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Central bank asset purchases: Insights from quantitative easing auctions of government bonds[1]

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Abstract

How willing are individual primary dealers to alter their offered yields in central bank quantitative easing auctions of government bonds in order to sell an additional share of the outstanding amount of a bond to the central bank? This question is of great importance for a central bank's potential to affect yields during quantitative easing purchase operations and the one I address in this paper. In order to do so I study a unique, and confidential, dataset consisting of all pairs of offered yields and quantities from individual dealers participating in the Riksbank's (central bank of Sweden) quantitative easing auctions from 2015 to 2021. I find, on average, that an offer by individual dealers to sell an additional one percent of the outstanding amount of a bond is associated with between 0.6 to 7.5 basis points lower yields. However, offers depend in a non-linear way on offered amounts. Offers are less elastic (steeper) for offered quantities below 10 per cent and above 20 per cent of outstanding amounts of bonds. The finding of a non-linear slope is new in the literature and is only possible to uncover with access to the whole distribution and significant size of the offered amounts at each auction. Moreover, I find that marginal yields (yields where supply equals demand) at the auctions are highly, and persistently, correlated with changes in market yields for an extended period after the auction suggesting that purchase operations have a more persistent impact on market yields than what has previously been found.

JEL-codes: D44, E52, E58, E63.
Keywords: Monetary Policy, Asset Purchases, Quantitative Easing, Sovereign Yields, Asset Purchase Auctions.

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1. Introduction

In a typical supply estimation setting a researcher observes one point on the supply curve at any point in time, that is, the equilibrium price and quantity. Hence one typically needs to utilize exogenous variation in prices that is attributable to shifts in demand in order to link the observed points together to be able to estimate the supply curve. Finding this exogenous variation and establishing causality among movements in macroeconomic variables and asset prices can in practice be very difficult.

This difficulty naturally also applies to the evaluation and estimation of the effects of the asset purchase programs adopted by several major central banks in the aftermath of the financial, economic and health crisis. When it comes to announcement, or stock, effects of asset purchase programmes, the event study literature addresses this challenge by exploiting the lumpy manner in which central bank news are released to the public. Analyzing the effects of central bank ongoing asset purchases, or flow effects, is more challenging due to the often in-built endogenous nature and set-up of central bank purchase operations. Yields may react to asset purchase flows, but flows may also react to yields if the central bank bases purchase decisions on yield movements and yield constellations. Consequently, only a few papers have been able to directly address this challenge. This is mainly due to the challenge of identifying exogenous variation in central bank demand of government bonds.[3]

In this paper I follow a different strategy. Instead of identifying exogenous variation in central bank demand, I study offer schedules in asset purchase auctions while holding demand fixed. To do so I use a unique confidential transaction-level data set on all submitted, and binding, supply/offer schedules, i.e. all pairs of yield and quantity, from individual dealers participating in the Riksbank's (Swedish central bank) asset purchase auctions from 2015 to 2021 to estimate the local supply curve of government bonds by individual dealers and the closely related question of the flow effects of the Riksbank's asset purchase programme. I use the terms "flow effects" and "local supply of government bonds by individual dealers" to describe the security-level association between offered prices/yields and volumes on days when asset purchase transactions (through auctions) are conducted.[4]

[3] De Santis and Holm-Hadulla (2020) and Arrata et al. (2020) take advantage of the legal and technical rules that the Eurosystem imposes on the public sector purchase programme (PSPP) as an instrument to identify exogenous variation in purchase volumes.

[4] My definition of local supply effects of purchases is consistent with similar papers in the literature such as Joyce and Tong (2012), D'Amico and King (2013) and Kandrac and Schlusche (2013). As noted by e.g. Kandrac and Schlusche (2013), the term flow effect may alternatively be used to refer to an overall and persistent shift in market conditions that may occur during the central bank's intervention in securities markets, but, unlike a stock effect, such a flow effect ceases when the purchases or sales end.

The slope of the supply curve of dealers during the auctions is informative for my basic question namely how much dealers are willing to alter their offered yields/prices to sell an additional amount of an individual bond to the Riksbank or, in other words, how potentially effective the large scale asset purchases are in affecting yields. Hence, understanding the slope of the supply curve of individual dealers is of fundamental importance for the understanding of the effectiveness of the asset purchase programme. I am estimating the supply of bonds from the perspective of auction participants. The association between offered prices/yields and volumes can also be seen from the investor's perspective, that is how much they value, and demand, the relative liquidity and safety of government bonds. Hence, the question I address is also related to the literature which estimates the aggregate demand for treasury debt and the substitutability between treasury bonds and bank deposits. See for example Krishnamurthy and Vissing-Jorgensen (2011, 2012) and Krishnamurthy and Li (2022).

To estimate the supply curve I need to control for both demand and supply factors that determine the purchases. What is unique in the Swedish case is that the Riksbank does not announce an *eligible set* of bonds to purchase. Instead it announces exactly which bonds it will purchase and how much of each bond it intends to purchase at a specific auction. Other central banks, like Federal Reserve, identifies the set of eligible bonds for purchase and then, at the auction day, they endogenously select which bonds and what amounts to purchase. This is quite evident, for instance, from the NY Fed's description of the details of the Treasury Large-Scale Asset Purchase Program: "In determining which offers to accept, the Fed compared each offer with the current secondary market prices of similar securities, as well as with its own assessment of the fair value of those securities, and took only those offers that appeared attractive. This procedure worked to ensure that the Fed received the best available prices for the securities it purchased".[5] Song and Zhu (2018) find that bond cheapness is a significant predictor of the Fed's purchase quantity. Hence, demand is affected by market, and supply, conditions. In the Swedish case, demand for assets is set, well known and telegraphed ahead of the auction. Furthermore, I use data on all offers by auction participants (both rejected and accepted). These bids are large and often account for more than 20 percent of outstanding amounts of individual bonds. This has several advantages compared with the related literature on flow effects of large scale asset purchases. First, this data allows me to control for dealers' supply using information from the

[5] Bank of England explains their procedure as follows: "We rank the offers according to the attractiveness of the yield for us relative to the market yield of each gilt at the end of the auction. We keep doing this until we have reached the amount we wish or sell". ECB explains how national central banks allocate purchases as follows: "…significant efforts are undertaken to avoid buying securities that are scarce, as measured by metrics such as relative value indicators, pricing in the repo market and trading volumes".

complete supply curve. Hence, the auction format and associated data lends itself very nicely to the focus of the analysis namely local supply of government bonds from individual dealers and flow effects of actual purchase operations. Second, the large volumes implies that I am able to analyze flow effects also for substantial offered amounts. I am in other words not limited to study flow effects around the comparably smaller central bank demand at each auction. This makes it possible to more properly, than what has previously been possible, compare estimates of comparably large flow and announcement effects.

While a substantial body of research has examined the stock effects of purchase programs, the existing literature on flow effects is much scarcer and has not utilized auction data to address the identification problem that arises in this context.[6] Moreover, the presence of economically relevant flow effects, beyond the anticipation and announcement effects at the onset of a program, would add to the debate on whether anticipated events are fully priced-in by financial markets.

To my knowledge, the only two existing papers to use offer-level data from central bank's asset purchase programmes are Song and Zhu (2014) and Boneva et al (2022). However, their papers focus on different questions. Song and Zhu empirically study the auction mechanism of the Fed's purchase of Treasury securities during quantitative easing (QE) and pay particular attention to the interaction between the Fed's preference and dealers' strategic behavior. Due to data constraints, the Song and Zhu study only uses data on accepted offers. Boneva et al. study the impact of corporate QE on liquidity. Joyce and Tong (2012) study the impact on gilt yields not just when announcements of future QE purchases are made but also when the auctions take place. However, they study the dynamics of market rates and not submitted offers in the auctions which I do. Hence, there do not seem to exist any exact antecedents of my approach in the literature.

All of my estimates, i.e. with and without auction, bonds and dealer fixed effects (and various combinations), and estimation with and without yields which accounts for possible strategic bidding behaviour, and estimates with and without non-linear terms and control variables, point to a statistically significantly negative slope of the supply curve of individual dealers. Effects are

[6] See Bhattarai and Neely (2022), Fabo et al. (2021), and BIS (2019) for surveys. For evidence on stock effects for the U.S. case, see Gagnon et al. (2011), Krishnamurthy and Vissing-Jorgensen (2011), D'Amico et al. (2012), D'Amico and King (2013) and Li and Wei (2013); for the UK, see Joyce et al. (2011), Joyce and Tong (2012), Meaning and Zhu (2011), Breedon, Chadha, and Waters (2012), Christensen and Rudebusch (2012) and McLaren, Banerjee, and Latto (2014); for the euro area, see Altavilla, Carboni, and Motto (2021), Andrade et al. (2016), De Santis (2020), and Blattner and Joyce (2020). For evidence on flow effects, see D'Amico and King (2013) and Kandrac and Schlusche (2013) for recent programs of the U.S. Federal Reserve, and Joyce and Tong (2012) for the United Kingdom; Andrade et al. (2016) and De Santis and Holm-Hadulla (2020) for the euro area; Schlepper et al. (2020) for Germany; and Arrata and Nguyen (2017) for France.

interestingly larger for index-linked bonds which is quite natural but a new result in the literature. This is intuitive since the outstanding stock and liquidity of index-linked bonds is much smaller than that of nominal government bonds. Furthermore, I find that the supply curve is significantly non-linear. My estimates point to a flow effect on yields – for the most common amount demanded by the Riksbank – is in the range of 0.5 to 7.5 basis points. Hence, dealers are willing to sell one additional percent of the outstanding amount of a bond to the Riksbank for a 0.5 to 7.5 basis point lower yield. Offered yields are flat over a range of offered volumes but is quite noticeably steeper for offered volumes above 20 per cent of the outstanding amounts. Local supply for these higher offered volumes are as high as 10-15 basis points. These estimates are robust and hold in all of my specifications. The non-linear slope for larger volumes is not something that has previously been found in the literature. Finally, I show that marginal yields at the auctions are highly correlated with changes in market yields for more than a week after the auction suggesting that purchase operations have a more persistent impact on market yields than what has previously been found in the literature.

The remainder of the paper is structured as follows. Section 2 provides the institutional background of asset purchases and the asset purchase auctions. Section 3 describes implications of auction theory for asset purchase auctions. Section 4 presents the empirical strategy. Section 5 presents the results. To set my local supply estimates in perspective I compute announcement, or stock effects, of asset purchases in section 6. Section 7 concludes.

2. Institutional background of asset purchases and the asset purchase auctions

Auctions of financial securities are often used to finance national and local government debt as well as to implement asset purchases by central banks around the world. Most of these auctions utilize a multi-unit auction format, following one of two main mechanisms: the discriminatory auction mechanism, also known as the "pay-as-bid" auction, and the uniform price auction. In both formats, bidders submit a vector of price-quantity pairs as their bids, defining bid functions. The seller computes the sum of the bid functions, and calculates the market clearing price. In the discriminatory/pay-as-bid auction, bidders pay the price they bid for their infra-marginal units. In the uniform price auction, bidders pay the market clearing price for their infra-marginal units. I will use the terminology from the common auction type where assets are being sold when discussing auctions theory but will adapt the terminology to reverse auctions where assets are being purchased when discussing the specifics of the asset purchase auctions I study in this paper.

From February 26, 2015 to June 11, 2021, the Riksbank conducted a series of 478 purchase auctions of Swedish nominal government bonds and a series of 144 auctions of index-linked government bonds (starting in June 2016). The characteristics of the purchased securities are summarized in Tables 1 and 2 and Figures 1 and 2. Overall, purchases of nominal bonds included 14 unique ISINs, spanning remaining maturities of about 0.7 to 24.9 years. Purchases of index-linked bonds included 9 unique ISINs, spanning remaining maturities of about 1.5 to 15.3 years. The total purchased amounts were 455.1 and 54.1 billion SEK for nominal and indexed-linked bonds respectively. This amounted to 50.8 and 23.3 percent of the outstanding bonds (up to almost 67 per cent for individual nominal bonds). The SEK-weighted years to maturity over the period February 2015 to December 2019 were roughly similar to the averages of all outstanding government bonds (see Table 1).

The auctions cover three distinct periods. During the first period, from February 26, 2015 to March 5, 2017 the Riksbank purchased government bonds, including nominal government bonds and inflation protected (index linked) bonds. The second period is characterized by somewhat more passive asset purchase activity mostly directed at reinvestment of coupons and matured bonds. The third period began in March, 2020 when the Riksbank implemented a number of measures to alleviate the economic effects of the COVID-19 pandemic.

During the first period asset purchases were seen as needed in order to reduce general interest rates in the economy to support the upturn in underlying inflation and to ensure that long-term inflation expectations were in line with the inflation target (Sveriges Riksbank 2015a). In February 2015 the Riksbank announced that it would purchase government bonds for an amount of 10 billion SEK. In March, April and July 2015 further announcements of purchases of government bonds were made for a total of 125 billion SEK. In October 2015, the Riksbank announced that it would increase purchases of government bonds by 65 billion SEK and that the planned total purchased volume would amount to 200 billion SEK by the middle of 2016, which was about 30 percent of the then outstanding stock of Swedish government bonds and approximately 5 percent in terms of GDP. In April 2016, the Riksbank added 45 billion SEK to its purchases of both nominal and inflation-linked bonds. In December 2016, the Riksbank decided to continue purchasing both nominal and inflation-linked bonds by an additional 30 billion SEK, bringing the total to 275 billion SEK. In April 2017, the total amount increased to 290 billion SEK.

During the second period, beginning in 2018, the Riksbank seized net purchases. Reinvestment purchases of coupons and matured bonds for about 60 billion SEK were conducted during 2018. The

reinvestments continued until the central bank announced at its monetary policy meeting in April 2019 that it would buy a further 45 billion SEK of government bonds. The total amount of government bonds held in February 2020, at the start of the pandemic crisis, was about 335 billion SEK.

The third distinctive period began in March, 2020 when the Riksbank implemented a number of measures to alleviate the economic effects of the COVID-19 pandemic. The securities bought by the Riksbank were broader this time and comprised government bonds, treasury bills, covered bonds (mortgage bonds), municipal bonds and corporate debt securities (commercial paper and corporate bonds). These purchases were according to the Riksbank done in order to contribute to low interest rates in the economy and facilitate access to credit, creating favourable conditions for the economy to recover and inflation to be close to the target of 2 per cent on a permanent basis. In March 2020 the Riksbank announced that it would purchase additional securities up to 300 billion SEK and in July and December 2020 it announced that it intended to purchase securities for an amount of up to SEK 500 billion and SEK 700 billion respectively, until 31 December 2021, in addition to the purchases planned prior to the pandemic.[7]

2.1 The asset purchase auction mechanism

The asset purchase auctions are designed as a series of sealed, multiple-offers, discriminatory price auctions. On the auction date, each dealer may submit multiple offers per security or ISIN. The minimum offer size and the minimum increment of offer size are both 50 million SEK. The sealed offers are submitted electronically between 09:00 and 10:00 on the auction day, and the awards are announced normally no later than 10 minutes after the last time for making an offer. Any number of offers may be submitted (and changed). Offers made are binding for the counterparty and may not be withdrawn or changed by the counterparty after the auction closes. Each awarded dealer receives what it offered, even if the cut-off price is higher. The offers are generally updated until the auction closes and the median difference between the transaction times when the offers were placed in each auction from 2015-2021 is around 90 seconds. Hence, new data releases and other types of information that might be announced during the auction is most likely incorporated into the offers. Figure A1 shows the distribution of the difference in minutes between the offers.

[7] On 30 June 2020, the Executive Board decided that, within its programme for bond purchases, the Riksbank would offer to purchase corporate bonds to a nominal amount of SEK 10 billion between 1 September 2020 and 30 June 2021. These auctions are not included in this study however.

All purchases were made through solicited offers from the central bank's monetary policy counterparties, as well as the Debt Management Office (DMO)'s primary dealers via auctions.[8] The Riksbank purchased only one type of government bond on a specific date, which means that it never purchased nominal bonds and inflation-linked bonds on the same day. Moreover, bonds of the same type were never bought on two different dates during the same week. The minimum (maximum) amount that the Riksbank purchased at a particular auction was 0.7 (9.9) percent of the outstanding stock. For index-linked bonds the corresponding numbers are 0.4 (7.9) percent. A summary of Riksbank's purchases is presented in Table 2 and Figure 2.

One week ahead of each auction the Riksbank announces which two bonds it will purchase, the maximum tendered volume and the minimum and maximum volumes that could be offered, together with details about day and time of the auction procedure. In contrast to the QE auctions the Federal Reserve conducted (e.g. between 2010 and 2011) each auction does not involve a set of securities. The Riksbank does not need to rank offers on different ISINs against each other. The goal is to fill the desired total announced purchase amount. Hence, the Riksbank does not announce a wide set of eligible bonds from which it endogenously picks the bonds it wants to purchase based on pricing errors as for example is done by the Federal Reserve. To evaluate dealers' offers across multiple bonds, the Fed relies on its internal yield curve model, fitted to secondary market bond prices (Potter 2013, Song and Zhu 2018). Subsequently, after each auction and on the same day of the auction it also makes public the volume offered and bought, the number of bids offered and accepted, the average yield, the lowest accepted yield, the highest yield and per cent accepted at lowest yield.

3. Implications of auction theory for asset purchase auctions

Optimal behavior in any auction mechanism can typically be described through an equation expressing the equilibrium bid approximately as willingness-to-pay, or offer, (W) minus a shading factor (S):

$$BID = W - S.^{9}$$

The strategic issues dealers face in the auction, which are a function of the rules of the mechanism and of the environment, make it more challenging for the econometrician to go from the observed

[8]There are 24 permanent monetary policy counterparties. On 26 March 2020, the Riksbank decided to grant Swedish credit institutions under the supervision of Finansinspektionen the opportunity to become temporary monetary policy counterparties to the Riksbank.
[9] See e.g. Kastl (2020).

data (bids/offers) to the willingness to pay (values). Hence, the difference in bids/offers over time may arise from two separate factors: differential ability to exercise market power, i.e., bid shading (offer markup in case of a procurement auction), versus differential willingness-to-pay the security in question.

The ability of bidders to "shade" their bids (or mark-up offers in the case of reverse auctions) depends on the elasticity of the residual supply curve they are facing.[10] If the bidder would be small among many others, the residual supply the bidder would be facing would in effect be flat, allowing for very little ability to bid-shade, as decreasing the quantity demanded would not result in any appreciable change in the market clearing price. The optimal bid then is to bid one's true demand curve. Therefore, the key to identify variation of W in the data is the (expected) shape of the residual supply curves that a dealer may face around the point where they intersect this dealer's bid. For example, if all bids were identical, no bidder would be able to affect the market clearing price individually and hence everyone would be bidding their values. The more heterogeneity in submitted bids and the lower the elasticity of the expected residual supply, the larger the bid shading component.[11]

In contrast to the empirical auction pricing literature which is mainly focused on comparing the efficiency of auction formats, strategic bidder behavior and the level of W and S per se, I am studying the slope of local supply by individual dealers. This question is empirically less demanding under the assumption that the incentive to shade bids does not increase in quantity. In this case shading can be treated as unobserved heterogeneity, or as a fixed effects, that shifts the offer schedules and the local supply curve but does not alter its slope. Hence, in my empirical analysis I allow bids to be shaded but assume that the incentive to shade bids does not increase in quantity. Furthermore, I allow incentives the possibility to change from auction to auction and in effect be time-varying. These assumption seem reasonable since an offer for an additional unit in a pay-as-bid auction has no effect on the price that is received for earlier units (Ausubel et al. 2014). Hence, it is possible for bidders with similar marginal valuations at different quantities to be shading their bids by similar amounts. These assumptions are overall consistent with empirical results reported by Nyborg et al. (2002) who

[10] Hortaçsu et al. (2018) and Hortaçsu, and McAdams. (2018).
[11] Hortacsu, Kastl and Zhang (2018) study US Treasury bill auction data and assess the market power of primary dealers relative to direct and indirect bidders (indirect bidders need to route their bids through primary dealers). Because primary dealers possess more information on the residual supply they face than their opponents, they are in the position of extracting more surplus. Considering asymmetry among the three types of bidders, the authors' empirical results confim that primary dealers enjoy more market power by bidding higher yields. This asymmetry, however, introduces modest efficiency losses.

analyse Treasury auctions in Sweden and find that that their measure of bid-shading (discussed below) exhibit little sensitivity to volume. This suggests that that the aggregate demand function is highly elastic. Moreover, there is no guarantee that bidders will play the same equilibrium across otherwise identical auctions so incentives to shade may change from auction to auction. An alternative approach, which is beyond the scope of this paper, would be to make assumptions on the expected distributions of residual supply and use simulation based methods to estimate W. [12] Finally, it is worth noting that if bidders, contrary to my assumptions, have incentives to shade their bids for each unit differently the slope of the aggregate bid function would be steeper. Hence, the estimates of the slope of the bid function should in this case be seen as an upper bound on the slope of the supply curve. Hence, if the estimated slope of local supply would be very flat it cannot be the case that willingness to pay is very high since the shading factor does not work against values in the submitted offers.

In order to get a sense of the magnitude of the shading factor S I compute a simple measure of bid shading, suggested by Nyborg et al. (2002), as the discount, between the secondary market yield and the quantity-weighted average offer by a dealer. [13] For bidder i in auction j the Nyborg et al (2002) discount measure is defined as

$$\delta_{i,j} = R_j - r_{i,j}^w,$$

where $r_{i,j}^w$ is the quantity-weighted average bid by bidder i in auction j, and R_j is the secondary market price at the end of the day of auction j. If all of a bidder's bids turned out to be winning bids, the bidder would receive r per unit. The discount is a measure of how much a dealer's offers are shaded relative to the post auction price. The validity of this measure relies on the assumption that one can control for factors that may have changed between the end of the auction and the start of trade in the resale market, including the release of new information that might affect bidders' valuations of the security. To at least partially address this concern I additionally compute the discount based on the previous day's closing market yield (in the charts below I call this measure "pre" and the original measure "post"). Since the auctions take place in the morning of the auction day, few – at least domestic – factors should have changed between the end of the trade in the resale market and the start of the auction.

[12] Two types of approaches have been developed to estimate the equilibrium distribution of residual supply. In the first approach the econometrician assumes that bidder values are drawn from the same distribution and bidders play the same equilibrium in all auctions in the panel data set available. The second approach uses the empirical distribution of individual bids to "simulate" the distribution of residual supply from panel data.
[13] See also Simon (1994), Nyborg and Sundaresan (1996) and Malvey and Archibald (1998).

Figures 3-5 show the distribution of various definitions of the Nyborg et al. (2002) discount measure compared with the distribution of the change in yields (the day before the auction compared with the yield at the end of the auction day) as well as the distribution of (absolute value of) the bid-ask spread for nominal and index-linked bonds for all auctions 2015-2021. The mode spread is 1.63 basis points for nominal bonds and 2.92 basis points for index-linked bonds. The distribution is very similar to the change in yields but slightly shifted. This indicates that part of the distribution of offer discounts can be attributed to changes in the information-set during the day of the auction. The distribution of the discount measure based on the marginal, or market clearing, bid is lower and around 1 and 2 basis points. Figure 5 compares the discount measure with the absolute value of the bid-ask spread and reveal that the discount is significantly lower. These results are somewhat smaller compared with Nyborg et al. (2002) who studied bidder behavior in Swedish Treasury auctions. The average discount in the auction they study is 0.092 percent of face value, and their broad interpretation is that the observed bidder behavior is consistent with an adjustment for the presence of the winner'scurse (i.e. bid shading). Figure A3 in the appendix compares the distribution of offered and bid volume as a share of allocated amounts in the Riksbank reverse auctions and in the National Debt Office regular auctions between 2015-2021. A higher offered volume in the Riksbank reverse auctions would indicate a strategic increase in supply in order to increase the price. The amounts do not appear to be different compared with allocated amounts in the two auction formats during this period.

4. Empirical strategy

4.1 Baseline model

To estimate local supply of government bonds by individual dealers I consider the linear unobserved effects model for *T* auction periods:

$$r_{i,j,b,t} = \alpha + \beta_1 q_{i,j,b,t} + \boldsymbol{\theta X}_{i,j,t,b} + \lambda_j + \delta_t + u_{i,j,t,b}, \quad (1)$$

$$i = 1,\dots,I, \qquad j = 1,\dots,J, \qquad t = 1,\dots,T, \qquad b = 1,\dots,B,$$

where $r_{i,j,t,b}$ denotes the i^{th} offered yield (in basis points) by dealer j in auction t of bond b. $q_{i,j,t,b}$ denotes the corresponding cumulative offered volume (as a percent of the outstanding amount) and

$u_{i,j,t,b}$ is an error term.[14] β_1 is a parameter of primary interest and captures the association, or slope, of the supply/offer curve.

To control for possibly time-varying strategic bidder behavior and duration effects and other shifts to the overall term structure at an auction frequency, I use auction fixed effects (δ_t). Note that δ_t is bidder-invariant and it accounts for any time-specific effect that is not included in the regression on the auction day. For example, it could account for changes in supply of bonds by the National Debt Office e.g. via its repos in government securities for market maintenance purposes, changing market conditions or disruptions in international bond markets. Moreover, I include dealer specific fixed effects (λ_j) to control for the possibility of strategic, dealer effects. $\boldsymbol{\theta}$ is $K \times 1$ vector of coefficients and $\boldsymbol{X}_{i,j,t,b}$ is a matrix on K explanatory variables given by

$$\boldsymbol{\theta X}_{i,j,t,b} = \beta_2 q^2_{i,j,t,b} + \beta_3 q^3_{i,j,t,b} + \gamma_1 Q_{b,t} + \gamma_2 Q_{b,t} \times q_{i,j,b,t} +$$

$$\gamma_3 D_{b,t} + \varphi M_t + \mu_1 m_{b,t} + \mu_2 m^2_{b,t} + \rho \hat{r}_{b,t-1}.$$

where $q^2_{i,j,t,b}$ and $q^3_{i,j,t,b}$ denotes the squared and cubed values of the offered volume and are included to capture potential non-linear local supply effects. $D_{b,t}$ is the announced volume demanded by the Riksbank. The Move Index is included to capture the so called localization hypothesis of Vayanos and Vila (2021).[15] The MOVE Index, M_t, is a well-recognized measure of U.S. interest rate volatility that tracks the movement in U.S. Treasury yield volatility implied by current prices of one-month over-the-counter options on 2-year, 5-year, 10-year and 30-year Treasuries. $\hat{r}_{b,t-1}$ is the market yield on bond *b* at the end of the day prior to the auction *t* and $m_{b,t}$ is the remaining maturity in years.[16] Riksbank holdings of bond *b* at the time of auction *t* as a share of outstanding amounts is denoted $Q_{b,t}$ and, importantly, an interaction effect is included which allows for the effect of a unit change in the offered volume to depend on the Riksbank holdings of bonds per type of bond. Direct effects on purchased securities may derive from the presence of preferred-habitat investors who value specific security characteristics and are willing to bid up their prices in order to restore their portfolios in response to the local scarcity in the supply of such

[14] The offers are ordered in descending order with the offers with highest yields first. All offers are awarded the offered volume at the offered price until demand is met.
[15] As arbitrageur risk aversion increases, demand shocks become more important as additional sources of risk. Arbitrageurs try to reduce their exposure to these sources of risk, leading to less propagation from the location of the demand shock to other parts of the term structure. Arbitrageurs become less willing to integrate bond markets across maturities, and hence the response of the yield curve becomes more localized around the location of a given demand shock. When the index is included I drop a time fixed effect.
[16] I adjust the number of fixed-effects to allow inclusion of variables that do not vary within each auction.

securities induced by central bank purchases. I follow D'Amico and King (2013) and De Santis and Holm-Hadulla (2020) and use normalized central bank purchase variables (in percent of outstanding amounts). This is motivated by the assumption that the scarcity induced by a given SEK amount of purchases depends inversely on the total size of the respective market segment (see Joyce and Tong 2012, D'Amico and King 2013, and Kandrac and Schlusche 2013).

An additional way to control for strategic bidding behaviour is to purge offered yields with my measure of bid-shading, i.e. the Nyborg et al. (2002) measure. Hence, I construct an alternative measure of the form:

$$r_{i,j,b,t}^{Nyborg} = r_{i,j,b,t} - \delta_{i,j}.$$

5. Results

5.1 Baseline

All of my estimates, i.e. OLS without auction and dealer fixed effects, estimates with both auction and dealer fixed effects (and various combinations) and estimation with and without yields purged with Nyborg et al. (2002) bid-shading, and estimates with and without non-linear terms and control variables, point to statistically significant flow effects of Riksbank purchase operations on Swedish sovereign bond returns (Table 3-5). Effects are generally larger for index-linked bonds.

The baseline specification (Table 3, columns 7 and 8), indicates that individual dealers are on average willing to sell one per cent of the outstanding stock in the respective bond for a lower yield of that security of -0.57 (-1.37) basis points on the auction day for nominal (index-linked) bonds.[17] The estimated coefficients are significant at the 1% level. In the regressions in Table 3 I additionally examine whether the slope of the supply curve depends not just on the value of offered yields but also whether the effects are non-linear. This is indeed the case. All specifications indicates that supply effects are significantly non-linear. To give a sense of magnitudes, Figure 6 depicts the estimated regression functions (i.e. illustrates results shown in columns 7 and 8) for nominal and index-linked bonds, i.e. the offered yield in basis points as a function of offered volume from 0 to 30 per cent of the outstanding amount. The most notable non-linearity pertain to offers from 0 to 10 percent and then for offers above 20 per cent and even more markedly so for index-linked bonds. Offers are however in 85-90 per cent of the cases below 10 per cent as are allocated offers (see Figure 7 and

[17] For example from Table 1, column (7): $-0.593 \times 1 + 0.0262 \times 1^2 - 0.000409 \times 1^3 = -0.567$

Table 2) but quite a few offers are as large as 20 per cent. A closer study of dealers' bid functions reveal that the non-linear effects appear when aggregating bid functions with different elasticities. Most bid functions are distributed around a common yields but a few are less elastic. Aggregating these implies that the less elastic bid functions dominate both at the highest and the lowest yields which results in a non-linear aggregated market supply function.

5.2 Comparison to estimates without accounting for unobserved strategic incentives

Given the potential need to account for unobserved strategic incentives, columns 1-2 in Table 3 present results from a simple OLS estimation of equation (1) that does not account for strategic incentives. Columns 3-6 in Table 3 present results with various combinations of fixed effects (auction and dealer fixed effects) to account for possible strategic incentives.

Table 4 reports the estimated regression coefficients from equations (1) for nominal government bond and index-linked bond auctions on the full sample 2015-2021 with and without directly adjusting for bid-shading measured with the Nyborg et al. (2002) discount measure. The resulting predicted local supply curves for all of these combinations are presented in Figure 8 for nominal government bonds and in Figure 9 for index-linked government bonds.

The resultant local supply curve is flat also for higher offered amounts and approach zero for regressions where I do not account for unobserved heterogeneity through either fixed-effects or purging the offered yields. Accordingly, the comparison between the results is qualitatively consistent with my conjecture that failing to account for strategic incentives may lead to inconsistent estimates of flow effects. It is worth noting that the estimated supply curves does not become visibly steeper but that the difference mainly pertains to a shift in local supply.

5.3 Riksbank asset holdings and the slope of the supply curve of individual dealers

Turning to the question if Riksbank asset holdings affect local supply – possibly through scarcity effects – rows 4 and 5 show how offered yields are affected by the Riksbank's holdings of assets. The baseline results in columns (7) and (8) in Table 3 reveal no, or barely significant, estimates. Neither the level of asset holdings nor the interaction with offered volumes reveal any significant results for nominal bonds. Estimates for index-linked bonds are significant at the 10 per cent level and indicates that a higher holdings of index-linked bonds by the Riksbank is associated with a slightly steeper local supply curve.

5.4 Results over three distinct phases of asset purchases

As I described above, the auctions cover three distinct periods. In Table 5 I report the estimated regression coefficients from equations (1) for nominal government bond and index-linked auction for each separate sample: 2015-2017, 2018-2019 and 2020-2021. Figure 10 depicts the estimated regression functions for each sample period for nominal (panel a) and index-linked (panel b) bonds. The estimated coefficients do not change noticeably over the periods for nominal bonds but does so for index-linked bonds. This is evident from panel (b) in Figure 10. The local supply curve for index-linked bonds appears to have changed most notably during the second period 2018-2019 which was a period characterized by more passive asset purchase activity mostly directed at reinvestment of coupons and matured bonds. Hence, demand was lower during this period and offers were fewer (see Figure 12). Figure 13 shows the distribution of excess supply per distinct subsample where excess supply is measured as the sum of all offered volumes per auction less the amount purchased by the Riksbank as a share of the outstanding volume. Median excess supply during the 2018-2019 period was 2.31 per cent of outstanding amounts compared with 4.43 per cent during the full sample period. Hence, the supply curves were actually not that different for offered volumes that were most often offered during the sample periods. The median offered amount during each subsample (4.38, 2.31 and 5.13) were associated with -4.71, -3.76 and -2.33 basis points lower yields.

5.5 Risk aversion

The findings presented so far are consistent with the predictions of the Vayanos and Vila (2020) preferred habitat model. Following for example the analysis in De Santis and Holm-Hadulla (2020) I make further investigations into the mechanisms of the preferred habitat model. In particular, the model assigns a central role to the level of risk aversion as affecting arbitrageurs' capacity to transmit local price pressures to market segments. Specifically, it predicts a stronger (weaker) transmission of local supply shocks if risk aversion among financial intermediaries is low (high). This prediction is possible to test in my empirical framework. To this end, I have augmented the model with a term that allows the offered yield to differ with the prevailing risk perceptions among financial intermediaries. First, in all specifications I add the MOVE index as a bond market specific measure of risk. A significant negative coefficient on this term would support the hypothesis that increases in the perceived riskiness of the financial market environment lowers yield for a given offered yield. Second, and to further measure risk perceptions among financial intermediaries, I also resort to the

CISS index maintained by the European Central Bank.[18] The CISS synthesizes a several financial stress measures, such as the realized volatility and risk spreads in a broad set of financial market segments. Table 6 shows estimates where I have interacted the CISS index with the offered volume. Consistent with the Vayanos-Vila model, the results broadly confirm that an increase in volatility leads to a decline the offered yields – but differently so for nominal and index-linked government bonds. The slope of the supply curve is not affected by risk perception for nominal bonds but offered yields are lower. The opposite is found to be the case for index-linked bonds. The slope of the supply curve is steeper and mostly so for higher offered volumes for index-linked bonds when risk perception is high.[19] These results differ somewhat over the distinct phases of asset purchases. In the latter part of the sample i.e. from 2018 to 2021 the offered yield on index-linked bond are significantly negatively affected by an increase in risk aversion but the contrary holds for nominal government bonds.

5.6 The dynamic association between offered and market yields

To investigate potential dynamic effects I study the correlation between the marginal offered yields (i.e. the yield where demand is met by offered supply) in each auction and cumulative change in the yields during the week following the auction. To do so I estimate the following local projection model with bond and time fixed effects:

$$r_{b,t+h} - r_{b,t-1} = \alpha_h + \beta_h\left(r_{b,t}^{Marginal} - r_{b,t-1}\right) + \lambda_b + \delta_t + u_{b,t+h}, \qquad h = 0,..,7, \qquad (2)$$

where $r_{b,t+h}$ denotes the market yield at the end of day $t+h$ and $h=0$ is the market yield of bond b at the end of the auction day. $r_{b,t}^{Marginal}$ is the marginal offered yield of bond b at auction t. Hence, the first estimate is the intra-day projection of market yields on the marginal yield.

Figure 14 shows the estimated impulse response, estimated using Equation (2). The horizontal axis measures days after each auction, the vertical axis measures the percentage point change in market yields. The change in the marginal yield at the auction days are highly, and persistently, associated with the change in market yields several days after the auctions. Coefficients are notably larger and

[18] The results are also robust to the use of the MOVE and VIX indices. The CISS index puts relatively more weight on situations in which stress prevails in several market segments at the same time. The MOVE index is narrower and is constructed in a roughly similar way to the Chicago Board Options Exchange Volatility Index (VIX). It is a yield curve weighted index of the normalised implied volatility on 1-month Treasury options which are weighted on the 2, 5, 10, and 30 year contracts over the next 30 days. While the MOVE and the VIX tend to co-move, their correlation changes over time. Post-crisis, the two measures have occasionally diverged.

[19] Robustness checks indicate that using $CISS_{t-1}$ instead of $CISS_t$ does not alter the results.

more persistent than what has previously been reported in the literature. De Santis and Holm-Hadulla (2020) show that, after an initial positive price impact, the coefficients lose significance after one to two days. This relatively short-lived response of the yields on securities being purchased is consistent with the findings in D'Amico and King (2013) where the price response of U.S. Treasury notes and bonds to purchase operations by the U.S. Federal Reserve vanishes after around two to six trading days. Hence, my finding shows that purchase operations have a more persistent impact on market yields than what has previously been found in the literature.

5.7 Comparison to related studies

I find that the supply curve is significantly non-linear which obviously means that a comparison to other related studies becomes dependent on offered amounts. My estimates point to a local supply effect on yields – for the most common amount demanded by the Riksbank – is in the range of 0.5 to 7.5 basis points. These estimates are robust and hold in all, or most, of my specifications. Offered yields are flat over a range of offered volumes but is quite noticeably steeper for offered volumes above 20 per cent of the outstanding amounts. Local supply for these higher offered volumes are as high as 10-15 basis points. My estimates for offers amounting to 1% of the outstanding stock in the respective bond is associated with a lower offered yield of that security on average by -0.57 (-1.37) basis points on the auction day for nominal (index-linked) bonds. If I use the offered prices (100 x log) instead of offered yields as dependent variable the corresponding numbers for the change in offered return are 0.049 (0.0896) per cent, or 4.9 (8.96) basis points (see Table A3 in the Appendix). To gain additional insights into the magnitudes of the estimated coefficients I have also estimated the slope using offered volume in billion SEK instead of share of outstanding stock (see Table A4 in the Appendix). One billion SEK (approximately 115 million USD and 98 million EUR) is associated with a lower yield of around 1 basis point for nominal bonds and around 4 basis points for index-linked bonds.

My estimates are greater than those reported in studies which do not account for the possible endogeneity between central bank demand and market, and supply, conditions. My results line up somewhere between those of D'Amico and King (2013), Joyce and Tong (2012), Schlepper et al. (2020), Kandrac and Schlusche (2013) and De Santis and Holm-Hadulla (2020). De Santis and Holm-Hadulla (2020) find, on Euro area returns, that ECB purchases of 1 per cent of the outstanding amount in the respective market segment raise the return of that security by 0.733% on the day of purchase which implies a price impact of 7.5 basis points per 100 million in purchases. Schlepper et al. (2020), using German data, estimates range from 1.1 basis points and 3.1 basis points for per 100 million in

purchases. Joyce and Tong (2012) find a downward yield impact of around 0.15 basis points per 100 million in purchases under the Bank of England's quantitative easing program from March 2009 to January 2010 which translates into a price impact of 1.5 basis points. D'Amico King (2013) estimate that the average purchase operation temporarily reduced yields by about 3.5 basis points in the sector of the purchase under the Federal Reserve's 2009 program to purchase $300 billion of U.S. Treasury securities. As pointed out by De Santis and Holm-Hadulla (2020) the differences in flow effect estimates across economies may reflect various factors. For instance, the structure of the sovereign bond market clearly differs, for example, in the United States consisting of a deep and liquid pool of fairly homogenous debt securities whereas, in the euro area, it displays substantial heterogeneity in terms of market depth and issuer characteristics. Further, discrepancies may arise due to different implementation modalities of central bank asset purchases in the different jurisdictions considered in these analyses.

5.8 Robustness

To assess the robustness of my main findings, I re-estimate the baseline specification in modified versions that: (i) account for interaction that allow the regressions functions relating yields and offered volumes to be different for low and high levels of Riksbank holdings; (ii) allow for clustered standard errors (iii) allow for time and asset (ISIN) fixed effects; and (iv) account for possible uncertainty regarding Riksbank demand.

In Table 7 I show results from a further examination of whether the slope of the supply curve not just depends on the value of offered yields and volumes but also on the Riksbank holdings of government bonds. By including interactions between the Riksbank holdings and offered volume, (offered volume)^2 and (offered volume)^3 I can check whether the (possibly cubic) regressions functions relating yields and offered volumes are different for low and high levels of Riksbank holdings. To do so, I test the restriction that the coefficients on the interaction terms are zero. The resulting F-statistic is 32.05 for nominal bond auctions and 3.76 for index-linked bonds. These statistics are significant at the 1% and 5% significance levels respectively. This provides some evidence that the regression functions are different for low and high Riksbank holdings of government bonds. To give a sense of magnitudes, Figure 11 depicts the estimated regression functions for nominal bonds for 0, 10, and 40 % Riksbank holdings of the overall stock of bonds. The most notable non-linearity mainly pertain to higher offered volumes of bonds.

Table A1 in the appendix presents results for the baseline estimates using clustered standard errors. Because it seems possible that the regression errors are correlated across auctions, I allow for

clustering within auctions for each security. This adjustment does not alter any of my results. I also clustered by security type (not shown) and did not observe any notable differences with the results reported above.

While the Riksbank's purchasing officers at the day of the auction have no leeway in allocating what individual bonds to purchase, they do have an option in deciding how much to purchase of each bond within a pre-specified range. These ranges are communicated in advance together with the auction announcement a week prior to the auction. Purchases are generally governed by achieving the stipulated and announced volume but in some cases the purchased volume has been higher. To further study if the results are sensitive to this potential source of uncertainty I first re-estimate the baseline specification using only auctions where purchased amounts are identical to prior advertised and announced volumes and, second, control for Riksbank demand uncertainty.

Table A5 in the Appendix shows results for the baseline estimates using only auctions where purchased amounts are identical to prior advertised and announced volumes. In order to investigate if my results are affected by times when the Riksbank purchased a different amount than what was announced I re-estimate the baseline results but only for auctions where the announced volume is identical to the actual purchased amount. My results and conclusions remain intact when using the more restrictive definition of purchases.

Table A6 in the Appendix shows results for the baseline estimates when also controlling for a measure of Riksbank demand uncertainty. This measure is computed as the ratio of the maximum range and the announced volume. Hence, if this measure is high it means that demand is more uncertain and that the Riksbank has the potential to deviate from the announced volume to a larger degree. The results and conclusions remain intact also when explicitly controlling for demand uncertainty.

6. The announcement effect by ISIN

To give my local supply estimates some perspective I compute Stock effects of asset purchases following the approach in D'Amico and King (2013). Another motivation for this final exercise is that a number of studies have previously examined the effects of asset purchase announcements on constant maturity Treasury yields and other asset prices, but only a few have employed data at ISIN level. While flow effects are defined as the response of prices to the ongoing purchase operations, stock effects are defined as persistent changes in prices that result from movements along government bond supply curves. To estimate stock effects, I use the cross-section of total yield changes in two

ways. In the first approach I compute the total changes in yields on announcement days between February 12, 2015 and November 26 2020, for all the available ISINs and order these by the mean maturity on the announcement days. In the second approach I model the cumulative change in each ISIN's yields (i.e., the cross-section of Treasury yields) as a function of the total amount that the Riksbank purchased of that ISIN. There are relatively few cross-sectional observations so this section can only be used as an indication of the magnitude of the stock effect. Because, over the life of the program, purchased amounts could have responded endogenously to price changes, I instrument these Riksbank holdings as I do in the appendix where I instrument the Riksbank holdings with ECB public sector purchase programme (PSPP) holdings.

The bottom parts of the two panels of Figure 15 shows the cumulative changes in yields on announcement days, for all the available ISINs ordered by the mean maturity on the announcement days (shown on the horizontal axis). After the announcements, short to medium dated yields fell rather dramatically, with the largest reactions in the two-to seven-year maturity range, where the yields declined around 40-70 basis points, with longer dated yields changing much less. This result is quite similar to D'Amico and King (2013) and indicates that the impact of the announcements were not entirely driven by the exposure to duration risk, but was affected by changes in local supply. This can be seen by comparing the yield changes to the maturity distribution of the Riksbank's purchases (as percentage of the outstanding amounts), which are shown in the top portion of each panel. The sectors in which yields fell the most on the announcement day match those in which the Riksbank had purchased the most regardless of duration.

Figure 16 shows the total change in the yield for each ISIN's yields (i.e., the cross-section of government bond yields) as a function of the total amount that the Riksbank purchased of that ISIN. The coefficients of -1.7 (nominal bonds) and -1.3 suggests that buying one percent of a security is associated with a -1.7 basis points (-1.3) lower yield of that security. Hence, the overall purchases of approximately 50% of the outstanding amount for nominal bonds and 25% for index-linked bonds lowered yields by around 80 and 30 basis points respectively. Interestingly, the coefficients are quite similar to the estimated slope of the supply curve by individual dealer that I estimate using auction data above.

7. Conclusions

The endogeneity between the allocation of purchases to individual securities and their prevailing market prices is an important challenge to overcome when estimating the relationship between prices

and quantities in certain securities market segments. To address this challenge I use a unique data set on all offered, and binding, offer schedules, i.e. all pairs of offered price and quantity (both rejected and accepted), from individual dealers participating in the Riksbank's asset purchase auctions from 2015 to 2021 to estimate local supply of government bonds by individual dealers and the closely associated question of "flow effects" of the Riksbank's asset purchase programme. Additionally, the time period and the granular transaction-level data offers both a detailed and a long-run perspective on asset purchases in both calmer and stressed market conditions. Finally, and importantly, my setting allows me to identify the slope for offered amounts of up to 40 percent of the outstanding stock. Previous papers on flow effects are limited to study effects only around actual purchased amounts which are relatively small relative to outstanding amounts of bonds. Hence, I present a set of new empirical results about the effects on yields from ongoing purchase operations. I find that the estimated local supply of offered government bonds by individual dealers in the auctions is highly elastic and significantly non-linear. My baseline estimates show that an offer to sell an additional one percent of the outstanding amount of a bond by individual dealers is associated with 0.6 to as much as 7.5 basis points lower yields for nominal government bonds and index-linked government bonds respectively. However, offers are non-linear and less elastic (steeper) for offered quantities below 10 per cent and above 20 per cent of outstanding volumes of bonds. The finding of a non-linear slope is new and is only possible to uncover due to access to the whole distribution and significant size of the offered volumes at each auction. Finally, I show that marginal yields at the auctions are highly, and persistently, correlated with changes in market yields for more than a week after the auction suggesting that purchase operations have a more persistent association with market yields than what has previously been found.

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Figures

Figure 1. Characteristics of nominal and index-linked government bond purchases 2015-2021.

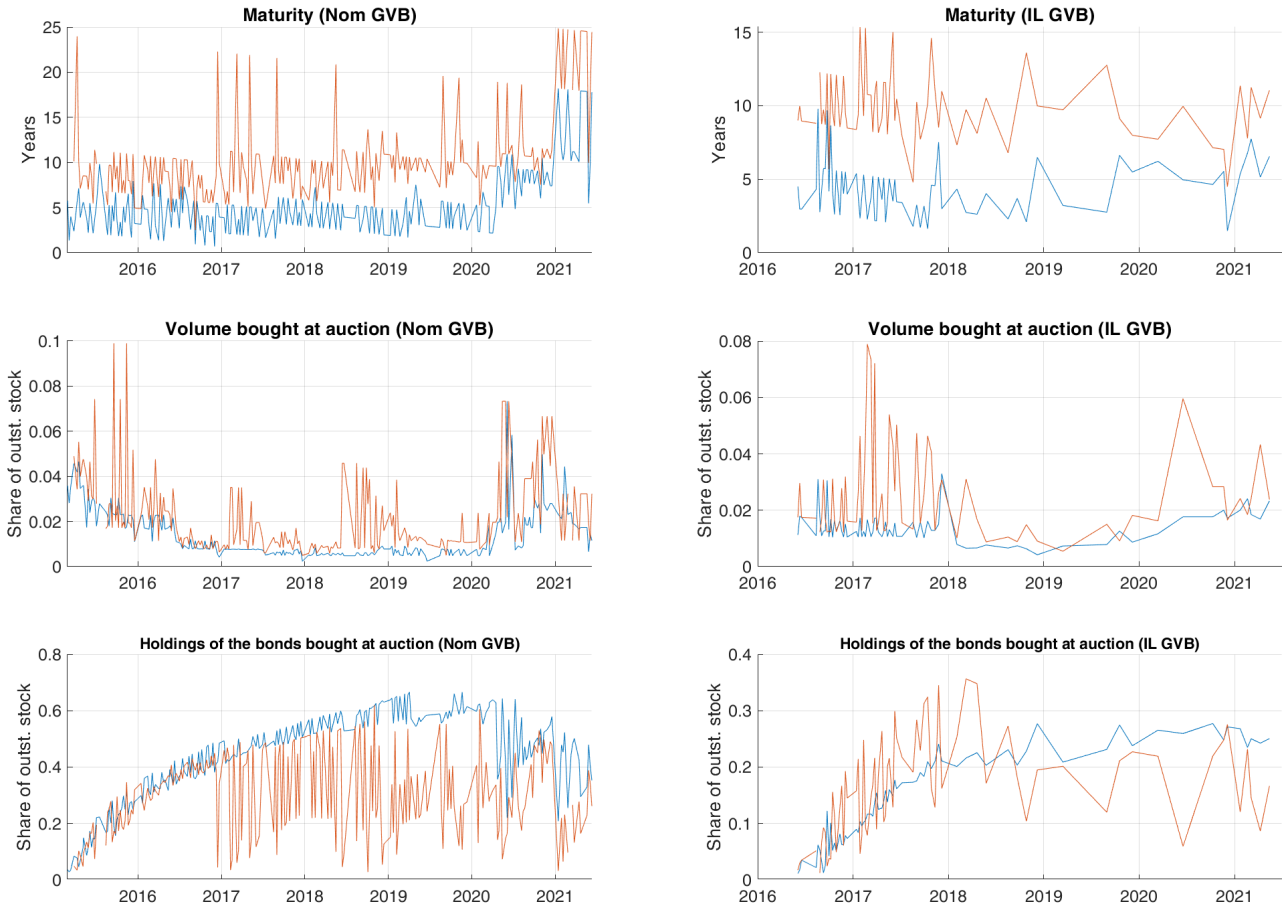
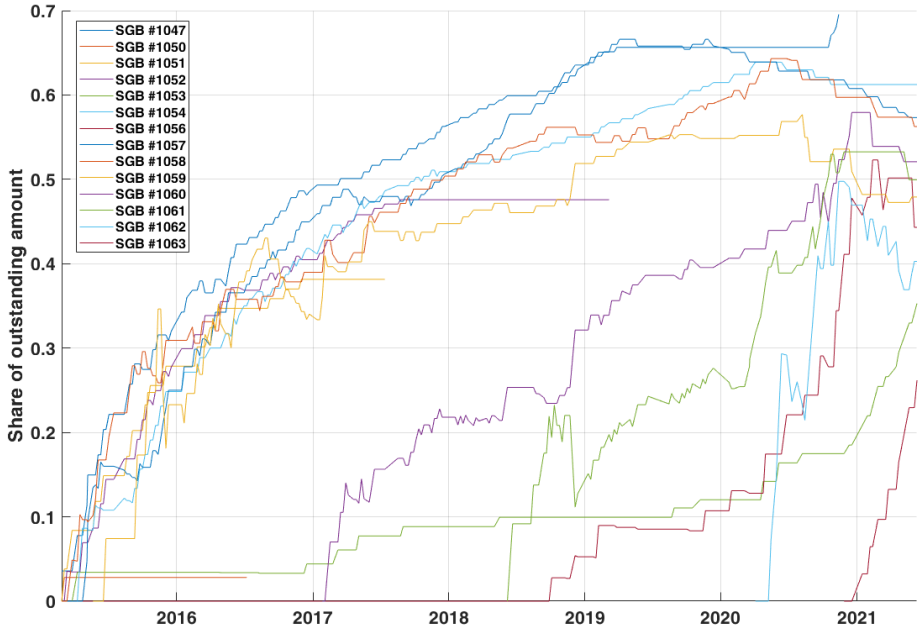


Figure 2. Riksbank holdings of nominal and index-linked government bonds 2015-2021. Share of outstanding amounts.

Panel a. Nominal government bonds



Panel b. Index-linked government bonds

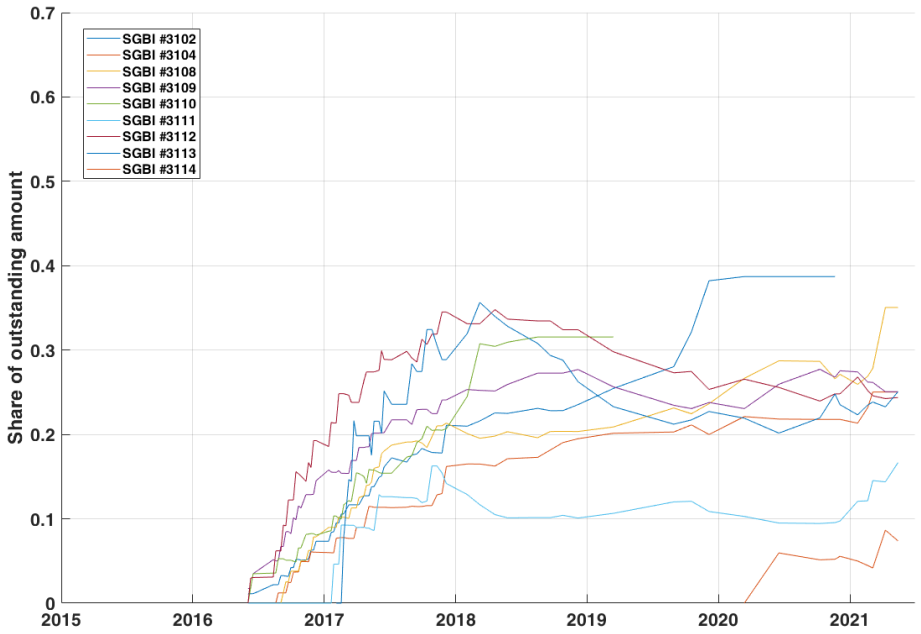


Figure 3. Distribution of Nyborg et al. (2002) measure of discount for nominal (first row) and index linked government bonds and the daily change in yields (the day before the auction with the closing yield at the day of the auction) 2015-2021. “Pre” denotes the discount measure computed with the yield on the day before the auction and “Post” measure computed with the yield on the day of the auction.

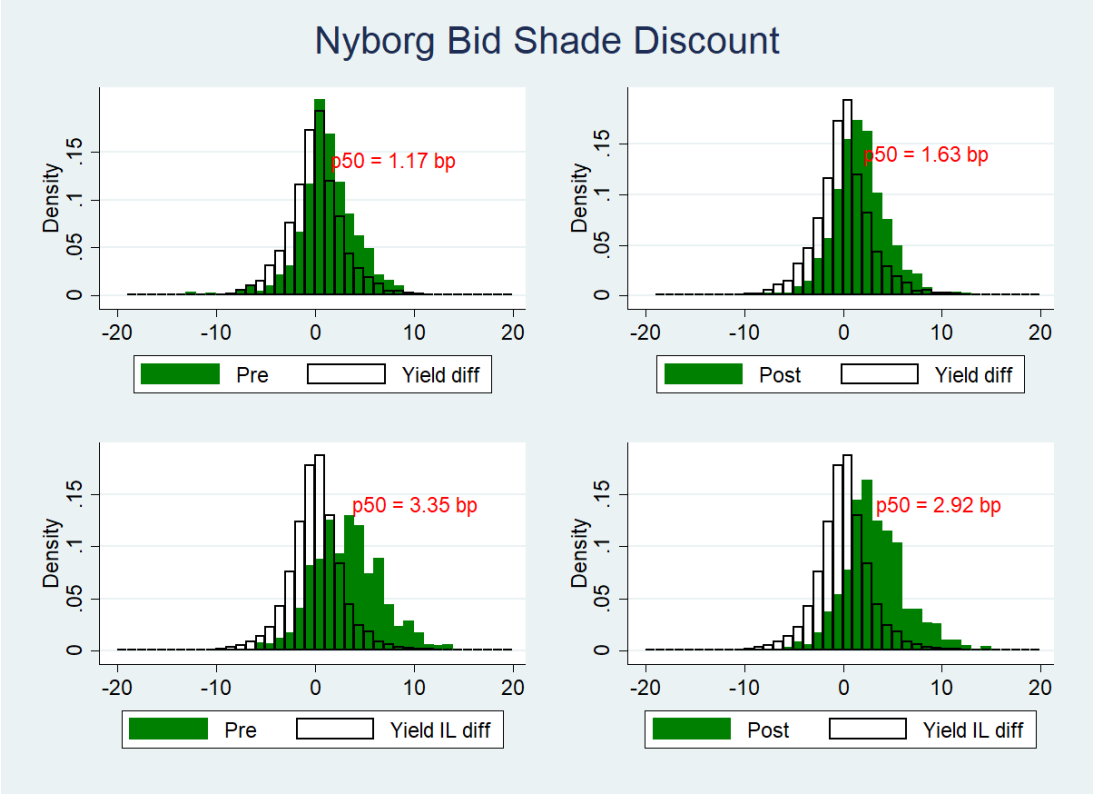


Figure 4. Distribution of Nyborg et al. (2002) measure of discount for nominal (left panel) and index linked (right panel) government bonds and the daily change in yields (the day before the auction with the closing yield at the day of the auction) 2015-2021. The discount is computed for the marginal, or market clearing, bid.

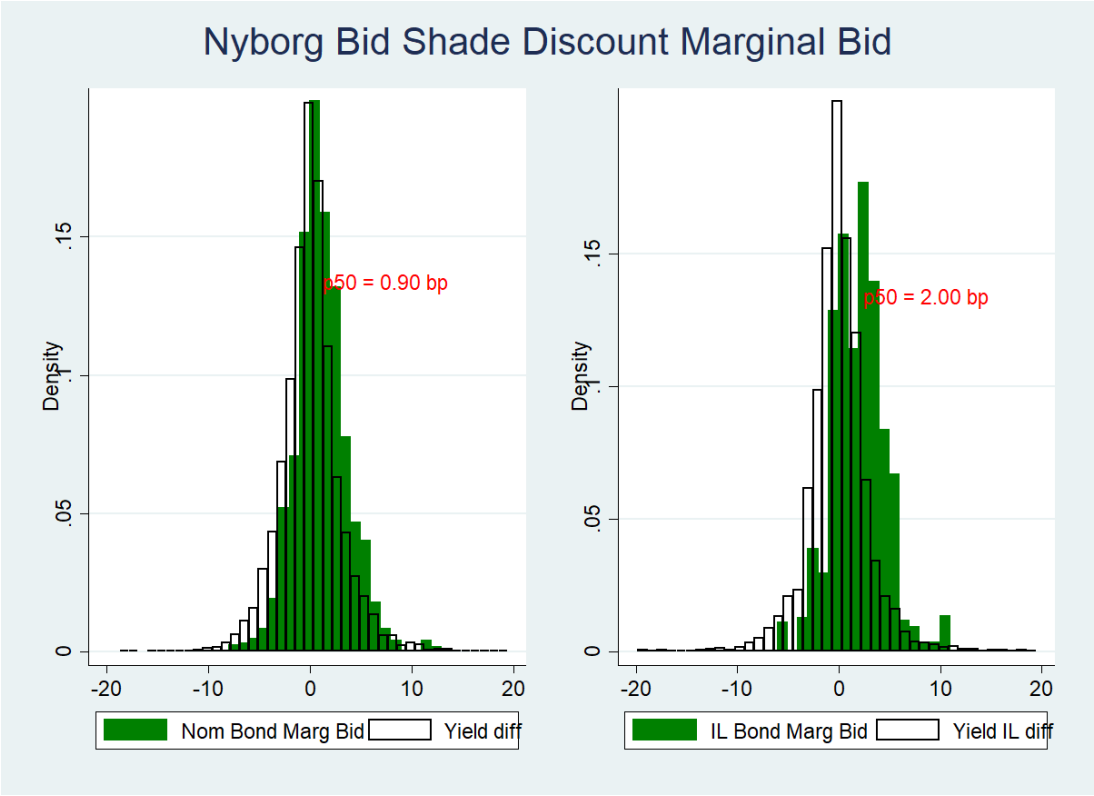


Figure 5. Distribution of Nyborg et al. (2002) measure of discount for nominal (left panel) and index linked (right panel) government bonds and the absolute value of the bid-ask spread of the yields 2015-2021.

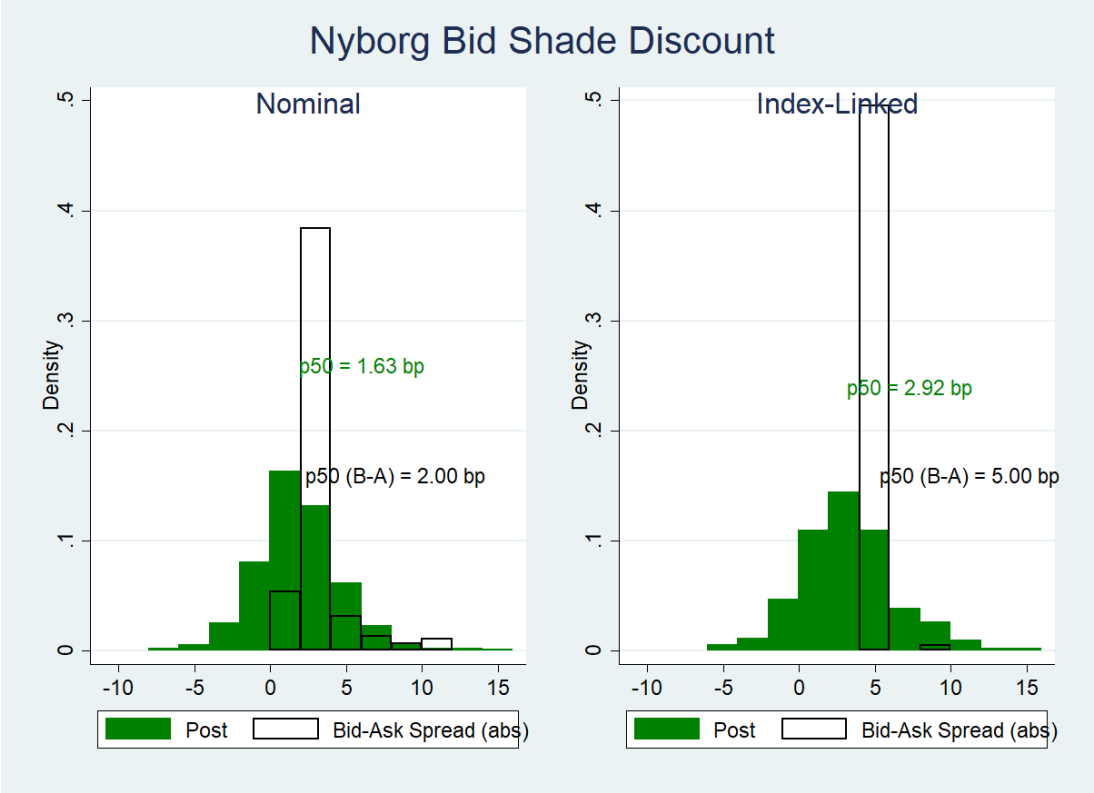


Figure 6. Estimated local supply curve by individual dealers. Auctions of nominal (green dashed line) and index-linked bonds (solid black line) with auction and dealer fixed effects, 2015-2021.

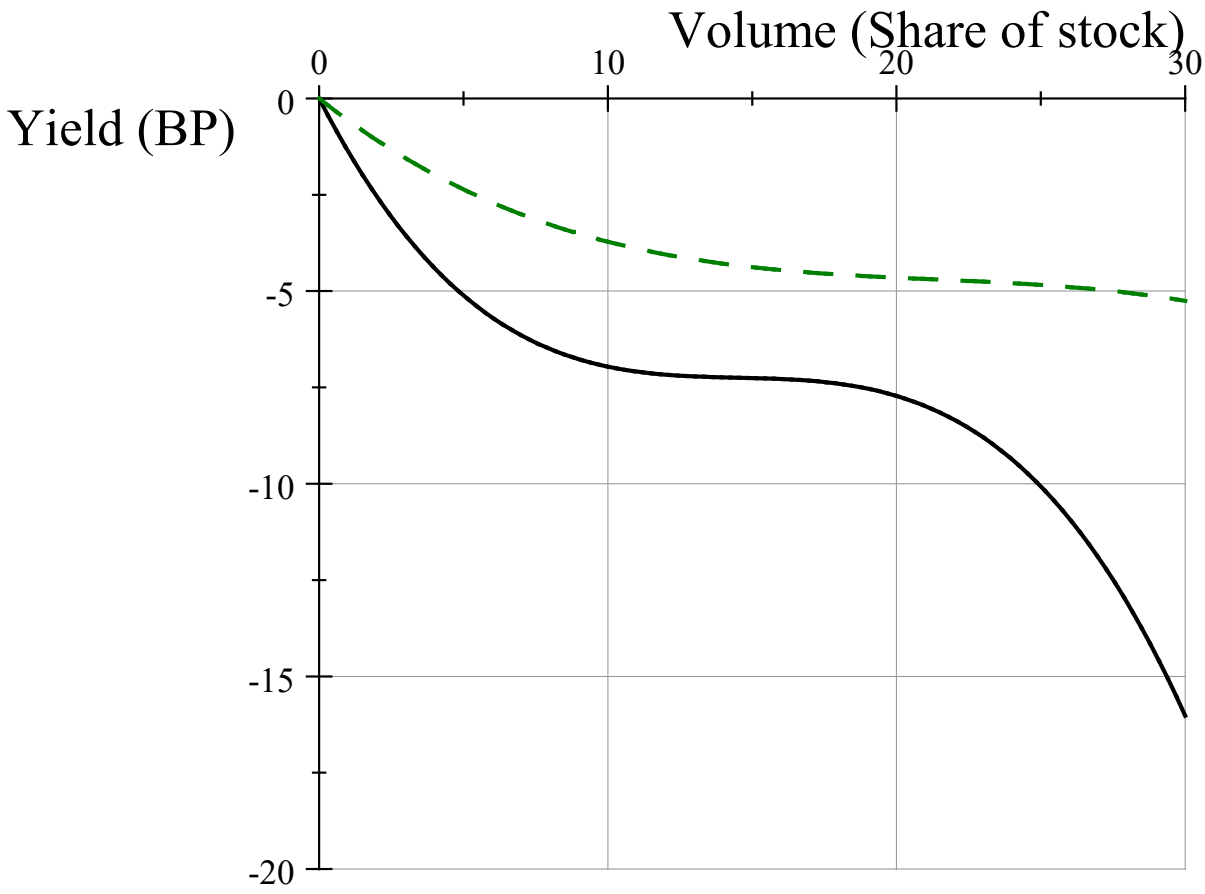


Figure 7. Distribution of offered volumes as share of outstanding amount.

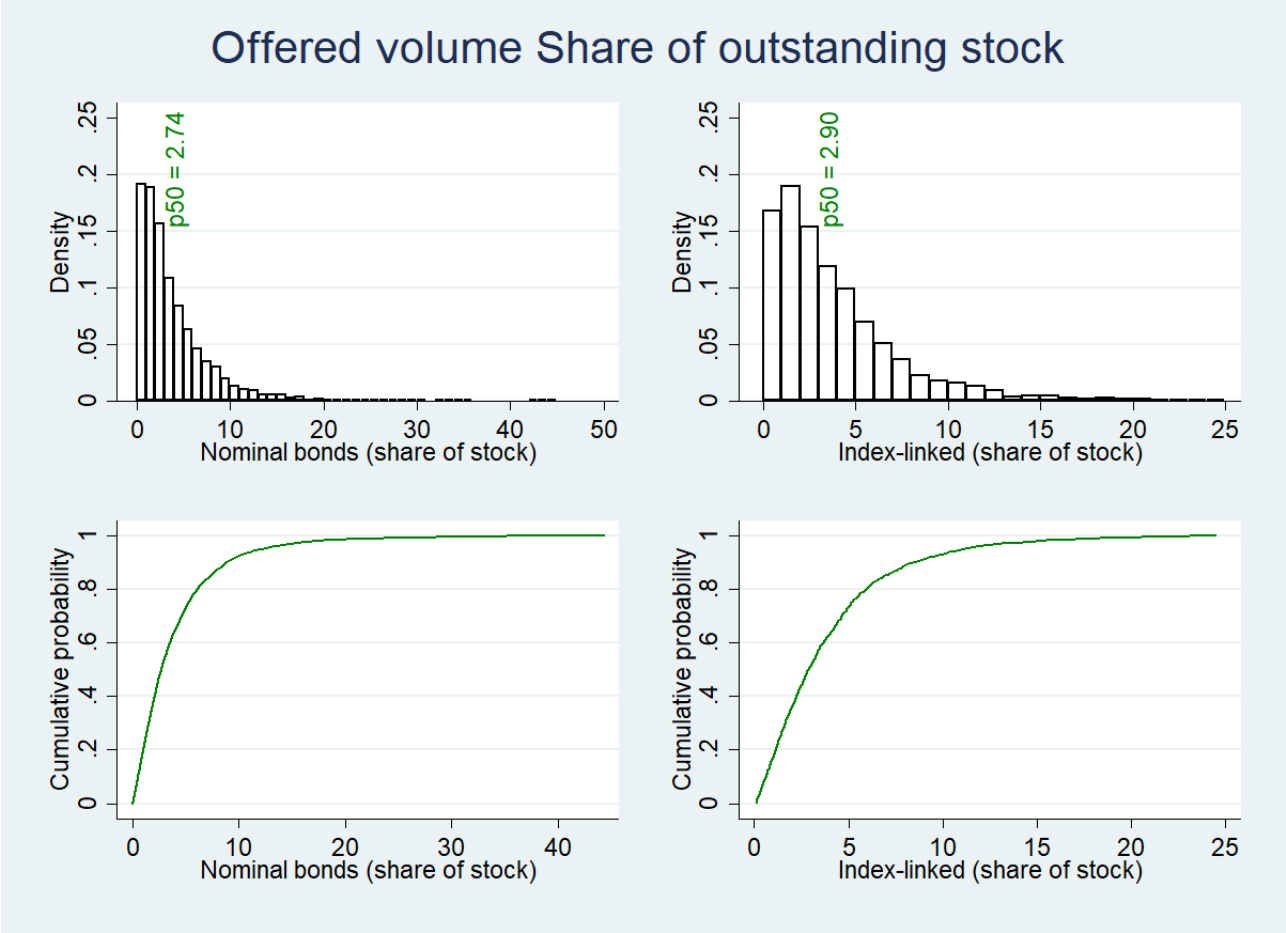
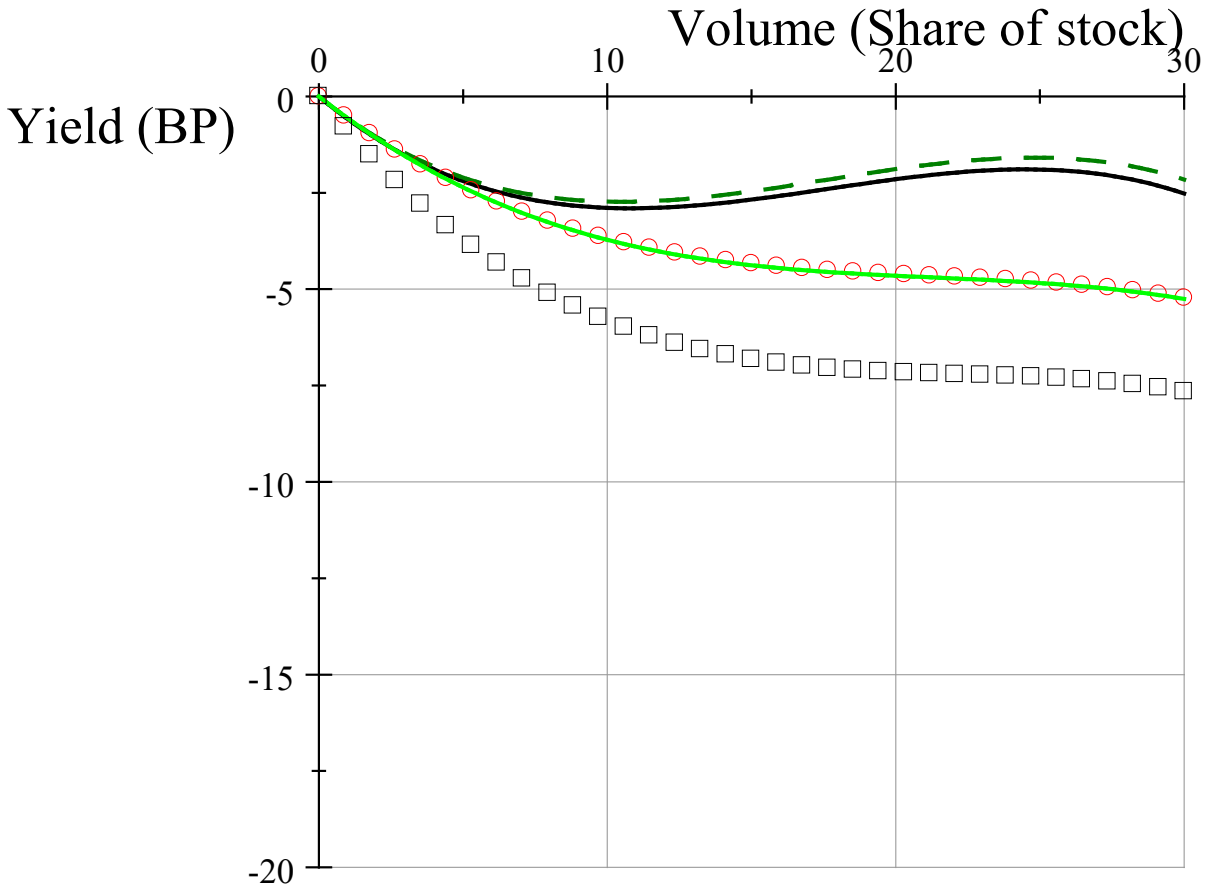
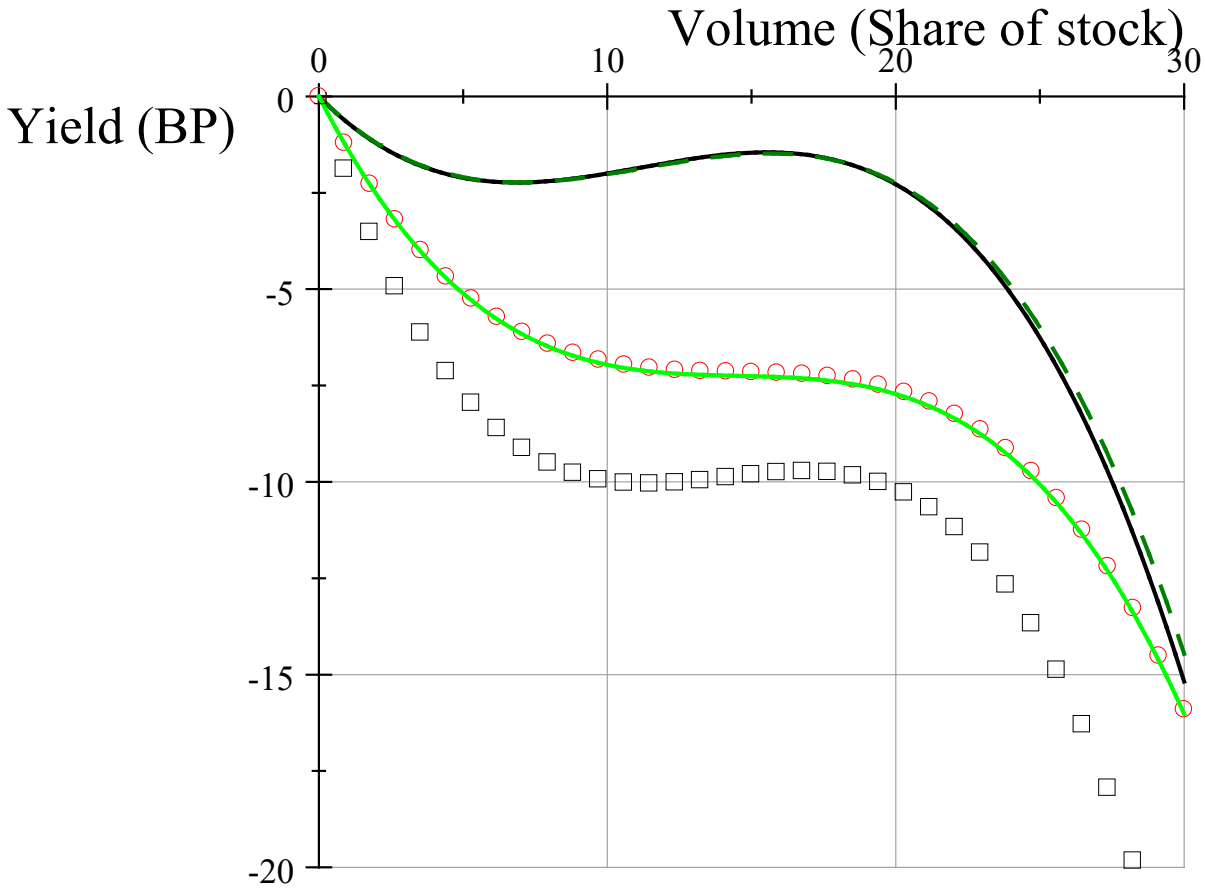


Figure 8. Estimated local supply curve by individual dealers. Auctions of nominal bonds with and without auction and dealer fixed effects and Nyborg (bid-shading) adjusted yields, 2015-2021.



Note. Simple OLS estimates without dealer and auction fixed effects: solid black line; Dealer fixed effects but no auction fixed effects: green dashed line; No dealer fixed effects but auction fixed effects: red circles; Both dealer and auction fixed effects: solid green line. Nyborg adjusted yields with both dealer and auction fixed effects: black boxes.

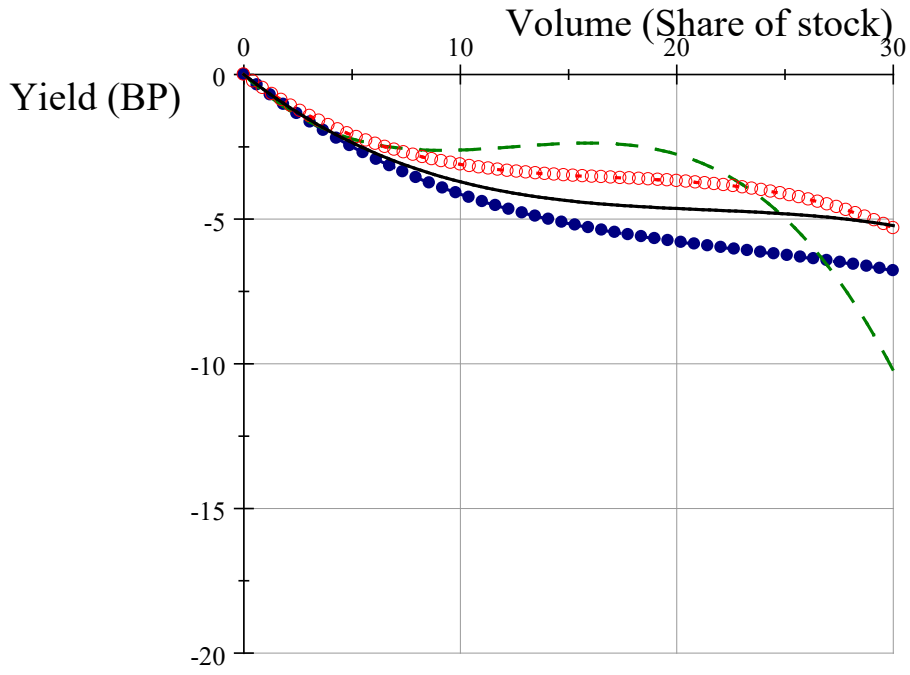
Figure 9. Estimated local supply curve by individual dealers. Auctions of index-linked bonds with and without auction and dealer fixed effects and Nyborg (bid-shading) adjusted yields, 2015-2021.



Note. No dealer and auction fixed effects: solid black line; Dealer fixed effects but no auction fixed effects: green dashed line; No dealer fixed effects but auction fixed effects: red circles; Both dealer and auction fixed effects: solid green line. Nyborg adjusted yields with both dealer and auction fixed effects: black boxes.

Figure 10. Estimated local supply curve by individual dealers. Auctions of nominal and index-linked bonds with auction and dealer fixed effects on four samples: 2015-2021 (black solid line), 2015-2017 (blue dotted line), 2018-2019 (green dashed line) and 2020-2021 (red circled line).

Panel (a). Nominal Government bonds



Panel (b). Index-Linked Government bonds

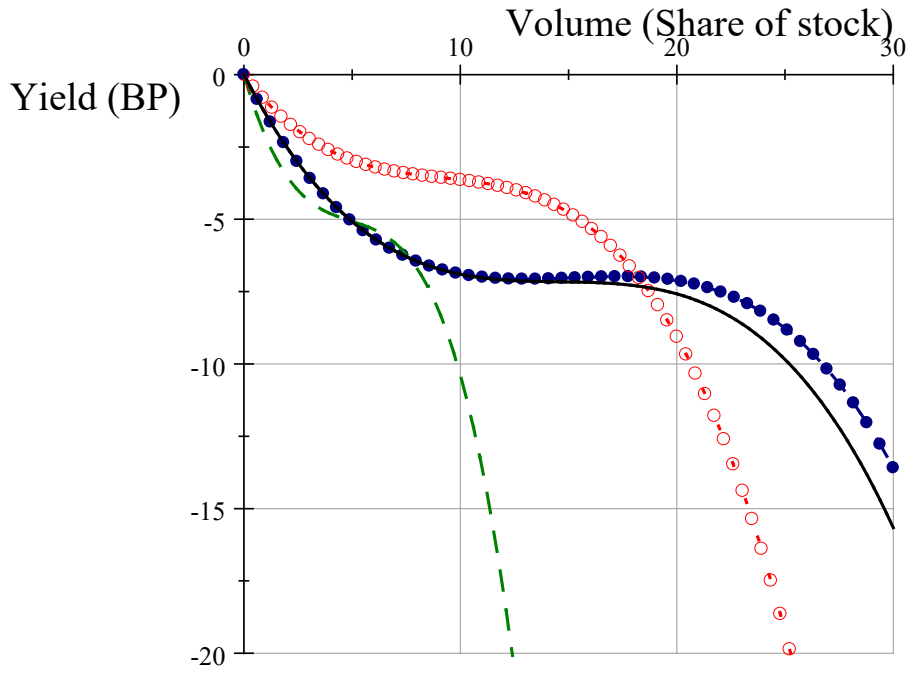


Figure 11. Estimated local supply curve by individual dealers. Auctions of nominal bonds with additional interaction effects evaluated at Riksbank holdings of zero (black solid line), 10 per cent (green dashed line), and 40 per cent (red circled line).

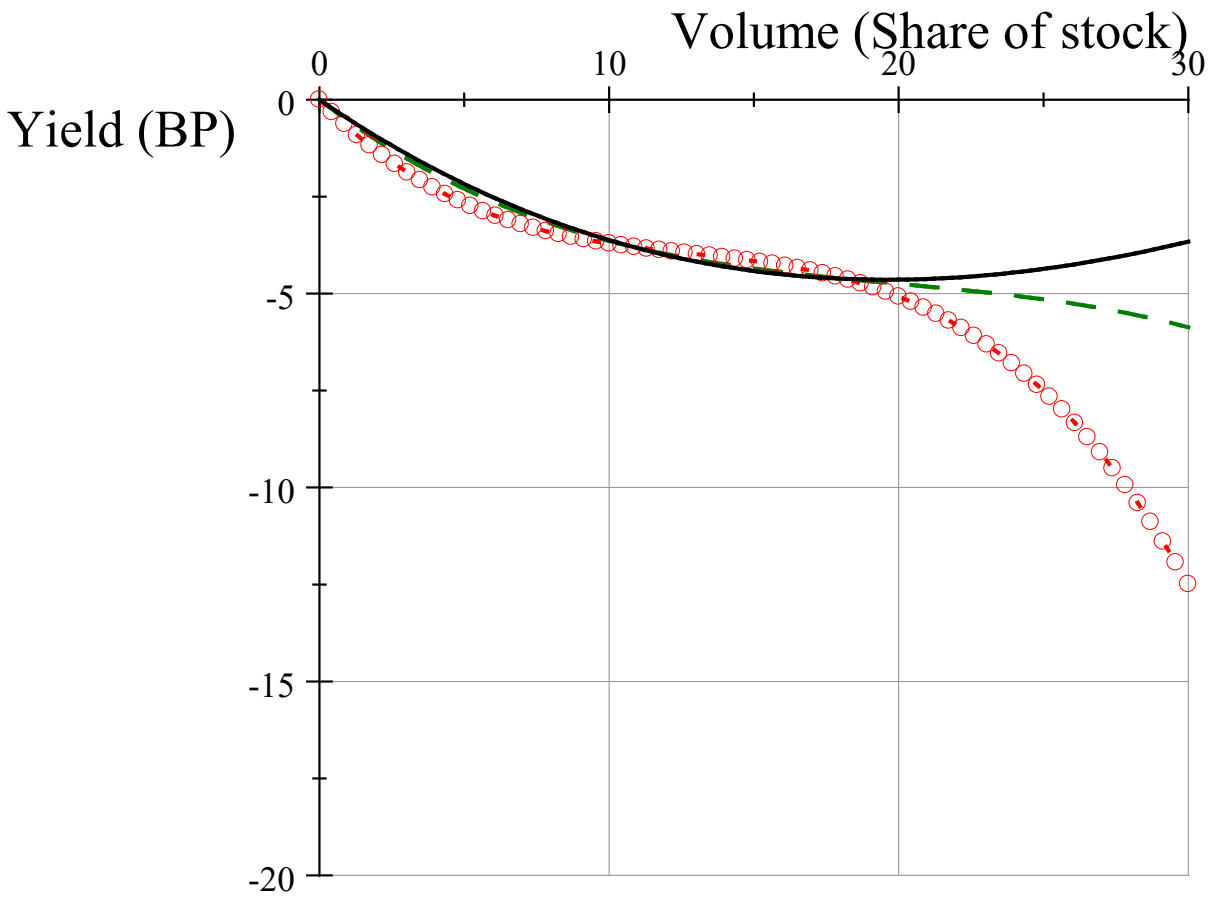
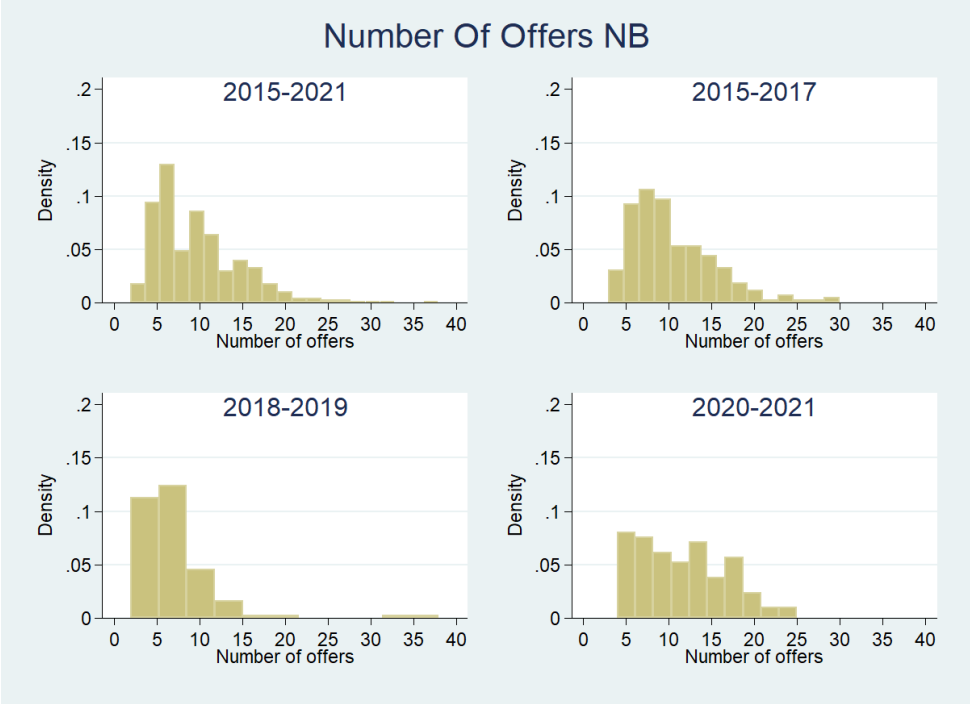


Figure 12. Number of offers per auction.

Panel (a) Nominal Government Bonds



Panel (b) Index-Linked Government Bonds

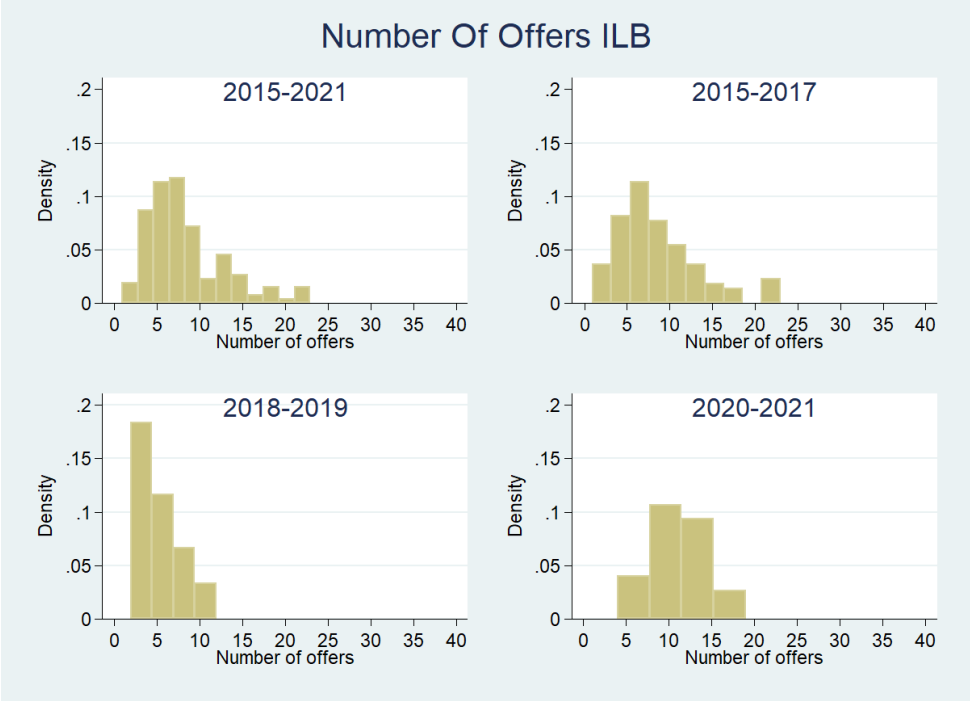
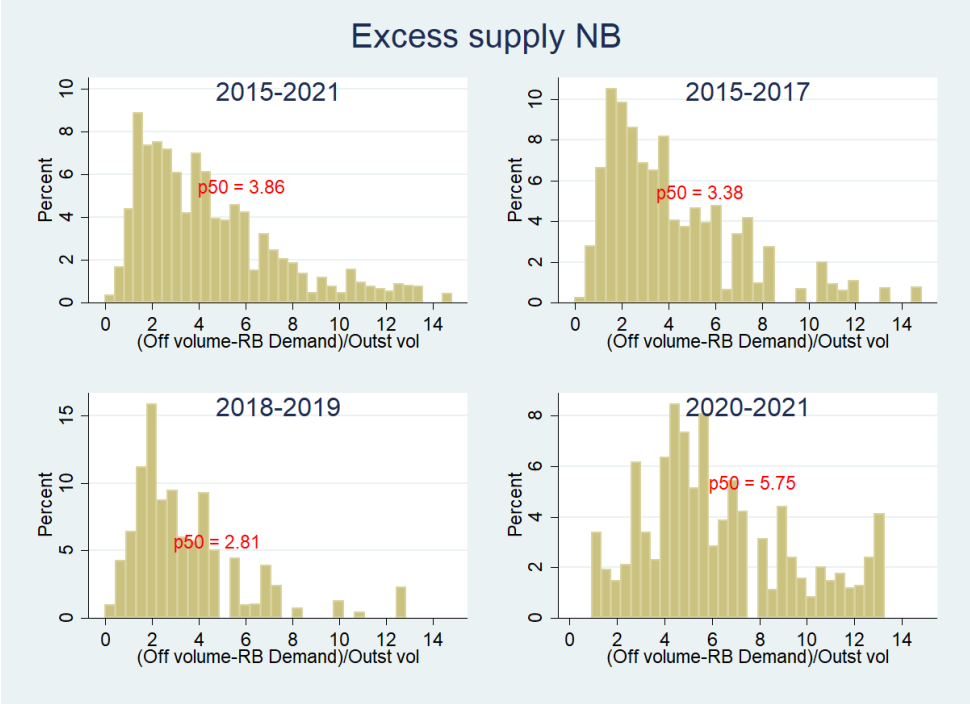
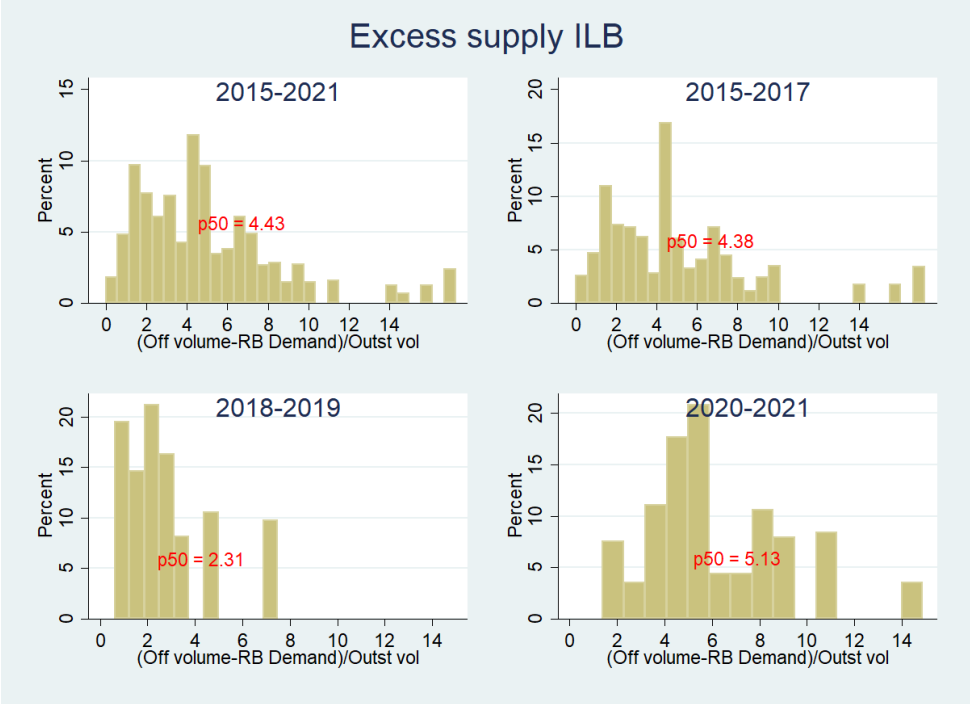


Figure 13. Distribution of excess supply per distinct subsample.

Panel (a) Nominal Government Bonds

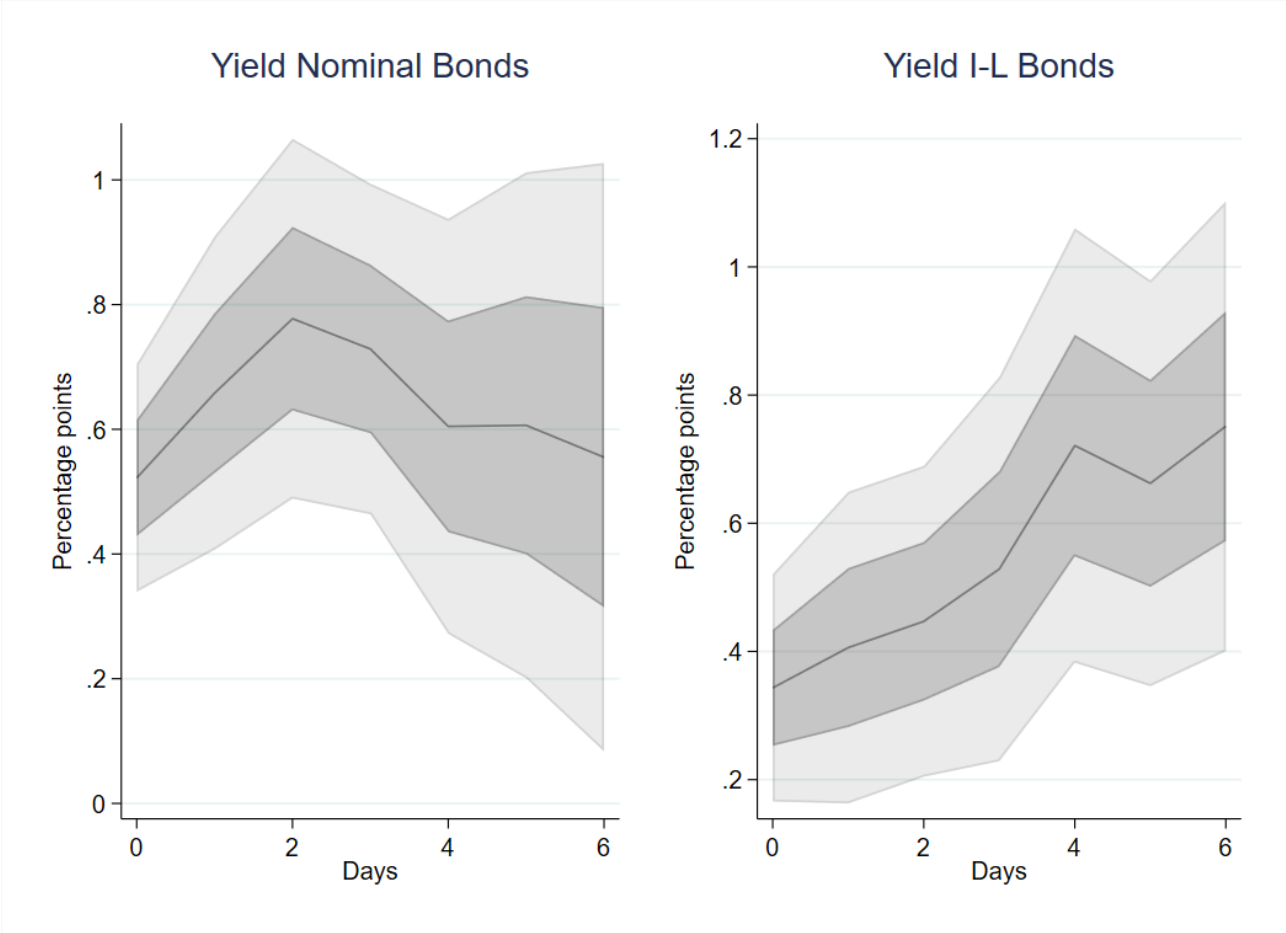


Panel (b) Index-Linked Government Bonds



Note. Excess supply is measured as the sum of all offered volumes per auction less the amount purchased by the Riksbank as a share of total outstanding volume.

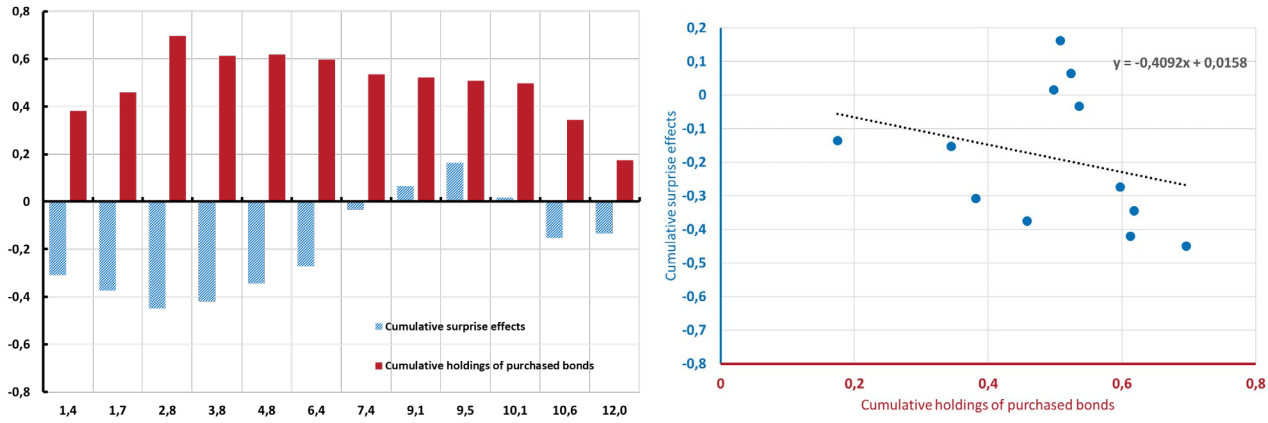
Figure 14. The dynamic effects of purchases on market yields



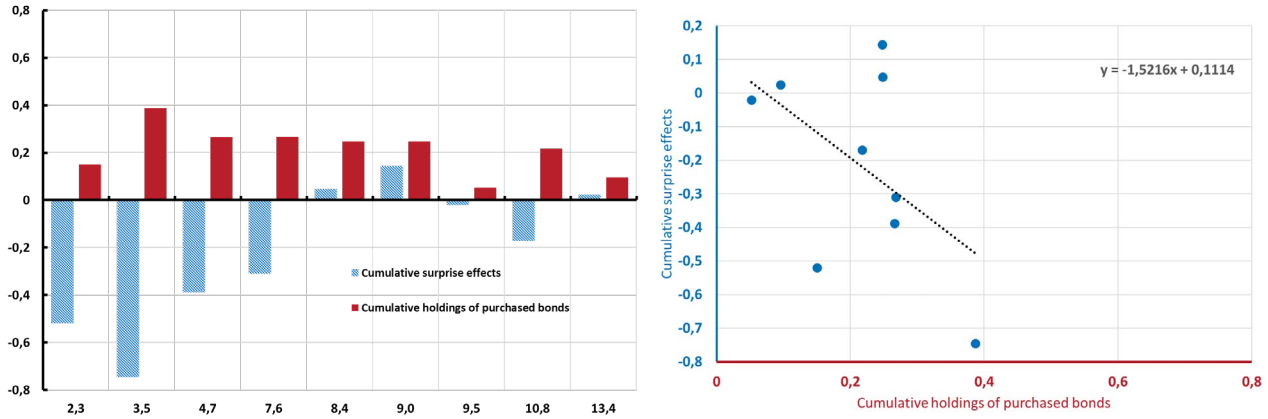
Note. The figure shows the coefficient on the change in the marginal yield from the yield at the end of the day prior to the auctions, in panel regressions where the dependent variables are cumulative percentage market yield changes for that security over horizons of zero to six days. The regressions control for fixed and time effects. 95 and 68 percent confidence bands shown, using Driscoll and Kraay (1998) standard errors.

Figure 15. The cumulative announcement effects on yields versus bond purchases.

Panel a. Nominal government bonds



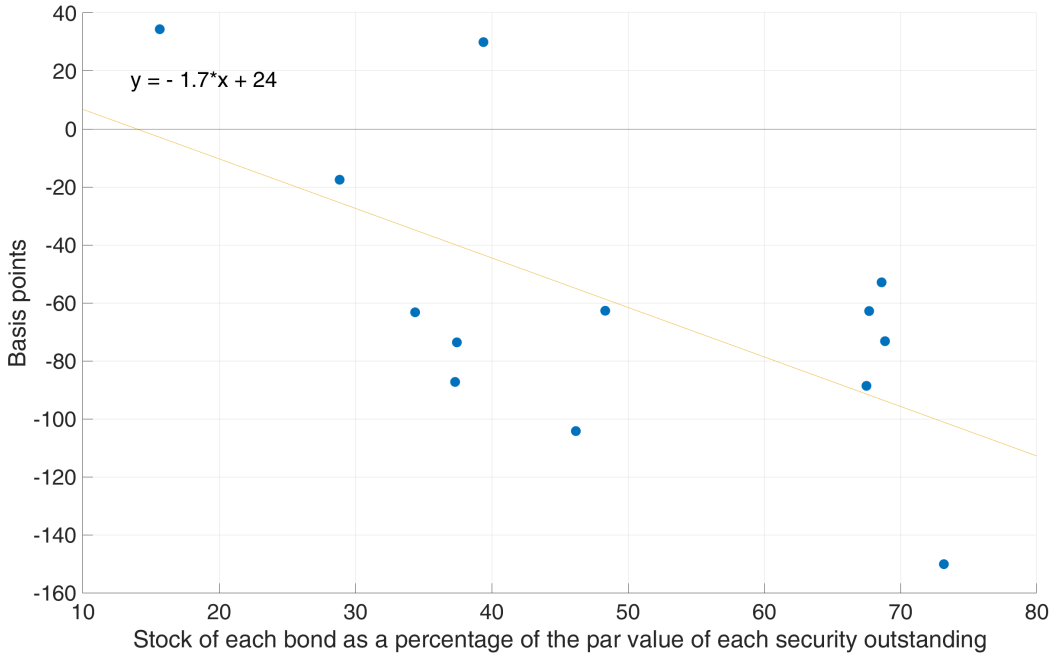
Panel b. Index-linked government bonds



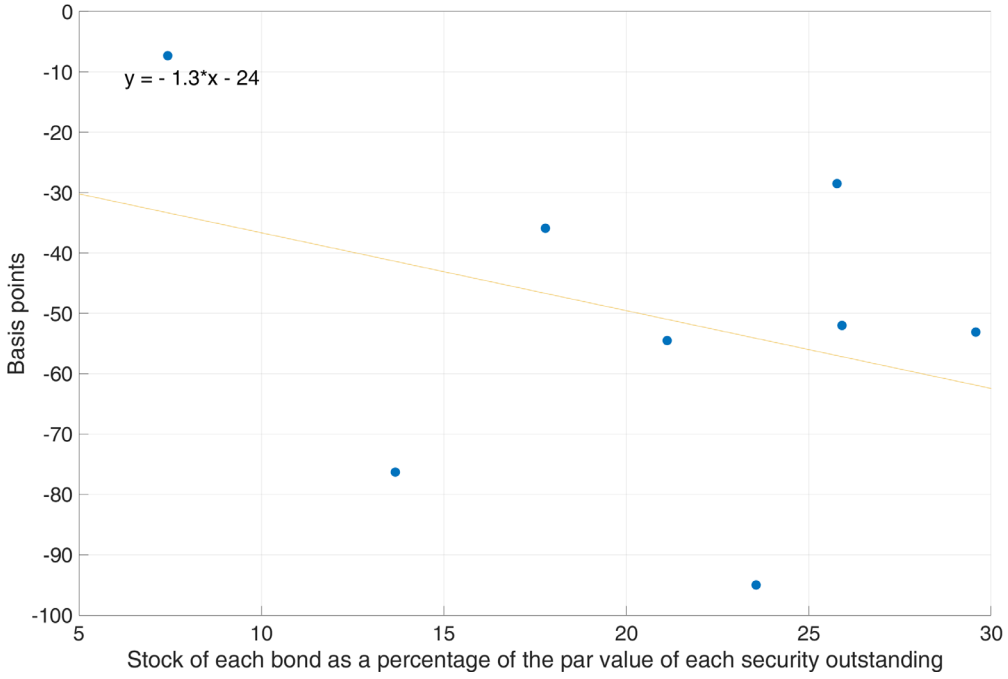
Note. The top part in each left hand side panel (red bars) show the cumulative amount of each security purchased by the Riksbank between February 12, 2015 and November 26, 2020, as a percentage of the total amount of that security outstanding. The bottom part of the left hand side panel (light blue bars) shows the cumulative change in the yield on the corresponding security on the days the purchases were announced. Securities in the chart are indexed by the mean of their remaining maturity at the time of the announcement, shown on the horizontal axis. The right hand side panels shows scatter plots depicting the data in the left hand side panels.

Figure 16. The total change in yields versus Riksbank bond holdings.

Panel a. Nominal government bonds



Panel b. Index-linked government bonds



Tables

Table 1. Characteristics of Riksbank purchases of nominal and index-linked government bonds vs. universe of government bonds. The table shows sample averages for securities that were bought by the Riksbank between February 2015 and December 2019, relative to the universe of outstanding Government securities. All figures are SEK-weighted averages over the period February 2015 to December 2019.

a. Nominal government bonds

Variable	Mean	Std. Dev.	Min	Max
Universe of government nominal bonds				
Years to maturity	6.564	.318	5.753	7.195
Coupon interest rate	3.094	.282	2.58	3.592
Years since issued	7.307	.427	6.608	8.155
Riksbank purchases of nominal bonds				
Years to maturity	5.873	1.683	2.054	11.19
Coupon interest rate	3.091	1.01	.95	5
Years since issued	6.783	2.551	1.467	14.423

b. Index-linked government bonds

Variable	Mean	Std. Dev.	Min	Max
Universe of government index-linked bonds				
Years to maturity	6.618	.499	5.694	7.807
Coupon interest rate	1.71	.196	1.43	2.206
Years since issued	10.146	.651	8.936	11.412
Riksbank purchases of index-linked bonds				
Years to maturity	6.687	1.566	3.184	10.361
Coupon interest rate	1.452	1.213	.125	3.84
Years since issued	8.413	6.123	.65	20.883

Table 2. Characteristics of Riksbank purchases of nominal and index-linked government bonds

	Security	Number of auctions	Number of offers	Total Purchased amount		Purchased volume per auction (Billion SEK)				Purchased volume per auction (Share of stock)			
				Billion SEK	Per cent of stock	Mean	sd	Min	Max	Mean	sd	Min	Max
Nominal bonds	SGB 1047	57	484	63,1	65,6	1,4	0,9	0,4	3,5	1,6	1,1	0,4	4,2
	SGB 1050	1	4	1,5	2,8	1,5	0,0	1,5	1,5	2,8	0,0	2,8	2,8
	SGB 1051	15	139	25,0	38,2	1,9	0,6	0,8	3,0	2,9	1,0	1,1	4,6
	SGB 1052	34	319	46,9	47,6	1,6	0,8	0,5	3,0	1,8	0,9	0,5	3,5
	SGB 1053	22	317	15,3	35,3	0,7	0,3	0,5	1,5	1,7	0,7	1,1	3,4
	SGB 1054	73	607	66,2	63,9	1,1	0,7	0,3	3,5	1,2	1,0	0,2	4,7
	SGB 1056	16	180	13,3	52,3	0,8	0,4	0,5	1,5	3,6	1,7	1,9	6,7
	SGB 1057	61	553	55,5	66,6	1,0	0,7	0,2	3,0	1,4	1,1	0,2	4,7
	SGB 1058	47	470	43,7	64,3	1,2	0,8	0,3	3,5	1,9	1,4	0,5	5,5
	SGB 1059	38	446	36,5	57,7	1,1	0,6	0,3	2,1	2,8	2,6	0,5	9,9
	SGB 1060	42	348	31,0	57,9	0,8	0,3	0,5	1,5	2,0	0,9	0,9	3,5
	SGB 1061	44	434	32,1	53,3	0,8	0,4	0,4	1,5	2,1	1,0	0,9	4,6
	SGB 1062	20	262	21,0	49,8	1,1	0,3	0,5	1,5	4,4	1,9	1,4	7,3
	SGB 1063	8	103	4,1	26,2	0,5	0,0	0,5	0,6	3,3	0,1	3,2	3,6
	∑	478	4666	455,1	50,8								
Index-linked bonds	SGBIL 3102	23	148	9,0	23,1	0,5	0,3	0,3	1,25	1,4	0,8	0,6	3,3
	SGBIL 3104	18	168	6,8	25,0	0,4	0,2	0,2	0,9	1,5	0,6	0,5	3,1
	SGBIL 3108	23	160	8,3	28,4	0,4	0,1	0,3	0,5	1,2	0,3	0,7	1,7
	SGBIL 3109	23	193	8,4	27,7	0,4	0,1	0,1	0,5	1,6	0,3	0,4	1,8
	SGBIL 3110	13	107	4,9	21,0	0,4	0,0	0,4	0,4	1,7	0,1	1,6	1,8
	SGBIL 3111	9	113	3,5	16,7	0,4	0,1	0,3	0,5	3,2	1,2	1,5	4,6
	SGBIL 3112	19	186	7,2	34,8	0,4	0,1	0,3	0,5	2,5	0,6	1,2	3,2
	SGBIL 3113	14	112	5,4	35,7	0,4	0,1	0,3	0,5	4,0	2,0	1,6	7,9
	SGBIL 3114	2	17	1,0	8,7	0,5	0,0	0,5	0,5	5,1	0,8	4,3	6,0
	∑	144	1204	54,3	23,3								

Table 3. Estimates of the slope of the local supply curve of nominal and inflation-linked government bonds by individual dealers. Baseline results with combinations of fixed-effects.

	(1) Nom Gov. Bond Offered Yield	(2) I-L Gov. Bond Offered Yield	(3) Nom Gov. Bond Offered Yield	(4) I-L Gov. Bond Offered Yield	(5) Nom Gov. Bond Offered Yield	(6) I-L Gov. Bond Offered Yield	(7) Nom Gov. Bond Offered Yield	(8) I-L Gov. Bond Offered Yield
Offered volume Share of Stock	-0.648***	-0.724***	-0.616***	-0.710***	-0.586***	-1.441***	-0.592***	-1.451***
	(0.0584)	(0.134)	(0.0513)	(0.132)	(0.0201)	(0.0812)	(0.0202)	(0.0822)
Offered volume Share of Stock ^2	0.0429***	0.0775***	0.0417***	0.0750***	0.0261***	0.0992***	0.0263***	0.0995***
	(0.00376)	(0.0190)	(0.00355)	(0.0185)	(0.00124)	(0.0107)	(0.00123)	(0.0107)
Offered volume Share of Stock ^3	-0.000799***	-0.00233***	-0.000784***	-0.00224***	-0.000409***	-0.00229***	-0.000410***	-0.00229***
	(0.0000813)	(0.000715)	(0.0000796)	(0.000698)	(0.0000273)	(0.000393)	(0.0000267)	(0.000390)
Riksbank Holdings Share of Stock	-0.00877*	-0.0895***	-0.00848*	-0.0795***	0.0693**	0.170	0.0640**	0.160
	(0.00510)	(0.0179)	(0.00493)	(0.0178)	(0.0324)	(0.117)	(0.0318)	(0.119)
Offered volume × RB Holdings	0.000848	-0.000784	0.00105	-0.00106	-0.000358	-0.00514**	-0.000230	-0.00486**
	(0.000841)	(0.00280)	(0.000767)	(0.00282)	(0.000418)	(0.00225)	(0.000421)	(0.00226)
Riksbank Volume demand	0.483***	-1.925***	0.173*	-2.041***	22.67***	-51.14	22.53***	-48.28
	(0.113)	(0.547)	(0.0990)	(0.556)	(2.314)	(31.28)	(2.320)	(31.69)
Market yield lag	0.995***	1.003***	0.995***	1.002***	1.707***	0.885***	1.714***	0.877***
	(0.00152)	(0.00402)	(0.00152)	(0.00401)	(0.104)	(0.0809)	(0.106)	(0.0820)
U.S. Move index	0.00849**	0.0350***	0.00920**	0.0353***	-2.073***	-0.328**	-2.075***	-0.309*
	(0.00364)	(0.00834)	(0.00369)	(0.00828)	(0.160)	(0.161)	(0.164)	(0.164)
Maturity	-0.0101	0.614***	-0.0428	0.633***	-6.343***	1.801	-6.438***	1.754
	(0.0385)	(0.122)	(0.0373)	(0.122)	(0.872)	(1.256)	(0.888)	(1.275)
Maturity ^2	0.00335**	-0.0419***	0.00424***	-0.0423***	0.131***	-0.0337	0.132***	-0.0310
	(0.00133)	(0.00709)	(0.00129)	(0.00710)	(0.0173)	(0.0798)	(0.0175)	(0.0809)
Auction fixed effects	No	No	No	No	**Yes**	**Yes**	**Yes**	**Yes**
Dealer fixed effects	No	No	**Yes**	**Yes**	No	No	**Yes**	**Yes**
Constant	-0.800*	-3.106***	0.401	-2.794**	139.6***	14.12	140.5***	10.46
	(0.475)	(1.152)	(0.608)	(1.173)	(10.93)	(31.06)	(11.33)	(31.52)
Observations	4535	1183	4535	1183	4535	1183	4535	1183
F-statistic testing coefficients on quadratic and cubic terms	68.99***	13.03***	77.02***	13.06***	327.54***	146.34***	324.95***	146.60***

This table reports the estimated regression coefficients from equations (1) for nominal government bond and index-linked bond auctions on the full sample 2015-2021 with combinations of fixed effects. The dependent variable is the offered yield in basis points, either nominal or index-linked (real). The independent variables are the offered volumes as a share of outstanding stock (including squared and cubed terms), the Riksbank holdings of government bonds as a share of the stock, the interaction between offered volumes and Riksbank holdings, the yield of the bond on the day before the auction, The announced volume of Riksbank demand, the U.S. ICE BofAML U.S. Bond Market Option Volatility index, years to maturity and auction and dealer fixed effects. Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The robust and the robust cluster estimators yield similar standard errors and inference.

Table 4. Estimates of the slope of the local supply curve of nominal and inflation-linked government bonds by individual dealers. Baseline results with offered yield adjusted for bid-shading using Nyborg et al. (2002) discount.

	(1) Nom Gov. Bond Offered Yield	(2) I-L Gov. Bond Offered Yield	(3) Nom Gov. Bond Offered Yield Nyborg Adjusted	(4) I-L Gov. Bond Offered Yield Nyborg Adjusted	(5) Nom Gov. Bond Offered Yield	(6) I-L Gov. Bond Offered Yield	(7) Nom Gov. Bond Offered Yield Nyborg Adjusted	(8) I-L Gov. Bond Offered Yield Nyborg Adjusted
Offered volume Share of Stock	-0.648***	-0.724***	-0.993***	-1.320***	-0.592***	-1.451***	-0.925***	-2.284***
	(0.0584)	(0.134)	(0.0951)	(0.209)	(0.0202)	(0.0822)	(0.0328)	(0.131)
Offered volume Share of Stock ^2	0.0429***	0.0775***	0.0626***	0.135***	0.0263***	0.0995***	0.0406***	0.168***
	(0.00376)	(0.0190)	(0.00653)	(0.0290)	(0.00123)	(0.0107)	(0.00206)	(0.0159)
Offered volume Share of Stock ^3	-0.000799***	-0.00233***	-0.00119***	-0.00388***	-0.000410***	-0.00229***	-0.000607***	-0.00399***
	(0.0000813)	(0.000715)	(0.000144)	(0.00107)	(0.0000267)	(0.000390)	(0.0000465)	(0.000548)
Riksbank Holdings Share of Stock	-0.00877*	-0.0895***	-0.0241***	-0.265***	0.0640**	0.160	0.0443	0.268
	(0.00510)	(0.0179)	(0.00804)	(0.0299)	(0.0318)	(0.119)	(0.0432)	(0.182)
Offered volume × RB Holdings	0.000848	-0.000784	0.00151	-0.000522	-0.000230	-0.00486**	0.000410	-0.00825**
	(0.000841)	(0.00280)	(0.00149)	(0.00461)	(0.000421)	(0.00226)	(0.000655)	(0.00360)
Riksbank Volume demand	0.483***	-1.925***	0.0626***	0.135***	0.0263***	0.0995***	0.0406***	0.168***
	(0.113)	(0.547)	(0.00653)	(0.0290)	(0.00123)	(0.0107)	(0.00206)	(0.0159)
Market yield lag	0.995***	1.003***	-0.00119***	-0.00388***	-0.000410***	-0.00229***	-0.000607***	-0.00399***
	(0.00152)	(0.00402)	(0.000144)	(0.00107)	(0.0000267)	(0.000390)	(0.0000465)	(0.000548)
U.S. Move index	0.00849**	0.0350***	1.037***	-4.652***	22.53***	-48.28	53.43***	-89.48*
	(0.00364)	(0.00834)	(0.172)	(0.929)	(2.320)	(31.69)	(3.502)	(49.75)
Maturity	-0.0101	0.614***	1.000***	1.010***	1.714***	0.877***	3.371***	0.969***
	(0.0385)	(0.122)	(0.00238)	(0.00688)	(0.106)	(0.0820)	(0.165)	(0.128)
Maturity ^2	0.00335**	-0.0419***	-0.0228***	0.00403	-2.075***	-0.309*	-4.929***	-0.481*
	(0.00133)	(0.00709)	(0.00627)	(0.0161)	(0.164)	(0.164)	(0.266)	(0.274)
Auction fixed effects	No	No	No	No	**Yes**	**Yes**	**Yes**	**Yes**
Dealer fixed effects	No	No	No	No	**Yes**	**Yes**	**Yes**	**Yes**
Constant	-0.800*	-3.106***	1.448*	0.574	140.5***	10.46	351.9***	46.11
	(0.475)	(1.152)	(0.760)	(2.075)	(11.33)	(31.52)	(19.06)	(49.66)
Observations	4535	1183	4535	1183	4535	1183	4535	1183

This table reports the estimated regression coefficients from equations (1) for nominal government bond and index-linked bond auctions on the full sample 2015-2021 with and without directly adjusting for bid-shading measured with the Nyborg discount measure. The dependent variable is the offered yield in basis points, either unadjusted, or adjusted for bid-shading, on nominal and index-linked (real) government bonds. The independent variables are the offered volumes as a share of outstanding stock (including squared and cubed terms), the Riksbank holdings of government bonds as a share of the stock, the interaction between offered volumes and Riksbank holdings, the yield of the bond on the day before the auction, the U.S. ICE BofAML U.S. Bond Market Option Volatility index, years to maturity and auction and dealer fixed effects. Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The robust and the robust cluster estimators yield similar standard errors and inference.

Table 5. Estimates of the slope of the local supply curve of nominal and inflation-linked government bonds by individual dealers with split sample.

	(1)	(2)	(3)	(4)	(5)	(6)
	Sample: 2015 - 2017		Sample: 2018 - 2019		Sample: 2020 - 2021	
	Nom Gov. Bond Offered Yield	I-L Gov. Bond Offered Yield	Nom Gov. Bond Offered Yield	I-L Gov. Bond Offered Yield	Nom Gov. Bond Offered Yield	I-L Gov. Bond Offered Yield
Offered volume Share of Stock	-0.603***	-1.463***	-0.711***	-2.530***	-0.559***	-0.886***
	(0.0287)	(0.0826)	(0.124)	(0.519)	(0.0387)	(0.187)
Offered volume Share of Stock ^2	0.0219***	0.0980***	0.0614***	0.463***	0.0306***	0.104***
	(0.00148)	(0.0106)	(0.0147)	(0.131)	(0.00286)	(0.0240)
Offered volume Share of Stock ^3	-0.000311***	-0.00216***	-0.00163***	-0.0312***	-0.000598***	-0.00390***
	(0.0000281)	(0.000355)	(0.000569)	(0.00976)	(0.0000714)	(0.000888)
Riksbank Holdings Share of Stock	0.0187	0.274	-0.0234	-0.861	0.0749	0.754***
	(0.0831)	(0.210)	(0.254)	(0.850)	(0.0714)	(0.192)
Offered volume × RB Holdings	0.00185**	-0.00222	-0.00625***	-0.0225**	-0.000811	-0.0271***
	(0.000816)	(0.00226)	(0.00158)	(0.0106)	(0.000570)	(0.00724)
Market yield lag	0.847***	-0.900	0.526***	-3.879***	0.621***	3.262***
	(0.0747)	(0.647)	(0.121)	(0.914)	(0.225)	(0.618)
U.S. Move index	-0.00713	4.125***	-0.132	-5.685***	2.568***	-0.0576***
	(0.104)	(1.449)	(0.124)	(1.002)	(0.743)	(0.0127)
Maturity	6.562***	59.47***	1.057	-30.46***	1.130	10.06***
	(2.400)	(19.68)	(1.730)	(5.198)	(2.202)	(2.278)
Maturity ^2	-0.378***	-2.313***	0.0862	3.412***	0.0102	-1.159***
	(0.120)	(0.745)	(0.199)	(0.469)	(0.0386)	(0.285)
Auction fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Dealer fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Constant	-25.19	-814.7***	-10.46**	-469.5***	-159.5***	342.8***
	(18.88)	(278.0)	(4.112)	(98.66)	(59.72)	(95.64)
Observations	2507	855	962	123	1049	205

This table reports the estimated regression coefficients from equations (1) for nominal government bond and index-linked auction for each reported sample. The dependent variable is the offered yield in basis points, either nominal or index-linked (real). The independent variables are the offered volumes as a share of outstanding stock (including squared and cubic terms), the Riksbank holdings of government bonds as a share of the stock, the interaction between offered volumes and Riksbank holdings, the yield of the bond on the day before the auction. The U.S. ICE BofAML U.S. Bond Market Option Volatility index, years to maturity and auction and dealer fixed effects. Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 6. Estimates of the slope of the local supply curve of nominal and inflation-linked government bonds by individual dealers with risk perception interaction effects.

	(1) Nom Gov. Bond Offered Yield	(2) I-L Gov. Bond Offered Yield
Offered volume Share of Stock	-0.598***	-1.144***
	(0.0369)	(0.175)
Offered volume Share of Stock ^2	0.0216***	0.0405
	(0.00346)	(0.0357)
Offered volume Share of Stock ^3	-0.000272***	-0.000748
	(0.0000757)	(0.00189)
Riksbank Holdings Share of Stock	0.0684	0.224*
	(0.0661)	(0.136)
Offered volume × CISS	0.0405	-4.660***
	(0.200)	(0.924)
Offered volume^2 × CISS	0.0270	0.790***
	(0.0197)	(0.156)
Offered volume^3 × CISS	-0.000840*	-0.0285***
	(0.000467)	(0.00770)
Market yield lag	-7.566***	2.667***
	(0.700)	(0.965)
Maturity	50.27***	2.515**
	(3.432)	(1.110)
Maturity ^2	-0.455***	-0.581*
	(0.0522)	(0.301)
Auction fixed effects	Yes	Yes
Dealer fixed effects	Yes	Yes
Constant	-162.8***	275.9*
	(10.69)	(162.2)
Observations	3253	631

This table reports the estimated regression coefficients from equations (1) for nominal government bond and index-linked bond auctions on the full sample 2015-2021 with combinations of fixed effects. The dependent variable is the offered yield in basis points, either nominal or index-linked (real). The independent variables are the offered volumes as a share of outstanding stock (including squared and cubed terms), the Riksbank holdings of government bonds as a share of the stock, the interaction between offered volume and the CISS index, the yield of the bond on the day before the auction, years to maturity and auction and dealer fixed effects. Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The robust and the robust cluster estimators yield similar standard errors and inference.

Table 7. Estimates of the slope of the local supply curve of nominal and inflation-linked government bonds by individual dealers with further interaction terms.

	(1) Nom Gov. Bond Offered Yield	(2) I-L Gov. Bond Offered Yield
Offered volume Share of Stock	-0.512***	-1.319***
	(0.0287)	(0.163)
Offered volume Share of Stock ^2	0.0160***	0.0955***
	(0.00203)	(0.0234)
Offered volume Share of Stock ^3	-0.000100**	-0.00260***
	(0.0000406)	(0.000887)
Riksbank Holdings Share of Stock	0.0696	0.313*
	(0.0547)	(0.160)
Offered volume × RB Holdings	-0.00637***	-0.0139
	(0.000929)	(0.00889)
Offered volume ^2 × RB Holdings	0.000939***	0.000334
	(0.0000991)	(0.00119)
Offered volume ^3 × RB Holdings	-0.0000324***	0.0000201
	(0.00000335)	(0.0000446)
Market yield lag	7.123***	2.647***
	(0.970)	(0.953)
U.S. Move index	-2.188***	0.256
	(0.232)	(0.174)
Maturity	-64.51***	6.040**
	(9.881)	(3.074)
Maturity ^2	1.326***	-0.808*
	(0.203)	(0.443)
Auction fixed effects	Yes	Yes
Dealer fixed effects	Yes	Yes
Constant	440.9***	242.9*
	(57.75)	(142.1)
Observations	4535	1183
F-statistic testing coefficients on three interaction terms	32.02***	3.76**

This table reports the estimated regression coefficients from equations (1) for nominal government bond and index-linked auction on the full sample 2015-2021 with additional interaction terms between offered volume and Riksbank holdings. The dependent variable is the offered yield in basis points, either nominal or index-linked (real). The independent variables are the offered volumes as a share of outstanding stock (including squared and cubed terms), the Riksbank holdings of government bonds as a share of the stock, the interaction between offered volumes and Riksbank holdings, the yield of the bond on the day before the auction. The U.S. ICE BofAML U.S. Bond Market Option Volatility index, years to maturity and auction and dealer fixed effects. Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Appendix

Table A1. Estimates of the slope of the local supply curve of nominal and inflation-linked government bonds by individual dealers. Main results with combinations of fixed-effects with clustered standard errors.

	(1) Nom Gov. Bond Offered Yield	(2) I-L Gov. Bond Offered Yield	(3) Nom Gov. Bond Offered Yield	(4) I-L Gov. Bond Offered Yield	(5) Nom Gov. Bond Offered Yield	(6) I-L Gov. Bond Offered Yield	(7) Nom Gov. Bond Offered Yield	(8) I-L Gov. Bond Offered Yield
Offered volume Share of Stock	-0.632***	-0.754***	-0.609***	-0.743***	-0.588***	-1.446***	-0.593***	-1.455***
	(0.0940)	(0.199)	(0.0910)	(0.193)	(0.0402)	(0.127)	(0.0408)	(0.128)
Offered volume Share of Stock ^2	0.0420***	0.0797***	0.0413***	0.0775***	0.0260***	0.0993***	0.0262***	0.0996***
	(0.00731)	(0.0277)	(0.00717)	(0.0266)	(0.00238)	(0.0155)	(0.00239)	(0.0154)
Offered volume Share of Stock ^3	-0.000791***	-0.00237**	-0.000781***	-0.00228**	-0.000408***	-0.00229***	-0.000409***	-0.00229***
	(0.000158)	(0.00101)	(0.000155)	(0.000973)	(0.0000501)	(0.000577)	(0.0000498)	(0.000568)
Riksbank Holdings Share of Stock	-0.0224	-0.0905**	-0.0130	-0.0805**	0.0106	0.118	0.0130	0.124
	(0.0148)	(0.0373)	(0.0131)	(0.0364)	(0.0482)	(0.118)	(0.0465)	(0.121)
Offered volume × RB Holdings	0.00153	-0.000945	0.00128	-0.00120	-0.000302	-0.00505	-0.000173	-0.00480
	(0.00181)	(0.00600)	(0.00178)	(0.00587)	(0.000913)	(0.00369)	(0.000924)	(0.00365)
Market yield lag	0.995***	1.004***	0.995***	1.003***	6.356***	1.613**	6.451***	1.642**
	(0.00539)	(0.00945)	(0.00538)	(0.00947)	(0.762)	(0.683)	(0.733)	(0.703)
U.S. Move index	0.0135	0.0407**	0.0110	0.0412**	-2.035***	0.0665	-2.061***	0.0766
	(0.0119)	(0.0180)	(0.0118)	(0.0177)	(0.159)	(0.116)	(0.153)	(0.120)
Maturity	-0.0407	0.621**	-0.0536	0.641**	-56.75***	2.720	-57.71***	2.869
	(0.119)	(0.309)	(0.116)	(0.307)	(7.730)	(2.159)	(7.429)	(2.232)
Maturity ^2	0.00316	-0.0423**	0.00419	-0.0428**	1.167***	-0.326	1.187***	-0.343
	(0.00414)	(0.0181)	(0.00392)	(0.0179)	(0.159)	(0.317)	(0.153)	(0.327)
Auction fixed effects	No	No	No	No	**Yes**	**Yes**	**Yes**	**Yes**
Dealer fixed effects	No	No	**Yes**	**Yes**	No	No	**Yes**	**Yes**
Constant	0.0226	-4.122*	0.731	-3.867	398.3***	90.57	404.3***	94.20
	(1.351)	(2.359)	(1.385)	(2.380)	(43.23)	(101.7)	(41.55)	(104.6)
Observations	4535	1183	4535	1183	4535	1183	4535	1183

This table reports the estimated regression coefficients from equations (1) for nominal government bond and index-linked bond auctions on the full sample 2015-2021 with combinations of fixed effects. The dependent variable is the offered yield in basis points, either nominal or index-linked (real). The independent variables are the offered volumes as a share of outstanding stock (including squared and cubed terms), the Riksbank holdings of government bonds as a share of the stock, the interaction between offered volumes and Riksbank holdings, the yield of the bond on the day before the auction, the U.S. ICE BofAML U.S. Bond Market Option Volatility index, years to maturity and auction and dealer fixed effects. Clustered standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A2. Estimates of the slope of the local supply curve of nominal and inflation-linked government bonds by individual dealers. Additional combinations of fixed-effects.

	(1) Nom Gov. Bond Offered Yield	(2) I-L Gov. Bond Offered Yield	(3) Nom Gov. Bond Offered Yield	(4) I-L Gov. Bond Offered Yield	(5) Nom Gov. Bond Offered Yield	(6) I-L Gov. Bond Offered Yield
Offered volume Share of Stock	-0.593***	-1.464***	-0.538***	-0.797***	-0.574***	-1.175***
	(0.0203)	(0.0795)	(0.0510)	(0.128)	(0.0301)	(0.0897)
Offered volume Share of Stock ^2	0.0262***	0.0997***	0.0334***	0.0701***	0.0304***	0.0894***
	(0.00123)	(0.0103)	(0.00319)	(0.0166)	(0.00200)	(0.0124)
Offered volume Share of Stock ^3	-0.000409***	-0.00229***	-0.000610***	-0.00187***	-0.000509***	-0.00208***
	(0.0000269)	(0.000379)	(0.0000675)	(0.000595)	(0.0000435)	(0.000447)
Riksbank Holdings Share of Stock	0.0549	0.273*	0.0159*	-0.0814***	-0.0260***	0.146***
	(0.0556)	(0.157)	(0.00862)	(0.0229)	(0.00339)	(0.0260)
Offered volume × RB Holdings	-0.000172	-0.00411*	-0.000603	-0.00556*	0.00116**	-0.00530**
	(0.000426)	(0.00232)	(0.000788)	(0.00296)	(0.000529)	(0.00229)
Market yield lag	7.101***	2.534***	1.001***	0.986***	1.002***	0.956***
	(0.972)	(0.953)	(0.00202)	(0.00439)	(0.00221)	(0.00618)
U.S. Move index	-2.194***	0.224	0.0254***	0.0129*	-0.231***	0.629***
	(0.230)	(0.173)	(0.00440)	(0.00725)	(0.0158)	(0.102)
Maturity	-64.31***	5.729*	-0.0840	1.021***	-0.178***	0.449***
	(9.904)	(3.083)	(0.115)	(0.229)	(0.0481)	(0.129)
Maturity ^2	1.322***	-0.758*	0.0183***	-0.0245*	0.00543***	0.00991
	(0.203)	(0.443)	(0.00401)	(0.0126)	(0.00129)	(0.00872)
Auction fixed effects	**Yes**	**Yes**	No	No	No	No
Dealer fixed effects	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Bond (ISIN) fixed effects	No	No	**Yes**	**Yes**	No	No
Time fixed effects	No	No	No	No	**Yes**	**Yes**
Constant	440.9***	227.0	-1.417	-7.966***	18.93***	-51.85***
	(57.71)	(142.1)	(0.892)	(1.161)	(1.487)	(7.428)
Observations	4535	1183	4535	1183	4535	1183

This table reports the estimated regression coefficients from equations (1) for nominal government bond and index-linked auction on the full sample 2015-2021 with additional combinations of fixed effects. The dependent variable is the offered yield in basis points, either nominal or index-linked (real). The independent variables are the offered volumes as a share of outstanding stock (including squared and cubed terms), the Riksbank holdings of government bonds as a share of the stock, the interaction between offered volumes and Riksbank holdings, the yield of the bond on the day before the auction. The U.S. ICE BofAML U.S. Bond Market Option Volatility index, years to maturity and various combinations of fixed effects. Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A3. Estimates of the slope of the local supply curve of nominal government bonds by individual dealers. Main results with combinations of fixed-effects with clustered standard errors.

	(1) Nom Gov. Bond	(3) Nom Gov. Bond	(5) Nom Gov. Bond	(7) Nom Gov. Bond
	Offered Price 100 log(Price)	Offered Price 100 log(Price)	Offered Price 100 log(Price)	Offered Price 100 log(Price)
Offered volume Share of Stock	0.0380***	0.0393***	0.0460***	0.0463***
	(0.00567)	(0.00567)	(0.00286)	(0.00288)
Offered volume Share of Stock ^2	-0.00251***	-0.00255***	-0.00160***	-0.00162***
	(0.000318)	(0.000318)	(0.000147)	(0.000146)
Offered volume Share of Stock ^3	0.0000508***	0.0000511***	0.0000239***	0.0000241***
	(0.00000618)	(0.00000614)	(0.00000310)	(0.00000303)
Riksbank Holdings Share of Stock	0.00148***	0.00160***	-0.00234	-0.00216
	(0.000429)	(0.000438)	(0.00315)	(0.00310)
Offered volume × RB Holdings	0.000114	0.0000863	-0.0000835	-0.0000885
	(0.0000803)	(0.0000802)	(0.0000625)	(0.0000626)
Market yield lag	1.005***	1.005***	1.006***	1.006***
	(0.000664)	(0.000655)	(0.00150)	(0.00148)
U.S. Move index	-0.00166***	-0.00178***	0.0856***	0.0850***
	(0.000394)	(0.000391)	(0.00776)	(0.00769)
Maturity	0.0401***	0.0406***	1.232***	1.221***
	(0.00405)	(0.00403)	(0.118)	(0.117)
Maturity ^2	-0.000260	-0.000274	-0.0427***	-0.0423***
	(0.000239)	(0.000239)	(0.00428)	(0.00424)
Auction fixed effects	No	No	**Yes**	**Yes**
Dealer fixed effects	No	**Yes**	No	**Yes**
Constant	-2.548***	-2.664***	-16.28***	-16.22***
	(0.319)	(0.321)	(0.888)	(0.882)
Observations	3245	3245	3245	3245

This table reports the estimated regression coefficients from equations (1) for nominal government bond auction on the full sample 2015-2021 with additional combinations of fixed effects. The dependent variable is the offered price (100xlog), either nominal or index-linked (real). The independent variables are the offered volumes as a share of outstanding stock (including squared and cubed terms), the Riksbank holdings of government bonds as a share of the stock, the interaction between offered volumes and Riksbank holdings, the yield of the bond on the day before the auction. The U.S. ICE BofAML U.S. Bond Market Option Volatility index, years to maturity and fixed effects. Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A4. Estimates of the slope of the local supply curve of nominal and inflation-linked government bonds by individual dealers. Offered volume in billion SEK instead of as share of outstanding amount.

	(1) Nom Gov. Bond Offered Yield	(2) I-L Gov. Bond Offered Yield	(3) Nom Gov. Bond Offered Yield	(4) I-L Gov. Bond Offered Yield	(5) Nom Gov. Bond Offered Yield	(6) I-L Gov. Bond Offered Yield	(7) Nom Gov. Bond Offered Yield	(8) I-L Gov. Bond Offered Yield
Offered volume Billion SEK	-1.373***	-5.346***	-1.422***	-5.030***	-1.149***	-6.111***	-1.177***	-6.204***
	(0.243)	(1.636)	(0.253)	(1.551)	(0.112)	(1.029)	(0.113)	(1.009)
Offered volume Billion SEK ^2	0.156**	4.729***	0.161***	4.440***	0.117***	2.216***	0.122***	2.268***
	(0.0604)	(1.489)	(0.0618)	(1.399)	(0.0263)	(0.792)	(0.0258)	(0.773)
Offered volume Billion SEK ^3	-0.00539	-1.176***	-0.00529	-1.121***	-0.00537***	-0.367*	-0.00560***	-0.380*
	(0.00424)	(0.421)	(0.00429)	(0.395)	(0.00183)	(0.196)	(0.00180)	(0.192)
Riksbank Holdings Share of Stock	-0.0240*	-0.0431	-0.0170	-0.0361	0.0453	0.0809	0.0524	0.0830
	(0.0139)	(0.0433)	(0.0126)	(0.0417)	(0.0384)	(0.136)	(0.0359)	(0.135)
Offered volume × RB Holdings	0.00571	-0.0864*	0.00661*	-0.0855*	-0.000326	-0.0422	0.000130	-0.0403
	(0.00386)	(0.0510)	(0.00384)	(0.0484)	(0.00205)	(0.0262)	(0.00208)	(0.0258)
Market yield lag	0.995***	1.000***	0.995***	0.999***	8.640***	1.066	8.784***	1.078
	(0.00527)	(0.00877)	(0.00524)	(0.00873)	(0.597)	(0.776)	(0.560)	(0.773)
U.S. Move index	0.0203*	0.0305*	0.0174	0.0310*	-2.615***	0.106	-2.648***	0.112
	(0.0117)	(0.0181)	(0.0116)	(0.0178)	(0.124)	(0.129)	(0.117)	(0.129)
Maturity	-0.146	0.631**	-0.156	0.645**	-79.52***	-0.342	-80.98***	-0.286
	(0.115)	(0.291)	(0.113)	(0.288)	(6.067)	(2.398)	(5.684)	(2.385)
Maturity ^2	0.00574	-0.0441**	0.00679*	-0.0443***	1.622***	-0.00453	1.652***	-0.0112
	(0.00400)	(0.0170)	(0.00377)	(0.0168)	(0.125)	(0.356)	(0.117)	(0.354)
Auction fixed effects	No	No	No	No	**Yes**	**Yes**	**Yes**	**Yes**
Dealer fixed effects	No	No	**Yes**	**Yes**	No	No	**Yes**	**Yes**
Constant	0.485	-3.774	1.354	-3.597	536.9***	5.439	545.4***	6.681
	(1.339)	(2.342)	(1.400)	(2.326)	(33.86)	(115.8)	(31.78)	(115.3)
Observations	4535	1183	4535	1183	4535	1183	4535	1183

This table reports the estimated regression coefficients from equations (1) for nominal government bond and index-linked auction on the full sample 2015-2021 with offered volume in billion SEK instead of as in share of outstanding amount (share of stock). The dependent variable is the offered yield in basis points, either nominal or index-linked (real). The independent variables are the offered volumes in billion SEK (including squared and cubed terms), the Riksbank holdings of government bonds as a share of the stock, the interaction of offered volumes and Riksbank holdings, the yield of the bond on the day before the auction. The U.S. ICE BofAML U.S. Bond Market Option Volatility index, years to maturity and various combinations of fixed effects. Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A5. Estimates of the slope of the local supply curve of nominal and inflation-linked government bonds by individual dealers. Baseline results estimated only on auctions where Riksbank requested exactly the same amount as it purchased.

	(1) Nom Gov. Bond Offered Yield	(2) I-L Gov. Bond Offered Yield	(3) Nom Gov. Bond Offered Yield	(4) I-L Gov. Bond Offered Yield	(5) Nom Gov. Bond Offered Yield	(6) I-L Gov. Bond Offered Yield	(7) Nom Gov. Bond Offered Yield	(8) I-L Gov. Bond Offered Yield
Offered volume Share of Stock	-0.565***	-0.648***	-0.579***	-0.617***	-0.594***	-1.438***	-0.597***	-1.433***
	(0.0669)	(0.194)	(0.0669)	(0.190)	(0.0249)	(0.119)	(0.0252)	(0.120)
Offered volume Share of Stock ^2	0.0389***	0.142***	0.0394***	0.137***	0.0262***	0.133***	0.0265***	0.133***
	(0.00439)	(0.0269)	(0.00438)	(0.0261)	(0.00144)	(0.0145)	(0.00143)	(0.0147)
Offered volume Share of Stock ^3	-0.000740***	-0.00615***	-0.000743***	-0.00594***	-0.000402***	-0.00445***	-0.000405***	-0.00443***
	(0.0000917)	(0.000996)	(0.0000911)	(0.000971)	(0.0000289)	(0.000539)	(0.0000281)	(0.000551)
Riksbank Holdings Share of Stock	-0.00272	-0.0378*	-0.00416	-0.0312	0.0128	0.205	0.0193	0.204
	(0.00524)	(0.0208)	(0.00536)	(0.0208)	(0.0554)	(0.135)	(0.0506)	(0.135)
Offered volume × RB Holdings	0.00144	-0.0287***	0.00175*	-0.0291***	-0.000430	-0.0152***	-0.000346	-0.0153***
	(0.000935)	(0.00517)	(0.000933)	(0.00500)	(0.000514)	(0.00402)	(0.000517)	(0.00402)
Market yield lag	0.992***	1.004***	0.992***	1.002***	1.242***	1.948**	1.261***	1.943**
	(0.00237)	(0.00463)	(0.00237)	(0.00458)	(0.0805)	(0.781)	(0.0793)	(0.779)
U.S. Move index	0.0175***	0.0258***	0.0184***	0.0252***	-1.264***	0.148	-1.283***	0.151
	(0.00425)	(0.00823)	(0.00426)	(0.00830)	(0.104)	(0.155)	(0.104)	(0.156)
Maturity	0.0241	1.220***	0.0238	1.233***	-16.63***	3.568	-17.14***	3.587
	(0.0542)	(0.204)	(0.0542)	(0.201)	(2.798)	(2.395)	(2.657)	(2.394)
Maturity ^2	0.00180	-0.0810***	0.00185	-0.0814***	0.541***	-0.469	0.557***	-0.469
	(0.00213)	(0.0135)	(0.00213)	(0.0134)	(0.0924)	(0.355)	(0.0870)	(0.354)
Auction fixed effects	No	No	No	No	**Yes**	**Yes**	**Yes**	**Yes**
Dealer fixed effects	No	No	**Yes**	**Yes**	No	No	**Yes**	**Yes**
Constant	-1.687***	-5.884***	-0.676	-5.697***	186.5***	139.2	190.2***	138.3
	(0.543)	(1.163)	(0.826)	(1.186)	(20.89)	(116.4)	(20.29)	(116.0)
Observations	2745	611	2745	611	2745	611	2745	611

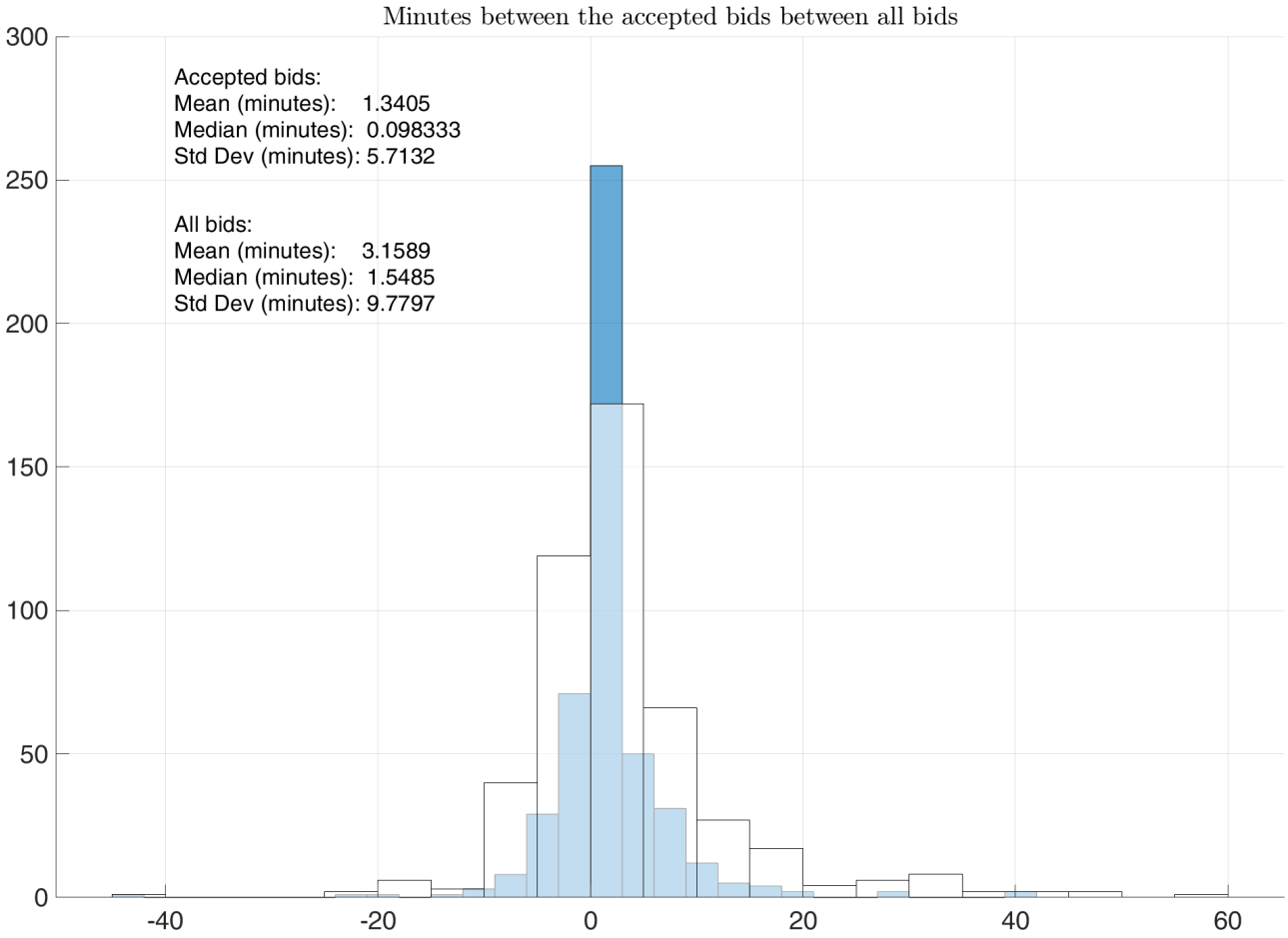
This table reports the estimated regression coefficients from equations (1) for nominal government bond and index-linked bond auctions on the full sample 2015-2021 estimated only on auctions where Riksbank requested exactly the same amount as it purchased (not available during 2017). The dependent variable is the offered yield in basis points, either nominal or index-linked (real). The independent variables are the offered volumes as a share of outstanding stock (including squared and cubed terms), the Riksbank holdings of government bonds as a share of the stock, the interaction between offered volumes and Riksbank holdings, the yield of the bond on the day before the auction, the U.S. ICE BofAML U.S. Bond Market Option Volatility index, years to maturity and auction and dealer fixed effects. Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The robust and the robust cluster estimators yield similar standard errors and inference.

Table A6. Estimates of the slope of the local supply curve of nominal and inflation-linked government bonds by individual dealers. Baseline results controlling for a measure of central bank demand uncertainty.

	(1) Nom Gov. Bond Offered Yield	(2) I-L Gov. Bond Offered Yield	(3) Nom Gov. Bond Offered Yield	(4) I-L Gov. Bond Offered Yield	(5) Nom Gov. Bond Offered Yield	(6) I-L Gov. Bond Offered Yield	(7) Nom Gov. Bond Offered Yield	(8) I-L Gov. Bond Offered Yield
Offered volume Share of Stock	-0.611***	-0.577***	-0.619***	-0.548***	-0.579***	-1.455***	-0.584***	-1.451***
	(0.0634)	(0.191)	(0.0632)	(0.188)	(0.0224)	(0.119)	(0.0225)	(0.120)
Offered volume Share of Stock ^2	0.0400***	0.133***	0.0403***	0.128***	0.0253***	0.136***	0.0255***	0.135***
	(0.00397)	(0.0269)	(0.00397)	(0.0262)	(0.00131)	(0.0145)	(0.00130)	(0.0147)
Offered volume Share of Stock ^3	-0.000739***	-0.00589***	-0.000743***	-0.00567***	-0.000390***	-0.00454***	-0.000392***	-0.00452***
	(0.0000819)	(0.000995)	(0.0000817)	(0.000977)	(0.0000274)	(0.000536)	(0.0000267)	(0.000548)
Riksbank Holdings Share of Stock	-0.00623	-0.0352*	-0.00817	-0.0289	0.0228	0.273**	0.0205	0.271**
	(0.00513)	(0.0209)	(0.00519)	(0.0211)	(0.0367)	(0.125)	(0.0367)	(0.126)
Offered volume × RB Holdings	0.00155*	-0.0299***	0.00177**	-0.0299***	-0.000434	-0.0157***	-0.000336	-0.0156***
	(0.000884)	(0.00512)	(0.000879)	(0.00492)	(0.000476)	(0.00403)	(0.000479)	(0.00403)
Central Bank Demand Uncertainty	-1.227***	-2.256***	-1.086***	-1.987**	-146.6***	54.21**	-145.0***	53.86**
	(0.376)	(0.861)	(0.376)	(0.841)	(52.74)	(24.38)	(51.46)	(24.67)
Market yield lag	0.992***	1.000***	0.992***	0.999***	4.635***	0.860***	4.610***	0.859***
	(0.00212)	(0.00496)	(0.00212)	(0.00494)	(1.242)	(0.0814)	(1.212)	(0.0825)
U.S. Move index	0.0161***	0.0348***	0.0173***	0.0339***	-7.174***	-0.410**	-7.119***	-0.403**
	(0.00403)	(0.00840)	(0.00404)	(0.00849)	(2.128)	(0.161)	(2.076)	(0.164)
Maturity	0.0250	1.041***	0.0242	1.067***	-81.41***	1.954*	-80.85***	1.983*
	(0.0510)	(0.209)	(0.0511)	(0.207)	(23.45)	(1.172)	(22.88)	(1.195)
Maturity ^2	0.00156	-0.0670***	0.00151	-0.0685***	2.296***	-0.0218	2.280***	-0.0239
	(0.00202)	(0.0143)	(0.00203)	(0.0141)	(0.634)	(0.0748)	(0.618)	(0.0767)
Auction fixed effects	No	No	No	No	**Yes**	**Yes**	**Yes**	**Yes**
Dealer fixed effects	No	No	**Yes**	**Yes**	No	No	**Yes**	**Yes**
Constant	-0.810	-5.348***	0.0776	-5.212***	991.1***	-40.82***	983.6***	-41.12***
	(0.528)	(1.157)	(0.766)	(1.189)	(290.0)	(8.741)	(282.9)	(8.851)
Observations	3253	631	3253	631	3253	631	3253	631

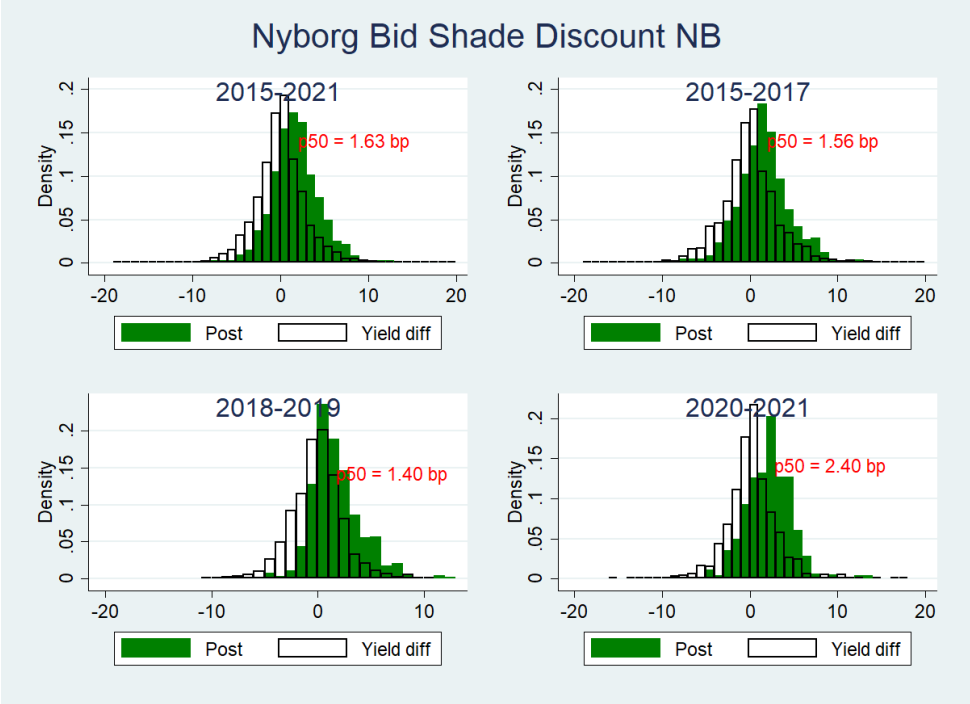
This table reports the estimated regression coefficients from equations (1) for nominal government bond and index-linked bond auctions on the full sample 2015-2021 controlling for a measure of Riksbank demand uncertainty (not available during 2017). The measure is defined as the share of the requested interval of the total requested volume. The higher the interval the more uncertain Riksbank demand is. The dependent variable is the offered yield in basis points, either nominal or index-linked (real). The independent variables are the offered volumes as a share of outstanding stock (including squared and cubed terms), the Riksbank holdings of government bonds as a share of the stock, the interaction between offered volumes and Riksbank holdings, the yield of the bond on the day before the auction, the U.S. ICE BofAML U.S. Bond Market Option Volatility index, years to maturity and auction and dealer fixed effects. Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The robust and the robust cluster estimators yield similar standard errors and inference.

Figure A1. Distribution of minutes between marginal bid and all submitted bids.



Note. The filled bars show the distribution of minutes between the accepted bids.

Figure A2. Distribution of Nyborg et al. (2002) measure of discount for nominal (first row) and index linked government bonds and the daily change in yields (the day before the auction with the closing yield at the day of the auction) for subsamples. “Pre” denotes the discount measure computed with the yield on the day before the auction and “Post” measure computed with the yield on the day of the auction.



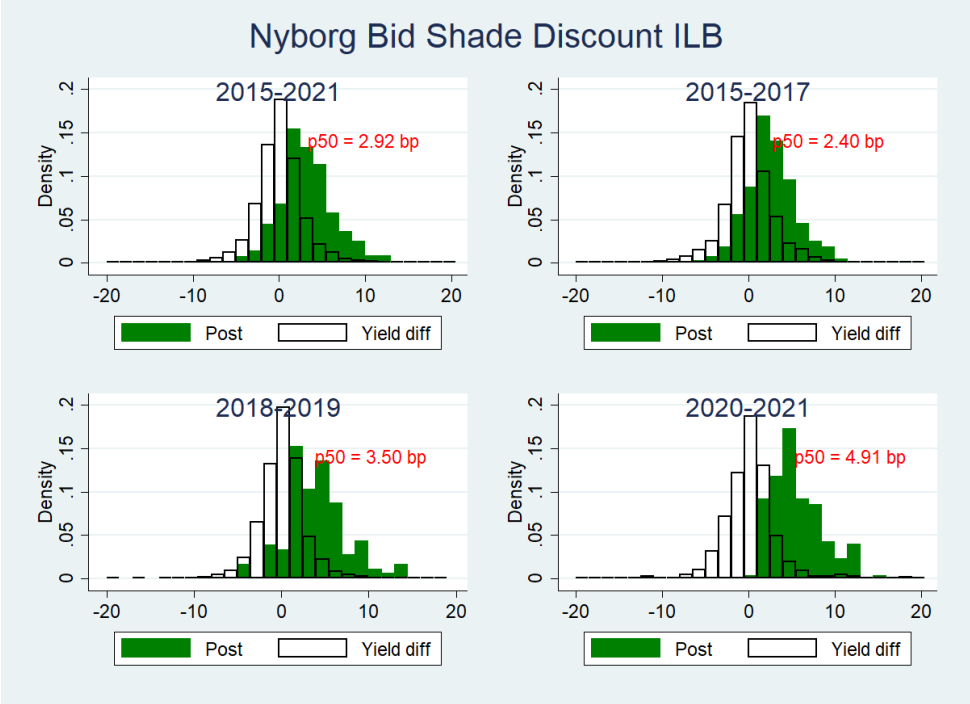
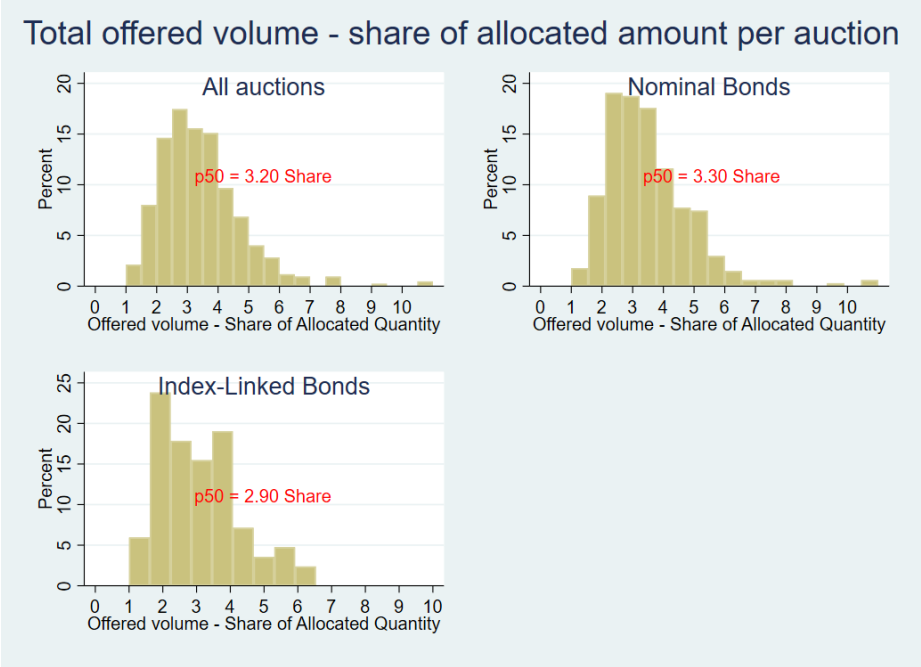
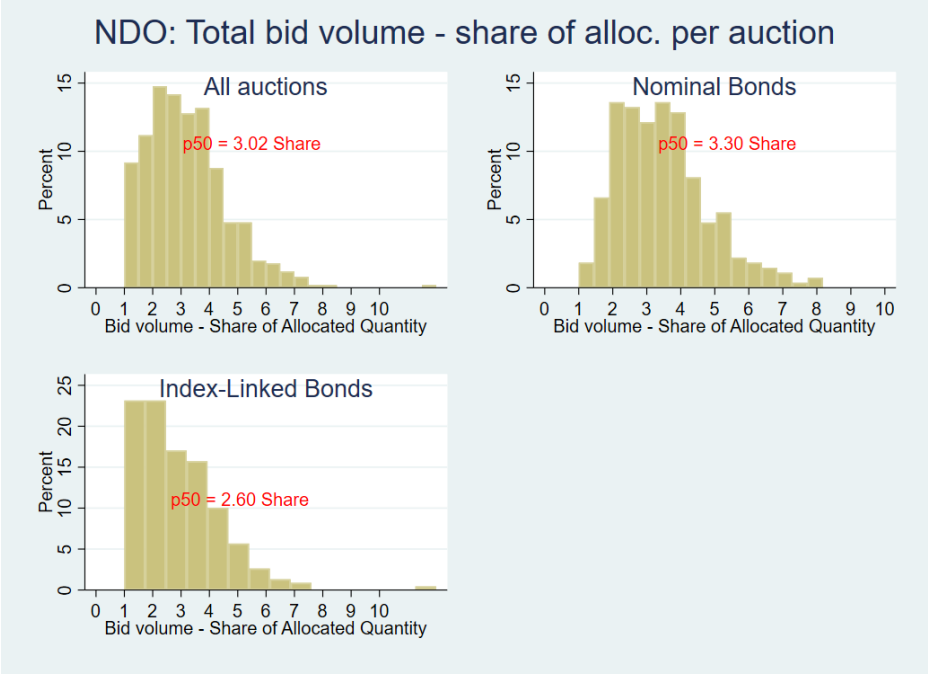


Figure A3. Distribution of offered and bid volume as a share of allocated amounts in Riksbank reverse auctions and in National Debt Office regular auctions 2015-2021.

Panel (a). Riksbank reverse auctions 2015-2021.



Panel (b). National Debt Office regular bond auctions 2015-2021.



Instrumenting the Riksbank holdings of government bonds

Even though the Riksbank's purchasing officers at the day of the auction have no leeway in allocating what individual bonds to purchase, the Riksbank's overall decisions regarding overall holdings of bonds might still be determined simultaneously with market conditions and potentially yield inconsistent estimates. To address the potential concern, I resort to IV estimation, exploiting the close connection between asset purchase programmes in Sweden and the Euro area. Euro area public sector asset purchases should be both a relevant and arguably exogenous instrument for Swedish government bond purchases.[20] Accordingly, the first-stage regressions in the 2SLS set-up take the form:

$$Q_{b,t} = \alpha Q_t^{PSPP} + \varphi M_t + \mu_1 m_{b,t} + \mu_2 m_{b,t}^2 + \lambda_b + \lambda_j + \varepsilon_{b,t}. \quad (2)$$

where Q_t^{PSPP} is the ECB holdings of public sector securities under the public sector purchase programme (PSPP), λ_b and λ_j denote security- and dealer-fixed effects, respectively, $\varepsilon_{b,t}$ is an error term, and all other variables are defined as above. I exploit the variation in ECBs PSPP holdings to compute fitted values of the Riksbank holdings $\hat{Q}_{b,t}$. Under the usual validity assumptions variation in $\hat{Q}_{b,t}$ is independent from Swedish conditions and returns. The second-stage regression corresponds to equation (1), but replaces the Riksbank holdings with its fitted values $\hat{Q}_{b,t}$ from equation (2).

Table A7 compare the baseline estimates with instrumental variable estimates. The estimates are very similar to the baseline estimates indicating that endogeneity of Riksbank holdings is not an essential concern here. The first-stage F-statistics are 1155.41 (column 3) and 642.64 (column 4) which indicates that the instruments are valid.

[20] The Eurosystem conducted net purchases of public sector securities under the public sector purchase programme (PSPP) between 9 March 2015 and 19 December 2018. As of January 2019, the Eurosystem continued to reinvest the principal payments from maturing securities held in the PSPP portfolio. As of 1 November 2019 the Eurosystem restarted net purchases under the PSPP. See e.g. the Minutes in February 2015 for a discussion (Sveriges Riksbank 2015b).

Table A7. Estimates of the slope of the local supply curve of nominal and inflation-linked government bonds by individual dealers. Comparison with instrumental variable estimates.

	(1)	(2)	(3)	(4)
	Panel fixed effects		Instrumental variable panel fixed effects	
	Nom Gov. Bond Offered Yield	I-L Gov. Bond Offered Yield	Nom Gov. Bond Offered Yield	I-L Gov. Bond Offered Yield
Offered volume Share of Stock	-0.593***	-1.464***	-0.612***	-1.478***
	(0.0203)	(0.0795)	(0.0276)	(0.0817)
Offered volume Share of Stock ^2	0.0262***	0.0997***	0.0264***	0.0995***
	(0.00123)	(0.0103)	(0.00123)	(0.0105)
Offered volume Share of Stock ^3	-0.000409***	-0.00229***	-0.000410***	-0.00228***
	(0.0000269)	(0.000379)	(0.0000268)	(0.000385)
Riksbank Holdings Share of Stock	0.0549	0.273*	-0.369	0.170
	(0.0556)	(0.157)	(0.477)	(0.544)
Offered volume # Riksbank Holdings	-0.000172	-0.00411*	0.000405	-0.00335
	(0.000426)	(0.00232)	(0.000751)	(0.00266)
Yield lag	7.101***	2.534***	7.282***	2.110
	(0.972)	(0.953)	(1.401)	(3.786)
U.S. Move index	-2.194***	0.224	-2.669***	0.308
	(0.230)	(0.173)	(0.853)	(1.148)
Maturity	-64.31***	5.729*	-66.45***	5.963
	(9.904)	(3.083)	(14.60)	(17.12)
Maturity ^2	1.322***	-0.758*	1.346***	-0.664
	(0.203)	(0.443)	(0.274)	(2.089)
Auction fixed effects	Yes	Yes	Yes	Yes
Dealer fixed effects	Yes	Yes	Yes	Yes
Constant	440.9***	227.0	499.6***	148.8
	(57.71)	(142.1)	(141.1)	(514.5)
Observations	4535	1183	4535	1183
F-statistic testing coefficients on quadratic and cubic terms	327.07***	153.50***	368.64***	152.30***

This table reports the estimated regression coefficients from equations (1) for nominal government bond and index-linked auction on the full sample 2015-2021 with instrumental variable regressions reported in columns (3) and (4). The dependent variable is the offered yield in basis points, either nominal or index-linked (real). The independent variables are the offered volumes as a share of outstanding stock (including squared and cubed terms), the Riksbank holdings of government bonds as a share of the stock, the interaction between offered volumes and Riksbank holdings, the yield of the bond on the day before the auction. The U.S. ICE BofAML U.S. Bond Market Option Volatility index, years to maturity and auction and dealer fixed effects. Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Instrumented variable (columns 3 and 4): Riksbank Holdings Share of Stock. Instruments: ECB Public sector purchase holdings in EUR, U.S. Move index, Maturity and Maturity ^2, bond, and dealer specific fixed effects. The first-stage F-statistics are 1155.41 (column 3) and 642.64 (column 4).

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