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 uncertain increase in the net supply of a risky asset. I show that investors face a trade-off between hedging the supply uncertainty with long positions, and speculating on the price change. Due to hedging, the equilibrium price is above the expected price. As the date of the supply shock approaches, uncertainty decreases, short speculation increases, and the price decreases. In line with the predictions, I find that meetings between the Treasury and primary dealers as well as auction announcements explain a 2.5-4.6 bps yield increase in Italian Treasuries.

JEL classification: G11, G12, E43.

Keywords: Anticipated supply shocks; Supply risk; Treasury auctions; Market making

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I. Introduction

Asset prices not only depend on current but also on future investment opportunities. These future investment opportunities are uncertain. One important example of investment opportunity is the provision of market liquidity, i.e. taking the opposite side of an investor’s trade in exchange for a price discount. In this paper, I show that uncertainty regarding opportunities to provide market liquidity can explain a series of price patterns documented in the empirical finance literature.

I develop and test a theory explaining why bond prices decrease gradually ahead of Treasury auctions (Duffie (2010), Lou, Yan and Zhang (2013)). 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. The existence of such pattern entails that the issuance cost born by the Treasury could be up to ten times as big as previously thought (Lou, Yan and Zhang (2013)).

The decreasing price pattern prior to an auction is a puzzle in that it implies that some investors are willing to buy bonds ahead of the auction at a price which, on average, exceeds the auction price. Admittedly, impatient buyers would be ready to buy at a premium before the auction rather than to wait and buy on auction day at an uncertain price. But conversely, impatient sellers would be ready to sell at a discount (Grossman and Miller (1988)). As a result, the pre-auction price should equal the expected price on auction day. Instead, the observed price pattern is such that the former exceeds the latter: Investors who buy the bond before the auction are effectively paying a premium exceeding the discount paid by sellers. There is therefore an asymmetry which this paper’s model relies on.

This model builds on Vayanos and Wang (2012) and introduces new assumptions in order to generate the pre-auction price pattern. The model’s key insight is that the gradually decreasing price pattern comes from a gradually decreasing demand for hedging the net supply risk, i.e. the uncertainty regarding the difference between the auction size and the demand from natural buyers. To test the model’s prediction, I exploit the fact that Italian sovereign bonds are issued in a staggered fashion; thus allowing to observe the secondary price of a bond prior to the bond’s auction. I also exploit the existence of meetings and announcements which decrease the bond’s net supply risk. In accordance with the prediction, I find that the yield of a bond increases
after the Treasury and primary dealers privately discuss the bond’s auction, as well as after the announcement of the auction size.

The main features of my model are as follows. There are three periods, a risky asset, a riskless asset, risk-averse liquidity traders and providers. In the third period, the assets pay off. In the second period, liquidity traders sell a certain quantity of risky asset to liquidity providers. In the first period, liquidity providers trade under uncertainty regarding the quantity bought in the second period, assumed to have a positive mean. This quantity can be interpreted as the asset’s net supply, i.e. the difference between the sale size (e.g. auction size) and the demand from natural buyers (e.g. mutual funds).\footnote{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. It has been found that there is significant variation as to who buys Treasury assets: Natural buyers may buy as much as 46% and as little as none of a given US Treasury issue at an auction (Fleming (2007))} Intuitively, the sale occurring in the second period represents a future investment opportunity for period-one investors: The larger the net supply, the larger the profits. And the more uncertain the net supply, the more uncertain this future investment opportunity.

The model’s main result is that period-one investors seek to hedge the investment opportunity of the second period with a long position. First, I find that there is a trade-off between speculating and hedging. Indeed, on the one hand, investors can speculate by shorting the asset in the first period with the hope to close their positions at a profit in the second period. On the other hand, they can hedge the first-period uncertainty of the return generated by the following strategy: Buying the asset in the second period and selling it in the third period. I find that they hedge this uncertainty by taking a long position between the first and the second periods: This is because the return between the first and the second periods is negatively correlated with the return between the second and the third periods. Second, I find that the equilibrium price is above the expected sale price due to the hedging demand. Third, as net supply uncertainty decreases, the relative share of hedging (speculative) positions decreases (increases), and thus the price decreases.

Then, I formulate a new implication: Upon the arrival of a missing piece of information about the net supply, the price should react more in cases of negative than in cases of positive information. Indeed, regardless of the nature of the information, its arrival reduces net supply uncertainty and therefore entails a price decrease. This price decrease amplifies (dampens) the price decrease (increase) due to the negative (positive) nature of the information.
Finally, I test the following corollary: When the sample contains as many negative as positive missing pieces of information, the arrival of a missing piece of information about the net supply entails a price decrease on average. To test the corollary, I use a sample consisting in 800 auctions of Italian Treasuries over 2000-2015. Conveniently, Italy issue bonds in a staggered fashion: A bond is systematically reopened (i.e. reissued) every month, until going off-the-run. Hence, this setting allows to observe the secondary price of the issued bonds before the auction. My empirical strategy consists in exploiting two pre-auction events: First, the meeting between the Italian Treasury and the primary dealers; second, the announcement of the issuance size by the Treasury. Both the dealers’ meeting and the size announcement reduce the uncertainty about net supply. As such, they can be considered as missing pieces of information about the net supply. As predicted, I find that the yield of the reopened bond increases by 2.5-4.6 bps than on non-information days. Also, I am able to exclude the on/off-the-run phenomenon (Krishnamurthy (2002)) because there is no change in on/off-the-run status in my setting.

The paper’s main contribution is to provide and test a theory explaining why prices have been documented to decrease ahead of predictable sales, in particular around Treasury auctions (Lou, Yan and Zhang (2013), Beetsma, Giuliodori, de Jong and Widijanto (2016), Keloharju, Malkamaki, Nyborg and Rydqvist (2002)). Besides Treasury auctions, the model can be adapted to fit the institutional details of other predictable sales (Rebalancings of future contracts, gold market fixes and Seasoned Equity Offerings).

It is important to understand the gradual price decrease ahead of auctions for several reasons. First, while the literature has studied prices following a large sale (Grossman and Miller (1988)), little is known about prices before a sale. Moreover, these theories of post-sale prices do not apply to pre-sale prices. For instance, Grossman and Miller (1988) assume that liquidity providers are as likely to buy as they are to sell, which does not apply to issuances. Hence, these theories explain well the post-auction price pattern but not the pre-auction pattern which is this paper’s focus. Second, the price decrease may ex-ante be due to front-running (Brunnermeier and Pedersen (2005)). Issuers would benefit from knowing whether it is indeed the case: If so, they would be better off revealing little information about the auction size rather than announce it as is common in practice (Sundaresan (1994), Admati and Pfleiderer (1991)). Third, a similar downward-and-upward price pattern has been documented in several other contexts of predictable sales: Rebalancings of future
contracts (Bessembinder, Carriott, Tuttle and Venkataraman (2016)), gold market fixes (Osler and Turnbull (2018)) and Seasoned Equity Offerings (Corwin (2003), Meidan (2005)). Understanding what happens around Treasury auctions might help to understand what happens in those other contexts as well. Finally, there is anecdotal evidence that some issuers use the market price of their outstanding securities in order to calibrate their new issuances. Failing to recognize the link between pre-auction prices and net supply uncertainty may lead some Treasury issuers to schedule a larger-than-warranted issuance in period of high uncertainty.

This paper is related to five papers: The research question is akin to Duffie (2010), Bessembinder et. al. (2016) and Beetsma et. al. (2016), while the theory shares similarities with Vayanos and Woolley (2013) and Vayanos and Wang (2012).

Duffie (2010), Bessembinder et. al. (2016), Beetsma et. al. (2016) and my paper share the same broad research question: Why do prices move prior to anticipated trades? However, they put forward a different mechanism. Concretely, in Bessembinder et. al. (2016), the agents are strategic and the price decrease may occur due to front-running. In Duffie (2010), the price gradually decreases as traders come to the market in a gradual fashion. As for Beetsma et. al. (2016), they show that the price can decrease due to market-maker limited risk capacity in a one-period model. Unlike my paper, none of these papers explain the gradual price decrease by a gradual decrease in the uncertainty about the net size of the trade. In fact, these papers do not assume the net size to be random. Therefore, their mechanisms cannot explain my paper’s empirical results.

My model is related to Vayanos and Woolley (2013) and is closest to the perfect-market benchmark in Vayanos and Wang (2012). Like my paper, these two papers feature an uncertain supply or an uncertain liquidity shock. Unlike my paper though, Vayanos and Woolley (2013) do not explore the price impact of a gradual decrease in supply uncertainty. Hence, I derive and test implications which Vayanos and Woolley (2013) do not. My model is closest to the perfect-market benchmark in Vayanos and Wang (2012). Unlike them, I test some of my empirical predictions. In addition, my model generates the downward price pattern, while Vayanos and Wang (2012) generate an upward price pattern. This is due to two assumptions. First, in my model, liquidity demanders are prevented from trading prior to the supply shock. Second, I assume that liquidity providers are more likely to buy than to sell on the date of the supply shock.

The paper proceeds as follows. Section 2 develops the model. Section 3 tests implications.
Section 4 reviews alternative explanations. Section 5 develops some conjectures in non-Treasury contexts. Section 6 discusses the policy implications. Section 7 concludes.

II. Model

A. Objective of the model

I build a model with the primary objective to rationalize why Treasury bond prices have been documented to gradually 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 gradually decreases and reaches a minimum on auction day. Duffie (2010) also studies this price pattern.

Figure 1 offers a graphical representation of the pattern around an auction: The secondary yield is seen to increase and to reach a maximum on auction date. Figure 1 is qualitatively similar to the pattern documented in Lou, Yan and Zhang (2013) but is built using a different setting and dataset which I present in detail in the empirical section of the paper. Note that the yield decreases back after the auction as illustrated in Figure 1. This phenomenon is studied in Grossman and Miller (1988) and is outside the scope of this paper.

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

B. Set-up

There are three periods (t = 1, 2, 3), a riskless and a risky assets. I use the riskless asset as numeraire. I denote by $P_t$ the price of the risky asset at time $t$.

At $t=1$, the size of the riskless and risky assets are $\eta$ and $\theta$, respectively. There is a measure one of investors with the following utility function:

$$U(W_3) = -exp\left\{-\alpha W_3\right\}$$ (1)
$W_3$ is the individual’s wealth in $t=3$ and $\alpha > 0$ is the coefficient of absolute risk aversion. Investors have an endowment $C_0$ in the risk-free asset and $\theta_0$ the risky asset at the start of $t=1$.

At $t=2$, there is an entry of new traders 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. $Z$ is determined at $t=2$ and uncertain at $t=1$ with a known distribution of $Z \sim N(Z; \sigma^2_Z)$, where $Z$ is assumed to be strictly positive.

At $t=3$, the risky asset pays off $D$ units, with $D \sim N(D; \sigma^2)$ and $D$ orthogonal to $Z$. By assumption, $P_3 = D$. Figure 2 illustrates the timing of the model.

C. Justification of the assumptions and interpretation in the Treasury auction context

Table I illustrates the interpretation of the various investors and variables in the context of Treasury auctions. First, I explain the various types of investors in the Treasury auction context. Investors are primary dealers. They absorb a quantity $Z$ of assets at the auction, where $Z$ is the net supply i.e. the share of the new issue which was not sold to "natural buyers" (e.g. foreign funds, investment funds, individuals). As for L, they are the dealers’ counterparty: L captures the behavior of the Treasury after having catered to the natural buyers.

Now I explain why it is appropriate to assume that net supply $Z$ is uncertain at $t=1$. Net supply $Z$ depends on the participation of occasional investors ("natural buyers"). Indeed, according to Fleming (2007), 40% of long-term US bond volume is bought by non-primary dealers, including foreign investors (21%) and investment funds (11%). Importantly, the share of these non-primary participants varies substantially from auction to auction, which may suggest that it is challenging to perfectly predict this demand: In the US, the share of non-primary participants has varied from 0% to 67% (Fleming (2007)). Primary dealers might not perfectly predict the demand from these investors for two reasons. First, because some of these non-primary dealers bid directly at the auction: Hence, their demand is only known after the auction. Second, the demand of those who bid through a primary dealer remains uncertain until the primary dealer has effectively collected all her clients’ orders. Even then, a given primary dealer only receives an imperfect signal of the overall demand, as each primary dealer collects a fraction of the total orders.
Finally, I justify why $Z$ is assumed to have a strictly positive average. A strictly positive average means that primary dealers are providing liquidity to the Treasury, on average. Consequently, the Treasury is issuing bonds at below-market prices on average. In practice, it seems to be the case: A majority of Treasury bonds is bought by primary dealers. These dealers require certain privileges as a mean of compensation, including a price discount (Fleming (2007), Dunes, Moore and Portes (2006)).

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. Of particular interest is the investors’ value function changes with net supply $Z$: In that regard, Lemma 1 gives some intuition about the model’s central results.

Investors maximize

$$\mathbb{E}_D \left[ - \exp \left\{ - \alpha (\theta_2 D + C_0 - (\theta_1 - \theta_0)P_1 - (\theta_2 - \theta_1)P_2) \right\} \mid \Omega_2 \right]$$

i.e. the expectation over the risky pay-off $D$, conditional on a set of information $\Omega_2$, of minus the exponential of minus the coefficient of absolute risk aversion $\alpha_i$ multiplied by the following quantity: The value $\theta_2 D$ of the total risky portfolio at $t=3$, plus the endowment in cash $C_0$ minus the cost $(\theta_1 - \theta_0)P_1$ of the additional risky position taken at $t=1$, minus the cost $(\theta_2 - \theta_1)P_2$ of the additional risky position taken at $t=2$.

I show that the demand function for the risky asset at $t=2$ of investors is

$$\theta_2^*(P_2) = \frac{\bar{D} - P_2}{\alpha \sigma^2}$$

where $\theta_2$ is the investors’ total holdings at $t=2$.

\textsuperscript{2}Alternatively, if net supply $Z$ had been assumed to have a zero mean, it would have meant that the Treasury is able to issue bonds at market prices, on average.
As for investors L, their demand function for the risky asset at t=2 is

$$\theta_{2,L}^*(P_2) = -Z$$  \hspace{1cm} (4)

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

$$\overline{\theta} = \theta_2^*(P_2^*) + \theta_{2,L}^*(P_2^*)$$  \hspace{1cm} (5)

Using (3), (4) and (5), I show that the equilibrium price for the asset at t=2 is

$$P_2^* = D - \alpha \sigma^2 (\overline{\theta} + Z)$$  \hspace{1cm} (6)

The equilibrium holdings at t=2 is

$$\theta_{2,i}^* = \overline{\theta} + Z$$  \hspace{1cm} (7)

Finally, using (2), (6) and (7), I show that the value function at t=2 is

$$V_2(Z, W_2) = -\exp \left\{ \alpha \left( W_2(Z) + \frac{1}{2} \alpha \sigma^2 (\overline{\theta} + Z)^2 \right) \right\}$$  \hspace{1cm} (8)

where $$W_2(Z) = C_1 + \theta_1 P_2(Z)$$

**Lemma 1:** Investors’ value function at t=2 is a function of Z, symmetric in a certain value $$Z_1$$ and increasing over $$[Z_1; +\infty)$$. Moreover, if $$\theta_1$$ is lower than a certain threshold, then $$Z_1 < Z$$ and the value function is concave over an interval comprising of $$[Z; +\infty)$$.

The interpretation of Lemma 1 is the following. The monotonicity and the symmetric feature of the function tell us that the more L buys or sells, the higher are the expected utilities of the investors. In addition, the concavity of the value function suggests that investors should be eager to avoid situations where net supply turns out to be smaller than expected. To that end, they should be ready to forego the extra expected utility derived from a situation where the net supply
turns out to be larger than expected. Overall, Lemma 1 gives the intuition that investors will try to hedge at \( t=1 \) the possibility that \( Z \) turns out to be smaller than \( Z \).

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.

The problem of investors consists in maximizing the expectation over \( Z \) of the value function given in Equation (8). More precisely, they choose \( \theta_1 \) such as to maximize the following:

\[
E_Z \left[ -\exp \left\{ \alpha \left( W_1 + \theta_1 \left[ D - \alpha \sigma^2 (\bar{\theta} + Z) - P_1 \right] + \frac{1}{2} \alpha \sigma^2 (\bar{\theta} + Z)^2 \right) \right\} \right] \tag{9}
\]

where \( W_1 = C_0 + \theta_0 P_1 \)

I show that the demand function of the investors is

\[
\theta_1^*(P_1) = \frac{E_Z(P_2) - P_1}{\alpha \text{Var}(P_2)/(1 + \alpha^2 \sigma^2 \sigma_Z^2)} + \alpha \sigma^2 (\bar{\theta} + Z) \frac{\text{Cov}(P_2, Z)}{\text{Var}(P_2)} \tag{10}
\]

where the second part of Equation (10) is equal to \( E_Z(\theta_2^*) \)

**Proposition 1:** Investors’ demand function for the risky asset at \( t=1 \) is composed of a speculative demand and a positive hedging demand.

Proposition 1 is based on Equation (10) 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 net supply $Z$ is a state variable which determines how lucrative the opportunity is. Hence, risk-averse liquidity providers seek to hedge these changes in investment opportunities (Merton (1973)) with an investment which negatively correlates to the state variable $Z$. 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. First, the absolute value of the speculative demand decreases in $\sigma_Z^2$. Indeed, the uncertainty about net supply $Z$ represents a cost for risk-averse investors: The higher $\sigma_Z^2$, the less willing they are to speculate. Second, the lower $\frac{Cov(P_2, Z)}{Var(P_2)}$, the higher the hedging demand. Indeed, $\frac{Cov(P_2, Z)}{Var(P_2)}$ is the “beta” of $Z$ with $P_2$: The lower the beta, the better the insurance provided by the risky asset. Third, the larger $\bar{Z}$, the larger the hedging demand. Indeed, after simplification, the hedging demand is equal to $E_Z(\theta_2^*)$. This means that investors buy in advance what they otherwise expect to buy at $t=2$. Hence, the more they expect to buy, the larger their hedging demand. Finally, the proportion of hedging increases in $\sigma_Z^2$. The proportion of hedging can be defined as the ratio between the hedging demand and the sum of the hedging demand and the absolute value of the speculative demand.

Replacing in Equation 10 the expression of $E_Z(P_2)$, $Var(P_2)$ and $Cov(P_2, Z)$ I get that investors’ demand for the asset at $t=1$ is:

$$\theta_1^*(P_1) = 1 + \frac{\alpha^2 \sigma^2 \sigma_Z^2}{\alpha^3 \sigma^4 \sigma_Z^2} (E_Z(P_2) - P_1) + E_Z(\theta_2^*)$$  \hspace{1cm} (11)$$

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

$$\theta_1^* = \bar{\theta}$$  \hspace{1cm} (12)$$
I then show that the equilibrium price for the asset at $t=1$ is

$$P_1^* = \mathbb{E}_Z(P_2) + \frac{\sigma^4 \sigma_Z^2 \alpha^3 \sigma^2 Z}{1 + \alpha^2 \sigma^2 \sigma_Z^2}$$

(13)

**Proposition 2**: The average return from investing in the risky asset between $t=1$ and $t=2$ is negative and decreases in the uncertainty about the net supply $\sigma_Z^2$.

The relationship between the uncertainty about net supply $\sigma_Z^2$ and the average return between $t=1$ and $t=2$ can be explained as such. As shown in Equation [10] investors have a speculative demand component. The speculative component makes them seek to sell when $P_1$ is above $\mathbb{E}_Z(P_2)$. As the uncertainty about net supply $Z$ decreases, speculators are seeking to short more of the risky asset and the price decreases.

Note that the link between returns and net supply uncertainty is solely driven by the speculative component of the investors’ demand function, not the hedging component. Still, one can say that the hedging demand relatively to the speculative demand decreases as uncertainty decreases. The reason why hedging does not depend on net supply uncertainty is because what drives hedging –the correlation between the return of the risky asset and net supply $Z$– is fixed and equal to -1. Had the correlation not been fixed, the hedging demand would have increased in the uncertainty about net supply $Z$, thus providing another mechanism of price decrease. Indeed, a higher uncertainty about $Z$ brings closer to -1 the correlation between $Z$ and the return of the hedging position. This means that a higher uncertainty about $Z$ increases the quality of the hedge which, in turn, increases the hedging demand, and ultimately increases the equilibrium price at $t=1$. In particular, such link between the price at $t=1$ and the uncertainty about $Z$ would exist in a setting where the price at $t=2$ of the asset used as a hedge is imperfectly correlated to the price at $t=2$ of the asset which investors seek to hedge. An example of such imperfect hedging is when investors use the off-the-run bond to hedge the price of a new bond.

**Lemma 2**: $P_1^*$ is above $\mathbb{E}_Z(P_2) - \alpha^3 \sigma^4 \sigma_Z^2 \theta$ and below $\bar{D} - \alpha \sigma^2 \bar{\theta}$. In addition, $P_1^*$ decreases in $Z$. 

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The lower-bound in Lemma 2 is the price in an economy where investors care only about one-period returns. In such economy, there would be no hedging and the price at $t=1$ would be below the expected price at $t=2$. The upper-bound is the price in an economy where the market does not expect any sale. Finally, Lemma 2 says that the price at $t=1$ decreases in the expected net supply: This is true even though the hedging demand increases in the expected net supply.

**E. Extension: Rationalizing trading and short-selling**

In this section, I modify the model in order to rationalize an empirical fact reported in the next section: Higher-than-usual trading and short-selling volumes around auctions. To that end, I introduce some heterogeneity in investment horizons. More precisely, I suppose a mass $\delta$ of short-term investors ("investors A") and a mass 1 of long-term investors ("investors B"). Investors A exit the market at $t=2$, while investors B exit the market at $t=3$. Furthermore, I suppose that the two types of investors have the same coefficient of risk-aversion. For brevity, I only give the equilibrium at $t=1$.

The equilibrium price for the risky asset at $t=1$ is

$$P^*_1 = \mathbb{E}Z(P_2) + \frac{\alpha^3\sigma_2^2\sigma_2^2 Z}{1 + \delta + \alpha^2\sigma_2^2\sigma_2^2}$$  \hspace{1cm} (14)

Investors A’s equilibrium holding of the risky asset at $t=1$ is

$$\theta^*_{1,A} = \frac{-Z}{1 + \delta + \alpha^2\sigma_2^2\sigma_2^2} < 0$$  \hspace{1cm} (15)

Investors B’s equilibrium holding of the risky asset at $t=1$ is

$$\theta^*_{1,B} = \bar{\theta} + \frac{\delta Z}{1 + \delta + \alpha^2\sigma_2^2\sigma_2^2} > 0$$  \hspace{1cm} (16)

**Proposition 3:** At $t=1$, short-term investors have a negative holding in the risky asset
(i.e. they short-sell). Furthermore, short-selling is inversely related to the uncertainty about net supply $\sigma^2_Z$.

\[ \text{F. Implications} \]

I now formulate the model’s implications. In this section, I call \textit{to-be-issued asset}, any asset with the same fundamental value as an asset which is scheduled to be issued in the near future.

\textit{Implication 1:} Before an issuance, the \textit{to-be-issued asset} trades at a price above the expected issuance price. The price 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. The predicted price pattern is documented in the empirical literature. Lou, Yan and Zhang (2013) show that, on average, the price of a on-the-run US Treasury bond is higher before the issuance of a new issue than on issuance day.

\textit{Implication 2:} Before an issuance, the arrival of a missing piece of information about the net supply entails an asymmetric change in the price of the \textit{to-be-issued asset}: 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, Proposition 2 and Lemma 2 using a dynamic interpretation of comparative statics. Indeed, the lower $\sigma^2_Z$, the lower the price before the auction, holding $\mathbb{E}(Z)$ constant.

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 net supply $Z$. First, the price should trivially reflect the information: As shown in Lemma

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Note that, in order to generate a decreasing price pattern, one would have to introduce an intermediate period (say $t=1.5$) where $\sigma^2_Z$ is scheduled to decrease.
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, upon information arrival, the price before the auction should decrease towards the expected auction price (Proposition 2). 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, one-period models of portfolio allocation would predict an opposite relationship: The price would change more in case of positive than negative information. Indeed, using comparative statics, one can show that a decrease (increase) 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 small (large) 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 corresponding to a strategy of buying to-be-issued assets before and selling them after an arrival of information about the assets’ net supplies. Suppose that there are as many positive as negative pieces of information in the sample. Then, the average sample return is negative.

The intuition for this corollary is as follows. Suppose that, in a given sample, the arrival of information about the asset’s net supply entails an asymmetric price reaction as predicted by Implication 2. For example, the price systematically increases (decreases) by 0.75 bps (1.25 bps) after the arrival of a positive (negative) piece of information. If there are as many positive as negative pieces of information, then on average the arrival of information entails a decrease of 0.25 bps. I test this corollary in the paper’s empirical section.
**Implication 3:** The difference between the pre-auction price and the expected auction price for the *to-be-issued asset* 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. 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 (e.g. mutual funds) might not be. This creates uncertainty regarding the provision of liquidity from primary dealers. On the contrary, when supply is not fixed but matches the demand observed on auction day, the uncertainty about net supply $\sigma^2_Z$ is lower. And a lower $\sigma^2_Z$ leads to a lower price difference between the first period and the intermediate period (Proposition 2).

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

Implication 4 is based on Proposition 3 using a dynamic interpretation of comparative statics. This pattern is documented in the empirical literature. Keane (1996) shows that specialness of a US Treasury bond issue increases as the auction date of a new issue approaches. Similarly, Lou, Yan and Zhang (2013) documents that the special repo rate of an old US Treasury issue is lower before than after the auction of a new issue. Finally, Sigaux (2017, chapter 1) finds that the demand for short-selling increases prior to an auction, and he rules out superior information.

### III. Tests

In the first part, I verify that the price patterns in Implications 1 and 4 are present in the data. In the second part, I test Implication 2’s corollary. The latter is this paper’s main test.

#### A. Institutional details

In Italy, two to thirty-year bonds are systematically *reopened* one or several times via an auction mechanism until reaching a certain minimum outstanding volume. Reopenings are not specific to
Italy; in particular, they also exist in the U.S. (Fleming (2002)). However, in Italy, reopenings are more systematic and extend to all medium-to-long maturities. Because the bonds are already trading on secondary markets, reopenings are an unique opportunity to observe a bond price before the bond is actually auctioned off.

This paper’s tests rely on the specificities of the Italian issuance timeline. Therefore, I now comment three important points of the issuance timeline represented in Figure 3. 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 the date of new issuances but not the reopening dates (The later are officially announced two to five days in advance). However, as indicated in Table II, the market is able to precisely predict the reopening dates for many bonds 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 on-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 dates of 2, 3, 5 and 7-year bonds can be inferred. In the paper, I assume that the market perfectly predicts all reopening dates before the official announcement. In the robustness section, I relax this assumption and keep only reopenings of on-the-run bonds for which Table II indicates a perfectly predictable pattern.

The second point of interest is the dealers’ meeting. According to a Treasury representative, the Italian Treasury organizes a meeting where the primary dealers share their views about the reopenings of the next two weeks. The meeting always occurs on the day when the Treasury is scheduled to communicate about the first issuance of the next two weeks. Interestingly, because several issuances occurring on different dates can be discussed at the same dealers’ meeting, there exists a cross-sectional heterogeneity regarding the number of days between this meeting and the reopening date. For example, a given meeting may occur five days before the reopening date of a 3-year bond while occurring only three days before the reopening date of a 2-year bond.

The final point of interest is the announcement of the auction size. Two to four days before the issuance, the Treasury announces the size of the reopening (after market close). The date of the announcement is indicated on the yearly calendar and always occurs after the dealers’ meet-
ing. The number of days separating this announcement from the reopening date depends on the bond’s maturity and the time period. For further details about the dealers’ meeting and the size announcement dates, refer to Table III.

B. Data

I study reopenings of fixed-rate 2-30 year Italian sovereign bonds over 2000-2015. I keep reopenings for which there exists yield data on Datastream for the reopened bond on the days preceding the reopening date. The largest sample is composed of 849 reopenings. The main yield data comes from Datastream (RY datatype). The yield curve data used as control comes from Bloomberg. In the preliminary check section, I also use secondary trading data and Repo data from MTS (Monte Titoli S.p.a). The secondary trading data covers the entire sample period, while the repo data covers January 2005-October 2012.

Table IV, Table V and Table VI report some summary statistics regarding the sample, including the amount sold at reopenings as well as key secondary and repo trading variables.

C. Preliminary checks

In this part, I check that the increasing yield, trading and short-selling volume patterns predicted by Implication 1 and 4 exist in the data. In detail, for each \( t \) in \((-5,+5) \setminus \{0\}\), I test for the null hypothesis \( \alpha_t = 0 \) in the following t-test specification:

\[
X_{it} - X_{i0} = \alpha_t + \epsilon_{it}
\]

where \( X_{it} \) denotes a relevant market variable (secondary yield, log of secondary trading volume, or log of special repo volume) for the to-be-reopened bond at reopening \( i \) in \( t \) business days.

I report the point estimates of \( \alpha_{-5}, \alpha_{-4}, \ldots, \alpha_{+5} \) in Table VII. The first column suggests that the yield increases gradually, and reaches a maximum on reopening day. Similarly, in the second and third column, I find that the trading volume and the special repo volume gradually increases.\(^4\) In an unreported analysis, I do not find that short-selling the bond ahead of the reopening date and

\(^4\)The volume of special repo volume is an indicator of short-selling activity
buying it on reopening day is profitable, after accounting for the repo cost of borrowing the bond: These short-selling costs might explain why the price pattern persists. Overall, Implications 1 and 4 are verified by the data. Interestingly, this paper’s setting allows to exclude the possibility that the price pattern is driven by the on/off-the-run phenomenon (Krishnamurthy (2002)). Indeed, reopenings do not entail any change in on-the-run status. In particular, an on-the-run bond does not become off-the-run once reopened.

D. Test of Implication 2’s corollary

**Empirical strategy**

My empirical strategy consists in using the dealers’ meeting and the auction size announcement as pieces of information which reduce net supply uncertainty \( \sigma_Z^2 \). Specifically, I test whether the yield increases more on these two occasions than on other days, as predicted by Implication 2’s corollary. I now justify why it is an appropriate empirical strategy. In the model, liquidity providers are uncertain about how much profit they will realize at the auction because they are uncertain about net supply \( Z \). In real life, the uncertainty about net supply \( Z \) may arise from two sources: First, uncertainty about the auction size; second, uncertainty about the demand of “natural buyers”. In the Italian setting, the auction size announcement suppresses 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. Hence, both events are good candidates for testing Implication 2’s corollary. Note that my test relies on the following assumption: There are as many positive as negative pieces of information about net supply \( Z \) over the data sample. This assumption is reasonable given that I use 16 years of reopening data.

**Test and results**

I test whether \( \beta > 0 \) (null hypothesis \( \beta = 0 \)) in the following regression:

\[
\text{Yield}_{it} - \text{Yield}_{it-1} = \beta \times 1_{\text{Info}_{it}} + \text{InterestRateControl}_t + \text{FixedEffects} + \epsilon_{it}
\]  

(18)
where \( t \) belongs to \((-5,-1)\) and denotes the number of days between an observation and the reopening date. \( 1_{Info_{it}} \) takes the value 1 if \( t \) is either the day on which the Treasury meets with dealers or the day following the announcement of the auction size for reopening \( i \); 0 otherwise. \( Yield_{i,t} \) measures the yield of the reopened bond \( t \) business days before reopening \( i \). \textit{FixedEffects} include maturity, time and days-to-auction fixed effects. \textit{InterestRateControl}_t \) include the one-day change in the main Spanish benchmark interest rates.

Table \textbf{[VIII]} gives some summary statistics and suggests that the yield indeed increases more on info than on non-info days. Table \textbf{[IX]} indicates the regression results. In the first column, I use a pooled specification and I control for one-day changes in the Spanish yield curve. Although the results are robust to removing the control, this control is designed to absorb the effect of most interest-rate and credit events. I find that the info dummy is equal to 1.27 bps and is significantly different from zero. This means that the yield increases by 1.27 bps more on each of these two information days than on non-information days. The total effect is therefore of \( 2 \times 1.27 \text{bps} = 2.54 \text{bps} \).

In the second column, I add time fixed effects at the bi-monthly-level, maturity fixed effects, and I cluster standard errors at the bi-monthly level. I find that the info dummy is still significantly different from zero and is equal to 1.28 bps.

In the third column, I control for the possibility that the information days are systematically closer to the auction date. This is an important control because Duffie (2010) predicts that the price decrease should accentuate as the auction date approaches. To control for the possibility that the results are driven by Duffie (2010), I exploit the heterogeneity in the distance between information days and reopening dates, as described in Table \textbf{[III]}. Concretely, I add fixed effects which capture the number of days that separate one observation to the auction date. I find that the info dummy is significantly different from zero and is equal to 2.32 bps. Based on this coefficient, the total effect is therefore \( 2 \times 2.32 \text{bps} = 4.64 \text{bps} \).

All in all, the total effect found ranges from 2.5 bps to 4.6 bps, depending on the presence of days-to-auction fixed effects. To put in perspective the magnitude of the effect, I gather data on the half-spread charged by dealers for buying or selling the bonds of the sample. I restrict the sample to two sub-periods due to data constraints. In 2004-2012, the half-spread using MTS data is 0.7 bps;
while the effect ranges from 2.2 to 5.4 bps. In 2009-2015, the half-spread using Datastream data is 1.1 bps; and the effect ranges from 4.1 to 7.6 bps. Hence, the effect that the model’s mechanism has on yields is at least three times as big as the half-spread charged by dealers for a buy or sell transaction.

Another way to put in perspective the magnitude of the effect is to understand how much of the pre-auction increase in yield can the model explain. I find that the average change in yield between t=-6 and t=-1 is 2.64 bps. For simplicity, to find how much of this 2.64 bps the model can explain, I run the specification reported in column 1 of Table IX without the Spanish yield control. I find that the coefficient is significant and equal to 0.93 bps. Hence, the model explains 70% (0.93 x 2 = 1.86 bps out of 2.64 bps) of the pre-auction yield phenomenon.

Overall, as predicted in Implication 2’s corollary and found in Table IX, the yield increases when net supply uncertainty decreases. The effect is statistically and economically significant.

E. Robustness

I argue that the yield increase found in Table IX comes from a reduction in uncertainty about net supply, as predicted in Implication 2’s corollary. Alternatively, the yield increase might come from the arrival of negative information. Specifically, suppose that the market does not predict that some reopenings are going to take place. Upon the dealers’ meeting or the size announcement, the market learns that these reopenings are going to take place and it revises upward its bond yield estimate. Even if these unexpected reopenings represent a small fraction of the sample, their existence has the potential to generate a yield increase on average over the sample. In order to shut down this alternative mechanism, I keep only the reopenings which date can be perfectly predicted by the econometrician using historical data. More precisely, I keep the types of bonds for which Table II indicates the existence of a predictable reopening pattern. Accordingly, the following reopenings are removed from the sample: Off-the-run bonds, 15 and 30-year bonds. Also, for each maturity, I suppress the calendar months where reopenings were infrequent: For example, I exclude the reopenings of 3 and 5-year bonds in August, November and December because there are years when no such reopenings occurred on these months. The (unreported) results are robust to these changes and are very similar to those of Table IX.
In addition, there might be periods when the market is systematically underestimating the net supply. In these periods, the yield would increase upon the dealers’ meeting and the size announcement; thus creating a bias on the results. There might also be periods where auction information is interpreted as signals about the bond’s fundamental value: The effects of these periods should be controlled for because the model relies on the assumption that information about net supply is orthogonal to the bond’s fundamental value. The primary suspect is the sovereign bond crisis. As the specification in column 2 and 3 of Table IX include time fixed effects, the effect of this period is already controlled for. Furthermore, to control for specific dynamics during this period, I interact the main right-hand side dummy with a dummy equal to one for the 2010-2012 period, and zero otherwise. In an unreported table, I find that the coefficient of interest (i.e. the non-interacted term) is still significant.

Finally, there could periods where yields are increasing for reasons that are orthogonal to reopenings, such as interest-rate and credit events: This would bias the results if, by chance, large negative events occurred on dealers’ meeting days or size announcement days. I already control for the Spanish sovereign yield curve. To the extent that Italian and Spanish yields are correlated, this set of controls should take out most of the effect coming from interest-rate and credit events. The results are robust to controlling also for the German yield curve, in addition to the Spanish yield curve. In addition, the results are robust to removing the 5% outliers of the left-hand side variable.

IV. Alternative explanations for the Treasury price pattern

My model explains why Treasury bond prices have been documented to decrease before auctions. In particular, the model rationalizes why investors agree to pay a negative return for obtaining a bond before the auction instead of buying the bond on secondary markets on auction day. In the model, the premium paid before the auction reflects the cost of hedging the possibility that the auction is a worse investment opportunity for liquidity providers than expected. In this part, I review the alternative explanations which could be considered.

First, there exist models where the premium paid reflects the informational, technological or
institutional disadvantage of the buyers. In Brunnermeier and Pedersen (2005) and Bessenbinder 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. Duffie (2010) shows that agents that only come back to the market after the auction agree to buy at a higher price the asset before the auction from agents which are permanently on the market. 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. These models do not introduce uncertainty regarding the sale price. Therefore, they cannot explain why the price decreases on average upon arrival of auction information. Also, my model differs from these models in that I suppose that any investor is aware of the auction, aware of the price pattern and able to access the secondary market on auction day.

Second, some alternative explanations are based on inventory management. In the empirical paper of Lou, Yan and Zhang (2013), the authors explain and show evidence that dealers are selling in advance their to-be-acquired participation in the auction in order to free up their risk budget. The fact that dealers are short-selling could explain a progressive drop in the price. But this rationale does not provide an explanation as to why some agents are buying from the short-sellers at the high price instead of buying later. More importantly, these models do not introduce uncertainty regarding the sale price. Therefore, they cannot explain why the price decreases on average upon arrival of auction information.

Third, there are models which explain why the price decreases after a non-predictable trade and increases afterwards (e.g. Grossman and Miller (1988)). The price decreases when the dealer buys from a customer and subsequently increases back when the dealer sells to another customer. The difference in price is a compensation to the dealer for bearing the risk of a price change between the time of the purchase and the time of the sale. This model explains well why the price increases after the auction. However, it does not address the case of a predictable trade. Therefore, the model predicts a price decrease at the time of the sale, but not before the sale. Moreover, if dealer compensation were to explain why the price at which dealers sell before an auction is above the price at which dealers buy at the auction, then the more dealers sell before the auction, the more compensation they require: Hence, the mechanism would predict a pre-auction price increase, not
a price decrease.

Finally, some alternative explanations can be drawn from the *when-issued* literature. In the empirical paper of Nyborg and Sundaresan (1996), investors trade in the when-issued market before the auction in order to be sure to get the desired quantity of new bond. While Nyborg and Sundaresan (1996) do not have a model, I argue that a model capturing Nyborg and Sundaresan (1996)’s mechanism could rationalize the price premium paid by some investors and could provide a credible alternative to my model. The model would feature a cost for failing to deliver the bond and risk-averse agents with heterogeneous levels of commitment regarding bond delivery. However, to my knowledge, such model is yet to be written.

V. Cases other than Treasury auctions

My model applies to cases where liquidity providers expect an uninformed sale of a risky asset but are uncertain about the natural demand at the time of the sale. Importantly, liquidity providers do not have to be designated (i.e. market-makers): They can also be thought as investors willing to occasionally provide market liquidity. Hence, the model also extends to the markets which are not officially intermediated.

In this section, I develop three conjectures inspired by Implication 1. In the next subsections, I explain how they relate to some findings in the empirical literature. However, I leave for future work the test of whether these empirical findings are indeed due to the model’s mechanism.

A. Conjectures

*Conjecture 1*: The price of an asset ahead of a predictable sale on the futures markets is higher than the expected sale price. It progressively decreases towards the expected sale price as the date of the sale approaches.

*Conjecture 2*: The stock price ahead of a Seasoned Equity Offering (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.

*Conjecture 3:* Conditional on the expected “fix 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. In the context of predictable trades**

Some investors roll-over their futures contracts in a predictable fashion. Bessembinder et. al. (2016) study a large ETF which tracks oil prices and invests in oil futures. On some predictable dates, the ETF sells its future contracts and invests in newer contracts. The strategy is known by the market 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 buyers on the futures market at the time of the trade might not be known in advance by would-be liquidity providers. My paper’s model can apply to this context.

A price pattern similar to that in Conjecture 1 is documented in Bessembinder et. al. (2016). In table 5 of their paper, for each day in a (-10;+10) window, they compare the cumulated one-day return of the future oil contract which is sold by the ETF (“front contract”) to the return of the contract bought (“second contract”). They find that the difference in cumulated returns is negative and becomes more and more negative as the date of the trade approaches. This means that the price of the front contract decreases as the trade date approaches, relatively to the price of the second contract.

**C. In the context of Seasoned Equity Offerings**

Seasoned Equity Offerings (SEOs) are predictable liquidations of stocks. The date of the offering is known in advance. One type of SEOs 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. This paper’s model could apply 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. Admittedly, 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.

A price pattern similar to that in Conjecture 2 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 negative. 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. Moreover, a short-selling pattern similar to that in Conjecture 2 is documented in Henry and Koski (2010). In their table 2, the mean and the median short-selling 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 in that window than on the announcement date.

D. In the context of fixing

In some markets such as the gold or the FX markets, a large part of trading is realized at particular benchmarks, called “fixes”. For example, the London Gold Fixing occurs twice each day at 10:30am and 3pm: On these two occasions, market-makers collect the orders from their clients, then communicate their demand schedules, an auction is conducted and the “fix” price clears the market (US District Court (2014); see also Hillion and Suominen (2004) for the FX market). Similarly, in the equity market, there is a large demand for trading at the close through a call auction (Hillion and Suominen (2004)). This paper’s model can apply to the contexts of fixing and of trading close in the special cases where market-makers expect that natural investors will sell on average.

A price pattern similar to that in Conjecture 3 is documented in Abrantes-Metz and Metz (2014). They find that the price of gold may decrease as the time of the fix approaches. Osler and Turnbull (2018) show that it may come from potential fraudulent manipulation of the price of gold. However, these could be compatible with portfolio management in cases where gold market-makers
expect the demand to be negative.

VI. Policy Implications

Anecdotal evidence suggests that Treasury issuers use the market price of their outstanding securities in order to calibrate their new issuances: All else equal, a high price ahead of a scheduled auction will lead the issuer to increase the issue size. Yet, one teaching of the model is that a high pre-auction price does not necessarily mean that the demand on auction day will be high. Instead, it may mean that the market is unable to precisely forecast the net supply. This can be seen in the model, in particular in Proposition 2 and in the Corollary: The higher the uncertainty, the higher the pre-auction price and the larger the price drop as the uncertainty is revealed. Failing to recognize the link between pre-auction prices and net supply uncertainty may lead Treasury issuers to schedule a larger-than-warranted issuance in period of high uncertainty.

VII. 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. While the literature has studied prices following a large sale (Grossman and Miller (1988)), little is known about prices before a sale. In the model, risk-averse investors anticipate an uncertain increase in the supply of a risky asset. I first show that investors face a trade-off: They can speculate on the difference between the pre-sale and the expected sale prices. Or they can hedge the net supply uncertainty with a long position which appreciates when net supply is small. Second, the equilibrium price is above the expected sale price due to hedging. Third, as net supply uncertainty decreases, the share of short speculative positions increases compared to hedging positions, and thus the price decreases. In line with the predictions, I find that meetings between the Treasury and primary dealers as well as auction announcements explain a 2.5-4.6 bps yield increase in Italian Treasuries.

[5] Although not directly linked to the use of the price of outstanding securities, Faulkender (2005) shows that corporate bond issuers are timing the market when choosing the maturity of their debt.
References


Nyborg, K.G. and Sundaresan, S., 1996. Discriminatory versus uniform Treasury auctions: Evi-


Appendix A. Figures

Figure 1. Reports the result of ten t-test specifications which test the null hypothesis that the secondary yield of the auctioned security t days before the auction is equal to the secondary yield on auction day, where t belongs to (-5,+5). I use 800 Italian reopenings over 2000-15. A reopening is a primary auction which results in the increase in outstanding volume of a bond that was first issued in the past. The solid line is the point estimate. The two other lines correspond to the 90% interval confidence. Secondary yield data from Datastream (RY datatype). Standard errors clustered at the maturity and daily levels.

![Graph showing secondary yield of the auctioned bond over days to/from auction.]

Figure 2. Model Timeline

- Investors know distribution of Z
- "Trading"

- Entry of L
- L sell Z to investors (Walrasian auction)
- Risky asset pays dividend D

<table>
<thead>
<tr>
<th>t=1</th>
<th>t=2</th>
<th>t=3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Figure 3.** Italian Reopenings timeline

<table>
<thead>
<tr>
<th>Start of year</th>
<th>t=−5 to −2</th>
<th>t=−4 to −2 (6pm)*</th>
<th>t=0 (11am-1pm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Issuance dates announced at the maturity-bucket level</td>
<td>Treasury meets with primary dealers</td>
<td>Reopening dates &amp; sizes officially announced</td>
<td>Auction &amp; auction results</td>
</tr>
</tbody>
</table>

Market can perfectly infer exact maturity in most cases

<table>
<thead>
<tr>
<th>Start of quarter</th>
<th>t=−1</th>
<th>t=+1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Issuance dates announced at the maturity-level for new bonds</td>
<td>Primary dealers stop collecting bids from clients</td>
<td>Dealers can buy more bonds at auction price</td>
</tr>
</tbody>
</table>

Market can perfectly infer dates for reopenings in most cases

* For 3-30Y bonds over 2000-11, the reopening date was announced two days before the announcement of the auction size*

---

**Appendix B. Tables**

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

<table>
<thead>
<tr>
<th>Model</th>
<th>Treasury auction context</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investors</td>
<td>Primary Dealers</td>
</tr>
<tr>
<td>L</td>
<td>The Treasury, after catering to Natural Buyers (foreign, investment funds, individuals)</td>
</tr>
<tr>
<td>Z</td>
<td>Net supply = Difference between issue size and demand of Natural Buyers</td>
</tr>
<tr>
<td>Z</td>
<td>Expected net supply = What Primary Dealers expect to buy at auction (&gt; 0)</td>
</tr>
<tr>
<td>Z - Z</td>
<td>Unexpected demand of Natural Buyers</td>
</tr>
</tbody>
</table>

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 > Z̄ or Z < −Z̄, Dealers provide more liquidity than expected

If −Z̄ < Z < Z̄, Dealers provide less liquidity than expected
Table II. Historical reopening frequency of Italian sovereign bonds over 2000-15. A potential exception is defined as a calendar month where there might not be any reopening because there was no reopening on that month for at least two years in the sample. A reopening is a primary auction which results in the increase in the outstanding volume of a bond which was first issued in the past.

<table>
<thead>
<tr>
<th>Maturity</th>
<th>Monthly reopening frequency</th>
<th>Part of month</th>
<th>Potential exceptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>30Y</td>
<td>Unclear</td>
<td>mid</td>
<td></td>
</tr>
<tr>
<td>15Y</td>
<td>Unclear</td>
<td>mid</td>
<td></td>
</tr>
<tr>
<td>10Y</td>
<td>1/month</td>
<td>end</td>
<td>Nov</td>
</tr>
<tr>
<td>7Y</td>
<td>1/month (2013-15)</td>
<td>mid</td>
<td>Aug, Dec</td>
</tr>
<tr>
<td>5Y</td>
<td>1/month (Q3 2000-15)</td>
<td>mid (Q3 2000-11), end (12-15)</td>
<td>Aug, Nov, Dec</td>
</tr>
<tr>
<td></td>
<td>2/month (2000-3)</td>
<td>mid + end (2000-3)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2/month (2001-Q2 02)</td>
<td>mid + end (2001-Q2 02)</td>
<td></td>
</tr>
</tbody>
</table>

Table III. Relative dates of dealers’ meeting (D) and auction size announcement (S). For example, the dealers’ meeting takes place five business days before the reopening date for 5 and 10 year bonds over 2000-11. Due to non-market holidays, there are a few exceptions to these dates. Note that the auction size announcement occurs after market close.

<table>
<thead>
<tr>
<th>Maturity</th>
<th>2000-11</th>
<th>2012</th>
<th>2013-15</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>D  S</td>
<td>D  S</td>
<td>D  S</td>
</tr>
<tr>
<td>2Y</td>
<td>t-3  t-3</td>
<td>t-2  t-2</td>
<td>t-3  t-3</td>
</tr>
<tr>
<td>5/10Y</td>
<td>t-5  t-3</td>
<td>t-4  t-3</td>
<td>t-5  t-3</td>
</tr>
<tr>
<td>3/7/15/30Y</td>
<td>t-5  t-3</td>
<td>t-4  t-3</td>
<td>t-4  t-3</td>
</tr>
</tbody>
</table>

33
Table IV. Sample summary statistics - Italian Treasury reopenings (2000-15). An on-the-run bond is defined as the most recent bond for a given maturity. The bid-cover ratio is defined as the ratio of the bid volume to the offered volume. A reopening is a primary auction which results in the increase in the outstanding volume of a bond which was first issued in the past.

<table>
<thead>
<tr>
<th>Maturity</th>
<th>On/off run</th>
<th>Obs.</th>
<th>Remaining maturity (Years)</th>
<th>Mean</th>
<th>Std.</th>
<th>Reissued amount (€MM)</th>
<th>Mean</th>
<th>Std.</th>
<th>Bid-cover ratio</th>
<th>Mean</th>
<th>Std.</th>
</tr>
</thead>
<tbody>
<tr>
<td>30Y</td>
<td>On</td>
<td>67</td>
<td></td>
<td>29.73</td>
<td>2.63</td>
<td>1,514</td>
<td>647</td>
<td>1.86</td>
<td>1.57</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Off</td>
<td>11</td>
<td></td>
<td>24.97</td>
<td>2.73</td>
<td>952</td>
<td>406</td>
<td>1.89</td>
<td>0.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15Y</td>
<td>On</td>
<td>53</td>
<td></td>
<td>14.78</td>
<td>1.68</td>
<td>1,819</td>
<td>547</td>
<td>1.63</td>
<td>0.31</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Off</td>
<td>27</td>
<td></td>
<td>11.77</td>
<td>2.30</td>
<td>1,256</td>
<td>605</td>
<td>1.74</td>
<td>0.31</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10Y</td>
<td>On</td>
<td>140</td>
<td></td>
<td>10.09</td>
<td>0.22</td>
<td>2,645</td>
<td>584</td>
<td>1.57</td>
<td>0.34</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Off</td>
<td>44</td>
<td></td>
<td>8.22</td>
<td>1.84</td>
<td>1,604</td>
<td>786</td>
<td>1.71</td>
<td>0.31</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7Y</td>
<td>On</td>
<td>17</td>
<td></td>
<td>7.06</td>
<td>0.18</td>
<td>2,367</td>
<td>282</td>
<td>1.5</td>
<td>0.11</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Off</td>
<td>8</td>
<td></td>
<td>3.69</td>
<td>0.33</td>
<td>730</td>
<td>205</td>
<td>2.28</td>
<td>0.48</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5Y</td>
<td>On</td>
<td>144</td>
<td></td>
<td>4.84</td>
<td>0.37</td>
<td>2,393</td>
<td>683</td>
<td>1.73</td>
<td>0.43</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Off</td>
<td>8</td>
<td></td>
<td>3.69</td>
<td>0.33</td>
<td>730</td>
<td>205</td>
<td>2.28</td>
<td>0.48</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3Y</td>
<td>On</td>
<td>172</td>
<td></td>
<td>2.82</td>
<td>0.15</td>
<td>2,407</td>
<td>745</td>
<td>1.79</td>
<td>0.48</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Off</td>
<td>3</td>
<td></td>
<td>2.74</td>
<td>0.24</td>
<td>1,760</td>
<td>885</td>
<td>1.88</td>
<td>0.71</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2Y</td>
<td>On</td>
<td>157</td>
<td></td>
<td>1.81</td>
<td>0.17</td>
<td>2,069</td>
<td>615</td>
<td>2.09</td>
<td>0.68</td>
<td></td>
<td></td>
</tr>
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<td>6</td>
<td></td>
<td>1.80</td>
<td>0.16</td>
<td>1,917</td>
<td>376</td>
<td>1.88</td>
<td>0.08</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table V. Sample summary statistics - Secondary market variables for reopened bonds. For each auction, the five-day pre-auction yield change is computed. Column 3, 4 and 5 reports the number of observations, the mean and the standard deviation of this measure. The five-day pre-auction yield change is defined as the difference between the yield at t=-1 and the yield at t=-5, where t=0 denotes the reopening date. Yields are from Datastream over the entire sample period (2000-15). For each auction, 11 secondary trading volume data is collected over the 11 days around the reopening date, if available. Column 6, 7 and 8 report the number of observations, the mean and the standard deviation of the trading volume, respectively. Trading volumes are from the MTS platform and are available over a subsample: April 2004-October 2012. An on-the-run bond is defined as the most recent bond for a given maturity. A reopening is a primary auction which results in the increase in the outstanding volume of a bond which was first issued in the past.

<table>
<thead>
<tr>
<th>Maturity</th>
<th>On/off run</th>
<th>Five-day pre-auction yield change (bps)</th>
<th>Daily trading volume (€MM)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Obs.</td>
<td>Mean</td>
<td>Std.</td>
</tr>
<tr>
<td>30Y</td>
<td>On</td>
<td>67</td>
<td>4.84</td>
</tr>
<tr>
<td></td>
<td>Off</td>
<td>11</td>
<td>4.57</td>
</tr>
<tr>
<td>15Y</td>
<td>On</td>
<td>53</td>
<td>3.43</td>
</tr>
<tr>
<td></td>
<td>Off</td>
<td>27</td>
<td>12.44</td>
</tr>
<tr>
<td>10Y</td>
<td>On</td>
<td>140</td>
<td>2.58</td>
</tr>
<tr>
<td></td>
<td>Off</td>
<td>44</td>
<td>12.68</td>
</tr>
<tr>
<td>7Y</td>
<td>On</td>
<td>17</td>
<td>-2.72</td>
</tr>
<tr>
<td>5Y</td>
<td>On</td>
<td>144</td>
<td>2.31</td>
</tr>
<tr>
<td></td>
<td>Off</td>
<td>8</td>
<td>5.42</td>
</tr>
<tr>
<td>3Y</td>
<td>On</td>
<td>172</td>
<td>1.57</td>
</tr>
<tr>
<td></td>
<td>Off</td>
<td>3</td>
<td>-27.41</td>
</tr>
<tr>
<td>2Y</td>
<td>On</td>
<td>157</td>
<td>3.35</td>
</tr>
<tr>
<td></td>
<td>Off</td>
<td>6</td>
<td>-1.87</td>
</tr>
</tbody>
</table>
Table VI. Sample summary statistics - Repo market variables. For each auction, 11 special Repo trading volume and specialness data is collected over the 11 days around the reopening date, if available. Column 3, 4, 5, 6 and 7 report the number of observations, the mean and the standard deviation of these measures. A Special Repo contract is a cash loan agreement where the ISIN of the bond serving as collateral is explicitly designated. Special Repo contracts are often thought to be security lending agreements. Specialness measures the cost of borrowing a security. Repo trading volumes and specialness data are from the MTS Repo platform and are available over a subsample: 2005-October 2012. An on-the-run bond is defined as the most recent bond for a given maturity. A reopening is a primary auction which results in the increase in the outstanding volume of a bond which was first issued in the past.

<table>
<thead>
<tr>
<th>Maturity</th>
<th>On/off run</th>
<th>Obs.</th>
<th>Special Repo Volume (€MM) Mean</th>
<th>Std.</th>
<th>Specialness (%) Mean</th>
<th>Std.</th>
</tr>
</thead>
<tbody>
<tr>
<td>30Y</td>
<td>On</td>
<td>264</td>
<td>556.51</td>
<td>362.25</td>
<td>0.07</td>
<td>0.09</td>
</tr>
<tr>
<td></td>
<td>Off</td>
<td>55</td>
<td>458.71</td>
<td>274.39</td>
<td>0.34</td>
<td>0.52</td>
</tr>
<tr>
<td>15Y</td>
<td>On</td>
<td>308</td>
<td>669.53</td>
<td>366.10</td>
<td>0.18</td>
<td>0.34</td>
</tr>
<tr>
<td></td>
<td>Off</td>
<td>231</td>
<td>548.13</td>
<td>342.58</td>
<td>0.28</td>
<td>0.33</td>
</tr>
<tr>
<td>10Y</td>
<td>On</td>
<td>668</td>
<td>1,006.89</td>
<td>540.78</td>
<td>0.32</td>
<td>0.89</td>
</tr>
<tr>
<td></td>
<td>Off</td>
<td>476</td>
<td>858.65</td>
<td>584.42</td>
<td>0.24</td>
<td>0.53</td>
</tr>
<tr>
<td>7Y</td>
<td>On</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>5Y</td>
<td>On</td>
<td>704</td>
<td>760.58</td>
<td>521.12</td>
<td>0.14</td>
<td>0.38</td>
</tr>
<tr>
<td></td>
<td>Off</td>
<td>88</td>
<td>485.65</td>
<td>238.41</td>
<td>0.19</td>
<td>0.29</td>
</tr>
<tr>
<td>3Y</td>
<td>On</td>
<td>767</td>
<td>655.77</td>
<td>383.98</td>
<td>0.11</td>
<td>0.31</td>
</tr>
<tr>
<td></td>
<td>Off</td>
<td>18</td>
<td>429.89</td>
<td>221.52</td>
<td>0.15</td>
<td>0.15</td>
</tr>
<tr>
<td>2Y</td>
<td>On</td>
<td>716</td>
<td>533.89</td>
<td>435.84</td>
<td>0.10</td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td>Off</td>
<td>66</td>
<td>864.26</td>
<td>435.47</td>
<td>0.03</td>
<td>0.03</td>
</tr>
</tbody>
</table>
Table VII. Preliminary check. I check that the yield, trading and Special repo volumes of the reopened bond gradually increase before the reopening day as predicted by Implication 1 and 4. The table reports the coefficients of t-test specifications which test the nullity of the difference in yield (or in log trading volume or log special repo volume) between date t and the reopening day, where t belongs to (-5,+5) and 0 denotes the reopening day. Sample: all 2-30 year fixed-rate Italian sovereign bonds reopened over 2000-15 for which yield data are available on Datastream. A reopening is a primary auction that results in the increase in the outstanding volume of a bond that was first issued in the past. t statistics in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01

<table>
<thead>
<tr>
<th></th>
<th>∆ Yield (bps)</th>
<th>∆ Trading vol. (%)</th>
<th>∆ Special Repo vol. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>t=-5 vs. t=0</td>
<td>-3.35***</td>
<td>-181.80***</td>
<td>-31.36***</td>
</tr>
<tr>
<td></td>
<td>(-3.86)</td>
<td>(-32.79)</td>
<td>(-10.96)</td>
</tr>
<tr>
<td>t=-4 vs. t=0</td>
<td>-3.60***</td>
<td>-165.32***</td>
<td>-27.94***</td>
</tr>
<tr>
<td></td>
<td>(-3.44)</td>
<td>(-30.46)</td>
<td>(-8.91)</td>
</tr>
<tr>
<td>t=-3 vs. t=0</td>
<td>-1.98***</td>
<td>-164.49***</td>
<td>-28.43***</td>
</tr>
<tr>
<td></td>
<td>(-2.85)</td>
<td>(-28.01)</td>
<td>(-12.50)</td>
</tr>
<tr>
<td>t=-2 vs. t=0</td>
<td>-1.43***</td>
<td>-153.13***</td>
<td>-23.66***</td>
</tr>
<tr>
<td></td>
<td>(-2.85)</td>
<td>(-28.44)</td>
<td>(-9.54)</td>
</tr>
<tr>
<td>t=-1 vs. t=0</td>
<td>-0.95***</td>
<td>-125.84***</td>
<td>-15.75***</td>
</tr>
<tr>
<td></td>
<td>(-3.06)</td>
<td>(-27.10)</td>
<td>(-5.89)</td>
</tr>
<tr>
<td>t=+1 vs. t=0</td>
<td>-0.99***</td>
<td>-136.43***</td>
<td>-45.71***</td>
</tr>
<tr>
<td></td>
<td>(-3.10)</td>
<td>(-26.51)</td>
<td>(-11.97)</td>
</tr>
<tr>
<td>t=+2 vs. t=0</td>
<td>-2.06***</td>
<td>-166.33***</td>
<td>-55.63***</td>
</tr>
<tr>
<td></td>
<td>(-3.85)</td>
<td>(-27.02)</td>
<td>(-21.84)</td>
</tr>
<tr>
<td>t=+3 vs. t=0</td>
<td>-3.06***</td>
<td>-165.57***</td>
<td>-55.60***</td>
</tr>
<tr>
<td></td>
<td>(-4.60)</td>
<td>(-30.96)</td>
<td>(-10.95)</td>
</tr>
<tr>
<td>t=+4 vs. t=0</td>
<td>-4.05***</td>
<td>-161.38***</td>
<td>-56.54***</td>
</tr>
<tr>
<td></td>
<td>(-4.68)</td>
<td>(-29.80)</td>
<td>(-19.36)</td>
</tr>
<tr>
<td>t=+5 vs. t=0</td>
<td>-4.27***</td>
<td>-171.63***</td>
<td>-57.06***</td>
</tr>
<tr>
<td></td>
<td>(-4.19)</td>
<td>(-30.15)</td>
<td>(-14.20)</td>
</tr>
</tbody>
</table>

Observations 849 414 396
Sample period 2000-15 2004-12 2005-12
Cluster level Bi-monthly Bi-monthly Bi-monthly
Table VIII. Reports the average daily change in yield before reopenings on info-days and on non-info days. $1_{Info}$ takes the value 1 if $t$ is either the day on which the Treasury meets with dealers or the day following the announcement of the auction size, where $t$ belongs to a (-5, -1) window before the reopening date, and 0 otherwise. The yield data comes from Datastream (RY datatype). Sample: all 2-30 year Italian sovereign bonds reopened over 2000-15. A reopening is a primary auction that results in the increase in the outstanding volume of a bond that was first issued in the past.

<table>
<thead>
<tr>
<th></th>
<th>$Yield_t - Yield_{t-1}$</th>
<th>$1_{Info} = 1$</th>
<th>$1_{Info} = 0$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Standard</td>
<td>Obs.</td>
</tr>
<tr>
<td></td>
<td>deviation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>1.106</td>
<td>11.03</td>
<td>1,609</td>
</tr>
<tr>
<td>2Y</td>
<td>0.843</td>
<td>7.07</td>
<td>325</td>
</tr>
<tr>
<td>3Y</td>
<td>0.945</td>
<td>9.89</td>
<td>329</td>
</tr>
<tr>
<td>5Y</td>
<td>1.937</td>
<td>18.17</td>
<td>273</td>
</tr>
<tr>
<td>10Y</td>
<td>0.883</td>
<td>11.59</td>
<td>355</td>
</tr>
<tr>
<td>15Y</td>
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<td>147</td>
</tr>
<tr>
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<td>0.861</td>
<td>4.35</td>
<td>146</td>
</tr>
<tr>
<td>2000-2004</td>
<td>0.230</td>
<td>7.52</td>
<td>521</td>
</tr>
<tr>
<td>2005-2009</td>
<td>0.821</td>
<td>4.45</td>
<td>440</td>
</tr>
<tr>
<td>2010-2015</td>
<td>1.862</td>
<td>14.70</td>
<td>738</td>
</tr>
</tbody>
</table>
Table IX. Main table. I test if the yield increases more after the arrival of information than on non-information days, as predicted in Implication 2’s corollary. The left-side variable is the one-day change in the yield of the reopened bond between t and t-1, where t belongs to a (-5, -1) window before the reopening date, and 0 is the reopening date. The variable of interest is $1_{Info}$ which takes the value 1 if t is either the day on which the Treasury meets with dealers or the day following the announcement of the auction size; 0 otherwise. The left-hand side yield data comes from Datastream (RY datatype). The Spanish yield curve data come from Bloomberg (I67 curve). Sample: 2-30 year fixed-rate Italian sovereign bonds reopened over 2000-15. A reopening is a primary auction that results in the increase in the outstanding volume of a bond that was first issued in the past. t statistics in parenthesis. *p < 0.10, **p < 0.05, ***p < 0.01

<table>
<thead>
<tr>
<th></th>
<th>$\Delta$ Yield</th>
<th>$\Delta$ Yield</th>
<th>$\Delta$ Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>One-day change (bps)</td>
<td>One-day change (bps)</td>
<td>One-day change (bps)</td>
</tr>
<tr>
<td>$1_{Info}$</td>
<td>1.267***</td>
<td>1.282**</td>
<td>2.319**</td>
</tr>
<tr>
<td></td>
<td>(4.24)</td>
<td>(1.98)</td>
<td>(2.32)</td>
</tr>
<tr>
<td>Observations</td>
<td>3,992</td>
<td>3,992</td>
<td>3,992</td>
</tr>
<tr>
<td>Controls</td>
<td>Spanish yield curve</td>
<td>Spanish yield curve</td>
<td>Spanish yield curve</td>
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<tr>
<td>Time fixed effect</td>
<td>None</td>
<td>Bi-monthly</td>
<td>Bi-monthly</td>
</tr>
<tr>
<td>Other fixed effects</td>
<td>None</td>
<td>Maturity</td>
<td>Maturity, Days-to-auction</td>
</tr>
<tr>
<td>Cluster</td>
<td>None</td>
<td>Bi-monthly</td>
<td>Bi-monthly</td>
</tr>
</tbody>
</table>

Appendix C. Proofs of Propositions

Proof of Lemma 1:

$$V_2(Z, W_2) = -\exp \left\{ \alpha \left( W_2(Z) + \frac{1}{2} \alpha \sigma^2(\bar{\theta} + Z)^2 \right) \right\}$$

where $W_2(Z) = C_0 + \theta_1 P_2(Z) = C_0 + \theta_1(D - \alpha \sigma^2(\bar{\theta} + Z))$

For all $Z$, $V_2(Z_1 + Z) = V_2(Z_1 - Z)$ where $Z_1 = \theta_1 - \bar{\theta}$. Therefore, $V_2(Z)$ is symmetric in $Z_1$. Furthermore, $\frac{dV_2(Z)}{dZ}$ is positive when $Z > Z_1$. Therefore, $V_2(Z)$ is an increasing function of $Z$ over $[Z_1; +\infty)$.

Finally, $\frac{d^2V_2(Z)}{dZ^2}$ is negative when $Z > Z_2$ where $Z_2 = (\theta_1 + \frac{1}{\alpha \sigma}) - \bar{\theta}$. Therefore, $V_2(Z)$ is a concave function of $Z$ over $[Z_2; +\infty)$.

In particular, when $\theta_1 < \bar{\theta} - \frac{1}{\alpha \sigma}$, then $Z_2 < 0$ and, in particular, $Z_2 < \bar{Z}$.

Proof of Proposition 1:
The squared term in $Z$ in equation [9] 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 problem is equivalent to:

$$\max_{\theta_1} \left[ W_1 + \theta_1 \left( E_z(P_2^*) - P_1 \right) - \frac{\alpha}{2} \left( \theta_1^2 \frac{\text{Var}(P_2)}{1 + \alpha^2 \sigma^2 \sigma_Z^2} + 2\theta_1 \alpha \sigma^2 (\bar{\theta} + Z) \frac{\text{Cov}(P_2, Z)}{1 + \alpha^2 \sigma^2 \sigma_Z^2} \right) \right]$$

(C2)

The following are the intermediary steps to get Equation C2. I first find that investor’s objective function is:

$$E_z \left[ - \exp \left\{ - \alpha \left( W_1 + \theta_1 \left( E_z(P_2^*) - P_1 \right) + \frac{\alpha}{2} \sigma^2 (\bar{\theta} + Z)^2 + (Z - Z) \left( - \alpha \sigma^2 \theta_1 + \alpha \sigma^2 (\bar{\theta} + Z) \right) + (Z - Z)^2 \frac{\alpha}{2} \sigma^2 \right\} \right\} \right]$$

(C3)

Using Vayanos and Wang (2012)’s notation, investors’ objective function can be written as:

$$E_z \left[ - \exp \left\{ - \alpha \left( A + (Z - Z)B + (Z - Z)^2 \frac{C}{2} \right) \right\} \right]$$

(C4)

With

$$A = W_1 + \theta_1 \left( E_z(P_2^*) - P_1 \right) + \frac{\alpha}{2} \sigma^2 (\bar{\theta} + Z)^2$$

(C5)

$$B = - \alpha \sigma^2 \theta_1 + \alpha \sigma^2 (\bar{\theta} + Z)$$

(C6)

$$C = \alpha \sigma^2$$

(C7)

Noting that $(Z - Z) \sim N(0; \sigma_Z^2)$, I can applying lemma 1 in Vayanos and Wang (2012):

$$E_z \left[ - \exp \left\{ - \alpha \left( A + (Z - Z)B + (Z - Z)^2 \frac{C}{2} \right) \right\} \right]$$

$$= - \exp \left\{ - \alpha \left( A - \frac{1}{2} \alpha B^2 \sigma_Z^2 (1 + \alpha C \sigma_Z^2)^{-1} \right) \right\} \left( 1 + \alpha C \sigma_Z^2 \right)^{-1/2}$$

(C8)

We now have a mean-variance problem. Specifically, investors’ problem is equivalent to:
\[
Max_{\theta_1} \left( \mathbb{E}_Z (A + B(Z - \bar{Z})) - \frac{1}{2} \alpha \text{Var}(A + B(Z - \bar{Z})) \right) \tag{C9}
\]

\begin{itemize}
\item 
\end{itemize}

**Proof of Proposition 2:**

\[
P_1^* - \mathbb{E}_Z(P_2) = \frac{\sigma^4 \sigma_2^2 \alpha^3 \bar{Z}}{1 + \alpha^2 \sigma^2 \sigma_2^2} > 0 \tag{C10}
\]

\[
\frac{d(P_1 - \mathbb{E}_Z(P_2))}{d\sigma_2^2} = \frac{\sigma^4 \alpha^3 \bar{Z}}{(1 + \alpha^2 \sigma^2 \sigma_2^2)^2} > 0 \tag{C11}
\]

\begin{itemize}
\item 
\end{itemize}

**Proof of Lemma 2**

In an economy where investors care only about one-period returns, CARA short-sighted investors maximize at \( t=1 \)

\[
\mathbb{E}_Z \left[ - \exp \left\{ - \alpha (\theta_1 P_2 + C_0 - (\theta_1 - \theta_0) P_1) \right\} \right| \Omega_1 \tag{C12}
\]

i.e. the expectation over net supply \( Z \), conditional on a set of information \( \Omega_1 \), of minus the exponential of minus the following quantity: The value \( \theta_1 P_2 \) of the total risky portfolio at \( t=2 \), plus the endowment in cash \( C_0 \) minus the cost \( \theta_1 - \theta_0 P_1 \) of the additional risky position taken at \( t=1 \).

This is a mean-variance problem. The equilibrium price is equal to

\[
P_{1,\text{shortsighted}}^* = \bar{D} - \alpha \sigma^2 (\bar{\theta} + Z) - \alpha^3 \sigma^4 \bar{\theta} \tag{C13}
\]

and therefore \( P_{1,\text{shortsighted}}^* < P_2^* < P_1^* \)

In addition, in an economy where investors do not expect any sale, the equilibrium price is given by setting \( Z \) equal to zero in \( \bar{D} \). More precisely, it is equal to

\[
P_{1,\text{nosale}}^* = \bar{D} - \alpha \sigma^2 \bar{\theta} \tag{C14}
\]

I find that \( P_1^* - P_{1,\text{nosale}}^* = -\frac{\alpha \sigma^2}{1 + \alpha^2 \sigma^2 \sigma_2^2} \bar{Z} < 0 \)
Finally, $P_t^*$ decreases in $Z$. Indeed:

$$\frac{dP_1}{dZ} = -\frac{\alpha \sigma^2}{1 + \alpha^2 \sigma^2 \sigma^2_Z} < 0$$ \hspace{1cm} (C15)

\[
\]

Proof of Proposition 3

First note that

$$\theta^*_{1,A} = \frac{-Z}{1 + \delta + \alpha^2 \sigma^2 \sigma^2_Z} < 0$$ \hspace{1cm} (C16)

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

$$\frac{d\delta \theta^*_{1,A}}{d\sigma^2_Z} = \frac{\delta Z \sigma^2}{(1 + \delta + \alpha^2 \sigma^2 \sigma^2_Z)^2} > 0$$ \hspace{1cm} (C17)

$$\frac{dP_1}{d\sigma^2_Z} = \frac{\alpha^3 \sigma^4 (1 + \delta) Z}{(1 + \delta + \alpha^2 \sigma^2 \sigma^2_Z)^2} > 0$$ \hspace{1cm} (C18)

\[
\]