Trading Ahead of Treasury Auctions

JEAN-DAVID SIGAUX*

January 2019

ABSTRACT

I develop and test a model explaining the gradual price decrease observed in the days leading up to anticipated asset sales such as Treasury auctions. In the model, risk-averse investors expect an uncertain increase in the net supply of a risky asset. They face a trade-off between hedging the supply uncertainty with long positions, and speculating with short positions. As a result of hedging, the equilibrium price is above the expected price. As the supply shock approaches, uncertainty decreases due to the arrival of information, investors hedge less and speculate more, and the price decreases. In line with these predictions, meetings between the Treasury and primary dealers, as well as auction announcements, explain a 2.4 bps yield increase in Italian Treasuries.

JEL classification: G11, G12, E43.
Keywords: anticipated supply shocks; supply risk; Treasury auctions; market making

*European Central Bank, Financial Research Division, Sonnemannstrasse 20, 60314 Frankfurt am Main, Germany. Email : Jean-david.sigaux@ecb.europa.eu. I am particularly indebted to Thierry Foucault, Dimitri Vayanos, Denis Gromb and Dion Bongaerts. I also benefited from comments by Geert Bekaert, Johannes Breckenfelder, Jean-Edouard Colliard, François Derrien, Darrell Duffie, Peter Hoffman, Marie Hoerova, Johan Hombert, Victoria Ivashina, Stefano Lovo, Simone Manganelli, Roberto Marfè (Discussant), Evren Örs, Clemens Otto, Christophe Perignon, Ioanid Rosu, Daniel Schmidt, Glenn Schepens, Zhaogang Song (Discussant), Christophe Spaenjers, Michael Troege, Guillaume Vuillemey, Adam Zawadowski (Discussant), conference participants at the 14th Paris December Finance Meeting, the 67th Midwest Finance Association Annual Conference, the 14th Paris December Finance Meeting, the 8th Annual Financial Market Liquidity Conference, and seminar participants at Brandeis University, Warwick Business School, Toulouse School of Economics, HEC Paris, Erasmus School of Management, the European Central Bank, BI Oslo, NHH Bergen, Dauphine University, ESCP and Audencia. Disclaimer: The views expressed do not necessarily reflect those of the European Central Bank or the Eurosystem.

I. Introduction

While the asset pricing literature has studied prices *following* large asset sales such as Treasury auctions, little is known about prices *before* a sale. In this paper, I highlight and test a new channel through which anticipated supply shocks affect asset prices in a predictable fashion. This channel can explain a series of price patterns documented in the empirical finance literature.

More precisely, I develop and test a theory explaining why bond prices decrease gradually in a predictable fashion ahead of Treasury auctions (Lou, Yan and Zhang (2013); Duffie (2010)). Lou, Yan and Zhang (2013) find that, in the few days leading up to US Treasury auctions, the price of current issues decreases gradually, reaches a minimum on auction day and then increases gradually. The existence of such patterns means that the issuance cost born by the Treasury is up to ten times larger than 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 a price asymmetry, which this paper's model generates.

The model's key insight is that the *net* supply shock resulting from the auction is *imperfectly* anticipated and leads primary dealers to have a hedging demand. This hedging demand turns out to be positive and prevents the price to adjust to the expected auction price. As the uncertainty of the shock decreases gradually, the hedging demand decreases and the price decreases gradually in a predictable fashion. More precisely, primary dealers seek to hedge the risk that the Treasury requires less liquidity than expected and offers to them a smaller-than-expected discount (*net supply risk*). This risk of lower income materializes in the case of a higher-than-expected presence of natural buyers on the auction day (e.g. insurance companies or mutual funds). On the auction day, primary dealers could recoup their income losses by selling to natural buyers assets that are in high demand, i.e. assets positively correlated with the auctioned bond. Hence, primary dealers seek to hold these assets prior to the auction, as a hedge. As the auction date approaches, uncertainty about the net supply decreases owing to the gradual arrival of information. Thus, the demand for these assets decreases and the price decreases gradually.

To test the model's prediction, I exploit the fact that an Italian sovereign bond is typically issued over several consecutive months in a staggered fashion, thus allowing the price of a given bond on the secondary market to be studied prior to the auction of this very same bond. As such, any potential on/off-the-run effect (Krishnamurthy (2002)) is absent from this setting. In addition, I exploit the existence of meetings and announcements which decrease the net supply risk. In accordance with the prediction, I find that the yield of an Italian bond increases by 2.4 bps after private meetings between the Treasury and primary dealers, and after the announcement of the auction size.

The model is in the spirit of Vayanos and Woolley (2013) and its main features are as follows. There are three periods, a risky asset (e.g. a Treasury bond), a riskless asset used as numeraire, risk-averse liquidity providers (e.g. primary dealers) and liquidity traders. In the third period, the assets pay off. In the second period, the liquidity traders sell a quantity of risky asset to the liquidity providers. In the first period, the 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 auction size and the demand from *natural buyers*. Intuitively, the sale occurring in the second period represents a future investment opportunity for the period-one liquidity providers: the larger the net supply, the larger the profits from buying in the second period and selling in the third period. And because the net supply is imperfectly anticipated, there is a *net supply risk* which creates uncertainty regarding this future investment opportunity.[1]

First, I find that period-one investors seek to hedge the net supply risk with long positions. This is because a long position between the first and second periods will have a high return precisely

[1]The uncertain net supply and the positive mean assumptions can be justified as followed. Even though issuers typically disclose in advance issuance sizes, the 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)). In addition, the inventory of Treasury dealers increases on average after auctions (Fleming and Rosenberg (2008)). This means that the Treasury fails to attract enough natural buyers, on average. Hence, the positive mean assumption.

when the net supply is low, i.e. when the return between the second and third periods is low. Second, investors also take short positions to speculate on the price difference between the first and the second periods: they seek to sell at a high price in the first period and to close their positions at a low price in the second period. Therefore there is a trade-off in period one between short speculative and long hedging positions. Third, I find that the equilibrium price is above the expected sale price as a result of the hedging demand. Fourth, as the net supply uncertainty decreases, the hedging (speculative) positions decrease (increase), and thus the price decreases. The price dynamics predicted by the model are consistent with the downward price patterns documented ahead of Treasury auctions (Lou, Yan and Zhang (2013); Beetsma, Giuliodori, de Jong and Widijanto (2016); Keloharju, Malkamaki, Nyborg and Rydqvist (2002)), as well as other anticipated sales such as seasoned equity offerings (SEOs) (Corwin (2003); Meidan (2005)), and the rebalancing of future contracts (Bessembinder, Carrion, Tuttle and Venkataraman (2016)).

Then, I formulate an implication of the model: upon the arrival of a *missing* piece of information about the net supply, the price moves more if the information indicates a larger-than-expected net supply than if it indicates a smaller-than-expected net supply. The asymmetry is due to the fact that the reduction in net supply uncertainty – which follows the arrival of missing pieces of information – always creates downward price pressure, but never upward price pressure. This downward price pressure amplifies the price decrease which trivially follows the arrival of information of a larger-than-expected net supply. Similarly, the downward price pressure dampens the price increase which follows the arrival of information of a smaller-than-expected net supply.

Finally, I test the model's implication. I use the fact that the model implies that the arrival of information about the net supply entails a price decrease, on average in a large sample. The sample consists of 849 auctions of Italian Treasuries from 2000 to 2015. Conveniently, Italy issues bonds in a staggered fashion: a bond is systematically reopened every month until going off-the-run. Hence, this setting allows the secondary price of the issued bonds to be observed before the auction. I exploit two pre-auction events: first, private meetings between the Italian Treasury and primary dealers where both parties talk about the upcoming auctions; second, announcements of issuance sizes by the Treasury. Both the dealers' meeting and the size announcement reduce the uncertainty about the net supply. As such, they can be considered as missing pieces of information. As predicted, I find that the yield of the reopened bond increases by 2.4 bps more on these two occasions than on non-information days.

It is important to study the gradual price decrease ahead of auctions for two main reasons. First, while the literature has studied prices following asset trades, little is known about prices before a trade. Moreover, these theories of *post-trade* prices do not apply to *pre-trade* prices. For instance, Grossman and Miller (1988) assume that security dealers are as likely to buy as they are to sell, which does not apply to issuances. Hence, they explain the post-auction price pattern but not the pre-auction pattern. Second, understanding what happens ahead of Treasury auctions can help the study of other anticipated trades where a similar pattern has been documented, e.g. SEOs (Corwin (2003); Meidan (2005)), and the rebalancing of future contracts (Bessembinder, Carrion, Tuttle and Venkataraman (2016)). This paper's model is general and can be adapted to fit the institutional details of these contexts as well.

This paper contributes to the theoretical literature on anticipated supply and demand shocks by highlighting a new link between these shocks and price predictability. Indeed, it is the first paper in predicting that a gradual decrease in the uncertainty of an imperfectly anticipated supply shock creates a gradual and predictable price decrease. The literature has identified four theoretical channels through which the price ahead of a supply shock stays above the expected price. My paper belongs to the fourth channel reviewed below, and develops a new prediction regarding the price dynamics. In detail, the first channel is highlighted in Bessembinder et. al. (2016) where the price ahead of an anticipated sale may be above the expected price because of the price impact of traders who sell ahead of the sale. In the same channel, Fardeau (2016) shows that the price ahead of a supply shock decreases gradually as arbitrageurs – who imperfectly compete to provide liquidity to the seller ahead of the shock – buy gradually to manage their price impact. A second channel is highlighted in Duffie (2010) where the price ahead of an anticipated sale stays above the expected price and decreases gradually as buyers arrive gradually in the market (see also Bogousslavsky (2016), among others). In a third channel, Beetsma, Giuliodori, de Jong and Widijanto (2016) use a model à la Ho and Stoll (1983), and show that the market maker sets the price higher before the auction because his risk exposure is lower than right after the auction.

My mechanism is different from these three channels as I rely on the uncertainty of the supply shock. On the contrary, the supply shock is perfectly anticipated in the first and second channel, and the third model is static. Another key difference in mechanism is that, in my model, investors are willing to hold the asset due to an endogenous hedging demand. In exchange, they accept a negative expected return. On the contrary, in the other models, those willing to buy the asset must be earning a positive expected return (in the long run). In addition, contrary to Bessembinder et. al. (2016) and the third channel, I have predictions regarding the gradual price decrease; and contrary to Fardeau (2016) and the second channel, the gradual price decrease comes from a decrease in uncertainty, and I carry empirical tests. Finally, Fardeau (2016) has a *risky arbitrage extension* where the supply shock is imperfectly anticipated, like in my model. He predicts that a decrease in the uncertainty of the supply shock would make the price increase, whereas I predict the opposite.

By focusing on imperfectly anticipated supply shocks, my model is close to Vayanos and Wang (2012) and Vayanos and Woolley (2013). In the *perfect benchmark* in Vayanos and Wang (2012), the shock is imperfectly anticipated, like in my model. However, unlike in my model, the shock has a zero mean. As a result, Vayanos and Wang (2012) do not predict that the price ahead of the shock is above the expected price (see also Lo, Mamaysky, and Wang (2004) and Huang and Wang (2009, 2010)). My paper is closest to the *symmetric case* in Vayanos and Woolley (2013) since that both papers feature an imperfectly anticipated shock with a non-zero mean. Hence, they both predict that the price ahead of the supply shock stays above the expected price due to an endogenous hedging demand. Importantly, Vayanos and Woolley (2013) does not formulate a prediction linking a gradual price decrease to a gradual decrease in the uncertainty of the shock. Therefore, my largest contribution with respect to their paper is to make that prediction. Another contribution with respect to their paper is that I carry empirical tests. In addition, the discrete-time setting of my model helps to clarify the mechanism and the role of the hedging demand.[2]

The paper also contributes to the empirical literature on anticipated supply and demand shocks by providing a test on the drivers of the price dynamics ahead of these shocks. It is the first in carrying such a test in the Treasury auction context. My paper is close to Lou, Yan and Zhang (2013) as both papers test the drivers of the observed price pattern around auctions. Lou, Yan and Zhang (2013) test whether market makers are selling in advance their auction participations, thus depressing the price. They find that the pre-auction pattern is stronger for auctions that occur

[2]Vayanos and Woolley (2013) have a continuous-time setting. The hedging mechanism is explained in the pages following the Corollary 5 of their paper. The anticipated negative shock occurs after an increase in C_t.

in periods when market makers are more constrained (see also Beetsma, Giuliodori, de Jong and Widijanto (2016)). The biggest difference between my paper and theirs is that I test the drivers of the price dynamics, instead of focusing on the drivers of the cross-section: I find that the pattern is stronger on the days of arrival of information, within a given auction. In addition, I exploit staggered auctions and remove from my sample all bonds that are about to go off-the-run; thus allowing me to more clearly reject the possibility that the pattern is driven by the on/off-the-run phenomenon (Krishnamurthy (2002)). Finally, I exploit private meetings between the primary dealers and the Treasury.[3]

The rest of this paper is organized as follows. Section 2 develops the model. Section 3 tests implications. Section 4 discusses further applications. Section 5 concludes.

II. Model

A. *Objective of the model*

I build a model that aims to rationalize why Treasury bond prices have been documented to decrease gradually before an auction. Lou, Yan and Zhang (2013) find that, in the few days ahead of an auction of a new US Treasury bond, the price of the current issue decreases gradually, reaches a minimum on auction day and reverts back. Duffie (2010) also studies this price pattern. Figure 1 offers a graphical representation of the pattern around an auction. 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.

It is well accepted that a large sale entails a temporary price pressure; i.e. an *immediate* price decrease *at the time of the sale*, followed by a slow increase. Instead, what Figure 1 shows is a *slow* price decrease *before the sale*, followed by a slow increase. The surprising part is therefore the pre-auction price dynamics, which is the focus of this paper's model. However, as discussed in Section 4, the model also explains the price reversal featured in Figure 1.

[3] My paper also belongs to the Treasury auction literature. While this paper mainly features net supply uncertainty and the existence of a pre-auction market, some papers focus on other features, such as strategic bidding behaviors (e.g. Cammack (1991); Nyborg, Rydqvist, and Sundaresan (2002)), information in the when-issued market (e.g. Nyborg, and Sundaresan (1996)), the obligation of primary dealers to participate (e.g. Fleming, Rosenberg and Joshua (2007)), primary dealers' private information (Boyarchenko, Lucca and Veldkamp (2016)), or auction design (e.g. Back and Zender (1993)).

The model is 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 supplies of the riskless and risky assets are $\bar{\eta}$ and $\bar{\theta}$, respectively. There is a mesure one of investors (simply called "Investors") with the following utility function:

$$U(W_3) = -exp\Big\{ - \alpha W_3 \Big\} \tag{1}$$

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 θ_0 in the risky asset at the start of t=1.

At t=2, there is an entry of new traders called "Liquidity Traders" (for which I use the initial "L"). L are in measure one, are infinitely risk-averse, 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 $Z \sim N(\overline{Z}; \sigma_Z^2)$, where $\overline{Z}$ is assumed to be strictly positive.

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

C. Discussion of the assumptions

Table I illustrates the interpretation of the various investors and variables in the context of Treasury auctions. 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). L captures the behavior of the Treasury after having catered to natural buyers. The model assumes that L is not present on the market before the second period. This assumption reflects the fact that the Treasury only goes to the market periodically.

Why is it appropriate to assume that net supply Z is uncertain at t=1? 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 United States, the share of non-primary participants has varied from 0% to 67% (Fleming (2007)). Primary dealers do not perfectly predict the demand from these investors for two reasons. First, 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 (Boyarchenko, Lucca and Veldkamp (2016)).

Finally, I justify why Z is assumed to have a strictly positive average. Alternatively, one could have assumed Z to have a zero mean. This depends on whether we assume the issuance to have a price impact, or not. If the issuance was unpredictable, there would necessarily be an impact: the probability of finding a natural buyer is smaller than one, so there is partially a need to trade with a dealer who charges a price discount (à la Grossman and Miller (1988)). However, issuances are predictable events. This predictability gives time to the Treasury to attract *some* natural buyers on auction day (à la Admanti and Pfleiderer (1991)). By assuming Z to have a positive mean, the model assumes that the Treasury does not succeed in attracting sufficient natural buyers on average. This failure to attract enough natural buyers is supported by empirical evidence, which shows that the inventory of Treasury dealers increases on average after auctions (Fleming and Rosenberg (2008)). Primary dealers being buyers on average, do they actually charge a risk-adjusted discount to the Treasury? They *can* because the primary dealer market is non-competitive (Bikhchandani and Huang (1993)). And the literature suggests that they indeed *choose to*, given that price discounts are found to be one of the privileges required by dealers (Fleming (2007), Dunes, Moore and Portes

(2006)).

D. Solution

I start by deriving the equilibrium at t=2. The results at t=2 are standard.

Investors maximize

$$\mathbb{E}_D\left[- exp\Big\{ - \alpha\big(\theta_2 D + C_0 - (\theta_1 - \theta_0)P_1 - (\theta_2 - \theta_1)P_2\big)\Big\} \,\Big|\, \Omega_2\right] \tag{2}$$

i.e. the expectation over the risky pay-off D (conditional on a set of information Ω_2) of the wealth at t=3 i.e. 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.

The optimal demand function for the risky asset at t=2 of investors is

$$\theta_2^*(P_2) = \frac{\overline{D} - P_2}{\alpha\sigma^2} \tag{3}$$

where θ_2 is the investors' total holdings at t=2.

As for L, their demand function for the risky asset at t=2 is

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

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

$$\bar{\theta} = \theta_2^*(P_2^*) + \theta_{2,L}^*(P_2^*) \tag{5}$$

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

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

The equilibrium holdings at t=2 is

$$\theta^*_{2,i} = \bar{\theta} + Z \tag{7}$$

Finally, using (2), (6) and (7), I obtain the value function at t=2 and Lemma 1.

Lemma 1: *Investors' value function at t=2 is a function of Z, symmetric in* $\theta_1 - \bar{\theta}$*, increasing over* $[\theta_1 - \bar{\theta}; +\infty)$*, and concave over* $[\theta_1 - \bar{\theta} + \frac{1}{\alpha\sigma}; +\infty)$

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

where $W_2(Z) = C_0 - (\theta_1 - \theta_0)P_1 + \theta_1 P_2(Z)$

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 the expected utilities of the investors who trade with L are. 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 suggests 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.

The investors' problem consists in maximizing the expectation over Z of the value function given in Equation (8). More precisely, they choose θ_1 such as to maximize the following:

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

where $W_1 = C_0 + \theta_0 P_1$

Proposition 1: *Investors' demand function for the risky asset at t=1 is composed of a speculative demand and a positive hedging demand:*

$$\theta_1^*(P_1) = -\frac{P_1 - \mathbb{E}_Z(P_2)}{\alpha Var_Z(P_2)/(1+\alpha^2\sigma^2\sigma_Z^2)} + \alpha\sigma^2(\bar{\theta}+\overline{Z})\frac{Cov(P_2,-Z)}{Var_Z(P_2)} \tag{10}$$

where $\alpha\sigma^2\frac{Cov(P_2,-Z)}{Var_Z(P_2)} = Corr(P_2,-Z) = 1$

Equation 10 offers an intuitive 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. Indeed, 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. Note that 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 the hedging demand is the following. The sale constitutes an investment opportunity for liquidity providers because they can buy cheap at t=2 and sell back at t=3. 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.

More concretely, holding the asset before the auction allows primary dealers to hedge the risk that the Treasury requires less liquidity than expected on auction day. This risk materializes in the case of a higher-than-expected presence of natural buyers on the auction day. In this case, the price of the auctioned bond is high and the discount enjoyed by primary dealers is low, which reduces their income. In this high-price situation, a primary dealer who holds the asset on auction day would make a gain and would, therefore, be able to recoup some of their income losses. Hence, primary dealers have a hedging demand for the asset prior to the auction.

Overall, Proposition 1 indicates the existence of a trade-off between short-term profits (speculating between t=1 and t=2) and hedging (decreasing the uncertainty of the future income derived from liquidity provision). It is a trade-off because hedging involves buying at t=1 and selling at t=2, while speculation involves selling at t=1 and buying back at t=2, as we shall see.

I now study some comparative statics. First, the absolute value of the speculative demand decreases in σ_Z^2. Indeed, the uncertainty about net supply Z represents a cost for risk-averse investors: the higher σ_Z^2, the less willing they are to speculate. Second, the lower $\frac{Cov(P_2,Z)}{Var_Z(P_2)}$, the higher the hedging demand. This is because $\frac{Cov(P_2,Z)}{Var_Z(P_2)}$ is the "beta" of Z with respect to P_2: the lower the beta, the better the insurance provided by the risky asset. Third, the larger $\overline{Z}$, the larger the hedging demand. Indeed, after simplification, the hedging demand is equal to $\mathbb{E}_Z(\theta_2^*)$. 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 level of hedging demand relatively to speculative demand increases in σ_Z^2.

Replacing in Equation 10 the expression of $\mathbb{E}_Z(P_2)$, $Var_Z(P_2)$ and $Cov(P_2, Z)$ I get that investors' demand for the asset at t=1 is:

$$\theta_1^*(P_1) = \frac{1 + \alpha^2\sigma^2\sigma_Z^2}{\alpha^3\sigma^4\sigma_Z^2}(\mathbb{E}_Z(P_2) - P_1) + \mathbb{E}_Z(\theta_2^*) \tag{11}$$

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

$$\theta_1^* = \bar{\theta} \tag{12}$$

Finally, using (11) and (12), I obtain the equilibrium price at t=1 and Proposition 2.

Proposition 2: *The average return from buying the risky asset at t=1 at price P_1^* and selling it at t=2 at price P_2^* is negative and decreases in the uncertainty about the net supply σ_Z^2:*

$$P_1^* = \mathbb{E}_Z(P_2) + \frac{\alpha^3\sigma^4\sigma_Z^2\overline{Z}}{1+\alpha^2\sigma^2\sigma_Z^2} \quad (13)$$

The relationship between the uncertainty of net supply σ_Z^2 and the average return between t=1 and t=2 can be explained as follows. As shown in Equation 10, investors have a speculative and a hedging demand component. The hedging component make them buy the asset, and the speculative component makes them seek to sell the asset given that P_1 is above $E_Z(P_2)$. As the uncertainty about net supply Z decreases, the ratio of hedging over speculation decreases and the price decreases. This is because, when uncertainty is low, speculation is relatively more attractive.[4]

Lemma 2: $\mathbb{E}_Z(P_2) - \alpha Var_Z(P_2)\bar{\theta} < P_1^* < \overline{D} - \alpha\sigma^2\bar{\theta}$. *In addition,* P_1^* *decreases in* $\overline{Z}$.

The lower bound in Lemma 2 is the price in an economy where investors care only about one-period returns. In such an 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.

E. Extension: rationalizing trading and short-selling

In this section, I introduce some heterogeneity in the investment horizons. More precisely, I suppose a mass δ 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. I use the upper-script *Extension*.

[4] Note that, technically, only the speculative demand moves with the net supply uncertainty. Hedging does not, because what drives hedging –the correlation between the return of the risky asset and net supply Z– is fixed and equal to -1. Still, one can say that the hedging demand relatively to the speculative demand decreases as uncertainty decreases. In a model where the hedge is imperfect (e.g. when using the off-the-run bond as a hedge), the *absolute amount* of hedging demand would decrease with uncertainty.

The equilibrium price at t=1, and the holding of investors B are:

$$P_1^{*,Extension} = \mathbb{E}_Z(P_2^{Extension}) + \frac{\alpha^3\sigma^4\sigma_Z^2\overline{Z}}{1+\delta+\alpha^2\sigma^2\sigma_Z^2} \tag{14}$$

$$\theta_{1,B}^* = \bar{\theta} + \frac{\delta\overline{Z}}{1+\delta+\alpha^2\sigma^2\sigma_Z^2} \tag{15}$$

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 σ_Z^2:*

$$\theta_{1,A}^* = \frac{-\overline{Z}}{1+\delta+\alpha^2\sigma^2\sigma_Z^2} < 0 \tag{16}$$

F. Empirical implications

I now formulate the model's empirical implications. Implications 3 and 4 are new to the literature. The mechanism driving the patterns in Implications 1 and 2 is new as well, although the patterns themselves have been predicted in a few other models. In this section, I call a *to-be-issued asset*, any asset with the same fundamental value as that of an asset scheduled to be issued in the near future.

Implication 1: *Suppose that the uncertainty about the net supply decreases gradually as the auction date approaches. Then, before the issuance, the price of the to-be-issued asset is above the expected issuance price, and it decreases gradually.*

Implication 1 is based on Proposition 2 using a dynamic interpretation of comparative statics.[5]

[5] Note that, in order to generate a decreasing price pattern in the model, one would have to introduce an intermediate period (say t=1.5) where σ_Z^2 is scheduled to decrease. This intermediate period has not been included in the model in order to keep the results in closed form. The other implications in this section are also based on comparative statics.

Lou, Yan and Zhang (2013) show that, on average, the price of an on-the-run US Treasury bond is higher before the issuance of a new issue than on issuance day.

Implication 2: *Suppose that the uncertainty about the net supply decreases gradually as the auction date approaches. Then, before the issuance, trading and short-selling volumes of the to-be-issued asset are higher than usual, and they increase gradually.*

Implication 2 is based on Proposition 3. Keane (1996) shows that specialness (an indicator of short-selling) increases as the auction date of a new issue approaches. Similarly, Lou, Yan and Zhang (2013) documents that special repo rates are lower before than after the auction of a new issue. Sigaux (2017, chapter 1) finds that the demand for short-selling increases prior to an auction, and he rules out superior information.

Implication 3: *Upon the arrival of a missing piece of information about the net supply, the price moves more if the information indicates a larger-than-expected net supply than if it indicates a smaller-than-expected net supply.*

Implication 3 is based on Proposition 2 and can be explained 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 the demand for the asset on auction day will be. These details provide information about net supply Z. The asymmetry in Implication 3 is a result of the fact that the reduction in net supply uncertainty – which follows the arrival of missing pieces of information – always creates a downward price pressure, but never an upward price pressure. This downward price pressure amplifies the price decrease which trivially follows the arrival of information of a larger-than-expected net supply. Similarly, it dampens the price increase which follows the arrival of information of a smaller-than-expected net supply.

The following is a formulation of Implication 3 in the context of a large sample, and is used in this paper's empirical section. "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 the sample is large, so that there are as many positive as negative pieces of information in the sample. Then, the average sample return is negative.". Indeed, suppose that the price systematically decreases (increases) by 1.25 bps (0.75 bps) after the arrival of information indicating a larger (smaller)-than-predicted net supply. 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. Interestingly, one-period models of portfolio allocation would predict an opposite relationship: buying before – and selling after – the arrival of information about the cash flows of an asset in positive supply would yield a positive return.

Implication 4: *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 4 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 σ_Z^2 is lower. And a lower σ_Z^2 leads to a lower price difference between the first period and the intermediate period.

III. Tests

In this section, I first check that the patterns in the data are similar to the patterns predicted in Implications 1 and 2. Then, I test the model's mechanism through a test of Implication 3.

A. Institutional details

In Italy, a sovereign bond is typically issued in a staggered fashion, over several consecutive months. More precisely, the bond is *reopened* several consecutive times on a monthly basis until reaching a certain minimum outstanding volume. For example, a two-year bond is issued on average over four months, while a ten-year bond is issued over seven months. Reopenings are not specific to Italy, for example, the US Treasury may decide to reopen a particular issue (Fleming (2002)). But few countries apply a staggered issuance process for a wide array of maturities and over many consecutive months. In particular, US reopenings are used for a limited set of bonds (ten- and 30-year bonds), a limited number times per issue (one to two) and do not always take place.

This paper's tests rely on the particular characteristics of the Italian issuance timeline. I will now discuss three important points related to that timeline, which is shown 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 latter 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, ten-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 ten-year bonds: these reopenings occur at the end of every month, on a day that is identified in advance, unless a new issuance has been scheduled on that date. Similarly, the reopening dates of two, three, five and seven-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 Treasury and 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.

The final point of interest is the announcement of the auction size. Two to four days before the issuance (after market close), the Treasury announces the size of the reopening (either the precise amount or an interval). The date of the announcement is indicated on the yearly calendar and always occurs after the dealers' meeting. The number of days separating the reopening date from the dealer meetings and the auction size announcement depends on the bond's maturity and the time period. For further details about the dealers' meeting and the size announcement dates, see Table III.

B. Data

I study reopenings of fixed-rate two to 30-year Italian sovereign bonds from 2000 to 2015. The sample also includes reopenings of off-the-run bonds. I keep reopenings for which there exists yield data on Datastream for the reopened bond on the days preceding the reopening date. Eight observations have been removed owing to data quality. The largest sample is composed of 849 reopenings. The yield data comes from Datastream (RY datatype). These are end-of-day yields based on dealer quotes. The yield curve data used as control comes from Bloomberg. I also use secondary trading data and Repo data from MTS (Monte Titoli S.p.A). The secondary trading data and repo data cover the period from 2004 to 2012 and 2005 to 2012, respectively. 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. Are the patterns in the data similar to the patterns in Implications 1 and 2?

In this part, I study the price and volume patterns present in the data. And I check that these patterns are similar to the patterns predicted in Implications 1 and 2. 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:

$$X_{n,d-t} - X_{n,d} = \alpha_t + \epsilon_{n,d-t} \tag{17}$$

where $d-t$ is the observation date, d denotes the reopening date of bond n, and t is the number of days before or after the reopening date and belongs to (-5,+5)$\setminus\{0\}$. $X_{n,d-t}$ denotes a relevant market variable (secondary yield, log of secondary trading volume, or log of special repo volume) for the reopened bond n on date $d-t$. The volume of special repo volume is an indicator of short-selling activity. The clustering is at the year-month-half level ("bi-weekly") i.e. for each month of each year, two clusters are created: one for the first half, and one for the second half of the month. This choice of clustering level is motivated by the fact that start-of-the-month auctions do not focus on the same part of the yield curve as end-of-the-month auctions (See Figure 5 and Table II).

Table VIII reports the point estimates of α_{-5}, α_{-4},...,α_{+5}. The first column suggests that the yield increases gradually, and reaches a maximum on reopening day. The output of the first column is plotted in Figure 1. Similarly, in the second and third column, I find that the trading volume and the special repo volume increases gradually. Interestingly, the empirical 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. Overall, the patterns found in the data are similar to the patterns predicted in Implications 1 and 2.

D. Test of Implication 3

Empirical strategy

The empirical strategy relies on the two following components. First, I use the dealers' meeting and the auction size announcement as arrivals of missing pieces of information which reduce net supply uncertainty σ_Z^2. Indeed, 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 practice, the uncertainty about net supply Z may arise from two sources: first, uncertainty about the auction size; and second, uncertainty about the demand of "natural buyers". In the Italian setting, during the dealers' meeting, liquidity providers are likely to acquire information about both the auction size and about what natural buyers' demand will be on auction day. In addition, the auction size announcement may contain further information about the demand of natural buyers.

Second, I exploit the size of the sample in order to circumvent some of the data requirements for testing Implication 3. Given that the sample includes 16 years of reopening data, it is reasonable to assume that there are as many positive as negative pieces of information about net supply Z in the sample. This allows to use the following formulation of Implication 3 in the context of a large sample: "Take a large 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. Then the average sample return is negative.". This formulation is convenient because it does not require data on the exact content of each pieces of information, such as the size and the sign of the surprise, or the amount of uncertainty elicited. Only the timing of arrival is needed. Consequently, I test whether the yield increases more after the dealers' meetings and the auction size announcements than on other days.

Test specification

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

$$Yield_{n,d-t} - Yield_{n,d-t-1} = \beta * \mathbb{1}^{Info}_{n,d-t} + Control^{InterestRate}_{d-t} + FE^{DaysToAuction}_{t} + FE^{Time,Maturity}_{n,d-t} + \epsilon_{n,d-t} \quad (18)$$

where

$$Control^{InterestRate}_{d-t} = \sum_{i} (InterestRate^{Spain}_{i,d-t} - InterestRate^{Spain}_{i,d-t-1})$$

$$FE^{DaysToAuction}_{t} = \sum_{days-to-auction \in (1,5)} \mathbb{1}^{days-to-auction}_{t}$$

$d - t$ is the observation date, d denotes the reopening date of bond n, t is the number of days before the reopening date and belongs to (1,5). $Yield_{n,d-t}$ measures the yield of the reopened bond n on date $d - t$. $\mathbb{1}^{Info}_{n,d-t}$ takes the value 1 if $d - t$ is either the date on which the Treasury meets with dealers to discuss the reopening of bond n, or the day following the announcement of the reopening size of bond n, 0 otherwise. $InterestRate^{Spain}_{i,d-t}$ is the benchmark interest rate in Spain of maturity i at date d-t, where i can take the value three, six, and 12 months, two to ten years, or 30 years. $FE^{DaysToAuction}_{t}$ consists of the sum of five dummies, each one indicating whether t is equal to 1, 2, 3, 4 or 5. $FE^{Time,Maturity}_{n,d-t}$ includes maturity fixed effects and time fixed effects. As justified in section C, the time fixed effects and standard error clusters are at the year-month-half level ("bi-weekly"), i.e. for each month of each year, two dummies (and clusters) are created: one for the first half, and one for the second half of the month. In the robustness section, I explore other levels.

There are two features in this specification: $Control^{InterestRate}$ and $FE^{DaysToAuction}$. First, $Control^{InterestRate}$ controls for the Spanish yield curve. Indeed, yields may move due to interest-rate or credit events such as changes in monetary policy, or changes in weaker European countries' ability to pay back their debts. These yield movements are unrelated to the model's mechanism and should be controlled for. The ideal control variable should be left unaffected by the demand for specific Italian bonds around auctions, but should be affected by the same interest-rate and credit events as the Italian bonds. Said differently, arbitrageurs should find it too expensive to close the price gap between the control variable and specific Italian bonds around auctions. But the "natural" demand for the control variable should react the same way as for Italian bonds around interest-rate and credit events. The Spanish yield curve is a prime candidate. First, the benchmark interest-rate of a given maturity being computed as a function of several Spanish bonds, buying (or selling) these bonds while selling (or buying) a specific Italian bond of the same maturity will prove expensive in terms of transaction and short-selling costs. In particular, the benefit-cost ratio for arbitrageurs is much lower than with the Italian yield curve since that the Italian curve includes the to-be-auctioned bonds. In addition, as one of the GIIPS countries (Greece, Ireland, Italy, Portugal and Spain), Spain's debt shares many fundamental characteristics with Italy's and is therefore likely to be affected by the same events. Table VII shows the correlation between the Italian yield curve and the yield curves of several other European countries over the sample time period.

Second, $FE^{DaysToAuction}$ controls for the number of days between the observation and the auction date ("days to auction"). Indeed, Duffie (2010) predicts that the decrease in price accentuates as the auction date approaches. More generally, the days to auction may matter for the yield dynamics, but this is not one of my model's predictions. As suggested by Figure 4, information and non-information days systematically differ in terms of the number of days that separate them from the auction. Hence, in absence of controls, β will be biased because it will capture effects that are unrelated to the model's mechanism. To properly test Implication 3, one should measure the effect of the arrival of information while fixing the number of days between the observation and the auction date. This is made possible by the existence of heterogeneity in the days to auction, as described in Table III: there is heterogeneity across maturities, across time periods and also within a given maturity-time. $FE^{DaysToAuction}$ exploits this feature.

Test results

The regression results are reported in Table IX. The first column reports the result of a pooled specification. As predicted, I find that the info dummy is significantly different from zero. It is equal to 1.20 bps. This means that the yield increases by 1.20 bps more on each of these two information days than on non-information days, while controlling for the days to auction. The total effect is therefore of 2 x 1.20 bps = 2.40 bps. In the second column, I cluster the standard errors, I add the time and maturity fixed effects, while keeping the days to auction dummies (the corresponding coefficients are not reported). The coefficient of interest is still statistically different from zero and its magnitude is largely unchanged.

One way to put the magnitude of the effect into perspective is to understand how much of the pre-auction increase in yield the model can explain. To that end, I turn to column 1 in Table IX. The change in yield between t=-6 and t=-1 without the effect of information can be approximatively computed as the sum of the day-to-auction coefficients plus five times the constant. It is therefore of 0.72 bps. When adding the effect of information, the change in yield between t=-6 and t=-1 is equal to 3.12 bps (0.72 + 2 x 1.20). The model can therefore explain 2 x 1.20 / 3.12 = 77% of the pre-auction increase in yield between t=-6 and t=-1. How can one reconcile this back-of-the-envelope calculation with the fact that the change in yield seems to be evenly distributed across days in Figure 1? The dummies in Table IX tell us that, in a world without the arrival of information, the pattern would not be smooth: in fact, the pattern would be flat between t=-6 and t=-5, and between t=-3 and t=-2. Since that t=-5 and t=-2 are –more often than not– information days, the yield increases on these two days by an amount close to the info-dummy coefficient. Hence, the smooth pattern.

Another way to put the magnitude of the effect into perspective is to compare it to a benchmark. One potential benchmark is the transaction cost. Indeed, given that bond returns are typically low, transaction costs are an important parameter for bond investors. If the model's effect is of the same magnitude as transaction costs, it would indicate that the effect is economically large. I restrict the sample to the period from 2004 to 2015 due to data constraints. I compute from Datastream (or from MTS when not available) spreads, expressed in yield basis points. From 2004 to 2015, the half-spread is 0.96 bps. I run the same specification in column 2 of Table IX and find the model's effect to be equal to 2 x 1.32bps = 2.64bps. Hence, the effect of the model's mechanism is 2.8 times larger than the half-spread charged by dealers for a transaction.

Overall, as predicted by Implication 3 in the context of a large sample, the yield increases on average with the arrival of information about the net supply. The effect is statistically and economically significant.

E. Robustness

One may seek to better control for the sovereign bond crisis period. Indeed, 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, but not because of the drop in uncertainty as featured in the model. There might also be periods where auction information is interpreted as signals about the bond's fundamental values, whereas the model relies on the assumption that information about net supply is orthogonal to the bond's fundamental value. The sovereign bond crisis is a main suspect where there might be both underestimation of net supply and correlation between net supply and fundamental value. The effect of this period is already controlled for by the time fixed effects. To control for specific dynamics during this period, I interact the main right-hand side dummy with a dummy equal to one for the period from 2010 to 2012, and zero otherwise. The results are shown in the column 1 of Table X. I find that the coefficient of interest (the non-interacted term) is still significant. Note that the coefficient corresponding to the crisis dummy is absorbed by the time fixed effects.

So far, the two information events are pulled together. Except in the extreme case where the uncertainty is always fully revealed after one of these events, the model predicts that the yield increases on average after both the dealer meeting and the auction size announcement. Column 2 in Table X shows the result of a specification that includes two dummies, one for each of the events. I find that the coefficient of each of these dummies is significant and equal to 1.13bps for the dealers meeting and 1.58bps for the auction size announcement.

The yield increase might come from the inability of the market to predict some reopenings. In that case, upon the dealers' meeting or the size announcement, the market learns that these reopenings are going to take place and it revises its bond yield estimates upward. This is different from the model's mechanism where the auction date is known in advance and the yield increase comes from uncertainty elicitation. In order to shut down this alternative mechanism, I only keep the reopenings whose dates 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. The results are shown in the column 1 of Table XI and are robust to these changes.

I perform some additional robustness tests. First, I use month-level fixed effects and clusters, instead of bi-weekly. The result is reported in column 2 of Table XI. Second, I add auction fixed effects. Third, I add week-day fixed effects. Fourth, I use log changes in clean prices instead of using yields, the prediction being that the coefficient of interest is negative. The results are robust to all these changes. In addition, Figure 6 reproduces the yield pattern plotted in Figure 1 while controlling for the movements in the Spanish yield curve.

IV. Discussion

This section discusses the application to non-Treasury markets. The model applies to cases where liquidity providers expect a sale of risky assets but are uncertain about the natural demand at the time of the sale. Importantly, liquidity providers do not have to be designated; they can also be thought of as investors willing to occasionally provide market liquidity. Hence, the model also extends to the markets which are not officially intermediated. This section also discusses post-auction price recovery.

A. Application to Seasoned Equity Offerings

SEOs are anticipated liquidations of stocks. The date of the offering is known in advance. One type of SEOs is known as "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 can apply to this context. Admittedly, an 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 an SEO about the stock's fundamental value.

Conjecture 1: *Suppose that the uncertainty about the net supply of a stock decreases gradually as the date of a SEO approaches. Then, before the SEO, the stock price is higher than the offer price, and it decreases gradually. In addition, the short-selling volume is larger than usual and increases gradually.*

Patterns similar to that in Conjecture 1 are documented in Corwin (2003), Meidan (2005) and Henry and Koski (2010). In figure 2 in Corwin (2003), the author shows that there is a negative cumulative abnormal return of holding the stock five days before the SEO and selling it one day before SEO day. Table 1 in Meidan (2005) shows a similar pattern. Moreover, in table 2 of Henry and Koski (2010), 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.

B. Application to predictable trades of futures contracts

Some investors roll-over their futures contracts in a predictable fashion. Bessembinder et al. (2016) study a large exchange-traded fund (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. It is possible that 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.

Conjecture 2: *Suppose that the uncertainty about the demand for a futures contract decreases gradually as the date of a predictable sale on the futures markets approaches. Then, before the sale date, the price of the futures is higher than the expected sale price, and it decreases gradually.*

A price pattern similar to that in Conjecture 2 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, relative to the price of the second contract.

C. Post-auction price recovery

This paper's model predicts also the post-auction price recovery. Indeed, the larger the net supply in Period 2, the larger the average price increase between Period 2 and Period 3 (Equation (6)). To make this point clearer, one could consider an extension of the model. The extension would feature an intermediate Period 2.5 where the net supply decreases by an (uncertain) amount Z, back to the initial level $\bar{\theta}$. To understand why this extension predicts the price reversal, one can take the current model, relabel Period 1, Period 2 and Z as Period 2, Period 2.5 and -Z, respectively. We now have a setting where the net supply decreases by an amount of Z between Period 2 and Period 2.5. Plugging these changes into Equation (13) gives the following equilibrium result: $P_2 < \mathbb{E}(P_{2.5})$, i.e. the price increases on average between Period 2 and Period 2.5.

V. Conclusion

In this paper, I highlight and test a new channel through which anticipated supply shocks affect asset prices in a predictable fashion ahead of the shock. This paper is the first in predicting that a gradual decrease in the uncertainty of an imperfectly anticipated supply shock creates a gradual and predictable price decrease. It is also the first in testing the drivers of the price dynamics ahead of Treasury auctions. More precisely, I develop and test a model explaining the gradual price decrease observed in the days leading to anticipated asset sales such as Treasury auctions. The model's key insight is that the *net* supply shock resulting from an auction is *imperfectly* anticipated and leads primary dealers to have a hedging demand. This hedging demand turns out to be positive and prevents the price to adjust to the expected auction price. As the uncertainty of the shock decreases gradually, the hedging demand decreases and the price decreases gradually in a predictable fashion. In line with the predictions, and in a context where the on/off-the-run effect is absent, I find that meetings between the Treasury and primary dealers as well as auction announcements explain a 2.4 bps yield increase in Italian Treasuries.

References

Back, K. and Zender, J.F., 1993. Auctions of divisible goods: on the rationale for the treasury experiment. The Review of Financial Studies, 6(4), pp.733-764.

Beetsma, R., Giuliodori, M., De Jong, F. and Widijanto, D., 2016. Price effects of sovereign debt auctions in the Euro-zone: the role of the crisis. Journal of Financial Intermediation, 25, pp.30-53.

Bessembinder, H., Carrion, A., Tuttle, L. and Venkataraman, K., 2016. Liquidity, resiliency and market quality around predictable trades: Theory and evidence. Journal of Financial Economics, 121(1), pp.142-166.

Bikhchandani, S. and Huang, C.F., 1993. The economics of treasury securities markets. Journal of Economic Perspectives, 7(3), pp.117-134.

Bogousslavsky, V., 2016. Infrequent rebalancing, return autocorrelation, and seasonality. The Journal of Finance, 71(6), pp.2967-3006.

Boyarchenko, N., Lucca, D.O. and Veldkamp, L., 2016. Taking orders and taking notes: dealer information sharing in financial markets. Federal Reserve Bank of New York Staff Reports, (725).

Cammack, E.B., 1991. Evidence on bidding strategies and the information in Treasury bill auctions. Journal of Political Economy, 99(1), pp.100-130.

Corwin, S.A., 2003. The determinants of underpricing for seasoned equity offers. The Journal of Finance, 58(5), pp.2249-2279.

Duffie, D., 2010. Presidential Address: Asset Price Dynamics with Slow Moving Capital. The Journal of Finance, 65(4), pp.1237-1267.

Fardeau, V., 2016. Dynamic Strategic Arbitrage.

Fleming, M.J., 2002. Are larger treasury issues more liquid? Evidence from bill reopenings. Journal of Money, Credit and Banking, pp.707-735.

———, 2007. Who Buys Treasury Securities at Auction? Current Issues in Economics and Finance, 13(1), p.1.

Fleming, M. and Rosenberg, J., 2008. How do Treasury dealers manage their positions?

Gao, X. and Ritter, J.R., 2010. The marketing of seasoned equity offerings. Journal of Financial Economics, 97(1), pp.33-52.

Grossman, S.J. and Miller, M.H., 1988. Liquidity and market structure. the Journal of Finance, 43(3), pp.617-633.

Henry, T.R. and Koski, J.L., 2010. Short selling around seasoned equity offerings. Review of Financial Studies, 23(12), pp.4389-4418.

Ho, T.S. and Stoll, H.R., 1983. The dynamics of dealer markets under competition. The Journal of finance, 38(4), pp.1053-1074

Huang, J. and Wang, J., 2009. Liquidity and market crashes. The Review of Financial Studies, 22(7), pp.2607-2643.

———, 2010. Market liquidity, asset prices, and welfare. Journal of Financial Economics, 95(1), pp.107-127.

Keane, F., 1996. Repo rate patterns for new Treasury notes. Federal Reserve Bank of New York Current Issues in Economics and Finance, 2(10).

Keloharju, M., Malkamki, M., Nyborg, K.G. and Rydqvist, K., 2002. A descriptive analysis of the Finnish treasury bond market 1991-1999.

Krishnamurthy, A., 2002. The bond/old-bond spread. Journal of financial Economics, 66(2), pp.463-506.

Lo, A.W., Mamaysky, H. and Wang, J., 2004. Asset prices and trading volume under fixed transactions costs. Journal of Political Economy, 112(5), pp.1054-1090.

Lou, D., Yan, H. and Zhang, J., 2013. Anticipated and repeated shocks in liquid markets. The Review of Financial Studies, 26(8), pp.1891-1912.

Meidan, D., 2005. A re-examination of price pressure around seasoned equity offerings.

Merton, R.C., 1973. An intertemporal capital asset pricing model. Econometrica: Journal of the Econometric Society, pp.867-887.

Nyborg, K.G., Rydqvist, K. and Sundaresan, S.M., 2002. Bidder behavior in multiunit auctions: Evidence from Swedish Treasury Auctions. Journal of Political Economy, 110(2), pp.394-424.

Nyborg, K.G. and Sundaresan, S., 1996. Discriminatory versus uniform Treasury auctions: Evidence from when-issued transactions. Journal of Financial Economics, 42(1), pp.63-104.

Sigaux, J.D, 2017. Are Short-Sellers of Sovereign Bonds Informed About Auctions? Doctoral thesis, chapter 1.

TreasuryDirect, 2016. http://www.treasurydirect.gov.

Vayanos, D. and Wang, J., 2012. Liquidity and asset returns under asymmetric information and imperfect competition. Review of Financial Studies, 25(5), pp.1339-1365.

Vayanos, D. and Woolley, P., 2013. An institutional theory of momentum and reversal. Review of Financial Studies, 26(5), pp.1087-1145.

Appendix A. Figures

Figure 1. Yield pattern around auctions. 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). The sample is composed of 849 Italian reopenings from 2000 to 2015. 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 are clustered at the year-month-half ("bi-weekly") level: each month of each year is divided into a first and a second half.

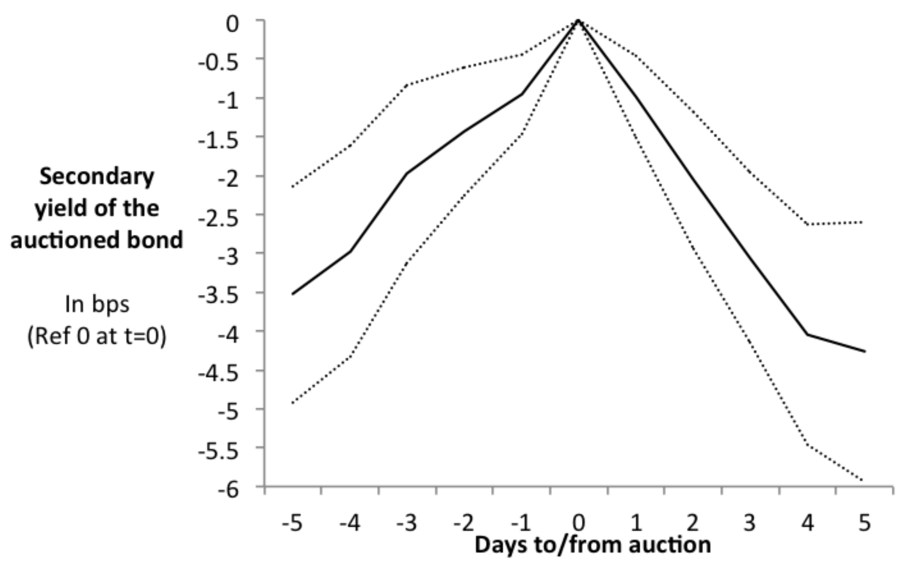


Figure 2. Model timeline

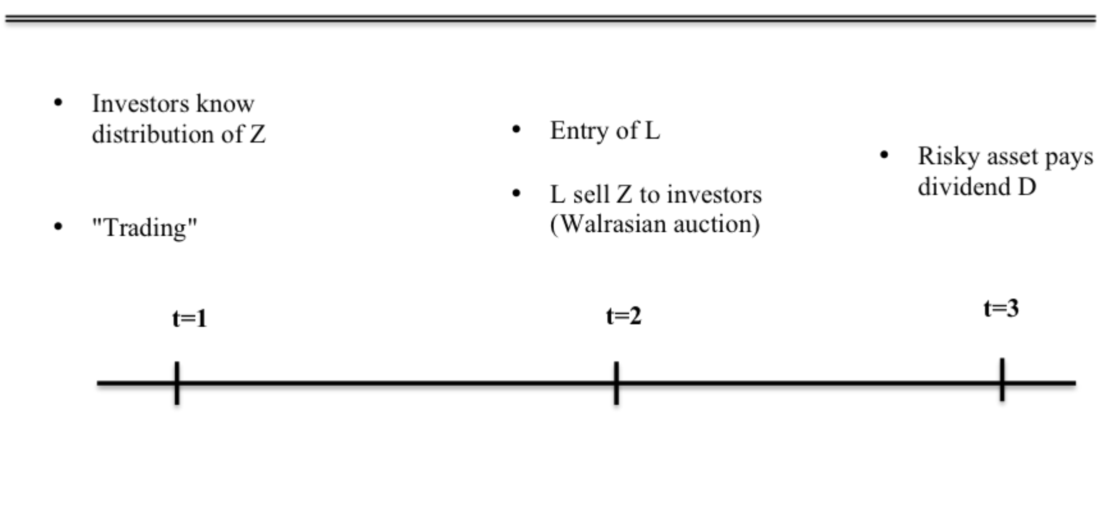
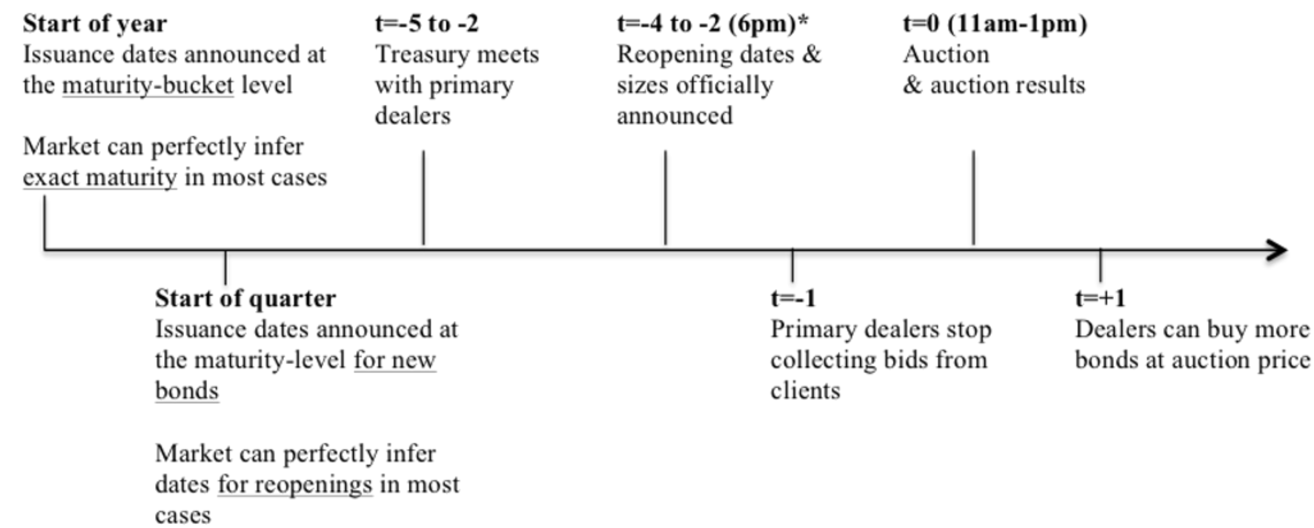


Figure 3. Italian reopenings timeline



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

Figure 4. Distribution of observations across days-to-auction

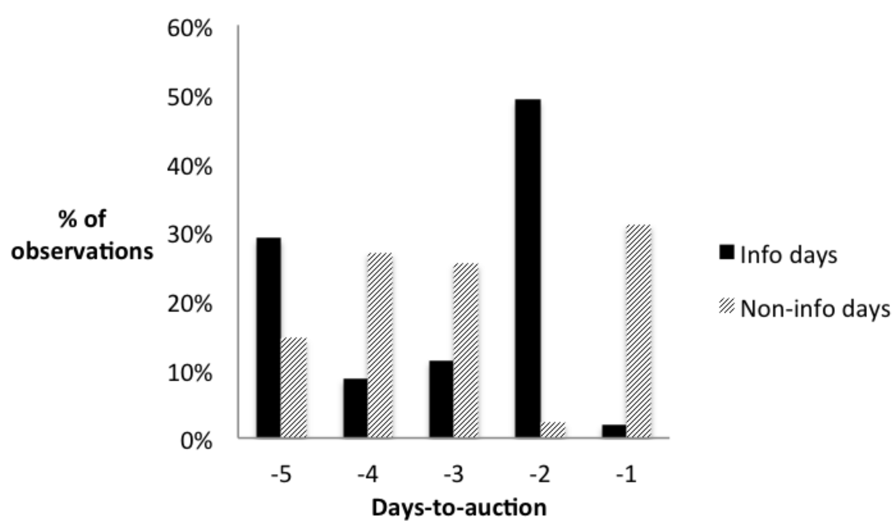


Figure 5. Distribution of observations within the month

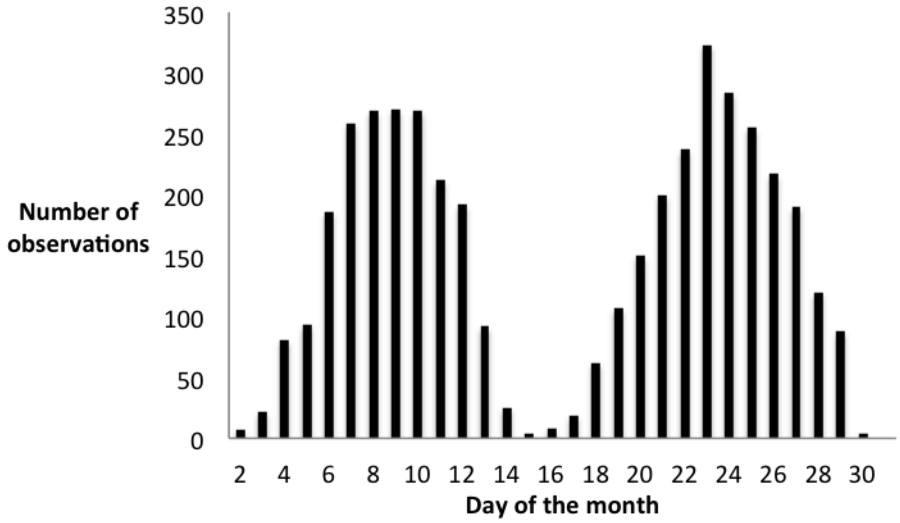
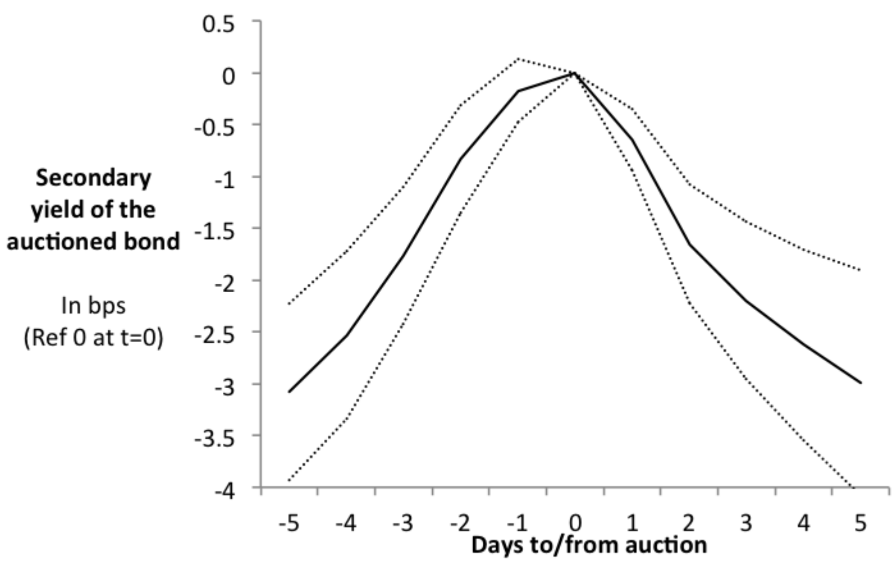


Figure 6. Yield pattern around auctions with Spanish yield curve control. Reports the result of ten t-test specifications which test the null hypothesis that the secondary yield of the auctioned security t days before the auction is equal to the secondary yield on auction day, where t belongs to (-5,+5). The specifications include interest-rate controls consisting in daily changes in benchmark interest rates of the Spanish yield curve. The sample is composed of 849 Italian reopenings from 2000 to 2015. 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). The Spanish yield curve data come from Bloomberg (I67 Bid curve). Standard errors are clustered at the year-month-half ("bi-weekly") level: each month of each year is divided into a first and a second half.



Appendix B. Tables

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

Model	**Treasury auction context**
Investors	Primary Dealers
L	The Treasury, after catering to Natural Buyers (foreign, investment funds, individuals)
Z	Net supply = Difference between issue size and demand of Natural Buyers
$\overline{Z}$	Expected net supply = What Primary Dealers expect to buy at auction (>0)
$\overline{Z}$ - Z	Unexpected demand of Natural Buyers
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
If $-\overline{Z} < Z < \overline{Z}$	Dealers provide less liquidity than expected

Table II. Historical reopening frequency of Italian sovereign bonds from 2000 to 2015. Bonds can be reopened in the first half ("start") or the second half ("end") of the month. A potential exception is defined as a calendar month when there was no reopening on that month for at least two years. 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.

Maturity	**Reopening frequency**	**Part of month**	**Potential exceptions**
30Y	Unclear	Start	
15Y	Unclear	Start	
10Y	1/month	End	Nov
7Y	1/month (2013-15)	Start	Aug, Dec
5Y	1/month (2000-15)	Start (2000-11), End (12-15)	Aug, Nov, Dec
3Y	1/month (2004-15) 2/month (2000-03)	End (2004-11), Start (12-15)	Aug, Nov, Dec
2Y	1/month (2000; 02-15) 2/month (2001-02)	End	Nov, Dec

Table III. Dates of dealers' meeting (D) and auction size announcement (S) relatively to the auction date. For example, for five and ten-year bonds over from 2000 to 2011, the dealers' meeting takes place five business days before the reopening date. Since the auction size announcement is made after market close, the table reports the next business day. There are some exceptions to these dates. The most frequent exceptions are reported in parenthesis, provided they occur at or after t-5. Before 2012, the Treasury used to announce on the same day the auction size of two-year auctions and the auction date of long-term bonds. Most exceptions before 2012 come from the fact that, for some months, the Treasury introduced a one-day difference between the announcement of the auction size of two-year auctions and the announcement of the auction date of long-term bonds. Most exceptions after 2012 come from the postponement or advancement of announcements which would otherwise have occurred during official Italian holidays which are not market holidays.

Maturity	**2000-11**		**2012**		**2013-15**	
	D	**S**	**D**	**S**	**D**	**S**
2Y	-3 (-4)	-2	-2	-1	-3 (-2)	-2 (-1)
5/10Y	-5	-2	-4 (-5, -3)	-2 (-3, -1)	-5 (-3)	-2 (-3)
3/7/15/30Y	-5	-2	-4 (-5, -3)	-2 (-3)	-4 (-3)	-2

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.

Maturity	**On/off run**	**Obs.**	**Remaining maturity (Years)**		**Reissued amount (€MM)**		**Bid-cover ratio**	
			Mean	**Std.**	**Mean**	**Std.**	**Mean**	**Std.**
30Y	On	67	29.73	2.63	1,514	647	1.86	1.57
	Off	11	24.97	2.73	952	406	1.89	0.4
15Y	On	53	14.78	1.68	1,819	547	1.63	0.31
	Off	27	11.77	2.30	1,256	605	1.74	0.31
10Y	On	140	10.09	0.22	2,645	584	1.57	0.34
	Off	44	8.22	1.84	1,604	786	1.71	0.31
7Y	On	17	7.06	0.18	2,367	282	1.5	0.11
5Y	On	144	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	172	2.82	0.15	2,407	745	1.79	0.48
	Off	3	2.74	0.24	1,760	885	1.88	0.71
2Y	On	157	1.81	0.17	2,069	615	2.09	0.68
	Off	6	1.80	0.16	1,917	376	1.88	0.08

Table V. Sample summary statistics – Secondary market variables for reopened bonds. The five-day pre-auction yield change is defined as the difference between the yield at t=0 and the yield at t=-5, where t=0 denotes the reopening date. Columns 3, 4 and 5 report the number of observations, the mean and the standard deviation of this measure. For each auction, 11 secondary trading volume data are collected over the 11 days around the reopening date, if available. Columns 6, 7 and 8 report the number of observations, the mean and the standard deviation of the trading volume, respectively. Yields are from Datastream over the entire sample period (from 2000 to 2015). Trading volumes are from the MTS platform and are available over a subsample (from April 2004 to 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.

Maturity	**On/off run**	**Five-day Δ yield (bps)**			**Daily trading volume (€M)**		
		Obs.	**Mean**	**Std.**	**Obs.**	**Mean**	**Std.**
30Y	On	67	4.84	11.26	297	75.91	87.53
	Off	11	4.57	12.13	55	41.9	43.41
15Y	On	53	3.43	12.97	319	98.61	114.01
	Off	27	12.44	19.60	231	48.17	77.89
10Y	On	140	2.58	10.76	741	277.87	225.64
	Off	44	12.68	24.63	480	117.11	167.83
7Y	On	17	-2.72	8.53	na	na	na
5Y	On	144	2.31	15.78	759	191.68	182.44
	Off	8	5.42	33.46	88	31.57	34.43
3Y	On	171	2.43	15.58	832	179.93	181.71
	Off	3	-27.41	39.05	18	111.39	125.58
2Y	On	157	3.35	17.21	779	167.73	153.59
	Off	6	-1.87	10.96	66	272.09	230.93

Table VI. Sample summary statistics – Repo market variables. For each auction, 11 special Repo trading volume and specialness data are collected over the 11 days around the reopening date, if available. Columns 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 (from 2005 to 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.

Maturity	**On/off run**	**Obs.**	**Special repo vol. (€MM)**		**Specialness (%)**	
			Mean	**Std.**	**Mean**	**Std.**
30Y	On	264	556.51	362.25	0.07	0.09
	Off	55	458.71	274.39	0.34	0.52
15Y	On	308	669.53	366.10	0.18	0.34
	Off	231	548.13	342.58	0.28	0.33
10Y	On	668	1,006.89	540.78	0.32	0.89
	Off	476	858.65	584.42	0.24	0.53
7Y	On	na	na	na	na	na
5Y	On	704	760.58	521.12	0.14	0.38
	Off	88	485.65	238.41	0.19	0.29
3Y	On	767	655.77	383.98	0.11	0.31
	Off	18	429.89	221.52	0.15	0.15
2Y	On	716	533.89	435.84	0.10	0.20
	Off	66	864.26	435.47	0.03	0.03

Table VII. Correlation between the Italian and the yield curves of several other European countries from 2000 to 2015. The data comes from Bloomberg (I40, I61, I84, I62, I14 and I16 curves). The numbers of observations are reported in parenthesis.

Maturity	Corr. (Spain, Italy)	Corr. (Portugal, Italy)	Corr. (Ireland, Italy)	Corr. (France, Italy)	Corr. (Germany, Italy)
3M	0.98 (4,001)	0.91 (2,887)	0.94 (3,904)	0.94 (4,040)	0.94 (4,090)
6M	0.99 (4,020)	0.90 (3,041)	0.91 (3,321)	0.91 (4,051)	0.90 (4,106)
1Y	0.98 (4,020)	0.73 (3,480)	0.72 (3,306)	0.87 (4,007)	0.85 (4,113)
2Y	0.97 (4,170)	0.59 (4,168)	0.67 (3,061)	0.83 (4,170)	0.79 (4,167)
3Y	0.96 (4,173)	0.58 (4,158)	0.67 (2,877)	0.78 (4,174)	0.72 (4,173)
4Y	0.96 (4,165)	0.60 (4,100)	0.82 (2,089)	0.76 (4,172)	0.69 (4,174)
5Y	0.96 (4,173)	0.61 (4,113)	0.75 (3,459)	0.73 (4,173)	0.64 (4,172)
6Y	0.95 (4,172)	0.61 (3,991)	0.83 (1,840)	0.73 (4,174)	0.64 (4,172)
7Y	0.95 (4,173)	0.60 (4,005)	0.96 (1,681)	0.72 (4,174)	0.62 (4,174)
8Y	0.95 (4,174)	0.62 (3,548)	0.76 (1,753)	0.73 (4,174)	0.62 (4,173)
9Y	0.95 (4,094)	0.64 (3,957)	0.79 (1,985)	0.73 (4,173)	0.61 (4,173)
10Y	0.96 (4,174)	0.68 (3,989)	0.72 (3,642)	0.70 (4,171)	0.57 (4,171)
30Y	0.94 (4,170)	0.80 (2,284)	0.93 (236)	0.68 (4,172)	0.52 (4,169)

Table VIII. Table for Implications 1 and 2. I check that the patterns present in the data are compatible with Implications 1 and 2. The table reports the coefficients of t-test specifications which test the null hypothesis for 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. Log coefficients have been converted to percentages. The specifications include fixed effects and clustering at the year-month-half ("bi-weekly") level: each month of each year is separated into a first and a second half. Sample: all two to 30-year fixed-rate Italian sovereign bonds reopened from 2000 to 2015 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. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

	Δ Yield (bps)	Δ Trading vol. (%)	Δ Special repo vol. (%)
t=-5 vs. t=0	-3.53***	-83.76***	-26.92***
	(-4.16)	(-32.79)	(-10.96)
t=-4 vs. t=0	-2.97***	-80.70***	-24.38***
	(-3.61)	(-30.46)	(-8.91)
t=-3 vs. t=0	-1.98***	-80.86***	-24.75***
	(-2.85)	(-28.01)	(-12.50)
t=-2 vs. t=0	-1.43***	-78.38***	-21.07***
	(-2.85)	(-28.44)	(-9.54)
t=-1 vs. t=0	-0.95***	-71.59***	-14.57***
	(-3.06)	(-27.10)	(-5.89)
t=+1 vs. t=0	-0.99***	-74.45***	-36.69***
	(-3.10)	(-26.51)	(-11.97)
t=+2 vs. t=0	-2.06***	-81.05***	-42.67***
	(-3.85)	(-27.02)	(-21.84)
t=+3 vs. t=0	-3.06***	-80.90***	-42.65***
	(-4.60)	(-30.96)	(-10.95)
t=+4 vs. t=0	-4.05***	-80.09***	-43.19***
	(-4.68)	(-29.80)	(-19.36)
t=+5 vs. t=0	-4.27***	-82.03***	-43.48***
	(-4.19)	(-30.15)	(-14.20)
Sample period	2000-15	2004-12	2005-12
Cluster level	Bi-weekly	Bi-weekly	Bi-weekly
Auction sample	849	414	396

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 3 in the context of a large sample. The left-hand 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 interest-rate controls consist of daily changes in benchmark interest rates of the Spanish yield curve. The time fixed effects and clustering are at the year-month-half ("bi-weekly") level: each month of each year is divided into a first and a second half. The days-to-auction fixed effects consist of the sum of five dummies, each one indicating whether t is equal to -1, -2, -3, -4 or -5. The dummy corresponding to t=-5 is used as a basis and thus set to zero. The constant and the coefficients of the days-to-auction dummies are reported for the pooled specification. The left-hand side yield data comes from Datastream (RY datatype). The Spanish yield curve data come from Bloomberg (I67 Bid curve). Sample: two to 30-year fixed-rate Italian sovereign bonds reopened from 2000 to 2015. 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. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

	Δ Yield One-day change (bps) *Pooled spec.*	Δ Yield One-day change (bps) *FE spec.*
1^{Info} (Variable of interest)	1.201***	1.198***
	(5.84)	(3.72)
$1_{t=-1}$	1.311***	
	(5.11)	
$1_{t=-2}$	0.226	
	(0.91)	
$1_{t=-3}$	1.330***	
	(5.42)	
$1_{t=-4}$	1.249***	
	(5.05)	
Constant	-0.679***	
	(-3.39)	
Interest-rate controls	Yes	Yes
Days-to-auction fixed effect	Yes (Coeff. reported)	Yes
Time FE and cluster	None	Bi-weekly
Other fixed effects	None	Maturity
Observations	3,985	3,984
Adj. R^2	0.57	0.60

Table X. Robustness table. I test if the yield increases more after the arrival of information than on non-information days, as predicted in Implication 3 in the context of a large sample. The left-hand 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 interest-rate controls consist in daily changes in benchmark interest rates of the Spanish yield curve. In column 1, I control for the effect of the sovereign bond crisis by adding a dummy equal to 1 on 2010-2012, 0 otherwise. Note that the coefficient corresponding to the dummy is absorbed by the time fixed effects. In column 2, I separate the effect of the dealer meeting from the effect of the size announcement. I create two dummies. The dealer (size) dummy takes the value 1 if t is the day on which the Treasury meets with dealers (the day following the announcement of the auction size), 0 otherwise. Includes fixed effects and clustering at the year-month-half ("bi-weekly") level: each month of each year is divided into a first and a second half. The left-hand side yield data comes from Datastream (RY datatype). The Spanish yield curve data come from Bloomberg (I67 Bid curve). Sample: two to 30 year fixed-rate Italian sovereign bonds reopened from 2000 to 2015. 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. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

	Δ Yield One-day change (bps) *Control for crisis*	Δ Yield One-day change (bps) *Two betas*
1^{Info} (Variable of interest)	1.125***	
	(3.95)	
1^{Info} x 1^{Crisis}	0.277	
	(0.42)	
$1^{DealerMeeting}$ (Variable of interest)		1.131***
		(3.06)
$1^{SizeAnnounce}$ (Variable of interest)		1.579***
		(3.55)
Interest-rate controls	Yes	Yes
Days-to-auction fixed effect	Yes	Yes
Time FE and cluster	Bi-weekly	Bi-weekly
Other fixed effects	Maturity	Maturity
Observations	3,984	3,984
Adj. R^2	0.60	0.60

Table XI. Robustness table (Cont.). I test if the yield increases more after the arrival of information than on non-information days, as predicted in Implication 3 in the context of a large sample. The left-hand 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 interest-rate controls consist of daily changes in benchmark interest rates of the Spanish yield curve. In column 1, I keep only "predictable" reopenings, defined as reopenings which dates can be perfectly predicted by the econometrician before the corresponding dealers' meeting as indicated in appendix Table II. Column 1 includes fixed effects and clustering at the year-month-half ("bi-weekly") level: each month of each year is divided into a first and a second half. Column 2 includes fixed effects and clustering at the year-month ("monthly") level. The left-hand side yield data comes from Datastream (RY datatype). The Spanish yield curve data come from Bloomberg (I67 curve). Sample: two to 30-year fixed-rate Italian sovereign bonds reopened from 2000 to 2015. 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. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

	Δ Yield One-day change (bps) *Predictable*	*Δ* Yield One-day change (bps) *Monthly FE*
1^{Info} (Variable of interest)	0.922***	1.192***
	(2.99)	(3.63)
Sample	Predictable only	Entire sample
Interest-rate controls	Yes	Yes
Days-to-auction fixed effect	Yes	Yes
Time FE and cluster	Bi-weekly	Monthly
Other fixed effects	Maturity	Maturity
Observations	2,476	3,985
Adj. R^2	0.65	0.60

Appendix C. Proofs of Propositions

Proof of Lemma 1:

$$V_2(Z, W_2) = -exp - \left\{ \alpha \left(W_2(Z) + \frac{1}{2}\alpha\sigma^2(\bar{\theta} + Z)^2 \right) \right\} \tag{C1}$$

where $W_2(Z) = C_0 - (\theta_1 - \theta_0)P_1 + \theta_1(\overline{D} - \alpha\sigma^2(\bar{\theta} + Z))$

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, $\frac{d^2V_2(Z)}{d^2Z}$ is negative when $Z > Z_1 + \frac{1}{\alpha\sigma}$. Therefore, $V_2(Z)$ is a concave function of Z over $[Z_1 + \frac{1}{\alpha\sigma};+\infty)$.

■

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 first find that investors' objective function is:

$$\mathbb{E}_Z\Bigg[-exp\Bigg\{-\alpha\Bigg(W_1+\theta_1\Big(\mathbb{E}_Z(P_2^*)-P_1\Big)+\frac{\alpha}{2}\sigma^2(\bar{\theta}+\overline{Z})^2+ \\ (Z-\overline{Z})\Big(-\alpha\sigma^2\theta_1+\alpha\sigma^2(\bar{\theta}+\overline{Z})\Big)+(Z-\overline{Z})^2\frac{\alpha}{2}\sigma^2\Bigg)\Bigg\}\Bigg] \tag{C2}$$

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

$$\mathbb{E}_Z\Bigg[-exp\Bigg\{-\alpha\Bigg(A+(Z-\overline{Z})B+(Z-\overline{Z})^2\frac{C}{2}\Bigg)\Bigg\}\Bigg] \tag{C3}$$

With

$$A = W_1+\theta_1\Big(\mathbb{E}_Z(P_2^*)-P_1\Big)+\frac{\alpha}{2}\sigma^2(\bar{\theta}+\overline{Z})^2 \tag{C4}$$

$$B = -\alpha\sigma^2\theta_1+\alpha\sigma^2(\bar{\theta}+\overline{Z}) \tag{C5}$$

$$C = \alpha\sigma^2 \tag{C6}$$

Noting that $(Z-\overline{Z}) \sim N(0;\sigma_Z^2)$, I can apply lemma 1 in Vayanos and Wang (2012). More precisely, the problem is equivalent to

$$Max_{\theta_1}\Bigg(\mathbb{E}_Z\Big(A+B(Z-\overline{Z})\Big)\Bigg) \tag{C7}$$

while replacing σ_Z^2 with $\sigma_Z^2(1+\alpha C\sigma_Z^2)^{-1}$

We now have a mean-variance problem. Investors' problem is equivalent to:

$$Max_{\theta_1}\left(\mathbb{E}_Z\Big(A+B(Z-\overline{Z})\Big)-\frac{1}{2}\alpha Var\Big(A+B(Z-\overline{Z})\Big)\right) \tag{C8}$$

i.e. equivalent to

$$Max_{\theta_1}\left[\theta_1\Big(\mathbb{E}_Z(P_2)\ -\ P_1\Big)\ -\ \frac{\alpha}{2}\left(\theta_1^2\frac{Var_Z(P_2)}{1+\alpha^2\sigma^2\sigma_Z^2}\ +\ 2\theta_1\alpha\sigma^2(\bar{\theta}\ +\ \overline{Z})\frac{Cov(P_2,Z)}{1+\alpha^2\sigma^2\sigma_Z^2}\right)\right] \tag{C9}$$

One then obtains the optimal demand function by using the first order condition.

■

Proof of Proposition 2:

$$\mathbb{E}_Z(P_2)-P_1^*=-\frac{\sigma^4\sigma_Z^2\alpha^3\overline{Z}}{1+\alpha^2\sigma^2\sigma_Z^2}<0 \tag{C10}$$

$$\frac{d(\mathbb{E}_Z(P_2)-P_1^*)}{d\sigma_Z^2}=-\frac{\sigma^4\alpha^3\overline{Z}}{(1+\alpha^2\sigma^2\sigma_Z^2)^2}<0 \tag{C11}$$

■

Proof of Lemma 2

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

$$\mathbb{E}_Z\left[-exp\Big\{-\alpha\big(\theta_1P_2+C_0-(\theta_1-\theta_0)P_1\big)\Big\}\ \Big|\ \Omega_1\right] \tag{C12}$$

i.e. the expectation over net supply Z –conditional on a set of information Ω_1– of 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

$$P_1^{*,shortsighted}=\mathbb{E}_Z(P_2)-\alpha Var_Z(P_2)\bar{\theta} \tag{C13}$$

Therefore $P_1^{*,shortsighted}<P_1^*$.

In addition, in an economy where investors do not expect any sale, the equilibrium price is given by setting Z equal to zero in (6). More precisely, it is equal to

$$P_1^{*,nosale} = P_2^{*,nosale} = \overline{D} - \alpha\sigma^2\overline{\theta} \tag{C14}$$

I find that $P_1^* - P_1^{*,nosale} = -\frac{\alpha\sigma^2}{1+\alpha^2\sigma^2\sigma_Z^2}\overline{Z} < 0$

Finally, we have

$$\frac{dP_1^*}{d\overline{Z}} = -\frac{\alpha\sigma^2}{1+\alpha^2\sigma^2\sigma_Z^2} < 0 \tag{C15}$$

■

Proof of Proposition 3
Note that

$$\theta_{1,A}^* = \frac{-\overline{Z}}{1+\delta+\alpha^2\sigma^2\sigma_Z^2} < 0 \tag{C16}$$

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

Also, we have:

$$\frac{d\delta\theta_{1,A}^*}{d\sigma_Z^2} = \frac{\delta\overline{Z}\alpha^2\sigma^2}{(1+\delta+\alpha^2\sigma^2\sigma_Z^2)^2} > 0 \tag{C17}$$

So the higher the uncertainty about Z, the less short-selling.

■

Proof of Implication 1
Let us compare the equilibrium prices at t=1 when σ_Z^2 changes to $\sigma_Z^2 + \mathit{\Delta}_1$ and when it changes to $\sigma_Z^2 + \mathit{\Delta}_2$, where $\mathit{\Delta}_2 < \mathit{\Delta}_1 < 0$. P_1^* , $P_1^{*,\mathit{\Delta}_1}$ and $P_1^{*,\mathit{\Delta}_2}$ denote the three respective prices.
Given that $\frac{dP_1^*}{d\sigma_Z^2} > 0$ as indicated in (C11), we have $P_1^* > P_1^{*,\mathit{\Delta}_1} > P_1^{*,\mathit{\Delta}_2}$.

■

Proof of Implication 2
Let us compare the holdings of investors A at t=1 in the extension of the model, when σ_Z^2 changes to $\sigma_Z^2 + \mathit{\Delta}_1$ and when it changes to $\sigma_Z^2 + \mathit{\Delta}_2$, where $\mathit{\Delta}_2 < \mathit{\Delta}_1 < 0$. $\theta_{1,A}^*$, $\theta_{1,A}^{*,\mathit{\Delta}_1}$ and $\theta_{1,A}^{*,\mathit{\Delta}_2}$ denote the three respective holdings.
Given that $\frac{d\theta_{1,A}^*}{d\sigma_Z^2} > 0$ as indicated in (C17), we have $0 > \theta_{1,A}^* > \theta_{1,A}^{*,\mathit{\Delta}_1} > \theta_{1,A}^{*,\mathit{\Delta}_2}$.

■

Proof of Implication 3
Let us change $\overline{Z}$ by an amount ϵ, where ϵ can be positive or negative and $\overline{Z} + \epsilon > 0$. Let us also change σ_Z^2 by an amount $\mathit{\Delta}$ where $\mathit{\Delta} < 0$ and $\sigma_Z^2 + \mathit{\Delta} > 0$. P_1^* and $P_1^{*,New}$ denote the price without

and with the changes, respectively. Let us study by how much the equilibrium price changes at t=1 in absolute value, depending on the sign of ϵ.

Using (13) and (6), we have

$$\left|P_1^{*,New} - P_1^*\right| = \left|\left(\overline{D} - \alpha\sigma^2(\bar{\theta} + \overline{Z} + \epsilon) + \frac{\alpha^3\sigma^4(\sigma_Z^2 + \Delta)(\overline{Z} + \epsilon)}{1 + \alpha^2\sigma^2(\sigma_Z^2 + \Delta)}\right) - \left(\overline{D} - \alpha\sigma^2(\bar{\theta} + \overline{Z}) + \frac{\alpha^3\sigma^4\sigma_Z^2\overline{Z}}{1 + \alpha^2\sigma^2\sigma_Z^2}\right)\right| \tag{C18}$$

It simplifies as

$$\left|P_1^{*,New} - P_1^*\right| = \left|\frac{\alpha^3\sigma^4\Delta\overline{Z} - \alpha\sigma^2\big(1 + \alpha^2\sigma^2\sigma_Z^2\big)\epsilon}{\big(1 + \alpha^2\sigma^2(\sigma_Z^2 + \Delta)\big)\big(1 + \alpha^2\sigma^2\sigma_Z^2\big)}\right| \tag{C19}$$

The denominator is positive, $\alpha^3\sigma^4\Delta\overline{Z}$ is negative, and $\alpha\sigma^2\big(1+\alpha^2\sigma^2\sigma_Z^2\big)\epsilon$ is of the sign of ϵ. Hence, for any value of $|\epsilon|$, $\left|P_1^{*,New} - P_1^*\right|$ is larger when $\alpha\sigma^2\big(1 + \alpha^2\sigma^2\sigma_Z^2\big)\epsilon$ is positive, i.e. when $\epsilon > 0$.
■

Proof of Implication 4
See proof of Implication 1.
■