Trading Ahead of Treasury Auctions

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ABSTRACT

I develop and test a model explaining the gradual price decrease observed in the days leading to large anticipated asset sales such as Treasury auctions. In the model, risk-averse investors anticipate an asset sale which magnitude, and hence price, are uncertain. I show that investors face a trade-off between hedging the price risk with a long position, and arbitraging the difference between the pre-sale and the expected sale prices. Due to hedging, the equilibrium price is above the expected sale price. As the sale date approaches, uncertainty about the sale price decreases, short arbitrage positions increase and the price decreases. In line with the predictions, I find that the price of Italian Treasuries decreases by 4.6 bps after the release of auction price information, compared to non-information days.

JEL classification: G11, G12, E43.
Keywords: Anticipated supply shocks; Treasury auctions; Treasury bonds; Market making

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I. Introduction

Market liquidity relies on intermediaries ("liquidity providers") acting as a buffer between buyers and sellers. These liquidity providers can profitably trade on demand due to continued presence in the market (Grossman and Miller (1988)). In particular, liquidity providers play a prominent role in auctions where they buy large volumes of assets at a discount. However, the profit derived from auction participation is uncertain because it depends on whether or not natural counterparties are present on auction day. Indeed, there is significant variation as to who buys Treasury assets: natural buyers –such as investment funds– may buy as much as 46% and as little as none of a given US Treasury issue at an auction (Fleming (2007)). Importantly, a larger-than-expected presence of natural buyers on auction day may considerably reduce the need for liquidity provision. In this paper, I relate asset prices to this auction uncertainty. In particular, understanding how secondary prices move ahead of auctions is of interest for issuers because they use these prices to take issuance decisions and to benchmark auction outcomes.

Specifically, I develop and test a theory explaining why bond prices decrease gradually ahead of Treasury auctions as reported by Lou, Yan and Zhang (2013) and as studied in Duffie (2010). Lou, Yan and Zhang (2013) find that, in the few days leading up to U.S treasury auctions, the secondary prices of current issues decrease gradually, reach a minimum on auction day and then increase gradually. This price pattern arises in various contexts: first, it occurs in Treasury auctions, including in cases where the on/off-the-run phenomenon is absent (see this paper's empirical section); in other types of auctions such as SEOs (Corwin (2003)) or gold fixing (US District Court (2014)); and ahead of predictable sales of future contracts (Bessembinder et. al. (2016)).

This price pattern is a puzzle in that it implies that some investors are willing to buy bonds before the auction at a price which, on average, exceeds the auction price. Admittedly, investors who *need* to buy the bond before the auction would be ready to do so at a premium (equal to the "half bid-ask spread") rather than to wait and trade on auction day at an uncertain price (Grossman and Miller (1988)). But conversely, sellers would be ready to trade at a discount. As a result, the pre-auction mid price should equal the expected mid price on auction day. Instead, the observed price pattern is such that the former exceeds the latter. Hence, investors who need to buy the bond before the auction are paying a premium exceeding the discount paid by sellers.

There is therefore an asymmetry which my model predicts and explains.

In the model, risk-averse investors anticipate an asset sale which magnitude, and hence price, are uncertain. First, I show that investors face a trade-off: they can arbitrage the difference between the pre-sale and the expected sale prices, or they can hedge the price risk with a long position. Specifically, the need for hedging comes from the uncertainty about the discount at which an investor buys from the seller: to hedge this uncertainty, one can take a long position which appreciates when the sale price is high and, thus, when the discount is low. Second, I show that the equilibrium price is above the expected sale price due to hedging. Third, as uncertainty about the sale price decreases, short arbitrage positions increase and the price decreases.

To test the model's implications, I use Italian Treasury auctions over 2000-15. As predicted, I show that bond prices decrease by 3.3-7.6 bps on the days when the Treasury meets with primary dealers ahead of an auction and when the Treasury announces the auction size. Moreover, bond prices decrease by 4.6 bps more during these days than other pre-auction days. Finally, my setting allows to exclude alternative explanations such as the on/off-the-run phenomenon.

Understanding the gradual price decrease ahead of Treasury auctions is important for several reasons. First, pre-auction prices serve as benchmarks for auction prices and may be used in issuance decisions (Faulkender (2005)). In addition, if the price decrease were due to front-running (Brunnermeier and Pedersen (2005)), the issuer might be better off revealing little information about the auction size rather than announce it as is common in practice (Sundaresan (1994)). Second, while the literature has studied prices *following* a large sale (Grossman and Miller (1988)), little is known about prices *before* a sale. Moreover, existing theories of *post-sale* prices do not apply to *pre-sale* prices. For instance, Grossman and Miller (1988) assume that liquidity provider are as likely to buy as they are to sell, which does not apply to issuances.

The main features of my model are as follows. There are three periods (t=1,2,3), a risky asset (e.g. a Treasury bond), a riskless asset, infinitely risk-averse liquidity traders and CARA liquidity providers. At t=3, the assets pay off. At t=2, liquidity traders sell a quantity of risky asset, Z. At t=1, liquidity providers trade under uncertainty about the sale quantity Z, assumed to have a positive mean. Quantity Z can be interpreted as the *net supply*: the difference between the auction size and the quantity bought by natural buyers. Indeed, even though issuers typically disclose in advance issuance sizes, net supply is uncertain because it depends on the presence or not of natural buyers on auction day.

My central result is that the demand from liquidity providers has two components: a hedging demand and an arbitrage (i.e. speculative) demand. The hedging demand implies taking a long position in the asset to hedge the uncertainty about the net supply, Z. The arbitrage demand consists in trading on the difference between the price at t=1 and the expected price at t=2. Moreover, I show that the arbitrage demand decreases when the uncertainty about Z is larger.

Indeed, the sale constitutes an investment opportunity while the net supply, Z, is a state variable which determines how lucrative the opportunity is. Hence, risk-averse liquidity providers will seek to hedge these changes in investment opportunities (Merton (1973)) with an investment which negatively correlates to the state variable Z. Said differently, investors would like to diversify away the risk of Z: therefore, their valuation of investment opportunities depends on the *beta* of that investment with Z. In that regard, a long position in the risky asset is valuable because the return of that investment is high when Z is low. Beside hedging, liquidity providers have an arbitrage demand: they can increase their expected final wealth by selling (buying) the asset at t=1 and buying (selling) it back at t=2 if the price at t=1 is above (below) the expected price at t=2.

I then derive the price at t=1 and show that it exceeds the expected price at t=2 because of the existence of the hedging demand. In particular, without hedging demand (or, equivalently, when all investors have a short horizon), the price would be below the expected sale price: indeed, investors would demand a discount for holding the asset at t=1 because of the uncertainty about the net supply. Moreover, I show that the difference between the price at t=1 and the expected price at t=2 increases with the uncertainty about the net supply, Z: this is because arbitrage is less intense when the uncertainty about the price at t=2 is larger. Consequently, as the uncertainty about Z decreases, arbitrage increases and the price decreases.[1]

Finally, I study how heterogeneity among investors affects trading. First, I consider the case where liquidity providers have heterogenous risk aversion. Second, I introduce risk-averse short-term investors. In particular, I show that short-term investors short-sell the asset and that short-selling decreases with the uncertainty about net supply, Z.

My model has a new implication: upon the arrival of a *missing* piece of information about the

[1]To be clear, there is no intermediate date in the model where the risk of the net supply, Z, decreases. The implication is obtained via a dynamic interpretation of a comparative static.

net supply, the price should react more in cases of *negative* than in cases of *positive* information.

Specifically, I define as *missing* any piece of information which allows to better estimate the net supply. First, and obviously, the price should reflect the nature of the information: it increases (decreases) in case of smaller (larger) than expected net supply. Second, there is another component which is always negative, regardless of whether the information is *positive* or *negative*: indeed, this piece of information has reduced uncertainty about the net supply and has made arbitrage easier. To sum up, a *positive* (*negative*) piece of information will entail a price increase (decrease) to reflect the information and a simultaneous price decrease to reflect the higher arbitrage due to lower uncertainty. Hence, the price will move more in *negative* than in *positive* cases.

Next, I test the following corollary of my implication: when the sample contains as many *negative* as *positive* news, the arrival of a missing piece of information about the net supply entails a price decrease on average. My sample consists of 1,000 auctions of Italian Treasuries over 2000-2015. To test my implication, I exploit two pre-auction events: first, the meeting between the Italian Treasury and the primary dealers; second, the announcement of the issuance size. Both the dealers' meeting and the size announcement represent missing pieces of information about net supply, Z: therefore, their arrival reduce the uncertainty about Z. Importantly, I use a setting that allows me to observe the secondary price of the auctioned bonds even before the auctions. Indeed, I study *reopenings*: these are auctions which increase the outstanding volume of existing bonds.

As predicted, I find that the bond price decreases on average by 4.6 bps more on those two days than on no-information days. Similarly, using 3-30 year bonds over 2000-10, I find that most of the price decrease occurs five and two days before the auction, which is when information arrives in that subsample. Finally, I am able to exclude the on/off-the-run phenomenon (Krishnamurthy (2002)) because there is no change in on/off-the-run status after*reopenings*.

This paper's main contribution is to propose and test a new mechanism to explain the price pattern around Treasury auctions as reported in Lou et. al. (2013) and Duffie (2010). Importantly, the theoretical contribution of the paper extends to a broader asset pricing literature which studies prices around predictable events. Indeed, this paper's theoretical mechanism can explain why prices have been shown to decrease ahead of predictable sales such as Seasoned Equity Offerings (e.g. Corwin (2003), Meidan (2005)), rebalancing of future contracts (Bessembinder et. al. (2016)) and the gold market fix (Abrantes-Metz and Metz (2014)). In particular, my model shows that the decrease in price is not necessarily symptomatic of front-running (Brunnermeier and Pedersen (2005)) or other price manipulations (Abrantes-Metz and Metz (2014)).

My model is related to three papers: Bessembinder et. al. (2016), Vayanos and Wang (2012) and Duffie (2010). Bessembinder et. al. (2016) study prices before an anticipated trade of future contracts by an oil ETF. In their model, the decrease in price may occur due to front-running. Conversely, in my model, investors are not strategic: they do not take into account their own price impact. In addition, Bessembinder et. al. (2016) assumes no randomness whereas, in my model, the auction price is uncertain.

Vayanos and Wang (2012) study how uncertainty about endowments in the second period affect prices in the first period. Similarly, I study how uncertainty about an auction's net supply affect prices in the first period (where net supply is modeled as an endowment). However, in their model, the uncertainty relates to endowments of investors who trade both in the first and the second periods; while, in my model, the uncertainty relates to traders who arrive in the market in the second period. Moreover, in my model, the average endowment has a positive mean. As a result, I show that the price in the first period is higher than the expected price in the second period, while Vayanos and Wang (2012) show the opposite.

Duffie (2010) and my paper both use a portfolio management approach to study price pattern around anticipated events. In Duffie (2010), the price pattern is generated by the fact that some traders cannot trade in a continuous fashion. On the contrary, I do not make the assumption that some investors cannot trade on sale date (i.e. auction date). Instead, I generate the price difference by assuming that liquidity providers do not perfectly forecast what will be the net supply.

The paper proceeds as follows. Section 2 develops the model. Section 3 tests implications. Section 4 reviews alternative explanations. Section 5 extends the implications to other contexts. Section 6 concludes.

II. Model

A. Objectives and key characteristics of the model

I build a model with the primary objective to rationalize why Treasury bond prices have been documented to progressively decrease before an auction. Lou, Yan and Zhang (2013) find that, in the few days ahead of an auction of a new U.S. treasury bond, the price of the current issue progressively decreases and reaches a minimum on auction day. Duffie (2010) also analyzes this price pattern.

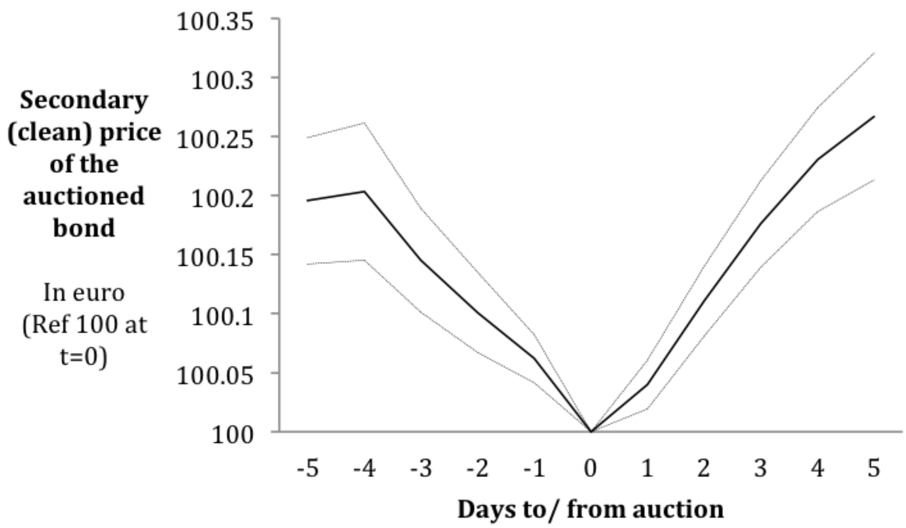

Figure 1. Reports the result of ten t-test specifications where I test the null hypothesis that the price of the auctioned security t days before the auction is equal to the price on auction day, where t belongs to (-5,+5). I use over 1,000 Italian re-openings over 2000-15, excluding 2011. A re-opening is a primary auction which results in the increase in outstanding volume of a bond which was first issued in the past. Datastream price (CP datatype). The solid line is the point estimate. The two other lines corresponds to the 95% interval confidence.

Figure 1 offers an graphical representation of the market reaction around a reopening. Figure 1 is qualitatively similar to the pattern documented in Lou, Yan and Zhang (2013) but is built using a different dataset which I present in detail in the empirical section of the paper. The decrease in price in Figure 1 is not due to the on/off-the-run phenomenon.[2]

I build a three-period portfolio management model with the entry of a liquidity trader in the intermediate period. There are two sets of crucial assumptions in the model. First, the demand for liquidity is imperfectly known in advance by the other traders and is has a positive mean. Second, traders are risk-averse and have a long-term horizon.

[2]Indeed, I use reopenings instead of using new issuances. A reopening is the increase in outstanding volume via for a bond which has been issued in the past. This bond does not lose its on-the-run status after the reopening. Therefore, it cannot be argued that this bond is less valuable after than before the reopening.

B. Set-up

There are three periods (t = 1, 2, 3), a riskless and a risky asset that pay off in Period 3. The free-float of the risky asset is $\bar{\theta}$ at t=1. The risky asset pays off D units at t=3, with $D \sim N(\overline{D}; \sigma^2)$. The distribution of D is the same at t=1 and t=2. I use the riskless asset as numeraire. I denote by P_t the price of the risky asset in Period t, where P_3 = D. There are two types of investors at t=1: investors with a low risk-aversion (for which I use the letter A as in "Adventurous") and investors with a high risk-aversion (for which I use the letter B). More precisely, there is a measure δ of investors A and 1-δ of investors B with the following utility function:

$$U_i(W_3) = -exp - \alpha_i W_{i,3} \tag{1}$$

where i is in {A;B}, $W_{i,3}$ is the individual's wealth in Period 3, $\alpha_i > 0$ is the coefficient of absolute risk aversion, with an endowment at start of t=1 of $\theta_{0,i}$ of the risky asset and $C_{0,i}$ of the riskless asset.

At t=2, there is an entry of a new trader called "Liquidity Trader" (for which I use the initial L). L are in measure one and seek to hedge an endowment Z in the risky asset which they will receive at t=3. Z is deterministic at t=2 but uncertain at t=1 with a known distribution of $Z \sim N(\overline{Z}; \sigma_Z^2)$, where $\overline{Z}$ is strictly positive ($\overline{Z} > 0$). In the main sections of the paper, I only solve the case where "Liquidity Trader" is infinitely risk-averse. In the internet appendix, I solve the general case where L has a utility function of $-exp - \alpha_L W_3$ where α_L is finite. Figure 2 illustrates the timing of the model.

Like in Vayanos and Wang (2012), to guarantee that the ex-ante expected utility is finite, I assume that the variances of D and Z satisfy the following conditions:

$$\alpha_i^2 \sigma^2 \sigma_Z^2 < 1; \alpha_A^2 \alpha_B^2 \sigma^2 \sigma_Z^2 < 1 \tag{2}$$

where i is in {A;B}

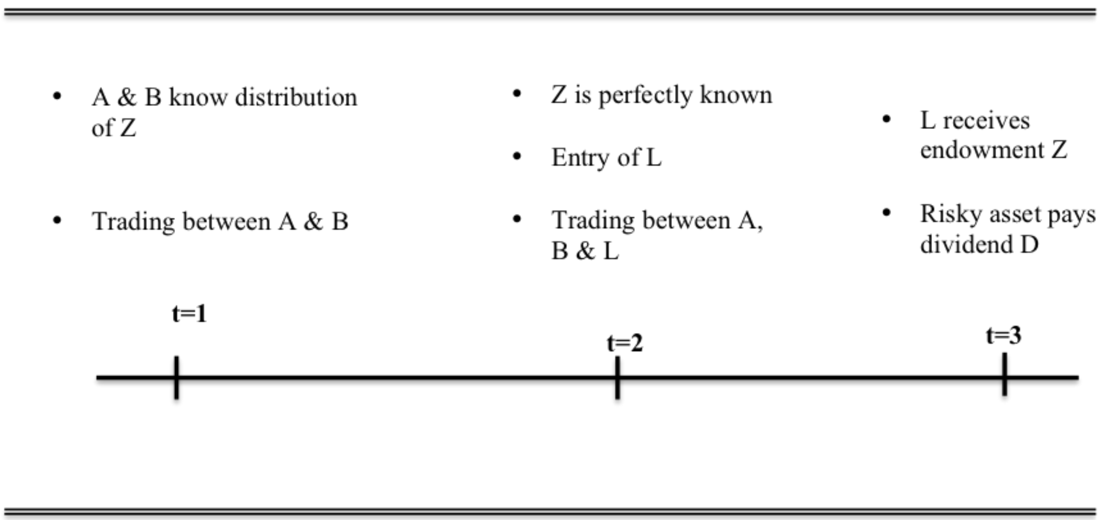

Figure 2. Model Timeline

C. Interpretation in the Treasury auction context

Table I illustrates the interpretation of the various investors and variables in the context of Treasury auctions.

Table I. Interpretation of the model in the context of Treasury auctions

Model	**Treasury auction context**
A	Primary Dealers with low capital constraints
B	Primary Dealers with high capital constraints
L	Treasury Office + Natural Buyers (foreign, investment funds, individuals)
$\overline{Z}$	Amount issued by Treasury Office = amount that dealers expect to buy
$\overline{Z}$ - Z	Part of issuance demanded by Natural Buyers (may be negative)
Z	Part of the issuance sold to Primary Dealers (may be negative)
If $Z > 0$	Dealers increase inventory: they provide liquidity to (=buy from) Treasury
If $Z < 0$	Dealers decrease inventory: they provide liquidity to (=sell to) Natural Buyers
If $Z > \overline{Z}$ or $Z < -\overline{Z}$	Dealers provide more liquidity than expected (=good for them)
If $-\overline{Z} < Z < \overline{Z}$	Dealers provide less liquidity than expected (=bad for them)

In an auction context, investors A and B are dealers with different capital constraints, $\overline{Z}$ is the issuance size, Z is the net supply: the share of the new issue which cannot be sold to "natural buyers" and is therefore sold to liquidity providers. Hence, investor L can be thought as both the Treasury office and the natural buyers.

Net supply Z is uncertain because it depends on the demand of "natural buyers"(i.e. occasional investors) such as foreign and international investors, investment funds, individuals, pension funds and insurance companies (Fleming (2007)). Those natural buyers are investors who are not usually on the market and who tend to participate to auctions indirectly through a primary dealer. Some of of them even participate directly to the auction by placing competitive or non-competitive bids (TreasuryDirect (2016); Fleming (2007)). In the US between 2003 and 2005, 40% of long-term bond volume is bought by non-primary dealers (Fleming (2007)). The two largest categories are foreign and international investors (21%) and investment funds (11%). The share of non-primary participants varies from auctions to auctions: in the US between 2003 and 2005, it has varied from

0% to 67%.

Primary dealers might not perfectly know in advance the demand from these investors: the demand of the direct bidders will not be known until the auction's results, while the demand of the indirect bidders will remain uncertain until the primary dealer's has collected orders from her clients. Even then, a given primary dealer will receive only an imperfect signal of the overall demand as each primary dealer collects a fraction of the total orders.

D. Model's solution

In this part, I present the model's solution. I start by deriving the equilibrium at t=2. The results at t=2 are standard but, of particular interest, is how the investors' value function changes with net supply Z: in that regard, Lemma 1 gives some intuition about the model's central results.

Investors of type i maximize

$$\mathbb{E}\left[-exp\Big\{ -\alpha_i\big(\theta_{2,i}D + C_{0,i} - (\theta_{1,i} - \theta_{0,i})P_1 - (\theta_{2,i} - \theta_{1,i})P_2\big)\Big\} \,\Big|\, \Omega_2\right] \tag{3}$$

i.e. the value $\theta_{2,i}D$ of the total risky portfolio at t=3, plus the endowment in cash $C_{0,i}$ minus the cost $\theta_{1,i} - \theta_{0,i}P_1$ of the additional risky position taken at t=1, minus the cost $\theta_{2,i} - \theta_{1,i}P_2$ of the additional risky position taken at t=2, conditional on a set of information Ω_2.

I show that the demand function for the risky asset in Period 2 of investors of type i is

$$\theta_{2,i}(P_2) = \frac{\overline{D} - P_2}{\alpha_i \sigma^2} \tag{4}$$

where $\theta_{2,i}$ is the investor's total holding at Period 2.

As for investors L, their demand function for the risky asset in Period 2 is

$$\theta_2^L(P_2) = -Z \tag{5}$$

Now, I compute the equilibrium prices and holdings. The market clearing condition is

$$\bar{\theta} = \delta\theta_{2,A}(P_2^*) + (1-\delta)\theta_{2,B}(P_2^*) + \theta_2^L(P_2^*) \tag{6}$$

Using (4), (5) and (6), I show that the equilibrium price for the asset at t=2 is

$$P_2^* = \overline{D} - \frac{\alpha_A\alpha_B}{\bar{\alpha}}\sigma^2(\bar{\theta} + Z) \tag{7}$$

where I define $\bar{\alpha} = \delta\alpha_B + (1-\delta)\alpha_A$

Moreover, using (4) and (7), I show that the equilibrium holdings at t=2 for investors of type i is

$$\theta_{2,i}^* = \frac{\alpha_{-i}}{\bar{\alpha}}(\bar{\theta} + Z) \tag{8}$$

where (i,-i) is (A,B) or (B,A)

Finally, using (3), (7) and (8), I show that the value function at t=2 of investors of type i is

$$V_2(Z, W_{2,i}) = -exp - \left\{\alpha_i\left(W_{2,i} + \frac{1}{2}\alpha_i\sigma^2\left(\frac{\alpha_{-i}(\bar{\theta} + Z)}{\bar{\alpha}}\right)^2\right)\right\} \tag{9}$$

where $W_{2,i} = C_{1,i} + \theta_{1,i}P_2$

***Lemma 1*: The investor's value function in Period 2 is a function of Z, symmetric in a certain value Z^{inf} and increasing and concave over $[Z^{inf}; +\infty)$. Under some conditions on $\theta_{1,i}$, $Z^{inf} < \overline{Z}$**

The interpretation of Lemma 1 is the following. The monotonicty and the symmetric feature of the function tells us that the more L buys or sells, the higher the investor's expected utility. Said differently, investors are better-off when net supply Z is very positive or very negative; and they are worse-off when net supply Z is somewhat positive or somewhat negative.

In addition, the concavity of the value function tells us that, at any point of $[Z^{inf}; +\infty)$, investors are eager to avoid situations where net supply turns out to be smaller than this point. To that end, they are ready to forego the extra expected utility derived from a situation where the net supply turns out to be larger than this point.

Overall, Lemma 1 gives the intution that investors will try to hedge at t=1 the possibility that Z turns out to be smaller than $\overline{Z}$.

I now derive the demand functions and the equilibrium price at t=1. This derivation leads to Proposition 1 which is the model's most important result.

Using the equilibrium results at t=2, I can write the expected utility of investors of type i in Period 1 as:

$$\mathbb{E}\Bigg[-exp-\Bigg\{\alpha_i\Bigg(W_{1,i}+\theta_{1,i}\Big(\overline{D}-\frac{\alpha_i\alpha_{-i}}{\bar{\alpha}}\sigma^2(\bar{\theta}+Z)-P_1\Big)+\frac{1}{2}\alpha_i\Big(\frac{\alpha_{-i}}{\bar{\alpha}}\Big)^2\sigma^2(\bar{\theta}+Z)^2\Bigg)\Bigg\}\Bigg] \tag{10}$$

where $W_{1,i} = C_{0,i} + \theta_{0,i}P_1$

I show the demand function of the investors of type i is

$$\theta^*_{1,i}(P_1) = \frac{\mathbb{E}(P_2)-P_1}{\alpha_i Var(P_2)/(1+\bar{\alpha}^{-2}\alpha_i^2\alpha_{-i}^2\sigma^2\sigma_Z^2)} + \alpha_i\Big(\frac{\alpha_{-i}}{\bar{\alpha}}\Big)^2\sigma^2(\bar{\theta}+\overline{Z})\frac{-Cov(P_2,Z)}{Var(P_2)} \tag{11}$$

where the second part of equation 11 is equal to $\mathbb{E}(\theta^*_{2,i}) = \frac{\alpha_{-i}}{\bar{\alpha}}(\bar{\theta}+\overline{Z})$

Proposition 1 (also holds when $\alpha_A = \alpha_B$***)* : The investor's demand function for the risky asset in Period 1 is composed of a speculative demand and a positive hedging demand. In particular, the speculative demand is negatively related to** σ_Z^2**.**

Proposition 1 is based on equation 11 which offers a clear decomposition of the demand function. The first term is speculative because it depends on the risk and reward of trading on the difference between the price at t=1 and the expected price at t=2: the demand for the risky asset is negative (positive) when the price at t=1 is higher (lower) than the expected price at t=2. The second term is a hedging demand because it depends on the covariance of the price with Z. The hedging demand translates into a positive demand for the risky asset because the correlation between the price at t=2 and Z is negative (it is equal to -1).

The economic interpretation of Proposition 1 is the following. The sale constitutes an investment opportunity while the net supply, Z, is a state variable which determines how lucrative the opportunity is. Hence, risk-averse liquidity providers will seek to hedge these changes in investment opportunities (Merton (1973)) with an investment which negatively correlates to the state variable Z. Said differently, investors would like to diversify away the risk of Z: therefore, their valuation of investment opportunities depends on the *beta* of that investment with Z. In that regard, a long position in the risky asset is valuable because the return of that investment is high when Z is low.

I now study some comparative statics about the speculative and hedging demands. First, the absolute value of the speculative demand decreases in σ_Z^2. Indeed, the uncertainty regarding net supply Z represents a cost of arbitrage for risk-averse investors: the higher σ_Z^2, the less willing they are to speculate.

Second, the hedging demand is of the opposite sign of $\frac{Cov(P_2,Z)}{Var(P_2)}$, which is the "beta" of Z with P_2: the lower the beta, the better the insurance provided by the risky asset.

Third, after simplification, the hedging demand is equal to $\mathbb{E}(\theta_2^*)$. This means that investors will buy in advance what they otherwise expect to buy at t=2 if Z turns out to be equal to $\overline{Z}$. In particular, the larger $\overline{Z}$, the larger the hedging demand.

Finally, while the absolute amount of hedging does not vary with σ_Z^2, the relative proportion of hedging in the investor's total demand increases with σ_Z^2.The relative proportion of hedging can be defined as the ratio between the absolute value of hedging and the sum of the absolute value of hedging and the absolute value of speculation.

Replacing the expression of $\mathbb{E}(P_2)$, $Var(P_2)$ and $Cov(P_2,Z)$ I get that the investor's demand for the asset at t=1 is:

$$\theta_{1,i}^*(P_1) = \frac{\bar{\alpha}^2 + \alpha_i^2\alpha_{-i}^2\sigma^2\sigma_Z^2}{\sigma^4\sigma_Z^2\alpha_i^3\alpha_{-i}^2}(\mathbb{E}(P_2) - P_1) + \mathbb{E}(\theta_{2,i}^*) \tag{12}$$

Having derived the demand, I now turn to the equilibrium at t=1. For the market to clear, aggregate demand must equals the supply $\bar{\theta}$

$$\delta\theta^*_{1,A} + (1-\delta)\theta^*_{1,B} = \bar{\theta} \tag{13}$$

I then show that the equilibrium price for the asset at t=1 is

$$P_1^* = \mathbb{E}(P_2) + \frac{\sigma^4\sigma_Z^2\alpha_A^3\alpha_B^3\overline{Z}}{\bar{\alpha}^3 + \bar{\alpha}\alpha_A^2\alpha_B^2\sigma^2\sigma_Z^2} \tag{14}$$

Lemma 2: **P_1^* is above $\overline{D} - \frac{\alpha_A\alpha_B}{\bar{\alpha}}\sigma^2(\bar{\theta} + \overline{Z})$ and below $\overline{D} - \frac{\alpha_A\alpha_B}{\bar{\alpha}}\sigma^2\bar{\theta}$. In addition, P_1^* decreases in $\overline{Z}$.**

Lemma 2 offers two interesting benchmarks. The lower bound is the expected price at t=2. The upper bound is the price at t=1 should the market expect no sale. In addition, Lemma 2 tells us that a large expected net supply entails a lower price at t=1 than a smaller expected net supply. This last bit holds even if hedging demand increases in the net supply.

***Proposition 2 (also holds when $\alpha_A = \alpha_B$)*: The average return from investing in the risky asset between t=1 and t=2 is negative and decreases in the uncertainty regarding the net supply, σ_Z^2. In particular, it is null when $\sigma_Z^2 = 0$.**

The relationship between the uncertainty regardig net supply, σ_Z^2, and the average return between t=1 and t=2 can be explained as such. As shown in equation 11, investors have a speculative component in their demand. The speculative component make them sell (buy) when P_1^* is above (below) $E(P_2)$. Since that P_1^* is above $E(P_2)$, investors sell the asset for speculative motives. As the uncertainty regarding net supply Z decreases, arbitrageur are more willing to short the risky asset and the price decreases.

Figure 3 illustrates the model's mechanism as reported in Proposition 1, Lemma 2 and Proposition 2.

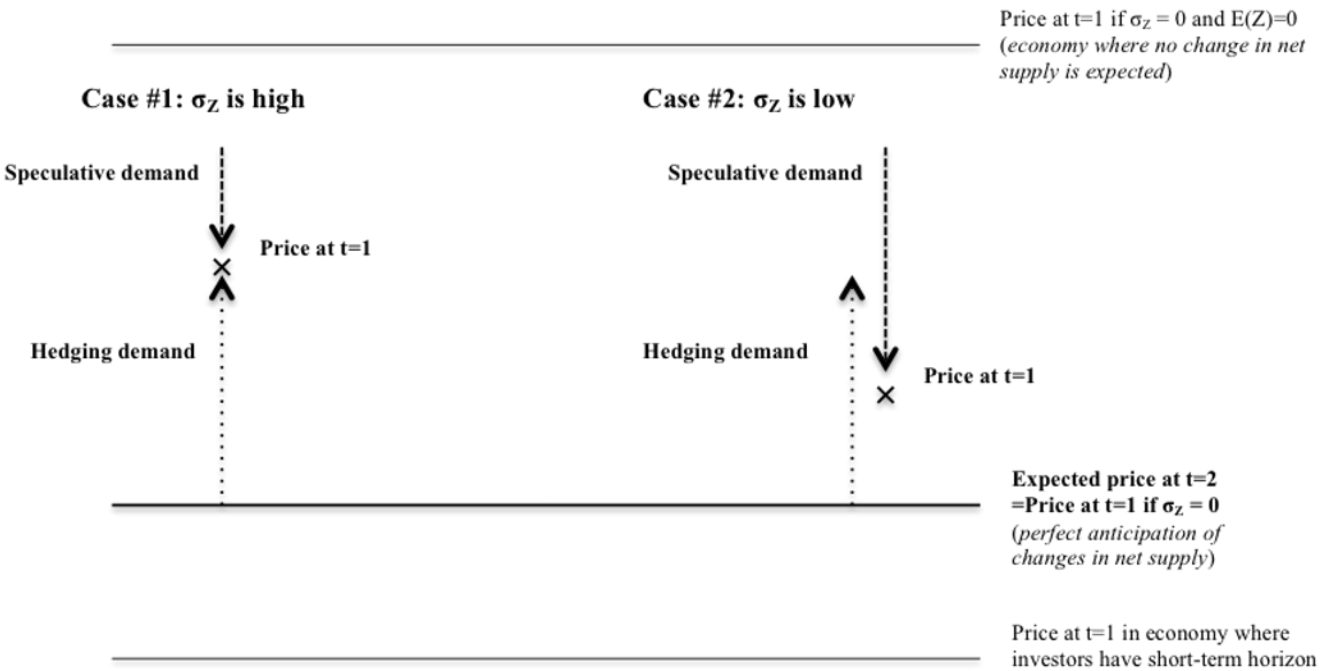

Figure 3. Illustration of the model's mechanism. The equilibrium price at t=1 is above the expected issuance price at t=2. It is also below the price prevalent in an economy where no change in net supply is expected. The equilibrium price at t=1 is the result of two opposite components of investors' demand functions : a speculative demand and a hedging demand. Through the speculative demand, investors seek to sell the security at t=1, conditional on the price at t=1 being above the expected issuance price at t=2. Through hedging demand, investors seek to have a long position in the security at t=1. The speculative demand is stronger when this uncertainty is lower. Hence, a lower uncertainty entails more selling pressure and a lower equilibrium price. The hedging demand ensures that the equilibrium price at t=1 is above the expected issuance price at t=2. Indeed, in an economy where the investors are short-term, investors would hold the risky asset but would ask for a compensation due to the uncertainty regarding next-period price. Hence, in such economy, the price at t=1 would be below the expected issuance price at t=2

Note that all results and propositions stated above go through if considering the special case where $\alpha_A = \alpha_B$ and $\delta = 1$. I now derive the equilibrium holdings at t=1 and make use of the heterogeneity in risk-aversion.

I show that the equilibrium holdings are the following:

$$\theta_{1,i}^{*} = \mathbb{E}(\theta_{2,i}^{*}) - \alpha_{-i}\frac{\bar{\alpha}^2 + \sigma^2\sigma_Z^2\alpha_i^2\alpha_{-i}^2}{\bar{\alpha}^3 + \bar{\alpha}\alpha_i^2\alpha_{-i}^2\sigma^2\sigma_Z^2}\overline{Z} \tag{15}$$

After simplification, I find

$$\theta^*_{1,i} = \frac{\bar{\theta}}{\bar{\alpha}}\alpha_{-i} \tag{16}$$

Lemma 3**: The hedging demand as a proportion of total demand is the same for investors of type A and B. Furthermore, the equilibrium holdings are invariant in** σ^2_Z **and** $\overline{Z}$

The first part of Lemma 3 is derived from Proposition 1. Investors of type A have both a larger speculative demand and a larger hedging demand, so that the ratio of the two demands is equal to that of investors of type B. In particular, the larger absolute demand for hedging of investors of type A comes from the fact that hedging demand is solely determined by the investor's wealth tied to the sale (this is due to the CARA utility function): since that investors of type A buy more at the sale than the other type, they have a larger wealth tied to the sale and therefore hedge more.

The second part of Lemma 3 is related to equation (16). It tells us that, contrary to the equilibrium price, equilibrium holdings are unaffected by the upcoming sale. In particular, the risk sharing among each types of investors is equal that of standard one-period models.

E. Extension: rationalizing trading and short-selling

In this section, I modify the model in order to rationalize an empirical fact documented in the next section: higher-than-usual trading and short-selling volumes around auctions. To that end, I introduce a difference in investment horizons among investors. More precisely, investors A are now short-term investors which exit the market at t=2, while B investors exit the market at t=3. Furthermore, the two types of investors have the same coefficient of risk-aversion and I suppose that the mass of investors A is δ while the mass of investors B is 1.

For brevity, I give only the equilibrium in Period 1.

The equilibrium price for the risky asset in Period 1 is

$$P^*_1 = \mathbb{E}(P_2) + \frac{\alpha^3\sigma^4\sigma^2_Z\overline{Z}}{1+\delta+\alpha^2\sigma^2\sigma^2_Z} \tag{17}$$

Investors A's equilibrium holding of the risky asset in Period 1 is

$$\theta^*_{1,A} = \frac{-\overline{Z}}{1 + \delta + \alpha^2\sigma^2\sigma_Z^2} < 0 \tag{18}$$

Investors B's equilibrium holding of the risky asset in Period 1 is

$$\theta^*_{1,B} = \bar{\theta} + \frac{\delta\overline{Z}}{1 + \delta + \alpha^2\sigma^2\sigma_Z^2} > 0 \tag{19}$$

***Proposition 3 (extension with investor A being short-term)*: At t=1, short-term investors have a negative holding in the risky asset (i.e. they short-sells). Furthermore, short-selling is inversely related to the uncertainty regarding net supply, σ_Z^2.**

F. Implications

I now formulate the model's implications.

***Implication 1*: Before an issuance, the bond trades at a price above the expected issuance price which decreases as the auction date approaches.**

Implication 1 is based on Proposition 2 using a dynamic interpretation of comparative statics, and supposing that the uncertainty about net supply decreases as the auction date approaches.[3]

The predicted price pattern is documented in the empirical literature. Lou, Yan and Zhang (2013) show that, on average, the price of the on-the-run bond is higher before the issuance of a new issue than on issuance day.

***Implication 2*: Before an issuance, the arrival of a missing piece of information about**

[3]Note that, in order to generate a increasing short-selling pattern, one would have to twist the model by introducing a period (say t=1.5) where σ_Z^2 decreases

the net supply will entail an asymmetric change in prices: the size of the price decrease in case of a "negative" information is larger than the size of the price increase in case of "positive" information.

This implication is based on Proposition 1, Lemma 2 and Proposition 2 using a dynamic interpretation of comparative statics. Indeed, the lower σ_Z^2, the lower the price before the auction, holding constant $\mathbb{E}(Z)$.

The intuition of Implication 2 is as follows. Missing pieces of information may come in the form of announcements about the auction size or the publication of an expert's opinion about what will be the demand for the asset on auction day: these pieces of information are informative about the net supply, Z.

First, the price should trivially reflect the information: as show in Lemma 2, the price should increase (decrease) when the information reveals that the net supply is lower (larger) than expected. This effect has the same magnitude and opposite sign for "good" and "bad" news. Second, the information arrival also decreases the uncertainty about net supply, regardless of whether the information is positive or negative: hence, uppon information arrival, the price before the auction should decrease towards the expected auction price (Proposition 2) due to larger arbitrage (Proposition 1). This effect has the same magnitude and the same sign for "good" and "bad" news.

Overall, a "positive" piece of information entails a price increase to reflect the information and a simultaneous price decrease to reflect the lower uncertainty. Similarly, a "negative" piece of information entails a price decrease to reflect the information and another simultaneous price decrease to reflect the lower uncertainty. Hence, the price will move more in cases where the information reveals larger-than-expected net supply than in cases where the information reveals smaller-than-expected net supply.

Implication 2 is new to the literature. In particular, this relationship is not predicted in Duffie (2010). In addition, one-period models of portfolio allocation would predict an opposite relationship. Indeed, using comparative statics, an increase (decrease) in the expected cash-flows of an asset in positive supply combined with a simultaneous decrease in the cash-flow's uncertainty would result in a large (smaller) change in the asset price. Another difference with one-period models is that, in my model, the change is about the asset's supply not the cash-flows.

***Implication 2's corollary*: Take a sample of asset returns realized from buying before and then selling after the arrival of information about the asset's net supply. Suppose that as many positive as negative pieces of information arrived in the sample. Then, on average over that sample, the arrival of a missing piece of information about the net supply entails a negative return.**

I test this corollary in the paper's empirical section. The intuition of this corollary is as follows. Suppose that, in a given sample, the arrival of a positive (negative) information entails a price increase (decrease) of 0.75 bps (1.25 bps). If there are as many positive and negative information, then on average the arrival of information entails a decrease of 0.25 bps.

***Implication 3*: The difference between the pre-auction price and the expected auction price is larger (lower) when the auction size is invariant in (varies with) the demand of natural buyers.**

Implication 3 is new to the literature. This implication is based on Proposition 2 using a dynamic interpretation of comparative statics. In a primary auction of Treasury assets, the size of the issuance is usually fixed and known in advance but the demand from other participants might not be. For example, mutual funds may demand more of the new issue than expected: since supply is fixed, this means that liquidity providers absorb less than expected.

On the contrary, when supply is not fixed in advance but adapts to the demand observed on auction day, issuance size would be larger (smaller) than expected in case the demand from mutual funds is larger (smaller) than expected. This would reduce σ_Z^2 for liquidity providers. A lower σ_Z^2 leads to a lower price difference between the first period and the intermediate period (Proposition 2). Hence, the implication that the difference in price between the auction price and the price before the issuance would be reduced if the Treasury Office adopts a flexible supply.

***Implication 4*: Before an issuance, trading and short-selling volumes of the bond are higher than usual and increase as the auction date approaches.**

Implication 4 is based on Proposition 3.[4] The implication appears in the empirical literature.

[4] Note that, in order to generate a increasing short-selling pattern, one would have to twist the model by introducing

Keane (1996) shows that specialness of a bond issue increases as the auction date of a new issue approaches. Admittedly, in Keane (1996) specialness peaks on the days when the auction volume is announced whereas Implication 4 predicts a peak right before the auction. Similarly, Lou, Yan and Zhang (2013) documents the special Repo rate of an old issue is lower before than after the auction of a new issue.

III. Tests

The section is composed of the two following parts. In the first part, I verify that Implication 1 and 4 are present in my data. Specifically, I show that the price of a to-be-issued bond decreases gradually and short-selling increases gradually ahead of the auction. To that end, I use a setting that allows me to observe the market price of the bond before the auction. In the second part, I test a corollary of Implication 2 – one of the model's new implications.

A. Institutional details

In Italy, two to thirty-year bonds are systematically *reopened* one or several times until reaching a certain minimum outstanding volume: *reopenings* are identical to regular issuances, except that they do not result in the issuance of new bonds but on the increase in the outstanding amount of bonds that were issued in the past (e.g. six months ago) and that are already trading on secondary markets. Therefore, this setting allows me to observe the price of a bond before it is reopened. Admittedly, reopenings are not specific to Italy; in particular, they also exist in the U.S. (Fleming (2002)). However, in Italy, reopenings are systematic and extend to all medium-to-long maturities.

The tests presented in the second part of this empirical section rely on the specificities of the issuance timeline. Therefore, I comment three important points of the timeline represented in Figure 4

The first point of interest is the reopening date. At the start of each quarter, the Treasury communicates the date of some of the quarter's issuances. Specifically, the Treasury announces

a period (say t=1.5) where σ_Z^2 decreases

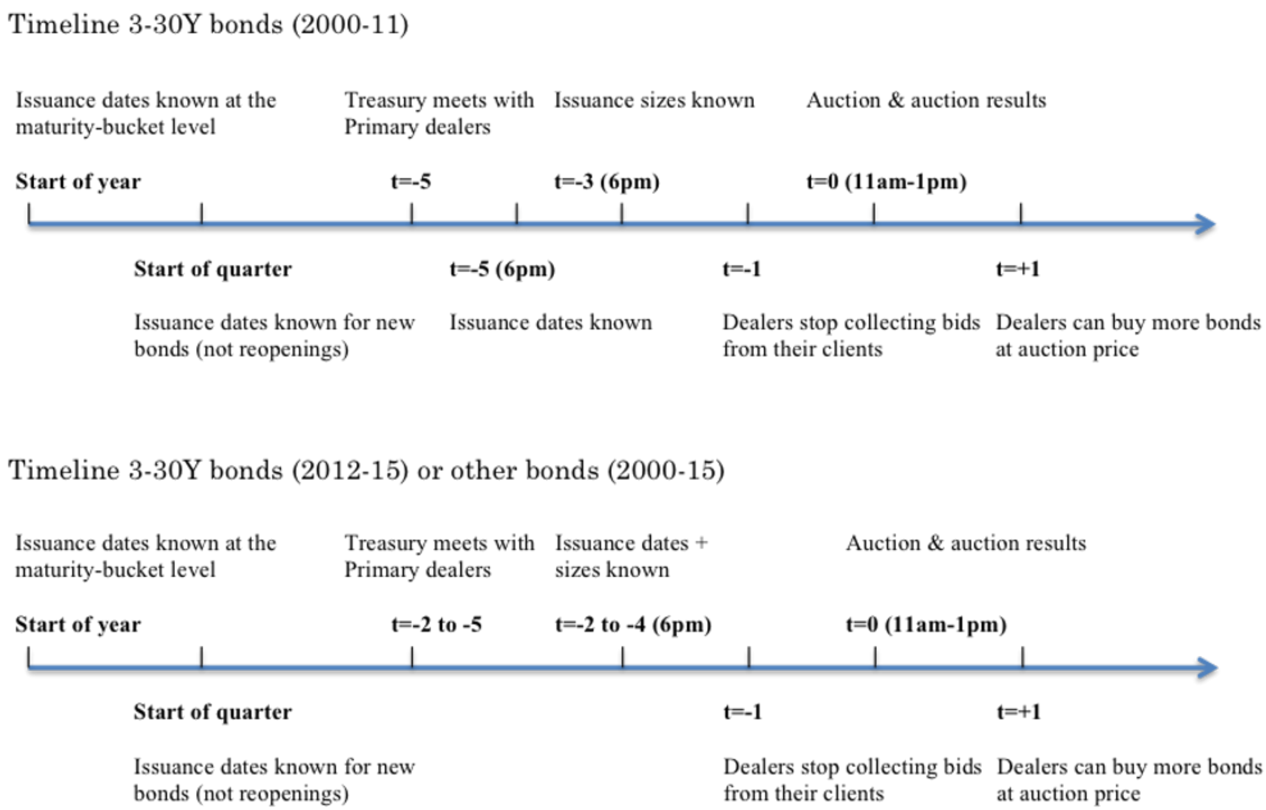

Figure 4. Issuance timeline for re-openings of Italian sovereign bonds

the date of new issuances but not the date of reopenings: the dates of reopenings are officially announced only two to five days in advance. However, as indicated in Table VI in the appendix, the market is able to precisely predict the reopenings dates of many on-the-run bonds, notably by using historical data. For example, 10 year bonds have always been issued or reopened at the end of each month on a date inferred from a calendar made available each January. Consequently, at the start of each quarter, the market can perfectly predict the date of all of the quarters' reopenings of one-the-run 10 year bonds: these reopenings occur every end-of-month, on a well-identified day, unless a new issuance has been scheduled on that date. Similarly, the reopening date of 2, 3, 5 year bonds and floating-rate bonds can be inferred. As a result, I assume that the market perfectly predicts reopening dates well before the official announcement. In the robustness section, I relax this assumption.

The second point of interest is the dealers' meeting. Twice a month, the Treasury organizes a meeting where all the primary dealers are present and share their views about which bond should be reopened in the next two weeks and what should be the issuance sizes. The date of this meeting can be precisely inferredfrom the calendar made available each year. Specifically, the meeting occurs on the day where the Treasury is scheduled to communicate about the first issuance of that part of the month. Interestingly, there exists a cross-sectional heterogeneity regarding the relative date on which the meeting takes place: this is because bonds of different maturity are not reopened on the same day while the dealers' meeting take place on the same day for all maturities.

The final point of interest is the announcement of the auction size. Two to four days before the issuance, the Treasury communicates to the market the size of the reopening. The date of the communication is indicated on the yearly calendar and the relative date on which this communication occurs depend on the maturity and the period. In particular, for several maturities and time periods, the size announcement occurs at the same time as the official announcement of the reopening date.

Table VII in the appendix indicates the relative date on which the dealers' meeting and the size announcement take place for each maturity and period. In particular, for 3-30 year bonds over 2000-11, the dealers' meeting takes place five days before reopening date and the size announcement take place three days (after market close; i.e. two days) before the reopening date.

B. Data

I study reopenings of Italian sovereign bonds for all maturities and coupon type over 2000-2015, provided market prices exist on Datastream for the reopened asset. I exclude 2011 from the sample, due to the market conditions linked to the Eurobond crisis.

The basic prices used in the analysis come from Datastream. My sample includes more elaborated pricing data from MTS which I exploit in the Internet Appendix. The trading volume data comes from the MTS platform over April 2004- October 2012. More precisely, Italian bonds trade on two MTS platforms: the MTS and the Euro-MTS platforms. The secondary trading volume is the sum of the trading volume on the MTS platform and on the Euro-MTS platform.

Reverse Repo data covers January 2005-October 2012 and comes from MTS's Repo platform. Reverse Repo volume for a given bond corresponds to the volume of transactions on the MTS Repo platform for which the bond was expressively specified as collateral in the Repo contract. On MTS platforms, traders are large financial institutions.

In the appendix, Table VIII, Table IX and Table X report some summary statistics regarding the sample, including the amount sold at reopenings as well as secondary trading and Repo variables.

C. *Are Implications 1 and 4 verified in the data?*

In this part, I verify that the decreasing price pattern and the increasing trading and short-selling patterns predicted by Implication 1 and 4 exist in my data. To do so, I perform a series of t-tests which compare the value of a market variable (e.g. the price) at date t and at date 0 for each t in a (-5,+5) window, where t denotes the number of trading days from/since the auction date. Then, I report the point estimates in Table II.

More precisely, for each t in (-5, +5), I test for the null hypothesis $\alpha = 0$ in the following t-test specification:

$$X_{i;t} - X_{i;t'} = \alpha + \epsilon_i \tag{20}$$

where $X_i(t)$ denotes a relevant market variable (log secondary price, quoted mid yield, log secondary trading volume, or log Special Repo volume) for the asset which is due to be reopened in auction i in t business days. t and t' belong to (-5,+5).

Table II reports the results. The first column suggests that the price decreases progressively, reaches a minimum on reopening day and increases back. The second column suggests that the trading volume and the special Repo volume progressively increase, reach a maximum on reopening day and revert (the volume of special Repo volume is an indicator of short-selling activity). In the internet appendix, I introduce alternative measures of prices and find that the results do not change qualitatively. Overall, Implications 1 and 4 are verified in the data.

Table II. Price and trading volumes over 2000-15 (excl. 2011) of the reopened bond t days before the re-opening compared to re-opening day, where t is between 5 days before the re-opening and 5 days after the re-opening. The table reports the coefficient of a t-test specification which tests the nullity of the difference in price or volume between date t and the re-opening day, where t belongs to (-5,+5). Clean price from Datastream (CP datatype). Trading volume from MTS. Special Repo volume as thevolume on MTS Repo, where the collateral demanded is specified to be the re-opened bond.

	Δ Clean price (%)	Δ Trading volume (%)	Δ Special Repo volume (%)
t=-5 vs. t=0	0.20***	-182.09***	-31.71***
	(6.00)	(-36.91)	(-11.04)
t=-4 vs. t=0	0.20***	-166.33***	-29.67***
	(5.75)	(-36.59)	(-10.43)
t=-3 vs. t=0	0.15***	-166.33***	-28.59***
	(5.43)	(-35.87)	(-10.63)
t=-2 vs. t=0	0.10***	-157.28***	-22.24***
	(4.88)	(-34.61)	(-8.89)
t=-1 vs. t=0	0.06***	-129.28***	-15.83***
	(5.03)	(-35.26)	(-6.28)
t=+1 vs. t=0	0.04***	-133.03***	-47.41***
	(3.20)	(-33.03)	(-12.89)
t=+2 vs. t=0	0.11***	-159.77***	-60.66***
	(6.19)	(-33.85)	(-15.15)
t=+3 vs. t=0	0.18***	-163.36***	-60.27***
	(7.91)	(-35.57)	(-15.21)
t=+4 vs. t=0	0.23***	-166.90***	-58.61***
	(8.65)	(-35.00)	(-14.36)
t=+5 vs. t=0	0.27***	-173.33***	-58.73***
	(8.14)	(-36.02)	(-15.37)
Observations	1,002	495	497
Sample period	2000-15	2004-12	2005-12
Source	Datastream	MTS	MTS Repo

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

D. Tests of Implication 2's corollary

In this section, I test Implication 2's corollary and disregard alternative explanations.

My empirical strategy consists in using the dealers' meeting and the announcement about the auction size as arrivals of information about the net supply. These are pieces of information that the market were expecting to receive and which reduce uncertainty regarding the net supply, i.e. it reduces σ_Z^2.

More precisely, in the model, liquidity providers are uncertain about how much profit they will realize at the auction. The profit depends on Z, i.e. how much the Treasury will sell to liquidity providers. In real life, this uncertainty about Z may arise from two sources of uncertainty: first, uncertainty about the auction size; second, uncertainty about the demand of "natural buyers" at the auction. The announcement of the auction size will suppress the first source of uncertainty and may contain information about the demand of natural buyers.

In addition, during the dealers' meeting, liquidity providers are likely to acquire information about both the auction size and about what will be the demand of "natural buyers" on auction day. Overall, it is appropriate to use the dealers' meeting and the auction size announcement as events which reduce uncertainty about net supply Z.

Importantly, my empirical strategy relies on the following assumption: the positive and negative surprises about changes in net supply cancel out over my sample. This assumption is reasonable given that I use 15 years of auction data.

Main test

In this part, I test whether the price decreases more after the arrival of information compared to non-information days.

As a first step, I verify that the price significantly decreases on dealers' meeting days and size announcement days. Table XI in the appendix shows that the price indeed significantly decreases on average by 0.033% on dealers' meeting day and 0.076% on auction announcement days. I then proceed with my main test and study whether this decrease is larger on these days than on other pre-auction days.

More precisely, my model predicts test that $1_{Info} < 0$ (null hypothesis $1_{Info} = 0$) in the following regression:

$$log(Price_{i;t} - Price_{i;t-1}) = \alpha + 1_{Info} + \epsilon_i \tag{21}$$

1_{Info} takes the value 1 if t is either the day on which the Treasury meets with dealers or the day after the announcement of the auction size; $Price_{i;t}$ is the datastream clean price on date t of the asset which is about to be reopened at reopening i. t belongs to (-5,-1).

Table III shows the result. In the first column, I find that the info dummy is negative, is equal to -0.046% and is significantly different from zero. This result confirms that the price decreases more on the days when information about the net supply arrive than on other days.

In the other columns, I perform robustness tests. Specifically, in the second column, I add time fixed effects at the half-month level, I control for macroeconomic events by using daily changes in risk-free rates (proxied by interests rates computed from prices of German sovereign bonds), and I cluster standard errors at the auction-level (i.e. clusters are built around observations which correspond to the same bond and occur within five days of the same auction). I find that the info dummy is still significantly different from zero and is equal to -0.045%. In addition, in the appendix, I use a similar specification with day-level clusters.

In the third column, I control for the possibility that the information days are systematically closer or further away from the auction date. In particular, Duffie (2010) predicts that the price decrease should accentuate as the auction date approaches. To control for the possibility that my results are driven by Duffie (2010)'s prediction, I add fixed effects which capture the number of days that separate one observation to the auction date. I find that the info dummies is significantly different from zero and equal to -0.066%.

Finally, in the appendix, I propose an alternative technology to ensure that the information days do not occur closer to the auction date than the non-information days. To that end, I keep only non-information days which occur after information days. Specifically, for a given auction, I keep two non-information days: one non-information day which occur one day after the dealers' meeting, and one non-information day which occur one day after the size announcement. I find that the results are robust to that change.[5]

Table III. One day log changes in price of the reopened bond on information days versus days without information about the Treasury's liquidity needs. Reports the log P(t)-P(t-1), where Y(t) is the Datastream clean price for the to-be-reopened bond on day t, t is one to five days away from the security's re-opening. 1_{Info} takes the value 1 if t is either the day on which the Treasury meets with dealers or the day after the announcement of the auction size. Sample: all maturities over 2000-15, except 2011.

	Δ Clean price One-day change (%)	Δ Clean price One-day change (%)	Δ Clean price One-day change (%)
1_{Info}	-0.046***	-0.045**	-0.066**
	(-2.93)	(-2.24)	(-2.21)
Constant	-0.012		
	(-1.27)		
Observations	5,344	5,225	5,225
Sample period	2000-15 ex. 11	2000-15 ex. 11	2000-15 ex. 11
Control	None	German interest rate	German interest rate
Time fixed effect	None	Half-month	Half-month
Other fixed effects	None	Maturity	Maturity , Days-to-auction
Cluster	None	Auction-level	Auction-level

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

[5] In some cases, there are two days separating an information and a non-information day. Also, in some cases, only one such day can be found: in those cases, I keep only one non-information day and one information day. In addition, when there is a choice as to which information day to keep, I keep the information day such that the number of days between the information and non-information days is minimal

Case study

In this part, I study a subsample. The previous results suggest the price is constant except on days when there is arrival of information about the net supply. In order to graphically observe such pattern, one would need to plug the price level as a function of the time-to-auction.

However, there is a large cross-sectional and time-series diversity regarding the relative day in which information arrives: for example, over 2000-10, the dealer meeting takes place at t=-5 for 3-30 year bonds but solely at t=-4 for inflation-linked bonds and t=-3 for 2 year bonds. Similarly, the day in which the auction size is announced ranges from t=-4 to t=-2 depending on the maturity and the time period. As a result, a graphical representation of one-day price change over the entire sample would result in a much smoother graph than it actually is.

Therefore, I decide to restrict the sample to 3-30 year bonds over 2000-10: this subsample is large and homogenous in term of date of information arrival. Indeed, in this subsample, the dealer meeting consistently takes place at t=-5 and the auction size is consistently announced at t=-3 after market close. I therefore predict that the price significantly decreases at t=-5, t=-2 and t=0, and does not decrease in other pre-auction days.

My predictions are reported in Table IV. Table V reports the results, while Figure 5 gives a graphical representation of the predictions and the results.

Table V shows that the price significantly decreases at t=-5, t=-2, t=-1 and t=0. Also, it shows that the price does not significantly decrease at t=-4 and t=-3. These results are nearly in line with the predictions, except for t=-1.

Table IV. Model's predictions. First, the Treasury meets with primary dealers at t=-5: the meeting should decrease uncertainty regarding net supply. Second, the Treasury announces the auction size at t=-3 after market close. This represents a decrease in uncertainty: the model predicts that the price decreases at t=-2. Third, after the auction, there is no more uncertainty regarding net supply: the model predicts that the price decreases at t=0. Fourth, the model does not predict the price to decrease at t=-3 and t=-1 because there is not event on that day. Fifth, the Treasury announces the auction size at t=-5 after market close. However, by assumption, I assumed that the market perfectly knows about the re-opening date at least since t=-6: therefore, I predict that the price will not move on that day.

Time	**Event**	**Net supply is...**	**Model's prediction**
$t = -5$	Treasury meets dealers	Less uncertain	Price drops
$t = -4$ ($t = -5$ after close)	Auction date announced	No change (assumption)	No change
$t = -3$		Unchanged	No change
$t = -2$ ($t = -3$ after close)	Auction size announced	Less uncertain	Price drops
$t = -1$		Unchanged	No change
$t = 0$ at 11am	Auction	Certain after auction	Price drops

Table V. One day log changes in price of the reopened bond. Reports the result of t-test where I test the nullity of the log P(t)-P(t-1), where Y(t) is the Datastream clean price for the to-be-reopened bond on day t, with t=0 being the day when the note re-opening auction is conducted. Sample: 3-30 year old bonds over 2000-10. I keep only bonds with 11 non-missing yield information in the (-6,0) window.

	Δ Clean price (%)
t=-5 vs. t=-6	-0.040**
	(-2.01)
t=-4 vs. t=-5	-0.010
	(-0.51)
t=-3 vs. t=-4	-0.023
	(-1.35)
t=-2 vs. t=-3	-0.037**
	(-2.16)
t=-1 vs. t=-2	-0.068***
	(-3.89)
t=0 vs. t=-1	-0.103***
	(-5.74)
Observations	382
Sample maturity	3-30 Y
Sample period	2000-10

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

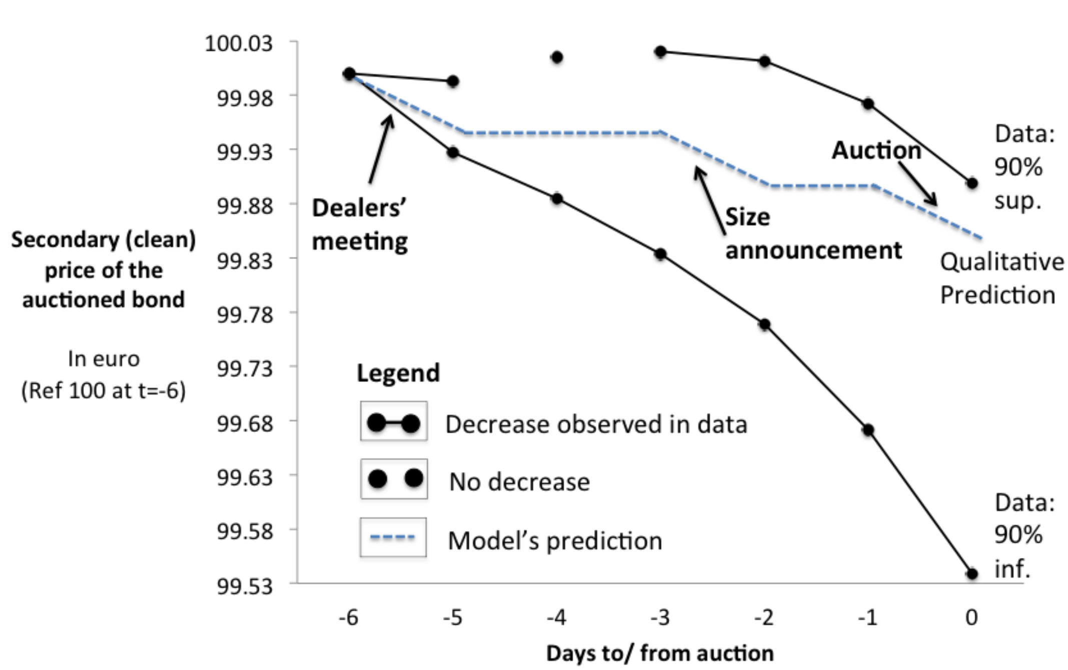

Figure 5. Price pattern ahead of auction for 3-30 year bonds over 2000-10. The light line represents the model's qualitative predictions. The upper and lower lines represent the 90% confidence interval and are the outcome of six t-tests. For clarity, the point estimates of the t-tests have not been represented. A solid line denotes a significant decrease observed in the data, no line denotes the absence of a significant decrease.

E. Robustness section

First, I check whether the results in Table III are robust to keeping only the following auctions: auctions which date can be predicted before the dealers' meeting by the econometrician using historical data. More precisely, I keep the auction of on-the-run bonds for which Table VI indicates the existence of a predictable monthly reopening frequency. The result is reported in the appendix.

I then perform a series of robustness checks of Table V. The outcome of most of these checks can be found in the appendix.

First, I alternatively cluster at the bond-level and both at the bond and year level. Second, I use yields instead of clean prices. I find that the results are qualitatively unchanged. Second, I control for interest-rate events. More precisely, I use changes in interest rates of German sovereign bonds to capture interest-rate events. Each bond of a given remaining maturity is associated to a time-series of German interest rate of same remaining maturity. I use this interest-rate movement as a control variable in the regression. I find that the results are qualitatively unchanged. Finally, in the internet appendix, I confirm that the auction size is not perfectly predicted by the market.

IV. Alternative explanations for the Treasury price pattern

My model explains the reason why investors agree to pay a one-day negative return for obtaining a bond instead of buying the bond during the auction (or on secondary markets right after the auction) when prices are lower. In my model, the premium paid before the auction reflects the cost of hedging the possibility that the auction is a worse investment opportunity than expected.

There are several types of alternative explanations which could be considered. First type: models where the premium paid reflects the informational, technological or institutional disadvantage of the buyers. In Brunnermeier and Pedersen (2005) and Bessembinder et. al. (2016), some agents are not informed about the price difference, do not have the technology or do not wish to exploit the price difference. They buy from "superior agents" before the liquidation and sell back to them after. In Duffie (2010), some agents are constantly on the market while others are periodically on the market. Agents that are periodically on the market are not sensitive to price movements that occur while they are away from the market. In particular, agents that are not present during the auction (i.e. when prices are lower) agree to buy the asset ahead of the auction at a higher price. Similarly, in models with market segmentation, some agents have access to the primary market while others do not: the agents that cannot participate in auctions agree to buy at a premium before or after the auction. My model differs from these models in that I suppose that any investor is aware of the auction and can participate.

Second type of alternative explanations: explanations based on inventory management. In the empirical paper of Lou, Yan and Zhang (2013), the authors explain and show evidence that dealers are hedging: they are selling in advance their to-be-acquired participation in the auction. The fact that some investors are short-selling could explain a progressive drop in the price. But primary dealers who are short-selling before the auction and buying back at the auction are earning a positive return which is not compatible with a hedging motive. Also, this rationale does not provide an explanation as to why some agents are buying from them.

Third type of alternative explanations: explanations from the *when-issued* literature. In the empirical paper of Nyborg and Sundaresan (1996), investors trade in the when-issued market for two notable reasons. First, they trade to extract information regarding the demand for the new bond and the bidding strategies of competitors. Second, investors trade on the when-issued market in order to be sure to get the desired quantity of new bond; in contrast, auction bidders do not know in advance the quantity that they will be awarded. I argue that a model based on this second explanation could rationalize the price premium paid by some investors and would provide a credible alternative to my model. Such model would feature risk-averse agents with heterogeneous levels of commitment to deliver the bonds and a cost for failing to deliver the bond. However, to my knowledge, such model has not been put forward in the literature.

V. Extension to cases other than Treasury auctions

A. Additional implications

My model makes the following three additional implications which I explain in more details in the next subsections.

Implication 5: The price of an asset ahead of a predictable ETF sale is higher than the expected sale price. It progressively decreases towards the expected sale price as the date of the sale approaches.

Implication 6: After controlling for the informational content of a SEO about the stock's fundamental value, the stock price ahead of a SEO is higher than the offer price. It progressively decreases as the SEO date approaches. In addition, the short-selling volume of a stock before a SEO is larger than usual and increases as the SEO date approaches.

Implication 7: Conditional on the expected "fixing demand" being negative, the price of an asset (e.g. gold) before the fix is higher than the price at the time of the fix. It progressively decreases as the time of the fix approaches.

B. Predictable ETF trading

ETF may trade in a predictable fashion. Bessembinder et. al. (2016) study a large ETF which tracks oil prices by investing in oil futures. On some predictable dates, the ETF sells its future contracts and invests in newer contracts. The strategy is known and the trading date is announced on the ETF's website. Possibly, the amount sold by the ETF is perfectly known in advance as well. However, the presence of natural buyers at the time of the trade might not be known in advance by would-be liquidity providers.

My model applies to this context where an ETF sell an asset and where the date and the quantity are known but not the demand for the asset at the time of the trade.

The price pattern predicted in Implication 5 is documented in Bessembinder et. al. (2016). In table 5 of their paper, for each day in a (-10;10) window, they compare the one-day return of the future oil contract which is sold by the ETF ("front contract") to the one-day return of the contract which is bought by the ETF ("second contract"). Finally, they build a measure which cumulates the one-day differences. They find that the cumulated return difference is less negative before the date of the trade than on they date of the trade. This means that the price of the front contract is higher before the date of the trade than on the date of the trade. Also, they find that the cumulated return difference becomes more and more negative as date of the trade approaches. This means that the price of the front contract decreases as the rebalancing date approaches.

C. In Seasoned Equity Offerings context

Seasoned Equity Offerings (SEOs) are predictable liquidations of stocks. The date of the offering is known in advance. There are several types of SEOs. One type is called "bought deal" whereby the issuer states the issuance amount, then an auction is realized among investment banks and the bank with highest bid buys the entire issue (Gao and Ritter (2010)). The issuance size is fixed but a given investment bank might not precisely know the demand of the other banks.

My model applies to this context where an issuer issues equity and where the date and the quantity are known but not the demand for the asset at the time of the issuance. The "liquidity trader" in my model and her stochastic endowment (with positive mean) can represent the combination of two features of SEOs: first, the sale of a deterministic volume of risky asset by the issuer (in the model, this is captured by the positive mean of the liquidity trader's endowment); second, the fact that a particular bank does not precisely know the demand of other banks (captured by the random part of Z).

Admittedly, contrary to the sale of Treasury assets, a SEO is not a true liquidity shock: the size of the SEO might send a signal about the fundamental value of the asset. Therefore, my model can apply only after controlling for the informational content of a SEO about the stock's fundamental value.

The price decrease predicted in Implication 6 is documented in Corwin (2003) and Meidan (2005). In figure 2 in Corwin (2003), the author shows that the cumulated abnormal return of holding the stock five days before the SEO and selling it one day before SEO day is equal to -2.2%. This means that the price one day before the SEO is lower than the price three day before. Similarly, table 1 in Meidan (2005) shows that holding the stock three days before the SEO and selling it one day before would result in an abnormal negative return of -1.1% to -2.3%. Moreover, the short-selling pattern predicted in Implication 6 is documented in Henry and Koski (2010). In their table 2, it can be seen that the mean and the median volume of short-selling (as percentage of trading volume) is abnormally high in a window of one day after the SEO announcement and one day before the SEO date. In addition, short-selling volume is larger on that window than on the announcement date.

D. In fixing context

In some markets such as the gold market or the FX market, a large part of trading is realized at particular benchmarks, called "fixes" while, in the equity market, there is a large demand for trading at the close. For example, the London Gold Fixing occurs twice each day at 10:30am and 3pm: on these two occasions, an auction is conducted. Market-makers collect the orders from their clients and their own proprietary desks and then communicate their demand schedules. The "fix" is the clearing price (US District Court (2014)). On the FX market, the 4pm London fix is similarly determined (Melvin and Prins (2015)). Finally, on other markets such as the equity market, a call auction is organized at the close (Hillion and Suominen (2004)).

My model applies to the context of fixing in the special case where market-makers expect that natural investors will sell on average at the fix.

The price pattern predicted in Implication 7 is compatible with some of the findings in Abrantes-Metz and Metz (2014). They find that, on some occasions, the price of gold is higher before the time of the fix than at the time of the fix. The price decreases as the time of the fix approaches, with a minimum reached at the time of the fix. The findings in Abrantes-Metz and Metz (2014) are published in a context of potential fraudulent manipulation of the price of gold. My model shows that some of the findings are compatible with portfolio management from gold market-makers who expect the demand to be negative but are not able to perfectly forecast what will be the demand at the fix.

VI. Conclusion

I develop and test a model explaining the gradual price decrease observed in the days leading to large anticipated asset sales such as Treasury auctions. In the model, risk-averse investors anticipate an asset sale which magnitude, and hence price, are uncertain. I show that investors face a trade-off between hedging the price risk with a long position, and arbitraging the difference between the pre-sale and the expected sale prices. Due to hedging, the equilibrium price is above the expected sale price. As the sale date approaches, uncertainty about the sale price decreases, short arbitrage positions increase and the price decreases. In line with the predictions, I find that the price of Italian Treasuries decreases by 4.6 bps after the release of auction price information, compared to non-information days.

References

Abrantes-Metz, Rosa M., and Albert D. Metz. "Are gold prices being fixed?" 2014. Cited in Southern District of New York Case Number 1:14-md-02548, http://www.bergermontague.com/media/434667/gold-complaint.pdf.

Bessembinder, Hendrik, et al. "Liquidity, resiliency and market quality around predictable trades: Theory and evidence." Journal of Financial Economics 121.1 (2016): 142-166.

Brunnermeier, Markus K., and Lasse Heje Pedersen. "Predatory trading." The Journal of Finance 60.4 (2005): 1825-1863.

Corwin, Shane A. "The determinants of underpricing for seasoned equity offers." The Journal of Finance 58.5 (2003): 2249-2279.

Duffie, Darrell. "Presidential Address: Security Price Dynamics with Slow-Moving Capital." The Journal of finance 65.4 (2010): 1237-1267.

Faulkender, Michael. "Hedging or market timing? Selecting the interest rate exposure of corporate debt." The Journal of Finance 60.2 (2005): 931-962.

Fleming, Michael J. "Who buys Treasury assets at auction?." Current Issues in Economics and Finance 13.1 (2007).

Fleming, Michael J. "Are larger treasury issues more liquid? Evidence from bill reopenings." Journal of Money, Credit and Banking (2002): 707-735.

Gao, Xiaohui, and Jay R. Ritter. "The marketing of seasoned equity offerings." Journal of Financial Economics 97.1 (2010): 33-52.

Grossman, Sanford J., and Merton H. Miller. "Liquidity and market structure." The Journal of Finance 43.3 (1988): 617-633.

Henry, Tyler R., and Jennifer L. Koski. "Short selling around seasoned equity offerings." Review of Financial Studies 23.12 (2010): 4389-4418.

Hillion, Pierre, and Matti Suominen. "The manipulation of closing prices." Journal of Financial Markets 7.4 (2004): 351-375.

Keane, Frank. "Repo rate patterns for new Treasury notes." Federal Reserve Bank of New York Current Issues in Economics and Finance 2.10 (1996).

Krishnamurthy, Arvind. "The bond/old-bond spread." Journal of financial Economics 66.2 (2002): 463-506.

Lou, Dong, Hongjun Yan, and Jinfan Zhang. "Anticipated and repeated shocks in liquid markets." Review of Financial Studies (2013): hht034.

Meidan, Danny. "A re-examination of price pressure around seasoned equity offerings." Available at SSRN 534942 (2005).

Melvin, Michael, and John Prins. "Equity hedging and exchange rates at the London 4p. m. fix." Journal of Financial Markets 22 (2015): 50-72.

Merton, Robert C. "An intertemporal capital asset pricing model." Econometrica: Journal of the Econometric Society (1973): 867-887.

Nyborg, Kjell G., and Suresh Sundaresan. "Discriminatory versus uniform Treasury auctions: Evidence from when-issued transactions." Journal of Financial Economics 42.1 (1996): 63-104.

Sundaresan, Suresh. "An empirical analysis of US Treasury auctions: Implications for auction and term structure theories." The Journal of Fixed Income 4.2 (1994): 35-50.

U.S. District Court (2014). Southern District of New York Case Number 1:14-md-02548

TreasuryDirect (2016). http://www.treasurydirect.gov/

Vayanos, Dimitri, and Jiang Wang. "Liquidity and asset returns under asymmetric information and imperfect competition." Review of Financial Studies 25.5 (2012): 1339-1365.

Appendix A. The reopening process and summary statistics

Table VI. Historical re-issuance frequency of Italian sovereign bonds

Maturity	Monthly re-issuance frequency	Part of month	Exceptions
30Y	Unclear	mid	
15Y	Unclear	mid	
10Y	1/month	end	Jul, Dec
7Y	1/month	mid	Aug, Dec
7Y floating	1/month (2000-Q210)	end	Nov
5Y	1/month (Q3 2000-15)	mid (Q3 2000-11), end (12-15)	Sep, Nov, Dec
5Y floating	1/month (Q3 2010-11; 13)	end	Dec
3Y	2/month (2000-3), 1/month (04-15)	end (2004-11), mid (12-15)	Aug, Nov, Dec
2Y	2/month (2001), 1/month (2000; 04-15)	end (2000; 04-15)	Nov
< 2Y	Seldom reopened		
Inflation-linked	Unclear		

Table VII. Relative dates of dealers' meeting (D) and auction size announcement (S). Note that the auction size announcement occurs after market close. Mid (End) designates auctions which occur at the middle (end) of the month.

Maturity	2000-11		2012		2013-15 Mid		2013-15 End	
	D	S	D	S	D	S	D	S
3-30Y incl. floating	t-5	t-3	t-4	t-3	t-4	t-3	t-5	t-3
2Y	t-3	t-3	t-2	t-2			t-3	t-3
5-30Y inflation-linked	t-4	t-4	t-2	t-2			t-3	t-3

Table VIII. Sample summary statistics - Italian Treasury reopenings (2000-10, 2012-15)

Maturity	On/off run	Obs.	Remaining maturity (Years)		Amount reissued (€MM)		Bid-cover ratio	
			Mean	Std.	Mean	Std.	Mean	Std.
30Y	On	65	29.73	2.68	1,508	655	1.86	1.59
	Off	11	24.97	2.73	952	405	1.89	0.4
15Y	On	50	14.77	1.73	1,794	536	1.65	0.32
	Off	22	11.9	2.39	1,256	658	1.77	0.33
10Y	On	130	10.08	0.22	2,627	595	1.59	0.35
	Off	36	8.25	1.92	1,740	797	1.71	0.32
7Y	On	17	7.06	0.18	2,367	282	1.5	0.11
5Y	On	135	4.84	0.37	2,393	683	1.73	0.43
	Off	8	3.69	0.33	730	205	2.28	0.48
3Y	On	165	2.82	0.17	2,367	743	1.81	0.48
	Off	3	2.74	0.24	1,760	885	1.88	0.71
2Y	On	147	1.81	0.17	2,065	629	2.11	0.69
	Off	6	1.8	0.16	1,917	376	1.88	0.08
<2Y	On	17	0.44	0.22	2,500	901	2.57	1
	Off	12	0.63	0.31	2,208	721	2.3	0.78
7Y float	On	91	6.53	0.37	2,009	840	2.04	0.59
	Off	12	5.3	1.24	1,359	769	1.9	0.36
Other float	On	26	5.6	0.98	1,516	509	1.7	0.45
	Off	16	5.44	0.87	1,366	466	1.72	0.33
Inflation-linked	On	42	9.41	4.77	1,060	532	1.99	0.43
	Off	81	13.82	8.95	724	348	2.09	0.55

Table IX. Sample summary statistics - Secondary market variables for reopened bonds over a (-5,+5) window around reopenings. Prices are from Datastream and extend over 2000-10 and 2012-15. Trading volumes are from the MTS platform and extend over 2005-10 and 2012

Maturity	**On/off run**	**Pre-auction** Datastream in bps	**one-day**	**price change**	**Trading** MTS in €MM	**volume**	
		Obs.	**Mean**	**Std.**	**Obs.**	**Mean**	**Std.**
30Y	On	325	-8.85	64.96	845	26.32	61.38
	Off	55	-18.87	85.03	143	17.75	34.24
15Y	On	250	-6.95	62.51	650	49.15	93.13
	Off	110	-18.57	56.17	286	35.55	69.23
10Y	On	650	-1.57	86.17	1,624	127.7	205.39
	Off	180	-4.61	57.33	538	115.5	168.83
7Y	On	85	2.12	32.24	221	0	0
5Y	On	675	-0.95	51.97	1,729	83.1	147.4
	Off	40	-2.98	160.25	104	30.6	32.63
3Y	On	815	-0.37	24.7	2018	75.51	141.95
	Off	15	10.06	35.57	48	47.6	97.63
2Y	On	735	0.7	10.28	1,849	70.68	128.49
	Off	30	2.2	5.69	81	250	217.35
<2Y	On	74	0.36	9.93	221	38.87	78.03
	Off	60	0.02	5.85	156	43.32	76.52
7Y float	On	360	-1.53	13.16	1,145	82.45	133.18
	Off	60	-2.34	9.94	194	116.49	175.18
Other float	On	130	-6.49	29.84	321	30.69	75.64
	Off	80	-0.36	31.94	218	0.31	2.73
Inflation-linked	On	210	-9.87	63.62	546	31.54	54.7
	Off	405	-5.14	83.71	1,053	21.62	41.3

Table X. Sample summary statistics - Repo market variables for reopened bonds over a (-5,+5) window around reopenings (2005-10, 2012)

Maturity	**On/off run**	**Special Repo Volume** MTS Repo in €MM			**Specialness** MTS Repo in %		
		Obs.	**Mean**	**Std.**	**Obs.**	**Mean**	**Std.**
30Y	On	286	552	368	286	0.07	0.1
	Off	65	460	276	65	0.33	0.51
15Y	On	325	653	384	325	0.12	0.21
	Off	208	490	291	208	0.19	0.2
10Y	On	656	1,001	541	656	0.31	0.88
	Off	466	877	587	465	0.17	0.41
7Y	On	na	na	na	na	na	na
5Y	On	715	761	550	715	0.12	0.37
	Off	104	483	244	103	0.19	0.28
3Y	On	804	659	390	804	0.09	0.3
	Off	18	361	163	18	0.15	0.16
2Y	On	720	540	442	717	0.09	0.19
	Off	78	838	426	78	0.03	0.03
Short	On	130	53	83	123	0.52	0.78
	Off	77	72	85	76	1.21	2.07
7Y float	On	581	340	260	581	0.14	0.41
	Off	179	347	324	179	0.05	0.07
Other float	On	92	292	174	92	0.15	0.23
	Off	5	78	75	4	0.06	0.05
Inflation-linked	On	335	411	347.95	335	0.09	0.14
	Off	699	331	291	698	0.05	0.07

Appendix B. Robustness

Table XI. One day log changes in price of the reopened bond after the dealers' meeting and the auction size announcement. Reports the results of t-tests where I test the nullity of log P(t)-P(t-1), where Y(t) is the Datastream clean price for the to-be-reopened bond on day t, where t is either the day of the dealers' meeting or the day after the auction size announcement. Sample: all maturities over 2000-15, except 2011.

	Δ Clean price One-day change (%)	Δ Clean price One-day change (%)
After dealers' meeting	-0.038**	-0.037**
	(-2.51)	(-2.81)
After auction size announcement	-0.075***	-0.071***
	(-3.43)	(-3.32)
Observations	980	960
Period	2000-15 ex. 2011	2000-15 ex. 2011
Control	None	German interest rate
Cluster	None	Original maturity

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table XII. Robustness Table. One day log changes in price of the reopened bond on information days versus days without information about the Treasury's liquidity needs. Reports the log P(t)-P(t-1), where Y(t) is the Datastream clean price for the to-be-reopened bond on day t, t is one to five days away from the security's re-opening. 1_{Info} takes the value 1 if t is either the day on which the Treasury meets with dealers or the day after the announcement of the auction size. In first column, I restrict the sample to auctions of on-the-run bonds which date can be forecasted before the dealers' meeting by the econometrician using historical data. In the second column, I keep only non-information days which occur after information days. Specifically, for a given auction, I keep two non-information days: one non-information day which occur one day after the dealers' meeting, and one non-information day which occur one day after the size announcement. In some cases, there are two days separating an information and a non-information day. Also, in some cases, only one such day can be found: in those cases, I keep only one non-information day and one information day. In addition, when there is a choice as to which information day to keep, I keep the information day such that the number of days between the information and non-information days is minimal. Sample: 2000-15, except 2011.

	Δ Clean price One-day change (%)	Δ Clean price One-day change (%)	Δ Clean price One-day change (%)
1_{Info}	-0.050*	-0.055**	-0.048*
	(-1.79)	(-2.00)	(-1.80)
Observations	2,790	3,084	5,225
Sample filter	Predictable only	Early info days	None
Sample period	2000-15 ex. 11	2000-15 ex. 11	2000-15 ex. 11
Time fixed effect	Half-month	Half-month	Half-month
Other fixed effects	Maturity	Maturity	Maturity
Cluster	Auction-level	Auction-level	Day and Auction-level

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table XIII. One day log changes in price of the reopened bond. Reports the cross-section average of P(t)-P(t-1) where Y(t) is either the log clean price or the yield for the to-be-reopened bond on day t, with t=0 being the day when the note re-opening auction is conducted. Sample: 3-30 year old bonds over 2000-10. I keep only bonds with 11 non-missing yield information in the (-6,0) window. The clean price and yield come from Datastream

	Δ Clean price (%)	Δ Clean price (%)	Δ Clean price (%)	Δ Yield (bps)
t=-5 vs. t=-6	-0.040**	-0.040**	-0.036*	0.768*
	(-2.36)	(-2.13)	(-1.89)	(1.75)
t=-4 vs. t=-5	-0.010	-0.010	-0.024	-0.123
	(-0.50)	(-0.32)	(-1.34)	(-0.26)
t=-3 vs. t=-2	-0.023	-0.023	-0.024	0.227
	(-1.44)	(-1.29)	(-1.40)	(0.88)
t=-2 vs. t=-3	-0.037*	-0.037**	-0.032*	0.445*
	(-1.91)	(-1.98)	(-1.95)	(1.96)
t=-1 vs. t=-2	-0.068***	-0.068***	-0.071***	0.733***
	(-3.16)	(-2.91)	(-4.19)	(2.64)
t=0 vs. t=-1	-0.103***	-0.103***	-0.073***	1.37***
	(-5.34)	(-4.71)	(-4.10)	(6.27)
Observations	378	378	378	382
Cluster-level	Bond	Bond-Year	No	Bond
Sample maturity	3-30 Y	3-30 Y	3-30 Y	3-30 Y
Sample period	2000-10	2000-10	2000-10	2000-10
Control	No	No	German interest rate	No

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Appendix C. Proofs of Propositions

Proof of Lemma 1:

$$V_{2,i}(Z) = -exp - \left\{ \alpha_i \left(C_{1,i} + \theta_{1,i} P_2 + \frac{1}{2} \alpha_i \sigma^2 \left(\frac{\alpha_{-i}(\bar{\theta} + Z)}{\bar{\alpha}} \right)^2 \right) \right\} \tag{C1}$$

For all Z, $V_{2,i}(Z^{inf} + Z) = V_{2,i}(Z^{inf} - Z)$ where $Z^{inf} = \theta_{1,i} \frac{\bar{\alpha}}{\alpha_{-i}} - \bar{\theta}$. Therefore, $V_{2,i}(Z)$ is symmetric in Z^{inf}.

Furthermore, $\frac{V_{2,i}(Z)}{dZ}$ is positive when $Z > Z^{inf}$. Therefore, $V_{2,i}(Z)$ is an increasing and concave function of Z over $[Z^{inf}; +\infty)$.

In particular, when investors i choose their holdings at t=1 independently from the existence of an issuance at t=2, then $\theta_{1,i} = \frac{\alpha_{-i}}{\bar{\alpha}} \bar{\theta}$ and $Z^{inf} = 0$.

■

Proof of Proposition 1:

The squared term in Z in equation 10 is not normally distributed. However, using lemma 1 in Vayanos and Wang (2012), the problem can be reduced to a mean-variance problem. Specifically, I find that investor i's objective function is:

$$Max_{\theta_1} \left[W_{1,i} + \theta_{1,i}(\mathbb{E}(P_2) - P_1) - \frac{\alpha_i}{2} \left(\theta_{1,i}^2 \frac{Var(P_2)}{1 + \alpha_i^2 \alpha_{-i}^2 \bar{\alpha}^{-2} \sigma^2 \sigma_Z^2} + 2\theta_{1,i} \alpha_i \left(\frac{\alpha_{-i}}{\bar{\alpha}} \right)^2 \sigma^2 (\bar{\theta} + \bar{Z}) \frac{Cov(P_2, Z)}{1 + \alpha_i^2 \alpha_{-i}^2 \bar{\alpha}^{-2} \sigma^2 \sigma_Z^2} \right) \right] \tag{C2}$$

■

Proof of Lemma 2

$$\frac{dP_1}{d\bar{Z}} = - \frac{\alpha_A \alpha_B \sigma^2 \bar{\alpha}^3}{\bar{\alpha}^4 + \bar{\alpha}^2 \alpha_A^2 \alpha_B^2 \sigma^2 \sigma_Z^2} < 0 \tag{C3}$$

■

Proof of Proposition 2:

$$P_1^* - E(P_2) = \frac{\sigma^4 \sigma_Z^2 \alpha_A^3 \alpha_B^3 \bar{Z}}{\bar{\alpha}^3 + \bar{\alpha} \alpha_A^2 \alpha_B^2 \sigma^2 \sigma_Z^2} > 0 \tag{C4}$$

$$\frac{d(P_1 - \mathbb{E}(P_2))}{d\sigma_Z^2} = \frac{\sigma^4 \alpha_A^3 \alpha_B^3 \bar{\alpha}^3 \bar{Z}}{(\bar{\alpha} + \bar{\alpha} \alpha_A^2 \alpha_B^2 \sigma^2 \sigma_Z^2)^2} > 0 \tag{C5}$$

■

Proof of Proposition 3

First note that

$$\theta_{1,A}^{*} = \frac{-\overline{Z}}{1+\delta+\alpha^{2}\sigma^{2}\sigma_{Z}^{2}} < 0 \tag{C6}$$

which means that investor A is short-selling at t=1

$$\frac{d\delta\theta_{1,A}^{*}}{d\sigma_{Z}^{2}} = \frac{\delta\overline{Z}\alpha^{2}\sigma^{2}}{(1+\delta+\alpha^{2}\sigma^{2}\sigma_{Z}^{2})^{2}} > 0 \tag{C7}$$

$$\frac{dP_{1}}{d\sigma_{Z}^{2}} = \frac{\alpha^{3}\sigma^{4}(1+\delta)\overline{Z}}{(1+\delta+\alpha^{2}\sigma^{2}\sigma_{Z}^{2})^{2}} > 0 \tag{C8}$$

■