On the Intermediation Cost of Public Debt*

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1 Introduction

National governments are the predominant issuers of securities worldwide, routinely raising billions via auctions to roll over debt and finance fiscal deficits. On the other side are investors, who defer consumption to purchase these securities, with primary market dealers often serving as intermediaries. The main economic role of dealers is to bridge the timing gap for investors who may be unable or unwilling to participate in Treasury security auctions when they occur (Grossman and Miller (1988)). Dealers facilitate smooth auctions by acquiring bonds and subsequently selling them to investors in the secondary market. On average, dealers profit from these transactions, and, from a government's perspective, such profit represents the intermediation cost of public debt.

This study demonstrates that, on average, the Brazilian federal government sells bonds at a 14 basis points (bps) discount compared to secondary market prices around auction times. Figure 1a illustrates this finding. Like Nyborg et al. (2002), all bond auctions in our sample are reopenings of existing issues, and thus, we can directly compare auction and secondary market prices. The data shows that bonds are, on average, auctioned at a 8 bps discount relative to their volume-weighted average secondary market price on auction day (t-stat=9.1). However, the total discount is larger, as the secondary market price of the auctioned bond is already depressed at the time of the auction (Lou et al. (2013)). Specifically, the auction price is, on average, 14 bps below the secondary market prices measured three days before and four days after the auction (t-stats=5.2 and 4.8).[1] This cost is five times larger than the 2.7 bps documented for U.S. Treasury notes by Boyarchenko et al. (2021).

Figure 1 [about here]

Our extensive sample of over $6,000$ auctions allows us to explore variation across auctions to investigate the economic mechanisms driving the intermediation cost of public debt. For example, Figures 1b and 1c show that costs are negligible for short-duration bonds but significantly higher for long-duration ones. This correlation between bond duration and intermediation costs supports the notion that long-duration bonds are costlier to issue. However, governments may choose to issue such bonds more frequently during high-cost periods to mitigate rollover risks, confounding this relationship.

Exploiting Brazil's unique institutional framework, we isolate duration effects. The Brazilian Treasury

[1] Unlike Lou et al. (2013), the lowest secondary market discount is one day after the auction rather than on auction day. This is because, unlike them, Figure 1 uses secondary market volume-weighted transaction prices rather than midquotes. Our Fiigure 5 shows that the lowest discount using midquotes is on the auction day, as in Lou et al. (2013). We discuss the difference in Appendix D.

schedules weekly auctions for both long- and short-duration bonds, with 98% being reopenings of existing issues. This feature ensures bond durations are predetermined and independent of current market conditions. Our findings confirm that longer-duration bonds incur higher intermediation costs, with each additional year of duration increasing costs by 5 bps for nominal bonds and 1 bps for inflation-indexed bonds.

Additionally, auction supply significantly impacts intermediation costs. However, while the type and duration of each bond to be sold at each auction is locally exogenous, its quantity is not. The government adapts supply quantities to unobservable market conditions, introducing substantial time-series variation.[2] Fortunately, there is exogenous variation in supply during our sample period. The Brazilian Treasury changed the frequency of long-term bond auctions three times between 2006 and 2023. In 2011, long-term nominal rate coupon bond auctions changed from weekly to every two weeks. In 2018, the schedule reverted to weekly. In 2020, the frequency of inflation-indexed bond auctions increased from every two weeks to every week. Less frequent auctions *mechanically* lead to larger average supply sizes. Figure 2 illustrates both time series variation in supply and the effect of the 2020 auction frequency change for an inflation-indexed bond maturing on August 15, 2030. Using auction frequency as an instrument for auction supply, we estimate that a 100 million BRL increase in supply raises intermediation costs by an economically large 2 bps for long-duration bonds, with negligible effects on short-duration bonds.

Figure 2 [about here]

Our results for duration and supply highlight the role of primary dealers' inventory risk in driving intermediation costs (Stoll (1978)). A third result provides further evidence for the inventory risk mechanism. Higher term premia in the nominal term structure of interest rates – reflecting greater interest rate risk or risk aversion – are associated with increased costs. A one standard-deviation increase in term premia increases intermediation costs by 4 bps.

Our analysis also highlights a crucial friction preventing primary dealers from costlessly hedging away inventory risk: the auction cycle in interest-rate futures. This cycle mirrors the pattern observed in cash Treasury bond markets, with futures prices dipping significantly around auction times. The low-point of the futures cycle is *precisely* at auction bidding time, providing high-frequency identification that

[2] Because different bond types are auctioned on different days, and the median number of auctioned bonds per bond type is just two, addressing unobservable market conditions using auction-day fixed effects is infeasible. While month-year fixed effects capture slow-moving conditions and seasonal patterns, we need an IV strategy that exploits exogenous variation in supply sizes.

auctions *causally* affect the Brazilian fixed income market. More importantly, if there was no auction cycle in futures, primary dealers could hedge their inventory risk costlessly, and the intermediation cost would be negligible in a competitive market without asymmetric information. However, the presence of slow-moving capital – insufficient arbitrage capital to exploit predictable price patterns as in Duffie (2010) – exacerbates these costs. To illustrate the degree of slow-moving capital, we show that a three-day trading strategy exploiting the auction cycle in futures earns an average of 34 bps with an annualized Sharpe Ratio of 2.04, and with returns that are virtually uncorrelated with both the local stock and foreign exchange markets.

We also find evidence that dealer competition influences costs. Unlike in the U.S., Brazilian primary dealers are not required to submit bids in all individual auctions. On average, only five of the 11.6 primary dealers bid in any given auction. Each additional bidder reduces costs by 2 bps, underscoring the impact of limited competition. We show that the identification of this effect comes largely from an August 2010 exogenous increase in the total number of dealers from nine to fourteen.

Finally, we look for but fail to find evidence that primary dealers' potential information advantage contributes to the intermediation cost of Brazilian public debt. In contrast to U.S. Treasury auction data analyzed by Boyarchenko et al. (2021), the share of the auction absorbed by primary dealers does not forecast returns of buying bonds at the auction. Moreover, the market-implied probability of local debt default appears too tiny for the specific information asymmetry mechanism in Cole et al. (2022) to play a key role in the cost of issuing Brazilian Treasury debt.

In summary, this study uses the largest sample of Treasury auctions in the literature to provide evidence on the mechanisms behind the 14 bps per auction average intermediation cost of Brazilian public debt. To that end, we exploit institutional features of the Brazilian debt market to circumvent endogeneity challenges. Our findings emphasize the roles of inventory risk, slow-moving capital, and dealer competition, while discounting information asymmetry as a primary driver. The paper is structured as follows: Section 2 reviews the literature and situates our contributions, Section 3 details the auction data and cost measurements, Sections 4 to 6 investigate economic mechanisms, and Section 7 concludes. Appendices provide additional context on Brazil's Treasury market and additional results.

2 Literature review and contribution

The costs associated with issuing government debt captivated Milton Friedman's attention for over three decades. In Friedman (1960) and Friedman (1991), he argues that the U.S. Treasury would save if it switched from multiple- to single-price bond auctions. He posited that multiple-price auctions discourage uninformed participants due to fears of the "winner's curse", and auctions with a small number of well-informed bidders are prone to collusion. This hypothesis influenced the U.S. Treasury auction format, which shifted experimentally in 1992 and definitely in 1998. Early studies, such as Simon (1994) and Goldreich (2007), validated Friedman's predictions but reported relatively low issuance costs. For example, Goldreich (2007) found that multiple-price auctions incurred underpricing of 3 bps compared to 1.5 bps for single-price auctions.[3]

A key limitation of these earlier studies was their reliance on contemporaneous benchmark prices, such as secondary market or when-issued prices, which may be temporarily depressed around auctions. Lou et al. (2013) addressed this issue by documenting transitory price effects in U.S. Treasury markets. They found that bond prices decline as auctions approach and recover afterward, creating an "auction cycle." Their study of 674 U.S. Treasury auctions from 1980 to 2008 estimated an average issuance cost of 8 bps across maturities, significantly higher than earlier estimates.[4]

Fleming et al. (2024) show that auctions are the main drivers of weekly changes in dealers' U.S. Treasury inventories and replicate the auction cycle in their sample of 933 U.S. Treasury auctions from 1990 to 2020. Compared to the earlier 1980 to 2008 sample in Lou et al. (2013), they report a dampening of the auction cycle phenomenon. They conclude that the growing participation of investment funds in auctions in the post-GFC period increased primary market competition and reduced the intermediation cost of U.S. Treasury debt. While carefully accounting for the on/off-the-run cycle, Boyarchenko et al. (2021) find an average issuance cost of 2.7 bps (t-stat=1.99) in their sample of 494 Treasury notes auctions from 2004 to 2014.

Lou et al. (2013), Fleming et al. (2024), and Boyarchenko et al. (2021) attribute the cost of issuing U.S. Treasury debt to compensation for primary dealers' inventory risk, as theorized by Stoll (1978), and to slow-moving capital preventing arbitrage, as per (Duffie (2010)). The inventory risk stems from a mismatch in the duration of primary dealers' portfolios, as they have overnight funding

[3] Goldreich (2007) finds yield underpricing of 0.6 and 0.3 bps for multiple- and single-price auctions, respectively, with the average duration of the Treasury bonds in his sample being 5 years, implying cost underpricing of 3 and 1.5 bps respectively.

[4] Lou et al. (2013) report two figures for the magnitude of the auction cycle, 13 and 8 bps. The 8 bps excludes repo specialness and the on/off-the-run cycle, thus representing a cleaner measure of issuance costs. The security serving as the benchmark for the newly issued bond in Lou et al. (2013) is the on-the-run one immediately before the auction, which then shifts to off-the-run status immediately afterwards. Duffie (1996) explains why on-the-run bonds are more valuable than off-the-run bonds because their "special" status in the repo market enables cheaper collateralized financing. The extra value for on-the-run securities depends on the remaining duration for which they will continue to be on-the-run, thereby enabling cheaper financing. Newly issued Treasury bonds are expected to remain on-the-run for much longer than the on-the-run bonds existing on the market just before an auction and become off-the-run afterwards. Boyarchenko et al. (2021) address this measurement issue in the U.S. Treasury primary market. The issue does not complicate our analysis since our auctions are reopenings of existing bonds.

on the margin while purchasing longer-maturity bonds at auctions. Slow-moving capital denotes the absence of enough arbitrageurs to close the price gap by competing to provide liquidity to the Treasury by purchasing bonds at auctions and selling shortly afterward in the secondary market. The auction cycle phenomenon reflects primary dealers' decision to spread inventory risk management over time.

The auction cycle phenomenon has also been documented internationally. Beetsma et al. (2016) and Sigaux (2024) observe similar effects in Italian bond markets, while Albuquerque et al. (2024) found an auction cycle in Portuguese bonds that led to issuance costs of 7 bps. These studies also emphasize the roles of inventory risk and slow-moving capital. For example, with full bid data for their sample of 66 auctions, Albuquerque et al. (2024) measure the counterfactual price drop the Portuguese Treasury would face if it opted to issue additional bonds on the margin. They show the auction cycle is significant only in the subsample where such marginal elasticity is low, suggesting that temporary secondary market price pressures around auctions occur only when dealers anticipate difficulties in quickly offloading bonds post-auction.

In contrast, and closer to Friedman's concerns, a separate body of research highlights strategic behavior and asymmetric information as key drivers of issuance costs. Umlauf (1993) finds evidence of collusion among a cartel of six large bidders leading to one-month Mexican Treasury bills auction underpricing. Nyborg and Sundaresan (1996) conclude that dealers shaded down their bids in multiple-price but not in single-price US Treasury bill auctions, suggesting that strategic behavior depresses prices in multiple-price auctions. In a sample of 458 Swedish Treasury auctions, Nyborg et al. (2002) conclude that dealers' concerns about the winner's curse lead to a 2 bps same-day average intermediation cost. They don't favor explanations based on dealer risk aversion because the coefficient on auction size in a regression of auction discounts is negative. Goldreich (2007) shows that a risk-neutral model of bidding behavior accounts for variations in the same-day cost of issuing US Treasury debt. Keloharju et al. (2005) find an average same-day issuance cost of 4 bps in a sample of 156 Finnish Treasury auctions and note that individual bidders' demand increases with the number of bidders, aligning with the idea that bidders exercise market power. Amin and Tédongap (2023) find that 10-year TIPS exhibit the same auction cycle phenomenon documented by Lou et al. (2013) for nominal bonds, with an issuance cost of 7 bps across 83 auctions from 2005 to 2019. They favor a predatory trading mechanism, whereby some bidders deliberately lower their demands before auctions to exert downward pressure on TIPS prices in order to affect auction outcomes. Cole et al. (2022) find that Mexican CETES government bonds are auctioned at a discount relative to their secondary market price after the auction and attribute such issuance cost to uninformed investors' fear of the winner's curse. The fear is justified because some bidders are presumably better informed about the probability of sovereign default in local debt.[5]

In contrast to us, and to all papers mentioned before, Hortaçsu and Kastl (2012) and Hortaçsu et al. (2018) do not rely on secondary market prices (or when-issued prices) to compute the intermediation cost of public debt. Instead, they use detailed bid data to compute model-based costs based on bidders' "infra-marginal surplus". Their models feature risk-neutral bidders and thus rule out inventory risk compensation as a mechanism for debt issuance costs. Hortaçsu and Kastl (2012) find that the average expected profit for primary dealers in their sample of 116 Canadian T-bill auctions is 1.7 bps. Hortaçsu et al. (2018) find an average cost of 3 bps in their sample of 975 U.S. Treasury auctions, primarily attributable to primary dealers' ability to exercise market power.

Building on Kastl (2011), Hortaçsu and McAdams (2010), and Hortaçsu and Kastl (2012), Elsinger et al. (2019) use detailed bid data to investigate the impact of the increase in the number of primary dealers in Austrian debt following EU accession. The average number of dealers bidding in auctions increased from 13 before 1995 to almost 25 between 1997 and 2008. Using model-based estimates in a sample of 112 Austrian bond auctions, they find that increased dealer competition decreased the intermediation cost of public debt by about 3.5 bps or 80%. As in Hortaçsu and Kastl (2012) and Hortaçsu et al. (2018), this calculation rules out inventory risk compensation as a potential driver of the cost of issuing public debt.

2.1 Contribution to the literature

Our paper contributes to the literature by offering new insights into the mechanisms driving the intermediation cost of public debt. First, we provide robust evidence that inventory risk remains a key determinant of these costs, challenging risk-neutral models that disregard this factor. Our findings align with the auction cycle literature but extend it by providing fresh evidence of duration, supply, and term premia effects with unprecedented granularity and attention to endogeneity concerns. Furthermore, we demonstrate the inability to costlessly hedge inventory risk due to an auction cycle in interest-rate futures, a predictable price pattern in a large and active market. The failure of slow-moving capital to arbitrage away predictive price patterns amplifies inventory risk for primary dealers.

Second, we highlight the impact of dealer competition on intermediation costs. Unlike the U.S.,

[5] Bigio et al. (2023) examine $2,077$ Spanish debt auctions between 2002 and 2018 and, surprisingly, find large *negative* same-day issuance costs for several maturity buckets, particularly longer-term ones (WAAM results on Table 1). They attribute this finding to primary dealers' errors.

where primary dealers are obligated to bid in every auction, Brazilian dealers participate selectively. This, and a 2010 exogenous increase in the total number of dealers from 9 to 14, allow us to identify the causal effect of competition on costs, finding that each additional bidder reduces costs by 2 bps. This result underscores the importance of market structure in shaping auction outcomes. Models with free entry of non-strategic risk-averse primary dealers *a la* Grossman and Miller (1988) leave out an important dimension of the primary market for government debt.

Lastly, unlike recent research, our results do not support an information asymmetry mechanism in which intermediation costs are influenced by uninformed investors' fear of the "winner's curse". Specifically, we do not find evidence consistent with primary dealers as a group exploiting an informational advantage over other bidders. We cannot, however, rule out the possibility that some primary dealers are better informed than others and that such informational advantage matters. In Section 6.2, however, we do show that it is unlikely that information asymmetry about the government's risk of default on local debt is a key friction in primary or secondary debt markets as in Cole et al. (2022).

3 Auctions and the intermediation cost of public debt

This section describes our auction dataset, explains how we measure intermediation costs, and presents cost results. Background institutional details on the Brazilian public debt market are provided in Appendix B.

3.1 Sample formation

Our dataset comprises $6,063$ auctions of Brazilian government bonds conducted by the National Treasury from July 2006 to October 2023. We derive the sample from a grand total of $6,910$ auctions through the following steps:

1. **Exclusion of extraordinary auctions**: We discard 289 *extraordinary* auctions, which are not in the regular schedule and are typically triggered by market disruptions.

2. **Focus on reopenings**: The dataset excludes 147 auctions of newly issued bonds, as these lack secondary market pricing benchmarks.

3. **Elimination of failed auctions**: We discard 272 instances in which the Treasury cancels a regularly scheduled auction before taking any bids, or takes bids but chooses not to sell any bonds. These failed auctions produce no auction prices and are discussed in Appendix E.

4. **Minimization of Overlap**: To isolate auction effects, we exclude 139 auctions that occur within four trading days of another auction for the same bond, typically because of holidays or *extraordinary* auctions.

The resulting dataset includes $6,063$ auctions distributed across $1,381$ auction days, with an average of 4.4 bonds auctioned per day. Bonds are classified into four types: fixed-rate zero-coupon, fixed-rate coupon, inflation-indexed, and floating-rate bonds. Detailed summaries of bond types are provided in Appendix B. Table 1 contains summary statistics, and Appendix A summarizes variable definitions and data sources.

Table 1 [about here]

3.2 Auction frequency and bond types

There are, respectively, $2,292$ and $1,289$ auctions of fixed-rate zero-coupon bonds and fixed-rate coupon bonds. The number of auctions for inflation-indexed and floating-rate bonds is $1,827$ and 655 respectively. Per bond type, the average number of bonds issued in an auction is 2.4, and the median is 2. We classify zero-coupon and floating-rate bonds as short-duration, and fixed-rate coupon and inflation-indexed bonds as long-duration.

Aside from very few exceptions, fixed-rate bond auctions are multiple-price auctions, while inflation-indexed bond auctions are single-price. Floating-rate bond auctions are single-price until March 2012, then multiple-price until February 2020, then single-price until the end of the sample period in October 2023.

While zero-coupon fixed-rate bonds are auctioned weekly on Thursdays throughout the sample, auction frequency changes over time for other bond types. Until December 2010, fixed-rate coupon bond auctions were held weekly, then shifted to semi-weekly until December 2017, returning to a weekly schedule then. These auctions are on Thursdays, too. Inflation-indexed bond auctions were on Tuesdays and transitioned from a semi-weekly to a weekly schedule after November 2020. These changes result in average auction frequencies equal to 0.88 and 0.62 auctions per week for fixed-rate coupon and inflation-indexed bonds, respectively. The fact that different bond types are auctioned on different days and that the median number of auctioned bonds per bond type is just two makes auction-day fixed effects infeasible.

Compared to other bond types, floating-rate bond auctions are somewhat irregularly spaced in time. Broadly speaking, floating-rate auctions were on Thursdays until December 2021, and Tuesdays thereafter. There were periods in which they were roughly auctioned every week, every two weeks, or every four weeks. Floaters are (approximately) auctioned on a four-week schedule from November 2011 to December 2014; weekly from December 2008 to September 2009, and after March 2020; and every two weeks in the remaining periods. These changes result in an average frequency of 0.76 auctions per week.

Maturity and duration Bond maturities and durations vary substantially by type. Fixed-rate zero-coupon bonds have relatively short maturities and durations, equal to 1.94 years on average. Floating-rate bonds have an average maturity of 4.65 years, but because they are indexed to overnight rates, their duration is zero. Fixed-rate coupon bonds have average maturity and durations equal to 7.22 and 5.02 years, respectively. The average maturity and duration of inflation-indexed bonds are 15.60 and 8.84 years, respectively.

Supply The supply of bonds in each auction, that is, the total value of bonds put up for sale, varies substantially in the cross-section and in the time series. Figure 2 in the Introduction displays the supply of one particular inflation-indexed bond around the November 2020 change in auction frequency. The figure below displays all auctions of long-duration bonds.

Figure 3 [about here]

Figure 3 reveals a very large variation in supply for both fixed-rate and inflation-indexed bonds.[6] The vertical lines in each graph mark the time of the auction frequency change. The horizontal lines show the average supply in each subperiod determined by auction frequency. We test whether average supply sizes change when auction frequency changes. The statistics of a test of the difference between averages are, respectively, 3.56 and -16.83 for the first and second frequency changes for fixed-rate zero-coupon bonds and 6.76 for the frequency change for inflation-indexed bonds. Less frequent auctions *mechanically* lead to higher average supply sizes and the opposite for more frequent auctions.

Table 1 shows that short-duration bonds (e.g., zero-coupon) are typically auctioned in larger quantities (average of 39.07 BRL hundred million) compared to long-duration bonds (e.g., fixed-rate coupon bonds, averaging 11.54 BRL hundred million).

[6] The supply of fixed-rate bonds trends down locally because we inflation-adjust the supplies. That is, if the National Treasury issues the same quantity of fixed-rate bonds in two subsequent weeks, the inflation-adjusted supply of the second week is slightly below that of the first week. There is no such local sloping down for inflation-adjusted bonds because their face value is automatically adjusted for inflation.

Auction pricing We define auction price as total revenue divided by the number of bonds sold, ensuring consistency across single- and multiple-price auctions. We compute yield-to-maturity at auction from the auction price. Appendix C has one example of such computation. The average auction yields of fixed-rate zero-coupon and coupon bonds are respectively 10.39% and 11.54% per year. The average auction yield of inflation-adjusted bonds is 5.66% per year. Floating-rate bonds are not quoted in terms of yield-to-maturity, but in terms of discount relative to face value. On average, floaters are auctioned at a 37.5 bps discount to face value.

Dealers On average, 4.94 primary dealers bid in each auction, significantly fewer than the total pool of 11.64 dealers. Unlike in the U.S. Treasury primary market, Brazilian primary dealers are not expected to bid in each single auction, and they don't.[7] On average, primary dealers absorb approximately 84% of auctioned bonds, highlighting their dominant role in the market. However, dealer participation varies widely, ranging from zero to 10 bidders per auction, as Figure 4 shows.

Figure 4 [about here]

Figure 4 plots the number of primary dealers bidding in non-floating-rate bond auctions. The number of dealer bidders is averaged across all auctions on the same day. Even with such averaging, the Figure reveals substantial variability. The figure also plots the total number of dealers over time. Such total also displays time variation. Following a wave of consolidation in the Brazilian banking sector, the number of primary dealers dropped from 12 in July 2006 to 9 at the end of the first week of August 2010. For example, primary dealers Itaú and Santander respectively acquired former primary dealers Unibanco and ABN AMRO Real. On August 6, 2010, the Central Bank and the National Treasury, through their *Atos Normativos Conjuntos* numbers 22 and 23, increased the total number of primary dealers to 14.

Figure 4 shows that the August 6, 2010 increase in the total number of dealers is associated with an immediate increase in the average number of dealers bidding in Treasury auctions. In untabulated results, we find that there are, respectively, 28 and 29 auctions in a one-month window just before and just after the change. The average number of dealers bidding in auctions just before the change is 4.75, whereas it is 7.52 for auctions just after the change. The t-statistics for a test of equal means is 4.69.

[7] The average number of U.S. Treasury primary dealers from 2006 to 2023 is 21. These dealers are expected to "bid on a pro-rata basis in all Treasury auctions at reasonably competitive prices". (https://www.newyorkfed.org/markets/primarydealers)

Term premia In one of our regression specifications, we remove month-year fixed effects and add the first principal component of term premia in Brazil's term structure of interest rates. Time variation in term premia in the Brazilian nominal term structure of interest rates was first documented by Tabak and Andrade (2003). Term premia are based on the prices of interest rate futures contracts and on Central Bank surveys of expectations about future monetary policy rates. Appendix B has details. The first principal component is standardized to have mean zero and variance equal to 1 in the time series. On average, across all bond types, the term premia is zero. This is not surprising, given that the auctions in our sample follow a regular schedule.

Control variables In addition to month-year and bond-type fixed effects, our baseline regression specification in Section 4 has four control variables. Table 1 has their summary statistics. ANBIMA, our source of dealer midquotes, also provides the standard deviation of each midquote calculated from individual dealer entries. Across all bond types, the standard deviation of dealer midquotes is 1.18 bps. The annualized secondary market turnover one day before the auction, averaged across all bond types, is 549%. The average outstanding value of previously issued bonds at each auction is 173.61 November 2023 one hundred BRL million. The average auction in our sample is a bond's 35th reopening auction.

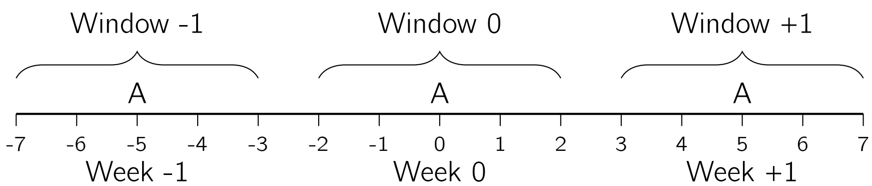
3.3 Intermediation cost

We estimate intermediation costs by comparing auction prices to secondary market prices before, during, and after auctions. Because of the time value of money, bond (dirty) prices tend to go up slightly every day, except for coupon payment days, when they drop substantially. To strip out the time value of the money effect, the cost is derived from yield-to-maturity changes for non-floating-rate bonds and from discount changes for floaters.

For non-floating-rate bonds, we compare yield-to-maturity at auction to yield-to-maturity in the secondary market both on the auction day and adjacent days. Yield differences are converted to price differences using the bond's modified duration at auction. Appendix C has a detailed example. For floating-rate bonds, it can be shown that discount differences translate to price differences directly. For each distance from the auction in trading days, intermediation costs are winsorized at 0.5% level in both tails.

Dealing with auction overlap Many auctions in our sample consist of a sequence of weekly auctions of the same security. For these auctions, we can't compare auction prices to secondary market prices five trading days before because there was another auction with the same security at that point. To address this, we define non-overlapping windows for each auction, ensuring that data used for one auction is not contaminated by adjacent auctions.

The diagram below illustrates this approach:



Here, "A" represents auctions on trading days -5, 0, and +5. For the auction on day 0, we focus on Window 0, encompassing five trading days before and after the auction. Adjacent auctions (e.g., on day -5 or +5) are assigned to separate windows. This separation avoids overlapping auction effects. For auctions spaced two weeks apart, window lengths are extended to ten trading days. Holidays and extraordinary auctions further introduce breaks in the regular schedule, allowing for extended windows.

3.3.1 Secondary market pricing sources

Secondary market prices are sourced from:

1. **Transaction Prices**: Provided by the Central Bank, these are volume-weighted averages of actual transactions, excluding repo agreements and transactions involving the Central Bank or the National Treasury as a counterpart.

2. **Dealer midquotes**: End-of-day midquotes from ANBIMA represent the average of dealer-reported secondary market quotes (*taxa indicativa*). ANBIMA surveys secondary market dealers daily. Dealer entries are filtered for outliers and averaged across dealers. ANBIMA quotes are widely used to mark bond portfolios to market.

Each source has trade-offs. Transaction prices capture full intermediation costs, including dealer markups in the secondary market, but are less available and noisier. Midquotes offer broader coverage and cleaner comparisons but understate full costs by excluding bid-ask spreads. To find the average all-in intermediation cost, it is better to use transaction prices. Midquotes are more appropriate in cross-sectional analyses to investigate the mechanisms generating the intermediation cost.

3.3.2 Intermediation cost estimates

Table 2 shows intermediation cost estimates for different sources of secondary market prices and different distances from the auction in trading days. The information there is used to construct Figure 1 in the Introduction. T-statistics in Table 2 are based on standard errors clustered by auction day.

Transaction prices The average intermediation cost on auction day is 8.19 bps (t-stat=9.13). That is, on average, bonds are auctioned at a 8 bps discount relative to secondary market transaction prices on the same day. The sample size for this analysis is $5,247$ auctions.

However, auction prices are 14.47 (t-stat=5.20) and 13.34 (t-stat=5.37) bps below secondary market prices three trading days before and four days after the auction, respectively. This is the 14 bps result mentioned in the Introduction and the Abstract. The sample sizes are respectively $3,046$ and $3,051$.[8] This is analogous to the auction cycle in U.S. Treasuries documented by Lou et al. (2013).

The calculation that follows offers a perspective on the economic significance of the intermediation cost of public debt in Brazil. According to Table 1, there are $6,063$ long-duration bond auctions in our seventeen-year period from July 2006 to October 2023. This amounts to 350 auctions per year. The average supply in each auction, also using the information in Table 1, is 3 BRL billion, adjusted for inflation up to November 2023. The average intermediation cost per auction is about 14 bps, as per Table 2. Hence, the annual average intermediation cost of Brazilian public debt is 1.5 BRL billion as of November 2023 ($350 \times 0.14\% \times 3 \approx 1.5$). This is more than 10% of the entire 2023 budget of Brazil's Ministry of Science, Technology and Innovation.

Table 2 also presents results for bond-type subsets. For long-duration bonds (fixed-rate coupon and inflation-indexed), secondary market prices three days before and four days after an auction are 22.03 and 20.15 bps above auction prices, respectively. In contrast, for short-duration bonds (fixed-rate zero-coupon and floating), the price differential four trading days away from the auction is economically small and statistically insignificant. This is the significant cross-sectional difference alluded to in the Introduction.

Midquotes As previously discussed, midquotes understate intermediation costs due to missing the difference between ask prices and midquotes. Nonetheless, results mirror those using transaction prices,

[8] Table 2 shows that sample sizes drop substantially when we compare auction prices to secondary market prices more than two trading days away from the auction. This is because, as mentioned earlier in this Section, a significant part of our sample consists of sequences of weekly auctions for the same security, limiting the observation window for each auction to five trading days.

with one important difference. Now, the lowest intermediation cost is on auction day, like in Lou et al. (2013) who also use midquotes. We explore the difference in Appendix D. Figure 5, analogous to Figure 1, illustrates Table 2 results using midquotes rather than transaction prices.

Figure 5 [about here]

On average, end-of-day midquotes on auction days are 1.51 bps *below* auction prices (t-stat=-2.50). This result strongly contrasts with the 8 bps same-day cost using transaction prices. Because midquotes are available even if there are no transaction prices, the sample size increases to $6,063$. Even though the same-day issuance cost using midquotes is negative, the overall cost is positive because there is an auction cycle too. Secondary market prices two days before and after the auction are 5.64 and 3.74 bps above auction prices, with sample sizes $6,063$ and $5,877$.[9]. Four days away from the auction, secondary market midquotes are 8.78 (t-stat= 3.37) and 6.45 (t-stat= 2.16) bps above auction prices. These results are averaged across all bonds in our sample. For long-duration bonds only, midquotes are 13.66 (t-stat=3.51) and 9.99 (t-stat=2.25) bps above auction prices.

3.3.3 Alternative approach

In addition to the direct comparison of auction and secondary market prices, we employ a complementary approach to document the auction cycle in Brazilian Treasury markets. This method leverages ANBIMA's full panel of end-of-day midquotes from July 2006 to October 2023 rather than focusing on midquotes of auctioned bonds in the vicinity of auctions. Moreover, we use midquote yields directly rather than using duration to express yield changes in terms of price changes. After restricting the sample to non-floating-rate bonds with at least one month to maturity, the unbalanced panel has $127,129$ bond-day observations during $4,353$ trading days. Thus, the average number of bonds per day is 29.

We regress daily changes in bond yields on dummy variables representing trading days relative to the auction. For instance, a dummy variable equals 1 for auctioned bonds on the day of the auction and 0 otherwise. Time fixed effects capture overall market trends, allowing us to isolate the auction-specific yield effects.

Table 3 [about here]

[9] It is not a coincidence that the sample size two days before the auction is the same as in the auction. It is because we restrict the sample of auctions to those for which there was no auction of the same bond at least four trading days before the auction.

Results in Table 3 confirm the presence of an auction cycle. Bond yields rise by 0.53 bps (t-stat=5.03) one day before the auction and by an additional 0.77 bps (t-stat=6.45) on the auction day. These yield increases translate to temporary price drops, which reverse in the days following the auction. The sum of the dummies before and including the auction day is 1.31, very close to the 1.37 sum of dummies after the auction. The p-value of such a difference is 0.79. Importantly, the yield changes sum to nearly zero across the full auction cycle, indicating a temporary price distortion rather than a lasting effect.

While this approach provides valuable cross-sectional insights, it underestimates total intermediation costs by focusing on midquotes rather than transaction prices and by absorbing some of the auction cycles into the daily fixed effects. Nonetheless, it corroborates the main findings from the primary analysis and highlights the robustness of the auction cycle phenomenon.

4 Investigating the mechanisms

This section explores the economic mechanisms driving the intermediation cost of public debt by analyzing variations in auction characteristics and outcomes.[10] We focus on three potential drivers of these costs: inventory risk, dealer competition, and primary dealer informational advantage. To conduct this analysis, we estimate the intermediation cost for each auction and examine how it correlates with auction supply, bond duration, market conditions, dealer participation, and dealer absorption.

4.1 Intermediation cost estimates

Our baseline cross-sectional analysis uses intermediation cost measured from the yield-to-maturity difference between auction prices and secondary market midquotes two trading days before the auction. Yield-to-maturity differences are converted to price differences and then orthogonalized with respect to contemporaneous foreign-exchange depreciation and stock market return. We show our conclusions are robust to using unorthogonalized Intermediation Cost measured using transaction prices on the day of the auction. While our preferred measure understates the full cost because it is based on midquotes and does not capture the full auction cycle, it allows for a larger sample and has less secondary market microstructure noise. It is also unaffected by the information content of the auction outcome[11], and less

[10] This type of analysis also appears in Nyborg et al. (2002), Keloharju et al. (2005), Goldreich (2007), Boyarchenko et al. (2021), and Gupta et al. (2021).

[11] Evidence that Treasury auction outcomes can influence secondary market prices is discussed in Bikhchandani and Huang (1989), Cammack (1991), Fleming and Remolona (1997), Boffelli and Urga (2015), Cole et al. (2022), and Phillot (2023). Compared to the U.S. case, an additional reason to consider that Brazilian Treasury auctions are information events is that, after seeing the bids, the Treasury can sell less than the full quantity of bonds supplied in the auction.

contaminated by macro news occurring between the time that auction and secondary market prices are observed. Before orthogonalization, we label this variable Intermediation Cost (2-day). Table 2 shows that its average across all bond types is 5.64 bps (t-stat=4.98). The averages by bond type are in Table 4, Panel A.

Table 4 [about here]

4.1.1 Filtering out contemporaneous macro news

Our measure of intermediation costs compares yield-to-maturities at auction to those in the secondary market two days before the auction. During those two days, any macroeconomic news that moves bond prices adds measurement error. Here, we describe how to use contemporaneous variation in foreign exchange and stock market futures to soak up the effect of macro news.

Table 4, Panel A shows the contemporaneous foreign exchange depreciation and the stock market return over the two-day interval over which Intermediation Cost (2-day) is measured. Specifically, we use high-frequency data from B3's futures exchange to find the midpoint of the nearest maturity FX and stock market futures contract at the end of the bidding window on auction day, and compare it with each contract's closing prices two days before.

Table 4, Panel B has the results of the orthogonalization regressions. Our Clean Intermediation Cost (2-day) variable collects the average plus the residuals of regressions of (raw) Intermediation Cost (2-day) onto four variables: standardized FX depreciation, standardized stock market return, and their interactions with duration orthogonalized with respect to FX depreciation and stock market return, and then standardized. These regressions are run for each of the four bond types separately. The average and t-statistics of the Clean Intermediation Cost (2-day) in Panel A are identical to those of the Intercept of the cost-cleaning regressions in Panel B because the former is defined as Intercept plus regression residuals. By construction, Clean Intermediation Cost (2-day) has the same average as (raw) Intermediation Cost (2-day) but is uncorrelated with contemporaneous FX depreciation and stock market returns. However, the Clean Intermediation Cost (2-day) has (slightly) higher t-statistics than its raw counterpart because the effect of macro news is filtered out.

The regressions in Table 4, Panel B shows that yield changes are significantly correlated with FX depreciation and stock market return over the same time interval. The interactions with duration are also highly significant for long-duration bonds. The positive sign on FX depreciation means that, on average, bond prices *decrease* when the BRL weakens relative to the USD, as a drop in bond prices in the two-day window before the auction signifies a higher *estimated* cost for the Treasury. The interaction with duration being positive means that this effect is pronounced for longer-duration bonds. This is not surprising, as longer-duration bonds are more volatile in response to macro news. The negative sign on stock market return and its interaction with duration means that bond prices tend to increase as the stock market goes up, and that this effect is stronger for longer-duration bonds.

4.2 Regression analyses

This subsection contains results of regressions of Clean Intermediation Cost (2-day). The purpose is to explore its variation across auctions to shed light on the economic mechanisms driving the cost. We begin by discussing our specification, including the need to account for the endogeneity of supply choices in these regressions. Appendix A has a summary of variable definitions.

4.2.1 Addressing endogeneity

Primary dealers buy longer-term government bonds at auctions and finance these purchases, on the margin, through short-term borrowing (Naik and Yadav (2003)). This results in a duration mismatch in their portfolios. This mismatch might not be frictionlessly hedged away in derivative markets. This unhedged mismatch persists until dealers resell the bonds in the secondary market. If dealers' portfolios are not fully diversified, the extra risk from auction participation requires compensation, even if it is idiosyncratic. Such compensation takes the form of discounts on auction prices. This mechanism could explain why dealers tend to buy bonds at lower prices in the primary market compared to secondary market prices.

We have three variables to test for an inventory risk channel for the intermediation cost of public debt. The first variable is Duration. The greater the bond duration, the greater the duration mismatch, and thus, inventory risk is higher. It is important to acknowledge that the duration of fixed-rate bonds is not directly comparable to the duration of inflation-adjusted bonds. The former is a nominal duration whose resulting risk exposure depends on the volatility of the nominal term structure. The latter is a real duration with risk exposure depending on the volatility of the real term structure. To account for this difference, we interact Duration with a dummy for nominal bonds (including floaters) and a dummy for real bonds. This separates out the effect of real and nominal duration. Bond-type fixed effects absorb average differences across bond types.

Fortunately, because of Brazil's institutional features, each specific bond's duration is locally exogenous. As explained in Appendix B, the National Treasury sequentially issues the same security week after week. It does not have the freedom to adapt a bond's duration to market conditions. This is evident in Appendix Figure 4.

Supply is a second, and perhaps more important, variable to test for an inventory risk mechanism. The larger the supply of bonds, the higher the inventory risk is. Like Nyborg et al. (2002), we test for an inventory risk explanation by regressing Intermediation Cost on auction supply. However, it is important to realize that supply is endogenous. Despite releasing a medium-term plan for the composition of the debt, and the auction schedule that results from it, the Brazilian Treasury only decides and announces the specific quantity of bonds to be auctioned the day before the auction, after informal consultations with primary dealers and end investors.

When the Treasury perceives it will be difficult or costly to place bonds in the primary market, it may respond by reducing the supply of all bonds and/or by substituting some of the supply of long-duration bonds for short-duration ones. Figures 2 and 3 show that supply is highly variable, even in the time series for a specific security. The endogeneity of supply choices biases OLS coefficients. Because the effects might be different or even opposite for long- and short-duration bonds, we must separately account for their supply effects. This is achieved by interacting Supply with dummies for long- and short-duration bonds. The specific nature of the endogeneity bias is discussed below.

Because we don't have a control variable that perfectly captures market conditions at auction time, and cannot afford to use auction-day fixed effects, unobserved heterogeneity in market conditions, coupled with the endogeneity of National Treasury supply choices, biases down OLS estimates for the effect of the supply of long-duration bonds. When the Treasury perceives it is an easy time to place long-duration bonds, it supplies a large quantity of them at a cost that is not too high. The opposite happens when times are difficult. This endogeneity dampens the effect of the supply of long-duration bonds on intermediation cost in OLS regressions. To address this endogeneity, we use auction frequency and its interaction with a dummy for fixed-rate coupon bonds to instrument for the supply of long-duration bonds.

The direction of the bias is unclear for short-duration ones. On the one hand, the Treasury might reduce its supply in bad times as well, when it perceives that selling bonds in general will be costly. This would bias *down* the coefficient on the supply of short-duration bonds. On the other hand, the Treasury might compensate for a reduction in the supply of long-duration bonds by increasing the supply of short-duration ones in bad times. This is because the Treasury knows short-duration bonds are less costly to issue in general and because the Treasury's capacity to pent up overall bond issuance might be limited. This would bias *upwards* the coefficient on the supply of long-duration bonds. There is no exogenous variation in the supply of zero-coupon fixed-rate bonds in our sample period, thus we do not have an instrument for the supply of short-duration bonds.

The third variable that tests for an inventory risk mechanism is the first principal component of term premia in the nominal term structure of interest rates. Term premia are higher when there is either more risk or more risk aversion, or both. It is plausible to assume that the first PC of term premia proxies for primary market conditions. When term premia are higher, there is more volatility in interest rates and/or more risk aversion, so there is more inventory risk and/or more inventory risk compensation.

The main variable to test the effect of competition among primary dealers is the number of dealers bidding in each auction. If lack of competition among dealers is a driver of the intermediation cost, we expect a negative sign on the variable. We also use the total number of dealers to test the same effect.

Thus, our baseline specification is:

$$\begin{aligned}\text{Intermediation Cost}_{i,t(\text{2-day})} = \beta_0 &+ \beta_1(\text{Supply}_{i,t} \times \mathbb{I}(\text{Long-duration}_i)) + \beta_2(\text{Supply}_{i,t} \times \mathbb{I}(\text{Short-duration}_i)) \\ &+ \beta_3(\text{Duration}_{i,t} \times \mathbb{I}(\text{Nominal}_i)) + \beta_4(\text{Duration}_{i,t} \times \mathbb{I}(\text{Inflation-Indexed}_i)) \\ &+ \beta_5\text{Number of Bidding Dealers}_{i,t} + \sum_{k=1}^{4}\gamma_k\text{Controls}_{k,i,t} \\ &+ \sum_{m=1}^{N_{months}-1}\theta_m\text{Month-Year FE}_m + \sum_{b=1}^{N_{bondtypes}-1}\lambda_b\text{Bond-Type FE}_b + \epsilon_{i,t}\end{aligned}$$

where $\text{Supply}_{i,t} \times \mathbb{I}(\text{Long-duration}_i)$ is instrumented by Auction $\text{Frequency}_{i,t}$ and its interaction with $\mathbb{I}(\text{Fixed-rate-coupon}_i)$. An inventory risk mechanism predicts that the coefficients β_1, β_3, and β_4 are positive. A primary dealer competition mechanism predicts that β_5 is negative. We compute the first stage's Cragg-Donald and Kleibergen-Paap Wald F statistics to test whether instruments are weak.

4.2.2 Main regression results

Table 5 has our main regression results. The dependent variable is the intermediation cost of public debt, measured using midquotes two days before the auction, and orthogonalized with respect to contemporaneous FX depreciation and stock returns. As discussed before, we use an IV approach to address the endogeneity of auction supply. Across all IV regressions, the first stage F statistics are much larger than the Stock-Yogo weak identification critical values, indicating that instruments are not weak.

Table 5 [about here]

Table 5, column (1) shows the baseline specification results. The coefficients β_1, β_3, and β_4 are positive and statistically significant at the 1% level, consistent with an inventory risk mechanism for the intermediation cost of public debt. The inventory risk coefficients are economically significant. A one hundred BRL million increase in the supply of long-duration bonds – corresponding to approximately 1/8 of the average and 1/8 of the standard deviation reported in Table 2 – increases the intermediation cost by 2.16 bps. This large effect helps to explain why the Brazilian Treasury actively manages supply quantities, as shown in Figures 2 and 3. A one-year increase in duration increases the issuance cost by 4.93 bps for nominal bonds and 0.99 bps for inflation-indexed bonds.

Column (1) results also show that competition among primary dealers plays a role in shaping the intermediation cost of Brazilian public debt. The coefficient β_5 is negative and statistically significant at the 1% level. Each additional bidding dealer reduces the cost by 2.09 bps.[12]

For completeness, column (2) shows OLS results. The coefficients β_1, β_3, and β_4 are positive, but only one of them is statistically significant at the 1% level. The β_1 coefficient is statistically significant at the 5% level but ten times smaller. The β_3 coefficient is negative but also ten times smaller. The Brazilian Treasury's active management of supply quantities in response to unobservable market conditions distorts OLS estimates.

Results in column (3) show that the presence or absence of the four control variables is irrelevant to our results. We repeat the baseline specification but drop the control variables. Results are very similar to those in column (1).

Column (4) shows that our conclusion about the effect of competition on intermediation cost is robust to using a coarser variable to measure competition. Rather than using the number of dealers bidding in each auction, we use the total number of dealers (see Figure 4). Our conclusion is unchanged: costs are smaller when there is more interdealer competition.

Results in column (5) further strengthen the case for an inventory risk mechanism. We drop the month-year fixed effects and add the first principal component of term premia in the nominal term structure of interest rates. The coefficient on the term premia is positive and statistically significant at the 1% level. A one standard deviation increase in term premia increases the intermediation cost by 4.20 bps.

[12] In a sample of 72 Brazilian Treasury auctions in 1998 and 1999, Silva (2003) finds that his proxy for the intermediation cost of issuing debt decreases with the number of bidders, but the result is not statistically significant at conventional levels.

Results in column (6) go against the notion that uninformed investors' fear of a winner's curse (because of primary dealers' superior information) plays a role in the intermediation cost of public debt. The coefficient on the fraction absorbed by dealers is economically small and statistically insignificant. This suggests that information asymmetry across the group of primary dealers and the other bidders does not play an important role in the Brazilian case. We cannot, however, rule out that there is important information asymmetry *within* the primary dealer group.

4.2.3 Robustness checks

In this subsection, we check the robustness of our results for different methodological choices and in different subsamples. The results are in Table 6. For ease of reference, column (1) of Table 6 has the same baseline specification as column (1) of Table 5.

Table 6 [about here]

Results in column (2) of Table 6 show the irrelevance of our baseline choice to orthogonalize the intermediation cost with respect to contemporaneous FX depreciation and stock market return before conducting regression analyses. The dependent variable in that regression is the raw, unorthogonalized Intermediation Cost (2-day), and the FX depreciation and stock market return are added as control variables. The magnitudes of the relevant coefficients and their t-statistics are somewhat higher than those in Column (1), but the broad conclusions are unchanged.

Results in column (3) show that results are robust to measuring the intermediation cost using transaction prices on auction day rather than using midquotes two days before. The sample size drops from $6,063$ to $5,427$ correspondingly. Because secondary market prices are measured (nearly) contemporaneously with auction prices, the need to filter out macro news disappears, and we use (raw) Intermediation Cost (0-day) as the dependent variable. The coefficients β_1, β_3, β_4, and β_5 remain statistically significant at the 1% level. The magnitudes of β_1, β_3, and β_5 are close to those in Column (1), while the magnitude of β_4 increases notably. The coefficient β_2 becomes statistically significant, but its magnitude is 40 times smaller than that of β_1.

Column (4) results show that baseline results are not driven by outliers. The sample size in that regression is $5,949$ rather than $6,063$ because we drop the observations whose residuals in the column (1) specification are more than three standard deviations away from zero. The conclusions are unchanged.

In columns (5) and (6), we break the sample in half. Column (5) has $3,034$ auctions before January 2016. Column (6) has $3,029$ auctions after January 2016. The major difference is in the coefficient of the number of dealers bidding in each auction. It changes from negative and statistically significant in Columns (1) and (5) to positive but small and statistically insignificant in Column (6). Thus, the identification of the effect of competition on the intermediation cost in Column (1) comes entirely from the first subsample. That period included a major change in competition around August 2010, as depicted in Figure 4.

In columns (7) to (10), we remove some bond-types from the sample. Column (7) discards floating-rate and inflation-indexed bonds. Column (8) removes short-duration bonds, that is, floating-rate and fixed-rate zero-coupon bonds. Column (9) drops inflation-indexed bonds. Lastly, column (10) drops floating-rate bonds. In all columns, the coefficients β_1, β_3, β_4, and β_5 remain statistically significant at the 5% level and of similar magnitude to those in Column (1).

5 High-frequency identification and slow-moving capital

Brazil has a large and active interest-rate futures market, featuring contracts whose maturities precisely match that of fixed-rate government bonds, including long-term ones (Appendix B.7). In principle, primary dealers would face inventory risk from participating in Treasury auctions only if they were unable to hedge their duration exposure costlessly using these interest-rate futures. This section demonstrates that the auction cycle observed in Brazilian Treasury bonds spills over into the local interest-rate futures market, thereby preventing zero-cost hedging of inventory risk via futures.

Specifically, we document a 20 bps auction cycle in the DI1 futures market that mirrors the pattern seen in the cash bond market. If sufficient capital were available to arbitrage away the auction cycle in futures, this cycle would not exist, and primary dealers would be able to hedge their inventory risk at no cost. If dealers could fully hedge inventory risk at no cost, behaved competitively in auctions, and were no better informed than other bidders, the intermediation cost of public debt would be negligible. Therefore, our analysis of futures markets indicates that the presence of slow-moving capital from non-dealer market participants significantly contributes to the cost of issuing Brazilian government debt.

Figure 6 illustrates the auction cycle in Brazilian interest-rate future contracts. We focus on fixed-rate coupon bond auctions and their maturity-matched DI1 futures contracts. Price differentials are computed relative to auction time, defined as the 15-minute window just before the National Treasury ends the bid collection period. A vertical dashed line in the figure indicates this exact moment, where the price differential is zero by construction. Another dashed line marks the start of the bidding period. The interval between these two vertical lines spans 30 minutes, corresponding to 11:00 to 11:30 am from December 2011 onwards and 12:30 to 1:00 pm before that. Price differentials at other times are calculated by comparing the last midquote yield of the DI1 contract in each 15-minute interval to the last midquote yield at the auction time, with yield changes converted to price changes using the contract's duration and convexity.

Figure 6 [about here]

The figure reveals a 20 bps auction cycle in interest-rate futures, closely resembling the cycle observed in the market for long-duration bonds (Figure 5). Strikingly, the lowest futures price – corresponding to the highest futures-market interest rate – occurs *precisely* during the auction bidding period. This provides high-frequency identification for the *causal* effect of Treasury auctions in the fixed-income market. The auction cycle in futures is evident enough that astute local market participants took notice: Carreira and Brostowicz (2016) (p.271) mention that DI1 rates "*mysteriously go up before weekly auctions, most of the time returning to previous levels after the results.*".[13]

Table 7 highlights the economic significance of slow-moving capital in Brazil's interest-rate futures market. It summarizes the profitability of a three-day trading strategy that exploits the auction cycle in futures. The strategy begins at market opening one day before the auction, shorting X units of the interest-rate futures contract that matches the maturity of the fixed-rate coupon bond set for auction. At auction time – defined as the 15-minute window just before bidding closes – the strategy purchases 2X units of the same contract, creating a net long position of X units. This position is closed at market close on the day after the auction. For auction days with two or more fixed-rate coupon bonds, the position is divided equally between the corresponding maturity-matched futures contracts. The strategy exploits predictable price movements induced by the auction cycle, with its profitability shedding light on the degree of slow-moving capital.

Table 7 [about here]

The trading strategy results underscore the extent of slow-moving capital in Brazil's fixed-income market. Over 666 fixed-rate coupon auction cycles, the strategy yields a mean return of 34 bps over three days (t-stat=5.74). The number of auction days here (666) is slightly higher than the number of fixed-rate coupon bonds auction days in Table 2 (655) because failed auctions are not excluded here,

[13] Although the amplitude of the auction cycle in futures matches the cost of issuing fixed-rate coupon debt (Table 2), the cycle's length in the futures market is compressed. In contrast to the week-long cycle observed in Figures 1 and 5, prices begin to decline at the market opening one day before the auction and return to normal by the market closing on the day after the auction.

avoiding potential bias in strategy results. The strategy's standard deviation is 155 bps, resulting in an annualized Sharpe Ratio of 2.04, calculated as $\frac{34}{155} \times \sqrt{\frac{252}{3}}$. Notably, the strategy's returns are almost uncorrelated with local stock and foreign exchange markets. A regression of strategy returns on contemporaneous stock market returns and FX depreciation produces an alpha of 35 bps (t-stat=5.79).

These results, particularly the high Sharpe Ratio and alpha, highlight significant market frictions that prevent primary dealers from costlessly hedging inventory risk. Figure 7 illustrates the cumulative return of the trading strategy, assuming no interest accrues during periods of inactivity (typically two out of five trading days per week). This visualization emphasizes the substantial degree of slow-moving capital in Brazil's fixed income market, contributing to the elevated cost of issuing public debt.

Figure 7 [about here]

6 More on information asymmetry

Section 4 provides evidence that asymmetric information, more specifically, other bidders' concerns about primary dealers' informational advantages, does not influence the intermediation cost of Brazilian public debt. This conclusion is supported by the regression of Clean Intermediation Cost (2-day), where the coefficient on the fraction absorbed by primary dealers is economically small and statistically insignificant. In this section, we delve deeper into this specific mechanism.

First, we provide evidence that the share of an auction absorbed by primary dealers has no predictive power for the return of buying a bond for its auction price and selling it later in the secondary market. Second, we attempt to reconcile our results with Cole et al. (2022). They propose an elegant theory in which asymmetric information about default risk plays a key role in primary and secondary bond markets. We show, however, that their calibration produces default probabilities that are strongly inconsistent with the market price of domestic Brazilian Treasury bonds.

6.1 The predictive power of dealers' share

We investigate whether the share of an auction absorbed by primary dealers predicts future secondary market returns. To do this, we create a dummy variable that flags auctions where the fraction absorbed by dealers exceeds the mean for each bond type (as reported in Table 2). We then regress the un-orthogonalized intermediation cost measured zero, one, two, three, and four days *after* the auction on this dummy variable. The regressions include bond-type and month-year fixed effects, and we use either midquotes or volume-weighted trade prices as sources of secondary market pricing. Figure 8 plots the results.

Figure 8 [about here]

Figure 8 shows that the fraction absorbed by primary dealers has no predictive power for the difference between future secondary prices and auction prices. The dummy variable for the above-mean primary dealer absorption remains economically small and statistically insignificant across all trading horizons and both pricing sources. This suggests that dealers are not disproportionately absorbing bonds when auction prices are particularly low compared to future secondary market prices. In sum, there is no evidence that the intermediation cost of Brazilian debt is influenced by primary dealers' potential informational advantages over other bidders.

6.2 The market-implied short-term probability of sovereign default

Cole et al. (2022) propose an elegant model of sovereign debt pricing under information asymmetry, calibrated to Mexican data. While other studies, such as Hortaçsu et al. (2018) and Boyarchenko et al. (2021), remain agnostic about the nature of asymmetric information, Cole et al. (2022) specifically attribute it to differences in bidders' knowledge about local debt sovereign default. Cole et al. (2022) claim their parameters match the prices of short-term CETES bonds issued by the Mexican government, reported in their Table 4. The table shows the mean price of a zero-coupon bond paying one unit of the numéraire at the end of one year is equal to 0.98 in the baseline specification, 0.97 in their preferred peso problem/rare disasters specification, and 0.98 in the data.

The 0.98 average price derived from the data is "*computed using the annual yield deflated by annual consumer price index inflation*" for 28-day CETES bonds. It is 0.98 because real short-term interest rates in Mexico averaged close to 2% per year from 2001 to 2017. That is, the calibration in Cole et al. (2022) assumes that default risk is the sole driver of non-zero real short-term interest rates in Mexico.

While this assumption may be debatable for Mexico, Brazil has a publicly traded security in which the effect of default risk can be disentangled from that of monetary policy. Floating-rate bonds issued by the Brazilian Treasury are indexed to the overnight monetary policy rate and typically traded at a discount relative to their face values. Brazilian researchers and fixed income traders have long used such discounts to infer the risk-neutral probability of default in local debt (Marques and Werlang (1990)).

Figure 9 plots the time series of the discount for Brazilian floating-rate bonds with maturity closest to one year, expressed in basis points and using midquote data. Compared to Table 2, we flip the sign here: positive values indicate that the bond trades below its face value. Additionally, the figure includes three horizontal lines corresponding to the calibration values from Cole et al. (2022): the 200 and 300 bps lines represent the mean prices (risk-neutral default probabilities) under the baseline and rare disasters calibrations, respectively, while the 65 bps line corresponds to the unconditional physical default probability in the rare disasters calibration.[14]

Figure 9 [about here]

The figure demonstrates that Brazilian market data strongly contradict the parameters in Cole et al. (2022). Despite Brazil's weaker S&P credit rating throughout the 21st century (except for a two-year overlap at BBB), the market-implied risk-neutral probability of default for Brazilian local debt remains below 20 bps per year throughout the entire 17-year sample period.This statement assumes zero recovery upon default, as Cole et al. (2022) do. This is significantly lower than the 200 and 300 bps annualized probabilities in Cole et al. (2022) and even below their 65 unconditonal physical probability of default.

At times, Brazilian floating-rate bonds with one year to maturity even trade at a premium relative to their face value. This suggests that the short-term probability of default in local debt is often negligible, with its effects overshadowed by microstructure factors, such as the usefulness of floating-rate bonds as collateral in derivatives contracts. Importantly, the message in Figure 9 is not peculiar to one-year maturities; we verified that similar conclusions apply across the entire floating-rate term structure.

In conclusion, Brazilian market data imply that the unconditional physical probability of sovereign default is much closer to zero than suggested by the parameters in Cole et al. (2022). These findings challenge the view that asymmetric information about local debt default is an economically meaningful friction in Brazilian primary or secondary public debt markets.

[14] In addition to reflecting the physical probability of default and the assumption of zero-recovery rate upon default in Cole et al. (2022), the risk-neutral probabilities embed a risk-premium too. Following Cole et al. (2022), the 65 bps per year assumes that the economy is in the favorable regime. It is the unconditional value, averaged over time across the good and bad states, that informed investors can discern, but uninformed investors can't. The conditional probabilities are 31 bps and 126 bps per year in the good and bad states, respectively.

7 Conclusion

Our findings contribute to the long-standing debate about the magnitude and the nature of the costs of issuing Treasury debt. Analyzing the largest sample of Treasury auctions to date, we estimate an average of 14 bps per auction cost of issuing Brazilian public debt from July 2006 to October 2023. This cost is five times larger than the 2.7 bps cost of issuing U.S. Treasury notes reported by Boyarchenko et al. (2021).

Compared to the existing literature, our large sample size and the unique institutional features of the Brazilian Treasury market allow for a more powerful statistical analysis of the economic mechanisms driving issuance costs. By leveraging plausibly exogenous variations, we identify three key drivers of these costs: inventory risk compensation for primary dealers, slow-moving capital, and limited competition among primary dealers.

The presence of slow-moving capital in the Brazilian fixed-income market is particularly significant, as it enables an interest-rate futures trading strategy with an annualized Sharpe Ratio of 2.04, capitalizing on predictable price movements around Treasury auctions. This highlights the inefficiencies within the market that contribute to the elevated cost of issuing debt.

In contrast to recent literature, we find no evidence to support the hypothesis that primary dealers' superior information plays a role in the intermediation cost of Brazilian public debt. Furthermore, we show that the calibration in Cole et al. (2022), which ties asymmetric information specifically to sovereign default probabilities, fails to align with Brazilian market data.

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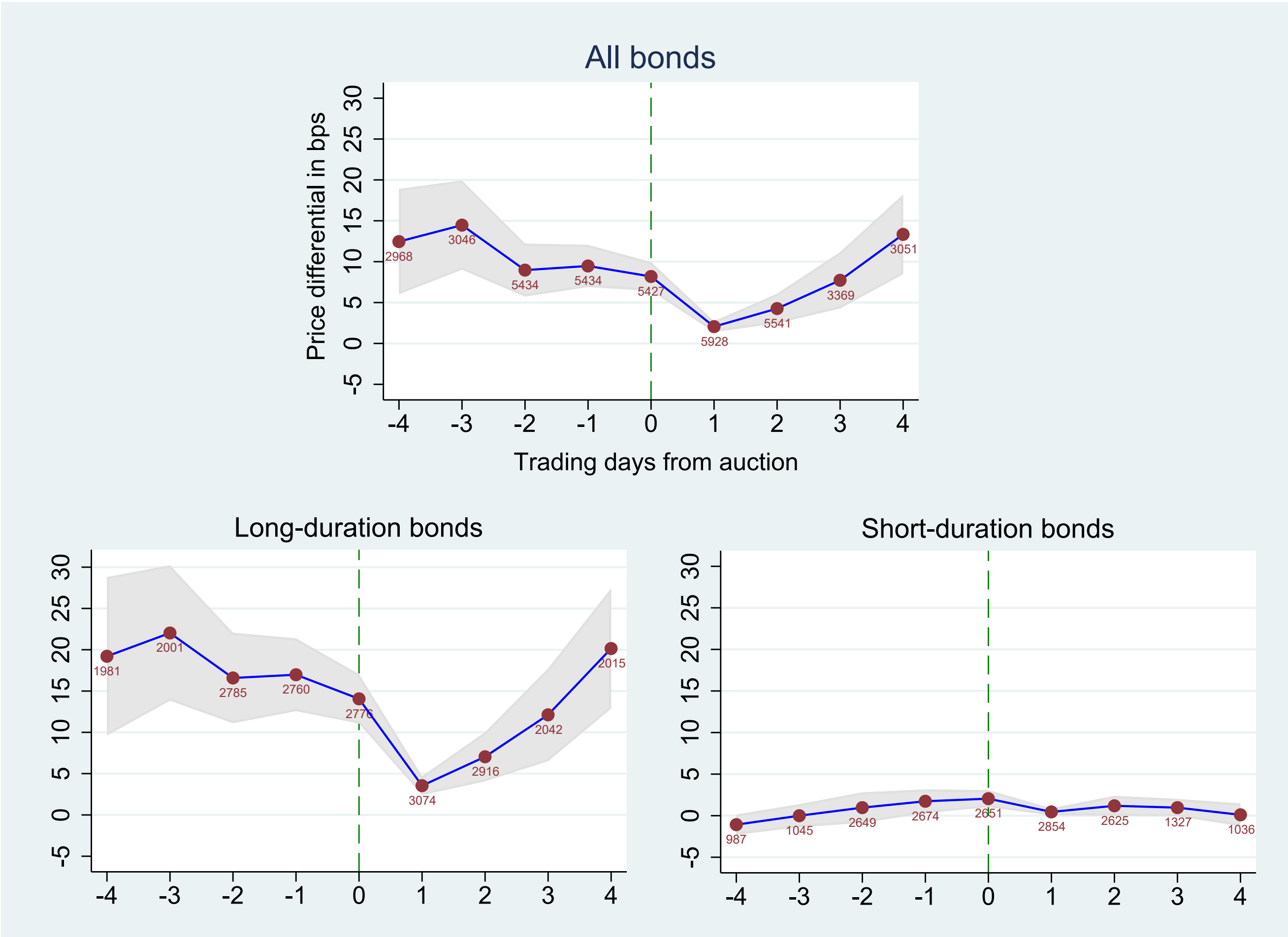


Figure 1: **Secondary market transaction prices relative to auction prices.**
The figures illustrate the intermediation cost of Brazilian public debt from July 2006 to October 2023. The vertical axes have the average relative difference between a bond's price in the secondary market and its price at a reopening auction, expressed in basis points. Positive differences mean higher secondary market prices compared to auction prices. The horizontal axes have the distance from auction day, in trading days. The auction price is the total proceeds divided by the number of bonds issued. The secondary market price is the volume-weighted average transaction price. Figure a in the first row has auctions of all bond types. Figures b and c in the second row have either long- or short-duration bonds only. The numbers below markers are sample sizes. 95% confidence intervals based standard errors clustered by auction day are displayed.

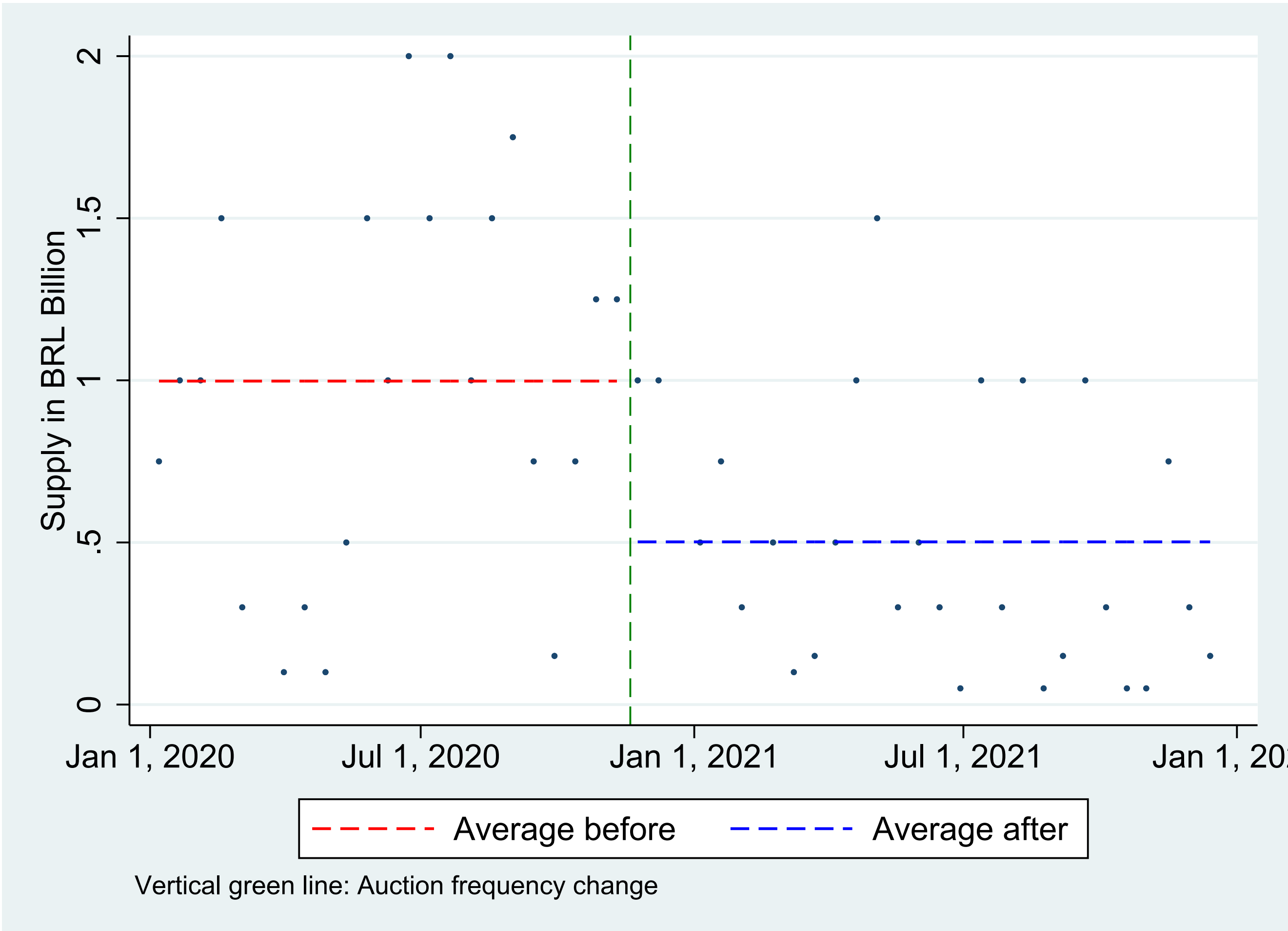


Figure 2: **Auction supply for an inflation-indexed bond maturing on August 15, 2030.**
The figure illustrates the change in average bond supply resulting from a change in auction frequency. In November 2020, the National Treasury changed the frequency of inflation-indexed auctions from every two weeks to every week. Each dot is an individual auction. The auction date is on the horizontal axis, and an auction supply, inflation-adjusted to November 2023 BRL billion, is on the vertical axis. The vertical dashed line is the date of the auction frequency change. The horizontal lines are the averages of the supply before and after the change.

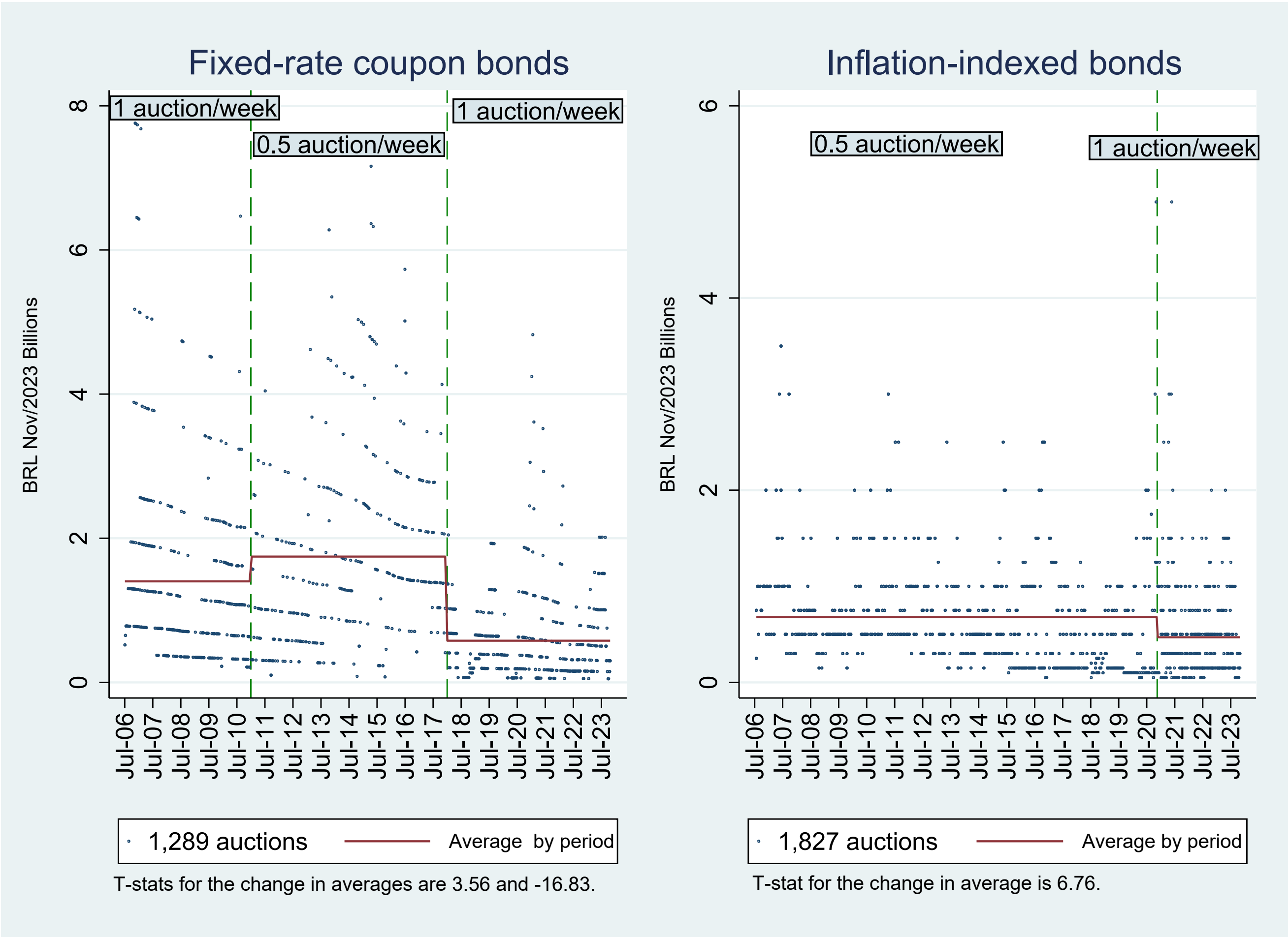


Figure 3: **Auction supply for long-duration bonds.**
The figure shows auction supply over time for long-duration bonds. Each dot is an individual auction. The auction date is on the horizontal axes, and an auction supply, inflation-adjusted to November 2023 BRL billion, is on the vertical axes. Vertical dashed lines mark the dates of auction frequency changes. The horizontal lines show the averages of the supply for each subperiod defined by auction frequency. T-statistics of tests of whether average supply changes around auction frequency changes are displayed.

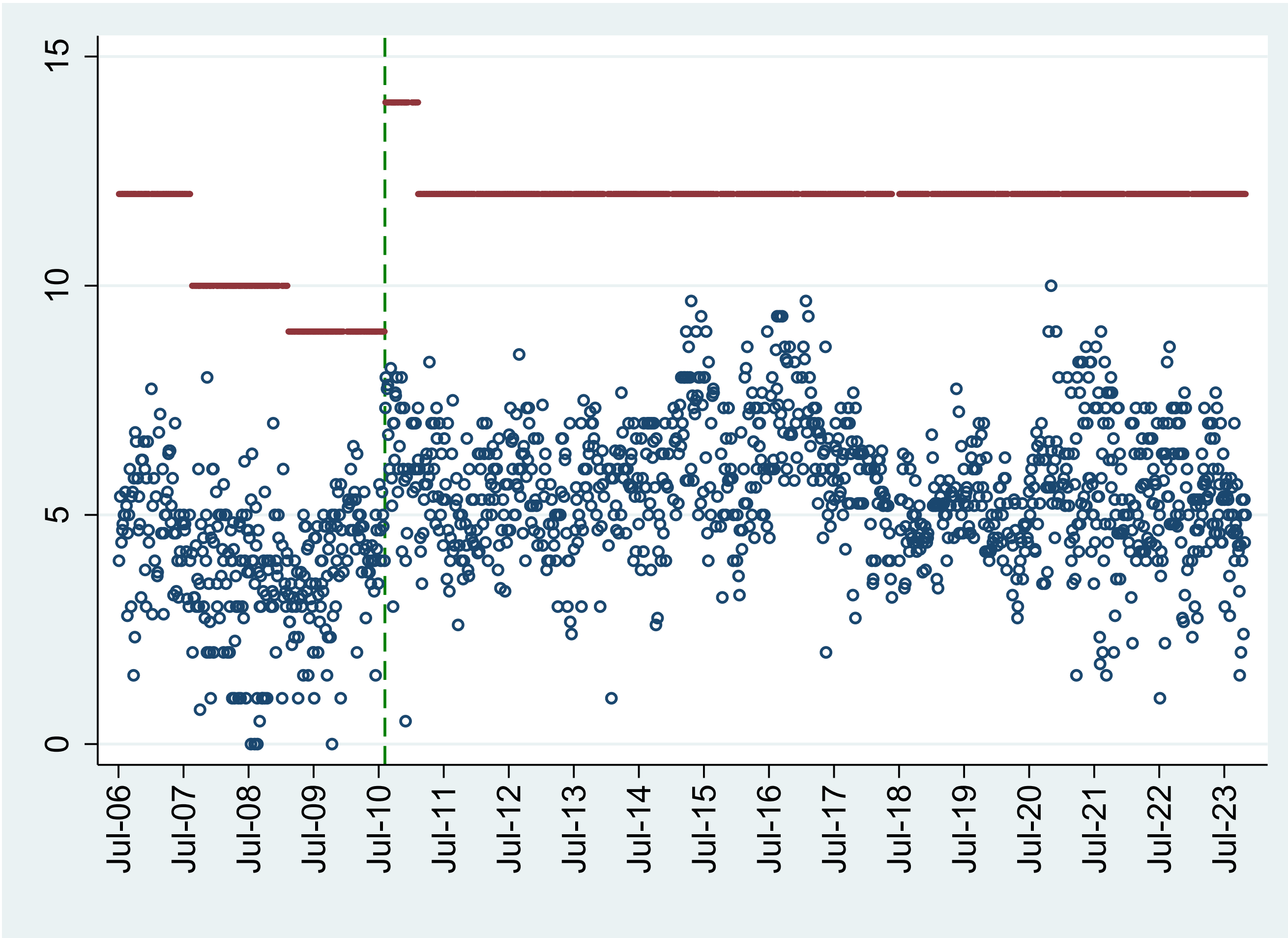


Figure 4: **Number of dealers over time.**
The blue hollow circles show the average number of dealers bidding on each auction day over time. The solid red circle shows the total number of primary dealers. The vertical dashed line marks the August 6, 2010, increase in the total number of dealers.

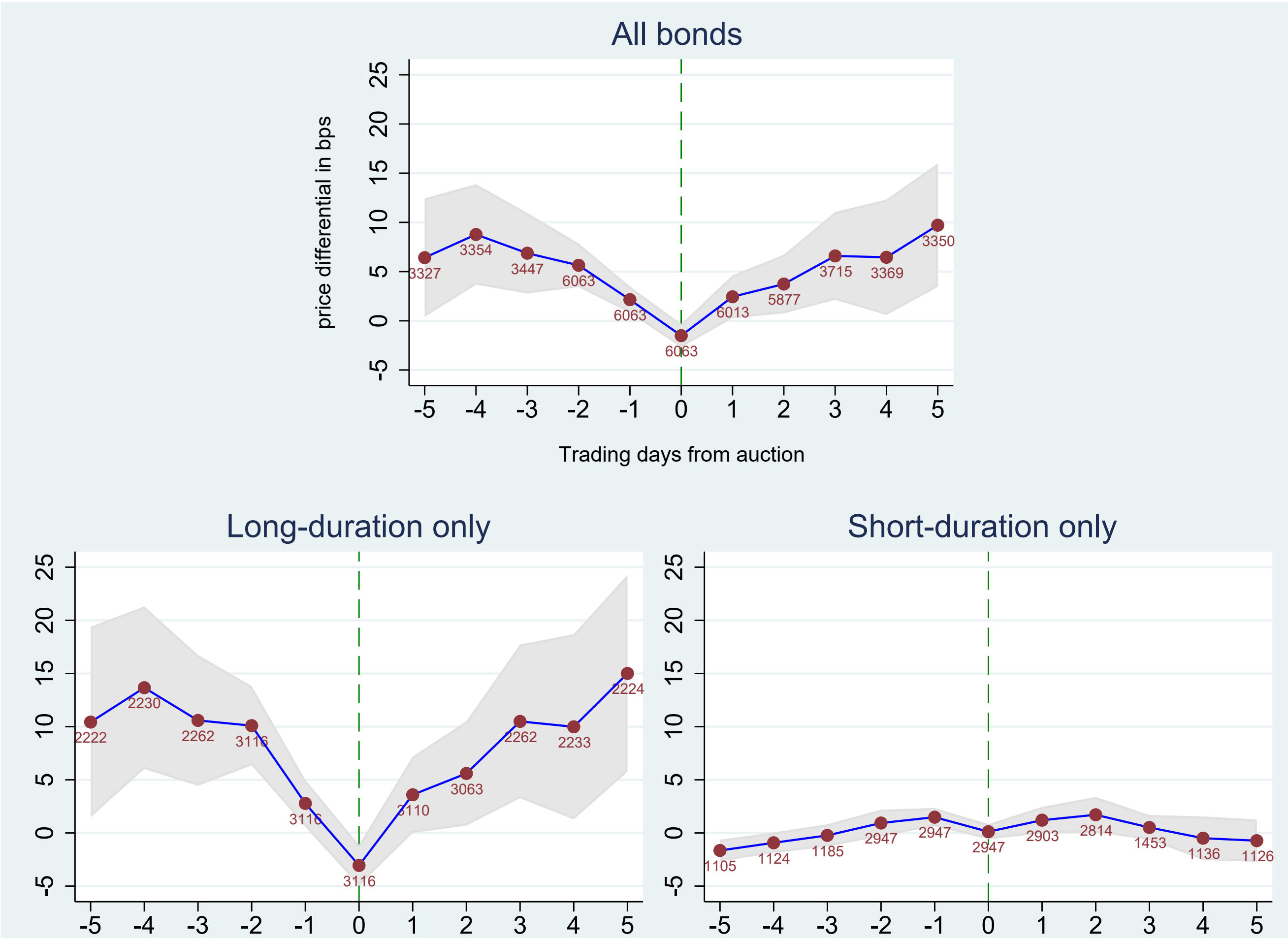


Figure 5: **Secondary market midquotes relative to auction prices.**
The figures illustrate the intermediation cost of Brazilian public debt from July 2006 to October 2023. The vertical axes have the average relative difference between a bond's price in the secondary market and its price at a reopening auction, expressed in basis points. Positive differences mean higher secondary market prices compared to auction prices. The horizontal axes have the distance from auction day, in trading days. The auction price is the total proceeds divided by the number of bonds issued. The secondary market price is based on end-of-day dealer midquotes. The first row has auctions of all bond types. The second row has either Long- or Short-duration bonds only. The numbers below markers are sample sizes. 95% confidence intervals based standard errors clustered by auction day are displayed.

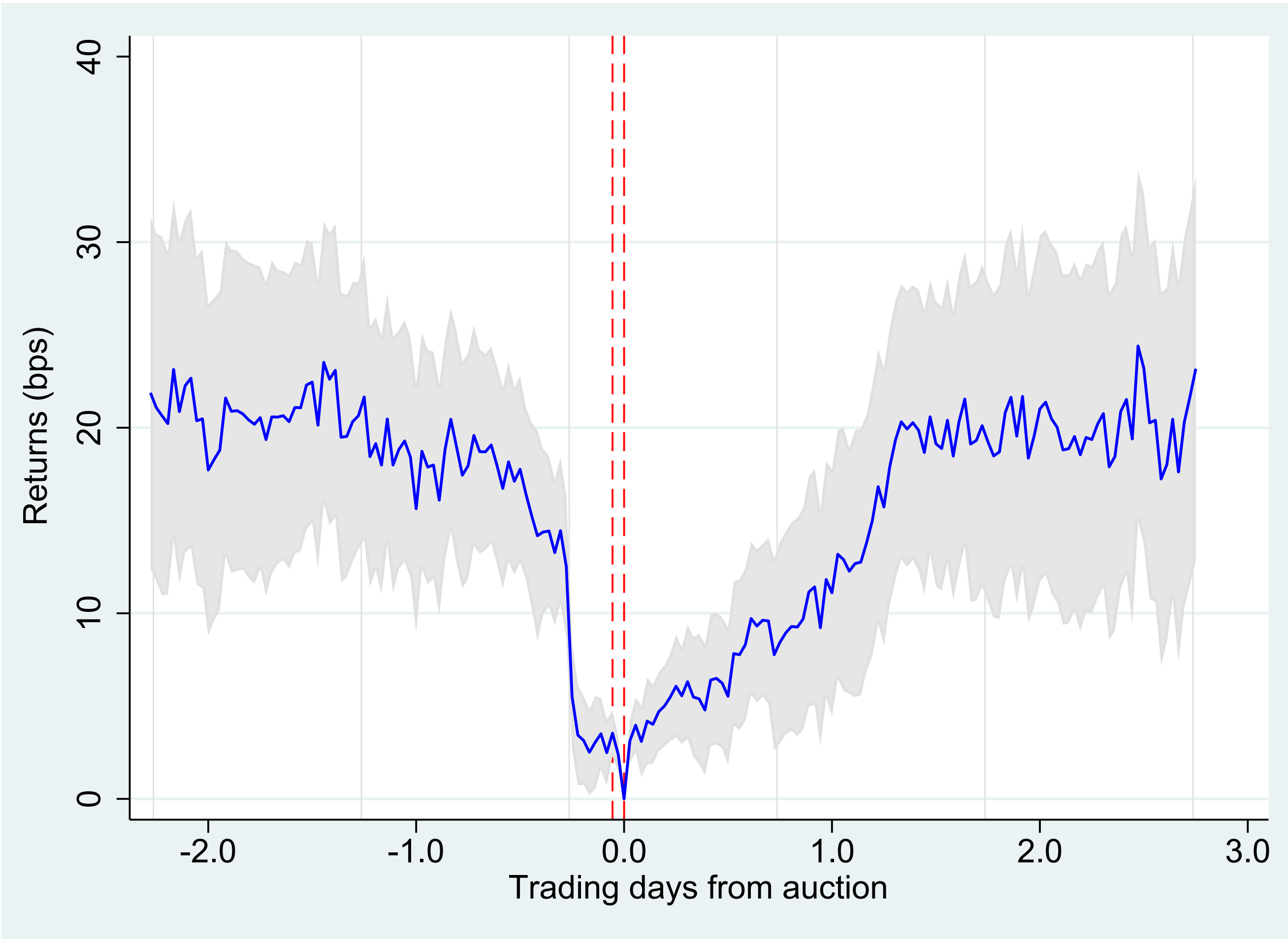


Figure 6: **The auction cycle in DI1 interest rate futures.**
The figure shows 15-minute price fluctuations in interest rate futures contracts around Brazilian Treasury auctions of fixed-rate coupon bonds. The contract is the DI1 futures contract whose maturity matches the maturity of the bond being auctioned. The vertical dashed lines mark the beginning and the end of the auction bidding period. Price differentials are calculated as the differences between the (last) midquote yield in the corresponding 15-minute interval and the (last) midquote yield in the 15 minutes immediately before the end of the bidding period, multiplied by the contract's duration. The sample period is July 2006 to October 2023 and includes 666 auction days. 95% confidence intervals are displayed.

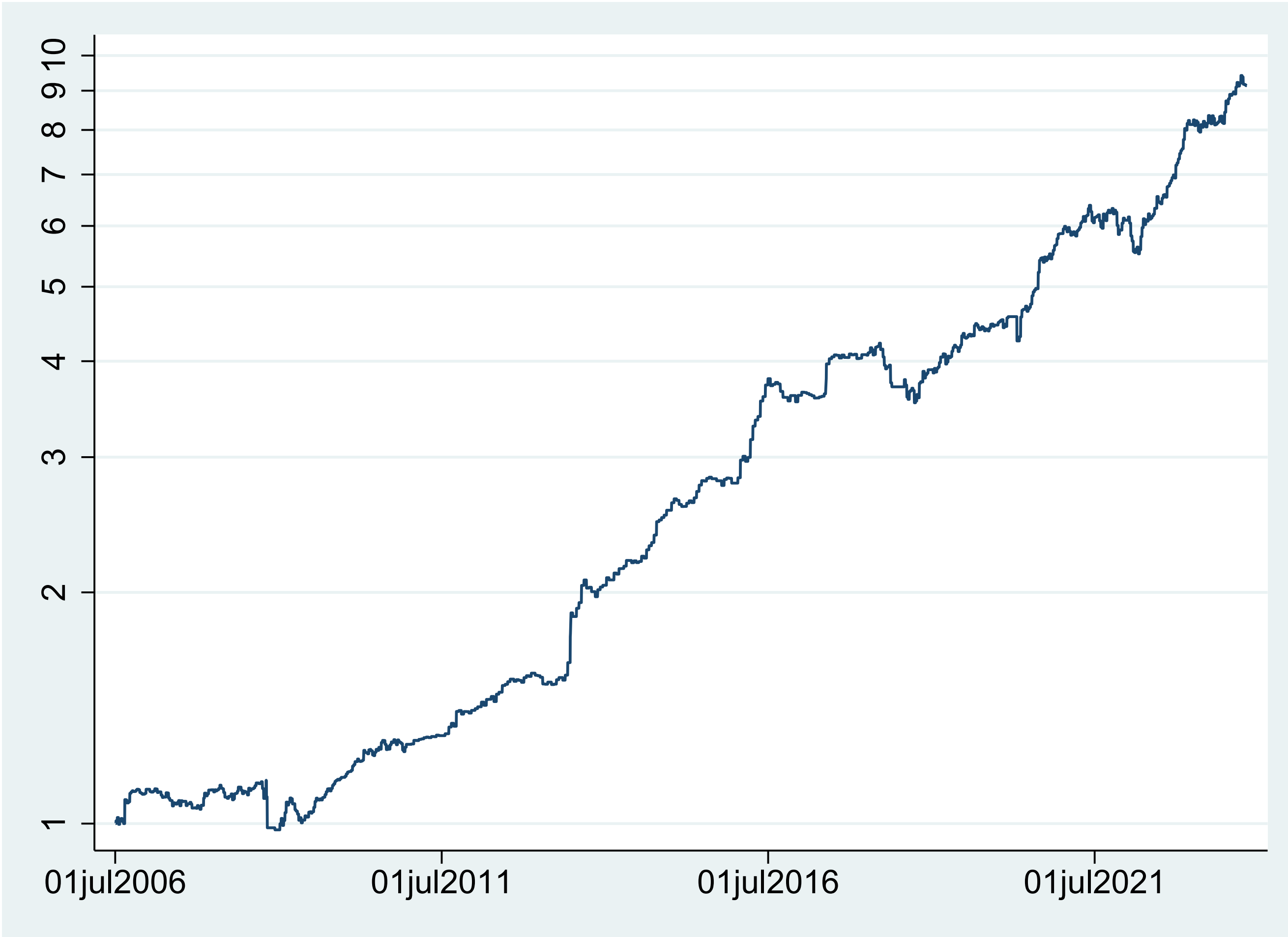


Figure 7: **Trading strategy cumulative return.**
The figure illustrates the cumulative return of a trading strategy that exploits the auction cycle in DI1 interest rate futures. One day before the auction, at the market opening, the strategy sells X contracts of the DI1 contract whose maturity matches that of the fixed-rate coupon bond to be auctioned. On the next day, closest to the end of the auction's bidding period, the strategy buys 2 X of the same contract. One day after the auction, the resulting long position of X contracts is liquidated at the market closing. Positions are even split across different contracts when more than one fixed-rate coupon bond is auctioned. The figure assumes no interest income received when the strategy is inactive, typically two out of five days in a week.

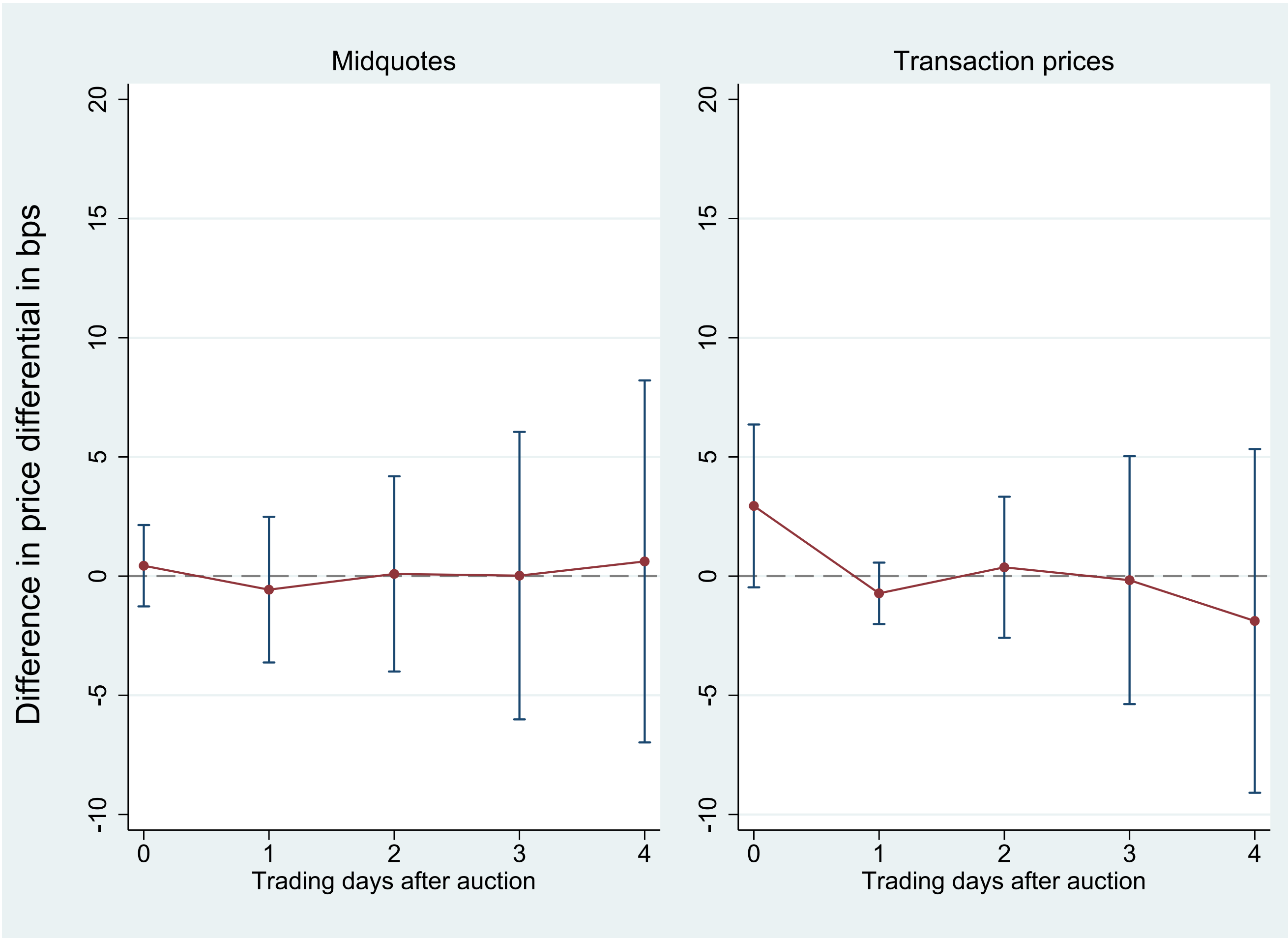


Figure 8: **Differential intermediation cost depending on primary dealer absorption.**
The figure plots the coefficients on a dummy variable that flags auctions in which primary dealers' absorption is higher than average in regressions of the Intermediation Cost of public debt. The average is separately defined for each bond type. The left panel uses end-of-day midquotes for secondary market prices, while the right panel uses volume-weighted transaction prices. The regressions include bond-type and month-year fixed effects. 95% confidence intervals based on standard errors clustered by auction day are shows. The sample period is July 2006 to October 2023.

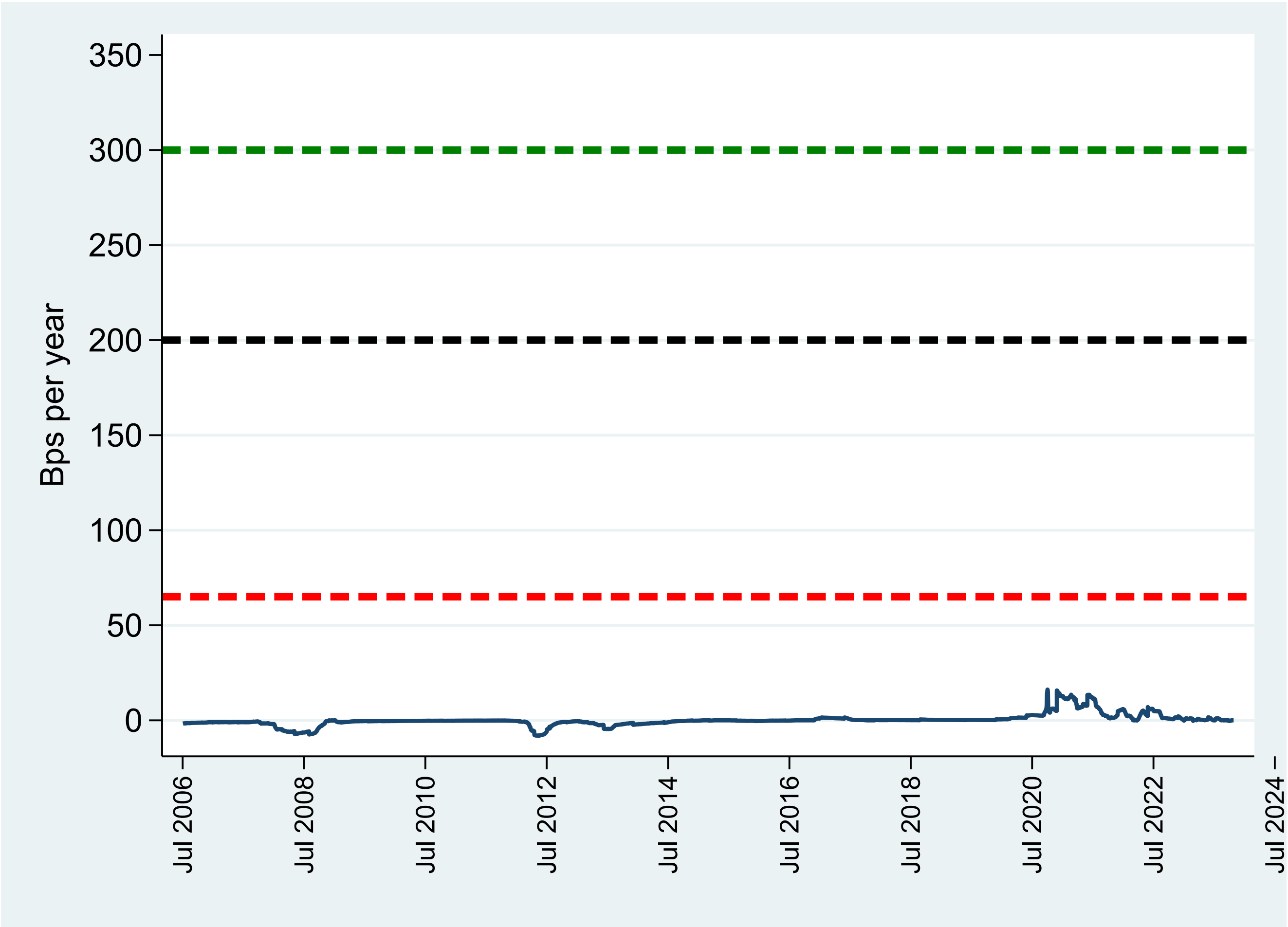


Figure 9: **Physical and risk-neutral probabilities of default.**
The figure plots the time series of the discount of the Brazilian floating-rate Treasury bond whose maturity is closest to one year. A positive number means the market price of the bond is below its face value. Under the assumptions of zero recovery upon default and that the discount is only due to default risk, the discount is equal to the annual risk-neutral default probability. The vertical lines show three values from the calibration in Cole et al. (2022): the risk-neutral probabilities of default in their baseline and "rare disasters" calibrations, and the physical probability of default in their "rare disasters" calibration. The sample period is July 2006 to October 2023.

	All bonds	Short-duration bonds		Long-duration bonds	
		Floating	Fixed Zero-Coupon	Fixed Coupon	Inflation-indexed
Auction format	-	Single price (79.8%)	Multiple price (100%)	Multiple price (99.8%)	Single price (99.8%)
Auction frequency (auction-days per week)	-	0.76 (Thu, Tue)	1.00 (Thu)	0.88 (Thu)	0.62 (Tue)
Maturity (years)	7.49 [8.86]	4.83 [1.58]	1.94 [1.13]	7.22 [2.43]	15.60 [12.11]
Duration (years)	4.65 [4.18]	0.00 -	1.94 [1.13]	5.02 [1.23]	8.84 [4.57]
Supply (BRL Nov 2023 100 Million)	30.67 [45.85]	106.89 [80.03]	39.07 [34.90]	11.54 [11.95]	6.31 [5.71]
Auction yield (% per year)	-	-	10.39 [2.93]	11.19 [2.18]	5.66 [1.39]
Auction discount (basis points)	-	37.5 [60.9]	-	-	-
Number of dealers bidding	4.94 [2.55]	4.57 [2.62]	5.60 [2.68]	3.82 [2.13]	5.03 [2.33]
Total number of dealers	11.64 [1.04]	11.52 [1.15]	11.70 [0.94]	11.54 [1.15]	11.66 [1.02]
Fraction absorbed by dealers	0.84 [0.24]	0.74 [0.27]	0.89 [0.21]	0.83 [0.24]	0.83 [0.26]
Secondary market yield quote dispersion	1.18 [1.95]	0.17 [0.24]	0.97 [1.89]	1.49 [2.17]	1.59 [2.06]
Secondary market annual turnover	5.49 [10.07]	2.19 [2.92]	7.89 [12.04]	4.83 [9.20]	4.13 [8.88]
Value outstanding before auction	173.61 [132.30]	240.72 [170.59]	193.01 [142.41]	143.84 [102.61]	146.22 [106.53]
Auction number in sequence	35.13 [35.19]	13.56 [10.22]	18.80 [12.15]	57.30 [42.25]	47.73 [40.27]
Term premia first PC	0.00 [0.98]	0.19 [1.00]	-0.06 [0.98]	0.02 [0.99]	-0.02 [0.94]
Number of auction-days	1,381	441	885	651	483
Number of auctions	6,063	655	2,292	1,289	1,827

Table 1 : **Auction summary statistics**
The table has summary statistics for the Brazilian public debt auctions in our sample. The sample period is July 2006 to October 2023. Standard deviations in brackets. The units of *Value outstanding before auction* is the same as *Supply*.

Pricing source	Bond types	D - 4	D - 3	D - 2	D - 1	Auction day	D +1	D + 2	D + 3	D + 4
Transaction prices	All bonds	12.46 ***	14.47 ***	8.97 ***	9.48 ***	8.19 ***	2.06 ***	4.27 ***	7.73 ***	13.34 ***
		(3.79)	(5.20)	(5.43)	(7.20)	(9.13)	(6.06)	(4.64)	(4.39)	(5.37)
		[2,968]	[3,046]	[5,434]	[5,434]	[5,247]	[5,928]	[5,541]	[3,369]	[3,051]
	Long-duration bonds only	19.21 ***	22.03 ***	16.58 ***	16.98 ***	14.06 ***	3.54 ***	7.04 ***	12.12 ***	20.15 ***
		(3.93)	(5.27)	(5.93)	(7.56)	(9.23)	(4.64)	(4.64)	(4.23)	(5.43)
		[1,981]	[2,001]	[2,785]	[2,760]	[2,776]	[3,074]	[2,916]	[2,042]	[2,015]
	Short-duration bonds only	-1.08 *	0.00	0.97	1.74 **	2.05 **	0.46 **	1.19 **	0.97 *	0.10
		(-1.73)	(0.00)	(1.03)	(2.39)	(3.90)	(2.10)	(1.96)	(1.83)	(0.15)
		[987]	[1,045]	[2,649]	[2,674]	[2,651]	[2,854]	[2,625]	[1,327]	[1,036]
Midquotes	All bonds	8.78 ***	6.87 ***	5.64 ***	2.15 ***	-1.51 **	2.44 **	3.74 **	6.59 ***	6.45 **
		(3.37)	(3.30)	(4.98)	(3.14)	(-2.50)	(2.20)	(2.46)	(2.90)	(2.16)
		[3,354]	[3,447]	[6,063]	[6,063]	[6,063]	[6,013]	[5,877]	[3,715]	[3,369]
	Long-duration bonds only	13.66 ***	10.59 ***	10.09 ***	2.78 **	-3.05 ***	3.60 **	5.60 **	10.50 ***	9.99 **
		(3.51)	(3.37)	(5.31)	(2.46)	(-3.10)	(1.96)	(2.24)	(2.85)	(2.25)
		[2,230]	[2,262]	[3,116]	[3,116]	[3,116]	[3,110]	[3,063]	[2,262]	[2,233]
	Short-duration bonds only	-0.93 *	-0.23 ***	0.94	1.49 ***	0.12	1.20 **	1.71 **	0.52	-0.49
		(-1.87)	(-0.43)	(1.47)	(3.40)	(0.32)	(1.90)	(2.00)	(0.87)	(-0.47)
		[1,124]	[1,185]	[2,947]	[2,947]	[2,947]	[2,903]	[2,814]	[1,453]	[1,136]

Table 2 : **Intermediation cost estimates**
The table has estimates for the average Intermediation Cost of Brazilian public debt, expressed in basis points. For each bond type, each pricing source, and each distance from auction day in trading days, we compute the average Intermediation Cost of public debt across all auctions from July 2006 to October 2023. The cost is defined by differences between yield-to-maturities or discounts at the auction and in the secondary market. T-statistics in parentheses are clustered by auction day. The number of auctions is in brackets.

	D - 4	D - 3	D - 2	D - 1	Auction day	D +1	D + 2	D + 3	D + 4	Fixed coupon dummy	Inflation-indexed dummy	Intercept	Time fixed effects	# clusters	# day-bonds
Daily midquote yield change	0.02 (0.15)	-0.03 (-0.25)	0.02 (0.20)	0.53 *** (5.03)	0.77 *** (6.45)	-0.27 ** (-2.18)	-0.49 *** (-4.09)	-0.38 *** (-3.25)	-0.23 *** (-2.18)	0.05 (0.63)	0.15 * (1.73)	-0.22 *** (-4.34)	Y	4,353	127,189

H_0: $D_{-4} + D_{-3} + D_{-2} + D_{-1} + \text{Auction Day} = -(D_{+1} + D_{+2} + D_{+3} + D_{+4})$

$F(1, 4352) = 0.07$ Prob > F = 0.7912

Table 3 : **Daily midquote yield changes around auctions**
The table has results of running a regression of daily changes in yield midquotes onto dummy variables for distances to an auction of the same bond. The regression has daily fixed effects and bond-type fixed effects. The sample includes all non-floating-interest rate bonds except those maturing in less than one month. T-statistics based on standard errors clustered by day are displayed. We test the null hypothesis that the sum of the dummy variables up to and including the auction day has the same magnitude as the sum of the dummy variables after the auction. The sample is from July 2006 to October 2023.

	Short-duration bonds		Long-duration bonds	
	Floating	Fixed zero-coupon	Fixed coupon	Inflation-indexed
Panel A: Averages and their t-statistics				
Intermediation Cost (2-day)	0.39 ***	1.09	7.76 ***	11.74 ***
	(3.72)	(1.34)	(3.08)	(4.34)
FX Depreciation (2-day)	-9.50	-0.76	-5.83	3.34
	(-1.45)	(-0.18)	(-1.21)	(0.58)
Stock market return (2-day)	24.96 **	6.96	11.96 *	15.76
	(2.35)	(1.05)	(1.71)	(1.63)
Clean Intermediation Cost (2-day)	0.39 ***	1.09	7.76 ***	11.74 ***
	(3.72)	(1.48)	(3.60)	(5.00)
Panel B: Coefficients and t-stats of Intermediate Cost (2-day) regressions				
FX Depreciation (2-day) [standardized]	0.02	6.47 ***	24.42 ***	14.42 ***
	(0.15)	(5.98)	(8.76)	(5.32)
Stock market return (2-day) [standardized]	-0.07	-5.26 ***	-12.38 ***	-16.28 ***
	(-0.69)	(-4.57)	(-4.86)	(-5.12)
FX depreciation * Duration [both standardized, Duration orthogonalized first]	-	6.05 ***	7.05 ***	6.23 ***
		(6.75)	(4.50)	(3.42)
Stock market return * Duration [both standardized, Duration orthogonalized first]	-	-3.63 ***	-1.61	-6.61 ***
		(-3.960)	(-1.11)	(-3.24)
Intercept	0.39 ***	1.09	7.76 ***	11.74 ***
	(3.72)	(1.48)	(3.60)	(5.00)
R^2	0.00	0.20	0.26	0.22
Number of auction-days (clusters)	441	885	651	483
Number of auctions	655	2,292	1,289	1,827

Table 4 : **Intermediation cost (2-day) statistics**
The table has statistics for the intermediation cost of Brazilian public debt measured using midquotes two days before auctions. Panel A has summary statistics. Panel B has results of cost cleaning regressions in which the (raw) Intermediation cost (2-day) is orthogonalized relative to contemporaneous foreign exchange depreciation and stock market return to create the Clean Intermediation Cost (2-day). The sample period is July 2006 to October 2023. T-statistics are based on standard deviations clustered by auction day.

	(1) Main IV	(2) OLS	(3) no controls	(4) no bidding info	(5) no time FE	(6) dealer fraction
Supply long-duration bond	2.16 ***	0.26 **	2.01 ***	2.16 ***	2.15 ***	2.16 ***
	(3.25)	(1.99)	(3.16)	(3.31)	(2.68)	(3.25)
Supply short-duration bond	0.02	-0.02 *	0.02	-0.01	0.03	0.02
	(1.10)	(-1.92)	(0.83)	(-0.92)	(1.62)	(1.10)
Duration nominal bond	4.93 ***	2.17 ***	3.93 ***	3.93 ***	5.72 ***	4.93 ***
	(3.97)	(3.43)	(3.59)	(4.18)	(3.39)	(3.97)
Duration real bond	0.99 ***	0.45	1.21 **	1.20 ***	0.98 **	0.99 ***
	(2.74)	(1.37)	(3.26)	(3.10)	(2.31)	(2.74)
Number of dealers bidding	-2.09 ***	-0.21	-1.94 ***	-	-2.12 **	-2.08 ***
	(-2.78)	(-0.55)	(-2.65)		(-2.37)	(-2.78)
Total number of dealers	-	-	-	-7.65 **		-
				(-2.36)		
Term premia first PC	-	-	-	-	4.20 ***	-
					(3.59)	
Fraction absorbed by dealers	-	-	-	-	-	0.10
						(0.03)
Bond-type fixed effects	Y	Y	Y	Y	Y	Y
Month-year fixed effects	Y	Y	Y	Y	N	Y
Controls	Y	Y	N	Y	Y	Y
R^2	0.12	0.16	0.12	0.11	-0.02	0.12
First Stage: F ; Cragg-Donald F	38 ; 178	-	41 ; 189	36 ; 181	30 ; 156	38 ; 179
Number of auction-days (clusters)	1,381	1,381	1,381	1,381	1,381	1,381
Number of auctions	6,063	6,063	6,063	6,063	6,063	6,063

Table 5 : **Intermediation cost (2-day) regressions**
The table has IV regressions of the intermediation cost of Brazilian public debt measured using midquotes two days before auctions and orthogonalizing with respect to contemporaneous FX depreciation and the stock market return (Intermediation cost (2-day)). Auction frequency and its interaction with a dummy for fixed-rate coupon bonds are instruments for the supply of long-duration bonds. The control variables are secondary market yield quote dispersion, secondary market annual turnover, value outstanding before auction, and auction number in sequence. The sample period is July 2006 to October 2023. T-statistics are based on standard deviations clustered by auction day.

	(1) Main IV	(2) no cleaning	(3) transaction prices	(4) no outliers	(5) first half	(6) second half	(7) only fixed rate	(8) only long-duration	(9) no inf.indexed	(10) no floating
Supply long-duration bond	2.16 ***	2.59 ***	2.62 ***	2.28 ***	2.22 *	1.54 **	1.61 ***	2.81 ***	1.31 **	1.52 **
	(3.25)	(3.42)	(3.38)	(3.88)	(1.89)	(2.19)	(2.75)	(2.84)	(2.41)	(2.51)
Supply short-duration bond	0.02	0.02	0.06 **	0.02	0.04	-0.03	0.02	-	0.02	0.00
	(1.10)	(0.89)	(2.46)	(1.31)	(1.22)	(-1.22)	(0.51)		(0.89)	(0.08)
Duration nominal bond	4.93 ***	5.82 ***	7.20 ***	4.55 ***	6.13 **	2.62 ***	5.20 ***	5.37 **	4.20 ***	4.16 ***
	(3.97)	(4.11)	(4.88)	(4.27)	(2.46)	(2.85)	(4.46)	(2.54)	(4.11)	(3.53)
Duration real bond	0.99 ***	1.20 ***	2.25 ***	1.27 ***	0.82	1.45 ***	-	1.05 ***	-	0.82 **
	(2.74)	(3.07)	(5.07)	(4.20)	(1.30)	(3.191)		(2.75)		(2.34)
Number of dealers bidding	-2.09 ***	-2.63 ***	-2.45 ***	-1.83 ***	-3.63 ***	0.15	-3.02 ***	-3.96 **	-2.01 ***	-1.74 **
	(-2.78)	(-3.13)	(-2.80)	(-2.94)	(-2.72)	(0.19)	(-3.22)	(-2.17)	(-3.02)	(-2.01)
FX depreciation (2-day)	-	0.10 ***	-	-	-	-	-	-	-	-
		(9.68)								
Stock market return (2-day)	-	-0.04 ***	-	-	-	-	-	-	-	-
		(-6.37)								
Bond-type fixed effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Month-year fixed effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
R^2	0.12	0.21	0.06	0.15	0.11	0.15	0.17	0.18	0.15	0.16
First Stage: F ; Cragg-Donald F	38 ; 178	38 ; 179	38 ; 186	38 ; 179	16 ; 40	51 ; 268	63 ; 220	47 ; 91	48 ; 155	60 ; 172
Number of auction-days (clusters)	1,381	1,381	1,370	1,379	728	653	890	1,133	989	1,372
Number of auctions	6,063	6,063	5,427	5,949	3,034	3,029	3,581	3,116	4,236	5,408

Table 6 : **Intermediation cost (2-day) robustness regressions**

The table has IV regressions of the intermediation cost of Brazilian public debt. Columns (4) to (10) use midquotes two days before auctions and orthogonalizing with respect to contemporaneous FX depreciation and the stock market return (Intermediation cost (2-day)). Column (2) uses orthogonalized cost measured using midquotes two days before auctions. Column (3) uses orthogonalized cost measured using transaction prices on auction day. Auction frequency and its interaction with a dummy for fixed-rate coupon bonds are instruments for the supply of long-duration bonds. The control variables are secondary market yield quote dispersion, secondary market annual turnover, value outstanding before auction, and auction number in sequence. The sample period is July 2006 to October 2023. T-statistics are based on standard deviations clustered by auction day.

	Mean	St. Dev.	Ann. Sharpe Ratio	Number of Auction-Days	Alpha
Three-day strategy returns (bps)	34 *** (5.74)	155	2.04	666	35 *** (5.79)

Table 7 : **Trading strategy returns**
The Table has statistics for the return of a three-day trading strategy that exploits the auction cycle in DI1 interest rate futures. One day before the auction, at the market opening, the strategy sells X contracts of the DI1 contract whose maturity matches that of the fixed-rate coupon bond to be auctioned. On the next day, closest to the end of the auction's bidding period, the strategy buys 2 X of the same contract. One day after the auction, the resulting long position of X contracts is liquidated at the market closing. Positions are even split across different contracts when more than one fixed-rate coupon bond is auctioned. Returns are in basis points.

Appendix to

"On the Intermediation Cost of Public Debt"

This Appendix presents supplementary material.

Appendix A has a table with variable definitions and data sources.

Appendix B provides institutional information about the Brazilian Treasury market.

Appendix C has a detailed example showing how the intermediation cost is computed from raw data.

Appendix D has a conjecture about the difference in timing when the intermediation cost is computed from transaction prices versus end-of-day midquotes.

Appendix E shows the results of auction failures.

A Variable definitions and data sources

Variables	Description	Data sources
Midquote yield change	Change in end-of-day dealer yield midquotes (*taxa indicativa*) for non-floating rate bonds. Expressed in basis points per year.	STN and ANBIMA
Intermediation Cost (2-day)	Secondary market price two days before the auction minus auction price, divided by auction price. Auction price is proceeds divided by quantity sold. For non-floating rate bonds, secondary market price before the auction is auction price plus the product of modified duration at auction and difference between auction yield-to-maturity and secondary market yield to maturity two days before the auction. For floating-rate bonds, the intermediation cost it is the difference between the auction discount, defined as auction price divided by face value (*valor nominal atualizado*) at auction settlement day, and the secondary market discount two days before the auction, defined as secondary market price two days before the auction divided by face value (*valor nominal atualizado*) two days before the auction. Secondary market prices and yield-to-maturities come from either end-of-day dealer midquotes (*taxa indicativa*) or from volume-weighted average transaction prices. Winsorized at the 0.5% level at both tails. Expressed in basis points.	STN, BACEN, and ANBIMA
FX Depreciation (2-day) and Stock Market Return (2-day)	Calculated from the closing price of nearest maturity futures contract two days before the auction and the mid-point between the inside quotes of the same contract at the end of the auction bidding period on auction day. The latter ends at 11:30 am after November 2011 and at 1 pm before that. Expressed in basis points.	B3
Clean Intermediation Cost (2-day)	Intercept plus residual of a regression of Intermediation Cost (2-day) on FX Depreciation (2-day) and Stock Market Return (2-day), and, for non-floating rate bonds, these interacted with bond duration at auction. Regressions are run for each of the four bond types separately. FX Depreciation and Stock Market Return are standardized to mean zero and variance one. Duration is first orthogonalized relative to Stock Market Return and FX Depreciation, and then standardized to mean zero and variance one. The orthogonalization and standardization preserve the average of Intermediation Cost (2-day) . Expressed in basis points.	STN, BACEN, ANBIMA, and B3
Supply	Total inflation-adjusted BRL value of bonds offered at the auction. BRL value is inflation-adjusted to November 1st 2023, using the face value (*valor nominal atualizado*) of IPCA inflation-indexed bonds. Expressed in one hundred BRL million.	STN and BACEN
Duration	Bond's Macaulay duration at auction, expressed in years.	STN
Number of dealers bidding	Number of primary dealers submitting bids to the auction.	STN (proprietary)
Total number of dealers	Total number of primary dealers.	STN
Fraction absorbed by dealers	Fraction of total issuance purchased by primary dealers.	STN (proprietary)
Sec. market yield quote dispersion	Standard deviation of dealers' end-of-day yield-to-maturity quotes (non-floating rate bonds) and discounts (floating rate bonds) one day before the auction. Expressed in basis points.	ANBIMA
Sec. market annual turnover	Number of bonds traded one day before the auction divided by quantity of bonds outstanding one day before the auction, multiplied by 252.	BACEN
Value outstanding before auction	Total inflation-adjusted BRL value of bonds issued before the auction. BRL value is inflation-adjusted to November 1st 2023, using the face value (*valor nominal atualizado*) of IPCA inflation-indexed bonds. Expressed in one hundred BRL million.	BACEN
Auction number in sequence	One for the first re-opening auction of a given bond, two for the second re-opening auction, three for the third re-opening auction and so forth.	STN
Term premia first PC	First principal component of four term premia tenors, ranging from one to four years, one day before the auction. Standardized to have mean zero and variance one in the time series. Term premia calculated daily using BACEN's FOCUS survey of interest rate expectations for the SELIC monetary-policy target rate at the end of one to four (or five) years and close prices of DI1 interest-rate future contracts of matching maturity. Calculation assumes monetary-policy changes are equally distributed across future Monetary Policy Committee meetings.	BACEN and B3

B The Brazilian Treasury market

This is a primer on Brazil's public debt market. It provides useful background information for the paper. We cover the market's size and the range of securities it offers. We identify the main investors and describe the secondary market. Additionally, we highlight the large and active Brazilian interest rate futures market. Some institutional details on the auction process that are more central to the paper are in its main body.

B.1 Volume and maturity outstanding

Figure A.1 shows the evolution of Brazil's federal government's domestic debt during our sample period. The plot uses accounting values (*preço na curva*) rather than market valuations, but the difference is irrelevant for our purposes here. We plot two types of interest-bearing debt, bonds and repurchase agreements with the Central Bank. After November 2021, voluntary, remunerated bank reserves are added to the latter. In these repos, the Central Bank borrows bank reserves in the very short term (a week or less) while providing longer-term Treasury bonds as collateral. The Central Bank obtains these collateral bonds at regular National Treasury auctions. The Central Bank does not bid in the auctions: for accounting purposes, it "purchases" the bond from the National Treasury at the auction price determined by market bids and the Treasury's cut-off decision.

Figure A.1 [about here]

Total domestic federal debt as a fraction of GDP remained fairly constant at 50% from July 2006 to the end of 2014. Then it increased steadily to 70% of GDP by the end of 2019, right before COVID. During COVID, debt-to-GDP growth accelerated, and the ratio reached 80%. The burst of inflation following COVID brought domestic debt back down to 70% of GDP at the end of our sample in October 2023.

B.2 Types of securities

The National Treasury issued four types of bonds in our sample period: fixed-rate zero-coupon (*LTN*), fixed-rate coupon (*NTN-F*), floating-rate (*LFT*), and inflation-indexed (*NTN-B*). Floating-rate bonds pay no coupon, and their principal is indexed to the overnight SELIC rate, Brazil's monetary policy rate. Hence, they have a duration equal to zero. Zero-coupon fixed-rate bonds are akin to U.S. Treasury bills, but their maturity may extend beyond one year. Fixed-rate coupon bonds have longer maturities. Differently from the U.S., their coupon rate is standardized to 10% per year. Inflation-indexed bonds are tied to the country's main consumer price index, the IPCA. They pay a standardized coupon rate of 6% per year, but their principal is adjusted by inflation on a monthly basis.

In addition to standardized coupon rates, Brazilian bonds also have standardized maturity days. Fixed-rate zero coupon bonds mature on the first day of January, April, July, or October. Fixed-rate coupon bonds mature on the first day of January with the exception of one bond maturing on July 1st 2010. Coupons are semi-annual, paid on the first day of January and July. Maturity dates for inflation-indexed bonds are set for May 15th and August 15th. Coupons are paid semi-annually, too. Although floating-rate bonds typically mature on March 7th or September 7th, their maturity dates were less standardized than those of nominal or inflation-indexed bonds at the beginning of our sample period.

To further facilitate pricing through standardization, all inflation-indexed bonds share the same principal value, set to $1,000$ in July 15th 2000 and updated monthly by the cumulative IPCA rate since then. The same applies to floating-rate bonds with a principal value set to $1,000$ in July 1st 2000 and updated by the cumulative SELIC rate since then. The face value of fixed-rate zero-coupon and coupon bonds is $1,000$.

Figure A.2 [about here]

Figure A.2 breaks down total domestic bond debt into five different bond types. The figure has the four bond types whose auctions we study plus "Other". Other include dollar-indexed domestic bonds and other bond types that were no longer issued during our sample period. Note the graph displays both high- and low-frequency variations. High-frequency variations occur when a specific bond matures, and the rate at which it is replaced by another bond of the same type is not constant. This high-frequency variation reveals active debt management by the National Treasury at a tactical level. The low-frequency variations denote active debt management at the strategic level. As an example of the latter, consider floating-rate bonds as a fraction of GDP. The total value of these bonds decreased from 18% of GDP at the beginning of our sample to 7% at the end of 2014. At that point, the National Treasury changed tack and gradually increased floating-rate bond issuance until reaching 23% of GDP at the end of our sample.

B.3 Auctions and primary dealers

While the National Treasury publishes a tentative calendar for debt to be issued over the coming months, the quantity of bonds to be supplied in each individual auction is announced the day or the day before the auction. The Treasury informally consults with primary dealers and end investors before defining such quantities. The Treasury, however, retains the option to sell less than the full supply of bonds in case the bids are deemed to be not fully satisfactory.

Hundreds of commercial banks, investment banks, and broker/dealers are eligible to bid in Treasury auctions. Pension funds and asset management companies, local or foreign, are not. However, the institutions that are eligible to bid can host sub-accounts for their clients to submit their own individual bids, possibly for a fee. There are 182 distinct bidders in the July 2006 to October 2023 period. Thirty of those bid through from sub-accounts, and only two of these are asset management companies, which bid through sub-accounts hosted by the commercial bank from the same financial conglomerate. There are no bids from foreign investors or pension funds.

The time window for bid submission on auction days has changed over time. It was from noon to 1 pm before December 2011, shifting to 11 to 11:30 am afterwards. Since December 2011, ordinary participants can submit up to three bids specifying price and quantity, while primary dealers may submit up to seven; before this date, the limit was five bids for all participants. Auction results were announced at 2:30 pm until November 2011, and at noon since. Financial settlement of auctions almost always occurs the following day.

The National Treasury, in collaboration with the Central Bank until August 2015 and independently thereafter, selects a group of primary dealers every six months. The total number of dealers changed over time, from a minimum of 9 to a maximum of 14. These dealers are expected to consistently participate in auctions by submitting competitive bids. On average, a quarter of the dealers are replaced during each selection cycle. The number of distinct primary dealers from July 2006 to October 2023 is 28.

In return for the requirement to bid consistently, primary dealers have the option to buy up to an additional 25% of an auction's offering at the average rate of the first round, provided that at least 50% of the offering was initially sold. These second rounds occur 85% of the time in our sample and, on average, increase issuance by 10%. Our analysis focuses on the first round, where prices are set. [15]

[15] Up until August 6, 2010, the Central Bank and the National Treasury also appointed a group of secondary market dealers, tasked with maintaining bid-ask quotes in the secondary market rather than participating in the primary market. These dealers could also take part in the auction's second round but were allocated a smaller portion of it.

B.4 Concentration and auction reopenings

Figure A.3 illustrates the bonds populating each of Brazil's term structures over time. There are three panels, one for each type of term structure: fixed-rate, inflation-indexed, and floating-rate. Each downsloping line represents an individual bond, tracked over time as its time to maturity decreases. At each point in time, the intersection of a vertical line at that time with the downsloping lines shows which bonds are outstanding and what their maturities are. The Figure reveals that, compared to the U.S. Treasury market, the Brazilian government bond market is concentrated in relatively few individual securities. For example, on average, in our sample period, the nominal term structure is populated by just 16 bonds and extends up to 9.5 years. The real term structure has 14 bonds on average and covers 37 years. In contrast, at any point in time, the U.S. Treasury bond debt is dispersed across more than 300 different securities. The number of bonds in the floating term structure decreased substantially at the beginning of the sample when the National Treasury belatedly began to apply to floating-rate bonds the policy of deliberate concentration that had been in place for non-floating bonds for years before.

Figure A.3 [about here]

Though the term structures are concentrated in relatively few bonds, there are weekly auctions. These auctions rarely increase the variety of bonds outstanding because most of them involve reopenings of existing securities. In our July 2006 to October 2023 sample period, there were $6,474$ reopening auctions, compared to only 147 initial auctions in which a new type of security is created. The same bond is re-auctioned again and again. For these reopening auctions, there is an identical bond already trading in the secondary market at the time of each auction. This allows for direct comparison between auction prices and secondary market prices, enabling us to directly measure the degree of underpricing at each auction, significantly facilitating the task of comparing auction to secondary market values compared to the U.S. case (see Boyarchenko et al. (2021)).

Figure A.4 [about here]

Figure A.4 shows the occurrence of auctions over time for each bond type. Each dot represents a separate auction. The y-axis has the maturity of the bond being auctioned. Each separate straight line with a fixed slope represents reopening auctions of the same security. The lines slope down because each time a bond is re-auctioned, its maturity is shorter. Figure A.4 reveals the locally exogenous nature of duration in bond auctions: aside from the first time a bond is issued, duration is predetermined at each auction.

B.5 Secondary market volume

Brazil's local Treasury debt traded mostly over-the-counter during our sample period, with a growing number of trades being negotiated electronically through platforms such as B3's Trader and Bloomberg's FIT towards the end of the sample. Over-the-counter trades typically settle in T+0, whereas electronic trades settle in T+1. All trades are settled through the Central Bank's SELIC system – which also keeps custody of the bonds – with delivery-over-payment. The secondary market trading data we use is based on SELIC data and includes all outright transactions in Brazilian Treasuries in the secondary market. Thus, repos are excluded, as is any outright trade in which the Central Bank or the National Treasury is a counterpart.

Figure A.5 [about here]

Figure A.5 plots the average annualized secondary market turnover of bonds in our sample. Turnover is the ratio of trading volume divided by quantity outstanding, not including quantity held by the Central Bank. It is calculated daily for each bond, then averaged across bonds of a given type within a month, and annualized by multiplying by 252. The Figure shows that, in general, Brazil's fixed income market was fairly active during our sample period, especially for non-floating bonds. The average turnover for non-floating-rate bonds was 370% per year. Turnover increased towards the end of the sample as electronic trading became more widespread. From 2013 to 2023, average turnover was 410%, on par with the UK Gilts secondary market over the period, as reported by the United Kingdom Debt Management Office.

B.6 Secondary market pricing

We use two sources of secondary market pricing data. The Central Bank of Brazil provides daily volume-weighted transaction prices, including all secondary market transactions in which neither the Central Bank nor the National Treasury is a counterpart. Data is from the Central Bank of Brazil.

The Brazilian Financial and Capital Markets Association (ANBIMA) provides daily end-of-day midquotes (*taxa indicativa*). ANBIMA's quotes are based on daily surveys with dealers in the secondary market of the Treasury bonds. Quotes are subject to statistical filters, averaged, and made public on the same day. These quotes are widely used by market participants to mark fixed income portfolios to market, an activity sanctioned by Brazil's CVM, the local SEC equivalent. ANBIMA's data include the standard deviation of the quotes based on individual dealer entries for each midquote.

In addition to providing midquotes, ANBIMA releases a daily inflation-adjusted face value for inflation-indexed bonds (*valor nominal atualizado*). It is based on ANBIMA's forecasts for the current month's inflation. These values are widely used to convert inflation-indexed yield-to-maturity quotes into BRL prices.

B.7 Interest rate futures

In the paper, we use prices of One-day Interbank Deposit Futures (DI1), one of the world's most liquid interest-rate futures contracts. In 2022, 657 million DI1 contracts were traded at B3, compared to 463 million 10-year Treasury future contracts at the CBOT, and 419 million 3-month SOFR contracts at the CME.[16]. DI1 contracts mature on the first day of each month, intentionally aligned with the maturity and coupon payment days of fixed-rate Treasury bonds.

A long position in a DI1 contract receives fixed and pays floating. The floating rate is the overnight CDI rate. That rate moves with and is typically within a couple of bps of the overnight SELIC rate, to which floating Treasury bonds are indexed. Thus, a long position in a fixed-rate zero-coupon bond coupled with an appropriately sized short position in a maturity-matched DI1 futures contract is nearly equivalent to a long position in a floating-rate bond. Conversely, a long position in a floating-rate bond coupled with a long position in a maturity-matched DI1 contract approximates a long position in a fixed-rate zero-coupon bond. There is very little basis risk.

Figure A.7 illustrates the size and liquidity of DI1 contracts. We plot two ratios during our sample period. The first ratio is the value of open interest in DI1 futures, adding across all contracts at the end of each month, divided by the value of all outstanding fixed-rate government bonds. This is the solid blue line in the Figure, and its axis is on the left. The figure shows that the stock of DI1 futures market contracts was larger than the stock of fixed-rate government bonds throughout our sample period. On average, the ratio is 1.42.

Figure A.7 [about here]

The second ratio is the total monthly trading volume in DI1 contracts divided by the total monthly trading volume in fixed-rate government bonds. It is the dashed red line in the Figure, with values read on the right axis. The figure shows that DI1 futures are much more liquid than fixed-rate government bonds. Recall that, with an annual turnover of 370%, the secondary market for Brazilian government

[16] https://www.b3.com.br/pt_br/noticias/b3-e-a-bolsa-que-mais-negocia-contratos-futuros-no-mundo.htm.

bonds is fairly active. Thus, given an average ratio of 10.66 during our sample period, the DI1 futures market is extraordinarily active.

B.8 Expectations and term premia

Longer-term bond yields reflect not only expectations of future short-term rates but also term premia. We compute term premia using expectations surveys continuously conducted by the Central Bank. The FOCUS surveys ask financial institutions their forecast for the SELIC monetary policy rate at the end of the current calendar year, as well as one, two, and three calendar years beyond that. Assuming that future rate changes are equally distributed across future Monetary Policy Committee (COPOM) meetings, we can compute the expected future path of short-term rates from the present to the end of the forecasting period. We compute risk premia by deducting cumulative future short-term rates from DI1 futures maturing from one to for years in the future.

Figure A.7 [about here]

Figure A.7 plots term premia for two tenors, one and four years. The average one-year term premia was 24 bps, and the average four-year term premia was 162 bps. In the paper, we use the first principal component of term premia considering the two tenors plotted, as well as the two and three-year tenors. Such first PC accounts for 92% of the variability across the four time series.

B.9 End investors

Brazilian Treasury fixed-rate coupon bonds are held by a diverse group of end investors. Using end-of-month aggregate holdings data spanning from December 2013 to November 2023, we find that foreigners are the predominant holders of fixed-rate coupon debt, owning on average 52% of the stock. Financial institutions (commercial banks, investment banks, and broker-dealers) come next, holding 18% of the outstanding volume, while pension funds rank third with 10%. Federal government organizations, excluding the Central Bank, rank fourth with 8%, while the remainder is nearly evenly split among mutual funds, insurance companies, and a diverse group labeled "Other", which includes individuals. Central Bank holdings, used for monetary policy purposes, are excluded.

The ownership distribution of inflation-indexed bonds differs notably from that of fixed-rate coupon bonds. Pension funds are the primary holders, with 42% of the outstanding volume, on average. Mutual funds are in a distant second, owning 20%, followed by financial institutions and federal state-owned organizations, holding 14% and 9%, respectively. The "Other" category, insurance companies, and foreign investors held 6%, 5%, and 4%, respectively.

Among short-duration bonds, there are also significant ownership differences between floating-rate and fixed-rate zero-coupon bonds. Fixed-rate rate zero-coupon bonds are predominantly held by financial institutions, with 43% of the holdings, followed by foreign investors (24%), mutual funds (12%), pension funds (9%), government organizations (5%), "Other" (4%) and insurance companies (3%). For floating-rate bonds, mutual funds lead the holdings with 44%, ahead of financial institutions (28%), pension funds (18%), "Other" (5%), insurance companies (4%), foreign investors (1%) and government organizations (virtually 0%).

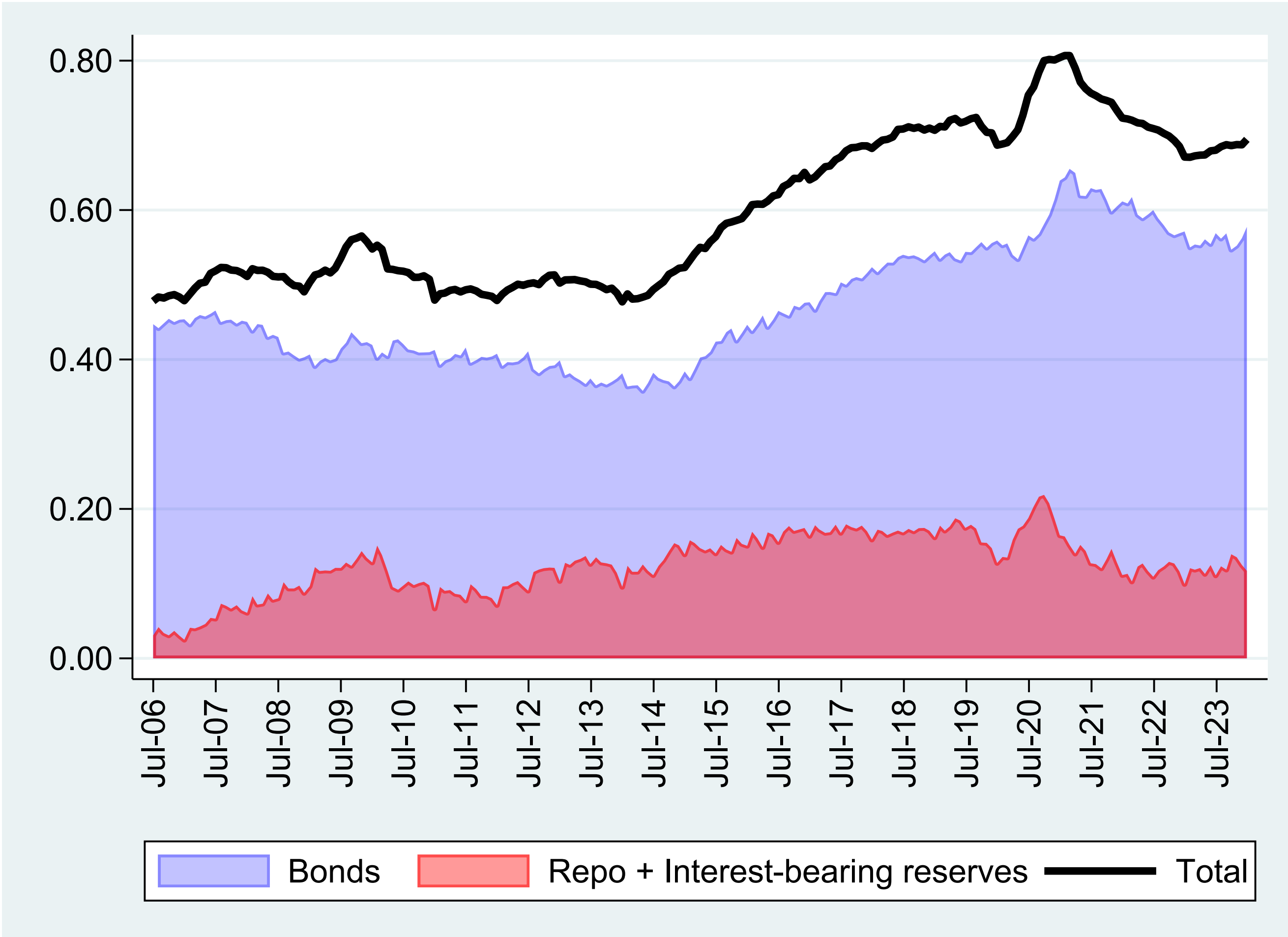


Figure A.1: **Brazilian federal interest-bearing domestic debt**
The figure shows the evolution of Brazilian federal interest-rate bearing domestic debt from July 2006 to October 2023, as a fraction of GDP.

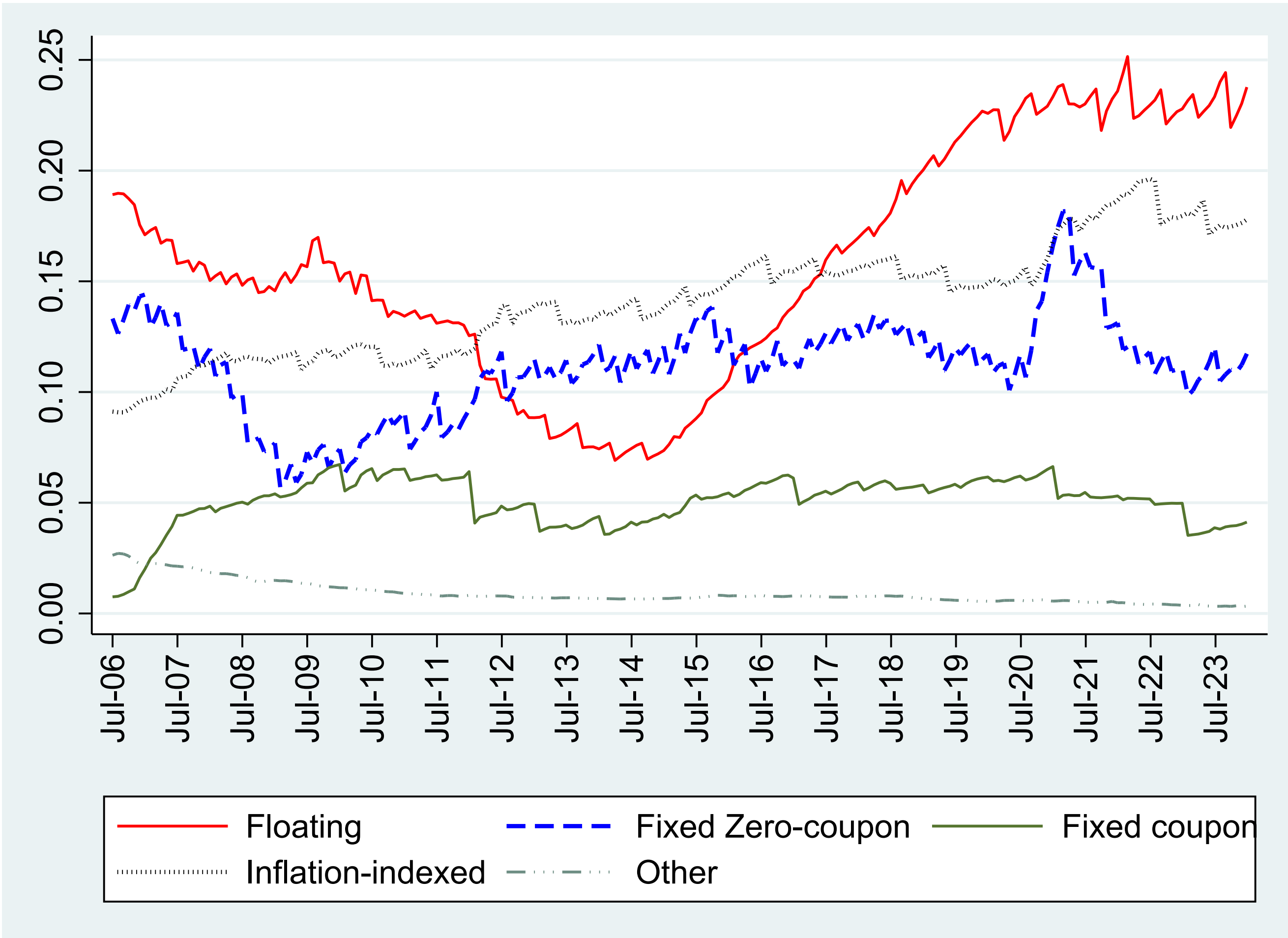


Figure A.2: **Brazilian federal bond debt composition**
The figure shows the composition of Brazilian bond debt by bond type. Each line is debt value as a fraction of GDP. The sample period is July 2006 to October 2023.

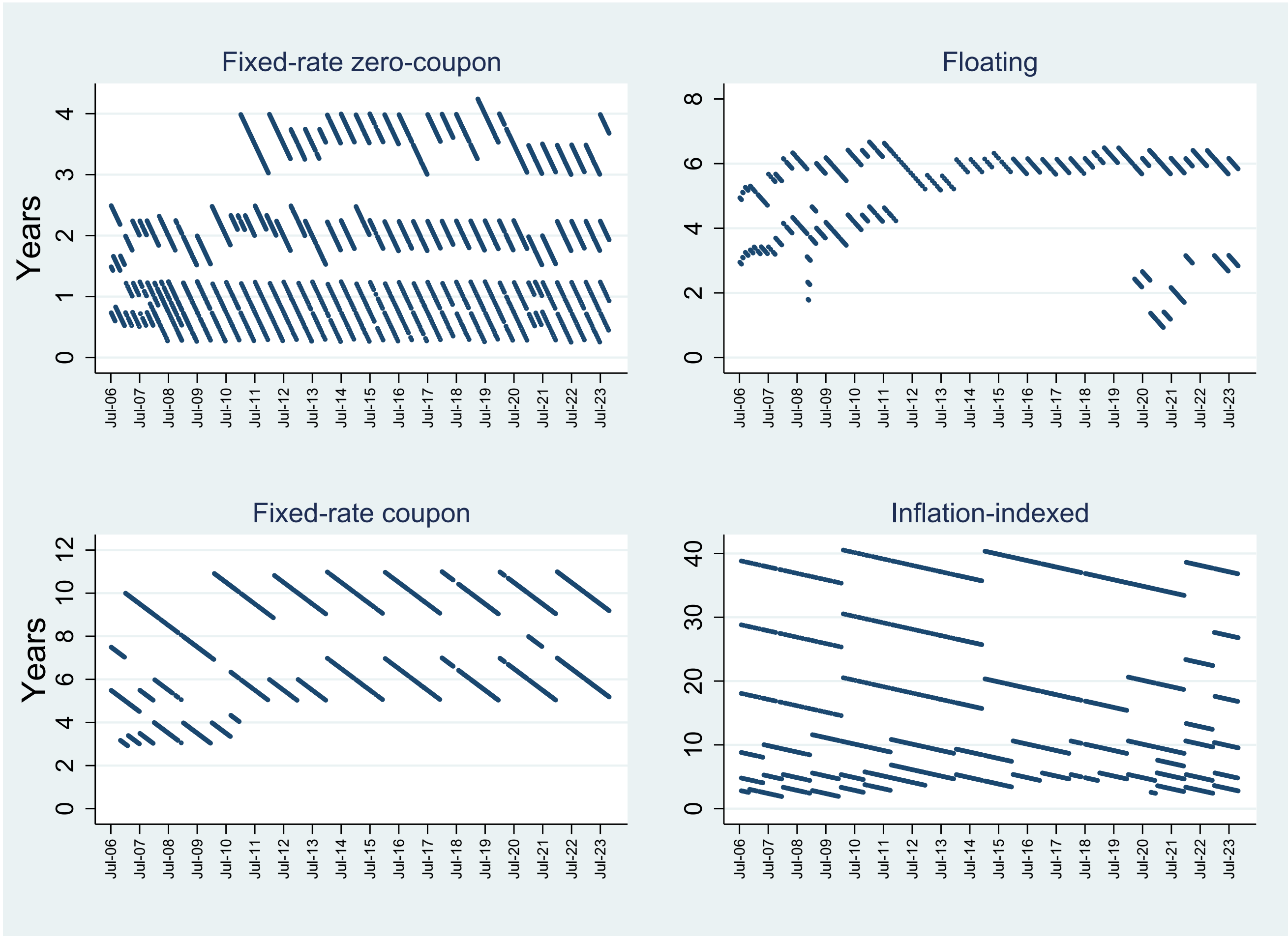


Figure A.3: **Brazilian federal bond debt composition**

The figure shows the maturity composition of the term structures of Brazilian bond debt. Each downsloping line represents an individual bond, tracked over time as its time to maturity decreases. At each point in time, the intersection of a vertical line at that time with the downsloping lines shows which bonds are outstanding and what their remaining maturities are. The sample period is July 2006 to October 2023.

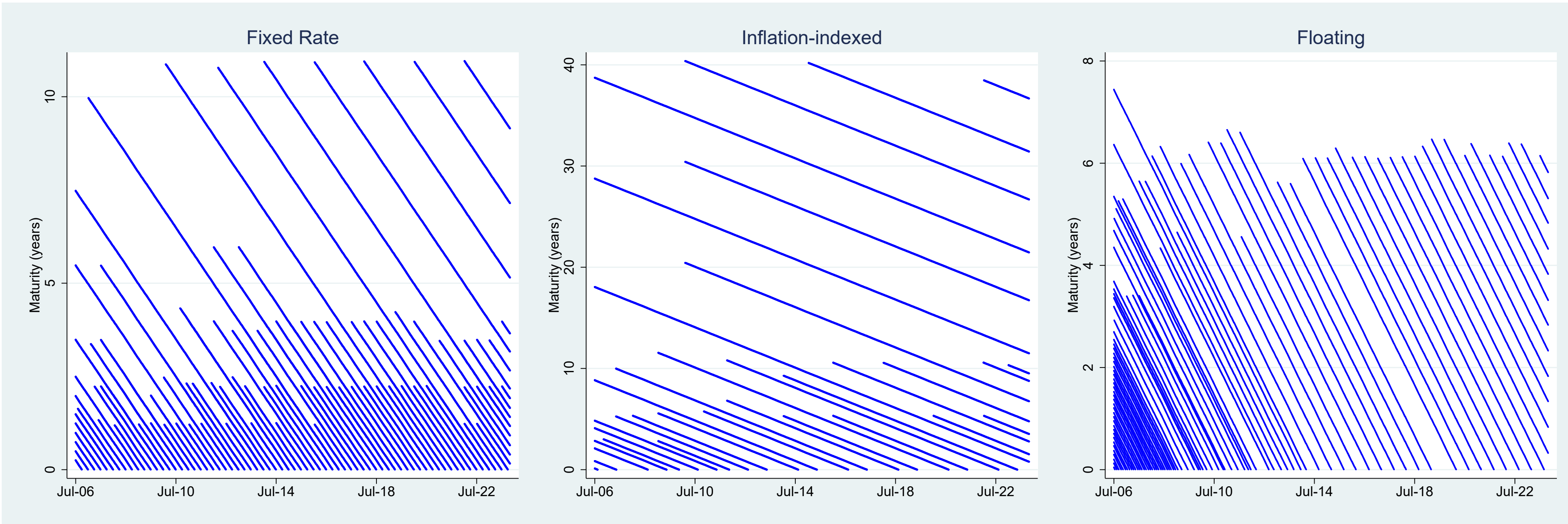


Figure A.4: **Brazilian Treasury auctions**
The figure shows the occurrence of auctions over time for each bond type. Each dot represents a separate auction. The y-axis has the maturity of the bond being auctioned. Each separate straight line with a fixed slope represents reopening auctions of the same security. The lines slope down because each time a bond is re-auctioned, its maturity is shorter. The sample period is July 2006 to October 2023.

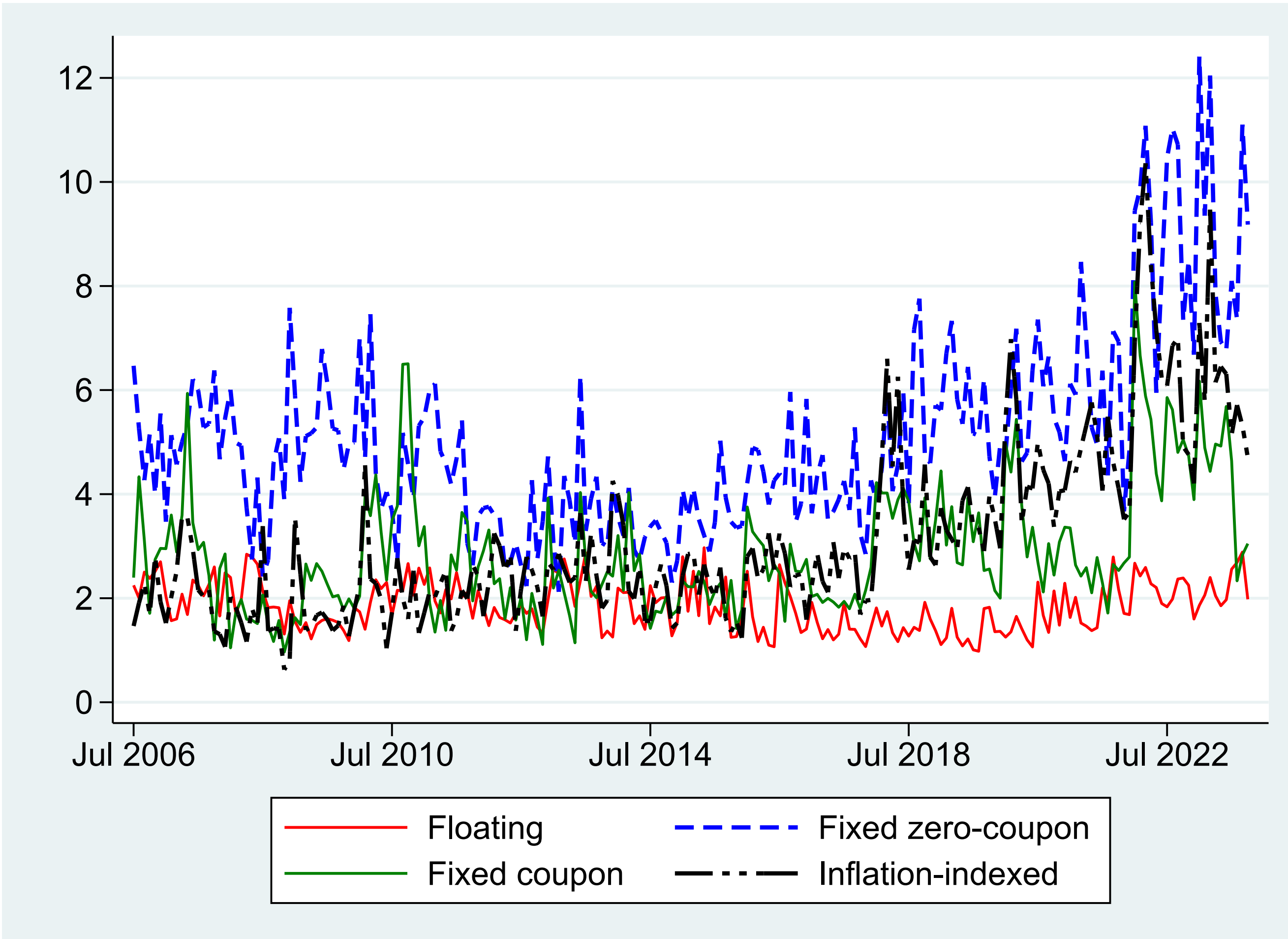


Figure A.5: **Annualized turnover of Brazilian Treasury bonds**
The figure shows the average annualized secondary market turnover of bonds in our sample. Turnover is the ratio of trading volume divided by the quantity outstanding, not including the quantity held by the Central Bank. It is calculated daily for each bond, then averaged across bonds of a given type within a month, and annualized by multiplying by 252. The sample period is July 2006 to October 2023.

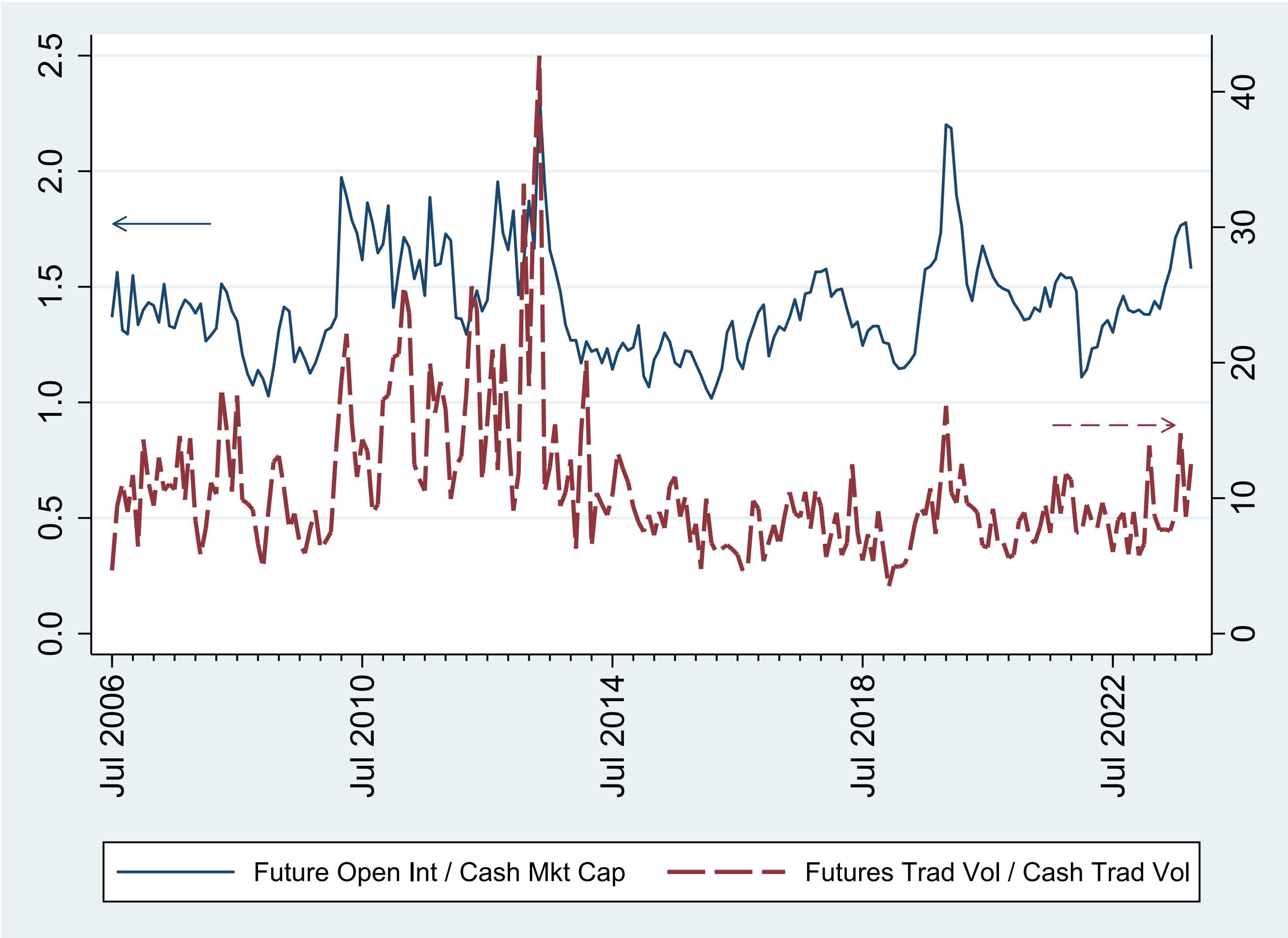


Figure A.6: **Brazil's DI1 interest-rate futures contracts versus Brazil's fixed-rate debt.** The figure compares the size and liquidity of Brazil's DI1 interest-rate futures contracts to the cash market of fixed-rate government bonds. The solid blue line is the ratio of the value of open interest in DI1 futures, adding across all contracts at the end of each month, divided by the value of all outstanding fixed-rate government bonds. Values are on the vertical axis on the left. The dashed red line is the ratio of the total monthly trading volume in DI1 contracts divided by the total monthly trading volume in fixed-rate government bonds. Values are on the vertical axis on the right. The sample period is July 2006 to October 2023.

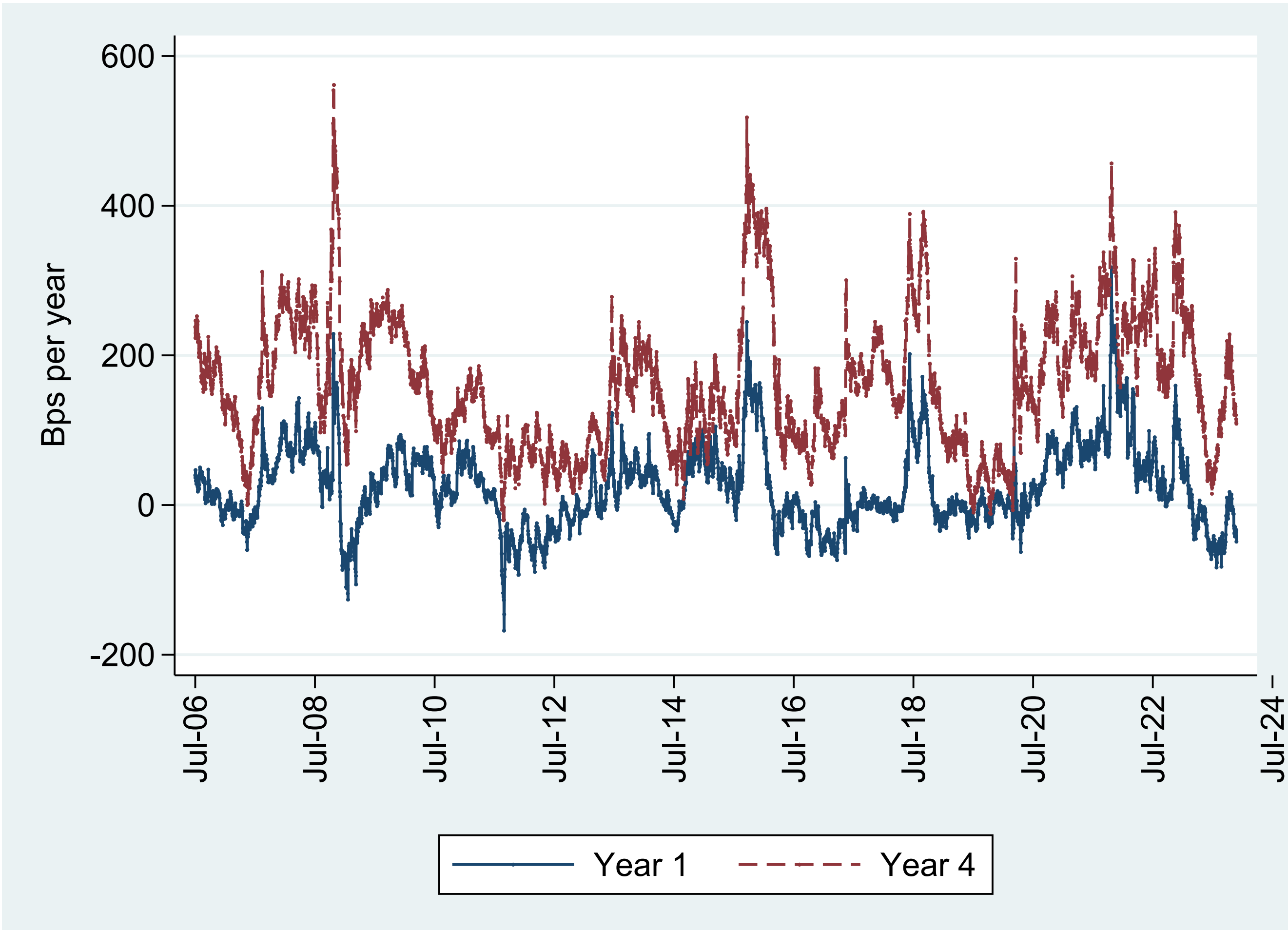
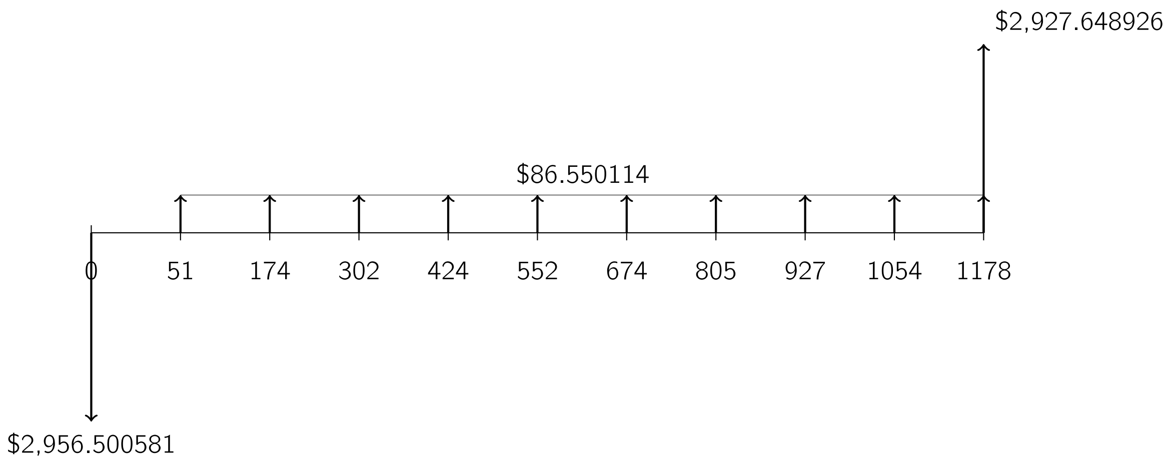


Figure A.7: **Term premia in the nominal term structure of Brazilian interest rates.**
The figure plots term premia in the nominal term structure of Brazilian interest rates for two tenors, one and four years. Term premia are calculated from prices of DI1 futures contracts and Central Bank surveys of expectations about the future SELIC monetary policy rate. The sample period is July 2006 to October 2023.

C Intermediation cost detailed computation

This Appendix provides an example to illustrate the computation of differences between auction and secondary market prices, using an inflation-indexed bond auction as a case study. The approach for calculating differences for other non-floating-rate bond types is similar but more straightforward, given the fixed nature of par values and coupon payments.

On August 30, 2016, the National Treasury auctioned two million units of an inflation-indexed bond maturing on May 15, 2021, with settlement occurring the following day. The total bonds sold amounted to $1,546,550$, each at a unit price of \$2,956.500581. On the settlement day, ANBIMA's updated par value of inflation-indexed bonds was \$2,927.648926. The semi-annual coupon payments are determined as $\sqrt{(1+6\%)}-1$ of the par value, equating to \$86.550114. Brazilian fixed income markets operate on a business rather than calendar day count, with inflation-indexed bonds' coupon payments taking place on the first business day after May 15 and November 15 each year until maturity. The figure below illustrates the bond cash flows, with time measured in business days from the settlement date.



The annualized yield-to-maturity y_a at the auction solves the equation below:

$$\begin{aligned}
2956.500581 = 86.550114 \Big(& (1+y_a)^{-\frac{51}{252}} + (1+y_a)^{-\frac{174}{252}} + (1+y_a)^{-\frac{302}{252}} + (1+y_a)^{-\frac{424}{252}} \\
& + (1+y_a)^{-\frac{552}{252}} + (1+y_a)^{-\frac{674}{252}} + (1+y_a)^{-\frac{805}{252}} + (1+y_a)^{-\frac{927}{252}} + (1+y_a)^{-\frac{1054}{252}} \Big) \\
& + (2927.648926 + 86.550114)(1+y_a)^{-\frac{1178}{252}}.
\end{aligned}$$

The solution is $y_a = 6.233293\%$ per year. Using y_a we find that the bond's Macaulay duration at the auction is $D_a = 4.0759$ years.

Four business days after the auction, on September 5, 2016, the volume-weighted average secondary market price of the bond was \$2,980.812609, ANBIMA's updated par value was \$2,929.362305, and updated coupon payments were \$86.600767. The annualized yield-to-maturity $y_{t+4} = 6.053537\%$ solves the equation below.

$$\begin{aligned}
2980.812609 = 86.600767 \Big(& (1+y_{t+4})^{-\frac{48}{252}} + (1+y_{t+4})^{-\frac{171}{252}} + (1+y_{t+4})^{-\frac{299}{252}} + (1+y_{t+4})^{-\frac{421}{252}} \\
& + (1+y_{t+4})^{-\frac{549}{252}} + (1+y_{t+4})^{-\frac{671}{252}} + (1+y_{t+4})^{-\frac{802}{252}} + (1+y_{t+4})^{-\frac{924}{252}} + (1+y_{t+4})^{-\frac{1051}{252}} \Big) \\
& + (2929.362305 + 86.600767)(1+y_{t+4})^{-\frac{1175}{252}}.
\end{aligned}$$

We use the bond's modified duration at the auction and a first-order approximation to compute the percent difference between secondary market and auction prices. The Intermediation Cost four trading days after the auction is the percent difference between the secondary market price four days after the auction and the auction price, after stripping out the effect of the time value of money. In this example, it amounts to 69 bps:

$$\begin{aligned}
\frac{\Delta P}{P} &\approx -\frac{D}{1+y_a} \cdot (y_{T+4} - y_a) \\
&\approx -\frac{4.0759}{1+0.06233293} \cdot (0.06053537 - 0.06233293) \\
&\approx 0.0069.
\end{aligned}$$

The average intermediation costs for different trading day horizons and different sources of secondary market prices are plotted in Figures 1 and 4, and tabulated in Table 2.

D Midquotes versus transaction prices

Figures 1 and 5 use different sources for secondary market pricing data. Figure 1 relies on volume-weighted average transaction prices (VWAP) from the Central Bank, while Figure 5 uses end-of-day dealer midquotes from ANBIMA. Although the auction cycle phenomenon is evident in both figures, there is one notable difference. In Figure 5, the lowest point of the cycle occurs on the auction day, consistent with Lou et al. (2013), whereas in Figure 1, it occurs the day after the auction. In this Appendix, we propose a conjecture to explain this difference.

We begin by computing the spread between the midquote and the VWAP for all non-floating-rate bonds with at least one month to maturity. There are $117,226$ bond-days from July 2006 to October 2023, with data available for both midquotes and VWAP. On average, midquotes and VWAP are statistically equal across the sample. The mean spread, calculated as midquote minus VWAP, is a negligible -0.025 basis points (t-stat=-0.16).

To investigate further, we regress the daily spread (midquote minus VWAP) on nine dummy variables representing trading days around an auction, similar to the approach in Table 3. These dummies are set to one only for bonds being auctioned. The regression includes time fixed effects, meaning that each bond's spread is compared to the average spread across all bonds on the same day, including non-auctioned bonds. Separate dummies are also included for long-duration bonds. The results are presented in Table A.1.

Table A.1 [about here]

Table A.1 reveals that that midquote yields increase *relative to* VWAP yields as the auction approaches. The spread rises monotonically from 0.68 four days before the auction to 1.85 bps on auction day (t-stat=6.20). While Figures 1 and 5 show that both transaction and midquote prices drop ahead of the auction, Table A.1 evidences that the decline is steeper for midquotes. As a result, midquote prices reach their lowest relative point compared to VWAP on auction day.

Interestingly, the midquote-VWAP spread suddenly dissipates after the auction. It drops sharply from 1.85 bps on auction day to 0.16 bps one day later and -0.16 bps two days after the auction. The reversal occurs because VWAP experiences a sudden drop in absolute terms, erasing the gap between midquote and VWAP that had built up gradually over the preceding four days.

One potential explanation for this sudden reversal is that dealers strategically manage their end-of-day midquote submissions to ANBIMA to influence both primary and secondary markets. Recall that primary dealers are also secondary market dealers providing quotes to ANBIMA. At auctions, when dealers purchase bonds from the Brazilian Treasury, midquotes are at their highest point relative to VWAP – i.e., bond prices are at their lowest. This disparity is reflected in Table 2 and Figures 1 and 5: while the same-day intermediation cost is 8.19 bps using VWAP, it is -1.51 bps using end-of-day midquotes. If same-day midquotes were used as the benchmark for evaluating the intermediation cost of Brazilian debt, one might conclude that the cost is negligible.

While primary dealers are buying from the Treasury on auction day, they are net sellers to end investors in the two days following the auction. Dealers aim to sell at the highest possible price. This incentive could explain the rapid disappearance of the midquote-VWAP spread, as midquote prices revert to their unconditional state of being statistically equal to VWAP.

	D - 4	D - 3	D - 2	D - 1	Auction day	D +1	D + 2	D + 3	D + 4	Fixed coupon dummy	Inflation-indexed dummy	Intercept	Time fixed effects	# clusters	# day-bonds
Yield spread: midquote minus transaction price	0.68 **	0.72 **	1.11 ***	1.29 ***	1.85 ***	0.16	-0.16	0.25	0.38	0.29	0.48 **	-0.564 ***	Y	4,353	117,226
	(2.45)	(2.57)	(3.61)	(4.41)	(6.20)	(0.53)	(-0.53)	(0.74)	(1.34)	(1.00)	(2.22)	(-3.98)			

Table A.1 : **Difference between midquotes and VWAP around auctions**
The table has results of running a regression of the difference between yields from end-of-day midquotes and yields from volume-weighted average transaction prices. We regress daily differences onto dummy variables for distances to an auction of the same bond. The regression has daily fixed effects and bond-type fixed effects. The sample includes all non-floating-interest rate bonds except those maturing in less than one month. T-statistics based on standard errors clustered by day are displayed. We test the null hypothesis that the sum of the dummy variables up to and including the auction day has the same magnitude as the sum of the dummy variables after the auction. The sample is from July 2006 to October 2023.

E Auction failures

This appendix describes events surrounding failures of *ordinary* auctions – cases where the Brazilian Treasury cancels a regularly scheduled auction before receiving any bids or chooses not to sell any bonds after receiving bids. There were 272 failed auctions from July 2006 to October 2023, compared to $6,621$ non-failed *ordinary* auctions, resulting in a failure rate of 4.0%. Importantly, our analysis indicates that primary dealers' losses around failed auctions are very unlikely to offset their gains from non-failed auctions.

Results from an (untabulated) logit regression show that a sudden increase in term premia during the week before an auction is the strongest predictor of auction failures. Figure A.9 illustrates this pattern, showing the first principal component (PC) of term premia before and after auctions, separately for failed and non-failed auctions. Note that the first PC is standardized to have a mean of zero and unit variance over the time series.

Figure A.9 [about here]

Figure A.9 reveals that term premia is, on average, 0.2 standard deviations above the mean ten trading days before failed auctions. This value is statistically significant at the 95% confidence level, with standard errors clustered by auction day. Notably, term premia continue to rise significantly in the week before the failed auction, increasing from 0.20 to 0.46 standard deviations above the mean. In contrast, for non-failed auctions, term premia remains at its mean level both before and after the auction.

Table A.2 examines the behavior of yield-to-maturity (YTM) around failed auctions, mirroring the analysis in Table 3 of the main text. The dependent variable is the daily change in YTM, based on end-of-day dealer midquotes and expressed in basis points. The sample includes all outstanding non-floating-rate Brazilian Treasury bonds with at least one month to maturity. Regressors include nine dummies marking the date relative to the auction, with fixed effects for bond type and trading day.

Table A.2 [about here]

Table A.2 reveals a modified auction cycle around failed auctions. On average, yields for bonds to be auctioned increase significantly during the two trading days before the auction, with a total increase of 5.30 bps (adding D-2 and D-1). This is larger than the increase documented in Table 3 for non-failed auctions. On the auction day, yields decrease by 1.11 bps, which is the opposite of the yield increase

(0.77 bps) observed during non-failed auctions (Table 3). In the four days following the failed auction, yields continue to decrease, similar to the pattern observed for non-failed auctions.

Thus, while the auction cycle is stronger around failed auctions, bond prices begin to rebound one day earlier compared to non-failed auctions. Overall, the cumulative effect of the auction on bond prices cannot be statistically distinguished from zero.

Figure A.10 is analogous to Figure 6 but restricted to the subsample of failed auctions of fixed-rate coupon bonds. The conclusions are similar to those drawn from comparing Table A.2 to Table 3.

Figure A.10 [about here]

Figure A.10 shows that the auction cycle around failed auctions is larger in magnitude, with interest-rate futures prices declining by 50 basis points, compared to 20 basis points in the full sample. However, the lowest prices no longer occur during auction bidding time; instead, prices begin rebounding before the bidding period.

The evidence from Table A.2, Figure A.9, and Figure A.10 is inconsistent with the view that primary dealers suffer significant losses during failed auctions. If the auction cycle reflects dealers spreading inventory risk management over time, these dealers are likely selling bonds ahead of the auction. When the auction is canceled, they repurchase the bonds in the secondary market. Net effects are neutral: while dealers do not incur significant losses, they forgo the average profits realized around non-failed auctions.

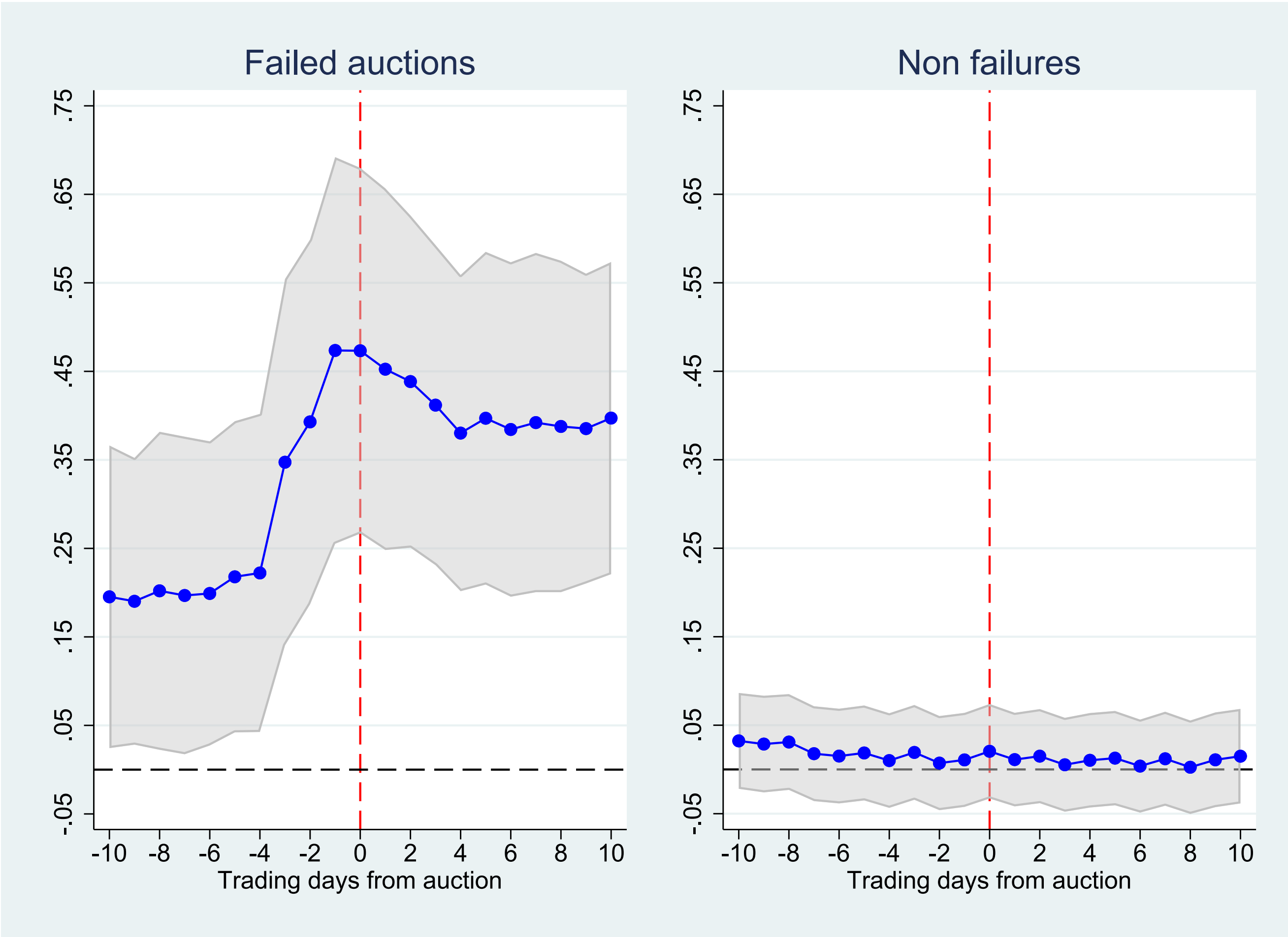


Figure A.8: **Term premia around auctions**
The figure plots the first principal component of risk premia in the Brazilian nominal term structure of interest rates around Brazilian Treasury auctions. The first principal component is standardized to zero mean and unit variance in the time series. The figure separately shows averages across 272 failed ordinary auctions and $6,621$ non-failed auctions. The sample is from July 2006 to October 2023, as a fraction of GDP. 95% confidence intervals based on standard errors clustered by auction day are displayed.

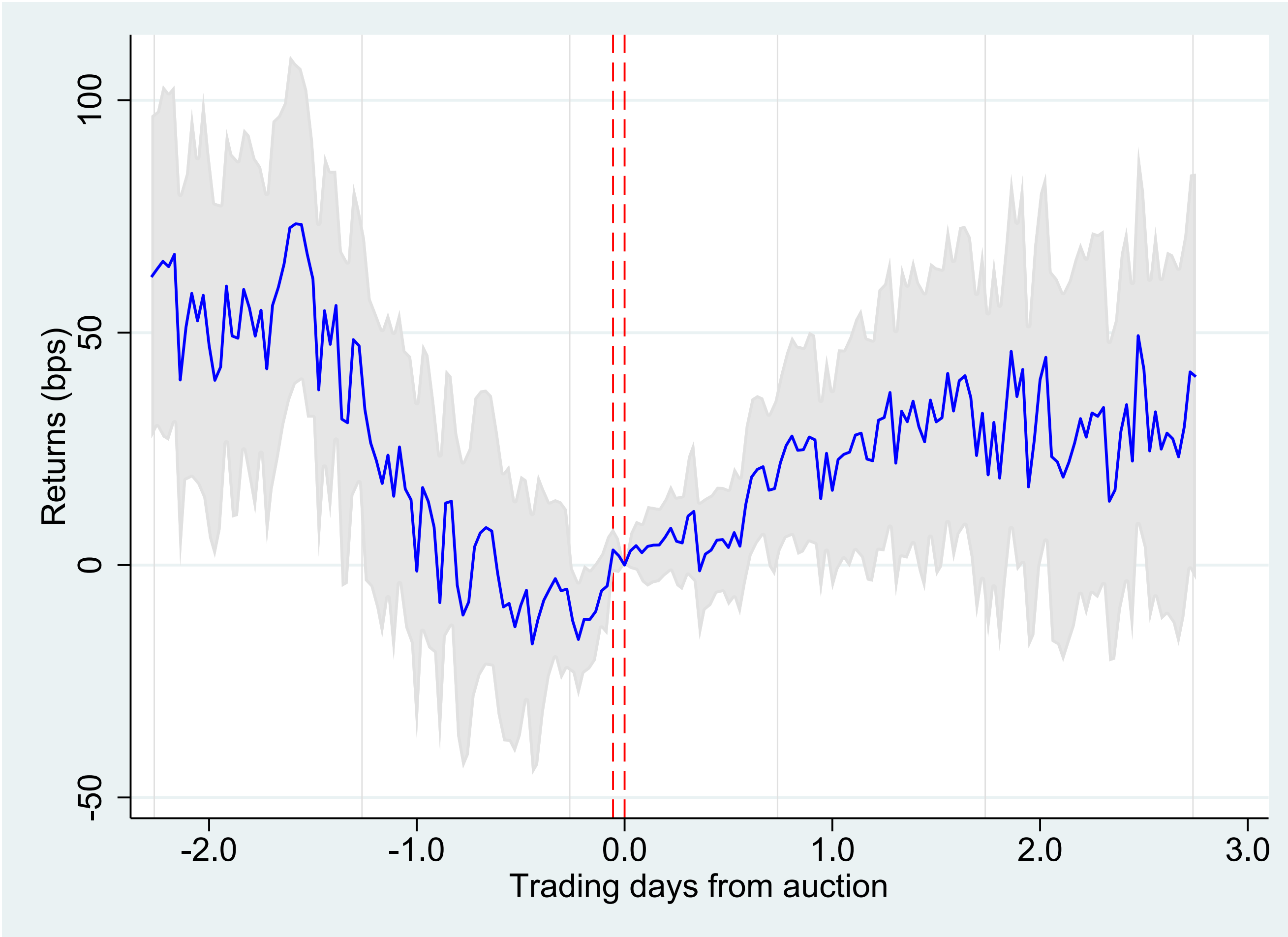


Figure A.9: **The interest-rate futures auction cycle around failed auctions**
The figure shows 15-minute price fluctuations in interest rate futures contracts around failed auctions of Brazilian Treasury auctions of fixed-rate coupon bonds. The sample of failed auctions is a subsample of total auctions used in Figure 6. The contract is the DI1 futures contract whose maturity matches the maturity of the bond being auctioned. The vertical dashed lines mark the beginning and the end of the auction bidding period. Price differentials are calculated as the differences between the (last) midquote yield in the corresponding 15-minute interval and the (last) midquote yield in the 15 minutes immediately before the end of the bidding period, multiplied by the contract's duration. The sample period is July 2006 to October 2023 and includes 73 auction days. 95% confidence intervals are displayed.

	D - 4	D - 3	D - 2	D - 1	Auction day	D +1	D + 2	D + 3	D + 4	Fixed coupon dummy	Inflation-indexed dummy	Intercept	Time fixed effects	# clusters	# day-bonds
Daily midquote yield change	-0.46	0.85	1.36 **	3.94 ***	-1.11	-1.28	1.11	-1.27	-1.54	0.05	0.15 *	-0.22 ***	Y	4,353	127,189
	(-0.64)	(1.47)	(2.23)	(3.02)	(-1.25)	(-1.56)	(1.56)	(-1.55)	(-1.51)	(0.62)	(1.77)	(-4.34)			

H_0: $D_{-4} + D_{-3} + D_{-2} + D_{-1} + \text{Auction Day} + D_{+1} + D_{+2} + D_{+3} + D_{+4} = 0$

$F(1, 4352) = 0.54$ Prob > F = 0.46

Table A.2 : **Daily midquote yield changes around failed auctions**
The table has the results of running a regression of daily changes in yield midquotes onto dummy variables for distances to a failed auction of the same bond. The regression has daily fixed effects and bond-type fixed effects. The sample includes all non-floating-interest rate bonds except those maturing in less than one month. T-statistics based on standard errors clustered by day are displayed. We test the null hypothesis that the sum of the dummy variables up to and including the auction day has the same magnitude as the sum of the dummy variables after the auction. The sample is from July 2006 to October 2023.