Public Debt Management Announcements: A Welfare-Theoretic Analysis

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Abstract

Public debt managers auction bonds to primary dealers (PDs) who may sell them to traders in the secondary market. PDs may have an information advantage about the bond's value. In a pooling equilibrium, the purchasing offers made by traders allow PDs to extract information rents. These rents give rise to two counteracting effects. First, they create an auction premium which incentivizes the debt manager to over-issue whenever the bond value is low. Data for U.S. Treasury auctions show a positive relationship between the auction premium and the issuance bias. Second, the information rents motivate traders to learn the bond value. This expertise mitigates the auction premium and the issuance bias. The announcement of a target debt level has welfare implications by depressing the issuance bias, limiting information rents, crowding out expertise, and increasing the auction premium.

Keywords: public debt management, announcements, sovereign debt markets, treasury auctions, state-inconsistent policy

JEL codes: D44, H63, D82, D83

1 Introduction

Governments borrow to finance current expenditures and refinance outstanding debt. Public debt managers (DMs) are tasked to ensure that governments meet their payment obligations at the lowest possible cost. However, only little theoretical or empirical research supporting debt managers in their operations is available. DMs widely acknowledge that a transparent and predictable framework is crucial for meeting their objectives. Consequently, they disclose their financing programs through annual, quarterly, and monthly issuance calendars.[1] In addition, Treasuries typically announce the pertinent information, including the targeted bond quantity, regarding the upcoming auction a few days before.[2] These measures are meant to enable investors to plan their investment strategy better, ensure that secondary market prices reflect future debt operations, reduce uncertainty over the "true" price of sovereign debt, broaden the investor base, and lower risk premiums. Ultimately, transparency and predictability in their operations provide credibility to DMs and supports them in the achievement of their cost objective.

This paper analyzes public debt auctions and DMs' announcements of quantities sold in the upcoming days. Since these announcements are soft but costly-to-deviate commitments, "beat-the-market" opportunities from exploiting private information about fair government bond rates can arise. As a consequence, DMs might be tempted to realize financial windfalls which will be reflected in a positive correlation between an "issuance bias", defined as the percentage difference between the actual and the announced auction volume, and the "auction premium", defined as the percentage difference between the auction price and the fundamental value of the bond.

We employ the following model setup to create "beat-the-market" opportunities endogenously: A government auctions bonds to Primary Dealers (PDs), who then sell them to

[1] The U.S. Treasury releases the schedule of Treasury securities auctions at the Treasury's Quarterly Refunding press conference, usually held on the first Wednesday of February, May, August, and November. See https://www.treasurydirect.gov/instit/annceresult/annceresult.htm.

[2] For example, in the U.S., these announcements include security information, the bidding closing times, the class of bidders that can participate in the auction, a description of auction rules, and the amount offered.

traders in secondary markets.[3] A bond's value is exogenously given and it can either be high or low, that is, they can be subject to a haircut, depending on a state of the world which reflects, for example, the government's fiscal condition or likelihood of repayment. The key is that while the DM and the PDs know whether and to what extent a haircut applies to a bond's redemption repayment, some traders, called non-expert traders, cannot tell whether bonds have a high or low value. Sometimes, non-experts offer separating trading contracts so that only "bad" bonds are traded in the secondary market. But sometimes there is a pooling equilibrium, where non-expert traders offer a price above the fundamental value, even when the bond is low value. This means that in a low state and in pooling equilibria, well-informed PDs profit from selling bonds at above their fair values to non-expert traders in the secondary market. We call this "beat-the-market" opportunities.[4] The primary market is assumed to be competitive, so dealers pass these profits on to the government in the form of an auction premium. The government, noticing that it can borrow cheaply, borrows more than it originally intended.

Assuming this incentive to over-issue under "beat-the-market" opportunities to cash in the auction premium, we analyze whether and how an announcement policy supports a well-functioning secondary market, which, in turn, helps minimize debt servicing costs. The DM announces publicly a target level for the upcoming auction before the bond repayment is determined. A deviation from this target leads to a penalty in the DM's payoff function. Overall, the DM has an incentive to announce borrowing amounts which are correct on average, but will tend to borrow more when we live in a low state and in pooling equilibria. This gives rise to a positive correlation between the issuance bias and the auction premium.

The final ingredient of our model is the response of traders to "beat-the-market" oppor-

[3] We use "bonds" as a generic name for Treasury debt securities and make no distinction between bonds, which in the U.S. refer to government securities with maturities of 20 to 30 years, notes, which have a maturity between 1 and 10 years, and bills, which mature within a year.

[4] Our definition of "beat-the-market" opportunities is similar to the definition given by Pecchi and Piga (1995) who consider "beat-the-market" a policy that exploits differences between market and debt manager views. The returns of such policy increase in the amount of private information at debt managers' disposal. Similarly, issuance calendars provide some discretion. However, any change needs to be well explained to avoid the appearance that other motives were instrumental for deviating from the original financing program.

tunities. Such opportunities motivate them to exert effort to become experts and acquire the knowledge about the bond's true value. This effort includes a variety of time-consuming and expensive activities, such as detailed examination and evaluation of credit rating information, complex bond analysis, research into government's debt sustainability, etc. Although all traders are initially assumed to be identical, only a portion of them have the means to make the effort to acquire the necessary expertise which leads to information asymmetry among expert traders and non-expert traders. Cole, Neuhann and Ordonez (2022) find ample evidence for information asymmetry among traders. Once traders have this expertise, they are no longer subject to an information loss when trading with PDs in the secondary market. The information loss is determined by the frequency and size of the haircut as well as the bond volume. A classic trade-off arises: An increase in DMs' commitment, that is making the soft commitment more binding, crowds out expertise and raises the auction premium which, in turn, increases DMs' incentives to deviate from their announcements. However, a higher degree of commitment poses limits to DMs' option to cash in the auction premium (financial windfall) that arises from exploiting advantageous market opportunities. Commitment is further detrimental when there is considerable uncertainty about borrowing requirements (OECD, 2020).

Our theoretical paper is informed by the observations on U.S. data shown in Figure 1. The left panel displays the issuance bias for 1,620 nominal Treasury securities with fixed coupon payments with a maturity of more than 365 days (notes and bonds) issued from September 30, 1992, to October 15, 2020. Red bars denote the period between July 2012 and December 2015, where the U.S. Treasury seems to have been strongly committed to their announcements, as evidenced by a lack of issuance bias.[5] However, the bulk of observations in blue suggests little commitment. To calculate the auction premium displayed in the central panel, knowledge of the bond's fundamental value is necessary. However, there is

[5]The Treasury only conducted one auction (of notes and bonds) where the issued volume equaled the announced volume exactly. The issuances of the remaining 1,334 auctions exceeded their respective announcements. The distribution of the issuance bias has an average of 9.2%, a median of 5.0%, and a maximum of 65.3%.

no empirical equivalent available. As a remedy we approximate the fundamental value by the discounted secondary market price of a comparable Treasury bond one week after the auction. The delay of one week is long enough to resolve any discrepancies in bond pricing in the secondary market, and short enough to identify an information advantage about the bond's fundamental value that auction participants may have. In particular, we observe that auction participants acquire more bonds, thereby creating an issuance bias, when they know the bond price is overvalued in the secondary market and hence will decrease in the following week. Finally, the right panel shows the t-statistics for the coefficient of the issuance bias taken from regressions where the auction premium is explained by a constant and the issuance bias and measured in days along the horizontal axis. The auction premium is measured as the difference between he auction price and the secondary market price of a similar bond over the next 28 days.

In particular, the number of days which are required for the fundamental value of a bond to be observed is an open question. We set this range between 1 and 28 days. The red line represents the t-statistics from the 28 regressions that rely on the observations when the Treasury was fully committed to its announcements andthe blue line the 28 regressions when it did not comply with its commitment. When the Treasury was not committed, the t-statistics are never larger than 1.72 and some are even negative which suggests there was no systemic relationship between the issuance bias and the auction premium. However, in the period when the Treasury seems to have been committed, the t-statistics exceed the critical value of 2.33 (one-tailed test with $\alpha = 1\%$) for the first 12 days. We provide additional empirical evidence that largely is in line with our model in section 6 in the Appendix.

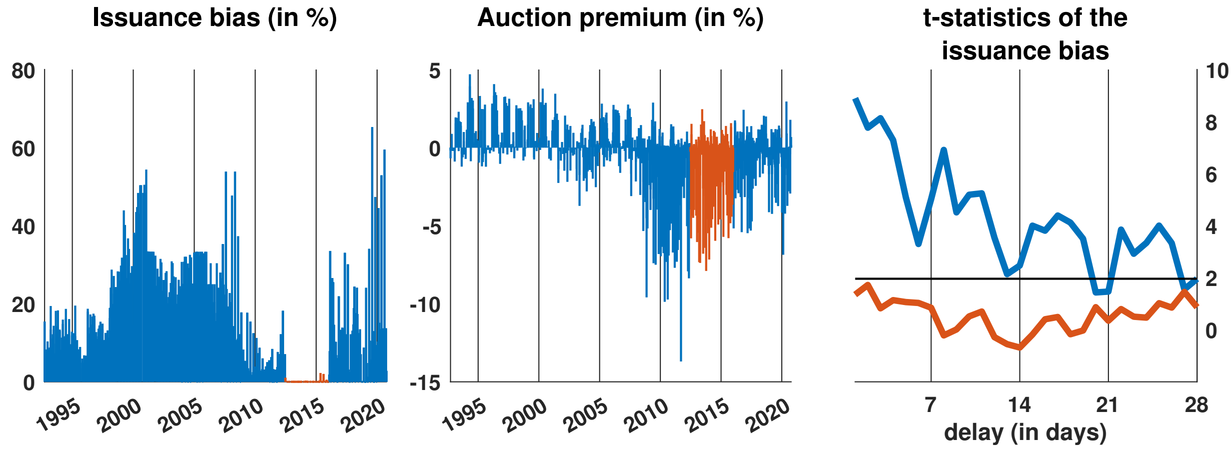

Figure 1: The left panel plots the issuance bias of 1,620 notes and bonds from September 30, 1992 to October 15, 2020. Red marks observations between July 2012 and December 2015 while the remainders are blue. The central panel shows the auction premiums of the same sample. The right panel shows the scatter plot in log-linear scale. The lines are linear fits but appear bent because of the log-transformation.

The empirical evidence suggests that trading in the secondary market is better characterized by pooling purchasing offers where "beat-the-market" opportunities exist and which are taken advantage of by the DM. Hence, we focus our discussion on pooling economies.

Central to our paper is the question, how a DM's announcement policy affects welfare. We provide three insights that answer specific questions summarized in what follows.

(i) Does an increase in the commitment to an announced issue volume reduce financial windfalls to the DM in the presence of "beat-the-market" opportunities? The answer is not clear. An increase in commitment reduces the issuance bias but increases the auction premium. The overall effect is difficult to pin down and ultimately depends on the parameter space. See the discussion in section 5.1.

(ii) Can such commitment be detrimental "to ensure [...] the lowest possible [lending] cost"? Yes, it can when "beat-the-market" opportunities are small or when the uncertainty regarding the government's financing needs is large. Unforeseen financing needs, as in the wake of the global financial crisis or the Covid-19 epidemic, require additional debt issuance which negatively impacts the DM's loss function. These considerations call for a careful analysis of commitment devices that constrain DMs in their freedom to issue debt. This analysis is provided in subsection 5.2.

(iii) Does such commitment increase public welfare? Yes, it does because it reduces the informational loss of traders. See the discussion in 5.3.

The remainder of the paper proceeds as follows. Section 2 gives an overview of related literature. Sections 3 and 4 describe the model. Section 5 shows how announcements affect welfare. Section 6 concludes the paper.

2 Related Literature

In this section, we relate our contribution to various branches of the literature. There is relatively little research that guides public debt managers to fulfill their mandates. While research on announcements by public debt managers is most akin to our work, papers on this topic are rare, although the importance of transparency and predictability in public debt management has long been recognized. Friedman (1959) characterized the practices of the U.S. Treasury's debt management of the time as irregular, unpredictable and a source of uncertainty for the secondary market. He proposed that the amount to be sold be specified in advance and vary little from one issuance to the next. Friedman campaigned also to sell securities only through auctions and, specifically, in the uniform-price format. The latter would reduce the incentive for collusion and widen the market.

The practice has fundamentally changed since then. To meet the government's borrowing needs at the lowest cost over time, the U.S. Treasury adheres to three principles: (1) to issue debt in a regular and predictable pattern, (2) to provide transparency in the decision-making process, and (3) to seek continuous improvements in the auction process (Driessen, 2015).[6] The importance of transparency and predictability in debt operations is by now widely acknowledged.[7]

[6] The regular and predictable pattern of issuance has served the U.S. Treasury well, as it has increased liquidity and lowered yields (Garbade, 2007).

[7] See the Revised Guidelines for Public Debt Management provided by the IMF and the Word Bank (Viñals and Lewis, 2014) as well as OECD (2018).

Another strand of literature explores the interplay between primary and secondary markets for sovereign bonds. Some authors found evidence of underpricing in the primary market relative to the secondary market[8] while others report overpricing.[9] A related phenomenon are "auction cycles", in which secondary-market yields rise before an auction and then fall again. This is shown in Fleming and Rosenberg (2008), Lou, Yan and Zhang (2013), and (Amin and Tédongap, 2023) on U.S. Treasury bonds, while Beetsma et al. (2018*a*; 2018*b*) and Sigaux (2020) provide evidence for the euro area.

Forest (2012) found no anomaly in the volatility of secondary market yields around announcement dates. One reading of this result is that announcements do not reveal new information because they are already priced in by the secondary market. Accordingly, announcements do not serve an information-transmitting function. However, if market participants are not surprised by debt managers' announcements, what is their purpose? As discussed by Beetsma et al. (2018*a*), one reason may be to avoid undersubscribed auctions that affect the government's credibility and raise borrowing costs in the future. By tightly linking announced issuance volumes to market circumstances, auction failures may be minimized. For example, by setting a lower target volume when financial markets are particularly turbulent, the chance of a failed auction would be reduced when the cost associated with a failure is relatively high. A higher bid-to-cover ratio leads to lower secondary market yields after the auction. As we will show, this is in line with our results.

[8] Cammack (1991) finds the mean auction price for 3-month U.S. bills on average below the comparable secondary market. Spindt and Stolz (1992) report that it is cheaper to buy a 13-week bill in the primary market than to buy the same bill in the secondary market. Umlauf (1993) finds evidence of underpricing in Mexican Treasury bill auctions, however smaller in uniform-price auctions (UPA) than in discriminatory-price auctions (DPA). Similarly, Keloharju, Nyborg and Rydqvist (2005) report underpricing in Finnish UPA that is lower than in Swedish DPA. Bjonnes (2001) finds underpricing in Norwegian DPA. Nyborg and Sundaresan (1996) and Malvey and Archibald (1998) do not find evidence of statistically significant underpricing in the U.S. However, Goldreich (2007), using a more detailed dataset than previous authors, does find a significant underpricing in UPA but was reduced by half relative to DPA. See Panels A and B in Table X on p. 1896 in Keloharju, Nyborg and Rydqvist (2005) for a summary of studies on underpricing. Hortaçsu, Kastl and Zhang (2018) show that primary dealers systematically bid lower prices than other classes of bidders in the U.S.

[9] For example, Rocholl (2005) reported overpricing in German Treasury auctions, although the estimates are not significant. Elsinger, Zulehner et al. (2007) found overpricing in Austrian Treasury auctions. Pacini (2007) provided evidence in 10 euro area countries, which he associated with the adoption of a Primary Dealer model that distorts the pricing function of the auction.

Bikhchandani and Huang (1989) investigated the link between primary and secondary markets from the perspective of strategic bidders. In their theoretical setup, resale opportunities can lead bidders to bid more aggressively at auctions to signal a high valuation of the bond to supposedly less-informed secondary market participants. In contrast, in our model, secondary market transactions occur before auction-related information is revealed.

The analysis in our paper also relates to the macroeconomic view on public debt management that highlights the negative welfare impact of distortionary taxes required to fund unforeseen financial needs. Optimal debt management mitigates the risk of tax rate fluctuations by providing "fiscal insurance".[10] However, Faraglia, Marcet and Scott (2010) note that the composition of the debt portfolio predicted by these normative analyses – large issuances of long-term debt and investment in short-term assets – differs from the observed portfolio structure. We capture a tax-smoothing/fiscal insurance rationale by punishing deviations from a stochastic target level due to unexpected financing needs in the debt managers' objective function.

Our paper also ties in with the micro portfolio optimization (or finance) perspective that focuses on debt servicing costs and is discussed in more detail in section 5.2.

Our analysis further relates to the time-inconsistency problem in monetary and fiscal policy. Calvo and Guidotti (1990) and Missale and Blanchard (1994), for example, show how the debt structure can be used to mitigate the incentive to inflate away nominal (long-term) debt. In contrast to the *time-inconsistency* literature, our source for advantageous market opportunities stems from a *state-inconsistency* where one of two states implies a (real) haircut to the final repayment. Alternatively, the haircut in our model can be attributed to growing fears about a government's ability to service its debts. Government bonds issued in a country's own currency are often viewed as a proxy for "risk-free rates" because they carry less idiosyncratic risk than other assets due to the government's powers to raise taxes and

[10] See Lucas Jr and Stokey (1983), Bohn (1990), Angeletos (2002), Barro (2003), Buera and Nicolini (2004), Faraglia, Marcet and Scott (2008), Lustig, Sleet and Yeltekin (2008), Missale (2012), and Debortoli, Nunes and Yared (2017), among others.

access to monetary financing. However, there are several examples of countries that have defaulted on their obligations, causing losses to investors.[11]

Recent research investigates debt issuance and signaling through austerity programs (Dellas and Niepelt, 2021; Gibert, 2022) or the auction volume Joo, Lee and Yoon (2023). In contrast to these papers, which are based on an asymmetric information friction between a government and the general public, in our model this friction can be overcome. In addition, we allow for varying degrees of government commitment to its debt volume announcements.

Finally, our paper is related to the literature on Treasury auctions. Two main types can be distinguished: a discriminatory-price auction (DPA) and a uniform-price auction (UPA). In both cases, participants submit sealed collections of bids and items are awarded in the order of descending price until supply is exhausted. The only but decisive difference concerns payment. In a DPA, the Treasury acts as a discriminating monopolist awarding the security to the highest bidders in descending order until the entire desired amount is placed. In a UPA, in contrast, each successful bidder pays the market-clearing price for all units awarded.[12] Whether debt management offices fare better under a UPA or DPA is still an open question.[13] While sharing several features in common with other auctions, Treasury auctions exhibit some characteristics that distinguish them from other markets. First, the secondary market for government bonds determines a re-sale option which, in turn, becomes a significant mechanism in the auction valuation. Second, bonds are divisible in their quantity.

[11]See Calvo (1988), Alesina, Prati and Tabellini (1990), Giavazzi and Pagano (1990), Cole and Kehoe (2000), Bohn (2011), Greenwood et al. (2015), Corsetti and Dedola (2016). There are many historical cases of default in advanced economies (Reinhart, Reinhart and Rogoff, 2015). Defaults are costly and include increased stress on financial institutions, lower international financing for domestic firms, and decreased export market access (Borensztein and Panizza, 2010; Hébert and Schreger, 2017). Keynes (1923) took the position that society would prefer inflation to high taxation or default as a means of getting rid of high debt.

[12]Bids may be submitted as noncompetitive or competitive. By submitting a non-competitive tender bidders bid up to a maximum amount without a price and accept the terms settled at the auction. In the UPA, non-competitive bidders pay the market-clearing price just like competitive bidders and in the DPA a volume-weighted average price. Since our set-up focuses on the secondary market rather than the primary market, we abstract from non-competitive bids. The only (although in practice the most relevant) bidders in our model are PDs who submit competitive price bids at the auction. We also implicitly assume revenue equivalence which posits that either type of auction yields the same result (Vickrey, 1961).

[13]While the U.S. and the Swiss Treasury, for example, rely on the uniform-price format, other countries, such as Israel and Sweden, have opted for the discriminatory format. Italy and Mexico are examples of countries that use both methods.

A newer strand of the literature concludes that divisible-good auctions differ from auctions for indivisible goods, therefore the results based on single-unit demands cannot be generalized to multiple-unit auctions.[14] The auction literature has not provided clear-cut evidence of the (revenue) superiority of one auction format over the other. Recent empirical studies confirm statistically insignificant differences between the uniform-price and the discriminatory-price auction (see, Bonaldi, Hortaçsu and Song, 2015; Barbosa et al., 2022).

Next to the primary and secondary markets, two additional markets play a role in the distribution of treasury securities. The first is a forward market for newly auctioned securities, known as the "when-issued" market. Before the auction, the “when-issued” market aggregates participants’ information, which affects the auction. The “when-issued” market is a double auction where bidders can be buyers or sellers (Wilson, 1985). The second is the “repo market” in which participants in addition to buying and selling the auctioned securities in spot trading in the secondary market also can borrow or lend their securities overnight on specified terms. We do not model explicitly these additional markets.

3 The Environment

We next describe the model environment in detail, from which we derive equilibrium predictions in section 4 and policy implications in section 5.

Sequence of events: The game evolves in five rounds that encapsulate a bond’s full life cycle. (1) A (single) debt manager (DM) announces a target volume a for the upcoming bond auction, and traders (Ts) exert effort $e(x)$ which makes a fraction x experts (X) while a fraction $1-x$ remain non-experts (N). (2) Nature reveals to Primary Dealers (PDs) and experts the repayment state $\theta \in \left\{\theta^H, \theta^L\right\}$, which determines the bond’s haircut, and to the DM θ and the government’s financing needs ν. The index H suggests a high repayment, and L implies a low repayment. (3) The DM auctions off B bonds to PDs at price p. (4) PDs

[14] Wilson (1977), Back and Zender (1993), Ausubel et al. (2014).

and Ts form pairs and exchange τ bonds for σ securities. (5) Financial claims are settled. Table 1 summarizes.

#	Period	Description
(1)	Announcement & Learning	**D**ebt **M**anager announces target bond volume a; **T**raders pay $e(x)$ to become e**X**perts (**N**on-experts) with probability x $(1-x)$
(2)	Nature	Nature reveals haircut $\theta \in \{\theta^H, \theta^L\}$ to **P**rimary **D**ealers and **X**s; and θ as well as financing needs ν to **DM**
(3)	Auction	**DM** auctions bonds to **PD**s
(4)	Secondary Market	**PD**s sell bonds to **X** (**N**) with probability x $(1-x)$; ***PD**s get info rent if **N**s pool and $\theta = \theta^L$ in equilibrium*
(5)	Settlement	Payment of claims

Table 1: Sequence of events.

Agents There are three types of agents, a DM, PDs, and Ts; all are risk-neutral. A DM faces a financing need and can commit to repaying a bond (subject to an exogenous haircut). All other trades require immediate compensation. There exists a unit mass of PDs who have early access to funds. Finally, there exists a unit mass of Ts who can trade with PDs bilaterally after the auction. We focus on type-symmetric equilibria to keep the exposition simple and drop individual indices.

Additional assets There are two additional assets besides government bonds. First, a financing asset serves as a payment device to acquire the bond at the auction and helps to settle claims at the bond's redemption. All payoffs are linear in the financing asset. Second, each trader initially holds s units of a security that pays one unit to traders and $1+\delta$ to PDs at the end of the game. The return differential $\delta > 0$ ensures constant gains from trade between PDs and Ts.[15] All agents agree on the security's valuation.[16]

[15] The return differential in favor of PDs can be motivated by a diversification motive, or PDs need to offer the securities to their customers. Further, PDs might have access to alternative markets where the security can be resold at a premium.

[16] The security is information-insensitive in the sense that all parties agree on the size and certainty of future dividends. An asset is information-insensitive if it is either risk-free or if both parties are symmetrically informed about the riskiness of future dividends.

State of the economy The state of the economy Θ is composed of two independent random variables, the repayment state θ, and DM's funding needs ν. Let $\nu \sim F$, where F has non-negative and compact support with an upper bound $\overline{\nu}$. Further, ν^E denotes the mean of ν. With probability κ the repayment (or, below, the equilibrium) is "high", that is the bond is repaid in full $\left(\theta = \theta^H = 1\right)$. With probability $1 - \kappa$ the repayment is "low" $\left(\theta = \theta^L < \theta^H\right)$ as a result of a haircut. A haircut can arise from an explicit breach of contract, such as a missed payment, data misreporting, debt restructuring, or unexpected inflation when the bond is nominal. The assumption that θ and ν are independent keeps the model tractable. We will take up this issue in the robustness section.

Information structure The information structure is as follows: When the DM announces its issuance target, it neither knows the government's financing needs ν nor the bond's fundamental value θ. However, the DM knows both, ν and θ, when the auction starts.[17] When the auction begins, PDs have the same (full) information about θ as the DM through an institutional advantage but no information about ν.[18] Hence, surprises to the government's financing needs ν reflect changes in government's revenue streams and payment obligations that were not anticipated at the time the DM made its announcement. For example, labor market conditions may entails a sudden shift in the deployment of assistance programs, or an ongoing weakening in the exchange rate gives rise to unexpected tax revenue from a boost in exports. Variations in θ are used to reflect fluctuations in expected inflation, monetary policy decisions, or the likelihood of the government's resolution to honor its repayment obligations, among other factors.

Traders, on the other hand, do not possess any information regarding the state of the economy $\Theta = \{\theta, \nu\}$ when the DM makes the announcement.[19] All traders are identical

[17] Alternatively, we could assume the DM does not learn about θ. Then, perfect competition among PDs in the primary market reveals θ to the DM in equilibrium. The results do not change.

[18] Linearity in the payoff function leads to a reservation price below which PDs accept any amount of bonds at the auction. Arguably, the idiosyncratic valuation of an asset dominates the diversification motive or other portfolio considerations.

[19] Similarly, Dellas and Niepelt (2021), Gibert (2022), and Joo, Lee and Yoon (2023) assume that traders

ex-ante. However, a share of them become experts and learn about θ. We interpret learning, that is exerting effort to get to know θ, as a private information acquisition process. As explained above, this effort can come in different forms. The net benefit of becoming an expert is realized by trading in the secondary market where Ts play an proposal/rejection game with PDs as described below. Further, traders' learning effort is socially wasteful because a) imperfectly informed traders are given a costly opportunity to become informed privately and b) over-the-counter trading under asymmetric information keeps the terms of trade private, unlike in a centralized market where the price can reveal the underlying states. Traders' efforts do not yield the required information with certainty. Rather, traders learn when the learning effort fails and are aware of their unchanged uncertainty.

The function of informational cost $e(x)$ to the traders is kept in general form. A scaling factor $\epsilon > 0$ parameterizes the difficulty in acquiring information about θ or simply the cost of information. In particular, let $e(x) = \epsilon \overline{e}(x)$. Further, let $\overline{e}(0) = 0$, and denote $\overline{e}_x(\upsilon) = \partial \overline{e}(x) / \partial x$. We assume $\overline{e}_x(x) > 0$, $\overline{e}_{xx}(x) > 0$, $\overline{e}_x(0) = 0$ and $\lim_{x \to 1} \overline{e}_x(x) = +\infty$.[20]

Market access Market access is exogenously given. However, only PDs have access to the auction and can buy bonds directly from the DM. PDs have (early) access to funds at constant marginal (unit) cost whereas DMs have (late) access to funds at a constant marginal (unit) cost to settle their claims. PDs can either resell the bonds to traders in the secondary market or hold them until redemption ("buy and hold"). Traders do not have direct access to the auction and/or to early funding opportunities. Further, we assume that DMs cannot accept securities as a payment.

Auction The DM sells bonds in an auction. PDs submit price-quantity bids. As a tie-breaking rule, the auctioned quantity is divided equally among all winning bids. Our results do not depend on the auction format (DPA or UPA) because PDs are identical prior to the

are less informed about the governments ability to repay a bond issuance.

[20] The first two conditions ensure that the inverse function of the first derivative is well defined. The latter two conditions ensure interior solutions.

auction and will behave competitively. There is neither over-bidding nor bid-shading.[21]

Terms of trade PDs and traders meet bilaterally with certainty. The terms of trade consist of a transfer of securities, σ, against a transfer of the bond, τ, and are established as follows: The trader states $u = \sigma/\tau$, a price he is willing to pay per unit of bond, and $\overline{\sigma}$, an upper bound for the security transaction. Traders initially hold $s \geq \overline{\nu}/(1+\delta)$ so that they always bring enough securities to the exchange. The PD either rejects the offer and the game ends for both or accepts the offer and exchanges any quantity of bonds, τ, for any quantity of securities offered by traders, σ, provided that $u\tau = \sigma$ and $\sigma \leq \overline{\sigma}$. This offer structure avoids information over-spills.[22] This trading round represents the secondary market for government bonds, which is characterized by decentralized over-the-counter trading. The motivation to trade arises from the different returns agents obtain from holding the security. In particular, $\delta > 0$ ensures that PDs have a higher marginal return for the security than traders do.

Payoffs To summarize, the payoff of a trader holding s units of the security is given by

$$T^C(s) = s - e\left(x^C\right) + x^C V_X^C(\Theta) + \left(1 - x^C\right) V_N^C(\Theta), \tag{1}$$

where $C \in \{P, S\}$ denotes the (generic) contracting regime of uninformed traders in the secondary market. The choice between shutdown (S) and pooling (P) offers is described in the next section. Traders hold s units of the security. They exert $e\left(x^C\right)$ units of effort to become an expert trader with probability x^C. If, on the other hand, their learning effort fails they become non-experts. This happens with probability $1 - x^C$. The learning decision

[21] A drawback of a PD system is that it can potentially limit competition and contribute to oligopolistic behavior. However, this potential "negative" can be avoided by careful design of the system and by an ongoing ranking of PDs based on their performance in primary and secondary market of government securities (OECD, 2021), thus implicitly guaranteeing a competitive level playing field.

[22] An example illustrates this point. Assume a non-expert offers to purchase a low quantity at a high price and a large quantity at a low price. This might lead the PD to reveal the actual repayment state. Assuming the uninformed trader makes a price offer first avoids a separating contracting equilibrium without a shutdown in at least one state.

x^C itself is not a function of the realized state of the economy, Θ, because traders need to form expectations at this stage. However, traders form expectations $\mathbb{E}$ over Θ over the terms of trade, which form the expected net benefits $V_X^C(\Theta) = \mathbb{E}\left[-\sigma_X^C(\Theta) + \tau_X^C(\Theta)\,\theta|\Theta\right]$ and $V_N^C(\Theta) = \mathbb{E}\left[-\sigma_N^C(\Theta) + \tau_N^C(\Theta)\,\theta|\Theta\right]$ from trading with PDs. The terms of trade $\left\{\sigma_X^C, \tau_X^C, \sigma_N^C, \tau_N^C\right\}$ result from a proposal/rejection game which we explain below and, in general, depend on Θ. The index X denotes the terms of trade involving an expert trader while the index N denotes the terms of trade where the trader is a non-expert.

A PD maximizes

$$PD^C = \mathbb{E}\left[\left(\theta - p^C\right) b^C + x^C W_X^C\left(b^C, \Theta\right) + \left(1 - x^C\right) W_N^C\left(b^C, \Theta\right) |\Theta\right], \tag{2}$$

where, in general, the bond's auction volume b^C and auction price p^C depend on the state of the economy Θ. Hence, the first term captures the net auction cost for the PD. PDs meet an expert with probability x^C and a non-expert with probability $1 - x^C$. The term $W_X^C(b, \Theta) = \sigma_X^C(1+\delta) - \tau_X^C\theta$ captures the net surplus from trading with an expert (X), where $1+\delta$ is the valuation for each unit of the security and θ is the per-unit valuation for the bond. The term $W_N^C(b, \Theta) = \sigma_N^C(1+\delta) - \tau_N^C\theta$ captures the net surplus from trading with a non-expert trader (N). PDs take expectations over the whole term as the auction outcome and the net surplus from trading in the secondary market is unknown at the beginning of the game.

The DM auctions B bonds to the PDs and individual acquisitions by PDs are denoted by b. Because bonds are uniformly distributed among a unit mass of PDs, $B = \int_0^1 b di = b$, allows us to drop the distinction from hereon. The DM maximizes

$$DM^C = \mathbb{E}\left[-\frac{\xi}{2}\left(b^C - a^C\right)^2 - \frac{\psi}{2}\left(b^C - v\right)^2 + \left(p^C - \theta\right) b^C|\Theta\right] \tag{3}$$

Deviating from the announcement a is punished with weight ξ while allotting an amount above or below government's financing needs ν is punished by a quadratic term with weight

ψ. ξ represents the level of commitment to the announcement. $\xi = 0$ means that bond announcements are completely non-binding in the sense that the DM issues bonds solely motivated by the government's financing needs and price considerations. In contrast, $\xi > 0$ mirrors (reputational) costs in the DM's payoff function from reneging on previous announcements; the higher ξ, the less the DM deviates from an announcement. We call an announcement *meaningful* if $\xi > 0$. While this formulation is ad hoc, it keeps the model tractable. Similar to the learning decision, a^C is independent of Θ. The last term represents the opportunities to "beat-the-market".

Equilibrium An equilibrium in this economy is described by the state of the economy $\Theta = \{\theta, \nu\}$, the terms of trade established between non-expert traders and PDs $\left\{\sigma_N^C(\Theta), \tau_N^C(\Theta)\right\}$ which yields a characterization of the contracting regime $C \in \{P, S\}$, the terms of trade between expert traders and PDs $\left\{\sigma_X^C(\Theta), \tau_X^C(\Theta)\right\}$, the auction volume and price $\left\{b^C(\Theta), p^C(\Theta)\right\}$, the DM's announcement $\left\{a^C\right\}$, and traders' learning decision $\left\{x^C\right\}$.

4 The Equilibrium

We next outline the periods of the model in reverse order, starting with the trading game played by PDs and traders, followed by the auction, the announcement and learning decisions when the game begins. Finally we discuss some features of the equilibrium.

Two key factors characterize the equilibrium outcome and, in turn, the presence of "beat-the-market" opportunities. First, bonds are either paid back in full $\left(\theta^H = 1\right)$ or with a haircut $\left(\theta^L < 1\right)$. Second, bond trading in the secondary market is subject to asymmetric information. Taken together, the offer made by uninformed traders sometimes shuts down trade when bonds are paid back in full $\left(\theta^H = 1\right)$. At other times, these offers result in pooling the purchases of bonds with and without haircut. Details are discussed in the next section.

The choice between shutdown $(C = S)$ and pooling $(C = P)$ offers depends on the parameter space, but all non-expert traders choose the same type of contract. Hence, we speak of shutdown and pooling regimes. The opportunities to "beat-the-market" arise from bond issuances with haircuts $\left(\theta^L < 1\right)$ when offers made by uninformed traders are characterized by pooling $(C = P)$.

4.1 Trading Game

We start with the second-to-last round, which mirrors over-the-counter trading in the secondary market directly following an auction. Bilateral matches between PDs and traders occur with certainty. A trader holds s securities but no bonds, whereas a PD enters the market without securities but with $b\,(\Theta)$ bonds. These quantities yield the transaction constraints for the bond (τ) and the security (σ) transfer. While a fraction x of expert traders and all PDs enter this round knowing θ, a fraction $1 - x$ of non-experts has imperfect information regarding θ.

The proposal/rejection trading game is as follows: Traders offer terms of trade in the form of a bond price (in terms of the security) u and an upper bound for the security transaction $\overline{\sigma}$. PDs accept (or reject) the bond price and choose a security quantity $\sigma \leq \overline{\sigma}$ as well as a bond quantity $\tau \leq \overline{\sigma}/u$.

Trading outcomes Traders always hold enough securities[23] and in equilibrium propose to the PD a security transaction constraint that coincides with their holdings. The optimal strategy of an expert trader makes the PD just indifferent between rejecting the terms of trade and transferring as much of the bond as feasible. As an equilibrium selection criterion, the PD transfers all bonds whenever the PD is indifferent between accepting the offer and rejecting it. The net surplus for a PD trading with an expert trader is zero, regardless of the state of the economy and the contracting regime.

Non-expert traders have two options, either offer a bond price that is accepted by the

[23] The technical condition is $s \geq \overline{\nu}/\,(1+\delta)$, where $\overline{\nu}$ is the upper bound of the support of the distribution over government financing needs, ν.

PD in both repayment states, or set a lower bond price that is only accepted by the PD in the low repayment state. The former yields a pooling contracting regime ($C = P$), while the latter yields a shutdown contracting regime ($C = S$).

Pooling contracts result in transactions in both repayment states. Compared to the full information case, the offer of the trader leaves informational rents on the table in low, but not in high repayment states. This is reflected in the information loss of a non-expert trader from purchasing bonds with a pooling offer in comparison to purchasing them as an expert trader,

$$\Omega^P = V_X^P(s, \Theta) - V_N^P(\Theta). \tag{4}$$

We refer to Ω^P as the information loss to non-expert traders offering pooling contracts. The difference between expert and non-expert net surpluses motivates a trader to become an expert earlier in the game.

In the high repayment state, the expected net surplus for a PD is zero. In the low repayment state, the PD can expect a net surplus from participating in the secondary market given by

$$W^P\left(b, \Theta^L\right) = \Phi^P b, \tag{5}$$

where $\Phi^P = \left(1 - x^P\right)\left(1 - \theta^L\right)$ are the unit information rents arising to the PD in a low repayment state with pooling contracts. In a low repayment state a PD can extract information rents when meeting a non-expert which occurs with probability $1 - x^P$. The unit transfer benefit is $1 - \theta^L$. The unit information rents are multiplied by the bond volume held, b, so that the expected net surplus of a low PD increases linearly in the bond volume.

Offers in the shutdown contracting regime are rejected by high PDs but make low PDs indifferent between rejecting and accepting. The expected net surplus for PDs in high and low repayment states is zero. The information loss of a non-expert trader from purchasing bonds with a shutdown offer in comparison to purchasing them as an expert trader is

$$\Omega^S = V_X^S(s, \Theta) - V_N^S(\Theta). \tag{6}$$

We equate Ω^S with the information loss to non-expert traders offering shutdown contracts.

The assumptions on the informational cost function $e(x)$, which will be described below, ensure that $0 < x < 1$ in all equilibria. DMs will never issue $b < 0$, that is there is no investment in bonds.[24] See the discussion below. The following lemma summarizes the relationship between information rents to PDs and losses to non-expert traders, expertise and bond volume.

Lemma 4.1. *The information rents for PDs increase strictly and linearly in the bond volume and decrease strictly and linearly in the level of expertise in pooling equilibria for $b > 0$. PDs do not receive any information rents in shutdown equilibria.*

The information loss arising to non-expert traders, Ω^S *and* Ω^P*, increases strictly and linearly in the bond volume brought by PDs to the secondary market, regardless of the type of contracting equilibrium.*

Contracting regime The final question in this round of the game concerns the type of contracting a non-expert will choose. The answer depends on the comparison of the information losses as described in the following lemma:

Lemma 4.2. *The contracting type non-expert traders offer minimizes the information loss, or $P \in C$ if $\Omega^P \leq \Omega^S$, and $S \in C$ if $\Omega^P \geq \Omega^S$.*

If $\Omega^P \leq \Omega^S$, non-expert traders offer pooling contracts. In other words, a non-expert trader offers pooling contracts if the information loss to low PDs is smaller than the expected gain from trades with high PDs who extract the full surplus. As mentioned above, the bond

[24]This contrasts with the fiscal insurance theory of debt management in which the DM optimally issues liabilities and at the same time invests in assets.

holdings between states and repayment regimes are, in general, not identical. Hence, the expected volume, which includes any issuance bias, becomes critical.

We discuss the decision over the contracting regime further in the Appendix. However, it is noteworthy that the (realized) state of the economy Θ is irrelevant to this choice. In particular, the government's actual financing needs and the repayment state are unknown to non-expert traders who determine what kind of contract to offer to PDs. The details on the derivation of the PD's acceptance/quantity and of the T's terms of trade are provided in the Appendix.

4.2 Auction

This subsection describes the solution concept for the auction problem. PDs know only the repayment state, θ, while the DM knows the government's financing needs, ν, and also θ.

Auction price A PD's valuation is

$$\max_{b \in \mathbb{R}_+} \left\{ W^C \left(b, \Theta \right) - pb + \theta b \right\} \tag{7}$$

A PD's net benefit of trading in the secondary market increases in the bond volume in a low economy with pooling contracts (compare equation (5)). In a high economy, on the other hand, the net benefit of trading is zero. Similarly, PDs always expect zero net surplus when non-expert traders prefer shutdown contracts.

An auction is "fundamental" if the auction price equals the repayment state, $p = \theta$. The optimal choice of b implicitly described in (7) yields the following lemma:

Lemma 4.3. *The bond price is fundamental if* $\{\Theta, C\} \in \left\{ \left\{ \Theta^L, S \right\}, \left\{ \Theta^H, S \right\}, \left\{ \Theta^H, P \right\} \right\}$, *or* $p^C(\Theta) = \theta$. *In a low repayment state with pooling contracts, it holds that*

$$p^P \left(\Theta^L \right) = \theta^L + \Phi^P > \theta^L, \tag{8}$$

where Φ^P *is the auction premium.*

Lemma 4.3 implies that bond demand is perfectly price-elastic and the auction price is fundamental unless the repayment state is low and non-expert traders pool contracts. In the latter case, a PD expects (unit) information rents Φ^P in the secondary market (compare lemma 4.1). PDs incorporate this windfall in their auction valuations and, since they behave competitively, the information rents translate one for one into an auction premium Φ^P in (8). The repayment state would fully determine the auction valuation by PDs and render every auction price fundamental by the PDs if they did not participate in the secondary market.

Auction volume At the beginning of the game, the DM makes an announcement, a, about the targeted bond volume, b, contingent on the state of the economy, Θ. At the auction stage, the DM maximizes (3) knowing ν and the given announcement a. The price-repayment difference $p-\theta$ provides a market-based incentive for the DM to over- or underissue bonds.[25] This provides the "beat-the-market" opportunities to the DM to over-issue. Similar to PDs, though, the DM behaves as a price-taker.

The next lemma describes the quantity of bonds auctioned by incorporating lemma 4.3 and the optimal choice of b. The weighted average of financing needs, ν, and announcement, a, is

$$b\left(a,\upsilon\right)=\frac{\psi\upsilon+\xi a}{\psi+\xi} \tag{9}$$

Lemma 4.4. *The bond volume determined at the auction is unbiased if the auction price is fundamental, that is,* $b^C\left(a,\Theta\right)=b\left(a,\upsilon\right)$. *A low repayment state with pooling contracts yields*

$$b^P\left(a,\Theta^L\right)=b\left(a,\upsilon\right)+\frac{\Phi^P}{\psi+\xi}>b\left(a,\upsilon\right), \tag{10}$$

where $\Phi^P/\left(\psi+\xi\right)$ *is the issuance bias.*

[25] As lemma 4.3 suggests, auction prices are always equal to or larger than the fundamental valuation so that bonds are never underissued.

Lemma (4.4) states that the bond volume in a fundamental auction is equal to a weighted average of financing needs and the announcement described in (9). In contrast, PDs can extract information rents from non-expert traders in low repayment states with pooling offers. This is typical in adverse selection problems. The information rents create a premium above the fundamental value at the auction (compare equation (8)), making debt issuance cheaper. A market-based issuance bias above this weighted average arises in a low repayment state with pooling contracts, implying that auction volumes generally differ between high and low repayment states when non-expert traders pool offers. The issuance bias is conditional on the given announcement a, proportional to the unit information rents, Φ^P, and dampened by the sum of the cost parameters, $\psi + \xi$. In contrast, an issuance bias does not arise in the high repayment state with pooling contracts.

4.3 Announcements and Expertise

This subsection describes the solution concept for the announcement and the learning problem. The DM and traders are engaged in a sequential game. After the announcement of a target volume by the DM, all traders make an effort to become experts. Both the DM and traders commit to their strategies. Nature draws the state of the economy, Θ, which is unknown to all parties at the time the announcement and learning decisions are made. Hence, complete and perfect information characterize the subgame and the expected solution concept is subgame perfect equilibrium (SPE). However, SPE provides the DM with a first-mover advantage, as the announcement precedes the traders' learning decisions. This, in turn, can translate into a policy decision which is not just state-inconsistent but also time-inconsistent, as in Kydland and Prescott (1977). We focus on state-inconsistency, which refers to diverging policy decisions in high and low repayment states under pooling contracts. This implies the selection of a different Nash equilibrium whose derivation is nested in a simultaneous-move game in which both sides assume their decisions have no direct impact on the decision of the other side. Besides being motivated by the fact that we are interested in the uncertainty across repayment states due to state inconsistency rather than a possible bias due to time inconsistency, this choice simplifies the derivation of results because the original SPE would mix these two inconsistencies. We provide some additional comments on this issue in the Appendix.

Optimal learning What determines the level of optimal expertise among traders, x, given the DM's announcement? Individual traders choose the probability $x \in [0,1]$ with which they become experts (Xs) in the secondary market and consequently learn about the true current repayment state. With probability $1-x$ traders remain non-experts (Ns). A trader weighs the benefit of becoming an expert relative to remaining a non-expert (compare equations (4) and (6)) by considering the cost of effort $e(x)$.[26] Optimal expertise is then determined by

$$x^C = \arg\max_{x \in [0,1]} \left\{ x\Omega^C - e(x) \right\}, \tag{11}$$

where $C \in \{P, S\}$.

The following lemma describes the best response of traders to an announcement, a.

Lemma 4.5. *A unique solution to the learning problem (11) is defined by the first-order condition*

$$e_x \left(x^C \right) = \Omega^C, \tag{12}$$

where Ω^C is the information loss with pooling ($C = P$) or shutdown ($C = S$) contracts (compare equations (4) and (6)).

The expected net surplus of experts weakly dominates that of non-experts, so that the marginal benefit is always non-negative. Given our assumptions on the informational cost

[26] All expressions are linear in the number of bonds brought to the secondary market by PDs, b. This is an unknown quantity at this stage but traders know the best response functions for the auction game as part of their equilibrium knowledge. In particular, b is determined in Lemma 4.4 as a function of the (given) announcement by the debt office, a, and its financing needs, ν. Traders simply take expectations over the latter.

function, a first-order condition for an optimal choice x^S is sufficient to pin down the unique optimal response.

In shutdown equilibria, the information loss is only realized in the high repayment state. However, in general, the auction volume does not change across expertise levels because all auctions are fundamental with shutdown contracts. Hence, the right-hand side of equation (12) is positive and constant in expertise when $C = S$ while the left-hand side strictly decreases from infinity to zero. Hence, a solution to condition (12) exists for $C = S$, lies inside the unit interval, and is unique.

In pooling equilibria, on the other hand, there is no information loss to a non-expert trader (compared to an expert counterpart) in the high repayment state. Hence, the expected information loss is determined solely by the expected bond volume in the low repayment state which is generally different from the high repayment state. This drives the wedge between being an expert and a non-expert. The right-hand side of equation (12) strictly decreases in x^P whereas the left-hand side strictly increases in x^P when $C = P$. Hence, a solution to condition (12) exists for $C = P$, lies inside the unit interval, and is unique.

Optimal announcements What determines an optimal announcement given expertise? The DM will adjust the actual bond issuance volume as described in Lemma 4.4. Hence, the objective function is given by plugging the best response given Lemma 4.4 into the DM's objective function (3) and taking expectations over the state of the economy. The following lemma summarizes the solution.

Lemma 4.6. *The optimal announcement is $a^S = \upsilon^E$ in shutdown equilibria. Pooling equilibria yield*

$$a^P = \upsilon^E + \frac{1-\kappa}{\psi}\Phi^P > \upsilon^E \tag{13}$$

where $(1-\kappa)\,\Phi^P/\psi$ is the announcement bias.

The Appendix contains the proof. Lemma 4.6 specifies that shutdown contracts do not provide any net surplus to PDs from the secondary market. DMs reduce the penalties for deviating from the announced volume in their loss function (3) by announcing their expected funding needs.[27] In contrast, with pooling contracts, information rents arise to DMs in low repayment states, which occur with probability $1-\kappa$. DMs will increase the auction volume proportional to the unit information rents, Φ^P, that PDs can extract in the secondary market. A larger denominator ψ dampens the announced volume by punishing deviations from actual financing needs. From equation (13), it follows that announcements with pooling contracts strictly decrease in expertise. Further, note that the announcement bias in pooling equilibria translates into a positive issuance bias in high repayment states.

Clearing We next determine the Nash equilibrium for the announcement-learning game. Plugging DMs' announcement responses, summarized in lemma 4.6, into Ts' learning strategies in lemma 4.5, determines a clearing condition. The following proposition describes the solution for shutdown and pooling equilibria.

Proposition 4.7. *The unique equilibrium learning decision is*

$$e_x\left(x^{C*}\right) = \Omega^{C*} \tag{14}$$

for $C \in \{S, P\}$. Ω^{S*} and Ω^{P*} are the equilibrium information losses with shutdown and pooling contracts defined analogously to equations (4) and (6), respectively. Optimal announcements are given by $a^{S*} = \upsilon^E$ for shutdown contracts and by condition (13) for pooling contracts.

This closes the model.

4.4 Comparative Statics

The comparative static analysis highlights the role of the degree of commitment to a DM's announcements. Table 2 in the Appendix summarizes the shifts in different equilibrium

[27]Note that at this point, nature has not yet established the actual funding requirement.

outcomes as we vary the degree of commitment, ξ, and two other key parameters.

The intuition for the comparative statics for the announcement and the expertise is the following:[28] First, in shutdown equilibria, a change in the DM's commitment to an announcement does not alter the announcement. There is, after all, no systematic bias to over- or under-issue debt. Similarly, an increase in the commitment does not prompt traders to learn more (or less) because the expected bond volume in the secondary market is unaltered and traders are risk-neutral. In other words, a (possible) reduction in bond dispersion due to an increase in the degree of commitment does not affect traders' learning behavior.[29]

Second, we motivate the predictions for pooling equilibria. In contrast to shutdown regimes, greater commitment penalizes differences between the announcement and the realized bond volume. This does not alter the equilibrium announcement with pooling contracts directly (compare equation (13)). Rather, it reduces the issuance bias in equation (10) in low periods and, in turn, lowers the bond volume traded in the secondary market. Hence, the information loss of a non-expert trader decreases and, consequently, also the motivation to become an expert. This reduction in expertise leads to an increase in the equilibrium announcement.

4.5 Robustness

In the paper we make two critical assumptions. One is that traders always hold enough securities. However, what happens when they do not have enough securities to exchange with the bonds offered by PDs? This case might arise in times of crises such as the global financial crisis in 2008-09, the European debt crisis, and the Covid-19 crisis. The second assumption is that θ, the fundamental value of debt, and ν, the government's financing needs, are two independent random variables. This assumption keeps the model tractable. However, one might argue about its plausibility. For example, a haircut in the low state can

[28] An explicit derivation is provided in the Appendix.
[29] See section 3.

derive from inflation. Since inflation can be affected by deficits and debts (Cochrane, 2022), the real payout of government bonds to investors will be a function of the government's financing needs. In the next two subsections we relax both assumptions and discuss how this affects the results.

4.5.1 Security-constrained traders

In this subsection we assume that traders never hold enough funds to cover all potential realizations of μ and θ, knowing, as shown in lemma 4.4, that θ only affects the issuance quantity in pooling equilibria in periods where haircuts are applied. Traders propose a bond price and an upper bound for the quantity to be transacted that does not exceed the bond volume held by the PD, $\overline{\sigma}/u < b\,(\Theta)$. This reduces the information loss for both pooling and separating contracting regimes, as it equally constrains the trading volume of both, experts and non-experts. Consequently, it also reduces the incentive to learn about the bond's true value, regardless of the contracting regime. The upshot from security constraints is, first, a reduction in the level of expertise in the economy, and, second, a limit to the information loss to traders.

In pooling equilibria this limitation diminishes the fraction of bad bond issuance that can be resold to non-expert traders at a premium. Nevertheless, under perfect competition among PDs, which we assume, the information rents will be returned to the DM, causing the auction to be subject to an auction premium. Whether there is an issuance bias depends on the quantity of securities held by traders. If the transaction constraint is in excess of the weighted average of financing needs and announcement volume (compare equation (9)) but below the unconstrained bond issuance (compare equation (10)), then an issuance bias will arise. In separating equilibria, the limited trading in the secondary market is not only due to the transaction constraint but also because the proportion of expert traders, who trade even when the bond is good, will decrease.

4.5.2 Independence of ν and θ

In this subsection we assume that the government's financing needs ν and the fundamental value of debt θ are positively correlated. This is motivated by the example stated above, where high government spending leads to unexpectedly high inflation. However, the average financing needs are assumed to be the same as in the case where ν and θ are independent.

As a result, in separating equilibria the bond volume in good states determines the level of information loss as non-experts do no longer trade. As the correlation between ν and θ becomes more positive, the information loss rises and increases the motivation for traders to become experts. As expertise in the secondary market increases, trade intensifies.

In pooling equilibria, when μ and θ are positively correlated, the information loss is determined by the trading volume in bad states, which is lower than in the case where θ and ν are independent. As a result, traders are less inclined to become experts, in turn reducing the level of expertise and increasing the auction premium and the incentive to over-issue by the DM.

5 Goals of an Announcement Policy

We next examine possible goals of an announcement policy and provide financial, welfare, and policy implications. Financial implications are discussed in section 5.1, followed by the welfare implications for the DM in section 5.2 and those for the general public in section 5.3. The derivations can be found in the Appendix.

5.1 Financial Windfall

As defined in the introduction, a financial windfall corresponds to the financial gain for DMs from exploiting advantageous "beat-the-market" opportunities. Formally, the next corollary summarizes:

Corollary 5.1. *No financial windfall arises in shutdown equilibria. The financial windfall in pooling equilibria is*

$$\mathbb{E}\left[q^{P*}(\Theta)\,|\Theta\right] = (1-\kappa)\,\Phi^{P*}\mathbb{E}_v\left[b^{P*}\left(\Theta^L\right)\right] \tag{15}$$

All auctions are fundamental in shutdown equilibria. In pooling equilibria, on the other hand, the average financial windfall from information rents is given by the product of auction premium, Φ^{P*}, and the average bond volume in low periods, $\mathbb{E}_v\left[b^{P*}\left(\Theta^L\right)\right]$,[30] down-weighted by the frequency of low periods, $(1-\kappa)$.

What happens to (15) when the commitment level changes? We begin by looking at the auction premium and the average bond volume in low periods separately. Table 2 in the Appendix exhibits a summary of the results. Notice that the auction premium and the level of expertise have an inverse relationship in equilibrium (compare equation (8)). The larger the level of expertise among traders, the less information rent a PD can expect to extract.

An increase in commitment reduces the issuance bias in low periods, as the DM avoids larger discrepancies between high and low periods. The reduction in the issuance bias leads to less expertise, which, in turn, pushes up the auction premium, raising the DM's benefit per unit of debt. The effect on the joint product is inconclusive and depends on the parameter space.

5.2 Accommodation of Financial Needs

The financial windfall is only one accounting measure relevant for a DM. More important from a policy view is the inclusion of opportunity costs from ignoring unforeseen financial needs. The latter may, for example, complicate budget planning and lead to frictions in the political process. Consequently, we look at the DM's expected payoff after taking unexpected funding needs into account.

[30] An exlicit solution to the average bond volume in low periods is given in (38) in the Appendix.

Corollary 5.2. *The DM's optimal expected payoff function is*

$$DM^{S*} = -\frac{1}{2}\frac{\psi\xi}{\psi+\xi}\left(\upsilon^{E2} - \upsilon^{E\,2}\right) \tag{16}$$

in shutdown equilibria, while in pooling equilibria we find

$$DM^{P*} = DM^{S*} \tag{17}$$

$$+\left(1 - x^{P*}\right)(1+\delta)\,\Omega^{P*} \tag{18}$$

$$-\frac{1}{2}(1-\kappa)\frac{\psi + (1-\kappa)\,\xi}{\psi\,(\psi+\xi)}\,\Phi^{P*\,2} \tag{19}$$

For the sake of simplicity in the exposition, we start with the DM's expected payoff in shutdown equilibria. According to equation (16), the DM is indifferent about the level of informational costs. Further, the DM's payoff weakly increases in average financing needs, υ^E. Since a higher commitment reduces a DM's flexibility to accommodate unforeseen financial needs, the DM's payoff strictly decreases in commitment, ξ. These results are summarized in Table 2 in the Appendix.

For pooling equilibria, we obtain several additional effects. First of all, equation line (17) captures the part of the penalty function that is identical to the shutdown regime. Equation line (18) captures the information loss Ω^{P*} the DM is able to retrieve from non-expert traders, $1 - x^{P*}$, rescaled by $1 + \delta$. Finally, equation line (19) shows the cost of running a state-inconsistent announcement policy where the DM issues systematically more (less) bonds in low (high) repayment states compared to the announcement.[31] We find

$$\frac{\partial DM^{P*}}{\partial \xi} = \frac{\partial DM^{S*}}{\partial \xi} - \frac{\kappa (1-\kappa)}{2(\psi+\xi)^2} \Phi^{P*\,2} \tag{20}$$

$$+ (1-\kappa) \underbrace{\frac{\partial \Phi^P}{\partial \xi}}_{+} \mathbb{E}\left[b^{P*}\left(\Theta^L\right)|\Theta^L\right] \tag{21}$$

where the first (negative) term $\left(\partial DM^{S*}/\partial\xi\right)$ in the first line is similar to the derivative with respect to ξ for the DM's optimal value function in the shutdown regime. That is, it captures the loss from an increase in commitment which we attribute to the inflexibility to accommodate unforeseen financing needs. The second summand in the first line denotes the increased loss due to the differences in auction volumes between high and low periods. The second line reflects the gains from the increase in the average auction price due to commitment, $\partial p^{P*}\left(\Theta^L\right)/\partial\xi$. Hence, the overall impact of commitment depends on the parameter space. An increase in financing needs depresses the payoff of the DM. On the other hand, a change to the informational costs strictly increases the payoff of the DM. See Table 2 in the Appendix.

5.3 Welfare

The main point of interest of our paper is the welfare implication for both types of members of the general public, traders and PDs, from DMs' commitment. In the model, carrying bonds from the auction to the secondary market reduces PDs to a mechanical role. The linear payoffs as well as perfect competition leave their (ex-ante) payoffs unaffected by changes in the degree of commitment. Hence, the PDs welfare effects are irrelevant.

The (ex-ante) payoff of traders, on the other hand, is subject to two effects. The first is

[31] Obviously, these cost do not exceed the benefit so that

$$DM^{P*} - DM^{S*} = (1-\kappa)\,\Phi^{P*}\left(\upsilon^E + \frac{1}{2}\frac{\psi+(1-\kappa)\xi}{\psi(\psi+\xi)}\Phi^{P*}\right) \geq 0$$

given by the information loss of a non-expert trader from purchasing bonds in comparison to being an expert trader. The second effect arises from the cost of acquiring information about the bond to become an expert. The total (ex-ante) loss to the trader's payoff attributable to imperfect information regarding the repayment state is

$$L^{C*} = \left(1 - x^{C*}\right) e_x \left(x^{C*}\right) + e \left(x^{C*}\right), \tag{22}$$

where we applied $\Omega^{C*} = e_x \left(x^{C*}\right)$ from proposition 4.7. This leads to the following corollary.

Corollary 5.3. *The (ex-ante) equilibrium loss to traders, L^{C*}, is monotonically increasing in the equilibrium level of expertise, x^{C*}, and the equilibrium information loss to uninformed traders in the secondary market, Ω^{C*}, for $C \in \{P, S\}$.*

The first result follows directly from equation (22). The relationship between L^{C*} and Ω^{C*} follows from proposition 4.7. Technically, the level of expertise and the information loss are determined endogenously in the model. Corollary 5.3 highlights that the equilibrium loss to traders increases in the information loss even when traders are given a (costly) opportunity to learn. In fact, the learning effort is socially wasteful when a) imperfectly informed trading partners are given a costly opportunity to become informed, and b) trading under asymmetric information is subject to over-the-counter trading where the terms of trade remain private.

6 Conclusion

In this paper, we show that asymmetric information in the secondary market can lead to misaligned incentives, which lead to an issuance bias. The issuance bias has a resemblance with the inflation bias in monetary policy but its origin does not lie in a time-inconsistency problem. Rather, debt managers face a state-inconsistency problem in the presence of "beat-the-market" opportunities which give rise to a positive comovement between issuance bias and auction premium. We analyze announcements as a strategic tool for public debt managers to affect auction results and expertise in the secondary market.

The main findings emerging from our welfare-theoretic analysis answer the following questions: Does increasing the commitment to an announcement provide a solution to the issuance bias? The answer is not straightforward. On the one hand, more commitment reduces the issuance bias in the presence of “beat-the-market” opportunities. On the other hand, a higher commitment increases the volume of debt issued when no “beat-the-market” opportunities are available. Furthermore, an announcement increases the average auction premium. This, combined with an increase in the average auction volume, gives rise to a financial windfall for debt managers and taxpayers, after all. However, the increase in auction volume is driven by a boost in periods when the auction premium is not present and decreases when the auction premium is available. The compound financial effect is unclear. Another effect from higher commitment is that it ties debt managers' hands to react to unforeseen financing needs. Finally, greater commitment also leads to less expertise among traders.

Does more predictability reduce uncertainty over the "true" price of government securities? This can be denied because increasing the degree of commitment lowers expertise among traders. What about broadening the investor base? This may have a bearing on the results but more research on this question is required. Does it lower the risk premium? Yes, it does: Auction prices rise in the pooling regime because the issuance bias decreases. Can borrowing costs be reduced by such a policy? Yes, this is also borne out by our analysis in the pooling regime. In contrast, we cannot generally confirm that it fosters secondary market liquidity.

How do our results compare with the benefits commonly attributed to predictability in monetary policy-making? One critical issue is the effect on credibility. The question of whether more predictability raises a debt manager's credibility cannot be answered because in our model credibility is an exogenous parameter. This points to an avenue for further research. DM's utility function characterizes the penalty from deviation from the announcement and deviation from the financing needs. However, it would be interesting to endogenize the DM's reputation cost similar to the monetary economics tradition Woodford (2003). However, as shown by monetary policy analyses of reputational effects in a time-inconsistency environment, the outcome is tricky. This fact motivated our choice of a state-inconsistent and not a time-inconsistent framework. Another related issue for future analysis may compare debt managers' announcements with the effects from forward guidance pursued by central banks.

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Appendix

In the following, we provide further analyses in Appendix A. We start with a comparative static analysis, followed by further empirical evidence and a discussion on roles of announcements. Appendix B provides details on technical derivations.

Appendix A

Appendix A.1: Comparative Statics

The comparative static analysis highlights the role of three key exogenous parameters: the degree of commitment to a DM's announcements, ξ, the expected government's financing needs, ν^E, and the difficulty in acquiring information about the fundamental value of a bond (the cost of information acquisition), ϵ. To recall, the latter is parameterized by reformulating the cost function $e(x) = \epsilon \bar{e}(x)$.

We motivate the choice of the three key parameters $\left\{\xi, \upsilon^E, \epsilon\right\}$ as follows: The fiscal authority may impose a specific degree of commitment, ξ, on the DM by a contract.[32] The DM chooses between the government's average financing needs, ν^E, and auction frequency. The fiscal authority may also compel the DM to deliver (more) information to PDs and traders. This, in turn, can reduce their information acquisition costs ϵ. Table 2 summarizes the shifts in different equilibrium outcomes as we vary our key parameters.

[32]Similar to the optimal contract between the government and the central bank, as analyzed by Persson and Tabellini (1993) and Walsh (1995).

	Shutdown contracts							
	a^{S*}	x^{S*}	Ω^{S*}	DM^{S*}	Σ^{S*}			
ξ	$=0$	$=0$	$=0$	<0	$=0$			
υ^E	$=1$	>0	$=\frac{\kappa\delta}{1+\delta}$	≥ 0	$=0$			
ϵ	$=0$	<0	<0	$=0$	$=0$			
	Pooling contracts							
	a^{P*}	x^{P*}	Ω^{P*}	DM^{P*}	Σ^{P*}	Φ^{P*}	$\mathbb{E}\left[b^{P*}\left(\Theta^L\right)\right]$	$\mathbb{E}\left[q^{P*}\left(\Theta\right)\right]$
ξ	>0	<0	<0	?	?	>0	≤ 0	?
υ^E	$0<\bullet<1$	>0	$0<\bullet<\frac{1-\theta^E}{1+\delta}$	<0	<0	<0	$0<\bullet<1$	?
ϵ	>0	<0	<0	>0	>0	>0	≥ 0	>0

Table 2: Comparative statics for various outcomes.

The intuition for the comparative statics of $\left(a^{C*}, x^{C*}\right)$ and our key parameters is the following:[33] First, in shutdown equilibria, neither a change in the DM's commitment to an announcement, ξ, nor a change in the information cost to traders, ϵ, alters the announcement a^{S*}. There is, after all, no systematic bias to over- or under-issue debt. Only a shift in expected funding needs, υ^E, raises the announcements a^{S*} accordingly. If the DM expects larger funding needs, the announced volumes will increase one-for-one. However, a rise in informational costs, ϵ, depresses the economy-wide level of expertise, x^{S*}, as learning becomes more costly. An increase in the commitment, ξ, does not prompt traders to learn more (or less) because the expected bond volume in the secondary market is unaltered and traders are risk-neutral. In other words, a (possible) reduction in bond dispersion due to an increase in the degree of commitment does not affect traders' learning behavior.[34]

Second, we motivate the predictions for pooling equilibria, as exhibited in the lower part of Table 2. The first-order arguments that connect changes in the key parameters $\left\{\xi, \upsilon^E, \epsilon\right\}$ to equilibrium predictions are similar to the arguments for shutdown equilibria. A larger auction volume leads to more expertise because the information loss in pooling equilibria increases in the trading volume as well. But there are some qualitative changes compared to the shutdown regime. A secondary transmission channel opens up because the information rents lead to an issuance bias and an auction premium, as described in the introduction of

[33]An explicit derivation is provided in the Appendix.

[34]See section 3.

this paper. For example, a reduction in traders' information cost does not only lead to more expertise. It also reduces the announced volume indirectly because PDs can extract fewer information rents in the secondary market which, in turn, depresses the auction premium. In contrast, greater commitment penalizes differences between the announcement and the realized bond volume. This does not alter the equilibrium announcement with pooling contracts, a^{P*}, directly (compare equation (13)). Rather, it reduces the issuance bias in equation (10) in low periods and, in turn, lowers the bond volume traded in the secondary market. Hence, the information loss of a non-expert trader decreases and, consequently, also the motivation to become an expert. This reduction in expertise leads to an increase in the equilibrium announcement, a^{P*}. Higher average financing needs on the other hand do not translate into a one-for-one increase in announcements. Instead, the expectation of increased trading volume induces more traders to become experts. This depresses the increase in the volume of announcements so that $0 < \partial a^{P*}/\partial v^{E} < 1$.

Appendix A.2: Predictions and Empirical Evidence

In this section, we discuss three stylized facts and confront them with the data. First, we highlight the issuance bias in the data. To this end we extended the sample employed in the introduction, that was kept small for expositional purposes, by including also 4,831 T-bills and 170 inflation-indexed securities (TIPS). Hence, our data set has a total of 5,141 observations.[35] Extending the sample allows us to compare the co-movement of the auction premium and the issuance bias across different classes of bonds. Second, we focus on the empirical relationship between the auction premium and the issuance bias. Third, we connect the data from individual auctions with aggregate weekly transaction data for all PDs from the New York Federal Reserve to assess the impact of announcements on trade in the secondary market. As mentioned in the introduction, the period between July 2012 and December 2015 resembles a regime where the U.S. Treasury was (almost fully) commit-

[35] This captures the majority of U.S. Treasury debt auctions between September 30, 1992, and October 15, 2020 with the notable exception of 2-year bonds with variable interest rates.

ted to its announcements. While we are uncertain about the motivation behind this policy shift, we consider this period as a quasi-natural experiment from which we deduce possible implications below. We refer to this period as the high-commitment window.

Two caveats arise from extending our static model to a dynamic environment. First, the model does not endogenize reputational effects. Rather, a penalty term in the DM's payoff function mimics their reputational concerns. Hence, evidence of past discipline, or its lack, does not alter the future priors or actions of PDs and traders which, in turn, could yield viable data predictions. Second, the government's financing needs are exogenously given, which presents two concerns when we bring our model to the data. The first is that the government's financing needs are subject to a political process whose (statistical) behavior is beyond the scope of this paper. Hence, it is difficult to find a proxy for ν^E. The second concern is that the announcement bias in pooling equilibria suggests a permanent over-issuance which would result in a reduction of future financing needs.

Having said that, our model's predictions are borne out by the data: 1) The issuance bias was smaller when the announcements became larger, decreased in the maturity of the bond, and did not vanish in the high-commitment window. 2) Most regression results displayed below are either in line with predictions in pooling equilibria, or estimates are not significantly different from predictions from shutdown equilibria, but the sign of the coefficients point in the direction of pooling equilibria.

Issuance Bias The issuance bias is defined as the difference between the issuance and the announcement. Our model predicts that, on average, the announcement matches the actual issuance, or $a^{C*} = \mathbb{E}\left[b^{C*}(\Theta)\,|\Theta\right]$. This implies that announcements are, on average, truth-telling.[36] To test this prediction, we first regress the issuance bias on a constant in column (1) in Table 3. Reported standard errors are robust with respect to heteroscedasticity. The constant is positive and significantly different from zero which conflicts with our prediction. In other words, the issuances of the U.S. Treasury were subject to a bias attributable to a

[36] See our discussion in 6 in the Appendix, in particular corollary 6.3.

time inconsistency.

Regression	(1)	(2)	(3)
Obs	5,141	5,141	5,141
R^2	0.000	0.320	0.376
Constant	11.2829***	11.2829***	13.0893***
	(0.2290)	(0.1889)	(0.2015)
(log-) Announcement		-17.8687***	-16.8666***
		(1.4050)	(1.3673)
(log-) Maturity		-1.9307***	-1.7179***
		(0.1726)	(0.1687)
High Commitment			-10.4815***
			(0.3118)

Table 3: Estimates from a regression explaining the (uncentered) issuance bias on a constant and several recentered regressors for individual auctions. *, **, and *** indicate that the value is different from zero with 10%, 5%, and 1% probability, respectively.

Next, we regress the issuance bias on a constant, the recentered (log-) announcement, and the recentered (log-) maturity of the respective auctions in column (2). Note that the announcement is part of the issuance bias as well as an explanatory variable. However, we do not claim causality but observe that the issuance bias decreases as the announcement increases and vice versa. Further, longer maturities also significantly depress the issuance bias.

Finally, column (3) introduces a dummy that is one in the high-commitment window. High commitment significantly reduces the issuance bias. The constant increases which suggests that the issuance bias in the remaining auctions was about 13%. A Wald-test reveals that the issuance bias in the period of commitment is not equal to zero, but positive and significantly different from zero.

Auction Premium and Issuance Bias The auction premium is defined as the auction price minus the fundamental value of the bond, $p^{P*}(\theta) - \theta$. Our model predicts an auction premium equal to $\Phi^{P*} > 0$ in the low repayment state when traders pool their offers and zero otherwise. The auction premium is independent of the government financing needs υ

regardless of the contracting regime. Further, the auction premium (under pooling contracts) has an inverse relationship with the level of expertise because $\partial\Phi^{P*}/\partial x^{P*} = -\left(1-\theta^L\right)$, as documented in Table 2. The empirical analogue of the auction premium is the percentage difference between the auction price and the (discounted) secondary market price of a similar Treasury bond one week after the auction.

The mean issuance bias, averaged over ν, in shutdown equilibria is zero, regardless of the repayment state. In pooling equilibria, on the other hand, the mean issuance bias depends on the repayment state. In particular, the mean issuance bias in the high repayment state is negative, or $\mathbb{E}\left[b^{P*}\left(\theta^H\right)|\theta^H\right] - a^{P*} = -\left(1-\kappa\right)/\left(\psi+\xi\right)\Phi^{P*}$, and positive in the low repayment state, $\mathbb{E}\left[b^{P*}\left(\theta^L\right)|\theta^L\right] - a^{P*} = \kappa/\left(\psi+\xi\right)\Phi^{P*}$. The next corollary summarizes the co-movement between the auction premium and the issuance bias attributable to the state-inconsistency that is at the heart of our model.[37]

Corollary 6.1. *The covariance Σ^{S*} between the auction premium and the issuance bias in shutdown equilibria is zero. The covariance between the auction premium and the mean issuance bias in pooling equilibria is*

$$\Sigma^{P*} = Cov\left(p^{P*}\left(\theta\right)-\theta, \mathbb{E}\left[b^{P*}\left(\theta\right)|\theta\right]-a^{P*}\right) = \frac{\left(1-\kappa\right)^3\kappa\left(1-x^{P*}\right)^2}{\xi+\psi} \tag{23}$$

which is always positive.

Table 4 contains the results. Reported standard errors are robust for heteroscedasticity. All variables are demeaned so that we omit the constant. The first column captures a univariate regression of the auction premium on the issuance bias. The coefficient of the issuance bias is positive and significantly different from zero. Further, it remains positive and significant and does not change sizably as we introduce other regressors. This result suggests that the U.S. Treasury expanded its issuance as the "beat-the-market" opportunities arose in line with pooling equilibria.

[37] Comparative statics are summarized in Table 2.

Regression	(1)	(2)	(3)	(4)
Obs	5,141	5,141	5,141	5,141
R^2	0.007	0.105	0.118	0.125
Issuance bias	0.0054***	0.0090***	0.0088***	0.0088**
	(0.0006)	(0.0011)	(0.0013)	(0.0019)
(log-) Announcement		0.2541***	0.1975***	0.2228***
		(0.0420)	(0.0412)	(0.0402)
(log-) Maturity		-0.1589***	-0.1411***	-0.1419***
		(0.0142)	(0.0157)	(0.0160)
Issuance bias × (log-) Announcement			-0.0016	-0.0031**
			(0.0013)	(0.0015)
Issuance bias × (log-) Maturity			0.0059***	0.0069***
			(0.0014)	(0.0014)
TIPS				-0.0982
				(0.2429)
Issuance bias × TIPS				-0.0545**
				(0.0215)
High Commitment				0.0661
				(0.1050)
Issuance bias × High Commitment				0.0081
				(0.0086)

Table 4: Estimates from a regression explaining the auction premium for individual auctions. All variables are demeaned so that the constant is dropped. *, **, and *** indicate that the value is different from zero with 10%, 5%, and 1% probability, respectively.

The regression in column (2) suggests that the auction premium increases in the (log-) level of the announcement and decreases in the (log-) maturity of the bond. Arguably, the announcement varies positively with the government financing needs, ν^E, while bonds with a longer maturity are more difficult to price which, in turn, implies an increase in ϵ. Our model, on the other hand, states $\partial\Phi^{P*}/\partial\nu^E < 0$ and $\partial\Phi^{P*}/\partial\epsilon > 0$ (compare Table 2). Hence, both model predictions do not match the data. Other factors seem to play a dominant role here.

Column (3) introduces two interaction terms. First, we let the issuance bias interact with the (log-) announcements. Our model predicts the covariance between the auction premium and the issuance bias in pooling equilibria, Σ^{P*}, decreases as the financing needs of the government increase. As traders expect larger issuances, they realize that the benefit from expertise increases, which reduces the covariance between the auction premium and the issuance bias (compare Table 2). In shutdown equilibria, we do not expect the coefficient to be significantly different from zero. As shown in column (3), while the coefficient is negative, it is not significantly different from zero.

The second interaction term involves the issuance bias and the (log-) maturity of the bond. Our model predicts that the covariance Σ^{P*} in pooling equilibria increases as the informational cost to price the fundamental value of the bond increases. Again, we do not expect the coefficient to be significantly different from zero in shutdown equilibria. The estimated coefficient in column (3) is positive and significant which, again, points to the availability of opportunities to "beat the market" which the U.S. Treasury seems to exploit, and the existence of pooling equilibria.

Column (4) introduces two additional elements, TIPS and the high-commitment regime. First, TIPS are, arguably, easier to price as inflation uncertainty drops. Our model predicts an increase in the auction premium as ϵ increases ($\partial\Phi^{P*}/\partial\epsilon > 0$, compare Table 2) when traders pool their purchasing offers. We expect that the coefficient is not significantly different from zero under shutdown contracts. Again, the sign of the coefficient is in line with pooling equilibria, albeit not significant. But a reduction in ϵ also reduces the covariance Σ^{P*} in pooling equilibria, which is in line with the sign of the coefficient of the interaction between the issuance bias and TIPS.[38]

Finally, the second novel element introduced in column (4) is the window of high commitment. An increase in ξ increases the auction premium in pooling equilibria, while it would not have an effect in shutdown equilibria. Again, the sign of the coefficient is in line with pooling equilibria but remains insignificant. The interaction between the window of high commitment and the issuance bias yields a positive but insignificant effect on the auc-

[38]

$$\frac{\partial\Sigma^{P*}}{\partial\epsilon} = -\frac{2\left(1-\kappa\right)^{3}\kappa\left(1-x^{P*}\right)\frac{\partial x^{P*}}{\partial\epsilon}}{\xi+\psi} > 0$$

tion bias. Unfortunately, we cannot sign the theoretical effect of an increase of ξ on Σ^{P*}.[39] To summarize, our results suggest a positive correlation between the issuance bias and the auction premium and the prevalence of pooling equilibria.

Dispersion of the Immediate Resale Volume Another measure of uncertainty for the general public is the dispersion of the immediate resale volume in the secondary market.

Corollary 6.2. *The dispersion of the immediate resale volume in shutdown equilibria is*

$$\mathbb{V}\left(\tau^{S*}\right) = \left(1 - \kappa\left(1 - x^{S*\,2}\right)\right)\frac{\psi^2}{\left(\xi+\psi\right)^2}\,\nu^{2E\,2} - \kappa\left(1-\kappa\right)\left(1 - x^{S*}\right)^2\nu^{E\,2} \tag{24}$$

and, in pooling equilibria, we find

$$\mathbb{V}\left(\tau^{P*}\right) = \frac{\nu^{2E\,2} + \kappa\left(1-\kappa\right)^3\left(1 - x^{P*}\right)^2}{\left(\xi+\psi\right)^2} \tag{25}$$

Both types of equilibria predict a reduction in the dispersion of the immediate resale volume as the commitment level rises. First, an increase in ξ reduces the (relative) weight a DM places on unforeseen financing needs. Notice that an increase in ξ does not alter x^{S*} (compare Table 2). For pooling equilibria, on the other hand, an increase in ξ also reduces the issuance bias, as mentioned above.[40]

We apply a 52-week moving average on the logarithmic transformation of the weekly transaction quantities of PDs and calculate the absolute differences between the original

39

$$\frac{\partial C}{\partial \xi} = -\frac{\left(1-\kappa\right)^3\kappa\left(1-x^{P*}\right)\left(1 - x^{P*} + 2\left(\xi+\psi\right)\frac{\partial x^{P*}}{\partial \xi}\right)}{\left(\xi+\psi\right)^2}$$

40

$$\frac{\partial \mathbb{V}\left(\tau^{S*}\right)}{\partial \xi} = -\frac{2\nu_{2e}^2\psi^2\left(1+\kappa\left(x^{S*\,2}-1\right)\right)}{\left(\xi+\psi\right)^3}$$

and

$$\frac{\partial \mathbb{V}\left(\tau^{P*}\right)}{\partial \xi} = -\frac{2\left(\nu^{2E\,2}\psi^2 + \kappa\left(1-\kappa\right)^3\left(1-x^{P*}\right)^2\right)}{\left(\xi+\psi\right)^3}$$

series and the filtered series as an approximation to the volume dispersion. Next we recenter this measure so that we can omit a constant and use a dummy that is equal to one in the high-commitment window, and zero otherwise, as the sole regressor. The point estimate of the coefficient is -0.0119 with a standard deviation of 0.0059 which implies the coefficient is significantly different at the 5% confidence level. This corroborates Friedman's claim that the unpredictability in debt management operations leads to uncertainty in the secondary market.

Appendix A.3: The Roles of Announcements

In this section, we describe three roles of announcements and provide a comparative statics analysis. The first role of announcements is to clear an implicit market. The second role is to anchor expectations, and the third role is to provide an incentive to acquire expertise.

The Implicit Market for Announcements We interpret announcements as market-clearing quantities and expertise as prices in an implicit market and provide a graphical intuition in Figure 2. The DM's announcement plays the role of a quantity in a conventional (good or financial) market, whereas expertise resembles the price dimension.

Figure 2 shows the announcement-expertise space $\mathbb{R}_+ \times [0,1]$. The left panel describes the implicit market when non-expert traders pool their offers. In case all traders are experts ($x = 1$), PDs cannot extract information rents, so that the announcement by the DM equals government's average financing need, $a = v^E$.[41] In contrast, decreasing expertise creates information rents for PDs. Hence, announcements are subject to an issuance bias when the level of expertise drops so that the (red) announcement curve slopes (strictly) downward from $\left(v^E, 1\right)$ to $\left(v^E + \frac{1-\theta^E}{\psi}, 0\right)$.

Announcements decrease in the economy's level of expertise, leading to a downward sloping announcement curve while traders' expertise curve slopes upward. As a result, there is a level of expertise where "the market clears". This implicit market is different from the

[41] Compare equation (13) where $\Phi = (1-x)\left(1-\theta^L\right)\big|_{x=1} = 0$.

concept of an implicit market with hedonic pricing, as in Rosen (1974), but similar to the concept of an implicit market for crime with a deterrence rate playing the role of a price, as proposed by Becker (1968) and recently analyzed by Smith and Vásquez (2015). While hedonic prices match demand and supply, they entail a transfer. In the price concept we have in mind when we refer to expertise there is no transfer, similar to the crime market. Learning, similar to the effort to deter a criminal, is a socially wasteful activity.

The right panel shows the implicit market for announcements in the absence of "beat-the-market" opportunities for the DM. Neither expert nor non-expert traders leave information rents to PDs so that the DM refrains from over-issuing bonds, resulting in announcements being equal to the expected financing needs for any level of expertise, or $a = \upsilon^E \, \forall x \in [0, 1]$, and making the announcement curve perfectly inelastic in expertise.

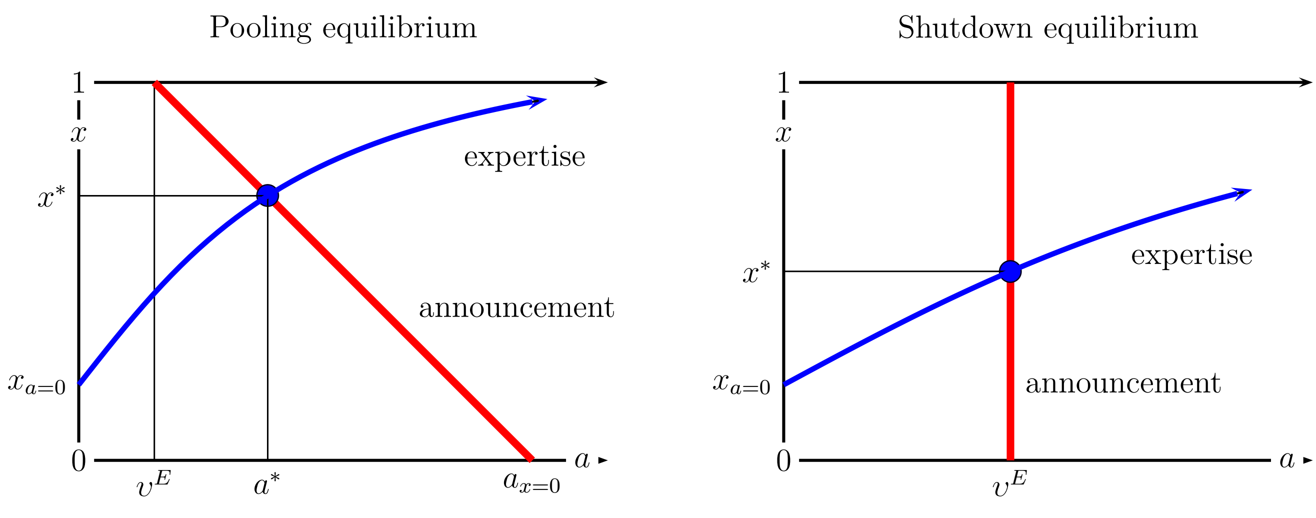

Figure 2: The implicit market for announcements and expertise when non-expert traders in the secondary market offer pooling contracts (left) or shutdown contracts (right). The horizontal axis reflects announcement quantities a, while the vertical axis displays expertise x.

Time Inconsistency What would a solution look like when debt managers considered the impact of their announcement on traders' learning decisions? The solution with shutdown contracts would remain unaffected. In pooling equilibria, three issues arise from the comparison of the announcement problem with the time-inconsistent problem analyzed in

Kydland and Prescott (1977). First, our debt manager would consider the responses of the other agents after receiving the announcement. In particular, traders' learning decisions could be affected. This implies that the constant x in equation (27) had to be replaced with the function $x(a)$. Second, monopolist theory suggests that debt managers would discourage traders from learning by under-announcing the expected trading volume. At the same time, debt managers are committed to their announcement through their payoff function when the auction starts. This dampens the strategic considerations to under-announce. Finally, debt managers in our setup do not possess private information. The latter would allow a debt manager to conflate private information with strategic motives. Unfortunately, even with (more) simplifying assumptions no conclusive analytical answer to the question of whether the debt manager under-announces, as our intuition suggests, can be obtained.

Announcements as an Expectation Anchor Announcements play the role of an information transmission device from the DM to the general public regarding the expected issuance volume. The following corollary addresses the lack of a bias in such announcements.

Corollary 6.3. *Announcements are truth-telling regardless of the contracting regime, or* $a^{C*} = \mathbb{E}\left[b^{C*}(\Theta)\,|\Theta\right] \; \forall C \in \{P, S\}$.

Announcements are truth-telling in the sense that they can serve as an unbiased anchor for expectation formation in the primary market. However, this result hinges on two assumptions. The first is that DMs have no private information that they could exploit for strategic signaling. The second is that DMs do not incorporate the direct effects their announcements have on secondary market expectations. This is equivalent to foregoing the first-mover advantage in a sequential game or ignoring the price impact of a monopolist when determining the supply quantity. Dynamic policy games refer to this outcome as time inconsistency, which we ignore as explained.

Announcements as an Incentive Announcements play the role of an incentive provided DMs stick to their commitment and announcements are "meaningful", that is, when $\xi > 0$. The incentive, which prompts traders to become experts, increases in the size of the announcement. As announcements are truth-telling, they are proportional to the information loss Ω^C non-expert traders experience compared to expert trades. Hence, the incentive to become an expert trader increases in the announcement level. The following corollary summarizes the shape of the expertise curve.

Corollary 6.4. *The expertise curve is non-decreasing in the announcement level. It is horizontal if $\xi = 0$ and strictly upward sloping otherwise, in which case $x^C \to 1$ as $a^C \to \infty$ for $C \in \{P, S\}$.*

Equation (12) yields $\frac{\partial x^C}{\partial a} \geq 0$ for $C \in \{P, S\}$, and the inequality is strict if $\xi > 0$. Therefore, the level of expertise increases in the announcement provided it is meaningful. Hence, the (blue) expertise curve in the left panel of Figure 2 (pooling contracts) is upward sloping, as larger expected trading volumes in the secondary market increase the benefit of becoming an expert. There is a single interior equilibrium where the two curves intersect at $\{a^*, x^*\}$ where $a^* > v^E$ and $x^* \in (0, 1)$. Similarly, the expertise curve in the right panel of Figure 2 (shutdown contracts) also slopes upwards because the benefit from (individual) expertise still increases in the expected trading volume in the secondary market. The two curves intersect only once at $\{a^*, x^*\}$ but now $a^* = v^E$.

Appendix B

Derivations

Equilibrium The left-hand side (LHS) of condition (14) represents the marginal cost of learning. In particular, $e_x\left(x^{C*}\right) \to 0$ as $x^{C*} \to 0$, $e_x\left(x^{C*}\right) \to \infty$ as $x^{C*} \to 1$, and increases strictly in x^{C*}, as $e_{xx}(x) > 0 \,\forall\, x \in [0, 1]$. The right-hand side (RHS) of condition (14) represents the marginal benefit of learning, namely, the equilibrium information loss as defined in equations (4) and (6) for $C = S$ and $C = P$, respectively. The solution to equation (14) in terms of x^{S*} exists and is unique when $C = S$. It strictly decreases in x^{P*}, and $0 < RHS_{x^{P*}=1} < RHS_{x^{P*}=0} < \infty$ so that a unique solution exists.

Optimal Expertise The right-hand side of the optimality condition (12) displays only private marginal benefits. While this does not matter in a shutdown equilibrium, there is an externality when traders pool their offers which can be motivated as follows: Experts extract all trading surpluses in the secondary market while non-experts leave some information rents to low PDs. This difference in expected net surpluses increases in the bond volume which, in turn, is determined by the issuance bias. As can be inferred from (10), the issuance bias decreases in the economy-wide expertise among traders, x. In other words, traders exert too much effort because they do not consider their private contribution to the economy-wide expertise. The economy-wide expertise depresses the bond volume and reduces the benefit of being an expert in the first place. Hence, becoming an expert creates a negative externality for other expert traders. This leads to the socially optimal level of expertise being strictly below the one chosen by traders individually.

Optimal Announcements Next, we motivate the solutions given in lemma 4.6. First, the objective function in (3) requires the debt manager to take expectations over the state of the economy. The results follows from plugging equation (26) into the objective function (26) and determining the first-order condition for a.

For auctions in shutdown equilibria we find

$$DM^S = \frac{1}{2} \frac{\xi\psi}{\psi + \xi} \left(2\upsilon^E a - a^2 - \upsilon^{E2}\right), \tag{26}$$

where $\upsilon^{E2} = \mathbb{E}_\upsilon\left[\upsilon^2\right]$ denotes the second (uncentered) moment of ν.

For pooling equilibria, the result is

$$DM^P = DM^S \\ + \underbrace{\frac{1}{\psi+\xi}\left(\psi\Phi\upsilon^E + \frac{1}{2}\,\Phi^2 + \xi\Phi a\right)}_{\substack{\text{expected information rents} \\ \text{from pooling in low periods}}}, \tag{27}$$

where the first line of the right-hand side resembles the right-hand side of equation (26). The second line captures the information rents the debt manager extracts from the secondary market. We can split the term inside the bracket further. The first part, $\psi\Phi\upsilon^E$, is the total information rent from issuing a volume corresponding to the average financing needs, $\Phi\upsilon^E$, weighted by the parameter ψ, which punishes deviations from realized financing needs. The second term, $\frac{1}{2}\,\Phi^2$, reflects the windfall profit from the issuance bias in equation (10). The last term, $\xi\Phi a$, induces debt managers to over-announce with the aim to minimize the penalty from deviating from the announcement later on, enabling them to extract information rents. The result for the optimal announcement with pooling contracts, equation (13) in lemma 4.6, follows.

The Implicit Market We start with shutdown equilibria. We can motivate the result in corollary 6.4 as follows. The derivation for the announcement curve is straightforward. The implicit function theorem for the slope requires us to restate equation (12) as $G^S = 0 = \epsilon\bar{e}_x\left(x^S\right) - \kappa\delta/\left(1+\delta\right) \times \left(\psi\upsilon^E + \xi a\right)/\left(\psi+\xi\right)$ where the issuance response in Lemma 4.4 is implemented. Then, we find the result. Next,

$$\frac{\partial^2 x^S}{\partial a^2} = -\frac{\bar{e}_{xxx}\left(x^S\right)}{\bar{e}_{xx}^2\left(x^S\right)}\frac{\partial x^S}{\partial a}A \leq 0 \tag{28}$$

where $A = \frac{\delta}{1+\delta}\frac{\kappa}{\epsilon}\frac{\xi}{\psi+\xi}$. Equation (28) shows that the expertise curve is strictly concave if $\bar{e}_{xxx}\left(x\right) \geq 0\,\forall x \in [0,1]$ which is indeed the case for $\bar{e}\left(x\right) = -x - \log\left(1-x\right)$. In the more general case, $x^S \to 1$ as $a \to \infty$ iff $\xi > 0$.

The results for $\left\{x^{S*}, a^{S*}\right\}$ follow directly from $a^{S*} = \nu^E$ and from equation (14) when $C = S$, stated in Proposition 4.7. Remember that $e_x^{-1}(\bullet)$ is strictly increasing. For the changes in equilibrium outcomes, as presented in Table 2, the following applies:

$$\frac{\partial x^{S*}}{\partial \epsilon} = -\frac{\bar{e}_x\left(x^{S*}\right)}{\epsilon \bar{e}_{xx}\left(x^{S*}\right)} \quad < 0 \tag{29}$$

$$\frac{\partial x^{S*}}{\partial \xi} \quad = 0 \tag{30}$$

$$\frac{\partial x^{S*}}{\partial \upsilon^E} = \frac{\delta}{1+\delta}\frac{\kappa}{\epsilon}\frac{\psi}{\bar{e}_{xx}\left(x^S\right)(\psi+\xi)} \quad > 0 \tag{31}$$

The changes in a^{S*} are straightforward.

Next, we document the derivation of the results for pooling equilibria. For corollary 6.4 we rewrite equation (12) when $C = P$ as $G^P = \epsilon \bar{e}_x\left(x^P\right) - \left(1-\theta^E\right)\left(\psi \upsilon^E + \xi a + \Phi^P\right) / \left((1+\delta)(\psi+\xi)\right)$ using equation (10) and set $G^P = 0$. Applying the implicit function theorem again with respect to $\{x, a\}$ yields the result and, also,

$$\frac{\partial^2 x^P}{\partial a^2} = \frac{-\xi \bar{e}_{xxx}\left(x^p\right)\frac{\partial x^P}{\partial a}B}{\left(\bar{e}_{xx}\left(x^p\right)B + 1 - \theta^L\right)^2} \leq 0, \tag{32}$$

where $B = (1+\delta)\frac{\psi+\xi}{1-\theta^E}\epsilon > 0$. Then, $x^P \to 1$ as $a \to \infty$ iff $\xi > 0$.

For the results in Table 2 we define $G^{P*} = \epsilon \bar{e}_x\left(x^{P*}\right) - \left(1-\theta^E\right)\left(\upsilon^E + (\psi + \xi(1-\kappa))\Phi^{P*} / ((\psi+\xi)\psi)\right) / (1+\delta)$. Then

$$\frac{\partial x^{P*}}{\partial \epsilon} = -\frac{\bar{e}_x\left(x^{P*}\right)}{C} \quad < 0 \tag{33}$$

$$\frac{\partial x^{P*}}{\partial \xi} = -\left(1-\theta^E\right)\frac{1}{1+\delta}\frac{\Phi^{P*}\kappa}{(\psi+\xi)^2}\frac{1}{C} \quad < 0 \tag{34}$$

$$\frac{\partial x^{P*}}{\partial \upsilon^E} = \left(1-\theta^E\right)\frac{1}{1+\delta}\frac{1}{C} \quad > 0 \tag{35}$$

where $C = \epsilon \bar{e}_{xx}\left(x^{P*}\right) + \left(1-\theta^E\right)\left(1-\theta^L\right)(\xi(1-\kappa)+\psi) / ((1+\delta)\psi(\psi+\xi)) > 0$. The equilibrium announcement a^{P*} increases in ϵ and ξ indirectly through x^{P*} found in the announcement bias. The effect of υ^E is $\frac{\partial a^{P*}}{\partial \upsilon^E} = 1 - \frac{\partial x^{P*}}{\partial \upsilon^E}\frac{1-\theta^E}{\psi}$ so that $0 < \frac{\partial a^{P*}}{\partial \upsilon^E} < 1$, as $1 \leq \frac{\partial x^{P*}}{\partial \upsilon^E}\frac{1-\theta^E}{\psi}$ yields a contradiction.

Auction Outcomes In this subsection we discuss equilibrium auction outcomes. First, we address the comparative statics regarding auction volume and price in shutdown equilibria. Then we highlight some features about the auction results in pooling equilibria. In particular, we show how the issuance bias spills over from the low periods to the high periods as we increase the level of DMs' commitment. At the same time, the differences in volume between low and high periods diminish.

Shutdown contracts The (unconditional) average auction volume, $\mathbb{E}\left[b^{S*}(\Theta)|\Theta\right]$, matches the DM's average financing needs in shutdown equilibria. This holds irrespective of the repayment state, so that $\mathbb{E}\left[b^{S*}|\Theta\right] = \mathbb{E}_{\upsilon}\left[b^{S*}\left(\Theta^H\right)|\Theta^H\right] = \mathbb{E}\left[b^{S*}\left(\Theta^L\right)|\Theta^L\right] = \upsilon^E$. Consequently, the average auction quantities coincide with the announced quantities, $a^{S*} = \mathbb{E}\left[b^{S*}(\Theta)|\Theta\right]$. In this sense, announcements are truth-telling. This implies that our key parameters affect $\mathbb{E}\left[b^{S*}(\Theta)|\Theta\right]$ the same way they affect a^{S*} which is summarized in Table 2. The auction price is fundamental so that the average auction price is $\mathbb{E}\left[p^{S*}(\Theta)|\Theta\right] = \theta^E$. Hence, in shutdown equilibria our key parameters $\left\{\xi, \upsilon^E, \epsilon\right\}$ do not affect auction pricing.

Pooling contracts The (unconditional) average auction volume, $\mathbb{E}\left[b^{P*}(\Theta)|\Theta\right]$, in a pooling regime is

$$\mathbb{E}\left[b^{P*}(\Theta)|\Theta\right] = \upsilon^E + (1-\kappa)\frac{\Phi^{P*}}{\psi} \tag{36}$$

where $\Phi^{P*} = \left(1 - x^{P*}\right)\left(1-\theta^L\right)$. The announcement in pooling equilibria is also truth-telling (compare equations (13) and (36)). Our key parameters affect $\mathbb{E}\left[b^{P*}(\Theta)|\Theta\right]$ the same way they affect a^{P*}, similarly to shutdown equilibria. The results are summarized in Table 2.

There are three more noteworthy aspects with respect to the auction volume in pooling equilibria. First, in general, the volume auctioned differs between high and low periods. In particular, the average volume in high and low periods is

$$\mathbb{E}\left[b^{P*}\left(\Theta^{H}\right)|\Theta^{H}\right] = \upsilon^{E} + \Phi^{P*}\frac{\xi\left(1-\kappa\right)}{\psi\left(\psi+\xi\right)} \tag{37}$$

$$\mathbb{E}\left[b^{P*}\left(\Theta^{L}\right)|\Theta^{L}\right] = \upsilon^{E} + \Phi^{P*}\frac{\psi+\xi\left(1-\kappa\right)}{\psi\left(\psi+\xi\right)} \tag{38}$$

respectively.

Second, the issuance bias in low periods carries over to high periods if announcements are "meaningful", that is when $\xi > 0$. In other words, meaningful announcements increase auction volumes even when the DM does not cash in an auction premium. More generally, the DM forgoes the opportunity, to react to favorable market conditions under commitment to a certain auction volume. However, rather than forgoing all opportunities the DM simply raises the announcements above the expected financing needs and over-issues even in high periods, at a fundamental price $p = \theta^{H}$.

Third, the equilibrium issuance bias $\Phi^{P*}/\left(\psi+\xi\right)$ decreases in ξ and ν^{E} but increases in ϵ. As can be seen in equation (10), a change in ϵ and υ^{E} on the equilibrium issuance bias realizes indirectly through the level of expertise, x^{P*}. An increase in ξ, however, also involves the direct punitive effect. DMs are more heavily punished when deviating from their announcements. As a result, the issuance bias decreases as commitment increases. But the indirect effect leads to less expertise which creates an upward bias on the issuance bias in low periods. The net effect of an increase in ξ on the issuance bias is negative.

The average auction price in a pooling equilibrium is

$$\mathbb{E}\left[p^{P*}\left(\Theta\right)|\Theta\right] = \theta^{E} + \Phi^{P*} > \theta^{E} \tag{39}$$

Debt financing becomes cheaper compared to fundamental pricing because of the last term. On the other hand, PDs pay a premium. Unlike in the shutdown regime, in pooling equilibria, the average auction price decreases in v^E and increases in ϵ and ξ. The latter result means that per-unit debt financing becomes cheaper as commitment increases. After all, the auction price is constant in high periods, so all changes derive from changes to the auction premium in low periods.[42]

Secondary Market Predictions

Trading Game We start with the second-to-last round, which mirrors over-the-counter trading in the secondary market directly following an auction. Bilateral matches between PDs and traders occur with certainty. A trader holds s securities but no bonds, whereas a PD enters the market without securities but with $b(\Theta)$ bonds. These quantities yield the transaction constraints for the bond (τ) and the security (σ) transfer. While a fraction x of expert traders and all PDs enter this round knowing θ, a fraction $1-x$ of non-experts has imperfect information regarding θ.

The proposal/rejection trading game is as follows: Traders offer terms of trade in the form of a bond price (in terms of the security) u and an upper bound for the security transaction $\overline{\sigma}$. PDs accept (or reject) the bond price and choose a security quantity $\sigma \leq \overline{\sigma}$ as well as a bond quantity $\tau \leq \overline{\sigma}/u$. We next discuss the acceptance/quantity problem of a PD, followed by the proposal of expert and non-expert traders. Finally, non-expert traders determine the contracting regime.

[42] This does not mean debt financing as a whole becomes cheaper even when the average auction volume also increases in commitment. The latter is driven by the spillover of the issuance bias from low periods to high periods mentioned above.

Acceptance by the PD The PD received an offer $\{u, \overline{\sigma}\}$ in repayment state θ and now chooses a τ to maximize the net surplus from the exchange

$$\max_{\tau} \{\tau (u (1 + \delta) - \theta)\} \tag{40}$$

subject to a) the bond transaction constraint $\tau \leq b$, b) the security transaction constraint proposed by the trader $u\tau \leq \overline{\sigma}$, and c) the lower bound $\tau \geq 0$. While a trader prefers a smaller u, the PD has a reservation price $u (1 + \delta) \geq \theta$. A PD can reject the terms of trade and choose $\tau = 0$. This is the no-trade solution. Given the linear payoff structure, any solution involving a transfer must be bound from above by either the bond transaction constraint or the security transaction constraint. The security transaction constraint can only bind if $\overline{\sigma} \leq ub$, that is, when the proposed security transaction is too small. However, traders always hold enough securities[43] and, in equilibrium, propose a security transaction constraint that coincides with their holdings ($\overline{\sigma} = s$). Hence, the bond transaction constraint binds and the PD's optimal response is $\tau (u, \overline{\sigma}|b, \theta) = b$ if $u (1 + \delta) \geq \theta$ and 0 otherwise.

Proposal of the expert trader The problem of the expert trader is

$$\max_{\{u, \overline{\sigma}\}} \{\mathbb{E} [(-u + \theta) \tau (u, \overline{\sigma}|b, \theta) |b]\} \tag{41}$$

subject to the transfer response $\tau (u, \overline{\sigma}|b, \theta)$ and the security transaction constraint $\overline{\sigma} \leq s$. The optimal strategy of an expert trader is $u = \theta / (1 + \delta)$ which makes the PD just indifferent between rejecting ($\tau = 0$) and transferring as much of the bond as feasible ($\tau = b$). As an equilibrium selection criterion the PD transfers all bonds whenever the PD is indifferent between accepting the offer and rejecting it.

The net surplus for a PD trading with an expert trader is zero, or $W_X^C \left(b, \Theta^H\right) = W_X^C \left(b, \Theta^L\right) = 0$, regardless of the state of the economy and the contracting regime. The

[43]The technical condition is $s \geq \overline{\nu} / (1 + \delta)$, where $\overline{\nu}$ is the upper bound of the support of ν.

profit per unit of bond transfer is strictly positive[44] so that the trader sets the security transaction constraint to the maximum $\overline{\sigma} = s$.

On the other hand, the expected net surplus for an expert trader is

$$V_X^C(\Theta) = \frac{\delta}{1+\delta}\mathbb{E}\left[\theta b^C(\Theta)|\Theta\right], \tag{42}$$

where $\Theta = \{\theta, \upsilon\}$, in general, depends on the contracting regime C.

Proposal of the non-expert trader Non-expert traders have two options, either offer a bond price $u^P = 1/(1+\delta)$ that is accepted by the PD in both repayment states, or set a lower bond price $u^S = \theta^L/(1+\delta)$ that is only accepted by the PD in the low repayment state. The former yields a pooling contracting regime ($C = P$), while the latter yields a shutdown contracting regime ($C = S$).

Pooling Pooling contracts result in transactions in both repayment states. Compared to the full information case, the offer price u^P leaves informational rents on the table in low, but not in high repayment states. This is reflected in the information loss of a non-expert trader from purchasing bonds with a pooling offer in comparison to purchasing them as an expert trader, or

$$\Omega^P = V_X^P(s, \Theta) - V_N^P(\Theta), \tag{43}$$

where

$$\Omega^P = \left(1-\theta^E\right)\frac{1}{1+\delta}\mathbb{E}\left[b^P\left(\Theta^L\right)|\Theta^L\right] \tag{44}$$

We refer to Ω^P as the information loss with pooling contracts. The difference between expert and non-expert net surpluses motivates a trader to become an expert earlier in the game.

In the high repayment state, the expected net surplus for a PD holding b bonds in a pooling contract regime is $W^P\left(b, \Theta^H\right) = 0$. In the low repayment state, the PD can expect

[44] The profit per unit of bond transfer is $-u+\theta$. Notice that $-u+\theta > 0 \Rightarrow (-1/(1+\delta)+1)\theta > 0$ because $u = \theta/(1+\delta)$ and $(1+\delta) > 1$.

a net surplus from participating in the secondary market given by

$$W^P\left(b, \Theta^L\right) = \Phi^P b, \tag{45}$$

where Φ^P are the unit information rents arising to the PD in a low repayment state with pooling contracts. In a low repayment state a PD can extract information rents when meeting a non-expert which occurs with probability $1 - x^P$. The unit transfer benefit is $1 - \theta^L$, which equals the liquidity premium of a bond in a low repayment state with pooling contracts. The product of these two terms, $\Phi^P = \left(1 - x^P\right)\left(1 - \theta^L\right)$, is multiplied by the bond volume held, b, so that the expected net surplus of a low PD increases linearly in the bond volume.

Shutdown Offers in the shutdown contracting regime are rejected by high PDs but make low PDs indifferent between rejecting and accepting. The expected net surplus for PDs in high and low repayment states is $W^S\left(\Theta^H\right) = W^S\left(\Theta^L\right) = 0$. The information loss of a non-expert trader from purchasing bonds with a shutdown offer in comparison to purchasing them as an expert trader is

$$\Omega^S = V_X^S\left(s, \Theta\right) - V_N^S\left(\Theta\right), \tag{46}$$

where

$$\Omega^S = \kappa \frac{\delta}{1+\delta} \mathbb{E}\left[b^S\left(\Theta^H\right) | \Theta^H\right] \tag{47}$$

We equate Ω^S with the information loss under shutdown contracts. It equals the net gains of an expert trader in a high repayment state times the probability of the state, κ.

The assumptions on the informational cost function $e\left(x\right)$, which will be described below, ensure that $0 < x < 1$ in all equilibria. DMs will never issue $b < 0$, that is there is no investment in bonds.[45] See the discussion below. The following lemma summarizes the

[45] This contrasts with the fiscal insurance theory of debt management in which the DM optimally issues liabilities and at the same time invests in assets.

relationship between information rents to PDs and losses to non-expert traders, expertise and bond volume.

Lemma 6.5. *The information rents for PDs increase strictly and linearly in the bond volume and decrease strictly and linearly in the level of expertise in pooling equilibria for $b > 0$. PDs do not receive any information rents in shutdown equilibria.*

The information loss arising to non-expert traders, Ω^S *and* Ω^P*, increases strictly and linearly in the bond volume brought by PDs to the secondary market, regardless of the type of contracting equilibrium.*

Contracting regime The final question in this round of the game concerns the type of contracting a non-expert will choose. The answer depends on the comparison of the information losses as described in the following lemma:

Lemma 6.6. *The contracting type non-expert traders offer minimizes the information loss, or $P \in C$ if $\Omega^P \leq \Omega^S$, and $S \in C$ if $\Omega^P \geq \Omega^S$.*

If $\Omega^P \leq \Omega^S$, non-expert traders can offer pooling contracts. In other words, a non-expert trader offers pooling contracts if the information loss to low PDs is smaller than the expected gain from trades with high PDs who extract the full surplus. As mentioned above, the bond holdings between states and repayment regimes are, in general, not identical, or $\mathbb{E}\left[b^P\left(\Theta^L\right)|\Theta^L\right] \neq \mathbb{E}\left[b^S\left(\Theta^H\right)|\Theta^H\right]$. Hence, the expected volume plays a role. We discuss this decision further in the Appendix. However, the (realized) state of the economy Θ is irrelevant to this choice. In particular, the the government's actual financing needs and the repayment state are unknown to non-expert traders who determine what kind of contract to offer to PDs.

The next issue relates to the initial acquisition cost of bonds.

Shutdown contracts For shutdown equilibria, the (daily) bond price is $1/\left(1+\delta\right)$ with probability κx^{S*} and $\theta^L/\left(1+\delta\right)$ with probability $1-\kappa$. The first observation is characterized by experts trading in high periods while the second materializes in low periods where non-experts abstain from trading. Since the probabilities do not add to one,[46] the average cost to purchase a bond is given by

$$\mathbb{E}\left[u^{S*}(\Theta)\,|\Theta\right] = \frac{\kappa x^{S*} + \theta^{L}(1-\kappa)}{(1+\delta)\left(\kappa x^{S*} + 1 - \kappa\right)} \tag{48}$$

which comoves positively with x^{S*}. As a result, an increase in commitment leaves the early acquisition cost unaltered. An increase in average financing needs and a decrease in informational cost induce larger expertise which boosts the bond price as more experts trade in high periods.

Pooling contracts What do pooling equilibria look like? A trader can either become an expert or remain a non-expert, and the period can turn out to be either high or low. Then, the secondary market price for bonds, u^{P*}, in terms of the security is $1/(1+\delta)$ with probability $1-(1-\kappa)\,x^{P*}$ and $\theta^{L}/(1+\delta)$ with probability $(1-\kappa)\,x^{P*}$. The average cost to acquire bonds becomes

$$\mathbb{E}\left[u^{P*}(\Theta)\,|\Theta\right] = \frac{1-\left(1-\theta^{E}\right)x^{P*}}{1+\delta} \tag{49}$$

Consequently, the average bond price correlates negatively with x^{P*}. Equation (49) shows that all changes to the early acquisition costs of bonds attributable to our key parameters are affected by the level of expertise alone. In other words, traders pay for their reduced efforts to become experts in equilibrium with a higher average cost to acquire bonds.

Primary Market Outcomes We omit the auction outcomes in the shutdown equilibrium because the results are straightforward. The issuance bias in the pooling equilibrium is

[46] Given that aggregation of bond prices from a secondary market across days usually is not trade-weighted, we chose to re-weight the probabilities rather than including trade volumes.

$b^{P*}\left(\Theta^L\right) - b^*\left(\Theta^H\right) = \Phi^{P*}/\left(\psi+\xi\right)$. Then,

$$\frac{\partial b^{P*}\left(\Theta^L\right) - b^*\left(\Theta^H\right)}{\partial \epsilon} = -\frac{\partial x^{P*}}{\partial \epsilon}\frac{\left(1-\theta^L\right)}{\psi+\xi} \qquad \geq 0 \tag{50}$$

$$\frac{\partial b^{P*}\left(\Theta^L\right) - b^*\left(\Theta^H\right)}{\partial \upsilon^E} = -\frac{\partial x^{P*}}{\partial \upsilon^E}\frac{\left(1-\theta^L\right)}{\psi+\xi} \qquad \leq 0 \tag{51}$$

$$\frac{\partial b^{P*}\left(\Theta^L\right) - b^*\left(\Theta^H\right)}{\partial \xi} = \left(-\frac{\partial x^{P*}}{\partial \xi}\left(\psi+\xi\right) - \left(1-x^{P*}\right)\right)\frac{1-\theta^L}{\left(\psi+\xi\right)^2} \qquad \leq 0 \tag{52}$$

because $-\frac{\partial x^{P*}}{\partial \xi}\left(\psi+\xi\right) > \left(1-x^{P*}\right)$ leads to a contradiction.

The changes to the average (unconditional) auction outcomes in the pooling equilibrium can be stated as

$$\frac{\partial \mathbb{E}\left[b^{P*}\left(\Theta\right)|\Theta\right]}{\partial \epsilon} = -\frac{\overbrace{\partial x^{P*}}^{-}}{\partial \epsilon}\frac{1-\theta^E}{\psi} \qquad \geq 0 \tag{53}$$

$$\frac{\partial \mathbb{E}\left[b^{P*}\left(\Theta\right)|\Theta\right]}{\partial \xi} = -\frac{\partial x^{P*}}{\underbrace{\partial \xi}_{-}}\frac{1-\theta^E}{\psi} \qquad \geq 0 \tag{54}$$

$$\frac{\partial \mathbb{E}\left[b^{P*}\left(\Theta\right)|\Theta\right]}{\partial \upsilon^E} = 1 - \frac{\partial x^{P*}}{\underbrace{\partial \upsilon^E}_{+}}\frac{1-\theta^E}{\psi} \qquad \geq 0 \tag{55}$$

Financial Windfall We next provide derivations that pin down the properties discussed in 5.1. For the average bond volume in low periods, we can infer that

$$\frac{\partial \mathbb{E}\left[b^{P*}\left(\Theta^L\right)|\Theta^L\right]}{\partial \epsilon} = -\frac{\partial x^{P*}}{\partial \epsilon}\frac{\left(\psi+\xi\left(1-\kappa\right)\right)\left(1-\theta^L\right)}{\psi\left(\psi+\xi\right)} \qquad \geq 0 \tag{56}$$

$$\frac{\partial \mathbb{E}\left[b^{P*}\left(\Theta^L\right)|\Theta^L\right]}{\partial \upsilon^E} = 1 - \frac{\overbrace{\partial x^{P*}}^{+}}{\partial \upsilon^E}\frac{\left(\psi+\xi\left(1-\kappa\right)\right)\left(1-\theta^L\right)}{\psi\left(\psi+\xi\right)} \qquad \geq 0 \tag{57}$$

$$\frac{\partial \mathbb{E}\left[b^{P*}\left(\Theta^L\right)|\Theta^L\right]}{\partial \xi} = -\frac{\frac{\psi+2\xi}{\psi+\xi}\kappa\left(1-x^{P*}\right) + \frac{\overbrace{\partial x^{P*}}^{-}}{\partial \xi}\left(\psi+\xi\left(1-\kappa\right)\right)}{\left(\psi+\xi\right)\psi}\left(1-\theta^L\right) \qquad \leq 0 \tag{58}$$

The two last statements are not straightforward. How do we get to our conclusion? First, we can flesh out parts of the statement (57):

$$\frac{\partial x^{P*}}{\partial \upsilon^E} \frac{(\psi + \xi (1-\kappa)) \left(1-\theta^L\right)}{\psi (\psi + \xi)} = \frac{1-\theta^E}{D + 1 - \theta^E} \tag{59}$$

where $D = \epsilon \bar{e}_{xx} \left(x^{P*}\right) (1+\delta) \psi (\psi + \xi) / \left(\psi \left(1-\theta^L\right) + \xi \left(1-\theta^E\right)\right) > 0$. Then, $1 < \frac{\partial x^{P*}}{\partial \upsilon^E} \frac{(\psi+\xi(1-\kappa))\left(1-\theta^L\right)}{\psi(\psi+\xi)}$ yields a contradiction so that statement (57) must be true.

According to statement (58) the derivative of the expected bond volume in low periods with respect to ξ is weakly negative. We can verify that the numerator is strictly positive by plugging in the derivative of expertise with respect to ξ.

The Optimal Contracting Regime Do non-expert traders prefer pooling their purchasing offers over high and low periods, or do they offer an exchange rate u that is rejected outrightly by PDs in high periods? The intuition for this result is that a non-expert trader in a shutdown equilibrium does not trade in high periods but will extract the full surplus in low periods. In a pooling equilibrium, such a trader extracts the full surplus in high periods but forgoes some information rent per unit of bond in low periods. However, the average trading volume is also higher in low periods which mitigates the last effect. The condition $\Omega^P \leq \Omega^S$ determines when a non-expert trader offers pooling contracts.

We can plug in the expected bond volume in (37) and (38) to find

$$\left(1-\theta^E\right) \left(\upsilon^E + \frac{\psi + \xi (1-\kappa)}{\psi} \frac{\Phi^{P*}}{\psi + \xi}\right) \leq \kappa \delta \upsilon^E \tag{60}$$

whenever $V_N^P(s,\Theta) \geq V_N^S(s,\Theta)$ which coincides with the equilibrium information loss described in 4.7, which determines the equilibrium level of expertise in both contracting regimes. In other words, non-expert traders choose the contracting regime that minimizes the welfare loss and the contracting regime is a substitute for acquiring expertise. Hence, the choice of the contracting regime ensures that the level of expertise is always smallest, or

$$x^{P*} \leq x^{S*} \Leftrightarrow P \in C$$
$$x^{P*} \geq x^{S*} \Leftrightarrow S \in C$$