already traded on the secondary market that are strictly correlated to the first one and market conditions (Eisl et al., 2019), and, finally, by the information released by the Treasury (Bikhchandani et al., 1993).

Secondly, yield movements can be altered by a specific indicator of the result of auctions. Beetsma et al. (2018) deal with the importance of the bid-to-cover ratio as proxy of the success of an auction, and test case for the creditworthiness of the government, to explain secondary market yield movement around auctions. The bid-to-cover ratio has been the only indicator used to explain the performance of an auction. For instance, Goldreich (2007) control for it to study the effect on underpricing, together with price tail to infer the impact of competition in discriminatory auctions. Moreover, it is an important criterion to signal the state of the Treasury markets and of the overall economy (Lou et al., 2013).

This predictable pattern, i.e. the auction cycle, is one of the two issuance cost's components faced by the debt management when issuing new securities. Depending on how a new bond has been allocated on the primary market, in terms of yields and prices, another cost can be associated to the issuance strategy followed by the Treasury, i.e. the underpricing (Lou et al., 2013). Underpricing regards the evidence of auction prices lower than contemporaneous market mid-quotes. In US Treasury market it is stronger when the protocol of the auction is discriminatory (Goldreich, 2007)⁷ or when there is the possibility for primary dealers to bid-shade⁸, especially in uniform price auctions (Hortaçsu et al., 2018).

Underpricing is an important feature in the framework of corporate bonds, when firms decide to go public to fund their growth. As a matter of fact, in an Initial Public Offering, only firms with the most favourable prospects find optimal to signal their type by listing their IPO at a

⁵ Auctions influence the secondary market yield also depending on the number of participants. Duffie (2010) explains that if capital constraints of market participants are less severe over time because more dealers arrive in the market, yields will be on a decreasing path in the days before the emission of the bond.

⁶ They don't deal with the Treasury market directly, but their work relates to trading strategies of market participants around large and predictable trades that affect the price pattern of securities traded.

⁷ Italian Government bonds (Cafiso, 2019) and others around Europe, e.g. in Spain (Alvarez et al., 2019) are not subject to the underpricing phenomenon.

⁸ As stated by auction theory, participants in common value auctions, may shade their bids because of their risk-averse behaviour regarding the winner's curse or any other kind of risk. Bid-shading is a matter of asymmetric information and market power.

price lower than the real value in the stock market, i.e. underpricing. In this way they can signal themselves on the stock market as investors, more or less informed, know that only the best issuers can recoup the cost of this signal from subsequent issues (Allen et al., 1989). Underpricing is, thus, a way for firms to signal and discriminate themselves on the stock market (Leland et al., 1977). Consequently, as long as managers are interested in heavily underpricing their firm only if they are sure that the firm is going to achieve higher market-adjusted returns, a good level of underpricing is a good way to signal the firm on the market. The signalling value of IPOs for high-quality firms may increase the demand of investors in the primary market but also of other investors trading the activity on the secondary market.

However, the strategy of the issuer is based also on secondary market conditions, because a certain level of liquidity guarantees an efficient allocation of bonds on auction day. Indeed, the practice of underpricing, however, is determined by important factors as the expected after-market liquidity (Corwin et al., 2004; Ellul et al., 2006). Worse liquidity conditions on the secondary market leads primary dealers to ask higher risk premia when bidding on the primary market, because of the higher liquidity risk perceived by dealers. This translates into lower prices and higher yields, that translate into greater costs for the Treasury.

News announcements are one of the factors that may alter market liquidity. Nguyen et al., 2018, study secondary market dynamics, i.e. liquidity, volatility and volume traded, for US Treasury securities at intraday frequency in correspondence of macro-announcements. In line with Fleming et al. (2014), liquidity is better on auction day before the auction takes place but decreases after macro-announcements (among which, auction's results) are released. Riordan et al. (2013) find that stock market intraday liquidity in the Toronto Stock Exchange is positively affected by good and neutral news, negatively by bad ones and these are particularly informative.

Liquidity conditions of the secondary market are also reflected by the characteristics of the bond issued on auction day (Arseneau et al., 2015; Eisl et al., 2019): amount allocated, maturity, price and other information revealed during the book-building period, in the specific case of an Initial Public Offering (Corwin et al., 2004), or on auction day, in the case of government securities' auctions. These decisions are then reflected on the portfolio composition of primary dealers. To this extent, Arseneau et al. (2015) identify a liquidity loop between primary and secondary market due to the fact that issuers and investors do not internalize how their behaviour affects secondary market liquidity when negotiating on the primary market. Moreover, they find that secondary market trading frictions, i.e. transaction and information costs, hinder the liquidity of assets trading on that market. This illiquidity is then reversed on the primary market to the extent that investors ask for a higher liquidity premium when they

participate at auctions. Indeed, the price of an asset has a liquidity component related to the security traded (Chaumont, 2018).

Depending on the financial market and on its specific regulation, secondary market liquidity may be affected by other features. Greco and Mormando (2018) find that when the Treasury changes the Specialists' Evaluation Criteria⁹, the liquidity condition in the secondary market for BTPs with a residual maturity longer than 10 years. Ferrari et al. (2019) point out that secondary market liquidity development of government bonds is also affected by the financial constraints of primary dealers. This is confirmed also at a corporate bond level: US corporate bonds' liquidity deteriorates because institutions more constrained by regulations reduce their intermediation and trading activities (Adrian et al., 2017).

Finally, liquidity discovery¹⁰ and price discovery of the cash market, i.e. the secondary market for Italian government bonds, are influenced by other markets where market makers may trade. They might trade on the futures market – the Eurex platform, in the case of Italian Government BTPs¹¹ - because of hedging and speculative motives (Eisl et al., 2019). By trading on the futures market, investors exert a price pressure on securities trading on the cash market – the secondary market for Italian government bonds. According to Pelizzon et al. (2014) a liquidity shock in the futures market for BTPs, closely related to the cash one, is transmitted to the market where the underlying is trading, i.e. the cash market, through arbitrage, speculation, hedging motives and by the market-making obligations of the market makers.

Furthermore, primary dealers can borrow (“repo”) or sell (“reverse repo”) on the repo market government securities to satisfy the demand of end-investors and manage scarcity needs. Indeed, if market makers want to trade a specific security that do not own in their inventory, they can create short-selling position in the cash market by acquiring that security on the repo market (Corradin et al., 2017). Thus, a good functioning of repo market is important for price and liquidity discoveries in the cash market.

⁹ Specialists are primary dealers satisfying specific criteria. Usually at the end of the year, the Treasury may modify monitoring and ranking criteria to foster liquidity and efficiency of secondary market. Similar mechanisms are adopted also in other European countries.

¹⁰ Liquidity discovery is the adjustment of liquidity conditional on the arrival of new information.

¹¹ Three are the futures contract available on the Eurex: Short-Term (3-year), Mid-Term (7-year) and Long-Term (10-year) Euro-BTPs, that have been introduced on the Eurex Exchange Platform in 2010, 2011 and 2009 respectively. Only Short-Term and Long-Term Euro BTPs futures contracts are effectively traded by market participants.

The contribution of this work is manifold. First, theoretically, we contribute to the strand of literature related to signals and liquidity conditions, by introducing the novelty of the heterogeneity of the government bond market makers with respect to each other, depending on their individual demand as, to my knowledge, no paper assumes informed market makers on government bond.

Differently, from what other works assume, in this model the uncertainty is in terms of total demand and not in terms of total supply as supposed by Sigaux (2018). So, we shift the focus from the Treasury perspective to the market makers perspective, since in our model we have that they are the uninformed part of the market.

Moreover, our work contributes to the literature relating to the relationship between primary and secondary treasury market. The novelty of this research is that we link auctions' performance, perceived as a signal of the credibility of the government, to the liquidity condition on the secondary market, by using both an already used index, i.e. the bid-to-cover ratio and a new one, i.e. the overpricing indicator.

Finally, it is related to the wider concept of market liquidity and market microstructure as we focus on the trading activities at the best quotes of the book, but also of the total book by applying a wider concept of liquidity, as it measured by price-related and quantity-related metrics.

Model

Introduction to the model

Market makers' status of informed trader with respect to other market makers has been theoretically studied, especially in the field of stocks. In the government bond market framework, the asymmetric information is between the market maker and the Treasury as the former do not know the net-total supply issued by the Treasury (Sigaux, 2018).

On the contrary, in this model, market makers are uninformed with respect to the total demand received by the Treasury on auction day. The total demand of the bond received by the Treasury is the real value that the bond accrues on auction day. As market makers base their strategy on the expected value of the bond, they will know better the distribution of this value only after they know their individual demand. The individual demand is known by the market maker only after the auction takes place.

Despite market makers are homogeneously informed before the auction, they are heterogeneously informed after the emission as they now know their respective demand, which is different among dealers. As the market makers do not have the same individual demand since they satisfy a different quantity of customers, also their level of information about the total demand is not the same. Once received the signal from the auction, based on the individual demand, market makers can infer more precisely the distribution of the true value of the bond, which is at the basis of their trading strategy.

Set-up

There are four periods ($t = 0, 1, 2, 3$, Figure 1), a risky treasury bond which is auctioned in a staggered fashion, market makers and final investors.

Market makers are equally risk-averse and have the following CARA¹² utility function:

$$U(W_t) = -e^{-aW_t} \quad (1)$$

Where W_t is the final-period wealth and $a > 0$ is the coefficient of absolute risk aversion, equal for all market makers and i is the subscript indicating market maker i , and $i = 1 \dots N$.

We assume, for the sake of simplicity, that there are only two market makers, but the results of the model are the same if we consider a larger number of market makers, with a different individual demand each.

¹² CARA utility function rules out wealth effects on portfolio choice. Wealth effects could be captured if, at $t = 3$, market makers have a different degree of risk-aversion.

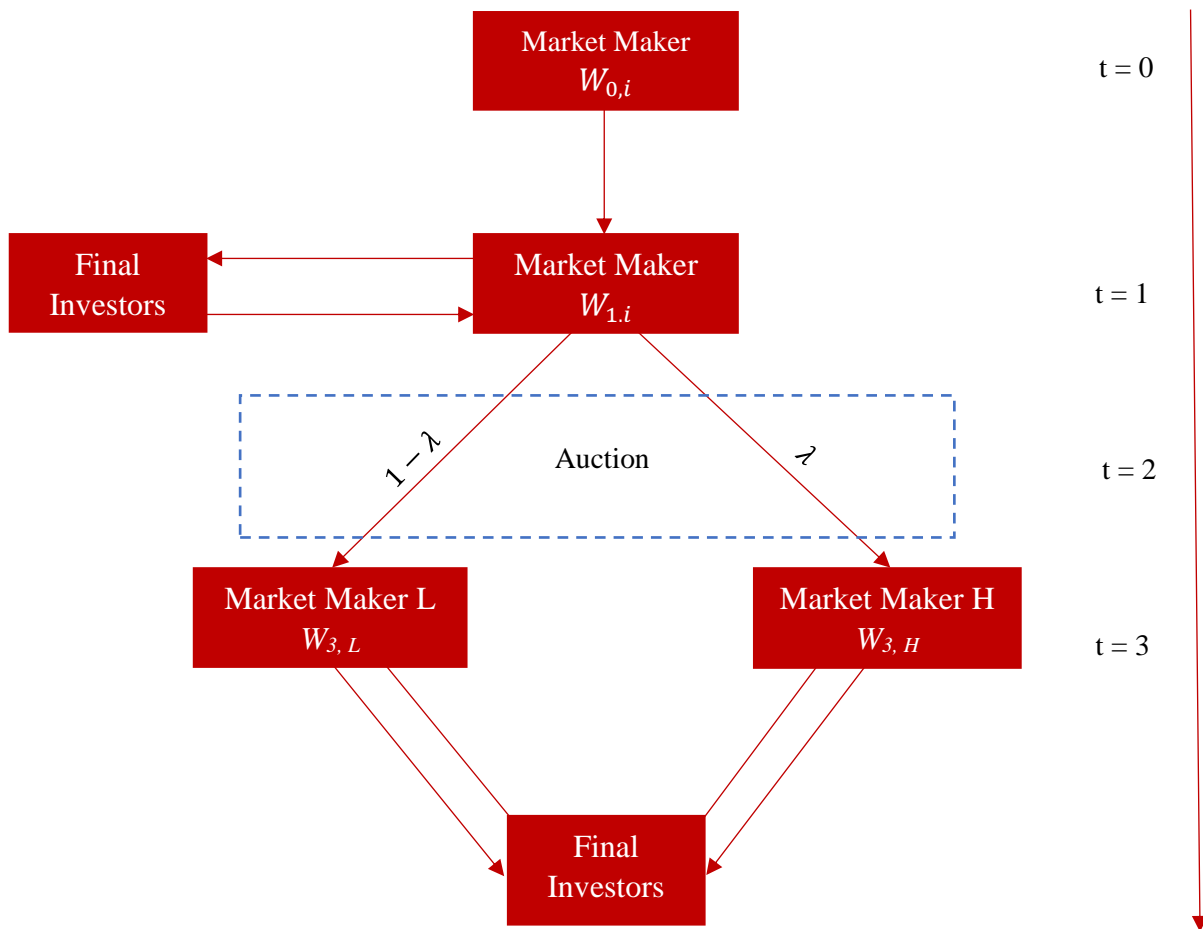


Figure 1 **Timeline**

As we can see from Figure 1, at $t = 0$ market makers are endowed with an initial level of wealth W_0 ¹³.

At $t = 1$, market makers trade the bonds in their inventory with final investors. Prices set on the secondary market depend on the real value of the bond, v . It is unknown, but market makers base their expectation of its distribution on that of the prior value, i.e. the value of the bond after the previous auction, which is of common knowledge. As in Grossman and Stiglitz (1980), the value of the asset is $v_1 \sim N\left(\varphi, \frac{1}{\rho_\varphi}\right)$, with φ the prior value of the asset and ρ_φ the precision of the prior. With the evaluation of the asset, and prices set in accordance to the prior common value of the bond, they have the following level of wealth:

¹³ The initial endowment owned by market makers at time 0 is the result of market operations that took place previously than those of the model, thus trading activities on the secondary market and previous auctions.

$$W_1 = W_0 + (\varphi - p_1^{bid})X_1^b + (p_1^{ask} - \varphi)X_1^a$$

(2)

The amount traded on the secondary market is assumed to depend on final investors' supply and demand function. We assume that final investors are price-taker and they will base their trading activity on the price set by market makers. Because of this, in the spirit of Copeland and Galai (1983)¹⁴, they trade these quantities:

$$X_t^b = p_t^{bid}$$

(3)

$$X_t^a = 1 - p_t^{ask}$$

(4)

At time 1 they maximize the following utility function

$$EU[W_1] = -e^{-a[E[W_1] - \frac{1}{2}a \cdot var(W_1)]}$$

(5)

which in mean-variance terms becomes:

$$\max_x E[W_1] - \frac{1}{2}a \cdot var(W_1)$$

(6)

Where the first term is the mean, the second is the risk-premium and a represents the coefficient of absolute risk aversion.

The first order condition at $t = 1$ is:

$$E[v] - p_1^{bid} + p_1^{ask} - E[v] - a \cdot X_1^b var(v) - a \cdot X_1^a var(v) = 0$$

(7)

² Copeland and Galai (1983) do not use prices directly, but the probability that trades at a certain price will be executed. Since prices are assumed to be distributed uniformly between 0 and 1, they can be substituted to the probability of execution of the price.

Where

$$E[v] = \varphi$$

(8)

$$var(v) = \frac{1}{\rho_\varphi}$$

(9)

Because of equations (3) and (4), we end up with:

$$-p_1^{bid} + p_1^{ask} - a \cdot p_1^{bid} \frac{1}{\rho_\varphi} - a(1 - p_1^{ask}) \frac{1}{\rho_\varphi} = 0$$

(10)

From which we can retrieve the prices that maximize the utility function and the relative bid-ask spread at time 1:

$$p_1^{ask} = \frac{a \cdot var(v)}{1 + a \cdot var(v)} + p_1^{bid}$$

(11)

$$p_1^{bid} = p_1^{ask} - \frac{a \cdot var(v)}{1 + a \cdot var(v)}$$

(12)

$$p_1^{ask} - p_1^{bid} = \frac{a \cdot var(v)}{1 + a \cdot var(v)}$$

(13)

Prices are equal for both market makers as they trade on the same expected value of the bond, i.e. the prior value.

At $t = 2$ a shock occurs. The shock consists of a signal θ coming from the auction on the primary market hitting market makers' expectation about the real value v of the bond. The signal θ has variance $\frac{1}{\rho_\theta}$, where ρ_θ is its precision. The shock coming from the auction is asymmetric as the signal hits heterogeneously the two market makers. This heterogeneity depends on the individual demand of the market maker, which is not the same for both dealers.

The difference is in terms of precision, i.e. high or low, although the mean value of θ is the same for the market makers. The variance of θ will be lower in the case of a high-precision signal and higher in case it is less precise. The high-precision signal is received by the market maker with bigger individual demand, MM_H , the low-precision one by the market maker with

a smaller market share, MM_L . Therefore, the precision of the signal is directly connected to the share of the entire market served.

At the auction, when market makers discover their individual demand, they know whether they bid a big amount of bonds or not, because they compare it to the individual amount bid at the previous auction.

At $t = 3$ they will update their prior beliefs with the signal received, to base their trading activity on the posterior value of the bond. Posteriors of the real value are made up as in Bayesian learning, thus the distribution of the posterior value v is:

$$v_2 \sim N \left(\frac{\rho_\varphi \varphi + \rho_\theta \theta}{\rho_\varphi + \rho_\theta}, \frac{1}{\rho_\varphi + \rho_\theta} \right) \quad (14)$$

Because of the two signals, the updated distribution of the fundamental value of the bond diversifies depending on the market maker

$$v_{3,H} \sim N \left(\frac{\rho_\varphi \varphi + \rho_\theta^H \theta}{\rho_\varphi + \rho_\theta^H}, \frac{1}{\rho_\varphi + \rho_\theta^H} \right) \quad (15)$$

$$v_{3,L} \sim N \left(\frac{\rho_\varphi \varphi + \rho_\theta^L \theta}{\rho_\varphi + \rho_\theta^L}, \frac{1}{\rho_\varphi + \rho_\theta^L} \right) \quad (16)$$

Where v_H and v_L are the new values of the bond according to MM_H and MM_L , respectively. As the expected value has changed, the strategy of market makers must be updated. Therefore, also quotes change with respect to time 1 prices and they will be different between market makers as they base their strategy on two different expected value of the bond.

The third-period level of wealth becomes:

$$W_{3,i} = W_2 + (v_i - p_{3,i}^{bid})X_3^b + (p_{3,i}^{ask} - v_i)X_3^a \quad (17)$$

where the subscript i specifies the market maker, whether of type L or H.

The expected wealth to maximize depends now on the signal received, so equation (6) becomes:

$$\max_X E[W_{3,i}|\theta] - \frac{1}{2}a \cdot \text{var}(W_{3,i}|\theta)$$

(18)

where a is always the coefficient of absolute risk aversion and it is the same for both market makers, i.e. they are equally risk-averse, despite their heterogeneity. By focusing only on the risk premium, we can notice that the higher the variance of the signal, thus the lower the precision, the higher the risk premium asked by the dealer on the market.

Accordingly, also prices that maximize the utility function and the relative bid-ask spread change and depend on the posterior variance:

$$p_{3,i}^{ask} = \frac{a \cdot \text{var}(v|\theta)}{1 + a \cdot \text{var}(v|\theta)} + p_{3,i}^{bid}$$

(19)

$$p_{3,i}^{bid} = p_{3,i}^{ask} - \frac{a \cdot \text{var}(v|\theta)}{1 + a \cdot \text{var}(v|\theta)}$$

(20)

$$p_{3,i}^{ask} - p_{3,i}^{bid} = \frac{a \cdot \text{var}(v|\theta)}{1 + a \cdot \text{var}(v|\theta)}$$

(21)

Market makers, differently from the previous literature, are not expected to behave as a monopolist, though in a competitive framework and without cooperation, thanks to the regulatory framework surrounding the market. Indeed, even though quotes are different depending on the type of the signal received, we assume there is no strategic interaction between the two dealers.

As we can see from (21), the higher the variance the larger the spread. Lower precision leads market maker to ask a higher risk premium, e.g. they increase transaction costs¹⁵.

Larger bid-ask spread indicates worse liquidity condition of the market. This is consistent with Stoll (1978) that demonstrates the linear dependence of the bid-ask spread on the risk-aversion and on the asset volatility

After the trading at $t = 3$ the value of the bond returns to be common knowledge, because less informed traders have now acquired all the information provided by the auction and it has been consolidated among all market makers.

¹⁵Transaction costs are one of the three components of the bid-ask spread.

Equilibrium

In general, at both time 1 and time 3, the equilibrium prices set by the single market maker can be obtained by setting

$$X_{t,i}^a = X_{t,i}^b \quad (22)$$

Such that every market maker i is in balance, i.e. the amount of the security sold at time t is the same as that bought from final investors,

Equation 22 develops as:

$$1 - p_t^{ask} = p_t^{bid} \quad (23)$$

If we put (23) in the first order condition (10) we have:

$$-(1 - p_{t,i}^{ask}) + p_{t,i}^{ask} - 2a(1 - p_{t,i}^{ask})var(v) = 0 \quad (24)$$

and the following equilibrium prices:

$$p_{t,e}^{ask} = \frac{1 + 2a \cdot var(v)}{2(1 + a \cdot var(v))} \quad (25)$$

$$p_{t,e}^{bid} = \frac{1}{2(1 + a \cdot var(v))} \quad (26)$$

Proposition 1: In equilibrium, market makers set a higher bid-price and a lower ask -price than the respective prices before the auction. Moreover, market makers now quote different prices.

Proof of Proposition 1:

$$var(v | \theta) = \frac{1}{\rho_\varphi + \rho_\theta^i} \quad (27)$$

and

$$var(v_1) = \frac{1}{\rho_\varphi} > \frac{1}{\rho_\varphi + \rho_\theta^i} = var(v_{3,i}) \quad (28)$$

On the basis of the proof to Proposition 1, we know that at time 3 the variance of the value decreases, whatever the quality of the signal received by the market maker at time 2. A lower variance leads to a decrease in the uncertainty about the true value of the bond. Because of this, at time 3 market makers set a lower ask-price and a higher bid-price with respect to quotes set at time 1:

$$p_1^{ask} > p_{3,i}^{ask}$$

(29)

$$p_1^{bid} < p_{3,i}^{bid}$$

(30)

where i stands for the type of the signal received by the market maker, L if with low precision and H if high.

Being the two market makers heterogenous, they set different prices. As equations (25) and (26) exploit, prices linearly depend on the variance of the value, thus on the precision of the signal. Therefore, both market makers adjust quotes according to the precision of the information received. These prices are:

$$p_{3,L}^{ask} > p_{3,H}^{ask}$$

(31)

$$p_{3,L}^{bid} < p_{3,H}^{bid}$$

(32)

Different prices mean that the quantity traded with final investors is not the same, either after the auction, by comparing the amount traded before and after the issuance, either between the two market makers. Higher ask-prices lead to a decrease in the amount demanded by final investors and lower bid-prices denote a lower supply. By following the reasoning in equations (29) and (30), at time 3 trades are larger on both sides of the market because of the lower uncertainty reflected by prices:

$$X_1^b < X_3^b$$

(33)

$$X_1^a < X_3^a$$

(34)

Moreover, because of the relationships in (31) and (32), the two market makers do not trade the same amount of bonds with final investors at time 3. The different prices set by market makers

make final investors adapt their bid and offered quantities. If market maker's orders with the best prices are filled, final investors trade at the best available price, that can be a second-best or worse ¹⁶, without waiting for new orders with better quotes. The amount traded for both market makers are:

$$X_{3,L}^a < X_{3,H}^a$$

(35)

$$X_{3,L}^b < X_{3,H}^b$$

(36)

This is consistent with the hypothesis that the signal is more precise for the market maker with a bigger number of customers. Indeed, the more precise the signal, the more the amount of bonds to trade in both direction of the market, the more, subsequently, the customers to satisfy.

Proposition 2: In equilibrium, liquidity conditions are better after the auction, whatever the precision of the information retrieved by the market makers.

Proof of proposition 2:

Equation (16) can be rewritten as:

$$p_{3,i}^{ask} - p_{3,i}^{bid} = \frac{a \cdot \frac{1}{\rho_\varphi + \rho_\theta^i}}{1 + a \cdot \frac{1}{\rho_\varphi + \rho_\theta^i}}$$

(37)

And the total value of market depth, can be generically stated as:

$$Depth_t = \frac{\sum(X_{t,i}^a + X_{t,i}^b)}{2}$$

(38)

Where i stands for the type of market maker.

On the basis of the proof of Proposition 1, receiving the signal lowers the variance of the value, whatever the precision of the signal. Consequently,

We can state that:

¹⁶ It could be a price worse than the second-best if there were more than two market makers, each one with its own perception of the real value of the bond.

$$p_1^{ask} - p_1^{bid} > p_{3,i}^{ask} - p_{3,i}^{bid}$$

(39)

as the bid-ask spread can be written in terms of variance of the value (Equation 37), the signal contributes to better liquidity conditions on the secondary market at time 3 with respect to time 1.

The same is valid for market depth.

The level of market depth at time 1 is given by:

$$Depth_1 = X_1^a + X_1^b$$

(40)

as the two market makers quote at the same prices.

At time 3, depth becomes:

$$Depth_3 = \frac{X_{3,L}^a + X_{3,M}^a + X_{3,L}^b + X_{3,M}^b}{2}$$

(41)

Then,

$$Depth_3 > Depth_1$$

(42)

Proposition 3: The extent to which market makers contribute to the liquidity provision depends on the precision of the signal.

As a result of Proposition 1 (Equations 31 and 32) and the proof of Proposition 2 (Equation 37), the bid-ask spread changes and the market maker with the low-precision signal has the broadest:

$$p_{3,L}^{ask} - p_{3,L}^{bid} > p_{3,H}^{ask} - p_{3,H}^{bid}$$

(43)

The broader spread can be explained by the compensation asked by small market maker for the bigger volatility of the bond's expected value. Larger spreads are index of worse liquidity conditions of the market.

The same reasoning applies to the individual depth. As it results from (35) and (36), with the same demand and supply schedule of final investors,

$$Depth_{3M} = \frac{X_{3,M}^a + X_{3,M}^b}{2} > \frac{X_{3,L}^a + X_{3,L}^b}{2} = Depth_{3L} \quad (44)$$

Proposition 4: The less informed market maker earns higher profits.

Proof of Proposition 4:

As:

$$E[v_{3,i}|\theta] = \frac{\rho_\varphi \varphi + \rho_\theta^i \theta}{\rho_\varphi + \rho_\theta^i} \quad (45)$$

$$\rho_\theta^H > \rho_\theta^L > \rho_\varphi \quad (46)$$

and

$$\pi_{3,i} = (E[v|\theta] - p_{3,i}^{bid})X_{3,i}^b + (p_{3,i}^{ask} - E[v|\theta])X_{3,i}^a \quad (47)$$

In equilibrium, with the given demand and supply schedule of final investors, market makers do not earn the same profit, even if there are changes on both sides of the market.

Since we know from Equation (47) that profits depend on the expected value the market maker has for the real value of the bond, i.e. $E[v|\theta]$, on prices set by market makers, and on quantities traded with final investors, a worse signal, with a lower precision as ρ_θ^L , implies higher profits. This is due to the higher risk premium requested by the market maker who receives a low-quality signal. Indeed, as we know from Proposition 2, this market maker, sets a broader bid-ask spread after the auction, so it benefits from the higher transaction costs and earns a higher profit.

On the other hand, the market maker with the more precise signal earns a lower profit. Consequently, market makers do not use their information advantage to make more profits, but to increase liquidity.

Institutional framework and dataset

Functioning of the Primary Market and instruments issued by the Treasury.

In the primary market, the sovereign issuer, that in Italy is the Minister of Economics and Finance (henceforth Treasury, or Italian Treasury), places different type of securities¹⁷ depending on the liquidity needed to finance its spending.

Depending on the kind of instrument, we can distinguish two different auction protocols: competitive yield auction and marginal price auction. The former, that involves BOTs' issuance, is in yield terms and each bid placed by the dealers is awarded at the rate proposed¹⁸. The latter regards all the other instruments and it is in terms of price and the winning bids are all settled at the same price, the lowest winning one, also called stop-out price¹⁹. Usually, auctions concern on-the-run bonds²⁰, the latest issued bond until a new one is issued and takes the place of the old one that obtains the off-the-run status. Off-the-run bonds can be issued as well, depending on the liquidity needs of the Treasury and on the market shortage of these specific bonds. Sometimes, tranches of off-the-run bonds can be placed on the market together with on-the-run ones. In this case, we talk about joint auction. This type of issuance provides that the total amount to be auctioned is in terms of total volume within a joint supply range. Thus, the minimum and maximum amounts offered must be considered for the two securities

¹⁷ Among Italian government bonds we can distinguish 17 segments of emission: 6-, 12-month BOTs, 24-month CTZ, 3-,5-, 7-, 10-, 15-, 20-, 30-, 50-year BTPs, 5-, 10-, 15-. 30-year BTP€I, CCTeu and the retail bond Btp Italia. Every year the Treasury publish a calendar where dealers can find the date of interest of the auction process (announcement, issuance and settlement dates).

¹⁸ The maximum numbers of bids that can be placed by a singular bidder are five, with yield differing one from the other by one thousandth of one percent. The minimum quantity to be bid is 1.5 million euros. The first bids to be allocated are those with the lowest yields. In order to avoid misbehaviour from primary dealers in placing the bids in terms of yields, a range from a minimum acceptable yield to a maximum one is calculated. For marginal price auction, primary dealers can place at most always 5 bids, but the minimum bidding amount is 500,000€ and less than the amount being issued. Prices must vary by at least one tick, which is one hundredth.

¹⁹ Concerning our four segments of BTPs, the 10-year maturity is issued at the end of the month and the 3- and 7-year BTPs at the middle.

²⁰ The *on-the-run* bond is usually the most liquid among the bonds with the same maturity. The price difference between *on-the-run* and *off-the-run* Treasuries is often referred to as the liquidity premium, as the more liquid Treasuries are obtained at a higher cost.

together. This choice of the Treasury is adopted when the securities to be issued are perceived to be highly requested by the market, but also to be more flexible in the issue distribution²¹.

Irrespective of the auction format, the process starts some days before the auction. During these days, the debt management office of the Treasury announces the auction in a press statement. The announcement for all auctions will be issued three business days prior to the placement date. The statement confirms the auction date, the maturity of the bond(s) to be auctioned and provides a target range for the volume (the minimum and the maximum amounts offered to the market, i.e., a “fork”). The to-be issued bond starts trading before the proper issue, i.e. the “grey market”, precisely the day after the announcement has been published.

On auction date t , primary dealers submit their bids during the pre-announced time window. Each primary dealer has at most five bids to place (the quantities and the correspondent prices at which they are willing to buy the bond) and they are sent electronically and anonymously to the Bank of Italy within 11 a.m. of the auction day. After the Bank of Italy receives all the bids from the market makers, a decrypting procedure starts and send the list of bids to the Treasury. The results are published as soon as possible after the cut-off of the auction, typically within 11.30 a.m. In the announcement of the results, the Treasury publishes all relevant information of the process. Concerning securities issued through a uniform price auction, we can find the ISIN code, the tranche of issuance, the coupon, the issue date, the maturity date, the date of the auction, the settlement date, the interval of the amount to be offered, the amount requested and the amount allotted, which usually corresponds to the top amount of the range disclosed (full allotment), the allotment price and the placement fee²² which has to be scaled down from the allotment price in order to know the real bid price, and the bid-to-cover ratio. Settlements take place on the second working day after the auction.

There are two main periods for auctions, one takes place at the middle of the month and concerns, regarding medium-long term allocation, 3-, 7-, higher than 10-year BTPs and the second one at the end of the month which involves 5- and 10-year BTPs.²³

For a more efficient placement of bonds to properly satisfy the aggregate investor demand and cut the borrowing cost, the Public Debt Management meets the Specialists (a subset of primary

²¹ Ministry of Economics and Finance, Public Debt Report 2017.

²² The amount of the placement fee depends on the type of security issued. Considering the four BTPs object of the analysis, we can find placement fees for 0.15%, 0.25%, 0.30%, 0.35% for the 3-, 5-, 7-, 10-year maturities, respectively.

²³ The reference is to on-the-run bonds. Off-the-run BTPs can be issued also in slots that do not concern their initial maturity.

dealers) before the announcement date. These meetings are very important for the Public Debt Management as in this way it is more informed about secondary market developments.

Moreover, there are other informative documents, published by the Treasury, that overcome the information asymmetry problem between issuer and dealer. These are, mainly, the Annual Calendar (published at the beginning of each year, it contains information about the dates of announcement size, issuance/re-opening and settlement of each security), the Guidelines on Public Debt Management (yearly documents that provide qualitative and quantitative information on the issuance and management of the government securities in the following year) and the Quarterly Issuance Program (where information about new bonds to be issued and re-openings of on-the-run bonds for the next quarter of the year are released). These documents, together with other information such as Public Debt Reports, are available on the website of the Italian Treasury.

Specialists' evaluation criteria

In order to be classified as a Specialist, and benefit from some privileges²⁴, a primary dealer must meet several requirements and accomplishments as outlined in the Decree no. 993039 of November the 11th 2011²⁵.

With the aim of being sure about Specialists' compliance with their obligations, the Italian Treasury continuously monitors their behaviour both in the primary and secondary markets.

The main evaluation criteria give the possibility to Specialists to gain points to better compete and be placed at the top of the final ranking. The final purpose of the Treasury is to foster demand at auctions, increase secondary market liquidity and receive advice from the Specialist on debt management policy issue. The points granted depend on the behaviour of Specialists in the primary and secondary markets. Different factors are at the heart of the evaluation: the quantity allocated by each bidder at auctions, the measure to which the specialists contribute to overpricing and overdemanding, the regularity of participation in all the auctions, the quality

²⁴ For example, only Government Bond Specialists that took part in the main auction can participate in the re-openings of the same bond. The maximum amount offered in the re-opening depends on the type of security, i.e. re-openings are equal to 15% of the ordinary issue (10% for BOTs), 30% for medium- and long-term bonds if newly issued.

²⁵ Among all the criteria, they must participate efficiently at the auctions in terms of quality, quantity and continuity of bidding, with a minimum allocation higher, or equal, than 3% of the overall amount auctioned, considering the characteristics of the subscribed securities. Furthermore, they have secondary market commitments *in terms of contribution to the volumes traded, to liquidity and to the depth of the market*.

of bid and ask price proposals on the secondary market and the quantities associated with them, the type of bonds and volumes traded with other investors, the number of bonds quoted and the number of those traded, the activity in the repo market, the market share in the special operations (i.e., exchange transactions and buyback operations), the overall contribution to the management of public debt (i.e., advisory and research activity). The most important index (that gives 33 out of 100 in 2019) concerns the primary market and it is a quantitative indicator that involves the share allocated obtained in the reference period.

Moreover, to make Specialists more compliant with the regulations, the Treasury makes, at the end of each year, a ranking and the top five is made public.²⁶

MTS Italy

A more efficient placement of bonds for sovereign issuers, in terms of cost and risk premia demanded by investors, is guaranteed by a good functioning of the secondary market, the market where primary dealers act as market makers, i.e. they trade to provide liquidity to other investors that cannot access the primary market directly.

MTS is an interdealer platform with a high level of pre and post trade transparency established in 1988 by the Italian Treasury. The MTS trading system is quote-driven, electronic limit-order interdealer market, in which market makers' quotes can be hit or lifted by other market participants via market orders.

MTS Italy is a branch of the entire MTS trading system and it is the secondary market where Specialists are monitored by the Italian Treasury. It is regulated by the Italian Treasury, the Bank of Italy and Consob. Here, there are two types of participants: market makers and market takers. The former are primary dealers that act on the basis of the Market Making Commitments, which establish the rule that market makers have to provide liquidity continuously by quoting two proposals (one for the bid side and one for the ask side) during the trading hours. They can place quote anonymously, at least until one of the two counterparties settles bilaterally. They issue standing quotes but are not obliged to display the maximum quantity they want to bid, but only a non-negative fraction of the quantity they are willing to trade. Quotes must be at least of 2 million on both ask- and bid side. The latter act as price takers, by hitting or lifting market makers' quotes by market orders.

²⁶ A placement at the top five of the ranking can signal the Specialist in the financial market as it gives a higher reputation (Greco and Mormando, 2018).

Finally, MTS Italy is divided into two segments: Cash and Repo. In the former, only Italian government debt securities are traded, in the latter we can find also government bonds of different Governments and non-government bonds, e.g. Asset-backed securities²⁷.

If the secondary market is not functioning in an orderly manner and is not liquid as it should be, the primary market suffers in terms of placements and buy-back operations carried out by the Treasury. If this situation exists, the Italian Treasury, together with the technical assistance of both the Bank of Italy and the main Specialists²⁸, can change the debt management and issuance choices to improve the overall level of efficiency and ensure a sufficient liquidity and breadth of trading in the secondary market.

Dataset

Two are the datasets employed for the analysis. The first one concerns primary market data, and the other the secondary market. Both datasets have been provided by the Italian Ministry of Economics and Finance, in the framework of research collaboration between the Ministry, MTS Italy and CRIEP.

The primary market dataset contains all the results of auctions, that is: auction day, settlement day, amount bid, offered, and allotted, allotment price, gross yield and fees. All data are observed on auction day from January 2016 to December 2019. Auctions' results are collected for all bonds of interest, that is 3-year, 7-year and 10-year BTPs²⁹. We have a total of 128 auctions, 40 for both the 3-year and the 7-year, 48 for the 10-year bond. All BTPs are described in the Appendix. For each BTP it is possible to see the reference ISIN code, the date of issuance, as it is the first day from which we select every BTP, the coupon and the maturity date.

The motivation of choosing these three segments relies on the idea that we want to infer whether auctions have an informative power on the liquidity of the benchmark and on two other

²⁷ These two markets are different also in terms of market hours. For the Cash Market, we can find the following hours: Pre-Market: 7:30am – 8:00am; Trading Hours: 8:00am – 5:30pm; Market Closed: from 5:30pm until the next morning. For the Repo Market, instead: Pre-Market: 7:30am – 7:45am; Market Open: 7:45am – 6:30pm; General Collateral allocation window: 6:30pm – 6:45pm; Market Closed: 6:45pm.

²⁸ As stated in the Specialists Decree: *The enrolment of the Candidate Specialist in the List of Specialists is dependent upon the satisfaction, during the observation period, of a series of requirements as [...] Assistance in choosing how to improve the overall efficiency of debt management, also by proposing useful contributions to issuance and debt management choices.*

²⁹ All BTPs are identified by an ISIN code and their description is given in the Appendix.

maturities that are close to the 10-year one and are on the same part of the yield curve, so that we do not have too much dispersion among the maturity of the bonds.

By choosing these three lines, we do not have to consider different type of auctions³⁰ and they are not issued with a joint auction, as it usually happens for longer-term maturity, so we do not have problems in discriminating the effect of one bond with respect to another one.

The secondary market dataset contains trades and quotes from January 2016 to December 2019 at five-minutes interval from 9:00 until 17:00 of the trading day. We decided to observe these 8 hours of trading because the trading activity is less significant at the beginning and at the end of the trading day. This granularity has been chosen to have more precise daily dynamics of liquidity metrics and to observe better the linkage between primary and secondary market³¹. As we considered only on-the-run BTPs, i.e. the most recently issued bonds within the sample, we had to use data only for a certain interval for each BTP. This means that we had to use trades and quotes for each ISIN, that is for each on-the-run BTP. In order to merge all data, we considered a single BTP from the day it was issued to the day before the auction of a new bond³².

The crucial point is to infer if auctions have informative power on the liquidity conditions of the secondary market of the specific bond on auction day by looking at two different performance indicators. One is the bid-to-cover ratio, already used to predict the yield movements around auctions (Beetsma et al., 2018), and the other is the overpricing indicator. For the purpose of the analysis, daily averages of liquidity measures from the entire dataset have been calculated since we are interested in the daily dynamics of secondary market liquidity.

For our empirical strategy, we first focus on the entire sample period, in a second stage of the analysis, we study the effect of our auction indicators in periods of financial turmoil to check if their informativeness changes. The choice of the period considered derives from the willingness to analyse the secondary market of government bond in recent years and to discover if the

³⁰ All these three securities are issued through uniform price auctions. If we would have wanted to consider shorter-term maturities, we would have analysed BOTs, but they are issued through discriminatory auctions.

³¹ As we will see later, for the computation of the overpricing value, it would have been impossible to analyse this measure without having such granular dataset.

³² We could have added the new bond from its public announcement, but the trading and quoting activity during the days before the auction, i.e. its grey market, is very thin and would have influenced too much the analysis.

informative power of auctions changes during crisis period. The crisis period we are referring to is after 29th May 2018, a period characterised by high political uncertainty. We have chosen this date as discriminant, because it is the day when financial markets experienced the highest turbulence. After May 2018, the liquidity of the secondary market of Italian government securities has deteriorated, e.g. the average market value of outstanding bonds has fallen about 9 per cent and yields recorded a marked rise. This growth replicates the steep increase in risk premiums and the CDS, the premium for insolvency risk on Italian government securities, was at its highest of the last five years, i.e. after the sovereign debt crisis³³.

The bid-to-cover ratio and the new indicator

Before knowing the impact of a good auction on the liquidity condition of our three segments of BTPs, we need an indicator of the performance of the auction to know how to establish whether an auction performed well or not. In the literature, the bid-to-cover ratio has been the only indicator used to explain the success of an auction.

Despite its easy comprehension and retrieval³⁴, it is not always a reliable indicator, since it can be manipulated by dealers submitting bids. For example, a high bid-to-cover ratio can be the result of a high demand coming from the bidders, but this aggregate demand does not consider the price at which the market makers are willing to buy that security at auction. If the price is too low, the Treasury will never deal with those bids, because it sets up a cut-off price under which it is not possible to issue the bond. Thus, the nominator of this ratio could be much higher than the denominator because of the low-price bids received.

Moreover, if the bid-to-cover ratio of two auctions is different, it does not mean that it is because the amount of bond demanded changed, whereas it could be because of a change in the amount offered by the Treasury.

In uniform price auctions, the amount of bond placed is not set beforehand. The Italian Treasury, indeed, announces in a press release, published some days before the auction, the range between a minimum and a maximum amount to be issued. Thus, nobody knows the exact amount that is going to be placed on the market. However, it must be said that, most of the times, the Treasury issues the top quantity of the range. There are some exceptions in the auctions studied for the analysis. For instance, the 10-year BTP, which is the benchmark, had three auctions in which the Treasury did not place the maximum amount of the range

³³ Bank of Italy, Financial Stability Report, November 2018.

³⁴ When the Ministry of Economics and Finance publishes the results of auction, it is one of the indicators available in the press release, therefore, there is no need to compute it.

published.³⁵ The biggest difference between the amount allocated and the maximum of the potential offer, was at the end of May 2018, the period when Italy had an important political uncertainty and, consequently, experienced a spike in the spread between the 10-year BUND and BTP.

Because of its drawbacks, after several interviews with other market operators, we decided to use another indicator, i.e. the overpricing, to explain the goodness of an auction. The reason why we adopted the overpricing as an indicator relies on the idea that this measure, differently to the bid-to-cover ratio, considers both the primary and the secondary markets in its calculation. Indeed, it is the difference between the allocation price net of placement fee and the relative fair price of the secondary market of the issued security. The fair price is, in our case, proxied by the mid-price of the security 5 minutes before the auction takes place. The more a BTP is overpriced relative to its fair price on the secondary market, the more it is overvalued. This means that for the Treasury the new emission was good since higher prices mean that the cost of issuance is lower as yields are not high.

Table 1 presents the summary statistics for the bid-to-cover ratio and the overpricing for all the three lines of emission and figure 2 and figure 3 the relative development of the indicators throughout the sample.³⁶

On average, bid-to-cover ratios are larger for the 3- and 7- year maturities than for the 10-year BTP. This should indicate that 10-year BTP auctions have been worse than the other. But if we look at the average amount allotted, the 7-year BTP ranks last. Because of the higher denominator, i.e. the amount issued, and the similar nominator, i.e. amount demanded by primary dealers, the bid-to-cover ratio of the 7-year BTP is consequently greater than the 10-year's one.

This can be also explained by the fact that, on average, 3-year maturity securities are more demanded than the other Treasury bonds. As we can see from figure 2, the worst bid-to-cover ratios' performances had been experienced in auction on 12th April 2017, 13th March 2017, 28th November 2019 for 3-, 7-, 10-year maturities, respectively.

³⁵ Other episodes of amount allotted lower than the maximum amount of the range offered by the Treasury, regard the auctions in May 2017 for the 3-year BTP and May 2016, June and February 2018 for the 7-year maturity.

³⁶ As explained before, BTPs are issued in couple, i.e. the 10-year BTP is issued on the same day as the 5-year maturity one, and the 3-year with the 7-year.

		3-year BTP	7-year BTP	10-year BTP			
N. auctions		40	40	48			
Average amount bid (mn)		4281	3792	3791			
Average amount allotted (mn)		2761	2680	2741			
		Mean	Min	10th	Median	90th	Max
Bid-to-cover ratio	3-year	1.58	1.22	1.37	1.56	1.78	1.96
	7-year	1.44	1.25	1.32	1.39	1.67	1.92
	10-year	1.40	1.22	1.28	1.37	1.6	1.82
Overpricing	3-year	0.02	-0.006	-0.005	0.015	0.067	0.165
	7-year	0.04	-0.05	-0.0125	0.025	0.11	0.235
	10-year	0.03	-0.19	-0.0585	0.015	0.12	0.48

Table 1 **Descriptive statistics of performance indicators of auctions**

Although we can notice that most of the minimum values of bid-to-cover ratios concern auctions in 2017³⁷, except for the 10-year BTP, we can detect low values also in 2018 (Figure 2).

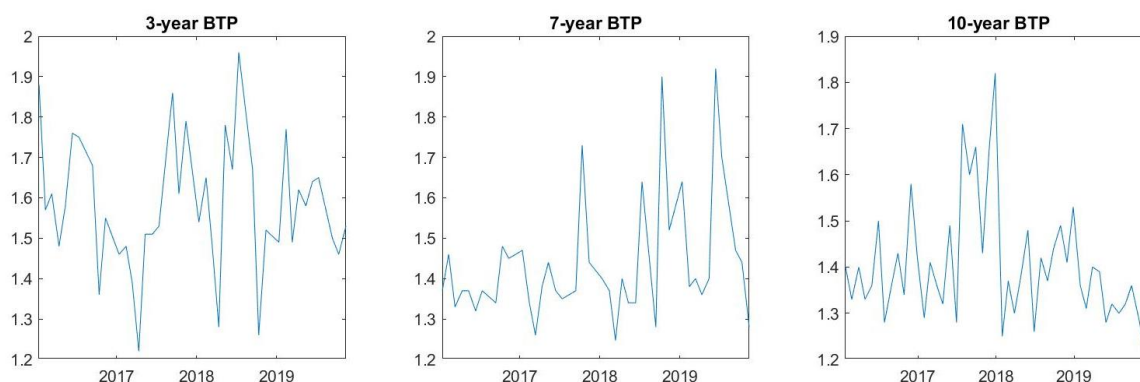


Figure 2 **Bid-to-cover ratios throughout the sample**

If we focus on the 2018 turmoil, we can see from Figure 2 that the 10-year BTP, which is the benchmark, had not been performing well in that period. Indeed, the bid-to-cover of the end-

³⁷ As we Figure 1 shows, we can notice that 10-year BTP's bid-to-cover performed poorly also at the beginning of 2017. We can recall that in that period there was the banks problem concerning Monte dei Paschi di Siena, Banca di Vicenza and Veneto Banca.

of-June auction was 1.26, close to the lowest value of the period analysed (1.22) and in the 10th percentile of the bid-to-cover distribution, as the last column of Table 1 demonstrates.

By looking at the Overprice indicator always in Table 1, we can see that on average, it is around 2 ticks regarding the 3-year BTP, 4 ticks concerning the 7-year maturity bond and 3 ticks with respect to the 10-year benchmark. We can observe that the distribution of the overpricing indicator is very different among the three maturities. The 3-year BTP is less dispersed than the 10-year one as we can infer from the range between the minimum and the maximum of both types of security. Indeed, as we can see from Figure 3, we can notice how much more the 10-year overpricing indicator varies.

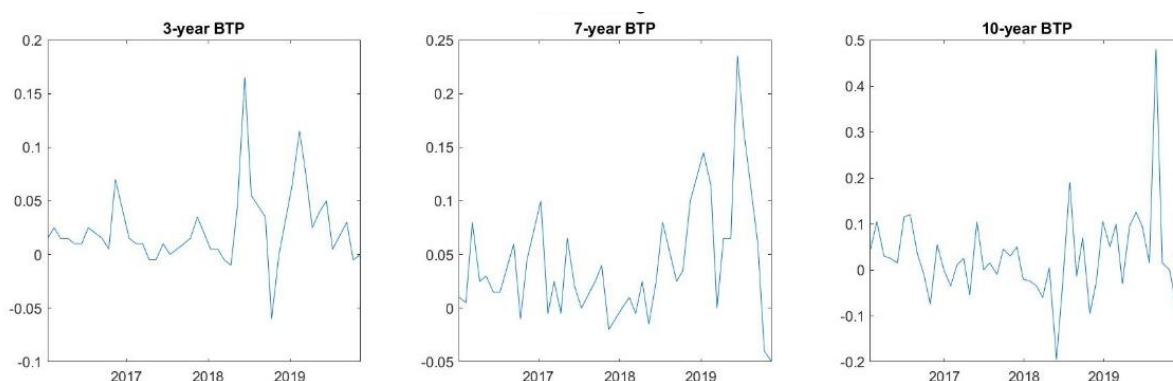


Figure 3 **Overpricing indicator throughout the sample**

From Figure 3 we can observe how the overpricing is usually negative, especially in high volatility period as May 2018. In other terms, we can also talk about underpricing. As we can see from Table 2, the minimum value of the overpricing is negative (-0.19). This means that on that auction, the allotment price was 19 ticks lower than the fair price, proxied by the midprice, of the secondary market 5 minutes before the auction. This was the worst auction of our sample in terms of the overpricing indicator.

Moreover, Italy hosted government elections in March and was in a period of political uncertainty until the second half of May of the same year. The importance of this political uncertainty can be perceived also by the BTP-BUND spread, as the spread between the two government securities' yields skyrocketed.

Liquidity measure

As Scheineder et al. (2016) remark, the bid-ask spread as only liquidity metric is misleading. Therefore, we compute different liquidity measures from the limit order book that corresponds. In the spirit of Sarr et al. (2002), who stated that liquidity measures can be classified in four

categories, i.e. transaction cost, volume based, equilibrium price-based and market-impact measures, and other works concerning liquidity (Greco and Mormando, 2018) we estimate the effect of auction's performance on the following liquidity metrics³⁸:

Bid-ask Spread (BA_{it}): the difference between the best bid- price and the best ask-price as a percentage of the midprice, i.e. the average between these two prices, to consider the fact that a given spread would be less costly the higher the prices and it is better for comparison purposes.

Volume-Weighted Bid-ask Spread (VWBA_{it}): it is calculated as the difference between the average of prices on both sides of the book, weighted by the respective quoted quantity and in percentage of the midprice.

Best quoted depth (BD_{it}): average between the depth related to the best bid- and ask-prices.

Total quoted depth (TD_{it})³⁹: average between the depth on the bid and ask side of the book.

Price impact of 20mm (PI_{it})⁴⁰: the difference between the midprice and the realizable execution price of a deal of 20mm. The execution price is calculated as, for a hypothetical execution of 20 million with three quotes:

$$PI_{i,t} = \frac{\left| MP_{i,t} - \sum_{i=1}^3 \frac{P_{i,t}^a \cdot Q_{i,t}^a}{20} \right| + \left| MP_{i,t} - \sum_{i=1}^3 \frac{P_{i,t}^b \cdot Q_{i,t}^b}{20} \right|}{2}$$

Where the difference in absolute terms is between the midprice at time t, where t is now the frequency at which we observed the data, i.e. five-minute interval, and the product between the price and the related quantity trade at that price, weighted by the target amount chosen, i.e. 20 million. Both differences are computed on the ask side, to which the *a* as apex is related, and on the bid side, indexed by the apex *b*, then the mean value is computed to find the Price impact on the book, for bond *i*.

Trading Volume (TV_{it}): to see the daily traded amount of each BTP.

Table 2 shows some descriptive statistics of the liquidity metrics used and Figure 3 (a, b) the development of the measures throughout the sample.

³⁸ All liquidity measures are calculated on the 5-minute interval. We then took daily averages.

³⁹ Both values of depth, i.e. the best and the total one, were analysed on both sides of the book. We thus have: best bid-depth, best ask-depth, total bid-depth, total ask-depth.

⁴⁰ As for the level of depth, the total price impact is calculated for both bid and ask side of the book.

		Mean	Min	10th	Median	90th	Max
Bid-Ask Spread	3-year	0.06	0.014	0.0217	0.042	0.0983	0.97
	7-year	0.11	0.035	0.059	0.089	0.17	1.39
	10-year	0.123	0.046	0.072	0.1	0.171	1.28
Volume-Weighted Bid-Ask	3-year	0.051	0.02	0.027	0.04	0.08	0.56
	7-year	0.085	0.0337	0.051	0.069	0.1237	0.775
	10-year	0.098	0.05	0.065	0.085	0.133	0.71
Price Impact	3-year	0.0315	0.008	0.0116	0.0224	0.053	0.48
	7-year	0.0589	0.019	0.0323	0.0467	0.085	0.66
	10-year	0.066	0.027	0.039	0.051	0.09	0.61
Depth of best quote	3-year	33.61	10.088	21.17	32.28	48.43	66.35
	7-year	20.03	7.66	14.776	1961	26.45	32.74
	10-year	14.80	5.63	9.94	14.82	19.23	24.04
Total Book Depth	3-year	122.74	51.17	100.76	124.85	142.92	166.55
	7-year	105.2	49.76	89.83	104.81	124.91	143.79
	10-year	95.63	44.32	80.61	96.95	110.88	137.71
Trading Volume	3-year	70.8	0	0	42	174.35	795
	7-year	58.13	0	0	35	128	574
	10-year	56.16	0	2	34	138.35	610.5

Table 2 Descriptive statistics of liquidity metrics

As we can see from Table 2, on average the liquidity conditions have been better for 3-year BTP and worst for the 10-year maturity segment. This is because the 10-year BTP is more vulnerable to market conditions. Indeed, as we can see from Figure 4 (a), the 10-year BTP segment, performed a huge increase in the bid-ask spread (BA), the volume-weighted bid-ask spread (VWBA) and the price impact (PI) during the crisis of May-June 2018 and a significant one in September 2019. Both events are linked to the political uncertainty in Italy. A second reason is linked to the different level of risk (i.e. measured in terms of duration) a 10-year bond has with respect the bonds with shorter maturities.

The level of depth at the best available quotes is important to analyse, especially the minimum values. As we can see from Table 2, the average depth traded on the best quotes, it is slightly bigger than 5 (5.63) for the 10-year BTP. This means that, since market makers have the obligation to quote at least 5 million on each side of the market, there is certainly only one

market maker trading at the best prices. The minimum best depth (BD) of the 10-year BTP is not related to 2018 crisis, but as Figure 4 (b) illustrates, it is in September 2019, even though the level of spread is tighter in that period than in May 2018.⁴¹ We can come to the same conclusion by looking at the depth of the 7-year. If we focus on the 3-year BTP, we can notice that there could be another market maker trading at the best available quotes since the average value at the best available prices is higher than 10 (10.088).

As we can see from the trading volume statistics in Table 2, the minimum value is zero. Indeed, as the last row of Figure 4 (b) proves, along the timeline analysed, no BTPs were traded between May and June 2018.

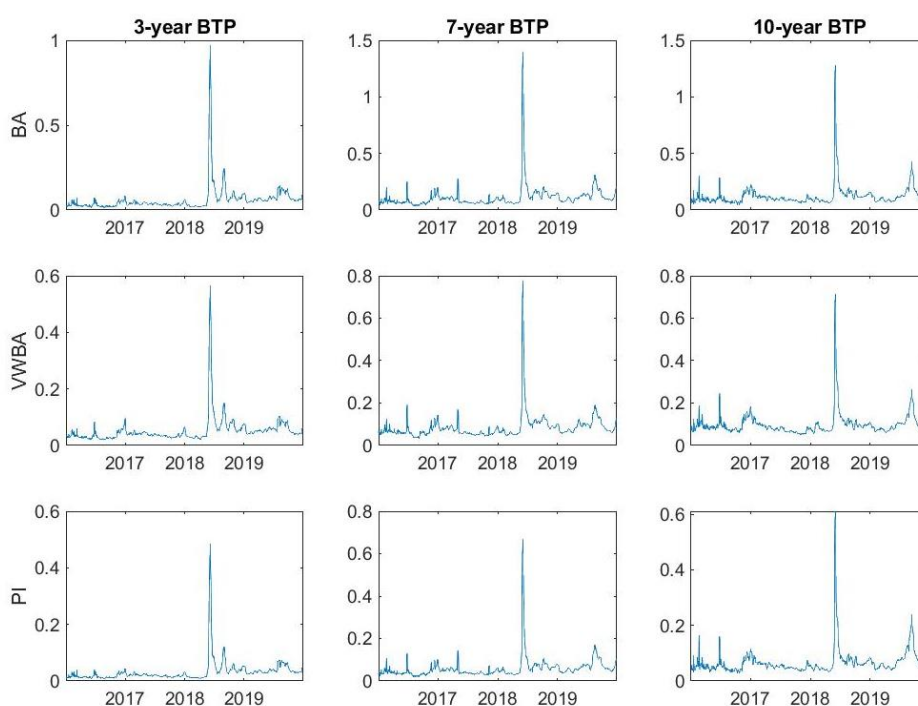


Figure 4 (a) **Liquidity throughout the sample.** The figure shows the dynamics of the bid-ask spread (BA), the volume-weighted bid-ask spread (VWBA) and the price impact of a 20 mn deal (PI).

⁴¹ This may be because market makers in 2019 were more competitive than in 2018 and less were those that quoted at the best prices.

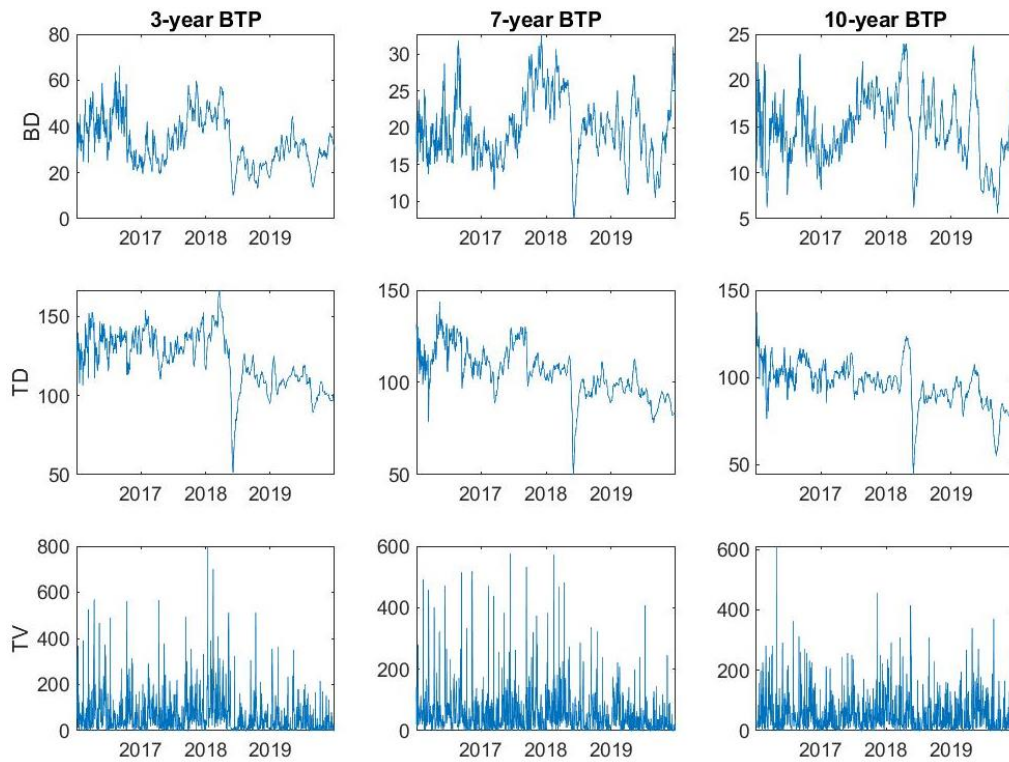


Figure 4 (b) **Liquidity throughout the sample.** The figure shows the dynamics of the depth at the best available quotes (BD), the total depth of the book (TD) and the trading volume (TV).

Liquidity and auctions

As we saw before in Section 2 (Related Literature), several studies have been conducted on the behaviour of prices and yields around auctions (Cafiso, 2019; Lou et al., 2013). It has been shown that they follow the so called “auction cycle”, i.e. prices start decreasing some days before the auction and increase thereafter, viceversa for the yield movement.

We decided to investigate whether liquidity follow a specific pattern around auctions. We aggregated all liquidity measures studied in the sample by selecting the snapshots on a 9-day window⁴² where the midpoint is the auction day, and then we took the average. By comparing the liquidity metrics in levels, we can conclude that, for all three lines of emission studied, also the liquidity follows a specific pattern around auction. As we can deduct from figures 5, showing the liquidity path around auctions, we can see that in the 9-day time window liquidity conditions get better around auction day, when market makers receive the information about the auction, e.g. range of the allotment size. In general, we can see from figures 5 that on auction day liquidity conditions are better than 3 days before, with the exception of the depth at the best available quotes (Figures 5, f, g, h). The liquidity metric that follows the most the

⁴² The width of the window is good to analyse the pattern of liquidity around auctions because we avoid overlaps between two consecutive auctions.

auction cycle as prices and the changes in yields is the trading volume (figure 5, n). The trading activity is indeed focused on the auction day, as market maker manage their inventories on the secondary market the same day of the auction.

In other cases, liquidity gets worse. Specifically, the best depth of the book (figure 5 f, g, h). These measures, after the disclosure of some information regarding the auction size, decline. If we link this fact by the tightening of the bid-ask spread in Figure 5 (a), it means that there are less market makers quoting at the new prices that are more competitive than some days before the auction announcement.

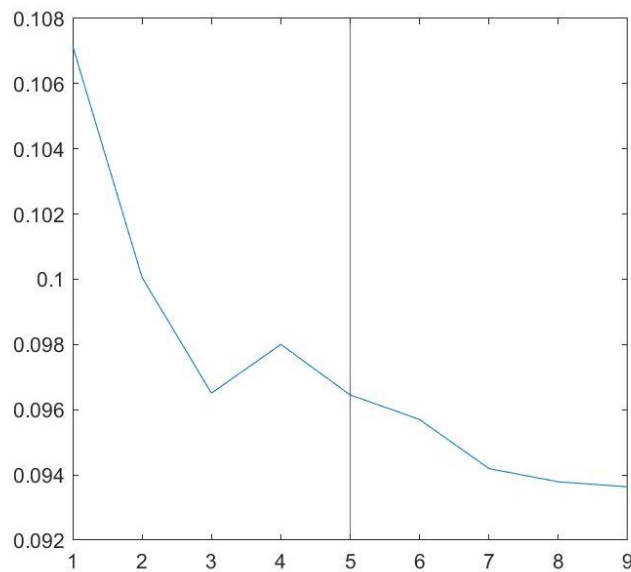


Figure 5-a Development of Bid-Ask spread around auctions

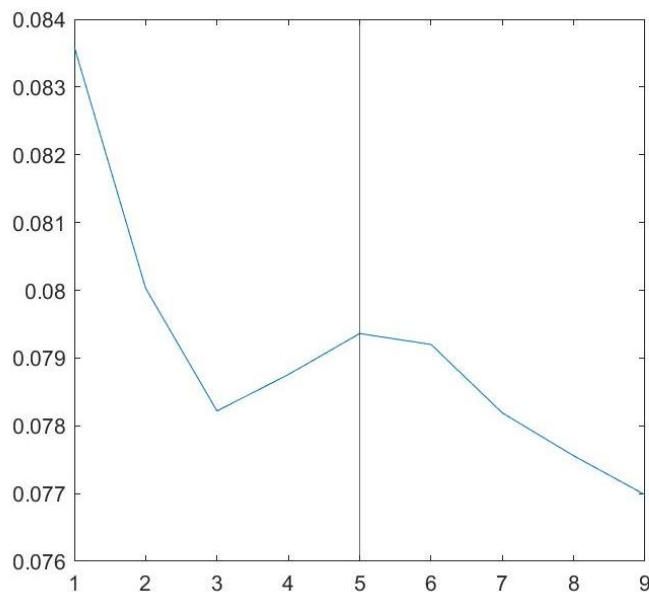


Figure 5-b Development of volume-weighted bid-ask spread around auctions

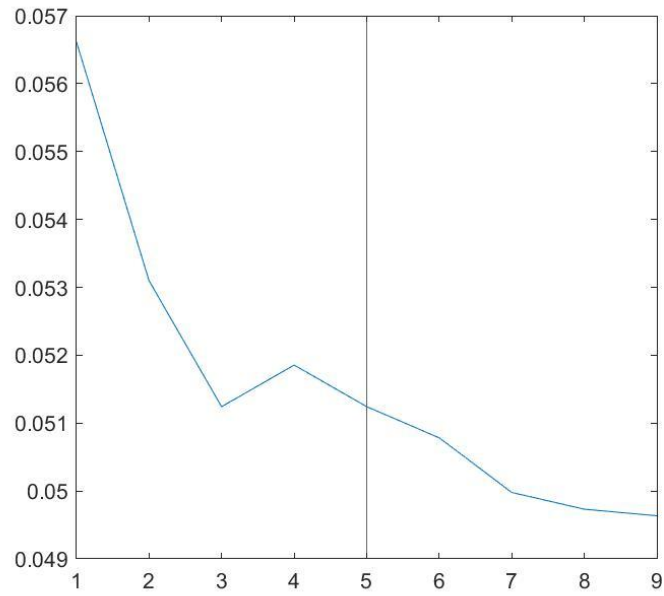


Figure 5-c **Development of price impact of a 20 mn deal around auctions**

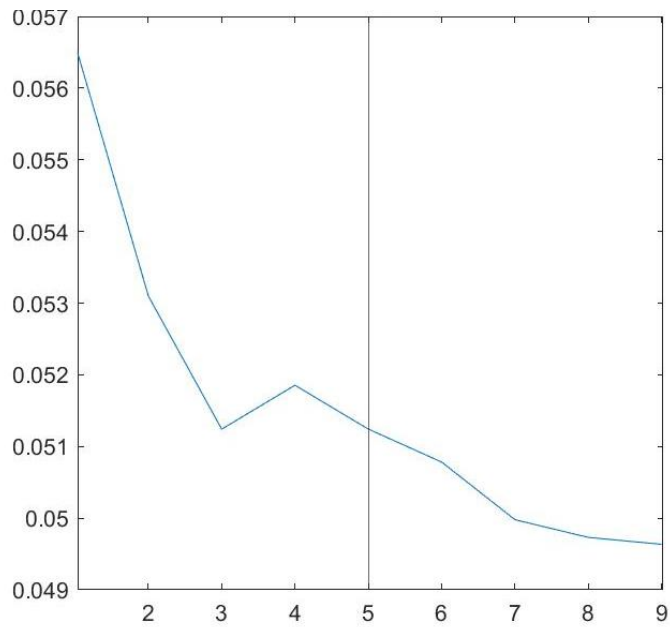


Figure 5-d **Development of price impact (ask side) of a 20 mn deal around auctions**

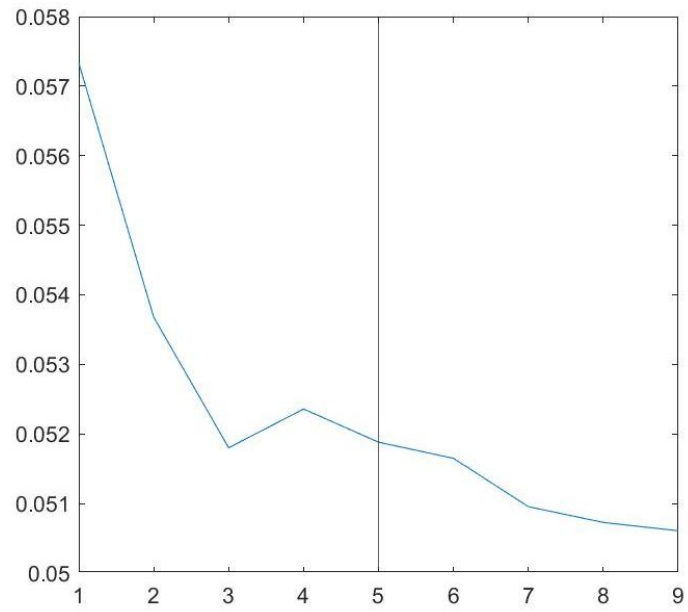


Figure 5-e **Development of price impact (bid side) of a 20 mn deal around auctions**

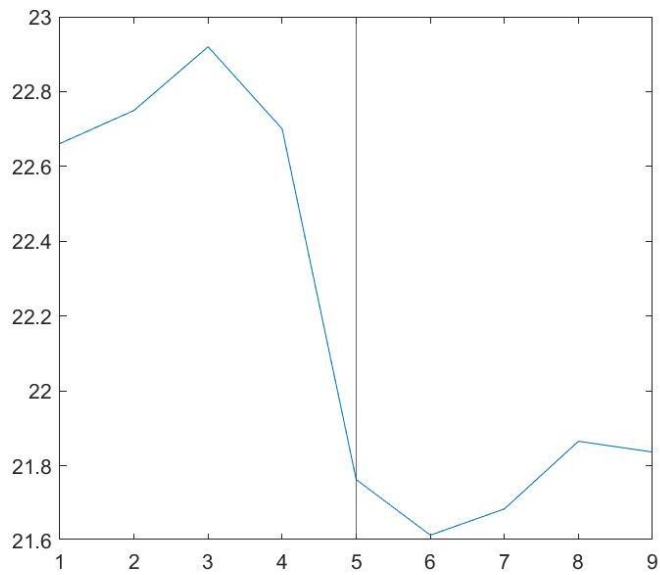


Figure 5-f **Development of best depth around auctions**

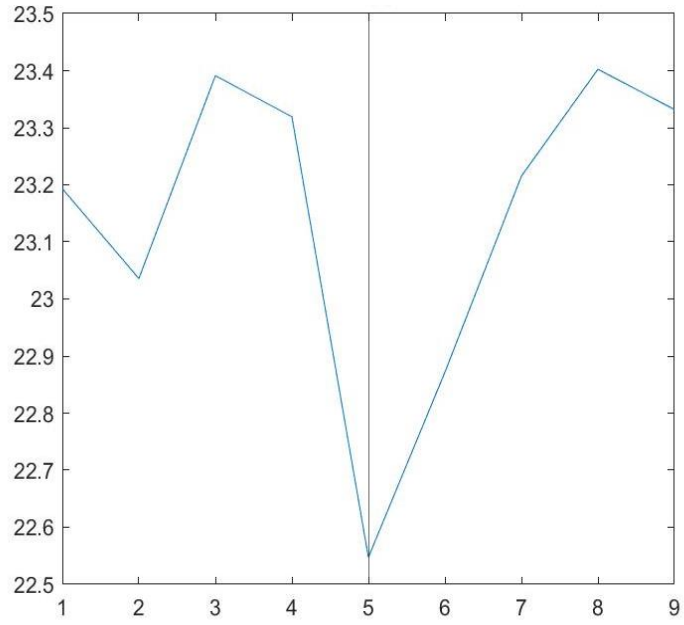


Figure 5-g Development of best depth (ask-side) around auctions

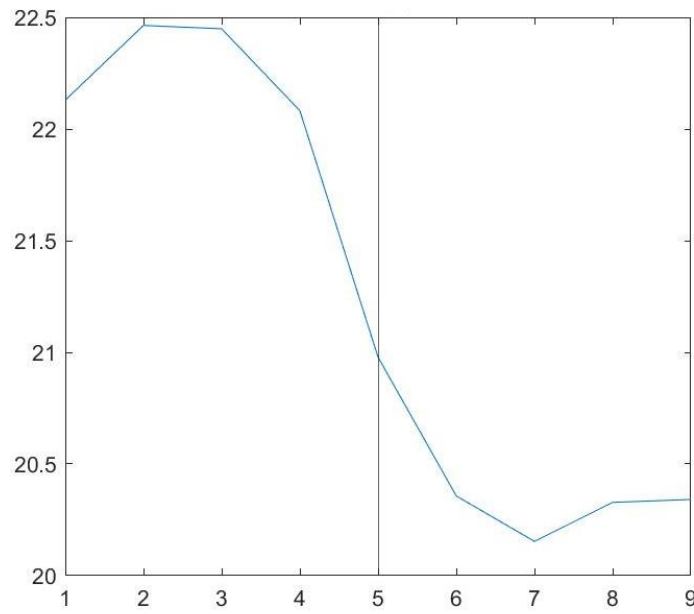


Figure 5-h Development of best depth (bid-side) around auctions

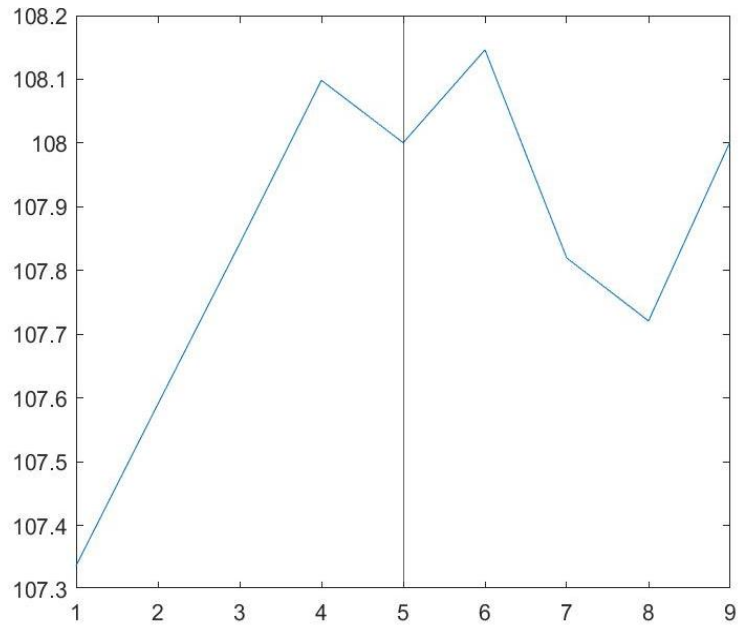


Figure 5-i Development of total depth around auctions

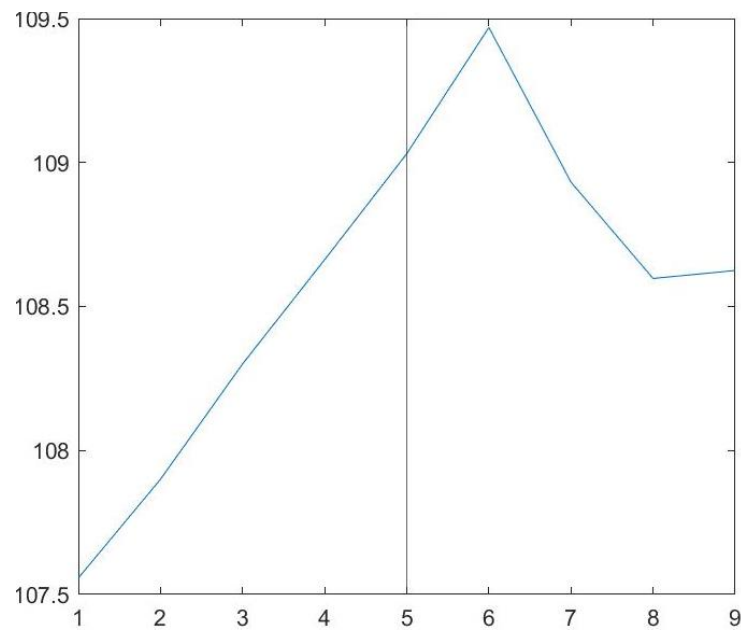


Figure 5-l Development of total depth (ask-side) around auctions

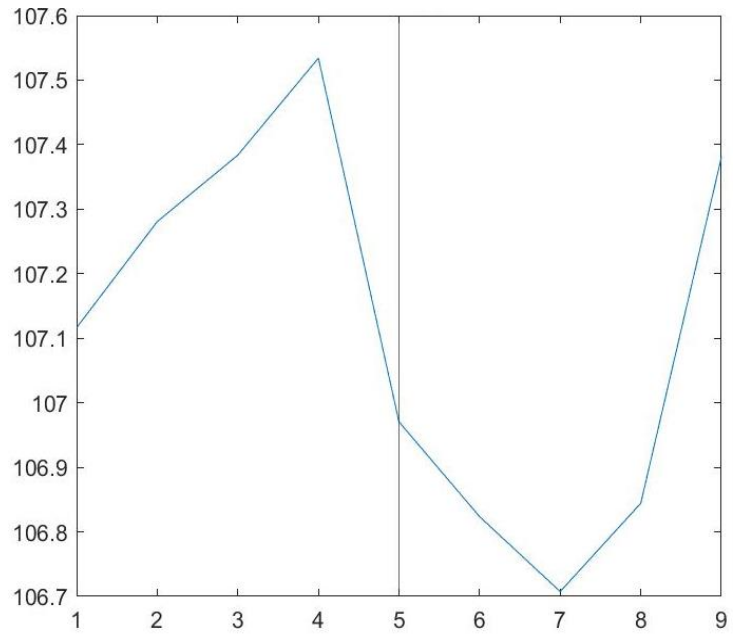


Figure 5-m **Development of total depth (bid-side) around auctions**

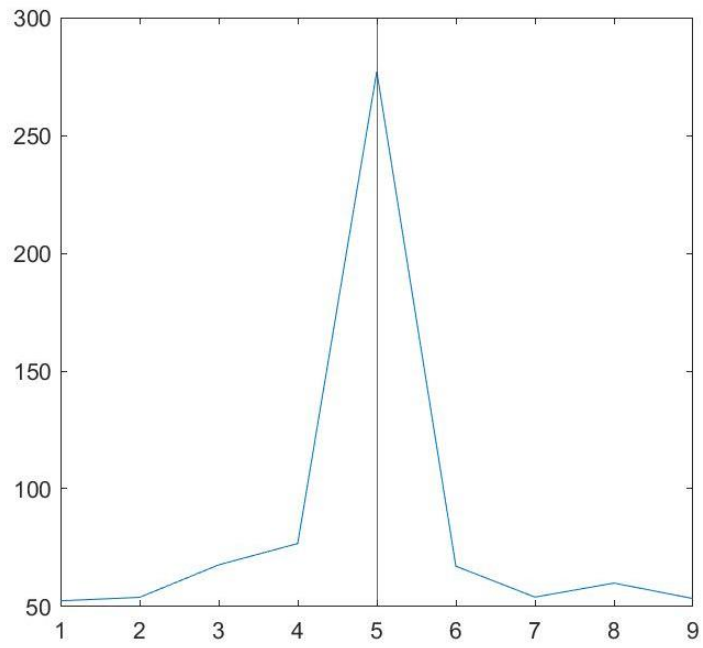


Figure 5-n **Trading volumes around auctions**

	Before	After
Bid-ask spread	0.1004	0.0943
Volume-weighted bid-ask spread	0.0801	0.078
Price impact (bid-side)	0.054	0.051
Price impact (ask-side)	0.0532	0.05
Price impact	0.0535	0.0505
Best depth (bid-side)	22.2809	20.295
Best depth (ask-side)	23.2348	23.2053
Best depth	22.7578	21.7502
Total depth (bid-side)	107.3287	106.9389
Total depth (ask-side)	108.1051	108.9058
Total depth	107.7169	107.9224
Trading volumes	62.7382	58.6683

Table 3 **Average values of liquidity metrics before and after the auction in a 9-day time window.** The values before the auction are averages of the 4 days before the auction. The values after the auction are averages of the 4 days next to the auction.

The pattern around auctions is also confirmed by the values in Table 3. Table 3 shows the average values in the four days before and after the auction day. In general, we can confirm what we said in the description of the figures. We can see better liquidity conditions after the auction than before the emission: price-related liquidity measures are lower and the total depth is greater. Indeed the bid-ask spread decreases, on average 0,6 ticks in the four days after the auction. The volume weighted bid-ask spread decreases less (0,2 ticks), but the effect is also on the entire book. Also the decrease in the price impact is not too much (0,3 ticks on both the bid- and ask-side) The exceptions concern depth at the best quotes which decreases, on average, by 1 million and the trading volumes, as already discussed.

Empirical results

To infer if the liquidity on auction day is affected by the emission and if the performance of auctions has an informative power on market sentiments and liquidity conditions of the secondary market treasury bond, we perform several OLS regressions with individual fixed effects by controlling for the two performance indicators of an auction.

Baseline regression

For a given panel of BTPs consisting of bonds of 3-, 7- and 10-year maturity, we estimate the following linear model, as baseline:

$$LIQ_{i,t} = AUC_t^i(\alpha_0 + \beta_1(BC_t^i) + \beta_2(OP_t^i) + \gamma_m X_m) + a_i + \varepsilon_t$$

(48)

Where $LIQ_{i,t}$ is the liquidity metric for bond with maturity i at day t , AUC is a dummy variable that takes value 1 if auction of bond i takes place at day t , α_0 is the constant term, β_1 and β_2 specify the effect of the different indicators used to establish the goodness of the auction. BC_t^i is the bid-to-cover ratio of the auction occurred and OP_t^i the overpricing indicator for bond i . a_i is bond fixed effect. Moreover, we control for market conditions, X_m , where m stands for the specific market variable, whose effect is described by γ_m . Three are the variables used to explain market conditions X_m . First, in the spirit of Pelizzon et al. (2014), the spread between the 3-month Euro Area Inter-Bank Offered Rate (EURIBOR) and the 3-month Euro OverNight Index Average (EONIA) to control for funding liquidity risk⁴³ expressed by the variable FRISK. Secondly, we control for sovereign risk, computed from the first difference of the 5-year CDS spread for Italy. And finally, we control for the futures market⁴⁴ prices development with the first difference of prices of the 10-year BTP futures, the most liquid future.

⁴³ It is the risk for a market maker, or a dealer in general, of not having enough resources to fund its purchases, is a threaten to liquidity condition of the secondary market. Without the possibility to finance its activity, the market maker has no ability to guarantee immediacy to the market (Drehmann et al. 2009).

⁴⁴ The reason why the future market is added to the regression is because it affects secondary market efficiency (Pelizzon et al., 2016). BTP futures are traded on the Eurex Exchange that, differently from the MTS Cash market, is an order driven market and transactions derive from the interaction of participating dealers' orders. The underlying bonds of these futures are BTPs issued by the Italian Government and three are the futures contracts available on the platform: Short-Term, Mid-Term and

We assume ε_t to be uncorrelated with the predictor variables. As Eisl et al. (2018) pointed out, this assumption may seem restrictive, because, in general, trading volumes, one of our liquidity measures, can be endogenous to economic conditions.

What we expect is that if an auction has informative power, the stronger it is, thus the higher the indicators, i.e. bid-to-cover ratio and overpricing indicator, the better the liquidity condition on the secondary market. Furthermore, we expect that risk, in terms of funding liquidity and sovereign risks, affects negatively secondary market liquidity. Finally, as futures market and cash market are closely related, and as the first causes price discovery on the latter (Pelizzon et al. 2014), we might see that a wider daily change in futures prices, that can be reconducted to an increase in volatility of the futures market, might affect negatively liquidity condition of the secondary cash market, as higher spikes in volatility are reflected in spikes in volatility of the secondary market (Panzarino et al., 2016).

In general, the informative power of auctions is significant on liquidity metrics on auction day as we can see from Table 4, but it is not homogeneous among all liquidity measures. As a matter of fact, on one hand, the bid-to-cover ratio, our first performance indicator, has a significant effect on liquidity metrics concerning quantities, i.e. those related to depth and to the trading volumes. On the other hand, the overpricing indicator (OP) has a significant effect on liquidity measures related to prices. This is in line with how the two indicators are formed: the bid-to-cover ratio is function of quantities, i.e. it is the ratio between amount bid and amount allotted, and the overpricing exploits the difference between the allocation price net of placement fees and the mid-price 5 minutes before the auction.

Table 4 (a) shows that an increase in overpricing is estimated to have a significant negative effect on the bid-ask spread (BA) and on its volume-weighted measure (VWBA) that capture the entire quoting book. If the overpricing increases by one, the bid-ask spread, on auction day, decreases by 0,33 basis points. If we think about a change in the overpricing indicator as a tenth of a tick, i.e. a thousandth, the change in the bid-ask spread after the auction is less than a

Long-Term Euro-BTPs, that have been introduced on the Eurex Exchange Platform in 2010, 2011 and 2009 respectively. Only Short-Term and Long-Term Euro BTPs futures contracts are effectively traded by market participants. For the analysis we consider only the long-term segment as it is most liquid and the one related to the benchmark.

At the beginning, the BTP futures market wasn't very liquid, but once the trading activity increased, the linkage between this market and MTS Cash market has become stronger. Indeed, price discovery on the secondary market is facilitated by the efficiency of the future market, since futures are objects of trading strategies, hedging and market making activities (Panzarino, 2016).

thousandth. This is in line with Figure 4 (a), where we could see that the bid-ask spread (BA) decreases, on average, on auction day.

Baseline Regression (a)

	BA		VWBA		PI-bid		PI-ask		PI	
BC	0.06		0.02		0.022		0.025		0.023	
OP	-0.33	***	-0.15	**	-0.13	***	-0.13	***	-0.13	***
FRISK	0.58	*	0.37	*	0.34	**	0.2	**	0.33	**
CDS	0.05	**	0.05	***	0.005	***	0.004	***	0.004	***
IK1	0.0034	***	0.03	***	0.023	***	0.023	***	0.023	***

Baseline Regression (b)

	BD-bid		BD-ask		BD	
BC	9.51	***	8.17		9.14	***
OP	-8.3		-3.5	**	-5.9	
FRISK	-	**	-8.49		-27	
	46.2					
CDS	-0.1	***	-0.1	***	-0.1	***
IK1	-1.1	**	-2.5	*	-1.5	**

Baseline Regression (c)

	TD-bid		TD-ask		TD		TV	
BC	31,8	***	35,2	***	33,5	***	149.3	***
OP	-36,3		-29,5		-32,8		29.88	
FRISK	-114	*	-156	*	-135	**	-478.61	
CDS	-0,2	***	-0,2	***	-0,2	***	-0.99	***
IK1	-0,63		-0,65		-0,64		-38.9	***

Table 4 **Baseline regression.** The table shows the coefficients of OLS estimation with individual fixed effects of the baseline regression. The causal effect of the auction performance and of market conditions is estimated on fourteen liquidity measures: best bid-ask spread (BA), volume weighted bid-ask spread (VWBA), price impact of a deal of 20 million on the bid side (PI-bid), on the ask side (PI-ask) an on the total quoting book (PI), the best depth on the bid side of the market (BD-bid), on the ask side (BD-ask) and on their average (BD), on the depth of the total quoting book on the bid side (TD-bid), on the ask side (TD-ask) and on their average (TD), on the market trading volume (TV). The P-value of the F-test rejects always the null hypothesis that coefficients are not significant. * marks significance at 10%, ** marks significance at 5%, *** marks significance at 1%.

The same association is not confirmed with the volume-weighted bid-ask spread (VWBA). As we could see in figure 5 (b), the path of VWBA around auction day may be influenced by the fact that not all market makers compete in tightening the spread. Moreover, the extreme impact of other market conditions during the crisis can hamper the liquidity condition of the entire book. Indeed, as we could see from the overpricing graph (figure 3), the indicator steeply decreased in correspondence to the 15 days after the crisis at the end of May 2018. The negative overpricing has such a strong impact that make VWBA increase, on average, on auction day. This means that the crisis might affect the competition among market makers in tightening the spread more than during periods of no turmoil.

Table 4 (a) shows that on auction day also the price impact on the bid side (PI-bid) decreases in response to a good auction performance. If a good auction has a high overpricing, then the impact on prices of a bid order of 20 million is lower. On the same hand, this happens on the ask side (PI-ask). Therefore, we expect that the overall effect of a good auction on the total price impact (PI) is the same and this is what we found by regressing it on all our predictors.⁴⁵ When the predicted variables are the liquidity measures related to quantities, the effect of the auction is still significant, but the indicator that has more importance is the bid-to-cover ratio. As Table 4 (b) illustrates, a change in the bid-to-cover ratio (BC) leads to an increase in depth if we consider the quantities related to the best quotes of the book (BD-bid and BD-ask, with strong and relatively low significance). The positive effect on both sides of the market is expected to be the same on the whole market at the best available quotes. Indeed, looking at the best quotes of the book (BD), we find that the effect remains significantly positive at the 5% level of confidence. Always significant, but stronger, is the outcome that the bid-to-cover ratio has on the whole trading book (Table 4, c). On the bid side (TD-bid), a unitary increase of the bid-to-cover ratio leads to an increase of more than 30 million of BTPs bought by market makers. On the ask side of the book depth (TD-ask), it still has a significantly positive impact, thus we expect that, on average, the total impact of an auction with a higher bid-to-cover ratio is significantly positive on the total book, as we can see from the third column of Table 4 (c). However, this is not in line with what we could see in figure 5 (g, h, i, m). On auction day, depth, both at the best quotes and of the total book, is worse than the day before. This effect

⁴⁵ In terms of magnitude this effect is less strong than on the bid-ask spread (BA). The reason of this is always linked by the degree of competitiveness among market makers. Since it is difficult to find an order of 20 mn at the best quotes, the impact of the auction is spread among market makers that quote at the second-best level and more, depending on how many quotes are needed in a certain day to trade this amount.

could be justified by the fact that the best depth is in function of the best prices of the quoted prices. As far as the bid-ask spread is tighter on auction day, I expect that the associated depth, i.e. best depth, is lower since only some market makers trade at a tighter the bid-ask spread.

Always in Table 4 (c), the positive impact of the bid-to-cover ratio (BC) remains significantly positive on the trading volumes (TV). If the indicator increases by one, market trading volumes steeply increase on auction day, as figure 5 (n) illustrates. This is in line with the inventory management of market makers, as they manage their inventories on the secondary market the same day of the auction.

As we can see from all baseline regressions, market conditions are important on auction day, especially the CDS, which has always a significant and adverse impact on the liquidity of the cash market for 3-, 7- and 10-year BTPs. Moreover, as expected, we can observe from the tables that also the funding liquidity risk has a significant negative impact on the liquidity condition of the market, as the lower the likelihood for a market maker to provide immediacy, because of the higher cost of funding, the lower the provision of liquidity in the market. The same negative effect is related to the impact of daily price changes of Long-term BTP futures. The exception is on the buy side of the market, since a higher change increases positively the buying pressure of the on-the-run BTPs.

In general, we find empirical support for our model implications on liquidity conditions of the market after the auction. The information that market makers receive from the auction events, i.e. auction's performance indicators, have an impact on liquidity. Specifically, a good auction has a positive effect on both the bid-ask spread and the level of depth with respect to the day before the main event (Proposition 2).

Furthermore, as we can see from the effect of the overpricing on BA and VWBA, because of how they are built⁴⁶, we can conclude that market makers contribute to the liquidity provision heterogeneously and quote at different prices (Proposition 1) as not all of them compete in reducing prices. The same rationale applies to the level of depth associated to the best quotes and to the depth of the total trading book. This finding gives strong support to Proposition 3.

⁴⁶ Recall: the bid-ask spread (BA) relates to the best quotes of the book at time t , the volume-weighted bid-ask spread, instead, relates to the quotes of the entire book at day t , weighted by the relative associated quantities.

Persistence on next-day liquidity

As the baseline specification shows that auctions have an important effect on liquidity on auction day, we want to infer whether the effect is persistent on next-day liquidity conditions. We thus regress each after-auction day liquidity metric on the performance indicators to know whether there is persistency in the informative power of the auction.

Over prices, as Table 5 (a) shows, liquidity metrics are still affected by the overpricing, even if with less significance than on auction day. Instead, looking at Table 5 (b, c), depth and market volume are no longer affected by the bid-to-cover ratio is no longer significant. This leads to the conclusion that auctions have still an effect on liquidity in the day after the emission and that the overpricing has a more persistent impact than the bid-to-cover ratio.

Panel estimates on next-day liquidity (a)

	BA		VWBA		PI-bid		PI-ask		PI	
BC	0,03		0,02		0,001		0,001		0,001	
OP	-0,28	**	-0,12	*	-0,11	**	-0,12	*	-0,11	**
FRISK	0.55	***	0,3	***	0,34	***	0,32	***	0,33	***
CDS	0,001	***	0,0004	***	0,0004	***	0,004	***	0,0004	***
IK1	0,004		0,001		0,001		0,001		0,001	

Panel estimates on next-day liquidity (b)

	BD-bid		BD-ask		BD	
BC	-0.63		-0.42		-0.53	
OP	-0.43		1.72		1.08	
FRISK	-38.8	***	-21.2	***	-30.1	***
CDS	-0,1	***	-0,11	***	-0,09	***
IK1	-0,2	***	-0,26	***	-0,23	***

Panel estimates on next-day liquidity (c)

	TD-bid		TD-ask		TD		TV	
BC	0.46		1.38		0.93		4.03	
OP	-15.1		-11.8		-13.4		-38.83	
FRISK	-71.5	***	-80.6	***	-76.1	***	-96.33	*
CDS	-0,18	***	-0,22	***	-0,21	***	-0.21	***
IK1	-0,51	***	-0,76	***	-0,63	***	-1.44	

Table 5 **Panel estimates on next-day liquidity**. The table shows the coefficients of OLS estimation with individual fixed effects and clustered standard errors. The causal effect of the auction performance and of market conditions is estimated on fourteen liquidity measures on the day after the auction: best bid-ask spread (BA), volume weighted bid-ask spread (VWBA), price impact of a deal of 20 million on the bid side (PI-bid), on the ask side (PI-ask) and on the total quoting book (PI), the best depth on the bid side of the market (BD-bid), on the ask side (BD-ask) and on their average (BD), on the depth of the total quoting book on the bid side (TD-bid), on the ask side (TD-ask) and on their average (TD), on the trading volume of the market (TV). The P-value of the F-test rejects always the null hypothesis that coefficients are not significant. * marks significance at 10%, ** marks significance at 5%, *** marks significance at 1%.

The role of the crisis

The results in Table 4 (a, b, c) could potentially be influenced by special market events that may hamper secondary market liquidity and change the degree of informativeness of the performance of the auction. We thus control for market events, by splitting the sample periods in two subsamples, one that goes from January 2016 to May 2018 (before the peak of the political uncertainty due to the new formation of the Government) and the other from May 2018 to December 2019.

The regression we estimate is the following:

$$\begin{aligned}
 LIQ_{i,t} = & C(AUC_t^i(\alpha_0^c + \beta_1^c BC_1^i + \beta_2^c OP_t^i + \gamma_m^c X_m^c)) \\
 & + (1 - C)(AUC_t^i(\alpha_0 + \beta_1 BC_t^i + \beta_2 OP_t^i + \gamma_m X_m)) + a_i + \varepsilon_t
 \end{aligned}
 \tag{49}$$

Where C is a dummy that let us discriminates between the effect of auctions during the crisis period, it is 1 for the pre-crisis period, 0 otherwise.

Table 6 shows the main results of this extended specification. After May 2018, as we can see from figure 3, overpricing has become more volatile and higher in absolute values than before

the crisis, thus its effect may be more important in periods of higher volatility also on other liquidity metrics.

Previous works (Pelizzon et al., 2016; Nguyen et al., 2018) have shown that liquidity of government bond secondary market is affected by volatility. The occurrence of a crisis manifests itself during period of high volatility. Since Beetsma et al. (2018) have shown that the bid-to-cover ratio has a stronger effect in explaining yield movements during periods of crisis, we expect that the effect of auction’s performance indicators is sounder during periods characterised by stronger turmoil.

As expected, we can observe from Table 6 (a) that the positive effect on liquidity changes due to overpricing on auction day is exclusively confined to the crisis period. The same is true for the bid-to-cover indicator, with the difference that effect is now negative on some predicted liquidity measures. As we can see from Table 6 (c), the total quoting book (TD-bid, TD-ask and TD) now decreases on auction day if an auction performs better during periods characterised by higher volatility. The same is true for the market volume. Table 6 (c) shows also that an increase in the bid-to-cover ratio decreases the volume significantly and with a significant impact. Moreover, the market volume is affected also by how much the issued bond is overpriced on auction day. Indeed, an increase by 1 of overpricing, during periods of turmoil, has a positive and significant effect on the market volume (TV) which increases by 370.24 with 95% confidence.⁴⁷ Overall, in line with Beetsma et al. (2018) the success of an auction provides a stronger signal, but only in periods characterised by higher uncertainty.

Pre and Post Crisis Effects (a)

	BA		VWBA		PI -bid		PI -ask		PI	
BC-pre	0.05		0.011		0.013		0.014		0.014	
OP-pre	-0.09		0.024		-0.023		-0.03		-0.02	
BC-post	0.02		0.03		0.01		0.01		0.011	
OP-post	-0.46	***	-0.22	***	-0.19	***	-0.2	***	-0.2	***

⁴⁷ The positive relationship between TV and OP is also confirmed by the data. On the days after 29th May, the first auction of the 10-year BTP resulted in a negative overpricing, i.e. underpricing. This strong decrease turned the Trading volume to 0 (Figure 4 (b), last panel).

Pre and Post Crisis Effects (b)

	BD-bid		BD-ask		BD	
BC-pre	3.58		4.16		3.58	
OP-pre	-32.7		-30.15		-31.6	
BC-post	4.37	*	4.6	**	4.46	**
OP-post	0.14		9.2		4.67	

Pre and Post Crisis Effects (c)

	TD-bid		TD-ask		TD		TV	
BC-pre	6.05		8.14		7.11		-106.6	
OP-pre	-31.6		-18.6		-25.1		591.54	
BC-post	-11	*	-14.1	**	-15.55	*	-345.8	***
OP-post	3.5		15.66		9.57		370.24	**

Table 6 **Pre and Post Crisis Effects**. The table shows the coefficients of OLS estimation with individual fixed effects as in the baseline regression, by discriminating between crisis and non-crisis period as defined in equation 47. The causal effect of the auction performance and of market conditions, not reported in the tables, is estimated on fourteen liquidity measures: best bid-ask spread (BA), volume weighted bid-ask spread (VWBA), price impact of a deal of 20 million on the bid side (PI-bid), on the ask side (PI-ask) and on the total quoting book (PI), the best depth on the bid side of the market (BD-bid), on the ask side (BD-ask) and on their average (BD), on the depth of the total quoting book on the bid side (TD-bid), on the ask side (TD-ask) and on their average (TD), on the trading volume of the entire market (TV). The P-value of the F-test rejects always the null hypothesis that coefficients are not significant. * marks significance at 10%, ** marks significance at 5%, *** marks significance at 1%.

Spillover effects

We now explore a further extension of the baseline regression to investigate the existence of spillover effects across maturities. Thus, we add the same auctions' indicators of the other bonds with different maturities.

We have now a panel of the three BTPs where the liquidity conditions can be influenced by the auction's results of bonds with different maturities. The model now becomes:

$$\begin{aligned}
 LIQ_{i,t} = & AUC_t^i(\alpha_0 + \beta_1 BC_t^i + \beta_2 OP_t^i) + AUC_t^n(\gamma_1 BC_t^n + \gamma_2 OP_t^n) + AUC_t^b(\delta_1 BC_t^b \\
 & + \delta_2 OP_t^b) + AUC(\rho_m X_m) + a_i + \varepsilon_t
 \end{aligned}
 \tag{50}$$

Where AUC_t^i is a dummy equal to 1 if a bond with maturity i is issued on day t . β_1 and β_2 specify, as before, the effect of auction's indicator related to the bond subject of the panel, with maturity i . AUC_t^n is a dummy equal to 1 if a bond with maturity n is issued on day t and γ_1 and γ_2 are the coefficients of the indicators of bond with maturity n . AUC_t^b is a dummy equal to 1 if a bond with maturity b is issued on day t and δ_1 and δ_2 are the coefficients of its auction's performance indicators. Market conditions are considered whenever there is an auction.

Since we have only one auction at the end of the month, it is fair to expect that the effect of the 3-year or the 7-year, issued together at the middle of the month, is more pronounced than the 10-year maturity, at least in absolute terms.

As we can see from Table 7 (a), we can notice that the overall change in liquidity metrics concerning prices are driven by the 3-year and 10-year auctions' performance indicators, but as expected, it is mostly determined by the 3-year BTP. Despite the overall positive effect of a good auction on secondary market liquidity on auction day (Baseline regression, table 4), confirmed by the overpricing indicator of the benchmark (OP10), the 3-year BTP auction has a negative spillover effect. If the auction of the benchmark performed well, its goodness spills over the other bonds' liquidity conditions positively. In contrast, if a 3-year BTP is overpriced when it is auctioned, it impacts negatively on price-related liquidity metrics of the 7-year BTP, issued on the same day, and of the 10-year benchmark.

Table 7 (b) demonstrates that quantity-related liquidity metrics are always driven by the bid-to-cover ratio. From the best depth on the bid-side (BD-bid), we can see that only the benchmark affects positively the best quoted quantities on the bid-side of the market. On the ask side (BD-ask) and on average (BD), rather, all BTPs spill over each other positively, with different degrees of significance. The most important spillover effect is given by the 10-year benchmark. By looking at all the quoted quantities, on both the bid and ask sides (TD-bid and TD-ask, Table 7, c), no BTP spills over the other, as if each market maker follows its own strategy without looking at the results of the auction of the other BTP. Only the 3-year BTP has a slightly significant effect on the total ask depth of the 7- and 10-year BTP.

Table 7 (c) demonstrates also that the spillover effects are confined to the 3- and 7-year security when dealing with market trading volume. The 10-year BTP bid-to-cover ratio has no spill over effects on the market volume of the other two securities. Its market volume is instead positively and significantly affected by how the other two securities performed at auction. The impact of the 3-year BTP is less strong than the 7-year maturity.

The overall effect may be more balanced if we would have included also the 5-year BTP. In this way, we would have had 2 auctions also at the end of the month, as the 5-year BTP is issued on the same day as the 10-year one.

Panel estimates of spillover effects (a)

	BA		VWBA		PI-bid		PI-ask		PI	
BC3	-0.04		-0.02		-0.02		-0.02		-0.02	
OP3	0.84	***	0.49	***	0.4	***	0.4	***	0.4	***
BC7	0.01		-0.008		-0.01		-0.01		-0.01	
OP7	-0.33	*	-0.18	*	-0.14		-0.14		-0.14	
BC10	-0.01		-0.01		-0.01		-0.01		-0.01	
OP10	-0.3	***	-0.16	***	-0.14	***	-0.14	***	-0.14	***

Panel estimates of spillover effects (b)

	BD-bid		BD-ask		BD	
BC3	1.42		4.65	**	3.03	**
OP3	-3.41		0.63		-1.39	
BC7	1.59		6.2	*	3.89	**
OP7	-7.49		-19.3		-13.4	
BC10	1.73	*	6.36	**	4.04	***
OP10	0.25		-6.55		-3.14	

Panel estimates of spillover effects (c)

	TD-bid		TD-ask		TD		TV	
BC3	11.02		12.57	*	11.8		92.42	*
OP3	-96.25		-90.37		-93.31		-213.6	
BC7	9.39		13.67		11.53		116.84	**
OP7	21.55		-8.44		6.55		-299.07	
BC10	8.66		11.31		9.98		-79.94	
OP10	1.59		-3.51		-0.96		282.1	

Table 7 **Panel estimates of spillover effects.** The table shows the coefficients of OLS estimation with individual fixed effects as defined in equation 48. The causal effect of the auction performance of the main BTP and of the other BTPs is estimated on fourteen liquidity measures: best bid-ask spread (BA), volume weighted bid-ask spread (VWBA), price impact of a deal of 20 million on the bid side (PI-bid), on the ask side (PI-ask) and on the total quoting book (PI), the best depth on the bid side of the market (BD-bid), on the ask side (BD-ask) and on their average (BD), on the depth of the total quoting book on the bid side (TD-bid), on the ask side (TD-ask) and on their average (TD), on the market trading volume (TV). Market conditions are not displayed in the table. The P-value of the F-test rejects always the null hypothesis that coefficients are not significant. * marks significance at 10%, ** marks significance at 5%, *** marks significance at 1%.

Robustness check

We check the robustness of these results by controlling for risk aversion and aggregate uncertainty. The variable added to the baseline specification is the VSTOXX, the implied volatility of EUROSTOXX 50 index options.

In this robustness check, we can detect that the performance indicators of auctions have always the same significant impact on liquidity conditions of the market on auction day. Table 8 (a, b, c) shows that the extended specification leads to similar results as the baseline regression. As we can observe in table 8 (a), the overpricing indicator remains statistically significant on all liquidity metrics concerning prices and, as table 8 (b, c) confirm, the bid-to-cover ratio has a significant impact on those related to quantities.

Thus, controlling also for market uncertainty (VSTOXX), even though it affects with significance other market liquidity metrics, does not affect the significance of all the other predictors.

Robustness estimates with VSTOXX (a)

	BA		VWBA		PI-bid		PI-ask		PI	
BC	0.05		0.002		0.0015		0.002		0.02	
OP	-0.34	***	-0.1	**	-0.13	**	-0.13	**	-0.13	**
FRISK	0.65	**	0.33	***	0.31	**	0.4	**	0.4	**
CDS	0.001	***	0.004	***	0.004	**	0.004	**	0.004	**
IK1	0.5	***	-0.01		0.006	**	0.005		0.005	
VSTOXX	0.001		0.004	**	-0.002		0.0001		0.0001	

Robustness estimates with VSTOXX (b)

	BD-bid		BD-ask		BD	
BC	9.32	***	8.4	**	8.9	***
OP	-7.2		-2.4		-5.1	
FRISK	-6.1	**	-34.9	*	-47	*
CDS	-0.1	***	-0.1	***	-0.1	***
IK1	-1.3		-2.5	**	-1.9	*
VSTOXX	-0.2	*	-0.3	**	-0.3	**

Robustness estimates with VSTOXX (c)

	TD-bid		TD-ask		TD		TV	
BC	33.9	***	37.6	***	35.8	***	149.15	**
OP	-39.7		-34.4		-36.1		30.19	
FRISK	-91.7		-124	*	-108		-31.21	*
CDS	-0.2	***	-0.15	***	-0.14	***	-0.85	*
IK1	-5.6	**	-6.63	**	-6.14	**	-28.62	
VSTOXX	0.23		0.31		0.27		7.34	**

Table 8 **Robustness estimates with VSTOXX**. The table shows the coefficients of Fixed Effect of the baseline regression (equation 46), by controlling also for market uncertainty (VSTOXX). The causal effect of the auction performance and of market conditions is estimated on fourteen liquidity measures: best bid-ask spread (BA), volume weighted bid-ask spread (VWBA), price impact of a deal of 20 million on the bid side (PI-bid), on the ask side (PI-ask) and on the total quoting book (PI), the best depth on the bid side of the market (BD-bid), on the ask side (BD-ask) and on their average (BD), on the depth of the total quoting book on the bid side (TD-bid), on the ask side (TD-ask) and on their average (TD), on the market trading volume (TV). The P-value of the F-test rejects always the null hypothesis that coefficients are not significant. * marks significance at 10%, ** marks significance at 5%, *** marks significance at 1%.

The positive effect of the VSTOXX on market trading volume (TV), as shown in table 8 (c), is in line with Choi (2019). In a situation characterised by high volatility, investors are more uncertain about future market developments and have more dispersed beliefs. Therefore, around announcements, e.g. the disclosure of auction's performance indicators, market makers increase their trades in BTPs.

Conclusion

Our empirical results emphasize the importance of auctions on efficiency of secondary market of Treasury bonds in terms of liquidity. As already documented by Beetsma et al. (2018), auction's performance indicators as the bid-to-cover ratio have an impact on yield changes around auctions. In this work we explore the effect of these indicators on liquidity conditions on auctions day. Despite the wide use of the bid-to-cover ratio, this indicator is not always a good mean to describe the goodness of an auction. Consequently, we include in our empirical analysis another measure to define the goodness of an auction, i.e. the overpricing indicator. We develop a model that demonstrates how signals coming from auctions, i.e. the results affect market makers behaviour that translates into a more efficient liquidity provision in the secondary market, even though they have not perfect perception of the information received

from the issuance of new bonds. From the solution of our model, we derive empirically testable predictions.

First, there is significant evidence that a good auction, in terms of bid-to-cover ratio and high overpricing, affects positively liquidity conditions on auctions day, i.e. the bid-ask spread, the volume-weighted bid-ask spread and the price impact of a deal of 20 million decline and depth and trading volumes grow.

In addition, by comparing the liquidity measures related to the best quotes and to the total quoting book, market makers do not follow the same strategy, i.e. they quote at different prices. Furthermore, we found strong evidence that the two predictors are complementary to each other, i.e. the bid-to-cover ratio affects only quantity-related liquidity metrics and the overpricing indicator affects price-related quantities. Additionally, in special circumstances as in periods characterised by higher volatility, the overpricing indicator is more informative of a goodness of an auction as it has a significant impact also on other liquidity measures on auction day.

Further research can be implemented in this framework. Instead of analysing a larger sample, future works could be conducted through an interaction between the indicators used and volatility in order to infer better how liquidity of secondary market of government bonds may change.

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Appendix

ISIN codes of BTPs analysed

ISIN Code	Description	From (dd/mm/yyyy)	To (dd/mm/yyyy)
IT0005139099	BTP 0,3% 15Ott18	01/01/2016	08/04/2016
IT0005177271	BTP 0,1% 15Apr19	09/04/2016	10/10/2016
IT0005217929	BTP 0,05% 15Ott19	11/10/2016	07/04/2017
IT0005250946	BTP 0,35% 15Giu20	08/04/2017	09/10/2017
IT0005285041	BTP 0,2% 15Ott20	10/10/2017	09/04/2018
IT0005330961	BTP 0,05% 15Apr21	10/04/2018	08/10/2018
IT0005348443	BTP 2,3% 15Ott21	09/10/2018	08/03/2019
IT0005366007	BTP 1% 15Lug22	09/03/2019	09/09/2019
IT0005384497	BTP 0,05% 15Gen23	10/09/2019	31/12/2019

Table 1A 3-year BTP

ISIN Code	Description	From (dd/mm/yyyy)	To (dd/mm/yyyy)
IT0005135840	BTP 1,45% 15Set22	01/01/2016	08/03/2016
IT0005172322	BTP 0,95% 15Mar23	09/03/2016	08/09/2016
IT0005215246	BTP 0,65% 15Ott23	09/09/2016	08/03/2017
IT0005246340	BTP 1,85% 15Mag24	09/03/2017	08/09/2017
IT0005282527	BTP 1,45% 15Nov24	09/09/2017	08/03/2018
IT0005327306	BTP 1,45% 15Mag25	09/03/2018	10/09/2018

IT0005345183	BTP 2,5% 15Nov25	11/09/2018	08/04/2019
IT0005370306	BTP 2,1% 15Lug26	09/04/2019	12/11/2019
IT0005390874	BTP 0,85% 15Jan27	13/11/2019	31/12/2019

Table 2A **7-year BTP**

ISIN Code	Description	From (dd/mm/yyyy)	To (dd/mm/yyyy)
IT0005127086	BTP 2% 01Dic25	01/01/2016	23/02/2016
IT0005170839	BTP 1,6% 01Giu26	24/02/2016	25/07/2016
IT0005210650	BTP 1,25% 01Dic26	26/07/2016	25/01/2017
IT0005240830	BTP 2,20% 01Giu27	26/01/2017	27/06/2017
IT0005274805	BTP 2,05% 01Ago27	28/06/2017	25/01/2018
IT0005323032	BTP 2% 01Feb28	26/01/2018	25/07/2018
IT0005340929	BTP 2,8% 01Dic28	26/07/2018	22/02/2019
IT0005365165	BTP 3% 01Ago29	23/02/2019	26/08/2019
IT0005383309	BTP 1,35% 01Apr30	27/08/2019	31/12/2019

Table 3A **10-year BTP**