Testing the Portfolio Rebalancing Channel of Quantitative Easing*

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Abstract

The Fed argues that quantitative easing (QE) lowers yields across asset markets via the portfolio rebalancing channel. I provide a direct test for this channel, quantify its magnitude, and document its real effects. I first construct a novel QE shock measuring the unexpected amount that the Fed purchases of each Treasury during each QE operation. Combining this shock with holdings data, I find that investors rebalance over 60% of proceeds from QE-induced Treasury sales into corporate bonds, predominantly into bonds with similar maturities to those the Fed purchased and bonds issued by firms whose bonds they already own. Consistent with the portfolio rebalancing channel, the yields of these bonds fall. To quantify the channel's magnitude, I use my reduced-form estimates to calibrate a preferred habitat model with investors who substitute between Treasurys and corporate bonds. I find a large effect: $100 billion of Treasury purchases lower corporate bond yields by 8bps on impact, with the effect dissipating over the following year. Turning to real effects, I find that affected firms increase bond issuance and do so at lower yields. Firms use the funds to increase their capital investment and cash buffers. Overall, the results point to a strong portfolio rebalancing channel.

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1 Introduction

To date, the Fed has purchased over \$5.6 trillion of Treasurys during its quantitative easing (QE) programs. The aim of these purchases is to stimulate the real economy by lowering the cost of capital. To achieve this, Fed purchases in the Treasury market need to have broad effects that span across other asset markets, including the corporate bond market. The Fed argues that QE achieves this via the portfolio rebalancing channel: when the Fed purchases a Treasury, investors who sell this Treasury purchase securities with broadly similar characteristics in other asset markets, leading to an increase in those securities' prices (Bernanke et al., 2010)[1]. Under this view, if the Fed purchases long-maturity Treasurys, investors who previously held these Treasurys will purchase other broadly similar securities, such as long-maturity corporate bonds. In this way, Fed purchases in the Treasury market then induce declines in yields in the corporate bond market.

Empirically measuring the effects of the portfolio rebalancing channel is difficult. Approaches based on low-frequency time-series analysis suffer from endogeneity problems, as the timing of QE is endogenous to the state of the economy. For this reason, much empirical work on QE has turned to high-frequency event study approaches.[2] These studies have found that announcements of QE programs cause yields in various asset markets to decline in the days immediately following each announcement, suggesting that QE affects yields in the short term. However, these studies cannot directly distinguish between the different channels through which QE operates.[3] Moreover, because it is not known how much of each QE announcement is anticipated by the market, event studies are not suited to quantifying the effects of QE. Furthermore, due to the high-frequency nature of this approach, tracing the effects of QE over longer horizons is difficult.

In this paper, I provide direct empirical evidence that the portfolio rebalancing channel reduces yields across asset markets and quantify its magnitude. I further show that the channel has real effects. To do this, I first construct a novel shock that captures unexpected Fed purchases of individual Treasurys during each QE operation. The shock is based on predictions that mimic how market participants predicted Fed purchases during QE op-

[1]Bernanke described the Fed's reasoning during his speech at the 2010 Jackson Hole Symposium as follows: "Specifically, the Fed's strategy relies on the presumption that different financial assets are not perfect substitutes in investors' portfolios, so that changes in the net supply of an asset available to investors affect its yield and those of broadly similar assets. Thus, our purchases of Treasurys likely both reduced the yields on those securities and also pushed investors into holding other assets with similar characteristics..."

[2]For example, see Gagnon et al. (2011), Joyce et al. (2011), Krishnamurthy and Vissing-Jorgensen (2011), Bauer and Neely (2014), Neely (2015), Swanson (2015), Altavilla et al. (2021).

[3]For example, QE may also operate through a signaling channel, whereby the Fed influences expectations of the future path of short-term interest rates. For example, see Woodford (2012), Bauer and Rudebusch (2014).

erations. I validate the shock by showing it has a sharp effect on Treasury yields. Second, using data on investors' holdings, I examine how investors holding Treasurys unexpectedly purchased by the Fed rebalance their portfolios. I measure the degree to which these investors rebalance from Treasurys into corporate bonds and investigate which bonds they purchase within the corporate bond market. I then identify the relative impact this has on the yields of the bonds that funds rebalance into. Third, informed by my reduced-form estimates, I develop a model to estimate the total effect size of the portfolio rebalancing channel on corporate bond yields. The model includes investors who are willing to substitute across Treasurys and corporate bonds within their preferred maturity segment and arbitrageurs who trade across maturities but with limited risk capacity. I calibrate the model to my reduced-form estimates. I find that the portfolio rebalancing channel has a substantial effect on yields in asset markets outside the Treasury market and that this effect slowly reverses over the next year. Through this channel, \$100 billion of Fed Treasury purchases reduce the yield of a typical corporate bond by an average of 7.87bps within the first month, with the effect reverting to 4.75bps after three months and to 3.13bps after twelve months.

The effect of the portfolio rebalancing channel on yields outside the Treasury market depends on the degree to which investors substitute across asset classes. If investors care only about risk-adjusted returns and view assets as otherwise perfect substitutes, then the Fed's asset purchases would not affect yields at all, including those of Treasurys (Curdia and Woodford, 2011). On the other hand, if markets are completely segmented, i.e., investors are unwilling to substitute across asset classes, then Fed purchases of Treasurys would affect yields only in the Treasury market, as investors who previously held Fed-purchased Treasurys would substitute only into other Treasurys. In practice, we observe investors who fall between these two extremes. For example, many bond funds have a mandate to invest in a particular maturity segment but are willing to substitute to a degree across fixed-income asset markets within this maturity segment. If markets are only partially segmented, i.e., investors view assets in different markets as imperfect substitutes, then asset purchases affect yields in both the Treasury market and other markets, such as that for corporate bonds. The size of this effect depends on the degree of investor substitution. Therefore, measuring this degree of investor substitution is central to determining the strength of the portfolio rebalancing channel.

To identify and quantify yield changes stemming from QE, in the first part of the paper, I construct a novel shock capturing unexpected Fed purchases of individual Treasurys during each QE operation. Before each operation, the Fed announces the broad group of eligible Treasurys from which it will purchase and the operation's total size. However, the

Fed does not announce how much of each individual Treasury it will purchase. During each operation, primary dealers submit bids to the Fed with the prices and quantities of each Treasury they are offering to sell. The Fed states that it considers closeness to market prices and relative value when selecting bids. Furthermore, to not impede liquidity in any given Treasury issue, it spreads purchases across a range of Treasurys and considers the amount outstanding of a Treasury when deciding how much of it to purchase. The Fed generally faces high bid-to-cover ratios in each auction; hence it is the Fed's decision of which bids to select that drives the outcome of each QE operation.

Based on these details of the Fed's decision rule, which are known to market participants, I form a prediction of how much the Fed will purchase of individual Treasurys in each operation that mirrors that of market participants. I first calculate the relative value of each Treasury as the difference between a model-implied price based on a fitted yield curve and the market price. This is how the Fed evaluates the relative value of Treasurys each operation.[4] Market participants, knowing this, also build such fitted yield curves in practice to predict the Fed's purchases. Mimicking this process, I use this calculated relative value to predict which Treasurys the Fed will purchase each operation. As the Fed, on average, chooses not to purchase from 40% of eligible Treasury issues at all, I predict that the Fed only purchases from the 60% of cheapest eligible Treasurys. Taking into account the Fed's aim to minimize its impact on liquidity, I construct purchase weights of the Treasurys it does purchase in proportion to their amount outstanding. This again aligns with how market participants predict the Fed's purchases: they incorporate into their predictions that the Fed considers the amount outstanding when deciding how much of each bond to purchase. I then multiply the purchase weights by the pre-announced total dollar size of the operation.

Many components of the Fed's decision rule for selecting bids remain confidential. This is because it is not in the interest of the Fed for its purchases to be fully predictable. If they were, the prices of Treasurys that the Fed will purchase would increase before they can do so, increasing the costs incurred by the Fed for the same overall effect. The Fed does not release information on which other characteristics it uses to decide which bids to accept, and it does not release the relative weight placed on each characteristic considered in its decision rule. The Fed also varies its decision rule over time, reducing the ability of market participants to learn about the private component of its decision rule. Due to these private components of the Fed's decision rule, the actual purchase amounts of individual Treasurys during each QE operation differ from the predicted purchase amounts. I define a security-level QE shock as the difference between the actual and the predicted amount

[4] See, for example, Sack (2011).

purchased of a given Treasury in a given operation.

Using these shocks, I investigate the impact of unexpected Fed purchases on Treasury yields. The yields of Treasurys experiencing a greater QE shock fall more following QE operations. There is no effect observed before the operation date. This result confirms that the constructed QE shock captures unexpected information about the Fed's demand for Treasurys during QE operations, not unexpected supply of Treasurys by investors. If the QE shock were driven by unexpected supply, prices of Treasurys experiencing a greater QE shock would fall more (and so their yields would rise more) following QE operations.

In the second part of the paper, I investigate whether Fed purchases of Treasurys affect yields in the corporate bond market through the portfolio rebalancing channel. The corporate bond market comprises a significant portion of firm financing. As of 2022, there are $10 trillion outstanding in corporate bonds in the US. If QE is to lower the borrowing costs that firms face, it is important that the portfolio rebalancing channel reduces yields in the corporate bond market. I study the channel using holdings data on mutual funds. Mutual funds are a natural candidate through which to study these effects, as they are important investors in the Treasury market and the corporate bond market. Additionally, many mutual funds hold both Treasurys and corporate bonds in the same portfolio: I observe an average of $2.68 trillion each month in total net assets of funds that do so, which constitutes 61% of all assets under management in the bond and hybrid fund universe.

To see how mutual funds rebalance their portfolios in response to QE shocks, I aggregate the shocks to the fund level. Specifically, I define a fund as experiencing a larger QE shock if it holds more in the prior month of the Treasurys that the Fed unexpectedly purchases. Using a difference-in-differences approach, I compare active sales of Fed-bought Treasurys by funds experiencing different levels of QE shocks over the following twelve months. I then investigate what assets these funds rebalance into.

Funds experiencing a larger QE shock sell more Fed-bought Treasurys and rebalance more into corporate bonds. Over the following year, these funds rebalance an average of 60.8% of the capital received through sales of Treasurys into corporate bonds. This suggests that, in line with the portfolio rebalancing channel, the Fed can influence funds to rebalance into corporate bonds through its Treasury purchases. I also investigate which bonds these funds rebalance into within the corporate bond market. I find that funds rebalance into bonds of similar maturities to the Treasurys the Fed unexpectedly purchases. This is in line with the idea that investors rebalance into assets with similar characteristics, as outlined in Bernanke et al. (2010). They also rebalance into bonds of issuers that they already hold in their portfolios. This can be explained by the costs associated with acquiring new information on other issuers (Van Nieuwerburgh and Veldkamp (2010), Zhu (2021)).

Then, I investigate whether this rebalancing affects corporate bond yields. To do so, I aggregate the QE shocks to the issuer level. Specifically, I define an issuer as experiencing a larger QE shock if its bonds are held more in the prior month by funds that experience a larger QE shock, i.e., by funds that also held more in the prior month of the Treasurys that the Fed unexpectedly purchases. Given that funds rebalance more into the corporate bonds of issuers they already hold in their portfolios, it follows that the bonds of issuers experiencing a larger QE shock should experience a greater decline in yields following the QE shock. Using a difference-in-differences approach, I compare the yields of corporate bonds of issuers that differ in the extent to which they will be rebalanced into in the twelve months after a QE shock.

The rebalancing of funds indeed reduces the yields of the corporate bonds that they rebalance into. For issuers whose corporate bonds are held by funds that also hold a given Treasury, when the Fed then unexpectedly purchases \$1 billion of that Treasury, the yields of the issuer's bonds fall by an average of 4.53bps initially. This effect then gradually reverts over the following twelve months. The sizeable immediate effect can be explained by the inelastic supply funds face in the corporate bond market initially. Over time, residual investors in the corporate bond market become more price elastic[5], and so the price impact of funds' demand for corporate bonds reverts.

My cross-sectional estimates identify the relative decline in yields of corporate bonds that funds holding more of a Fed-purchased Treasury rebalance into. Next, I wish to quantify the total effect of the portfolio rebalancing channel on all corporate bonds. A model enables me to back out the aggregate effect of the channel implied by my empirical estimates in the presence of investors willing to substitute to a degree between Treasurys and corporate bonds and slow-moving residual investors in the corporate bond market. It also enables me to estimate the effects of the Fed's entire purchases in the Treasury market across its QE programs and analyze counterfactual policy designs. I develop a model that builds on the preferred-habitat model of Vayanos and Vila (2021). In the model, there are Treasurys and corporate bonds available across a continuum of maturities. Motivated by what I find in the empirical results of the paper, the model includes investors who are willing to substitute between Treasurys and corporate bonds within their preferred maturity segment. In addition, there are arbitrageurs who trade across maturities within the Treasury market but have limited risk-taking capacity. There are also residual investors in the corporate bond market who take the other side of the preferred-habitat investors' trades,

[5]This is in line with the idea of slow-moving capital, i.e., that investors take time to redeploy capital to new trading opportunities (see Duffie (2010)). It is also in line with empirical findings by Van der Beck (2022*b*) that investors become more price elastic over longer investment horizons.

and their demand is more elastic at lower frequencies, in line with the idea of slow-moving capital in the corporate bond market (Duffie, 2010).

To calibrate the model, I match three sets of empirical moments measured in the empirical results of the paper: the degree of investor substitution between Treasurys and corporate bonds, the relative price impact of rebalancing on securities within the corporate bond market, and the impact of unexpected Fed purchases on Treasury yields. I calibrate the cross-price elasticity of the preferred-habitat investors and the horizon-dependent elasticity of the residual investors in the corporate bond market jointly using the first two sets of moments, and the risk-taking capacity of the arbitrageur using the third moment. Using the model, I quantify the effect of QE purchases in the Treasury market on yields in the corporate bond market due to the portfolio rebalancing channel at each point in time between 2009-2022.

I find that the portfolio rebalancing channel has a large and time-varying effect on yields in the corporate bond market. A $100 billion purchase of Treasurys by the Fed reduces the yield of a typical corporate bond by an average of 7.87bps on impact. The effect reverts to 4.75bps after three months and 3.13bps after twelve months. This result has policy implications: how the Fed distributes its purchases over time determines the effect on yields. If it front-loads purchases, this will have a larger initial impact on yields that, however, will dissipate more quickly. If, instead, it spreads purchases more evenly across a QE program, the effect on yields will be smaller initially but more persistent. Given the transient nature of the portfolio rebalancing channel's effect on yields, the effect's size depends more on the recent flow of Fed purchases than the total stock of the Fed's holdings.

In the final part of the paper, I analyze the effect of the portfolio rebalancing channel on firms' financing and real outcomes. First, I find that affected issuers issue more bonds in the year following the QE shock. These issuers also take advantage of favorable market conditions and issue bonds at lower initial offering yields. Next, I investigate how they use the additional capital raised in the corporate bond market. I find that they increase investment, as measured through capital expenditures and R&D. They also increase their cash and short-term security buffers, which improves their liquidity and financial resilience. They do not use the additional capital raised from new issuances to retire old debt.

Overall, my findings show that the Fed's purchases of Treasurys substantially lower corporate bond yields through the portfolio rebalancing channel. The channel enables firms to borrow more and at lower yields in the corporate bond market, and to increase their investment as as result.

1.1 Related Literature

This paper contributes to the body of literature that empirically studies the transmission channels of monetary policy. Several papers explore the channels through which conventional monetary policy, i.e. changes in the Fed funds rates, transmit to the rest of the economy (for example, Bernanke and Blinder (1992), Drechsler et al. (2017), Gertler and Karadi (2015)). For unconventional monetary policy, Chakraborty et al. (2020), Di Maggio et al. (2020), and Rodnyansky and Darmouni (2017), provide evidence that Fed purchases of MBS stimulated lending in the real estate market through the bank lending channel. Other work investigates the extent to which direct purchases of corporate bonds by central banks stimulate lending to firms in the corporate bond market (see Haddad, Moreira and Muir (2021), Falato et al. (2021), Todorov (2020)). I investigate whether Fed purchases of Treasurys during QE programs lead to more favorable borrowing conditions in the corporate bond market through the portfolio rebalancing channel. I also investigate how firms that are able to borrow in these more favorable conditions use the additional capital.

This paper also contributes to the literature investigating the effects of QE on asset prices. The vast majority of this literature employs event studies to study price changes in the hours around early QE announcements. Some of this work investigates the channels through which QE impacts prices in the hours immediately following QE announcements (for example, Bauer and Rudebusch (2014), Christensen and Rudebusch (2012), Bauer and Neely (2014)). They decompose Treasury yield changes around QE announcements into changes in the expected future short-rate and changes in the term premia, interpreting the former as evidence of signaling and the latter as evidence of portfolio rebalancing. The results are mixed as to whether the portfolio rebalancing channel is effective. I contribute to this literature by taking an alternative approach that allows me to directly test the portfolio rebalancing channel. Combining data on investors' holdings with a novel QE shock, I can show directly that QE purchases induce investors to rebalance their portfolios into other asset classes and that this rebalancing affects the yields of securities that investors rebalance into.

Event studies also find mixed results regarding the impact of QE purchases on prices in asset markets that the Fed does not purchase in directly (for example, Altavilla et al. (2021), Gagnon et al. (2011), Joyce et al. (2011), Krishnamurthy and Vissing-Jorgensen (2011), Swanson (2015)). These studies focus on price changes in the immediate hours following QE announcements. However, the effects of the portfolio rebalancing channel on prices across asset markets may differ in the short- vs. long-term if markets are partially segmented, with capital moving slowly between markets (Duffie (2010), Greenwood et al.

(2018)). Therefore, high-frequency studies that focus on the immediate impact of QE purchases in one market on prices in other asset markets may not measure the long-term effect, which is likely what matters most for real outcomes. My empirical approach enables me to estimate the effects of the portfolio rebalancing channel on yields in other asset markets over longer horizons. Furthermore, it is often not clear how much of each QE announcement was anticipated by the market, making it difficult to quantify the effect size per dollar of QE. Through the construction of a QE shock that measures unexpected purchases by the Fed in dollar terms, I can quantify the effect of the portfolio rebalancing channel of QE on yields.

This paper further relates to the empirical literature investigating the effect on yields of changing the relative supply of bonds with differing characteristics within the Treasury market. Several papers examine the effects of changing the maturity structure of the supply of Treasurys on yields in the Treasury market itself (for example, Greenwood and Vayanos (2010), Greenwood and Vayanos (2014), Greenwood et al. (2023), D'Amico et al. (2012), Ross (1966), Swanson (2011), Wallace (1967)). I focus instead on the relationship between the relative supply of bonds within the Treasury market and yields in other fixed-income markets. I find that reducing the publicly available supply of particular Treasurys through QE purchases increases the yields of corporate bonds that are held by the same investors as those who held the Fed-purchased Treasurys.

This paper extends the theoretical literature on preferred habitats (for example, Culbertson (1957); Modigliani and Sutch (1966), Riedel (2004), Ray et al. (2019), Vayanos and Vila (2021), Gourinchas et al. (2022)). Vayanos and Vila (2009; 2021) model the term structure of interest rates in the presence of preferred-habitat investors and risk-averse arbitrageurs. The former invest only within a maturity segment of the Treasury market. In this setting, the authors analyze the effects of reducing the publicly available supply of Treasurys through QE purchases on yields in the Treasury market. I extend the model in Vayanos and Vila (2021) by including investors who invest within a maturity segment but are willing to substitute to a degree between asset classes within this maturity segment. Using my empirical estimates of the degree to which investors substitute between asset classes, I quantify the total effect size of the portfolio rebalancing channel on yields across asset classes.

This paper is complementary to the literature on demand system asset pricing, which also uses holdings data to quantify asset price movements due to changes in investor demand (for example, Koijen and Yogo (2019), Jiang et al. (2022), van der Beck (2022*a*)). The closest related paper is Koijen et al. (2021), which finds that non-Euro area investors are the primary sellers to the ECB during its asset purchase programs and estimates a demand system for European government bonds to measure the impact of this selling on prices within the government bond market. I extend these findings by identifying which assets investors rebalance into following QE operations and quantifying the impact of this rebalancing on prices in asset classes beyond those the Fed directly purchases in. I also contribute to the demand system asset pricing literature that estimates elasticities for various asset classes. To date, this literature has focused on own-price elasticities, the elasticity of demand of an asset to its own price. For example, Bretscher et al. (2022) estimates elasticities in the corporate bond market, while Haddad, Huebner and Loualiche (2021) estimates elasticities in the equity market. I provide new estimates of cross-asset price elasticities, in particular the elasticity of demand for corporate bonds to Treasury prices.

2 Data

2.1 QE Operations Data

During a QE program, the Fed conducts operations in the Treasury market on several days each week. In advance of upcoming operations, the Fed releases schedules providing tentative details. These detail the operation date, a guide on the total amount to be purchased, and the broad maturity range from which the Fed will purchase. The Fed has released these schedules at varying frequencies, ranging from once a day to once a month. I obtain the Fed's tentative Treasury purchase operation schedules from the NY Fed's website. The Fed has released schedules on its QE operations since 2009, but only since November 2010 do the schedules include a guide on the total amount to be purchased in an operation, which I require to construct the QE shock described in the next section.

I obtain data on the results of each Fed purchase operation in the Treasury market from the NY Fed's website. These detail the operation date, the securities that were included and excluded from each operation, and, for successful bids only, detail the CUSIP, the amount purchased, the counterparty (primary dealer), and the bid price. I also obtain data on the security-level composition of the Fed's balance sheet from the NY Fed's weekly release on the System Open Market Account (SOMA) holdings.

In the analysis, I focus on Treasury coupon purchase operations. My sample includes 1173 Treasury coupon purchase operations, split over 77 months during the period between November 2010 and December 2021. In total, the Fed purchased \$5.34 trillion of Treasury coupons over this period.

2.2 Price and Characteristics Data

For Treasurys, I obtain daily prices from CRSP, which provides end-of-day price quotes sourced from GovPX. I also obtain data on Treasurys' characteristics from CRSP, detailing the issue date, maturity date, amount outstanding, security type, and coupon rate. For corporate bonds, I obtain data from TRACE. TRACE provides historical transaction-level data on bond trades, including execution time, price, and volume. I follow the procedures in Dick-Nielsen (2009) and Bessembinder et al. (2009) to clean and filter the TRACE data, generating a monthly time series. Most corporate bonds are traded only a few times per month, so a monthly frequency is appropriate for a time series of traded corporate bond prices. I exclude bonds with a variable coupon rate and convertible bonds. I obtain corporate bond characteristics from Mergent FISD, detailing the issue date, maturity date, amount outstanding, issuer, rating, coupon rate, and coupon payment frequency.

2.3 Mutual Fund Holdings Data

I use holdings data on US-based mutual funds obtained from Morningstar, which detail a fund's entire security-level holdings across asset classes for each reporting date. This includes the CUSIP, face value or quantity held, market value of the position, security type, and reporting date. Mutual funds are required to report at least once a quarter, but many report every month. They report their holdings as of the end of the month. I include all funds that report monthly in order to observe month-to-month rebalancing. I filter for all funds with strictly positive holdings in Treasurys and corporate bonds. This leaves an average of $2.68 trillion in total net assets that I observe across fund reports each month. For scale, on average, this is 61% of the US-domiciled bond and hybrid fund universe. Interestingly, an average of 91% of funds that hold Treasurys in their portfolios also hold corporate bonds.

2.4 Data on Firm Outcomes

For my analysis on real outcomes, I use data from Compustat. I retrieve quarterly data at the firm-level on capital expenditures, R&D expenditures, cash and short-term instrument holdings, and long-term debt reduction. To scale these outcomes, I also retrieve quarterly data on total assets.

3 Constructing the QE Shock

In this section, I begin by outlining how the Fed conducts its QE purchases in practice. Next, I describe how I construct a QE shock, motivated by these institutional details. Finally, I validate that the constructed shock captures unanticipated demand for individual Treasurys by the Fed.

3.1 QE Operations in Practice

In advance of each Treasury operation, the Fed releases a schedule detailing the date of the operation, the maturity range it wishes to purchase in, and the total purchase amount. On the day of the operation, the Fed releases a list of eligible securities for which it will accept bids. Which securities are included on this list is predictable based on ex-ante characteristics that the Fed states it will abstain from purchasing, e.g., cheapest to deliver in an active futures contract, on-the-run, or trading on special in the repo market. This means that the market knows in advance the broad group of securities that the Fed will purchase from in a particular operation. However, the Fed does not announce in advance how much of each security within this group it will purchase in the operation.

Each Treasury operation lasts under an hour (usually between 20-45 minutes). During this time, primary dealers submit bids to the Fed, detailing the CUSIP, the par amount, and the price offered. Primary dealers may submit multiple offers per CUSIP. The Fed's exact decision rule on which bids to select is private information and is flexible over time. Furthermore, as rejected bids remain confidential, it is not possible to learn the Fed's exact decision rule from past operation outcomes over time. The Fed does not disclose its full decision rule, as it is not in its interest for its purchases to be fully predictable. If they were, prices of Treasurys the Fed is predicted to purchase would rise before the Fed could do so. This would increase the Fed's costs, without increasing the overall effect size of its operations on yields.

However, certain details about the Fed's decision rule are known to market participants. In particular, the Fed evaluates each bid based on its proximity to prevailing market prices, as well as on measures of the bids' relative value, in order to minimize its costs. The Fed computes the relative value of securities based on a confidential spline model fitted on the market prices of Treasurys (Sack, 2011). Dealers have constructed their own fitted yields curves in order to predict which Treasurys the Fed might purchase. Market participants also know that the Fed limits the amount they purchase of each individual security during each operation. The Fed does this to minimize its impact on the liquidity of any given Treasury security. These purchase limits are based on the total amount outstanding of each security and how much the Fed already holds of it. The more the Fed already holds of a security, as a percentage of its total amount outstanding, the less the Fed can additionally purchase of it in an operation. Once the Fed holds 70% of the total amount outstanding of a security, the Fed can purchase no more of it. Dealers take these limits into account when predicting how much of a given Treasury the Fed will purchase during an operation.

3.2 Constructing the QE Shocks

Based on the components of the Fed's decision rule that are known to market participants, for each QE operation, I first construct a prediction of the purchase amount of each Treasury security that reflects that of the market. Each security not eligible for purchase in the operation receives a predicted purchase amount of zero. For eligible securities, I construct a measure of relative value as of the time of the operation. The exact method that the Fed uses to construct a fitted yield curve to measure relative value is confidential. However, popular methods return estimates that are highly correlated with one another (Song and Zhu, 2018), and therefore return consistent results on which Treasurys are cheap or expensive in relative value terms. I proxy for the Fed's measure of relative value using Gürkaynak et al. (2007)'s daily end-of-day estimates of the yield curve. The authors use Svensson (1994)'s method to fit a yield curve excluding on-the-run securities, which tend to trade at a premium due to their enhanced liquidity (Warga, 1992; Baker et al., 2020). As on-the-run securities are ineligible for purchase in QE operations, this makes their estimates well-suited for evaluating relative value in the context of QE operations. I first construct a model price for each Treasury security by discounting each Treasury's cash flows using the discount function implied by Gürkaynak et al. (2007)'s estimates. Using daily end-of-day price data, I define Treasury i's relative value on operation date t as follows:

$$RelativeValue_{i,t} = \frac{ModelPrice_{i,t-1} - ActualPrice_{i,t-1}}{ActualPrice_{i,t-1}} \tag{1}$$

where $ModelPrice_{i,t-1}$ refers to the price implied by Gürkaynak et al. (2007)'s estimates and $ActualPrice_{i,t-1}$ refers to the actual price of Treasury i, both at the end of the day prior to the operation. The larger a Treasury's relative value, the cheaper it is relative to other securities. Given that the Fed evaluates bids based on relative value, preferring those that are relatively cheap compared to their model-implied value, I rank all eligible securities based on their relative value and predict that the Fed will purchase those with greater relative value. This process reflects how dealers construct their predictions of which Treasurys the Fed is likely to purchase.

In the absence of liquidity concerns, the optimal approach for the Fed would be to purchase as much as they can of the cheapest security at each auction. So they should purchase the maximum amount allowed by their purchase limits of the cheapest security, and only if they breach this limit move onto the next cheapest security, and so on, until they reach the desired total operation size. Typically, the Fed's purchase limits set an upper bound of $\sim 5\%$ of the amount outstanding of a CUSIP per operation. This would result in the Fed purchasing large quantities of only two or three CUSIPs during each operation.

However, the Fed is concerned about the impact its purchases have on the liquidity of each Treasury, and its trading costs. Large trades in the Treasury market affect liquidity and have price impact, as shown in Adrian et al. (2017). Therefore, the more the Fed purchases of a given security, the greater the per-unit cost of that security, and the greater the impact on that security's liquidity. This explains why, in practice, we do not see the Fed behave in the way described above. Purchases of 5% of a CUSIP's total amount outstanding within the short time span of an operation would likely impede its market functioning, and increase the Fed's trading costs.

These liquidity considerations alter the optimal approach of the Fed. In Appendix A, I derive the optimal approach for the Fed in the presence of costs that increase in the amount purchased of a security as a fraction of its amount outstanding, reflecting the Fed's concerns regarding liquidity. I show that it is not optimal for the Fed to simply purchase the cheapest security, but rather for it to spread its purchases across securities that are relatively cheaper, in proportion to their amount outstanding. Dealers are aware of this, and incorporate it into their predictions of how much the Fed will purchase of each Treasury issue. The extent to which the Fed should spread its purchases optimally depends on the market depth of each individual Treasury on each operation date, which I do not observe. However, I assume that, on average, the Fed optimizes its costs. Using this assumption, I approximate the optimal choice by measuring the degree to which the Fed spreads purchases across securities on average in practice. In an average operation, the Fed purchases some amount of 60% of the eligible listed CUSIPs.

Therefore, I predict that, during each operation, the Fed first ranks the list of eligible CUSIPs by relative value and then purchases some amount of the cheapest 60% of them. To predict these purchase amounts, I generate portfolio weights in proportion to the total amount outstanding of each CUSIP. Dealers incorporate the Fed's consideration of the total amount outstanding of each CUSIP into their predictions of how much the Fed will purchase of each security, and my prediction process reflects this. To translate these weights to quantities, I multiply by guide total dollar amount the Fed pre-announces for the operation. In practice, the Fed's actual total operation sizes are very similar to its pre-announced guides. So, the predicted dollar amount purchased of a Treasury i in operation o is:

$$Predicted_{i,o} = \frac{\mathbb{1}\{RV_{i,o} \geq RV(P_{40}^{o})\} \times AmountOutstanding_{i,o}}{\sum_i \mathbb{1}\{RV_{i,o} \geq RV(P_{40}^{o})\} \times AmountOutstanding_{i,o}} \times Size_o \tag{2}$$

where the indicator variable takes a value of 1 if Treasury i has a relative value that is above the 40th percentile for all eligible securities in that operation o. $AmountOutstanding_{i,o}$ refers to the face value outstanding of Treasury i as of operation date o. $Size_o$ refers to the stated total dollar size of the operation in the schedule. Then, the unexpected dollar amount purchased by the Fed on a given operation day o of Treasury i is $Actual_{i,o} - Predicted_{i,o}$.

To analyze how funds rebalance in response to QE shocks, I aggregate QE shocks up to the monthly level, matching the monthly frequency at which we observe fund holdings. For each security, I sum the unexpected dollar amounts purchased in each operation that occurred within a month. The QE shock for a CUSIP i in month t is defined as follows:

$$QEShock_{i,t} = \sum_{o \in t} \frac{Actual_{i,o} - Predicted_{i,o}}{TreasuryCouponsOutstanding_t} \tag{3}$$

where $TreasuryCouponsOutstanding_t$ is the total amount outstanding of all Treasury coupons as of month t. So, for each operation o that occurs during month t, I subtract the predicted dollar amount purchased from the actual dollar amount purchased, which is the unexpected dollar amount purchased by the Fed. I then sum this value across all operations that occurred during month t. Lastly, in order to capture the scale of the shock purchases relative to the size of the market, I scale the shock by the total amount of all Treasury coupons outstanding in month t.

3.3 Impact of QE on Treasury Yields

At the outcome of each QE auction, two types of information could be revealed. One concerns the unexpected demand by the Fed for particular Treasurys, which is unpredictable due to the fact that the Fed's full decision rule is confidential. The other concerns the unexpected supply by dealers and their clients (including funds) of particular Treasurys. The shock constructed in the previous section may be driven by either of these two types of information. However, I wish to capture the unexpected demand by the Fed for particular Treasurys, as this demand is exogenous to the rebalancing decisions of funds.

We can deduce which type of information is driving the constructed shock by observing price movements following the operation. Each information type has different implications for the relative price movements we should observe for securities experiencing larger shocks. Suppose that the information revealed by the Fed purchasing an unexpectedly large quantity of a Treasury is that the Treasury was in unexpectedly large supply during the auction. Then, the shock captures a positive supply shock, so we should observe the price of Treasurys with a larger shock value to decrease more following the operation. On the other hand, suppose the information revealed by the Fed purchasing an unexpectedly large quantity of a Treasury is that the Fed demanded an unexpectedly large quantity of the Treasury during the auction. Then, the shock captures a positive demand shock, so we should observe the price of Treasurys with a larger shock value to increase more following the operation.

To estimate the relationship between the shock and price changes of Treasurys following the operation, I use the following specification:

$$\Delta y_{i,t-1\to t+\tau} = \sum_{\ell=-6}^{6} \beta_\ell QEShock_{i,t} \times \mathbb{1}\{\tau = \ell\} + \sum_{\ell=-6}^{6} \gamma_\ell \mathbb{1}\{\tau = \ell\} + \lambda_i + \lambda_t + \epsilon_{i,t,\tau} \tag{4}$$

I estimate this specification only for Treasurys that were included in operations during a given week t, as the information revealed following an operation concerns only those Treasurys that could have been purchased during that operation. $QEShock_{i,t}$ is the total unexpected dollar amount purchased by the Fed of Treasury i during week t, scaled by the total amount outstanding of all Treasury coupons. $\Delta y_{i,t-1\to t+\tau}$ is the change in the yield of Treasury i between the end of the week before the Fed's purchases take place, $t-1$, and τ weeks later. λ_i and λ_t are security and calendar-time fixed effects respectively, and $\gamma_\ell \mathbb{1}\{\tau = \ell\}$ are event-time fixed effects.

I estimate the dynamics of the relationship over the twelve weeks around the shock. β_ℓ measures the difference in yield changes between Treasurys that the Fed unexpectedly purchased more of compared to other included Treasurys in week t, ℓ weeks after the purchases occurred. If the information captured by the shock concerns unexpected supply by dealers and their clients, then we would expect β_ℓ to turn positive at $\tau = 0$ as the yield of Treasurys experiencing a positive supply shock should rise (i.e., price should fall) relative to other Treasurys. On the other hand, if the information captured by the shock predominantly concerns unexpected demand by the Fed, then we would expect β_ℓ to turn negative at $\tau = 0$ as the yield of Treasurys experiencing a positive demand shock should fall relative to other Treasurys.

Figure 1 plots the coefficients β_ℓ, and Table 1 reports the estimates for $\tau = -3, ..., 6$. β_ℓ turns negative at $\tau = 0$, suggesting that the constructed QE shock captures information about unexpected demand by the Fed for Treasurys. The magnitude of the coefficient for $\tau = 0$ implies that an unexpected Fed purchase of a Treasury of size equivalent to 0.01% of the total amount outstanding of all Treasury coupons[6] would result in a 0.4bps decline in that Treasury's yield. β_ℓ remains negative for several weeks following the shock, so the impact of the Fed's purchases on Treasury prices does not immediately revert. This relatively slow reversal suggests that markets are partially segmented.

The shock captures unexpected demand by the Fed, where demand is unanticipated because the Fed's full decision rule is unknown. Analogies can be drawn to conventional monetary policy shocks (for example, those measured by Kuttner (2001)). The Fed's full decision rule regarding conventional monetary policy is also not public: it is well-documented that the Fed's true reaction function, namely how it adjusts short-term interest rates in response to macroeconomic news, is not fully known (for example, see Khoury (1990); Judd et al. (1998)). As a result, changes in the target funds rate often consist of both an anticipated and an unanticipated component. Similarly, the Fed's demand for individual Treasurys during QE operations consists of an anticipated component and an unanticipated component. The constructed shock captures this unanticipated component.

Next, I re-estimate specification 4 at a broader level of aggregation in order to investigate whether the concentration of purchases of a given dollar size changes the size of the effect on yields. I group Treasurys based on their time to maturity, with the first group containing all Treasurys between 0 and 1 year to maturity, the second bucket containing all Treasurys between 1 and 2 years to maturity, and so on. $\Delta y_{i,t-1\rightarrow t+\tau}$ is the change in the value-weighted average yield of Treasurys in group i between week $t-1$ and τ weeks later. $QEShock_{i,t}$ is the total unexpected amount purchased by the Fed of all Treasurys in group i during week t, scaled by the total amount outstanding of all Treasury coupons. The estimated coefficients β_ℓ are shown in Table 2. The magnitude of the coefficient for $\tau = 0$ implies that an unexpected Fed purchase within a Treasury maturity group of size equivalent to 0.01% of the total amount outstanding of all Treasury coupons during a week would result in a 0.167bps decline in that maturity group's average yield during that week. This effect is smaller than the effect for individual Treasurys. We are comparing shocks of the same size but concentrated to different degrees: for a given purchase size, purchases of only a single Treasury will make up a considerably larger portion of that Treasury's total amount outstanding than purchases across a maturity group will make up of that group's total amount outstanding. Thus, price impact is likely to be greater in the former

[6] In sample, this is equivalent to approximately $1 billion.

scenario, as we observe here.

4 QE-Induced Portfolio Rebalancing by Funds

In this section, I begin by constructing a fund-level QE shock using the Treasury-level QE shocks from the previous section. I show that funds that hold more of the Treasurys that the Fed unexpectedly purchases in a month (and so experience a larger QE shock in that month) actively sell more of the Treasurys that the Fed purchases during that month. Next, I analyze what securities these shocked funds rebalance into. At the asset-class level, I find that they rebalance into corporate bonds. Within the corporate bond market, they rebalance more into bonds of issuers that they already hold in their portfolios. They also rebalance more into bonds that are similar in maturity to those the Fed purchased. Finally, I investigate whether this rebalancing has an impact on yields. Corporate bonds that shocked funds rebalance into more experience a greater decline in yields following a QE shock.

4.1 Constructing Fund-Level QE Shocks

In order to investigate the effect of unexpected QE purchases by the Fed on fund rebalancing behavior, we first require a fund-level measure of the QE shock each fund experiences. The fund-level QE shock should capture the extent to which a fund is induced to rebalance its portfolio due to the QE shocks. I define a fund as experiencing a greater QE shock in month t, if it holds a greater fraction of its portfolio ex-ante in the Treasurys that the Fed unexpectedly purchases more of in month t. The QE shock that fund f experiences during month t is defined as:

$$QEShock_{f,t} = \sum_{i} w_{i,f,t-1} \times QEShock_{i,t} \tag{5}$$

$w_{i,f,t-1}$ is the fraction of fund f's total net assets that it holds in Treasury i as of the end of month $t-1$. $QEShock_{i,t}$ is the monthly security-level QE shock constructed in the previous section, defined as in Equation 3. In Appendix B, I provide descriptive statistics regarding the fund-level QE shock. As shown in Figure B.7, there is a broad dispersion in funds' QE shocks within my sample. Also, as shown in Table B.4, the serial correlation of fund-level QE shocks across time within a fund is essentially zero, which allows us to identify the dynamic effects of fund-level QE shocks over several periods. As almost all fund portfolio weights on Treasurys are positive (see Table B.1 for descriptive statistics), a positive value of $QEShock_{f,t}$ denotes that fund f placed an ex-ante positive weight on Treasurys that the Fed purchases more of than expected. A negative value of $QEShock_{f,t}$ denotes that fund f placed an ex-ante positive weight on Treasurys that the Fed purchases less of than expected.

4.2 Measuring Active Rebalancing by Funds

To measure outcomes regarding fund rebalancing decisions, I construct a measure of active rebalancing. I define active rebalancing of a fund f into an asset type A between month $t-1$ and $t+\tau$ as follows:

$$\Delta Holdings^{A}_{f,t-1\to t+\tau} = \sum_{a\in A} \frac{P_{a,t-1} \times (N_{a,f,t+\tau} - N_{a,f,t-1})}{TNA_{f,t-1}} \tag{6}$$

$P_{a,t-1}$ is the price of security a of asset type A, as of the end of the month before the QE shock purchases. $N_{a,f,t-1}$ is the face value of security a held by fund f at the end of month $t-1$ and $N_{a,f,t+\tau}$ is the face value of security a held by fund f at the end of month $t+\tau$. $TNA_{f,t-1}$ is fund f's total net assets, as of the end of month $t-1$, defined using $t-1$ prices. Given that we hold prices constant at the $t-1$ level in this calculation, we are capturing active rebalancing decisions made by the fund, as opposed to passive rebalancing that stems from valuation changes in the portfolio. This is important, as it is active rebalancing decisions that may impact prices and reduce yields in the case of partially segmented markets. I construct this measure for the following asset types A: Treasurys that the Fed purchases during a month, Treasurys that the Fed does not purchase during a month, all Treasurys, corporate bonds, agency MBS, non-agency residential MBS, non-agency commercial MBS, municipal bonds, agency bonds, and CMOs.

4.3 Do funds that experience a larger QE shock sell more Treasurys?

Funds experience a greater QE shock if they place a greater ex-ante weight in their portfolio on Treasurys that the Fed unexpectedly purchases more of. If this captures differences in fund-experienced rebalancing pressures induced by QE shocks, we would expect more shocked funds to rebalance out of Treasurys to a greater degree, in particular out of the Treasurys that the Fed purchased. To test this prediction, I estimate the dynamic effects of fund-level QE shocks in month t on active rebalancing in Treasurys that the Fed purchases in month t, in the 24 months around the shock:

$$\Delta Holdings_{f,t-1\to t+\tau} = \sum_{\ell=-12}^{12} \beta_\ell QEShock_{f,t} \times \mathbb{1}\{\tau = \ell\} + \sum_{\ell=-12}^{12} \gamma_\ell \mathbb{1}\{\tau = \ell\} + \lambda_f + \lambda_t + \epsilon_{f,t,\tau} \quad (7)$$

$\Delta Holdings_{f,t-1\to t+\tau}$ measures active rebalancing by fund f between the end of month $t-1$ and τ months later, as defined in Equation 6, where the asset type A is Treasurys that the Fed purchases during month t. A negative value represents active selling by the fund. $QEShock_{f,t}$ measures fund f's QE shock during month t, as defined in Equation 5. The greater the value, the more the fund holds at the end of month $t-1$ in Treasurys that the Fed unexpectedly purchases more in month t. There are event-time fixed effects for leads $\tau = \{-12, -11, ..., 12\}$, denoted by $\gamma_\ell \mathbb{1}\{\tau = \ell\}$. There are also fund and calendar-time fixed effects, denoted by λ_f and λ_t.

The coefficient β_ℓ estimates the effect of the QE shock a fund experiences in month t on the fund's active rebalancing into Treasurys that the Fed purchases in month t, ℓ months later. If the fund QE shock captures the propensity of funds to sell Treasurys and rebalance following a QE shock, then we would expect β_ℓ to turn negative at time $\ell = 0$.

The estimates for β_ℓ are shown in Figure 2. Table 3 also presents the coefficient estimates for $\ell = -3, ..., 12$. The coefficients are insignificant for $\tau < 0$, so there is no evidence of differential pre-trends in fund sales of Treasurys that the Fed purchases in month t between funds that experience QE shocks of different levels in month t. The coefficients turn negative at $\tau = 0$. This suggests that funds with a larger QE shock in month t indeed sell more of the Treasurys that the Fed purchases during that month. The fund-level QE shock captures the differences in QE-induced portfolio rebalancing pressures that different funds experience following QE operations.

To interpret the magnitude of the coefficient β_ℓ, suppose a fund holds 1pp more of its total net assets (TNA) in a particular Treasury.[7] If the Fed unexpectedly purchases that Treasury with a purchase size equal to 0.01% of all Treasury coupons outstanding (in sample, this is on average $1 billion), that fund sells approximately 0.1pp of its TNA more Treasurys that the Fed purchases during that month. This suggests that the fund-level QE shock captures the QE-induced portfolio rebalancing pressure that a fund experiences.

To investigate whether funds also sell Treasurys other than those the Fed purchases during month t, I re-estimate the specification in Equation 7, defining $\Delta Holdings_{f,t-1\to t+\tau}$

[7] In the sample, the average fund position in a single Treasury security is 0.96% of their TNA, with 98% of all positions falling between 0% and 8.89% of TNA. More descriptive statistics can be found in Table B.1.

as active rebalancing by fund f between month $t-1$ and month $t+\tau$ into all Treasurys. The results are shown in Table 5 and Figure 3. The coefficients are similar to the previous estimation. This suggests that shocked funds concentrate their Treasury sales in securities that the Fed purchased. I also re-estimate the specification in Equation 7, defining $\Delta Holdings_{f,t-1\to t+\tau}$ as active rebalancing by fund f between month $t-1$ and month $t+\tau$ into Treasurys that the Fed does not buy in month t. The results are shown in Table 4. Overall, the estimates do not provide evidence that shocked funds rebalance into other Treasurys.

I investigate how much funds rebalance out of particular Treasurys relative to the QE shock-induced decline in those Treasurys yields. This provides an estimate of funds' price elasticity of demand for Treasurys. I conduct the analysis at the maturity year level, i.e., grouping Treasurys that have less than one year to maturity together, one to two years to maturity together, and so on. First, I construct fitted values of yield changes stemming from QE shocks, denoted by $\widehat{y_i}$, from the estimates in Table 2 obtained in Section 3. These estimates are obtained by regressing the change in the value-weighted average yield of each Treasury maturity group i on the group's QE shock. These fitted yield changes are used to estimate the following equation:

$$\Delta Holdings_{i,t-1\to t} = \beta\widehat{\Delta y}_{i,t} + \lambda_i + \lambda_t + \epsilon_{i,t} \tag{8}$$

where $\Delta Holdings_{i,t-1\to t+1}$ is active rebalancing by funds into Treasury group i between the end of month $t-1$ and the end of month t, scaled by the total amount outstanding of Treasurys in that group. This provides a measure of the demand elasticity of funds for Treasurys. The results are shown in Table 6. For a 1bp decline in the average yield of Treasurys in a maturity group, funds in the sample actively sell 0.016pp of that Treasury group, expressed as a fraction of the total amount outstanding of that group.

4.4 What asset classes do funds that experience a greater QE shock rebalance into?

We observe that funds that experience a greater QE shock actively sell more Treasurys after the shock. What do these shocked funds rebalance into? I first investigate whether more shocked funds actively rebalance more into corporate bonds by estimating the following regression:

$$\Delta Holdings^{CorporateBonds}_{f,t-1\to t+\tau} = \sum_{\ell=-12}^{12} \beta_\ell QEShock_{f,t} \times \mathbb{1}\{\tau=\ell\} + \sum_{\ell=-12}^{12} \gamma_\ell \mathbb{1}\{\tau=\ell\} + \lambda_f + \lambda_t + \epsilon_{f,t,\tau} \tag{9}$$

$\Delta Holdings^{CorporateBonds}_{f,t-1\to t+\tau}$ measures active rebalancing by fund f between the end of month $t-1$ and τ months later, as defined in Equation 6 with asset type A being all corporate bonds. As before, $QEShock_{f,t}$ measures fund f's QE shock during month t, as defined in Equation 5. There are event-time fixed effects for leads $\tau = \{-12, -11, ..., 12\}$, denoted by $\gamma_\ell \mathbb{1}\{\tau=\ell\}$, as well as fund and calendar-time fixed effects, denoted by λ_f and λ_t.

The coefficient β_ℓ estimates the effect of experiencing a QE shock in month t on the fund's active rebalancing into corporate bonds ℓ months later. If funds that experience larger QE shocks rebalance more into corporate bonds following the shock, then the coefficients would turn positive at time t, and remain so if funds do not reverse these purchases over the following months. The series of estimated coefficients β_ℓ are shown in Figure 4, and Table 7 provides point estimates for leads $\ell = \{-3, ..., 12\}$. The estimates are insignificant for $\ell = \{-12, ..., -1\}$, so there is no evidence of differential pre-trends in how more shocked funds rebalance their portfolios into corporate bonds relative to less shocked funds. The estimates turn positive at $\tau = 0$, indicating that more shocked funds actively rebalance more into corporate bonds following QE purchases. To interpret the magnitude, suppose a fund holds 1pp more of its total net assets (TNA) in a particular Treasury. If the Fed unexpectedly purchases \$1 billion of that Treasury in a month[8], that fund purchases 0.065pp of its TNA more corporate bonds over the following year. Comparing this to the estimate of 0.107pp of TNA that an identically shocked fund sells more of Treasurys, the shocked fund rebalances 60% of the capital received from Treasury sales into corporate bonds.[9]

The estimates of the coefficients β_ℓ remain positive for twelve months following the QE shock. This suggests that QE induces shifts in investors' portfolio allocations that are not reversed over the following year. We also observe a continuation in active rebalancing in the month following the shock, both for Treasurys and corporate bonds. However,

[8]During the sample period, this is the average dollar magnitude of 0.01% of the total amount outstanding of all Treasury coupons.

[9]As shown in Figure B.1, funds in the sample allocate the majority of their total net assets to corporate bonds and Treasurys, with an average portfolio share of 32.9% in corporate bonds and 20.3% in government bonds, which helps to explain the plausibility of this large flow of capital into corporate bonds.

the majority of active rebalancing following the shock has occurred by the end of month $t+1$. This slight lag in rebalancing behavior is in line with the literature on slow-moving capital (Duffie, 2010). Mutual funds managers are slow to deploy capital (Dong et al., 2022), and it is not atypical to observe a rebalancing frequency at the weekly level or lower (Bogousslavsky, 2016). Mutual funds report their holdings once per month, as of the end of the month, and so if a QE operation occurs towards the end of one month, it is unlikely that the mutual fund fully rebalances in time for this to be reflected in their report for the end of that month. Instead, it is likely that the full extent of their rebalancing occurs with a slight delay.

In Appendix B, I also provide estimates of Equation 9 for asset classes other than corporate bonds. I find that funds that experience larger QE shocks also rebalance more into non-agency commercial and residential mortgage-backed securities and collateralized mortgage obligations following QE operations. I find no evidence of rebalancing into ABS, agency MBS, municipal bonds, or agency bonds.

4.5 Within an asset class, what securities do investors rebalance into?

Next, I investigate which securities shocked funds rebalance into within the corporate bond market. First, I test whether shocked funds rebalance more into corporate bonds of issuers whose bonds they already hold following a QE shock. I estimate the following regression:

$$\begin{aligned}\Delta Holdings_{i,f,t-1\to t+12} &= \beta_1 QEShock_{f,t} + \beta_2 Holdings_{i,f,t-1} \\ &+ \gamma QEShock_{f,t} \times Holdings_{i,f,t-1} + \lambda_f + \lambda_i + \lambda_t + \epsilon_{i,f,t} \qquad (10)\end{aligned}$$

$\Delta Holdings_{i,f,t-1\to t+12}$ represents active purchases of fund f of corporate bonds of issuer i between the end of the month before the QE shock occurs and twelve months later, expressed as a fraction of fund TNA. $Holdings_{i,f,t-1}$ represents the portfolio weight fund f placed on corporate bonds of issuer i as of the end of the month before the shock takes place. λ_f, λ_i and λ_t represent fund, issuer and calendar time respectively. The results are reported in Table 8. The coefficient on the interaction $QEShock_{f,t} \times Holdings_{i,f,t-1}$ is significantly positive: this means that funds that experience a greater QE shock in month t actively rebalance into the corporate bonds of issuers that they hold more of as of the end of month $t-1$. To interpret the magnitudes, if the Fed buys a Treasury (with purchase size equal to 0.01% of all outstanding Treasury coupons), then a fund that held 1pp of its portfolio more in that Treasury will buy 0.5bps of its TNA more of an issuer's corporate bond per 1pp of its TNA that it holds in that issuer's corporate bonds.

Second, I test whether funds that experience a greater QE shock are likelier to rebalance into corporate bonds that are similar in maturity to the Treasurys that the Fed unexpectedly purchases. First, I construct a measure $MaturityDifference_{b,t}$ that captures the similarity in maturity between corporate bond b and Treasurys that the Fed unexpectedly purchases in month t. I define the measure as follows:

$$MaturityDifference_{b,t} = |Maturity_{b,t-1} - \sum_{i \in TSY} w_{i,t}^{Fed} \times Maturity_{i,t-1}| \tag{11}$$

$Maturity_{b,t-1}$ is the maturity of corporate bond b as of the end of the month $t-1$. $w_{i,t}^{Fed}$ is the weight of Treasury i in the Fed's surprise purchase portfolio of Treasurys in month t. $Maturity_{i,t-1}$ is the maturity of Treasury i as of $t-1$. It follows that $\sum_{i \in TSY} w_{i,t}^{Fed} \times Maturity_{i,t-1}$ is the portfolio-weighted average maturity of Treasurys that the Fed unexpectedly purchases in month t. $MaturityDifference_{b,t}$ is the absolute difference in the maturity of corporate bond b and the average maturity of Treasurys that the Fed unexpectedly purchases in month t: the smaller its value, the more similar the maturity of the corporate bond is to the average maturity of the Treasurys that the Fed unexpectedly purchases.

I estimate the following regression for all funds that experience a positive QE shock in month t:

$$\begin{aligned} \Delta Holdings_{b,f,t-1 \to t+12} = {} & \beta_1 QEShock_{f,t} + \beta_2 Mat.Diff_{b,t} \\ & + \gamma QEShock_{f,t} \times Mat.Diff_{b,t} + \lambda_f + \lambda_b + \lambda_t + \epsilon_{b,f,t} \end{aligned} \tag{12}$$

The results are shown in Table 9. The coefficient on the interaction $QEShock_{f,t} \times Mat.Diff_{b,t}$ is significant and negative. This suggests that funds that experience a larger QE shock in a month t purchase corporate bonds that are more similar in maturity to those the Fed unexpectedly purchased in month t. Comparing the coefficient on the interaction term to that on the standalone $QEShock_{f,t}$ term, for each additional year of difference in a corporate bond's maturity to the average maturity purchased by the Fed, there is a 12% reduction in the amount purchased of the corporate bond by shocked funds. This aligns with the idea that mutual funds are willing to substitute corporate bonds for Treasurys following a QE operation within the same maturity segment.

4.6 Does fund rebalancing have an impact on yields?

Next, I investigate whether the rebalancing behavior of funds following a QE shock has an impact on the yields of the bonds that they rebalance into. In the previous section, we find that following a QE shock, funds rebalance more into the corporate bonds of issuers whose bonds they already hold. This is in line with the findings of Zhu (2021), who find that mutual funds holding existing bonds of a firm have a higher propensity to purchase new issuances from that same firm. This behavior can be explained by the costs involved in retrieving information about new potential investments (Van Nieuwerburgh and Veldkamp, 2010).

To investigate whether the portfolio rebalancing channel has an effect on corporate bond yields, I construct two QE shocks, which capture the extent to which a corporate bond will be rebalanced into by funds following a QE shock. For the first measure, I define an issuer to experience a greater QE shock if its corporate bonds are held more ex-ante by funds that experience a greater QE shock in that month. For a corporate bond b, its issuer i's QE shock during month t is defined as:

$$QEShock_{i(b),t} = \sum_{f \in F} \frac{Holdings_{f,i(b),t-1}}{AmountOutstanding_{i(b),t-1}} \times QEShock_{f,t} \tag{13}$$

where $Holdings_{f,i(b),t-1}$ is the face value of all bonds issued by issuer i of bond b held by fund f as of the end of the month before the shock takes place, $t-1$. $AmountOutstanding_{i(b),t-1}$ is the total amount outstanding of all bonds issued by issuer i of bond b as of the end of the month before the shock takes place, $t-1$. $QEShock_{f,t}$ is the QE shock fund f experiences during month t, as defined in Equation 5.

For the second measure, I construct the QE shock based on funds' ex-ante holdings at the corporate bond level rather than the issuer level. I define a corporate bond to experience a greater QE shock if that corporate bond is held more ex-ante by funds that experience a larger QE shock in that month. For a corporate bond b, its QE shock during month t is defined as:

$$QEShock_{b,t} = \sum_{f \in F} \frac{Holdings_{f,b,t-1}}{AmountOutstanding_{b,t-1}} \times QEShock_{f,t} \tag{14}$$

$Holdings_{f,b,t-1}$ is the face value of corporate bond b held by fund f as of the end of the month before the shock takes place, $t-1$. $AmountOutstanding_{b,t-1}$ is the total amount outstanding of bond b as of the end of the month before the shock takes place, $t-1$. As before, $QEShock_{f,t}$ is fund f's QE shock during month t, as defined in Equation 5.

Using these measures, I estimate the effects of fund rebalancing on corporate bond yields as follows:

$$\Delta y_{b,t-1\to t+\tau} = \sum_{\ell=-12}^{12} \beta_\ell QEShock_{b,t} \times \mathbb{1}\{\tau=\ell\} + \sum_{\ell=-12}^{12} \gamma_\ell \mathbb{1}\{\tau=\ell\} + \lambda_b + \lambda_t + \epsilon_{b,t,\tau} \tag{15}$$

$\Delta y_{b,t-1\to t+\tau}$ is the change in the yield of bond b between the end of month $t-1$ and τ months later. $QEShock_{b,t}$ is one of the two QE shocks defined above in Equations 13 and 14. $\gamma_\ell \mathbb{1}\{\tau=\ell\}$ denotes event-time fixed effects for leads $\ell = \{-12, -11, ..., 12\}$. λ_b and λ_t denote bond and calendar-time fixed effects, respectively.

If the portfolio rebalancing behavior of funds following a QE shock impacts corporate bond yields, then the coefficients β_ℓ should turn negative at $\tau = 0$. This would show that yields on corporate bonds that are more rebalanced into following a QE shock decline relatively more following a QE shock. Estimated coefficients β_ℓ from specifications employing $QEShock_{i(b),t}$ and $QEShock_{b,t}$ are plotted in Figures 5 and 6 respectively. The estimates are also presented in Tables 10 and 11 respectively for $\ell = (-3, ..., 12)$.

In both cases, estimates are insignificant for $\ell = (-12, ..., -1)$, suggesting that there are no differential pre-trends in yield changes for differently shocked bonds before the QE shock occurs. The coefficient turns negative at $\tau = 0$, and remains negative for multiple months following the shock. This suggests that corporate bonds that experience a greater QE shock experience greater declines in yields following the QE shock. To interpret the magnitude of the estimates using the issuer-level QE shock in Equation 13, suppose 10% of an issuer's total corporate bonds outstanding are held by funds who also hold 1% of their TNA in a particular Treasury. When the Fed purchases \$1 billion of that Treasury, that issuer's corporate bonds experience a 6.38bps greater decline in yields compared to other issuers' corporate bonds less held together with the Fed-purchased Treasury, immediately following the Fed's purchase.[10] For estimates using the corporate bond-level QE shock as

[10] The average percentage of an issuers' bonds outstanding held by funds is 7.379% in sample. The average portfolio weight of an individual Treasury is 0.962% for funds in sample. Suppose 7.379% of an issuer's total corporate bonds outstanding are held by funds who also hold 0.962% of their TNA in a particular Treasury. When the Fed purchases \$1 billion of that Treasury, that issuer's corporate bonds experience a 4.53bps greater decline in yields compared to other issuers' corporate bonds less held together with the Fed-purchased Treasury, following the Fed's purchase. See Tables B.1 and B.2 for summary statistics.

in Equation 14, suppose 10% of a corporate bond's total amount outstanding is held by funds who also hold 1% of their TNA in a particular Treasury. When the Fed purchases $1 billion of that Treasury, that corporate bond experiences a 2.71bps greater decline in yields immediately following the Fed's purchase compared to other corporate bonds less held together with the Fed-purchased Treasury. In both cases, the effects on yields revert gradually over the following twelve months.

I also estimate an alternative specification that directly estimates the impact of shocked funds' active rebalancing on yields in the corporate bond market:

$$\begin{aligned}\Delta y_{b,t-1\to t+\tau} = &\sum_{\ell=-12}^{12} \beta_\ell \Delta Holdings_{b,t-1\to t+\tau} \times \mathbb{1}\{\tau=\ell\} \\ &+ \sum_{\ell=-12}^{12} \gamma_\ell \mathbb{1}\{\tau=\ell\} + \lambda_b + \lambda_t + \epsilon_{b,t,\tau}\end{aligned} \tag{16}$$

$\Delta Holdings_{b,t-1\to t+\tau}$ is total active rebalancing in dollars into corporate bond b between month $t-1$ and τ months later by funds experiencing a positive QE shock at time t, scaled as a percentage of the total amount outstanding of the bond. The estimates for the coefficients are shown in Table 12. The coefficients turn negative and significant at $\tau = 0$, indicating that as shocked funds rebalance into corporate bonds, this places downward pressure on the bonds' yields. Turning to the estimate for $\tau = 0$, a 1pp increase in demand by shocked funds (expressed as a percentage of the total amount outstanding of the bond) leads to a 7.09bps decline in the bond's yield initially. The coefficients decrease in magnitude as the horizon considered increases, suggesting that the price impact weakens over time. For example, turning to the estimate for $\tau = 3$, a 1pp increase in demand by shocked funds leads to a 4.33bps decline in the bond's yield over a three-month horizon. This reduced impact at lower frequencies could be because residual investors in the corporate bond market become more price elastic over time. This is in line with Van der Beck (2022*b*)'s result that price elasticity varies depending on the horizon examined.

I also estimate this alternative specification 16 at the maturity bucket level, with each bucket being one year in width. $\Delta y_{b,t-1\to t+\tau}$ is now the value-weighted average yield change for corporate bonds in maturity bucket b. $\Delta Holdings_{b,t-1\to t+\tau}$ is total active rebalancing in dollars into maturity bucket b between month $t-1$ and τ months later by funds experiencing a positive QE shock at time t, scaled by the total amount outstanding of all Treasury coupons as of time t. The estimates for the coefficients are shown in Table 13. Similarly to the bond-level results, the effects are large initially and decline over the following twelve months. However, compared to the bond-level results, the maturity-level effect is significant for longer. This could be explained by the fact that maturity buckets are less close substitutes for one another than individual bonds, and so the relative differences in yields take less time to revert at the bond level.

This suggests that the portfolio rebalancing of funds has an effect on the yields of the corporate bonds that they rebalance into. In the next section, I introduce a model that allows me to estimate the total effect size of the portfolio rebalancing channel on yields implied by these relative effect sizes.

5 Quantifying the Total Effect Size of the Portfolio Rebalancing Channel on Yields

In this section, I develop and calibrate a structural model in order to estimate the total effect size of the portfolio rebalancing channel on corporate bond yields. So far, we have seen that when the Fed unexpectedly purchases Treasurys, funds who own these Treasurys (and thus experience a larger QE shock) sell them and rebalance to a degree into corporate bonds. Funds that experience a greater QE shock rebalance into corporate bonds with a more similar maturity to the Treasurys the Fed purchases. This rebalancing reduces the yields of corporate bonds that shocked funds rebalance into, with the effects reverting over the following year. The empirical estimates identify relative effects when the Fed unexpectedly purchases particular Treasurys on the rebalancing of funds that hold more of these Treasurys and on corporate bond yields that are more rebalanced into following QE shocks. The model maps these empirical moments estimated in Section 4 to the implied total effect size of the portfolio rebalancing channel on yields.

5.1 Model Setup

5.1.1 Investor Types and Available Assets

In the model, time is continuous and goes from 0 to T. There exist Treasury and corporate zero coupon bonds of maturities $\tau \in (0, T)$. A Treasury of maturity τ has a price of $P_t^{(\tau)}$ and a face value of 1, paying $\$1$ with certainty at maturity. A corporate bond of maturity τ has a price of $\tilde{P}_t^{(\tau)}$ and has a risky payoff $\$D_{t+\tau} = \$e^{d_t}$ at maturity, where d_t is a stochastic process. The short rate i_t is the yield on a Treasury as $\tau \to 0$, representing the federal funds rate.

There are three groups of agents in the model. The first group are preferred-habitat investors, who each invest within a particular maturity segment but are willing to substitute between Treasurys and corporate bonds within that maturity. They face idiosyncratic demand shocks. One example of these investors could be bond funds, which invest within a maturity segment defined by their investment mandate but can invest both in government bonds and corporate bonds. The idiosyncratic demand shocks can be thought of as exogenous shocks to certain funds' demand for assets due to fund flows into mutual funds specializing in a particular maturity segment. Formally, there exists a continuum of preferred-habitat investors who specialize in one maturity each across the Treasury and corporate bond markets. A τ-maturity investor has demand Z_t of riskless assets:

$$Z_t^{(\tau)} = -\alpha(\tau) log P_t^{(\tau)} + \beta(\tau) log \tilde{P}_t(\tau) + w(\tau) f_t(\tau) \tag{17}$$

and demand $\tilde{Z}_t$ of corporate bonds:

$$\tilde{Z}_t^{(\tau)} = -\tilde{\alpha}(\tau) log \tilde{P}_t^{(\tau)} + \tilde{\beta}(\tau) log P_t^{(\tau)} + (1 - w(\tau)) f_t(\tau) \tag{18}$$

The functions $\alpha(\tau)$ and $\tilde{\alpha}(\tau)$ are the τ-habitat investor's price elasticity of demand for Treasury and corporate bonds, respectively. The functions $\beta(\tau)$ and $\tilde{\beta}(\tau)$ are the τ-habitat investor's cross-price elasticities of demand: they reflect the degree to which these investors are willing to substitute between Treasury and corporate bonds. The greater $\tilde{\beta}(\tau)$, the more the investor is willing to substitute into corporate bonds of maturity τ when the price of Treasurys of maturity τ increases. Similarly, the greater $\beta(\tau)$, the more the preferred-habitat investor is willing to substitute into Treasurys of maturity τ when the price of corporate bonds of maturity τ increases.

Each τ-habitat investor also faces idiosyncratic shocks to demand, modeled by $f_t(\tau)$. An increase in $f_t(\tau)$ increases the τ-habitat investor's demand for both τ maturity Treasury and corporate bonds. In the context of mutual funds, these can be thought of as exogenous flows into τ-maturity funds. The fraction of the change in demand $f_t(\tau)$ that is allocated to Treasurys is $w(\tau)$; the remainder is allocated to corporate bonds. $w(\tau)$ can be thought of as reflecting the τ-maturity fund's baseline asset mix.

The second group of agents in the model are specialized arbitrageurs, as in Merton et al. (1987); Shleifer and Vishny (1997); Gromb and Vayanos (2002). The arbitrageurs are risk-averse and specialize in Treasurys across maturities and in the short rate. These can be thought of as dealers who specialize in the government bond market. Formally, arbitrageurs have mean-variance preferences and allocate their wealth W_t to holdings $\{X_t^{(\tau)}\}_{\tau=1,\ldots,T}$. They solve:

$$\max_{\{X_t^{(\tau)}\}_{\tau=1,\ldots,T}} E_t[dW_t] - \frac{a}{2}Var_t[dW_t] \tag{19}$$

$$s.t. dW_t = W_t i_t dt + \int_0^T \{X_t^{(\tau)}(\frac{dP_t^{(\tau)}}{P_t^{(\tau)}} - i_t dt)\}d\tau \tag{20}$$

$a \geq 0$ is the arbitrageur's coefficient of absolute risk aversion, representing the trade-off they make between the mean and variance of their portfolio's return.

The third group of agents in the model are residual corporate bond market investors, who take the other side of the preferred-habitat investors' trades in the corporate bond market. There exists a continuum of such investors who trade in one maturity each. These agents demand $V_{t+h}^{(\tau)} = 0$ of Treasurys at all horizons h, and $\tilde{V}_{t+h}^{(\tau)}$ of corporate bonds:

$$\tilde{V}_{t+h}^{(\tau)} = -\tilde{\gamma}_h(\tau) log \tilde{P}_t^{(\tau)} \tag{21}$$

The function $\tilde{\gamma}_h(\tau)$ captures the residual corporate bond market investors' price elasticity of demand for corporate bonds at horizon h. The greater $\tilde{\gamma}(\tau)$, the more willing they are to sell corporate bonds to preferred-habitat investors when corporate bond prices rise. To capture slow-moving capital in the corporate bond market, I let $\tilde{\gamma}(\tau)$ vary depending on the horizon h considered. In the calibration, I find that $\tilde{\gamma}(\tau)$ becomes larger, and so residual demand becomes more price elastic, as the horizon considered increases. This is in line with Van der Beck (2022*b*)'s finding that elasticities vary depending on the horizon considered and also explains the gradual reduction of price impact in the corporate bond market as the length of time since the QE shock increases.

5.1.2 Supply and QE

There is a publicly available supply of $\theta_0(\tau)$ of each Treasury of maturity τ and a publicly available supply of $\tilde{\theta}_0(\tau)$ of each corporate bond of maturity τ. During QE operations in the government bond market, the Fed reduces the amount of publicly available supply of the τ-maturity Treasury $\theta_0(\tau)$ by an amount $QE(\tau)$. The Fed does not purchase any corporate bonds, and so for a corporate bond of maturity τ, the publicly available supply is always $\tilde{\theta}_0(\tau)$.

5.1.3 State Variables

There are five state variables in the model: the short rate i_t, the corporate bond payoff d_t, idiosyncratic demand shocks for short-maturity and long-maturity habitat investors f_{st} and f_{lt}, and the Fed's holdings QE_t. The state variables $s_t = (i_t, d_t, f_{st}, f_{lt}, QE_t)$ follow Ornstein-Uhlenbeck processes:

$$ds_t = -\Gamma(s_t - \overline{s})dt + \Sigma dB_t \tag{22}$$

Γ is diagonal with elements $\kappa_i, \kappa_d, \kappa_{f_s}, \kappa_{f_l}, \kappa_{QE}$ and Σ is diagonal with elements $\sigma_i, \sigma_d, \sigma_{f_s}$, $\sigma_{f_l}, \sigma_{QE}$, so the processes are independent. $\overline{s}$ contains the long-term means of the variables. dB_t is a vector of 5 independent Brownian motions.

5.1.4 Equilibrium

I posit that asset prices take the following form:

$$-logP_t^{(\tau)} = A(\tau)s_t + C(\tau) \tag{23}$$

$$-log\tilde{P}_t^{(\tau)} = \tilde{A}(\tau)s_t + \tilde{C}(\tau) \tag{24}$$

Applying Ito's Lemma and using the state vector dynamics in 22, it follows that the instantaneous return of bonds with maturity τ is:

$$\frac{dP_t^{(\tau)}}{P_t^{(\tau)}} = \mu_t^{(\tau)}dt - A(\tau)'\Sigma dB_t \tag{25}$$

$$\frac{d\tilde{P}_t^{(\tau)}}{\tilde{P}_t^{(\tau)}} = \tilde{\mu}_t^{(\tau)}dt - \tilde{A}(\tau)'\Sigma dB_t \tag{26}$$

where

$$\mu_t^{(\tau)} = \frac{\partial A(\tau)}{\partial t}s_t + \frac{\partial C(\tau)}{\partial t} + A(\tau)\Gamma(s_t - \overline{s}) + \frac{1}{2}A(\tau)\Sigma\Sigma A(\tau) \tag{27}$$

$$\tilde{\mu}_t^{(\tau)} = \frac{\partial \tilde{A}(\tau)}{\partial t}s_t + \frac{\partial \tilde{C}(\tau)}{\partial t} + \tilde{A}(\tau)\Gamma(s_t - \overline{s}) + \frac{1}{2}\tilde{A}(\tau)\Sigma\Sigma\tilde{A}(\tau) \tag{28}$$

Using this, the arbitrageur's first-order condition can be written as:

$$\mu_t^{(\tau)} - i_t = \sum_s A_s(\tau)\lambda_{s,t} \tag{29}$$

where

$$\lambda_{s,t} = a\sigma_s^2 \left[\int_0^T X_t^{(\tau)} A_s(\tau) d\tau \right]$$

Equation 29 can be interpreted as equating the τ-maturity Treasury's excess return $\mu_t^{(\tau)} - i_t$ to the sum across risk factors s of the product of the τ-maturity bond's sensitivity to each risk factor $A_s(\tau)$ and the price of that risk factor $\lambda_{s,t}$, which is constant across all bonds. The price of each risk factor depends on how exposed the arbitrageur's portfolio is to that risk factor, $\int_0^T X_t^{(\tau)} A_s(\tau) d\tau$. The more exposed the arbitrageur is to a risk factor, the higher that risk factor's price.

As derived in Appendix C, combining market clearing conditions with the arbitrageur's first-order condition yields an affine equation in the state variables. Comparing the coefficients on each of the state variables yields a system of ODEs, which determines the coefficients $A(\tau)$ and constant $C(\tau)$. The system of ODEs can be solved numerically to obtain $A(\tau)$ and $C(\tau)$.

In Appendix C, I also derive the relationship between the coefficients on states for the price of Treasurys $A(\tau)$ and the coefficients on states for the price of corporate bonds $\tilde{A}(\tau)$. Here, I focus on the interpretation of the relationship for the state variable QE_t. The relationship between the coefficients is:

$$\tilde{A}_{QE}(\tau) = \frac{\tilde{\beta}(\tau)}{\tilde{\alpha}(\tau) + \tilde{\gamma}(\tau)} A_{QE}(\tau) \tag{30}$$

The relative effect of QE on the corporate bond price compared to the Treasury price, $\frac{\tilde{A}_{QE}(\tau)}{A_{QE}(\tau}$, captures the relative degree of pass-through of QE's effects on yields in the Treasury market to yields in the corporate bond market. The greater $\tilde{\beta}(\tau)$, the greater the preferred-habitat investor's willingness to substitute into corporate bonds when the price of Treasurys rises, and so the greater the pass-through. For example, when the Fed purchases τ-maturity Treasurys (represented by an increase in $QE(\tau)$ and a decrease in $\theta_0(\tau)$), this has a positive effect on Treasury prices. The degree to which this effect is passed on to corporate bond prices depends on the degree to which investors are willing to substitute between corporate bonds and Treasurys. The more they substitute into corporate bonds, the greater the effect of QE purchases in the Treasury market on corporate bond prices.

A second determinant of the degree of pass-through of QE's effects to the corporate bond market is $\tilde{\gamma}(\tau)$, the residual corporate bond market investors' price elasticity for corporate bonds. The lower $\tilde{\gamma}(\tau)$, the greater the pass-through of QE's effects to the corporate bond market. When τ-habitat investors' demand for corporate bonds increases following Fed purchases of τ-maturity Treasurys, this puts upward pressure on the corporate bond price. With a lower $\tilde{\gamma}(\tau)$, the residual investors reduce their demand by less, putting further upward pressure on the corporate bond price. A third determinant of the degree of pass-through is $\tilde{\alpha}(\tau)$, the preferred-habitat investor's own-price elasticity for corporate bonds. The greater $\tilde{\alpha}(\tau)$, the lower the degree of pass-through. With a greater $\tilde{\alpha}(\tau)$, preferred-habitat investor's demand for corporate bonds is dampened more by the increase in the corporate bond prices that follows a demand shock, which dampens the overall increase in their demand for corporate bonds, and thus the overall effect of QE on the corporate bond price.

5.2 Model Calibration

To fit the model to the data, I proceed in two steps. First, I estimate numerous parameters regarding the state variable processes, as described in Appendix D. I also use my earlier empirical estimate for the price elasticity of preferred-habitat investors, as shown in Table 6.[11] Second, I calibrate the cross-price elasticities for the preferred habitat investors, the level of risk-taking capacity of arbitrageurs, and the elasticity of demand for the residual investors in the corporate bond market at short-, medium-, and long-term horizons.

For the calibration, I assume that the preferred-habitat investors' price elasticity for Treasurys takes the following functional form: $\alpha(\tau) = \frac{\alpha_0}{\tau}$. This functional form implies a constant elasticity of demand with respect to yields across all τ-maturity investors. Similarly, preferred-habitat investors' price elasticity for corporate bonds takes the form $\tilde{\alpha}(\tau) = \frac{\tilde{\alpha_0}}{\tau}$, and the elasticity of the residual participants in the corporate bond market takes the form $\tilde{\gamma}(\tau) = \frac{\tilde{\gamma_0}}{\tau}$. The cross-price elasticity $\tilde{\beta}(\tau)$, the increase in demand for the corporate bond, given an increase in the price of the Treasury, takes the form $\tilde{\beta}(\tau) = \alpha(\tau) \times dos$. dos can be interpreted as the investor-perceived degree of substitutability between corporate bonds and Treasurys. I assume that substitutability is symmetric in both directions, i.e., that we would see the same level of substitution into Treasurys when there is an increase in the price of the corporate bond. So the cross-price elasticity $\beta(\tau)$, the increase in

[11] For more details, see Appendix D.3.

demand for the Treasury, given an increase in the price of the corporate bond, takes the form: $\beta(\tau) = \tilde{\alpha}(\tau) \times dos$.

Section 4 delivers the moments which I use to calibrate the investor-perceived degree of substitution between corporate bonds and Treasurys, dos, the parameters governing the price elasticity of demand for the residual corporate bond market investors, $\tilde{\gamma}_0$, and the level of arbitrageur risk-taking capacity, a. The first set of moments describes the fraction of capital received from Treasury sales that is rebalanced into corporate bonds by exposed funds initially, three months later, and twelve months later.[12] The second set of moments is the relative price impact the rebalancing of exposed funds following a QE shock has within the corporate bond market, initially, over three months and over twelve months.[13] Together, these moments will determine the cross-price elasticity of demand of the preferred-habitat investors and the residual corporate bond investors' elasticity of demand at short-, medium-, and long-term horizons. To illustrate intuitively how these parameters determine the observed moments, suppose the Fed purchases Treasurys of maturity τ, reducing their publicly available supply and increasing their price. τ-maturity investors who previously held these Treasurys rebalance into τ-maturity corporate bonds. The degree to which they rebalance is determined by how substitutable they perceive Treasurys and corporate bonds to be, dos, together with their price elasticity of demand for corporate bonds $\tilde{\alpha}(\tau)$. The price impact this increased demand has on τ-maturity bonds within the corporate bond market depends on $\tilde{\gamma}(\tau)$, the willingness of the residual corporate bond market participants to sell bonds as the price rises. The third moment used is the effect of unexpected Fed purchases of Treasurys of a maturity on that maturity's yield.[14] This will determine the level of arbitrageur's risk-taking capacity in the Treasury market. The model-implied moments are derived formally in Appendix D.5.

I summarize the calibrated parameters, together with their sources, in Table 17. The results of the calibration are shown in Table 18. The model is able to match the dynamics observed in investor rebalancing between Treasurys and corporate bonds and its effect on yields over various horizons.

5.3 Model Results

I now use the model to estimate the total effect that QE Treasury purchases have on corporate bond yields through the portfolio rebalancing channel. To do so, I first calculate the Fed's total Treasury coupon purchases for each maturity year, during each month of their

[12] This is the ratio of coefficients for $\tau = 0$, $\tau = 3$ and $\tau = 12$ in Tables 5 and 7.

[13] These are the coefficients for $\tau = 0$, $\tau = 3$ and $\tau = 12$ in Table 13.

[14] This is the coefficient for $\tau = 0$ in Table 2

QE programs between 2009 and 2021. I scale this by the total amount outstanding of all Treasury coupons at that point in time. I input these as monthly shocks into the model to estimate the effect on corporate bond yields each month relative to a counterfactual where the Fed conducts no Treasury coupon purchases. The results with the baseline calibrated parameters are shown in Figure 8. I find that the portfolio rebalancing channel has a large effect on yields in the corporate bond market. In terms of magnitudes, a Fed purchase of size 1% of the total amount of all Treasury coupons outstanding[15], with the same average maturity decomposition as the Fed's entire Treasury coupon purchases, lowers the yield of 7-year corporate bonds by 7.87bps initially, 4.75bps after three months, and 3.13bps after twelve months through the portfolio rebalancing channel with the effect reverting to 0 after that.

Figure 8 suggests that it is more the flow of the Fed's purchases rather than the size of the Fed's balance sheet that matters for the size of the portfolio rebalancing channel's effect. For example, in 2016, the Fed's balance sheet stood steady at over $4 trillion of assets. However, the effect of the portfolio rebalancing channel on corporate bond yields during this time is zero. This highlights that what matters most for the portfolio rebalancing channel to have an effect is the size of the Fed's purchases over the previous twelve months rather than the level of the Fed's balance sheet.

Next, I use the model to investigate how changes in the Fed's purchases of Treasury coupons might alter the effect size of the portfolio rebalancing channel on yields.

5.3.1 Impact of Pace of Fed Purchases

First, I investigate the effect of the pace of the Fed's purchases on the effect of the portfolio rebalancing channel on yields. The counterfactual I investigate keeps the total size and maturity decomposition of the Fed's purchases in each of the four QE programs constant but changes the pace of purchases each month so that the Fed purchases an equal amount each month of each QE program. The top panel in Figure 9 shows the actual size of Fed purchases each month and the size of purchases in the 'Constant Pace' counterfactual that is analyzed. The bottom panel shows the model-estimated effects of the portfolio rebalancing channel stemming from the Fed's purchases of Treasury coupons on corporate bond yields each month for actual and counterfactual purchases by the Fed.

I find that the pace of the Fed's purchases has a substantial impact on the impact profile of the rebalancing channel on yields. For example, the Fed front-loaded its purchases during 2020-2021 in the early months of the pandemic, as shown by the 'Actual' line in the top panel. This resulted in a sharp, immediate decline in corporate bond yields, with the

[15] In sample, this is equivalent to approximately $100 billion purchases.

7-year corporate bond yield falling by approximately 60bps. However, the effect reverts rather quickly, with the effect on 7-year corporate bond yields standing at just over 20bps a year later. In the counterfactual policy design, the Fed does not front-load purchases but rather spreads them evenly across the months of the QE program in 2020-2021. This results in a very small initial effect of less than 10bps, and a maximal effect of approximately 40bps, which is reached after one year of the QE program. However, yields remain at this level for longer. This highlights that the Fed has a choice regarding the type of impact they have on yields through the portfolio rebalancing channel. If they conduct a large portion of their purchases at the beginning of a QE program, this results in a larger initial effect on yields that reverts more quickly compared to if they spread their purchases more evenly across the duration of a QE program.

5.3.2 Impact of Maturity of Fed Purchases

Second, I investigate the effects of changes in the average maturity of the Fed's purchases. The counterfactual I investigate keeps the total size of the Fed's purchases each month constant but changes the maturity decomposition of purchases each month so that the average years to maturity purchased is twenty (with purchases spread evenly across Treasury coupons between ten to thirty years in maturity). The top panel of Figure 10 shows the actual average maturity of Fed purchases each month and the average maturity in the 'Long Maturity' counterfactual that is analyzed. The bottom panel shows the model-estimated effects of the portfolio rebalancing channel stemming from the Fed's purchases of Treasury coupons on corporate bond yields each month for actual and counterfactual purchases by the Fed.

The maturity decomposition of the Fed's purchases has a substantial impact on the size of the rebalancing channel's effect on corporate bond yields, with the counterfactual long maturity purchases lowering seven year corporate bond yields by an average of approximately twice that of the actual purchases. This is in line with previous findings by Vayanos and Vila (2021) that longer maturity purchases have larger effects on Treasury bond yields across the curve, as such purchases remove more duration risk from the market, and so reduce the premia that investors require to hold duration risk.

6 Effects on Corporate Bond Issuance and Real Outcomes

So far, I have shown that the portfolio rebalancing channel substantially lowers corporate bond yields. Next, I investigate whether the channel affects corporate bond issuance and whether this translates to changes in real outcomes, e.g., firm investment.

6.1 Is there an effect on issuance quantities?

I first analyze the effects of the portfolio rebalancing channel on the quantity of corporate bond issuance. If the portfolio rebalancing channel affects the quantity of corporate bond issuance, then issuers that experience a greater QE shock should issue relatively more following the shock. To analyze this, I estimate the following specification:

$$\begin{aligned} Issuance_{i,t-1\to t+\tau} = &\sum_{\ell=-12}^{12} \beta_\ell QEShock_{i,t} \times \mathbb{1}\{\tau = \ell\} \\ &+ \sum_{\ell=-12}^{12} \gamma_\ell \mathbb{1}\{\tau = \ell\} + \lambda_i + \lambda_t + \epsilon_{i,t,\tau} \end{aligned} \tag{31}$$

$Issuance_{i,t-1\to t+\tau}$ is the total new issuance by issuer i between the end of month $t-1$ and τ months later, scaled by the total amount outstanding of all bonds by the issuer as of the end of month $t-1$. $QEShock_{i,t}$ is the issuer-level QE shock, as defined in Equation 13. Event-time fixed effects for leads $\tau = \{-12, -11, ..., 12\}$ are denoted by $\gamma_\ell \mathbb{1}\{\tau = \ell\}$, and fund and calendar-time fixed effects are denoted by λ_f and λ_t respectively.

The estimated coefficients β_ℓ are shown in Table 14, and in Figure 7. Issuers that experience a greater QE shock indeed issue a greater quantity of new corporate bonds following the shock. To recap, issuers with a greater QE shock in month t are issuers that are likelier to be rebalanced into following month t as they are held more ex-ante by funds that experienced a greater QE shock. Issuers seem to take advantage of the increased demand by shocked funds for their corporate bonds by issuing a larger quantity of corporate bonds in the months that follow the shock. In terms of magnitudes, if the Fed purchases Treasury (with a purchase size of 1% of all outstanding Treasury coupons), then if an issuer's bonds are held by funds that hold 1pp of their portfolio more in the Treasury, the issuer issues 0.102pp more bonds over the following year (as a percentage of the total amount outstanding of their bonds).

We see the effects on new issuance begin to materialize early on. This may be capturing firms using shelf registration. Shelf registration allows companies to pre-register security issues with the SEC and then sell them up to three years later. This allows firms to quickly take advantage of favorable market conditions and could explain why we already see some effects on new issuance in the first monthly immediately following a QE shock.

The increase in the supply of bonds by issuers that experience a greater QE shock in the months following the shock could partly explain the reversal in the decline in yields that we observe for these issuers (as seen in Figure 5). The dynamics of the effects on yields mirror those of the effects on issuance, increasing steadily from t until $t+8$ and then leveling off. This provides suggestive evidence that the steady increase in the relative supply of bonds through new issuance by issuers that experience a larger QE shock following the shock might be contributing to the steady increase in those issuers' corporate bond yields observed following their initial sharp decline.

This also suggests that even though the effects on yields are temporary, the portfolio rebalancing channel of QE has other effects that persist beyond twelve months. Due to the channel, issuers are able to borrow more through new bond issuances, and most of these bond issues likely remain in existence long beyond twelve months.

6.2 Is there an effect on initial offering yields?

Next, I analyze the effects of the portfolio rebalancing channel on the initial offering yields of new corporate bond issuances. Given that the yields of issuers with a greater QE shock fall more in the secondary market, one should expect that issuers will also face lower yields at issuance. To analyze this, I estimate the following specification for all issuers that issue one month before the QE shock and τ months later:

$$\Delta y_{i,t-1 \to t+\tau} = QEShock_{i,t} + \lambda_i + \lambda_t + \epsilon_{i,t,\tau} \tag{32}$$

$\Delta y_{i,t-1 \to t+\tau}$ is the change in the value-weighted average new issuance yields of issuer i for issuances occurring in month $t-1$ and issuances occurring τ months later. $QEShock_{i,t}$ is the QE shock that the issuer experiences, as defined in Equation 13. λ_i and λ_t denote issuer and calendar-time fixed effects, respectively.

The results are presented in Table 15. I find that firms that issue new corporate bonds are able to take advantage of favorable conditions and issue at lower yields in the primary market. In terms of magnitudes, if the Fed purchases a Treasury (purchase size of 0.01% of all outstanding Treasury coupons), then if an issuer's bonds are held by funds that hold 1pp of their portfolio more in the Treasury, the issuer's initial offering yields after three months decline by 6.615bp more.

6.3 What do firms do with the additional capital received through new issues?

So far, we have seen that firms that experience a greater QE shock issuer more bonds at lower yields following the QE shock. Next, I analyze what these firms use the additional capital for. To do so, I estimate the following specification across all firms in my sample:

$$\Delta Outcome_{i,t-1\to t+\tau} = \sum_{\ell=-4}^{8} \beta_\ell QEShock_{i,t} \times \mathbb{1}\{\tau = \ell\}$$
$$+ \sum_{\ell=-4}^{8} \gamma_\ell \mathbb{1}\{\tau = \ell\} + \lambda_i + \lambda_t + \epsilon_{i,t,\tau} \quad (33)$$

$\Delta Outcome_{i,t-1\to t+\tau}$ is the change in an outcome for issuer i between the end of quarter $t-1$ and τ quarters later. I analyze the following outcomes: capital expenditure, total investment (capital expenditure + R&D expenditure), cash balance changes, cash + short-term instrument balance changes, and long-term debt reduction. All outcomes are scaled by the firm's total asset as of $t-1$ end. $QEShock_{i,t}$ is the QE shock that issuer i experiences in quarter t, defined as the total across all funds of the product of the fund's holdings of the issuers' bonds as of the end of quarter $t-1$, and the average monthly QE shock that the fund experiences during quarter t.

The results are shown in Table 16. I find that firms that experience a greater QE shock gradually increase investment in the quarters following the QE shock (as shown in columns 1 and 2). They also increase their cash buffers: there is an increase in their holdings of cash and other short-term instruments (as shown in columns 4 and 5). Comparing the magnitudes on the coefficients, over the following year, firms allocate roughly twice as much capital of the capital raised to their cash buffers as they do to investment. There is no evidence that firms use the capital raised from new issuances to retire existing debt (as shown in column 3).

Overall, the results in this section suggest that through the portfolio rebalancing channel, firms are able to issue more debt with more favorable terms and use the capital raised to increase their investment and financial resiliency.

7 Conclusion

In this paper, I provide direct empirical evidence that the Fed reduces firms' cost of capital through the portfolio rebalancing channel of QE. I find that funds that hold more in the prior month of the Treasurys that the Fed unexpectedly purchases rebalance out of Treasurys and into corporate bonds. This rebalancing has an impact on the yields of corporate bonds. I find a large and time-varying effect: a $100 billion Treasury bond purchase by the Fed lowers the yield of a typical corporate bond by 7.87bps on impact through the portfolio rebalancing channel. This effect reverts to 4.75bps after three months and 3.13bps after twelve months. The dynamics of the effect have policy implications: how the Fed distributes its purchases over time determines the effect on yields. Through the portfolio rebalancing channel, firms can issue more bonds over the following year at lower initial offering yields. Firms use the additional capital raised in the corporate bond market to increase their investment and their cash buffers.

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8 Figures

Yield Changes in Treasurys Around QE Shocks

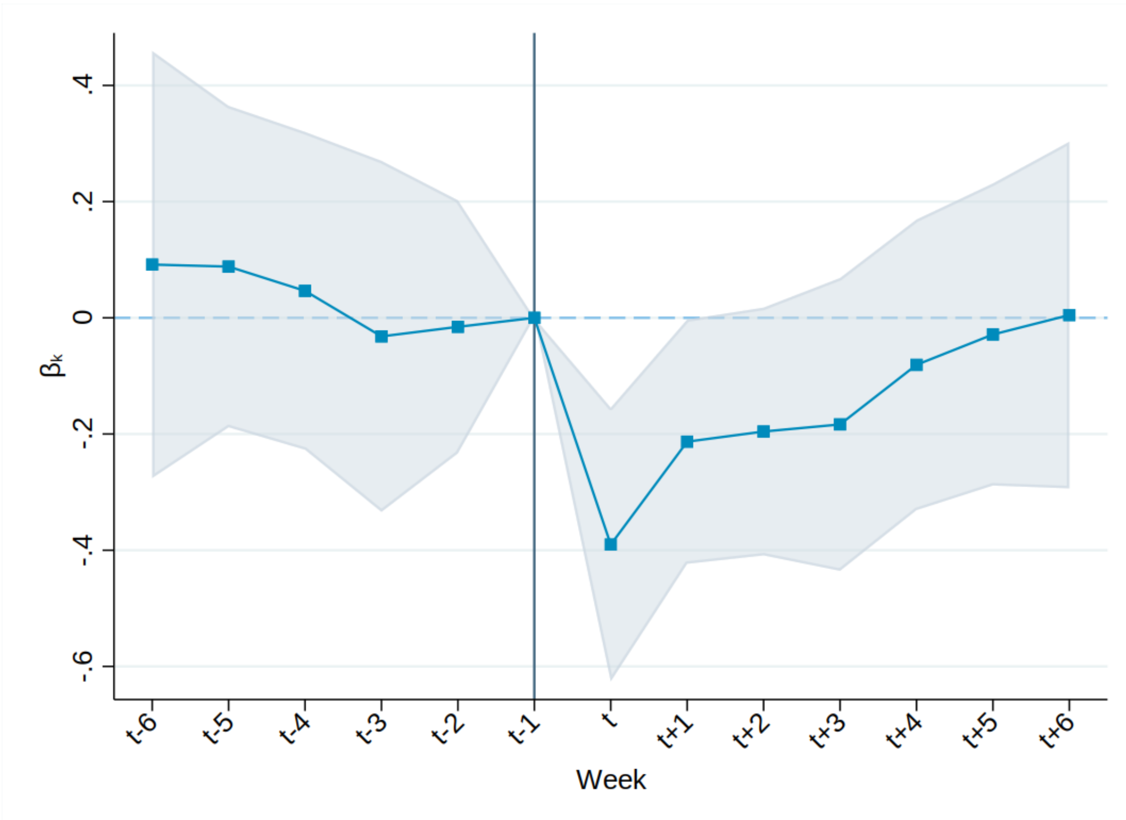

Figure 1: This figure plots the estimates for coefficients β_ℓ in the regression equation:

$$\Delta y_{i,t-1\to t+\tau} = \sum_{\ell=-6}^{6} \beta_\ell QEShock_{i,t} \times \mathbb{1}\{\tau = \ell\} + \sum_{\ell=-6}^{6} \gamma_\ell \mathbb{1}\{\tau = \ell\} + \lambda_i + \lambda_t + \epsilon_{i,t,\tau}$$

$QEShock_{i,t}$ is the total unexpected dollar amount purchased by the Fed of a Treasury i during week t, scaled by the total amount outstanding of all Treasury coupons. $\Delta y_{i,t-1\to t+\tau}$ is the change in the yield of Treasury i between the end of the week before the Fed's purchases take place, $t-1$, and τ weeks later. λ_i and λ_t are security- and calendar-time fixed effects, respectively, and $\gamma_\ell \mathbb{1}\{\tau = \ell\}$ are event-time fixed effects. The shaded area represents the 95% confidence bands.

Active Rebalancing by Funds into Fed-Purchased Treasurys around QE Shocks

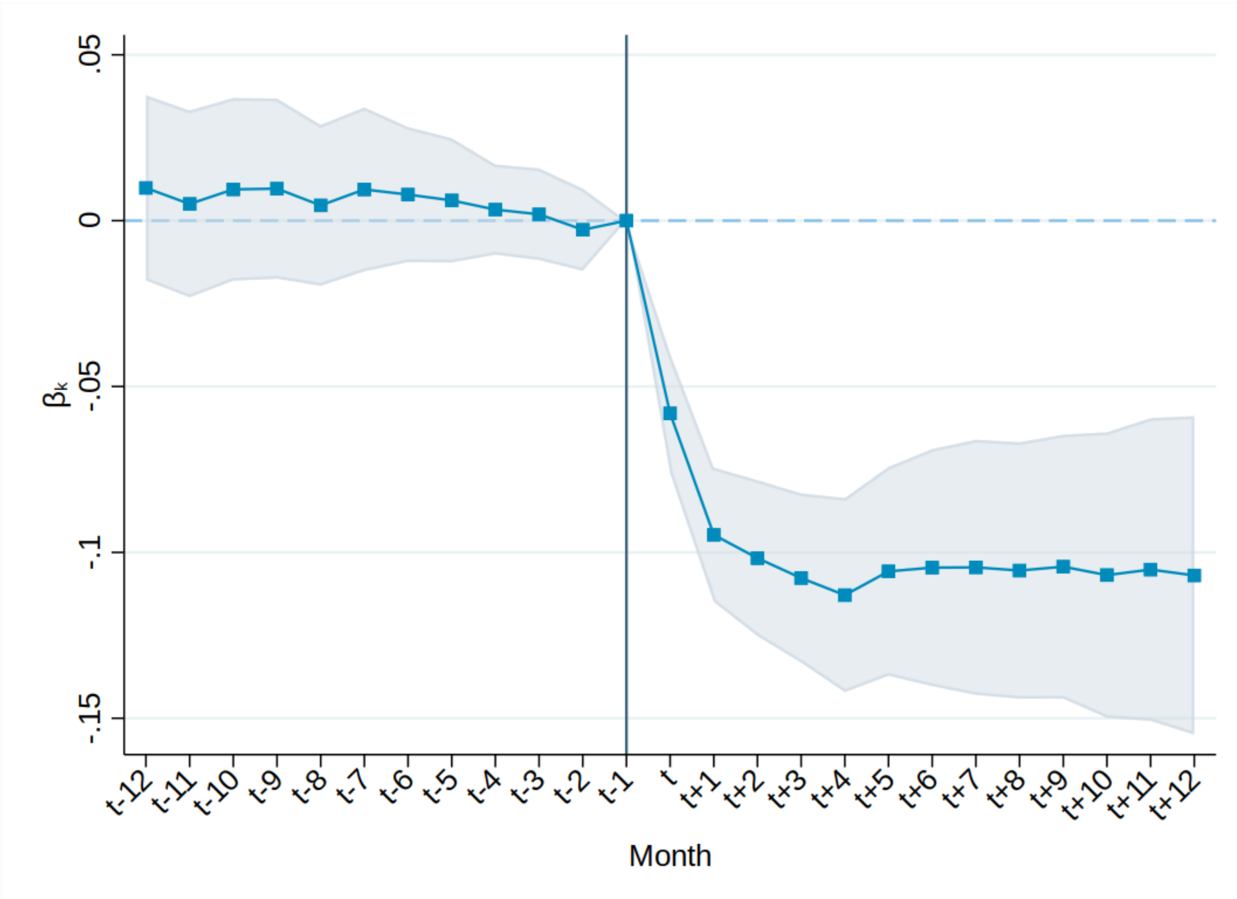

Figure 2: This figure plots the estimates for coefficients β_ℓ in the regression equation:

$$\Delta Holdings_{f,t-1\to t+\tau} = \alpha + \sum_{\ell=-12}^{12} \beta_\ell QEShock_{f,t} \times \mathbb{1}\{\tau = \ell\} + \sum_{\ell=-12}^{12} \gamma_\ell \mathbb{1}\{\tau = \ell\} + \lambda_f + \lambda_t + \epsilon_{f,t,\tau}$$

$\Delta Holdings_{f,t-1\to t+\tau}$ measures active rebalancing by fund f between the end of month $t-1$ and τ months later, into Treasurys that the Fed purchases during month t. A negative value represents active selling by the fund. $QEShock_{f,t}$ measures fund f's QE shock during month t. The greater the shock value, the more the fund held at the end of month $t-1$ in Treasurys that the Fed unexpectedly purchased more in month t. There are event-time fixed effects for leads $\tau = \{-12, -11, ..., 12\}$, denoted by $\gamma_\ell \mathbb{1}\{\tau = \ell\}$. There are also fund and calendar-time fixed effects, denoted by λ_f and λ_t. The shaded area represents the 95% confidence bands.

Active Rebalancing by Funds into All Treasurys around QE Shocks

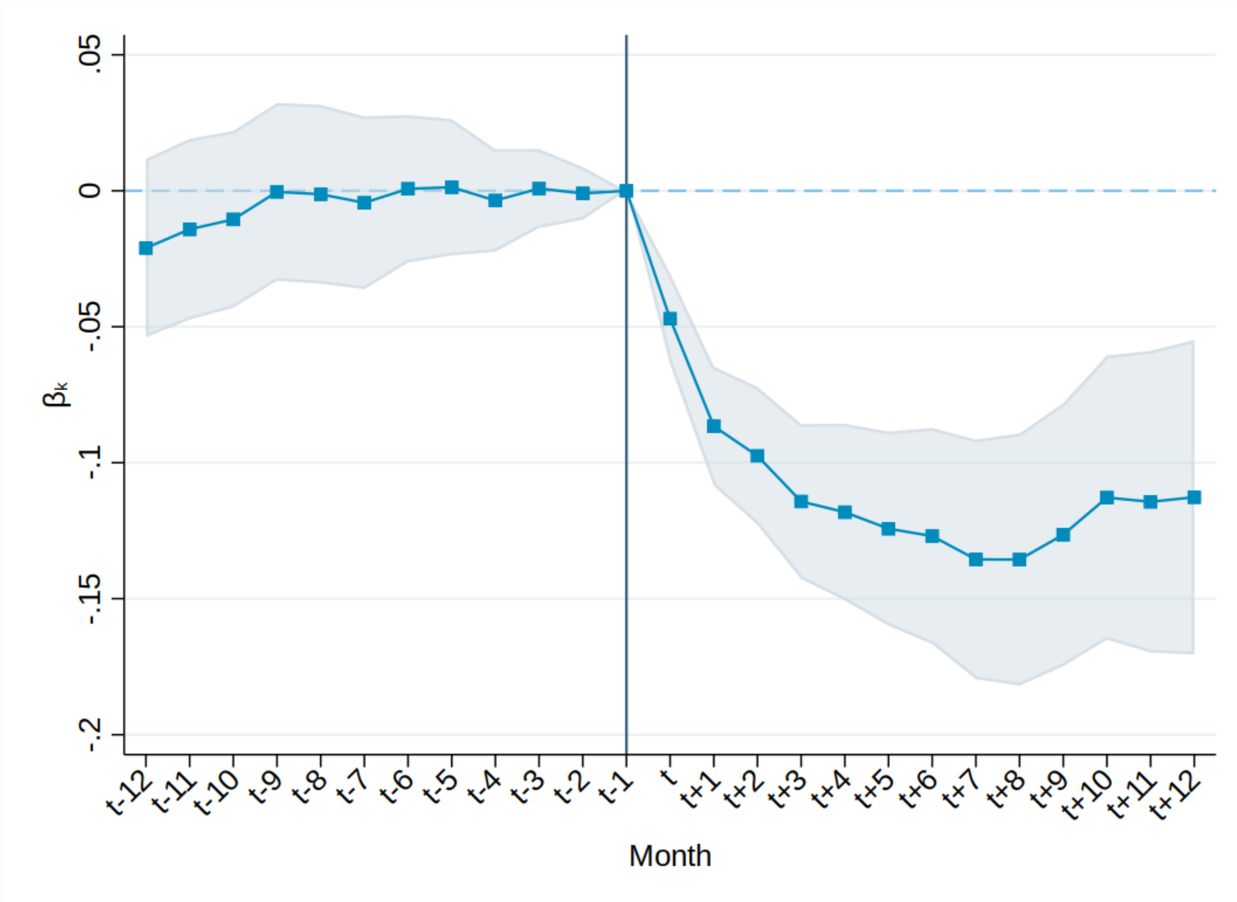

Figure 3: This figure plots the estimates for coefficients β_ℓ in the regression equation:

$$\Delta Holdings_{f,t-1\to t+\tau} = \alpha + \sum_{\ell=-12}^{12} \beta_\ell QEShock_{f,t} \times \mathbb{1}\{\tau = \ell\} + \sum_{\ell=-12}^{12} \gamma_\ell \mathbb{1}\{\tau = \ell\} + \lambda_f + \lambda_t + \epsilon_{f,t,\tau}$$

$\Delta Holdings_{f,t-1\to t+\tau}$ measures active rebalancing by fund f between month $t-1$ and month $t+\tau$ into all Treasurys. A negative value represents active selling by the fund. $QEShock_{f,t}$ measures fund f's QE shock during month t. The greater the value, the more the fund held at the end of month $t-1$ in Treasurys that the Fed unexpectedly purchased more in month t. There are event-time fixed effects for leads $\tau = \{-12, -11, ..., 12\}$, denoted by $\gamma_\ell \mathbb{1}\{\tau = \ell\}$. There are also fund and calendar-time fixed effects, denoted by λ_f and λ_t. The shaded area represents the 95% confidence bands.

Active Rebalancing by Funds into Corporate Bonds around QE Shocks

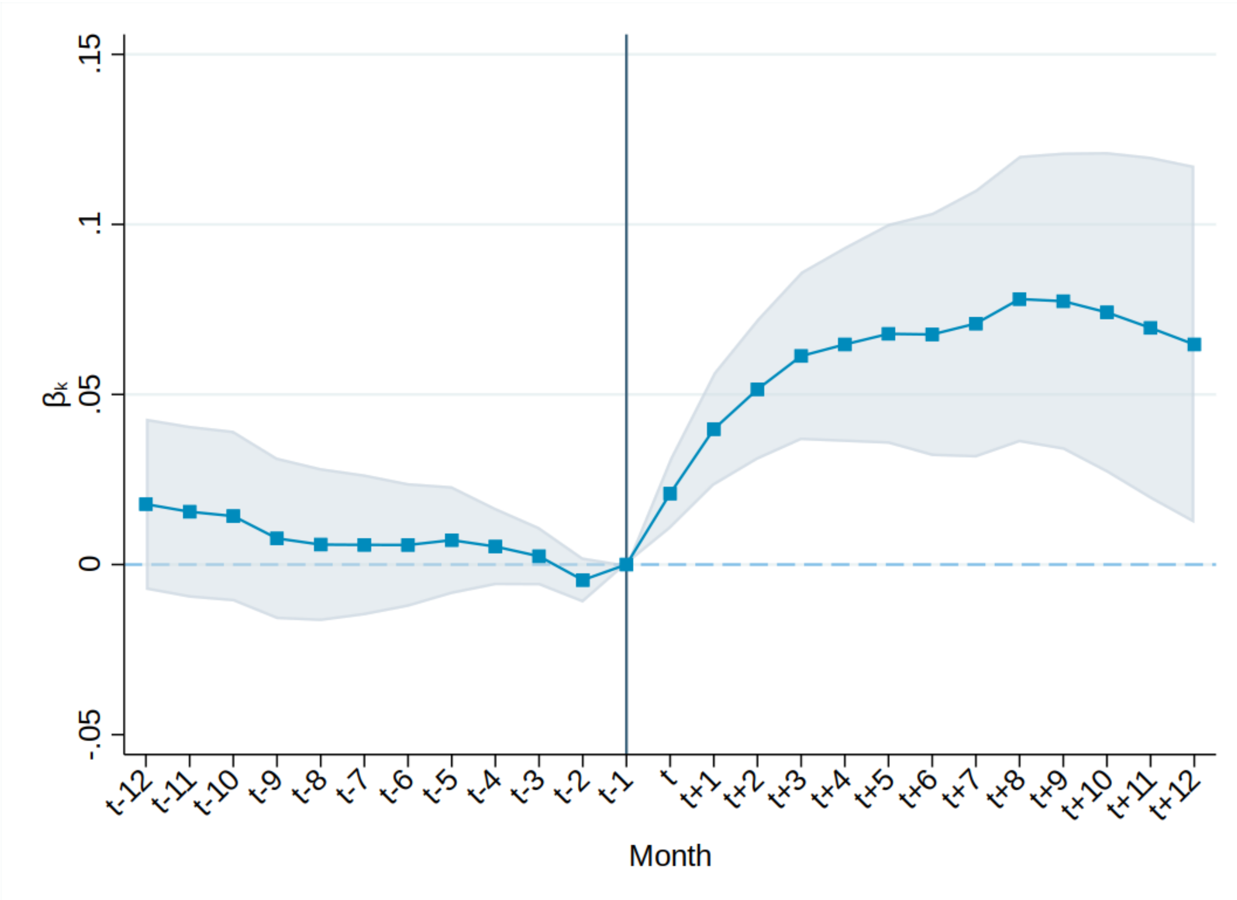

Figure 4: This figure plots the estimates for coefficients β_ℓ in the regression equation:

$$\Delta Holdings^{CorporateBonds}_{f,t-1\rightarrow t+\tau} = \alpha + \sum_{\ell=-12}^{12} \beta_\ell QEShock_{f,t} \times \mathbb{1}\{\tau = \ell\} + \sum_{\ell=-12}^{12} \gamma_\ell \mathbb{1}\{\tau = \ell\} + \lambda_f + \lambda_t + \epsilon_{f,t,\tau}$$

$\Delta Holdings^{CorporateBonds}_{f,t-1\rightarrow t+\tau}$ measures active rebalancing by fund f between the end of month $t-1$ and τ months later, into all corporate bonds. $QEShock_{f,t}$ measures fund f's QE shock during month t. There are event-time fixed effects for leads $\tau = \{-12, -11, ..., 12\}$, denoted by $\gamma_\ell \mathbb{1}\{\tau = \ell\}$, as well as fund and calendar-time fixed effects, denoted by λ_f and λ_t. The shaded area represents the 95% confidence bands.

Yield Changes in Corporate Bonds around QE Shocks: Issuer-Level Exposure

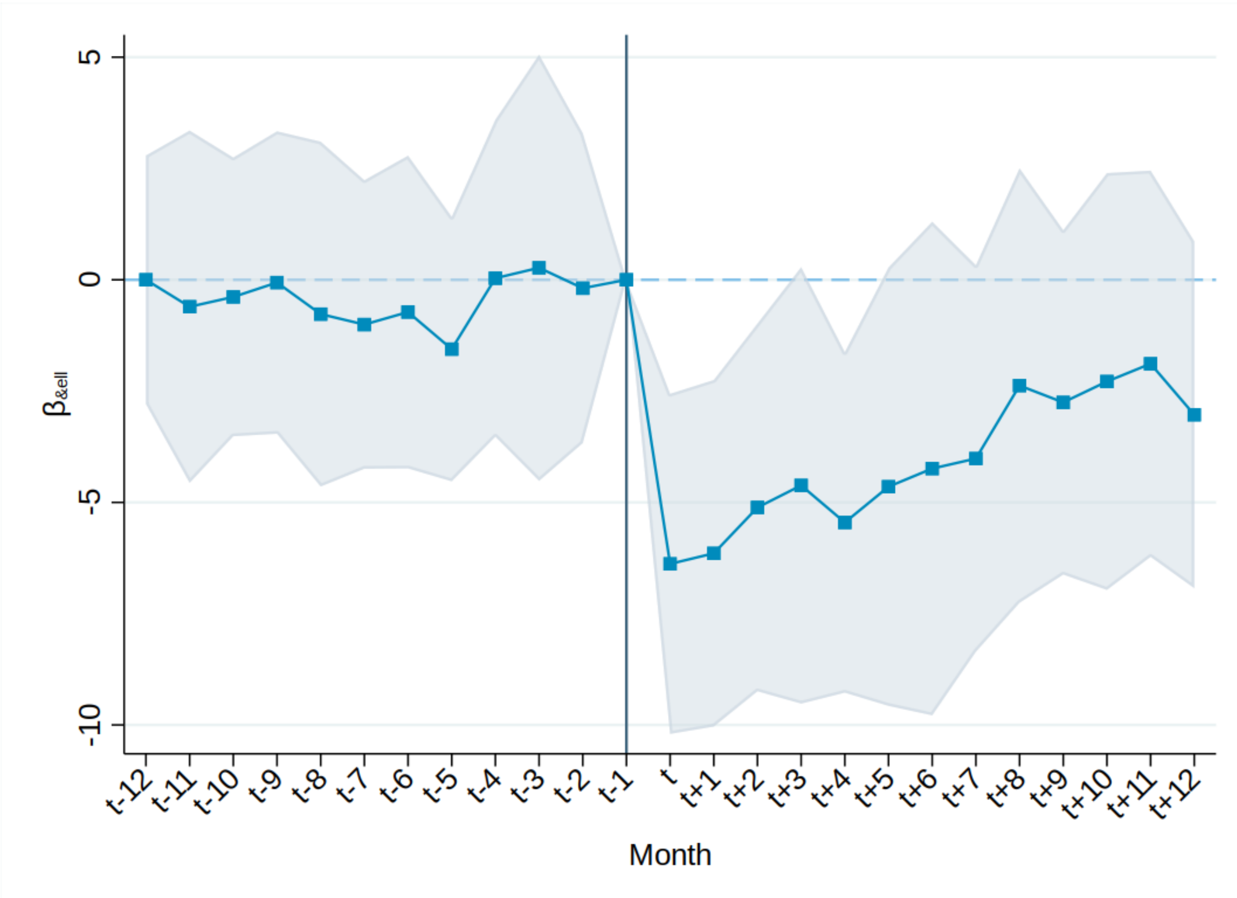

Figure 5: This figure plots the estimates for coefficients β_ℓ in the regression equation:

$$\Delta y_{b,t-1\to t+\tau} = \alpha + \sum_{\ell=-12}^{12} \beta_\ell QEShock_{i(b),t} \times \mathbb{1}\{\tau = \ell\} + \sum_{\ell=-12}^{12} \gamma_\ell \mathbb{1}\{\tau = \ell\} + \lambda_b + \lambda_t + \epsilon_{b,t,\tau}$$

$\Delta y_{b,t-1\to t+\tau}$ is the change in the yield of corporate bond b between the end of month $t-1$ and τ months later. $QEShock_{i(b),t}$ is the QE shock issuer i of corporate bond b experiences in month t, as defined in Equation 13. $\gamma_\ell \mathbb{1}\{\tau = \ell\}$ denotes event-time fixed effects for leads $\ell = \{-12, -11, ..., 12\}$. λ_b and λ_t denote bond and calendar-time fixed effects, respectively. The shaded area represents the 95% confidence bands.

Yield Changes in Corporate Bonds around QE Shocks: Bond-Level Exposure

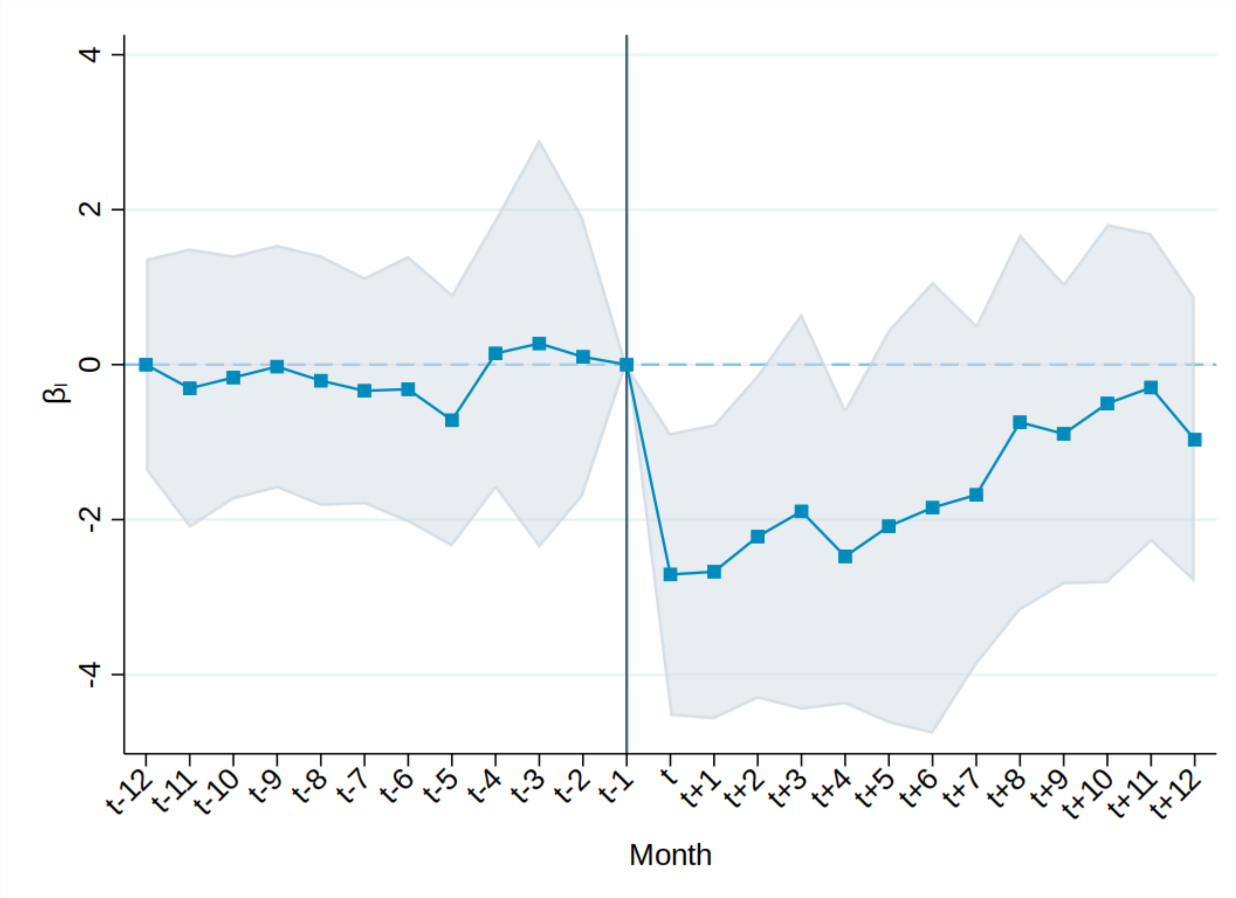

Figure 6: This figure plots the estimates for coefficients β_ℓ in the regression equation:

$$\Delta y_{b,t-1\to t+\tau} = \alpha + \sum_{\ell=-12}^{12} \beta_\ell QEShock_{b,t} \times \mathbb{1}\{\tau = \ell\}$$
$$+ \sum_{\ell=-12}^{12} \gamma_\ell \mathbb{1}\{\tau = \ell\} + \lambda_b + \lambda_t + \epsilon_{b,t,\tau}$$

$\Delta y_{b,t-1\to t+\tau}$ is the change in the yield of corporate bond b between the end of month $t-1$ and τ months later. $QEShock_{b,t}$ is bond exposure to portfolio rebalancing induced by QE shocks defined in Equation 14. $\gamma_\ell \mathbb{1}\{\tau = \ell\}$ denotes event-time fixed effects for leads $\ell = \{-12, -11, ..., 12\}$. λ_b and λ_t denote bond and calendar-time fixed effects, respectively. The shaded area represents the 95% confidence bands.

Issuance Amounts around QE Shocks

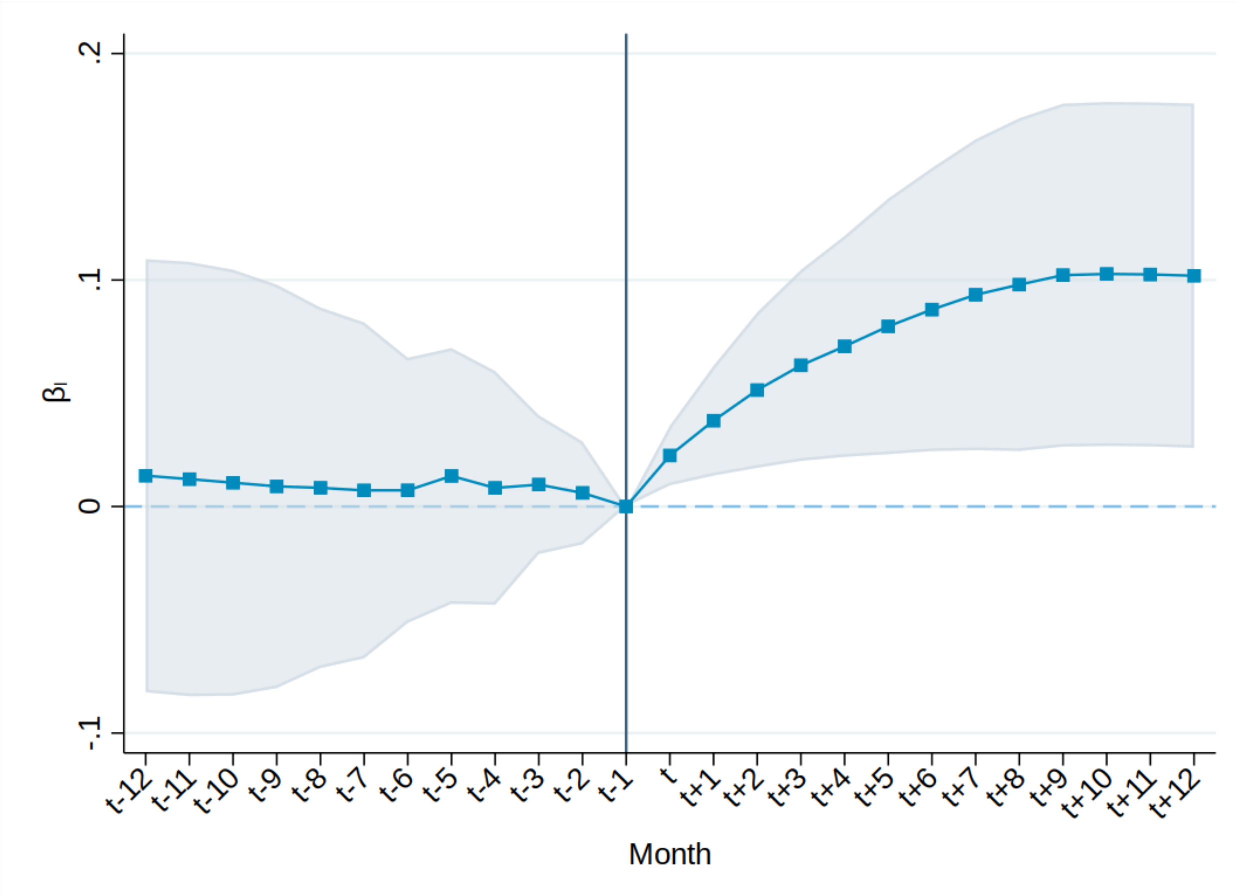

Figure 7: This figure plots the estimates for coefficients β_ℓ in the regression equation:

$$Issuance_{i,t-1\rightarrow t+\tau} = \alpha + \sum_{\ell=-12}^{12} \beta_\ell QEShock_{i,t} \times \mathbb{1}\{\tau = \ell\} + \sum_{\ell=-12}^{12} \gamma_\ell \mathbb{1}\{\tau = \ell\} + \lambda_i + \lambda_t + \epsilon_{b,t,\tau}$$

$Issuance_{i,t-1\rightarrow t+\tau}$ is the cumulative issuance of issuer i between the end of month $t-1$ and τ months later, scaled by total amount outstanding of all bonds by issuer i as of the end of $t-1$. $QEShock_{i,t}$ is issuer exposure to portfolio rebalancing induced by QE shocks defined in Equation 14. $\gamma_\ell \mathbb{1}\{\tau = \ell\}$ denotes event-time fixed effects for leads $\ell = \{-12, -11, ..., 12\}$. λ_i and λ_t denote issuer and calendar-time fixed effects, respectively. The shaded area represents the 95% confidence bands.

Effect of the Portfolio Rebalancing Channel of QE on Yields: Baseline Estimate

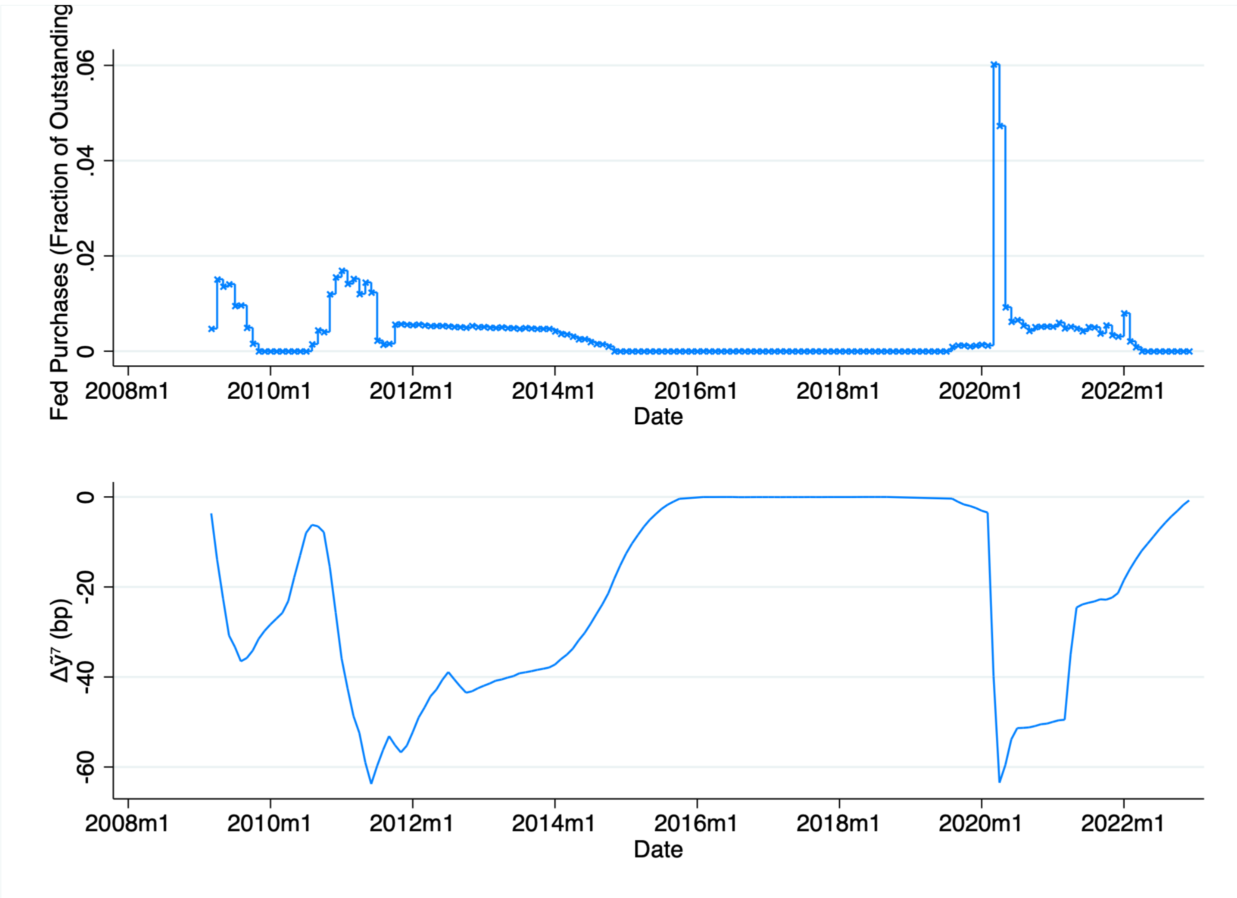

Figure 8: This figure shows the model-estimated change in yields of corporate bonds with seven years to maturity due to the portfolio rebalancing channel each month. The top panel shows the total size of the Fed's purchases of Treasury coupons as a fraction of all Treasury coupons outstanding each month. The bottom panel shows the model-estimated effects of the portfolio rebalancing channel stemming from the Fed's purchases of Treasury coupons on corporate bond yields each month. The results are estimated for the actual size and maturity decomposition of the Fed's purchases each month.

Effect of the Portfolio Rebalancing Channel of QE on Yields: Constant Pace of Purchases

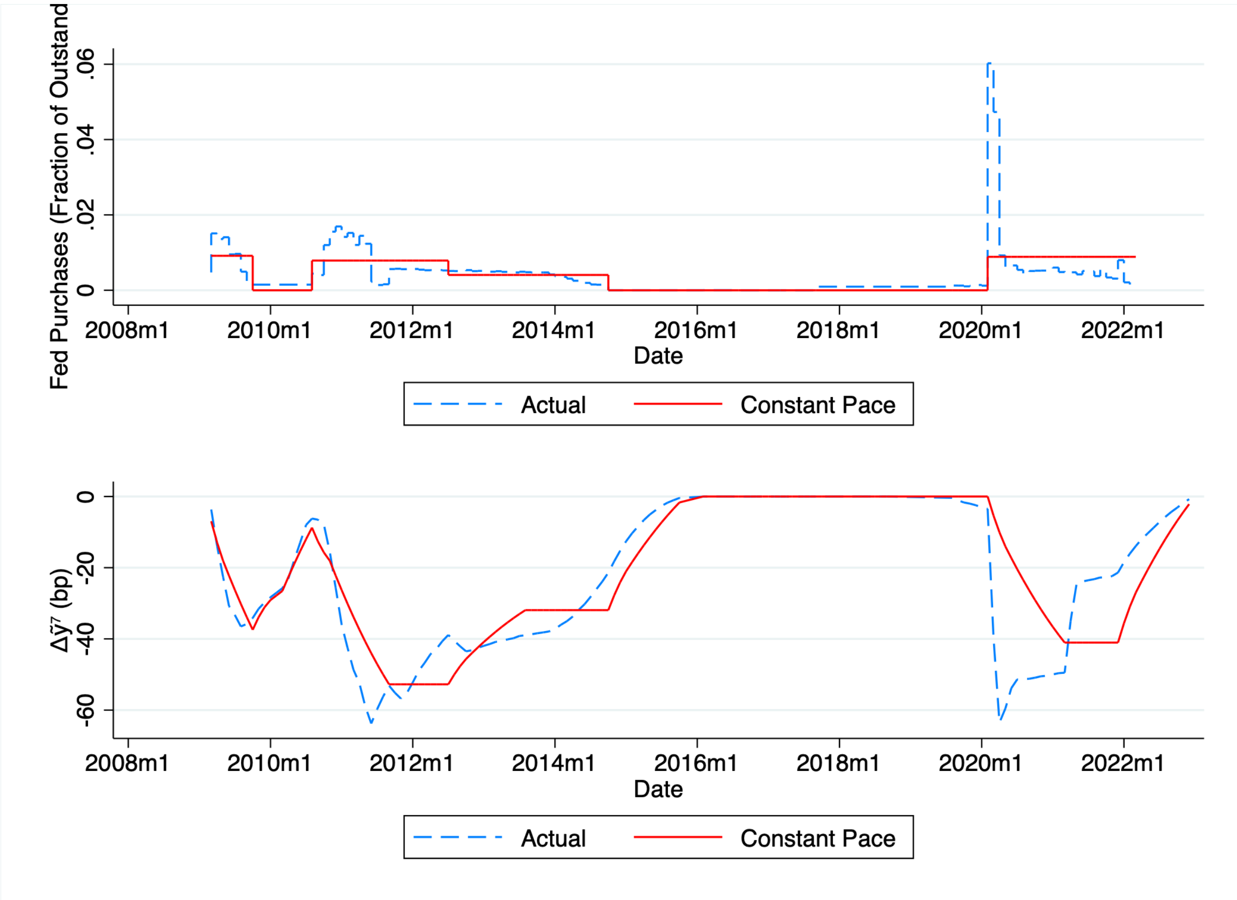

Figure 9: This figure shows the model-estimated change in yields of corporate bonds with seven years to maturity due to the portfolio rebalancing channel each month. The top panel shows the actual size of Fed purchases each month and the size of purchases in the 'Constant Pace' counterfactual that is analyzed. The bottom panel shows the model-estimated effects of the portfolio rebalancing channel stemming from the Fed's purchases of Treasury coupons on corporate bond yields each month for actual and counterfactual purchases by the Fed. The counterfactual keeps the total size and maturity decomposition of the Fed's purchases in each of the four QE programs constant but changes the pace of purchases each month so that the Fed purchases an equal amount each month of each QE program.

Effect of the Portfolio Rebalancing Channel of QE on Yields: Longer Maturity Purchases

Figure 10: This figure shows the model-estimated change in yields of corporate bonds with seven years to maturity due to the portfolio rebalancing channel each month. The top panel shows the actual average maturity of Fed purchases each month and the average maturity in the 'Long Maturity' counterfactual that is analyzed. The bottom panel shows the model-estimated effects of the portfolio rebalancing channel stemming from the Fed's purchases of Treasury coupons on corporate bond yields each month for actual and counterfactual purchases by the Fed. The counterfactual keeps the total size of the Fed's purchases each month constant but changes the maturity decomposition of purchases each month so that the average years to maturity purchased is twenty.

9 Tables

Yield Changes in Treasurys Around QE Shocks - Security Level

	Δy
$QEShock \times \mathbb{1}\{\tau = -3\}$	-0.032
	(0.154)
$QEShock \times \mathbb{1}\{\tau = -2\}$	-0.015
	(0.111)
$QEShock \times \mathbb{1}\{\tau = 0\}$	-0.390***
	(0.120)
$QEShock \times \mathbb{1}\{\tau = 1\}$	-0.213**
	(0.107)
$QEShock \times \mathbb{1}\{\tau = 2\}$	-0.196*
	(0.109)
$QEShock \times \mathbb{1}\{\tau = 3\}$	-0.184
	(0.129)
$QEShock \times \mathbb{1}\{\tau = 4\}$	-0.081
	(0.128)
$QEShock \times \mathbb{1}\{\tau = 5\}$	-0.029
	(0.133)
$QEShock \times \mathbb{1}\{\tau = 6\}$	0.005
	(0.152)
Event Time FEs	✓
Calendar Time FEs	✓
CUSIP FEs	✓
R^2	0.458
N	315,564

Table 1: This table presents the estimates for coefficients β_ℓ, $\ell \in (-3, ..., 6)$ in the regression equation:

$$\Delta y_{i,t-1\to t+\tau} = \sum_{\ell=-6}^{6} \beta_\ell QEShock_{i,t} \times \mathbb{1}\{\tau = \ell\} + \sum_{\ell=-6}^{6} \gamma_\ell \mathbb{1}\{\tau = \ell\} + \lambda_i + \lambda_t + \epsilon_{i,t,\tau}$$

$QEShock_{i,t}$ is the total unexpected dollar amount purchased by the Fed of a Treasury i during week t, scaled by the total amount outstanding of all Treasury coupons. $\Delta y_{i,t-1\to t+\tau}$ is the change in the yield of Treasury i between the end of the week before the Fed's purchases take place, $t-1$, and τ weeks later. λ_i and λ_t are security and calendar-time fixed effects, respectively, and $\gamma_\ell \mathbb{1}\{\tau = \ell\}$ are event-time fixed effects. Standard errors are provided in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively.

Yield Changes in Treasurys Around QE Shocks - Maturity Level

	Δy
$Shock \times \mathbb{1}\{\tau = -3\}$	0.029
	(0.026)
$Shock \times \mathbb{1}\{\tau = -2\}$	-0.004
	(0.028)
$Shock \times \mathbb{1}\{\tau = 0\}$	-0.167***
	(0.021)
$Shock \times \mathbb{1}\{\tau = 1\}$	-0.080**
	(0.031)
$Shock \times \mathbb{1}\{\tau = 2\}$	-0.067**
	(0.029)
$Shock \times \mathbb{1}\{\tau = 3\}$	-0.032*
	(0.019)
$Shock \times \mathbb{1}\{\tau = 4\}$	0.035
	(0.043)
$Shock \times \mathbb{1}\{\tau = 5\}$	0.033
	(0.040)
$Shock \times \mathbb{1}\{\tau = 6\}$	0.054
	(0.040)
Event Time FEs	✓
Calendar Time FEs	✓
Maturity FEs	✓
R^2	0.440
N	72,940

Table 2: This table presents the estimates for coefficients β_ℓ, $\ell \in (-3, ..., 6)$ in the regression equation:

$$\Delta y_{i,t-1\to t+\tau} = \sum_{\ell=-6}^{6} \beta_\ell QEShock_{i,t} \times \mathbb{1}\{\tau = \ell\} + \sum_{\ell=-6}^{6} \gamma_\ell \mathbb{1}\{\tau = \ell\} + \lambda_i + \lambda_t + \epsilon_{i,t,\tau}$$

$QEShock_{i,t}$ is the total unexpected dollar amount purchased by the Fed of all Treasurys with time to maturity (in years) i during week t, scaled by the total amount outstanding of all Treasury coupons. $\Delta y_{i,t-1\to t+\tau}$ is the value-weighted average change in the yield of Treasurys with years to maturity i between the end of the week before the Fed's purchases take place, $t-1$, and τ weeks later. λ_i and λ_t are security and calendar-time fixed effects, respectively, and $\gamma_\ell \mathbb{1}\{\tau = \ell\}$ are event-time fixed effects. Standard errors are provided in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively.

Active Rebalancing by Funds into Fed-Purchased Treasurys around QE Shocks

	Cumulative Change in Holdings of Fed-Purchased Treasurys
$QEShock \times \mathbb{1}\{\tau = -3\}$	0.002
	(0.007)
$QEShock \times \mathbb{1}\{\tau = -2\}$	-0.000
	(0.006)
$QEShock \times \mathbb{1}\{\tau = 0\}$	-0.058***
	(0.009)
$QEShock \times \mathbb{1}\{\tau = 1\}$	-0.095***
	(0.010)
$QEShock \times \mathbb{1}\{\tau = 2\}$	-0.102***
	(0.012)
$QEShock \times \mathbb{1}\{\tau = 3\}$	-0.108***
	(0.013)
$QEShock \times \mathbb{1}\{\tau = 4\}$	-0.113***
	(0.015)
$QEShock \times \mathbb{1}\{\tau = 5\}$	-0.106***
	(0.016)
$QEShock \times \mathbb{1}\{\tau = 6\}$	-0.105***
	(0.018)
$QEShock \times \mathbb{1}\{\tau = 7\}$	-0.105***
	(0.020)
$QEShock \times \mathbb{1}\{\tau = 8\}$	-0.105***
	(0.020)
$QEShock \times \mathbb{1}\{\tau = 9\}$	-0.104***
	(0.020)
$QEShock \times \mathbb{1}\{\tau = 10\}$	-0.107***
	(0.022)
$QEShock \times \mathbb{1}\{\tau = 11\}$	-0.105***
	(0.023)
$QEShock \times \mathbb{1}\{\tau = 12\}$	-0.107***
	(0.024)
Event Time FEs	✓
Calendar Time FEs	✓
Fund FEs	✓
R^2	0.157
N	462,717

Table 3: This table presents the estimates for coefficients β_ℓ, $\ell \in (-3, ..., 12)$ in the regression equation:

$$\Delta Holdings_{f,t-1 \to t+\tau} = \alpha + \sum_{\ell=-12}^{12} \beta_\ell QEShock_{f,t} \times \mathbb{1}\{\tau = \ell\} + \sum_{\ell=-12}^{12} \gamma_\ell \mathbb{1}\{\tau = \ell\} + \lambda_f + \lambda_t + \epsilon_{f,t,\tau}$$

$\Delta Holdings_{f,t-1\to t+\tau}$ measures active rebalancing by fund f between the end of month $t-1$ and τ months later, into Treasurys that the Fed purchases during month t. A negative value represents active selling by the fund. $QEShock_{f,t}$ measures fund f's QE shock during month t. The greater the value, the more the fund held at the end of month $t-1$ in Treasurys that the Fed unexpectedly purchased more in month t. There are event-time fixed effects for leads $\tau = \{-12, -11, ..., 12\}$, denoted by $\gamma_\ell \mathbb{1}\{\tau = \ell\}$. There are also fund and calendar-time fixed effects, denoted by λ_f and λ_t. Standard errors are provided in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively.

Active Rebalancing by Funds into Fed-Unpurchased Treasurys around QE Shocks

	Cumulative Change in Holdings of Fed-Unpurchased Treasurys
$QEShock \times \mathbb{1}\{\tau = -3\}$	-0.002
	(0.014)
$QEShock \times \mathbb{1}\{\tau = -2\}$	0.000
	(0.011)
$QEShock \times \mathbb{1}\{\tau = 0\}$	0.012*
	(0.006)
$QEShock \times \mathbb{1}\{\tau = 1\}$	0.011*
	(0.006)
$QEShock \times \mathbb{1}\{\tau = 2\}$	0.008
	(0.009)
$QEShock \times \mathbb{1}\{\tau = 3\}$	-0.003
	(0.011)
$QEShock \times \mathbb{1}\{\tau = 4\}$	-0.004
	(0.012)
$QEShock \times \mathbb{1}\{\tau = 5\}$	-0.016
	(0.013)
$QEShock \times \mathbb{1}\{\tau = 6\}$	-0.021
	(0.013)
$QEShock \times \mathbb{1}\{\tau = 7\}$	-0.028*
	(0.015)
$QEShock \times \mathbb{1}\{\tau = 8\}$	-0.027*
	(0.014)
$QEShock \times \mathbb{1}\{\tau = 9\}$	-0.020
	(0.014)
$QEShock \times \mathbb{1}\{\tau = 10\}$	-0.011
	(0.015)
$QEShock \times \mathbb{1}\{\tau = 11\}$	-0.016
	(0.017)
$QEShock \times \mathbb{1}\{\tau = 12\}$	-0.012
	(0.017)
Event Time FEs	✓
Calendar Time FEs	✓
Fund FEs	✓
R^2	0.135
N	462,717

Table 4: This table presents the estimates for coefficients β_ℓ, $\ell \in (-3, ..., 12)$ in the regression equation:

$$\Delta Holdings_{f,t-1\to t+\tau} = \alpha + \sum_{\ell=-12}^{12} \beta_\ell QEShock_{f,t} \times \mathbb{1}\{\tau = \ell\} + \sum_{\ell=-12}^{12} \gamma_\ell \mathbb{1}\{\tau = \ell\} + \lambda_f + \lambda_t + \epsilon_{f,t,\tau} \quad (34)$$

$\Delta Holdings_{f,t-1\to t+\tau}$ measures active rebalancing by fund f between the end of month $t-1$ and τ months later, into Treasurys that the Fed did not purchase during month t. A negative value represents active selling by the fund. $QEShock_{f,t}$ measures fund f's QE shock during month t. The greater the value, the more the fund held at the end of month $t-1$ in Treasurys that the Fed unexpectedly purchased more in month t. There are event-time fixed effects for leads $\tau = \{-12, -11, ..., 12\}$, denoted by $\gamma_\ell \mathbb{1}\{\tau = \ell\}$. There are also fund and calendar-time fixed effects, denoted by λ_f and λ_t. Standard errors are provided in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively.

Active Rebalancing by Funds into All Treasurys around QE Shocks

	Cumulative Change in Treasury Holdings
$QEShock \times \mathbb{1}\{\tau = -3\}$	0.001
	(0.007)
$QEShock \times \mathbb{1}\{\tau = -2\}$	-0.001
	(0.005)
$QEShock \times \mathbb{1}\{\tau = 0\}$	-0.047***
	(0.009)
$QEShock \times \mathbb{1}\{\tau = 1\}$	-0.087***
	(0.011)
$QEShock \times \mathbb{1}\{\tau = 2\}$	-0.097***
	(0.013)
$QEShock \times \mathbb{1}\{\tau = 3\}$	-0.114***
	(0.015)
$QEShock \times \mathbb{1}\{\tau = 4\}$	-0.118***
	(0.017)
$QEShock \times \mathbb{1}\{\tau = 5\}$	-0.124***
	(0.018)
$QEShock \times \mathbb{1}\{\tau = 6\}$	-0.127***
	(0.020)
$QEShock \times \mathbb{1}\{\tau = 7\}$	-0.136***
	(0.022)
$QEShock \times \mathbb{1}\{\tau = 8\}$	-0.136***
	(0.024)
$QEShock \times \mathbb{1}\{\tau = 9\}$	-0.126***
	(0.025)
$QEShock \times \mathbb{1}\{\tau = 10\}$	-0.113***
	(0.027)
$QEShock \times \mathbb{1}\{\tau = 11\}$	-0.114***
	(0.028)
$QEShock \times \mathbb{1}\{\tau = 12\}$	-0.113***
	(0.029)
Event Time FEs	✓
Calendar Time FEs	✓
Fund FEs	✓
R^2	0.189
N	462,717

Table 5: This table presents the estimates for coefficients β_ℓ, $\ell \in (-3, ..., 12)$ in the regression equation:

$$\Delta Holdings_{f,t-1\rightarrow t+\tau} = \alpha + \sum_{\ell=-12}^{12} \beta_\ell QEShock_{f,t} \times \mathbb{1}\{\tau = \ell\} + \sum_{\ell=-12}^{12} \gamma_\ell \mathbb{1}\{\tau = \ell\} + \lambda_f + \lambda_t + \epsilon_{f,t,\tau}$$

$\Delta Holdings_{f,t-1\rightarrow t+\tau}$ measures active rebalancing by fund f between month $t-1$ and month $t+\tau$ into all Treasurys. A negative value represents active selling by the fund. $QEShock_{f,t}$ measures fund f's QE shock during month t. The greater the value, the more the fund held at the end of month $t-1$ in Treasurys that the Fed unexpectedly purchased more in month t. There are event-time fixed effects for leads $\tau = \{-12, -11, ..., 12\}$, denoted by $\gamma_\ell \mathbb{1}\{\tau = \ell\}$. There are also fund and calendar-time fixed effects, denoted by λ_f and λ_t. Standard errors are provided in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively.

Active Rebalancing by Funds into Treasurys: Yield Changes

	$\Delta Holdings$
$\Delta\widehat{y}$	0.016**
	(0.008)
Maturity FEs	✓
Calendar Time FEs	✓
R^2	0.229
N	3,776

Table 6: This table presents the estimates for coefficients β_ℓ in the regression equation:

$$\Delta Holdings_{i,t-1\to t+1} = \beta\widehat{\Delta y}_{i,t-1\to t+1} + \lambda_i + \lambda_t + \epsilon_{i,t}$$

$\Delta Holdings_{f,t-1\to t+1}$ measures active rebalancing by funds between month $t-1$ and month $t+1$ into Treasurys with time to maturity (in years) of i, scaled by the total amount outstanding of Treasurys in maturity group i. There are also maturity and calendar-time fixed effects, denoted by λ_f and λ_t. Standard errors are provided in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively.

Active Rebalancing by Funds into Corporate Bonds around QE Shocks

	Cumulative Change in Corporate Bond Holdings
$QEShock \times \mathbb{1}\{\tau = -3\}$	0.002
	(0.004)
$QEShock \times \mathbb{1}\{\tau = -2\}$	-0.005
	(0.003)
$QEShock \times \mathbb{1}\{\tau = 0\}$	0.021***
	(0.005)
$QEShock \times \mathbb{1}\{\tau = 1\}$	0.040***
	(0.008)
$QEShock \times \mathbb{1}\{\tau = 2\}$	0.052***
	(0.011)
$QEShock \times \mathbb{1}\{\tau = 3\}$	0.061***
	(0.013)
$QEShock \times \mathbb{1}\{\tau = 4\}$	0.065***
	(0.015)
$QEShock \times \mathbb{1}\{\tau = 5\}$	0.068***
	(0.017)
$QEShock \times \mathbb{1}\{\tau = 6\}$	0.068***
	(0.018)
$QEShock \times \mathbb{1}\{\tau = 7\}$	0.071***
	(0.020)
$QEShock \times \mathbb{1}\{\tau = 8\}$	0.078***
	(0.021)
$QEShock \times \mathbb{1}\{\tau = 9\}$	0.077***
	(0.022)
$QEShock \times \mathbb{1}\{\tau = 10\}$	0.074***
	(0.024)
$QEShock \times \mathbb{1}\{\tau = 11\}$	0.070***
	(0.026)
$QEShock \times \mathbb{1}\{\tau = 12\}$	0.065**
	(0.027)
Event Time FEs	✓
Calendar Time FEs	✓
Fund FEs	✓
R^2	0.115
N	462,717

Table 7: This table presents the estimates for coefficients β_ℓ, $\ell \in (-3, ..., 12)$ in the regression equation:

$$\Delta Holdings^{CorporateBonds}_{f,t-1\to t+\tau} = \alpha + \sum_{\ell=-12}^{12} \beta_\ell QEShock_{f,t} \times \mathbb{1}\{\tau = \ell\} + \sum_{\ell=-12}^{12} \gamma_\ell \mathbb{1}\{\tau = \ell\} + \lambda_f + \lambda_t + \epsilon_{f,t,\tau}$$

$\Delta Holdings^{CorporateBonds}_{f,t-1\to t+\tau}$ measures active rebalancing by fund f between the end of month $t-1$ and τ months later, into all corporate bonds. $QEShock_{f,t}$ measures fund f's QE shock during month t. There are event-time fixed effects for leads $\tau = \{-12, -11, ..., 12\}$, denoted by $\gamma_\ell \mathbb{1}\{\tau = \ell\}$, as well as fund and calendar-time fixed effects, denoted by λ_f and λ_t. Standard errors are provided in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively.

Relative Rebalancing into Bonds Already Owned

	ΔHoldings
$Holdings_{t-1}$	-0.207***
	(0.000)
QE Shock	-0.001***
	(0.000)
$Holdings_{t-1}$ × QE Shock	0.005***
	(0.000)
R^2	0.356
N	2253432

Table 8: This table presents coefficient estimates and standard errors for the following regression:

$$\Delta Holdings_{i,f,t-1\rightarrow t+12} =$$
$$\beta_1 Holdings_{i,f,t-1} + \beta_2 QEShock_{f,t} + \gamma Holdings_{i,f,t-1} \times QEShock_{f,t} + \lambda_f + \lambda_i + \lambda_t + \epsilon_{i,f,t}$$

$\Delta Holdings_{i,f,t-1\rightarrow t+12}$ measure active rebalancing of fund f into corporate bond i between the end of the month before the QE shock occurs, $t-1$, and 12 months later. $Holdings_{i,f,t-1}$ is fund f's holdings of corporate bond i as of the end of month $t-1$. Active rebalancing and holdings are both expressed as as a fraction of fund TNA. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively.

Similarity between Corporate Bonds Rebalanced into by Funds and Treasurys Purchased by the Fed

	$\Delta Holdings$
QE Shock	0.143*
	(0.079)
Mat. Diff	-0.000
	(0.000)
QE Shock $\times$ Mat. Diff	-0.017**
	(0.007)
R^2	0.006
N	19543745

Table 9: This table presents coefficient estimates and standard errors for the following regression:

$$\Delta Holdings_{b,f,t} = \beta_1 QEShock_{f,t} + \beta_2 Mat.Diff_{b,t} + \gamma QEShock_{f,t} \times Mat.Diff_{b,t} + \lambda_f + \lambda_b + \lambda_t + \epsilon_{b,f,t}$$

$Mat.Diff_{b,t}$ measure the absolute difference in average maturity of Treasurys that the Fed unexpectedly purchases in month t, and of corporate bond b. $QEShock_{f,t}$ is fund f's QE shock during month t. $\Delta Holdings_{b,f,t}$ is active rebalancing by fund f into bond b between end of month $t-1$ and month $t+12$. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively.

Yield Changes in Corporate Bonds around QE Shocks: Issuer-Level QE Shock

	Δy
$QEShock \times \mathbb{1}\{\tau = -3\}$	0.270
	(2.442)
$QEShock \times \mathbb{1}\{\tau = -2\}$	-0.189
	(1.775)
$QEShock \times \mathbb{1}\{\tau = 0\}$	-6.381***
	(1.948)
$QEShock \times \mathbb{1}\{\tau = 1\}$	-6.144***
	(1.986)
$QEShock \times \mathbb{1}\{\tau = 2\}$	-5.114**
	(2.106)
$QEShock \times \mathbb{1}\{\tau = 3\}$	-4.619*
	(2.500)
$QEShock \times \mathbb{1}\{\tau = 4\}$	-5.451**
	(1.950)
$QEShock \times \mathbb{1}\{\tau = 5\}$	-4.648*
	(2.512)
$QEShock \times \mathbb{1}\{\tau = 6\}$	-4.240
	(2.828)
$QEShock \times \mathbb{1}\{\tau = 7\}$	-4.015*
	(2.214)
$QEShock \times \mathbb{1}\{\tau = 8\}$	-2.376
	(2.489)
$QEShock \times \mathbb{1}\{\tau = 9\}$	-2.754
	(1.973)
$QEShock \times \mathbb{1}\{\tau = 10\}$	-2.286
	(2.388)
$QEShock \times \mathbb{1}\{\tau = 11\}$	-1.886
	(2.213)
$QEShock \times \mathbb{1}\{\tau = 12\}$	-3.032
	(1.988)
Event Time FEs	✓
Calendar Time FEs	✓
CUSIP FEs	✓
R^2	0.140
N	1620175

Table 10: This table presents the estimates for coefficients β_ℓ, $\ell \in (-3, ..., 12)$ in the regression equation:

$$\Delta y_{b,t-1\to t+\tau} = \sum_{\ell=-12}^{12} \beta_\ell QEShock_{i(b),t} \times \mathbb{1}\{\tau = \ell\} + \sum_{\ell=-12}^{12} \gamma_\ell \mathbb{1}\{\tau = \ell\} + \lambda_b + \lambda_t + \epsilon_{b,t,\tau}$$

$\Delta y_{b,t-1\to t+\tau}$ is the change in the yield of bond b between the end of month $t-1$ and τ months later. $QEShock_{i(b),t}$ is the QE shock for issuer i of bond b in month t as defined in Equation 13. $\gamma_\ell \mathbb{1}\{\tau = \ell\}$ denotes event-time fixed effects for leads $\ell = \{-12, -11, ..., 12\}$. λ_b and λ_t denote bond and calendar-time fixed effects, respectively. Standard errors are provided in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively.

Yield Changes in Corporate Bonds around QE Shocks: Bond-Level QE Shock

	Δy
$QEShock \times \mathbb{1}\{\tau = -3\}$	0.274
	(1.348)
$QEShock \times \mathbb{1}\{\tau = -2\}$	0.101
	(0.918)
$QEShock \times \mathbb{1}\{\tau = 0\}$	-2.708***
	(0.933)
$QEShock \times \mathbb{1}\{\tau = 1\}$	-2.672**
	(0.972)
$QEShock \times \mathbb{1}\{\tau = 2\}$	-2.218**
	(1.068)
$QEShock \times \mathbb{1}\{\tau = 3\}$	-1.894
	(1.307)
$QEShock \times \mathbb{1}\{\tau = 4\}$	-2.475**
	(0.974)
$QEShock \times \mathbb{1}\{\tau = 5\}$	-2.085
	(1.298)
$QEShock \times \mathbb{1}\{\tau = 6\}$	-1.846
	(1.489)
$QEShock \times \mathbb{1}\{\tau = 7\}$	-1.681
	(1.122)
$QEShock \times \mathbb{1}\{\tau = 8\}$	-0.743
	(1.240)
$QEShock \times \mathbb{1}\{\tau = 11\}$	-0.893
	(0.992)
$QEShock \times \mathbb{1}\{\tau = 10\}$	-0.501
	(1.183)
$QEShock \times \mathbb{1}\{\tau = 11\}$	-0.295
	(1.017)
$QEShock \times \mathbb{1}\{\tau = 12\}$	-0.968
	(0.941)
Event Time FEs	✓
Year-Month FEs	✓
CUSIP FEs	✓
R^2	0.140
N	1620175

Table 11: This table presents the estimates for coefficients β_ℓ, $\ell \in (-3, ..., 12)$ in the regression equation:

$$\Delta y_{b,t-1\to t+\tau} = \sum_{\ell=-12}^{12} \beta_\ell QEShock_{b,t} \times \mathbb{1}\{\tau = \ell\} + \sum_{\ell=-12}^{12} \gamma_\ell \mathbb{1}\{\tau = \ell\} + \lambda_b + \lambda_t + \epsilon_{b,t,\tau}$$

$\Delta y_{b,t-1\to t+\tau}$ is the change in the yield of bond b between the end of month $t-1$ and τ months later. $QEShock_{b,t}$ is the QE shock for bond b in month t as defined in Equation 14. $\gamma_\ell \mathbb{1}\{\tau = \ell\}$ denotes event-time fixed effects for leads $\ell = \{-12, -11, ..., 12\}$. λ_b and λ_t denote bond and calendar-time fixed effects, respectively. Standard errors are provided in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively.

Yield Changes in Corporate Bonds around QE Shocks: Rebalancing at Bond Level

	Δy
$\Delta Holdings \times \mathbb{1}\{\tau = -3\}$	1.297
	(2.394)
$\Delta Holdings \times \mathbb{1}\{\tau = -2\}$	0.597
	(2.297)
$\Delta Holdings \times \mathbb{1}\{\tau = 0\}$	-7.089**
	(3.392)
$\Delta Holdings \times \mathbb{1}\{\tau = 1\}$	-6.993*
	(3.574)
$\Delta Holdings \times \mathbb{1}\{\tau = 2\}$	-7.382**
	(2.912)
$\Delta Holdings \times \mathbb{1}\{\tau = 3\}$	-4.330**
	(2.055)
$\Delta Holdings \times \mathbb{1}\{\tau = 4\}$	-2.517
	(1.545)
$\Delta Holdings \times \mathbb{1}\{\tau = 5\}$	-1.955
	(1.346)
$\Delta Holdings \times \mathbb{1}\{\tau = 6\}$	-3.660**
	(1.596)
$\Delta Holdings \times \mathbb{1}\{\tau = 7\}$	-3.521**
	(1.683)
$\Delta Holdings \times \mathbb{1}\{\tau = 8\}$	-1.588
	(1.805)
$\Delta Holdings \times \mathbb{1}\{\tau = 9\}$	-0.821
	(2.009)
$\Delta Holdings \times \mathbb{1}\{\tau = 10\}$	-1.376
	(2.202)
$\Delta Holdings \times \mathbb{1}\{\tau = 11\}$	0.542
	(2.299)
$\Delta Holdings \times \mathbb{1}\{\tau = 12\}$	2.663
	(2.088)
Event Time FEs	✓
Calendar Time FEs	✓
CUSIP FEs	✓
R^2	0.232
N	1276399

Table 12: This table presents the estimates for coefficients β_ℓ, $\ell \in (-3, ..., 12)$ in the regression equation:

$$\Delta y_{b,t-1\to t+\tau} = \sum_{\ell=-12}^{12} \beta_\ell \Delta Holdings_{b,t-1\to t+\tau} \times \mathbb{1}\{\tau = \ell\} + \sum_{\ell=-12}^{12} \gamma_\ell \mathbb{1}\{\tau = \ell\} + \lambda_b + \lambda_t + \epsilon_{b,t,\tau}$$

$\Delta y_{b,t-1\to t+\tau}$ is the change in the yield of bond b between the end of month $t-1$ and τ months later. $\Delta Holdings_{b,t-1\to t+\tau}$ is active rebalancing by funds who experience a positive QE shock in month t into corporate bond b between the end of month $t-1$ and τ months later, expressed as a fraction of the total amount outstanding of bond b. $\gamma_\ell \mathbb{1}\{\tau = \ell\}$ denotes event-time fixed effects for leads $\ell = \{-12, -11, ..., 12\}$. λ_b and λ_t denote bond and calendar-time fixed effects, respectively. Standard errors are provided in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively.

Yield Changes in Corporate Bonds around QE Shocks: Rebalancing at Maturity Level

	Δy
$\Delta Holdings \times \mathbb{1}\{\tau = -3\}$	-14.732
	(9.573)
$\Delta Holdings \times \mathbb{1}\{\tau = -2\}$	-11.348
	(8.241)
$\Delta Holdings \times \mathbb{1}\{\tau = 0\}$	-92.112**
	(35.883)
$\Delta Holdings \times \mathbb{1}\{\tau = 1\}$	-61.248**
	(29.081)
$\Delta Holdings \times \mathbb{1}\{\tau = 2\}$	-48.302*
	(26.950)
$\Delta Holdings \times \mathbb{1}\{\tau = 3\}$	-33.265
	(22.403)
$\Delta Holdings \times \mathbb{1}\{\tau = 4\}$	-27.213*
	(14.812)
$\Delta Holdings \times \mathbb{1}\{\tau = 5\}$	-14.610
	(11.378)
$\Delta Holdings \times \mathbb{1}\{\tau = 6\}$	-12.622
	(9.668)
$\Delta Holdings \times \mathbb{1}\{\tau = 7\}$	-13.939
	(8.771)
$\Delta Holdings \times \mathbb{1}\{\tau = 8\}$	-18.171*
	(9.302)
$\Delta Holdings \times \mathbb{1}\{\tau = 9\}$	-22.138**
	(9.525)
$\Delta Holdings \times \mathbb{1}\{\tau = 10\}$	-21.881**
	(9.047)
$\Delta Holdings \times \mathbb{1}\{\tau = 11\}$	-18.069*
	(9.402)
$\Delta Holdings \times \mathbb{1}\{\tau = 12\}$	-17.161
	(10.314)
Event Time FEs	✓
Calendar Time FEs	✓
Maturity FEs	✓
R^2	0.187
N	39,117

Table 13: This figure plots the estimates for coefficients β_ℓ in the regression equation:

$$\Delta y_{b,t-1\to t+\tau} = \sum_{\ell=-12}^{12} \beta_\ell \Delta Holdings_{b,t-1\to t+\tau} \times \mathbb{1}\{\tau = \ell\} + \sum_{\ell=-12}^{12} \gamma_\ell \mathbb{1}\{\tau = \ell\} + \lambda_b + \lambda_t + \epsilon_{b,t,\tau}$$

$\Delta y_{b,t-1\to t+\tau}$ is the value-weighted average change in the yield of maturity bucket b between the end of month $t-1$ and τ months later. $\Delta Holdings_{b,t-1\to t+\tau}$ is active rebalancing by funds who experience a positive QE shock in month t into corporate bonds of maturity b between the end of month $t-1$ and τ months later, expressed as a fraction of the total amount outstanding of all Treasury coupons. $\gamma_\ell \mathbb{1}\{\tau = \ell\}$ denotes event-time fixed effects for leads $\ell = \{-12, -11, ..., 12\}$. λ_b and λ_t denote maturity and calendar-time fixed effects, respectively. Standard errors are provided in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively.

Effects on New Issuance

	$Issuance$
$QEShock \times \mathbb{1}\{\tau = -3\}$	0.010
	(0.016)
$QEShock \times \mathbb{1}\{\tau = -2\}$	0.006
	(0.012)
$QEShock \times \mathbb{1}\{\tau = 0\}$	0.023***
	(0.007)
$QEShock \times \mathbb{1}\{\tau = 1\}$	0.038***
	(0.012)
$QEShock \times \mathbb{1}\{\tau = 2\}$	0.051***
	(0.018)
$QEShock \times \mathbb{1}\{\tau = 3\}$	0.062***
	(0.022)
$QEShock \times \mathbb{1}\{\tau = 4\}$	0.071***
	(0.025)
$QEShock \times \mathbb{1}\{\tau = 5\}$	0.080***
	(0.029)
$QEShock \times \mathbb{1}\{\tau = 6\}$	0.087***
	(0.032)
$QEShock \times \mathbb{1}\{\tau = 7\}$	0.093***
	(0.035)
$QEShock \times \mathbb{1}\{\tau = 8\}$	0.098**
	(0.037)
$QEShock \times \mathbb{1}\{\tau = 9\}$	0.102**
	(0.039)
$QEShock \times \mathbb{1}\{\tau = 10\}$	0.103***
	(0.039)
$QEShock \times \mathbb{1}\{\tau = 11\}$	0.102**
	(0.039)
$QEShock \times \mathbb{1}\{\tau = 12\}$	0.102**
	(0.039)
Event Time FEs	✓
Calendar Time FEs	✓
Issuer FEs	✓
R^2	0.103
N	113,897

Table 14: This figure plots the estimates for coefficients β_ℓ in the regression equation:

$$Issuance_{i,t-1\to t+\tau} = \sum_{\ell=-12}^{12} \beta_\ell QEShock_{i,t} \times \mathbb{1}\{\tau = \ell\} + \sum_{\ell=-12}^{12} \gamma_\ell \mathbb{1}\{\tau = \ell\} + \lambda_i + \lambda_t + \epsilon_{b,t,\tau}$$

$Issuance_{i,t-1\to t+\tau}$ is the cumulative issuance of issuer i between the end of month $t-1$ and τ months later, scaled by total amount outstanding of all bonds by issuer i as of the end of $t-1$. $QEShock_{i,t}$ is issuer's QE shock in month t as defined in Equation 14. $\gamma_\ell \mathbb{1}\{\tau = \ell\}$ denotes event-time fixed effects for leads $\ell = \{-12, -11, ..., 12\}$. λ_i and λ_t denote issuer and calendar-time fixed effects, respectively. Standard errors are provided in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively.

Effects on New Issuance Yields

	Δy_0	Δy_1	Δy_2	Δy_3	Δy_4	Δy_5	Δy_6	Δy_7	Δy_8	Δy_9	Δy_{10}	Δy_{11}	Δy_{12}
QE Shock	-0.836	-0.041	-1.273	-6.615***	-6.175***	-4.757***	-0.871	-3.414**	-6.201***	-1.429	-0.905	-1.305	-9.053***
	(1.160)	(1.463)	(1.142)	(1.630)	(1.514)	(1.288)	(1.002)	(1.683)	(1.505)	(1.112)	(1.145)	(0.996)	(1.939)
R^2	0.157	0.146	0.187	0.139	0.160	0.152	0.209	0.314	0.155	0.222	0.231	0.198	0.221
N	899	960	1,015	932	940	1,003	890	861	946	844	813	938	788

Table 15: This table presents the estimates for the regression equation:

$$\Delta y_{i,t-1\to t+\tau} = \beta QEShock_{i,t} + \lambda_i + \lambda_t + \epsilon_{i,t,\tau} \tag{35}$$

$\Delta y_{i,t-1\to t+\tau}$ is the change in the value-weighted average new issuance yields of issuer i for issuances occurring in month $t-1$ and issuances occurring τ months later. $QEShock_{i,t}$ is issuer's QE shock in month t as defined in Equation 14. λ_i and λ_t denote issuer and calendar-time fixed effects, respectively. Standard errors are provided in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively.

Effects on Real Outcomes

	(1) CAPX & R&D	(2) CAPX	(3) Debt Reduction	(4) Cash & ST Inv.	(5) Cash
$QEShock \times \mathbb{1}\{\tau = -4\}$	-0.002	-0.003	0.135	-0.002	-0.001
	(0.011)	(0.011)	(0.116)	(0.048)	(0.036)
$QEShock \times \mathbb{1}\{\tau = -3\}$	-0.003	-0.001	-0.010	-0.003	-0.004
	(0.008)	(0.008)	(0.166)	(0.033)	(0.023)
$QEShock \times \mathbb{1}\{\tau = -2\}$	0.011	0.012	-0.052	0.011	0.006
	(0.009)	(0.009)	(0.094)	(0.024)	(0.016)
$QEShock \times \mathbb{1}\{\tau = 0\}$	0.011	0.013	-0.116	-0.006	-0.006
	(0.010)	(0.011)	(0.105)	(0.036)	(0.024)
$QEShock \times \mathbb{1}\{\tau = 1\}$	0.014	0.015	-0.108	0.001	0.002
	(0.012)	(0.012)	(0.093)	(0.024)	(0.017)
$QEShock \times \mathbb{1}\{\tau = 2\}$	0.003	0.002	-0.096	0.051	0.038*
	(0.010)	(0.010)	(0.117)	(0.031)	(0.022)
$QEShock \times \mathbb{1}\{\tau = 3\}$	0.036**	0.034**	-0.071	0.104***	0.079***
	(0.015)	(0.015)	(0.112)	(0.031)	(0.024)
$QEShock \times \mathbb{1}\{\tau = 4\}$	0.077***	0.073***	-0.036	0.132**	0.097**
	(0.025)	(0.024)	(0.106)	(0.051)	(0.037)
R^2	0.162	0.337	0.094	0.332	0.301
N	185,122	185,122	185,122	185,122	185,122

Table 16: This table presents the estimates for the regression equation:

$$\Delta Outcome_{i,t-1\to t+\tau} = \sum_{\ell=-4}^{8} \beta_\ell QEShock_{i,t} \times \mathbb{1}\{\tau = \ell\} + \sum_{\ell=-4}^{8} \gamma_\ell \mathbb{1}\{\tau = \ell\} + \lambda_i + \lambda_t + \epsilon_{i,t,\tau} \tag{36}$$

$\Delta Outcome_{i,t-1\to t+\tau}$ is the change in an outcome for issuer i between the end of quarter $t-1$ and τ quarters later. All outcomes are scaled by the firm's total asset as of $t-1$ end. $QEShock_{i,t}$ is the QE shock that issuer i experiences in quarter t, defined as the total across all funds of the product of the fund's holdings of the issuers' bonds as of the end of quarter $t-1$, and the average monthly QE shock that the fund experiences during quarter t. λ_i and λ_t denote issuer and calendar-time fixed effects, respectively. Standard errors are provided in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively.

Baseline Parameter Values used in the Model

Parameter	Value	Description	Source
Elasticities:			
$\alpha_0 = \tilde{\alpha_0}$	0.813	PH own-price elasticity	Measured fund demand elasticity, flow of funds
dos	0.920	PH degree of substitutability	Match rebalancing between asset classes
$\tilde{\gamma}_{0,0}$	0.048	Residual immediate price elasticity	Match relative price impact in corporate bond market
$\tilde{\gamma}_{0,3}$	0.140	Residual medium-term price elasticity	Match relative price impact in corporate bond market
$\tilde{\gamma}_{0,12}$	0.260	Residual long-term price elasticity	Match relative price impact in corporate bond market
Base Supply:			
$\theta_0(\tau)$	Vector	Supply of riskless bonds	CRSP Daily Treasury Data
$\tilde{\theta}_0(\tau)$	$0.792 \times FracOut(\tau)$	Supply of risky bonds	SIFMA Corporate Bond Data
State Process Parameters:			
κ_i	0.197	Mean-reversion rate of short rate	AR(1) using Gurkaynak et al. (2007)
κ_d	0.879	Mean-reversion rate of risky payoff	Droste et al. (2022)
κ_f	4.105	Mean-reversion rate of fund flows	AR(1) using computed fund flows
σ_i	0.004	Volatility of short rate	AR(1) using Gurkaynak et al. (2007)
σ_d	0.002	Volatility of risky payoff	Droste et al. (2022)
σ_f	0.001	Volatility of fund flows	AR(1) using computed fund flows
L	10	Short-maturity classification cutoff	Assumption
w	0.313	Baseline riskless-risky asset mix	Portfolio weights of funds
Arbitageur Preferences:			
a	5.2	Arbitrageur risk aversion	Match price impact in Treasury market

Table 17: This table describes the calibrated parameters in the model. For each parameter, its baseline value is provided, together with a brief summary of the moment matched or the source of data used to estimate the parameter.

Description	Empirical Value	Model-Implied Value
Matched Moments		
Ratio of Rebalancing between Asset Classes ($t = 0$)	-0.362	-0.303
Ratio of Rebalancing between Asset Classes ($t = 3$)	-0.565	-0.542
Ratio of Rebalancing between Asset Classes ($t = 12$)	-0.608	-0.668
Relative Price Impact in Corporate Bond Market ($t = 0$)	-92.1	-96.6
Relative Price Impact in Corporate Bond Market ($t = 3$)	-33.3	-32.4
Relative Price Impact in Corporate Bond Market ($t = 12$)	-17.2	-17.1
Price Impact in Treasury Market ($t = 0$)	-0.167	-0.163
Estimated Parameters		
dos		0.920
$\tilde{\gamma}_{0,0}$		0.048
$\tilde{\gamma}_{0,3}$		0.140
$\tilde{\gamma}_{0,12}$		0.260
a		5.2

Table 18: This table summarizes the results of the moment-matching exercise. It includes the parameter estimates for dos, the degree of investor-perceived substitutability between riskless and risky bonds, as well as $\tilde{\gamma}_0$, the parameter governing the residual risky bond market investors' elasticity. It also includes a description of each moment matched, together with its empirical value from Section 4 and its model-implied value using the calibrated parameter values in Table 17.

A The Fed's Cost Minimization Problem

For each security i, the Fed's spline model provides a predicted price, $\tilde{P}_i$. The difference between the predicted and market price P_i is a security's richness, $V_i = P_i - \tilde{P}_i$. V_i is a cost that the Fed wishes to minimize, as shown by their statement that they select CUSIPs based on relative value.

First, suppose that trading does not have price impact in the Treasury market. Then the Fed's problem is as follows:

$$\min_{\{Q_1,\ldots,Q_N\}} \sum_i^N V_i Q_i \tag{37}$$

$$s.t. \sum_i^N Q_i = X \tag{38}$$

where X is the total amount to be bought in an auction, Q_i is the amount bought of security i and V_i is the relative value of security i with a lower value signifying a cheaper security. It follows that the Fed will simply buy $Q_i = X$ for security i that has the lowest V_i, i.e. is the cheapest, and will purchase 0 of the other securities.

These conclusions change when the Fed's trades have price impact. Suppose that for each security i, price impact is linear as in Kyle (1985), taking the form $\gamma(Q_i/T_i)$ where T_i is the total amount outstanding of security i. So the more the Fed purchases of a particular security i, as a fraction of its total amount outstanding, the more expensive per-unit it becomes for the Fed to purchase. The price the Fed pays for security i can be modelled as $P_i = \tilde{P}_i + V_i + \gamma(Q_i/T_i)$. Now the Fed faces two costs to minimize when conducting its asset purchases: richness, and price impact. So the Fed's problem becomes:

$$\min_{\{Q_1,\ldots,Q_N\}} \sum_i^N (V_i + \gamma \frac{Q_i}{T_i}) Q_i \tag{39}$$

$$s.t. \sum_i^N Q_i = X \tag{40}$$

The Lagrangian for this optimization problem is:

$$L(Q_1, ..., Q_N, \lambda) = \sum_i^N (V_i + \gamma \frac{Q_i}{T_i}) Q_i - \lambda (\sum_i^N Q_i - X) \tag{41}$$

The first-order conditions are:

$$\frac{dL(Q_1, ..., Q_N, \lambda)}{dQ_i} = V_i + 2\gamma \frac{Q_i}{T_i} - \lambda = 0 \tag{42}$$

$$\frac{dL(Q_1, ..., Q_N, \lambda)}{d\lambda} = \sum_i^N Q_i = X \tag{43}$$

Rearranging the FOC for Q_i yields:

$$Q_i = T_i \frac{\lambda - V_i}{2\gamma} \tag{44}$$

Plugging this into the FOC for λ:

$$\sum_i^N T_i \frac{\lambda - V_i}{2\gamma} = X \tag{45}$$

$$\frac{\lambda}{2\gamma} \sum_i^N T_i - \frac{1}{2\gamma} \sum_i^N T_i V_i = X \tag{46}$$

$$\lambda = \frac{2\gamma X + \sum_i^N T_i V_i}{\sum_i^N T_i} \tag{47}$$

Plugging this back into our expression for Q_i yields:

$$Q_i = T_i \frac{\frac{2\gamma X + \sum_i^N V_i T_i}{\sum_i^N T_i} - V_i}{2\gamma} \tag{48}$$

This is positive whenever the following condition holds:

$$2\gamma \frac{X}{\sum_i^N T_i} + \frac{\sum_i^N V_i T_i}{\sum_i^N T_i} > V_i \tag{49}$$

From this, it follows that the Fed purchases some of security i as long as its richness V_i lies below the sum of the size-weighted average richness of all securities the Fed can purchase from ($\frac{\sum_i^N T_i V_i}{\sum_i^N T_i}$) and the average price impact if all N securities were purchased proportionally to their amount outstanding, $\gamma \frac{X}{\sum_i^N T_i}$. [16] So now, it is optimal for the Fed to spread its purchases across securities as long as they are relatively cheap, rather than

[16] If the Fed purchases $Q_i = X \frac{T_i}{\sum_i^N T_i}$ dollars of each security i, i.e. they distribute the total size of purchases across securities purely based on relative total amounts outstanding, then the Fed purchases $\frac{Q_i}{T_i} = \frac{X}{\sum_i^N T_i}$ of each security i expressed as a fraction of T_i, so the trading cost for each security i is $\gamma \frac{X}{\sum_i^N T_i}$.

simply to purchase only the cheapest one. It is also optimal for the Fed to scale their purchases of a security i by its total amount outstanding T_i. These optimal choices are reflected in our construction of the prediction of what the Fed will purchase. γ determines the optimal degree to which to spread purchases of securities. We do not directly observe γ on QE auction dates, but we can approximate the optimal choice of spread by observing what fraction of CUSIPs the Fed typically purchases in its auctions, assuming that the Fed optimizes on average.

B Additional Empirics

B.1 Decomposition of Mutual Funds' Holdings by Asset Class

Figure B.1 shows the average portfolio weight placed on each asset class by the mutual funds in my sample. The largest weight is placed on corporate bonds (32.9%), followed by government bonds (20.3%). The mutual funds also place an average of 14.5% in mortgage-backed securities.

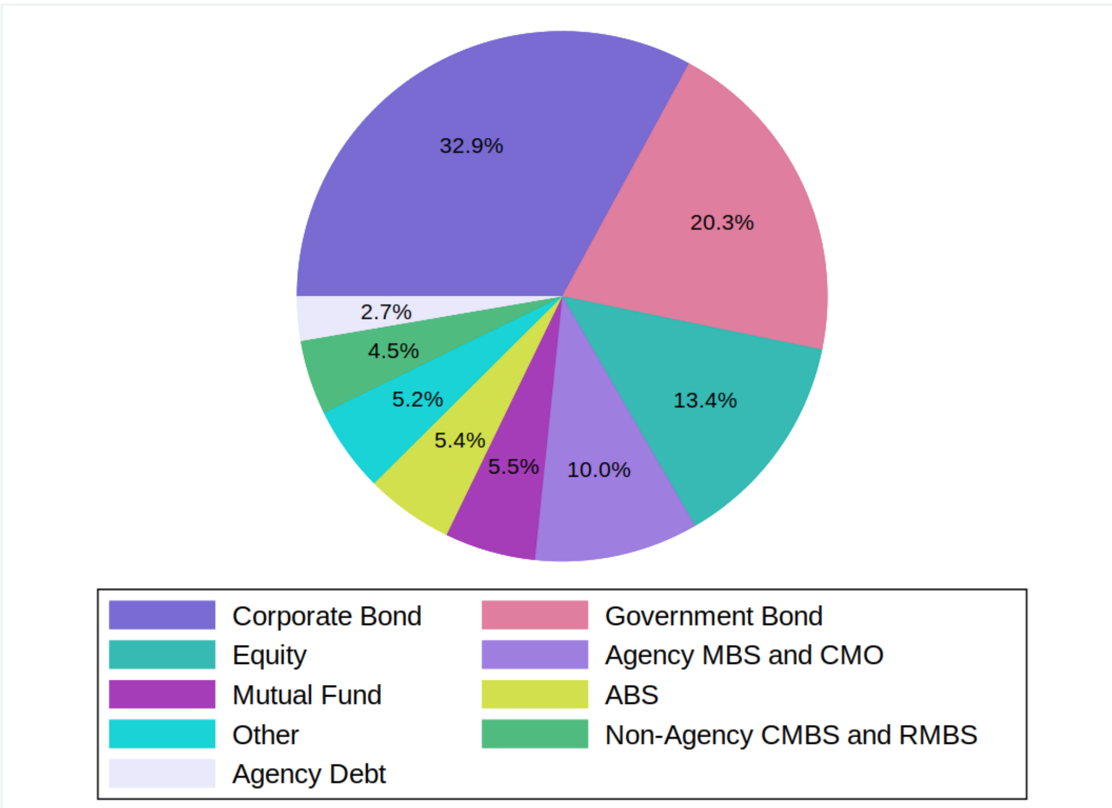

Figure B.1: Average portfolio weight placed on each asset class in sample

B.2 Holdings of Corporate Bonds by Investor Type Over the Sample Period

Figure B.2 shows the fraction of corporate bonds outstanding held by different investor types, over the period 2009-2022. The data used to compute these shares comes from the the Financial Accounts of the United States released by the Federal Reserve. Over the sample period, mutual funds, foreign investors, insurance companies and pension and retirement funds have increased their holdings of corporate bonds, relative to the total amount of corporate bonds outstanding. Banks, money market funds, households (including hedge funds), and security brokers and dealers have reduced their holdings of corporate bonds.

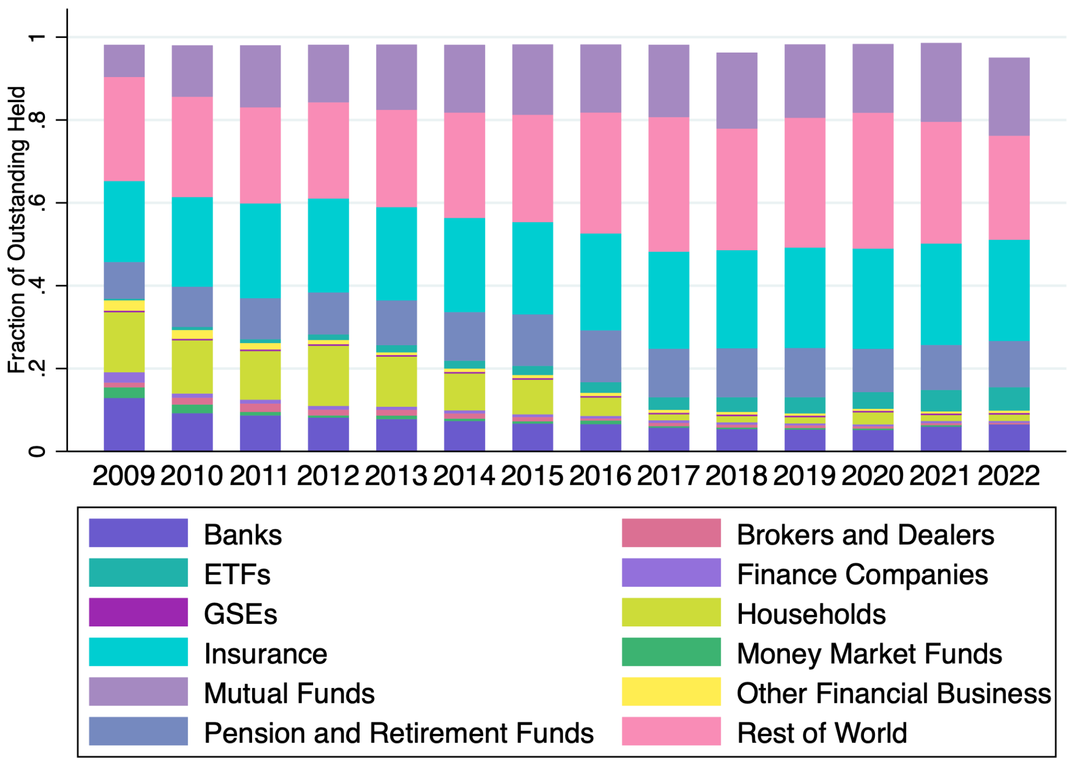

Figure B.2: Fraction of corporate bonds outstanding held, broken down by investor type, between 2009-2022

B.3 Mutual Fund Position Sizes in Treasurys

In Table B.1, I provide summary statistics for fund portfolio weights on individual Treasury securities.

	Mean	St.Dev.	p1	p10	p25	p50	p75	p90	p99	N
Fund Portfolio Weight (%)	0.962	1.914	0.002	0.023	0.091	0.300	1.010	2.536	8.894	1,321,217

Table B.1: This table presents summary statistics for the fund portfolio weights on individual Treasurys in the sample. The weights are expressed in percentage points of a fund's total net assets.

B.4 Holdings of Corporate Bond Issuers by Mutual Funds

In Table B.2, I provide summary statistics for the fraction of the total amount outstanding of an issuers' bonds held by funds in my sample.

	Mean	St.Dev.	p1	p10	p25	p50	p75	p90	p99	N
% of Outstanding	7.379	8.376	0.013	0.595	2.081	4.798	9.505	17.239	39.858	266,813

Table B.2: This table presents summary statistics for the total face value of an issuers' bonds held by funds in my sample, expressed as a percentage of the total amount outstanding of the issuers' bonds.

B.5 Fraction of Funds Who Hold Shocked Treasurys

I investigate the number of funds that hold a given shocked CUSIP. The distribution of the fraction of funds that own a particular shocked CUSIP in the month before it was shocked is shown in Figure B.3. The distribution of the fraction of funds that own any shocked CUSIP in a given month is shown in Figure B.4. The vast majority of funds hold at least one shocked CUSIP in a given month (an average of 62%). Even at the security level, a significant fraction of funds hold any given shocked CUSIP (an average of 6%). So unexpected purchases by the Fed directly affect a large proportion of funds in our sample.

B.6 Fraction of Funds Who Sell Shocked Treasurys

In Figure B.5 I plot the distribution of the fraction of funds who actively sold at least one shocked Treasury in the month following the shock. It shows that a very large fraction of funds sell shocked Treasurys each month in the sample, with a mean of 58%. Even at the security level, multiple funds sell a shocked security in a given month. I plot the distribution of the fraction of funds who actively sold a particular shocked Treasury in the month following the shock in Figure B.6. For a given shocked CUSIP, an average of 1.8% of funds sell it over the following month.

B.7 Descriptive Statistics for Fund-Level QE Shock

In Figure B.7 I plot the distribution of $QEShock_{f,t}$. This shows that there is a broad distribution of fund-level QE shocks each month, with a relatively equal number of funds experiencing positive and negative QE shocks. There is also a significant fraction of funds in our sample each month who experience a QE shock of 0, so we have a decently sized control group.

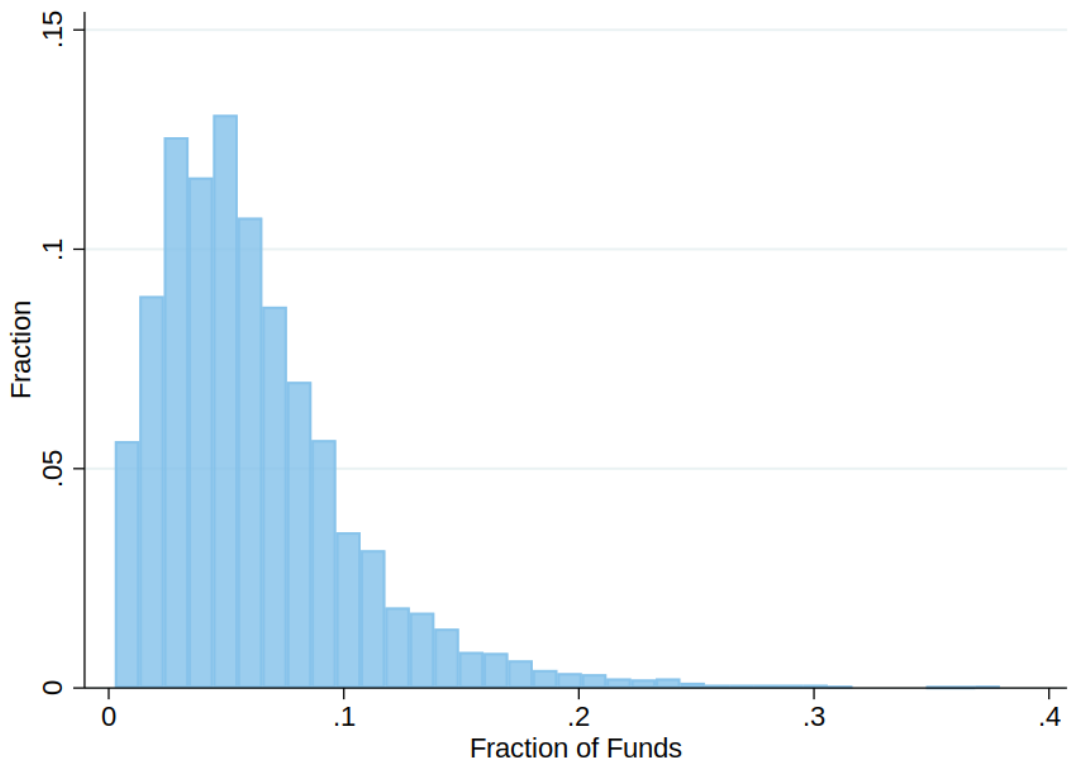

Figure B.3: Distribution of fraction of funds that hold a given shocked CUSIP in the month before it was shocked

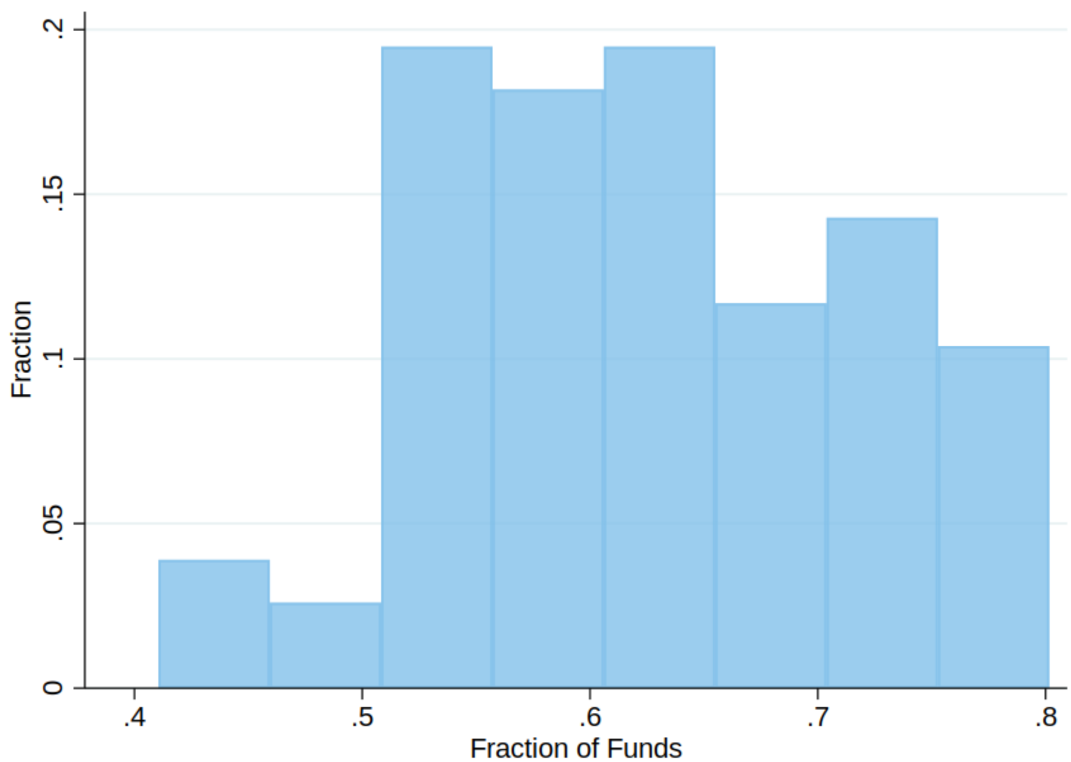

Figure B.4: Distribution of fraction of funds that hold any shocked CUSIP in the month before it was shocked

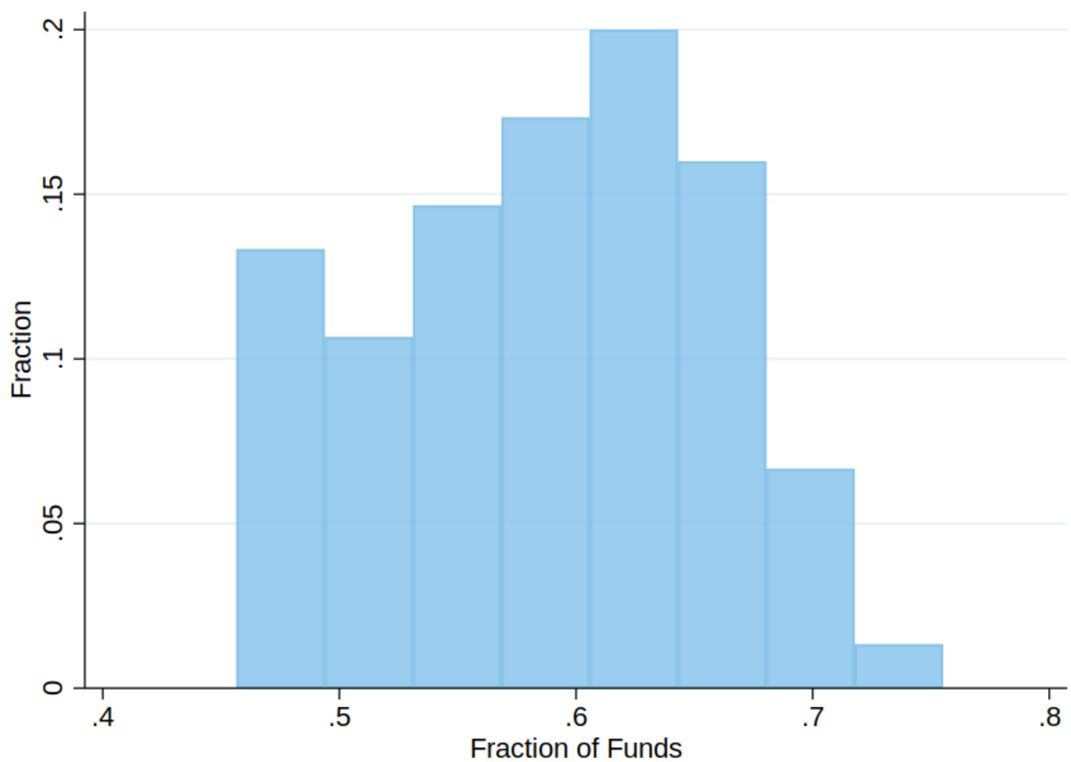

Figure B.5: Distribution of fraction of funds that sell at least one shocked Treasury in the month following the shock

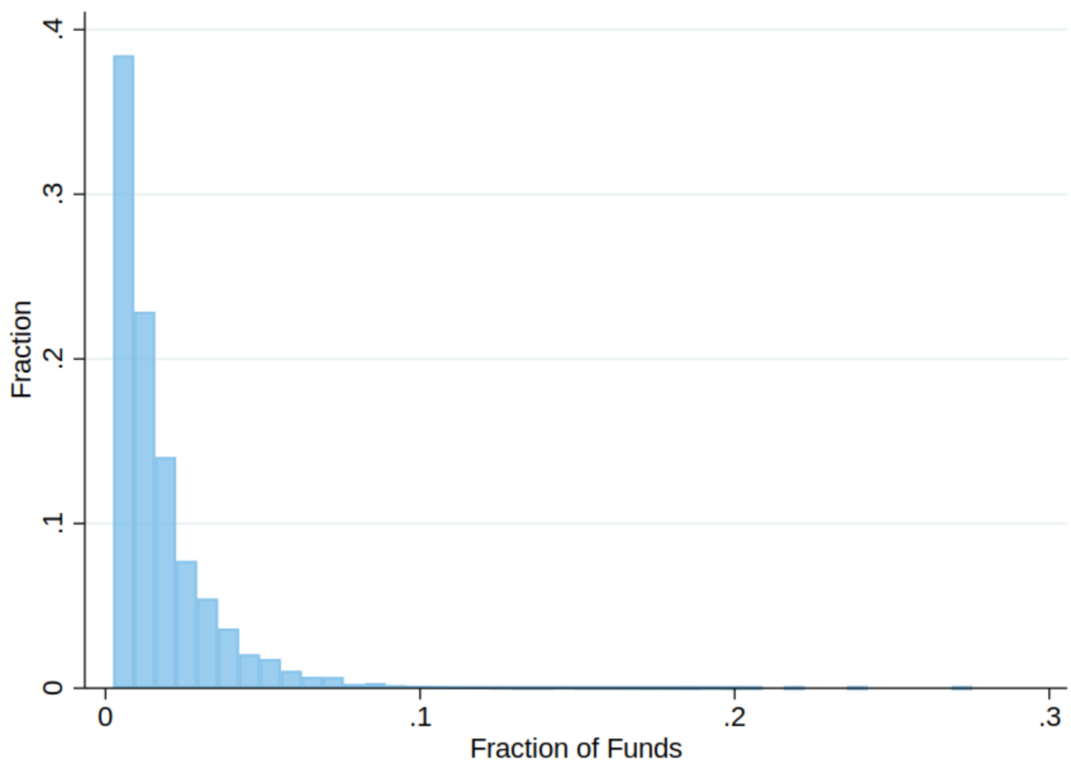

Figure B.6: Distribution of fraction of funds that sell a particular shocked Treasury in the month following the shock

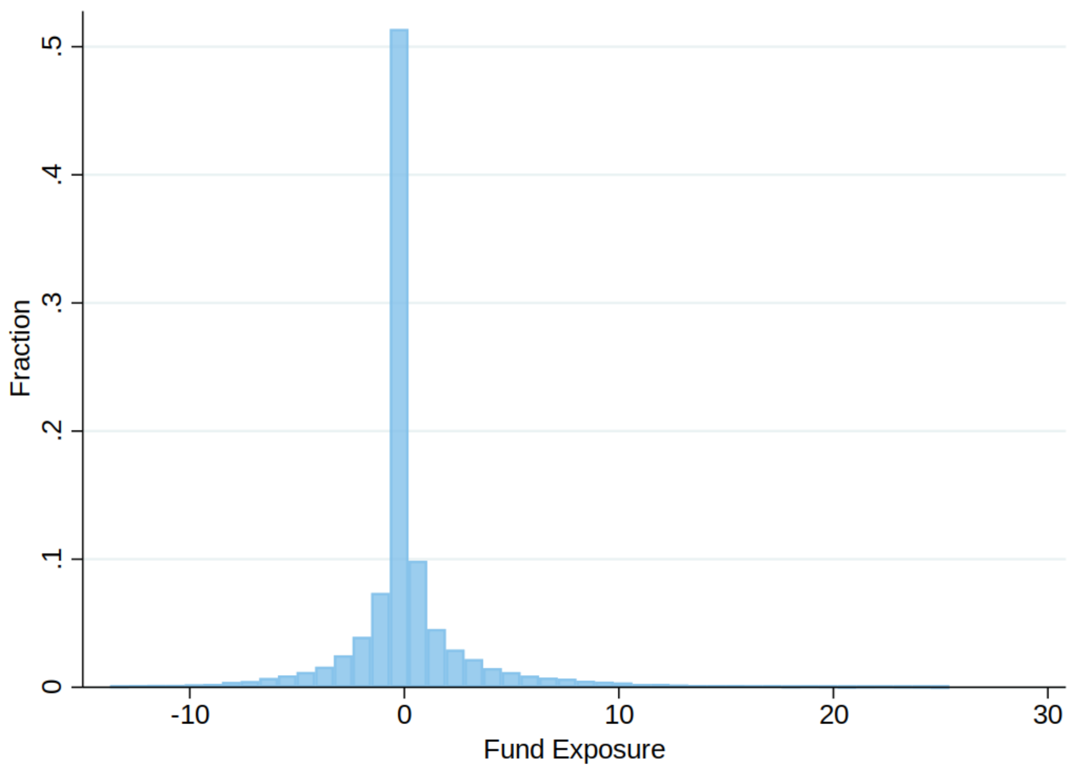

Figure B.7: This figure plots the distribution of $QEShock_{f,t}$ in the sample, at the fund-month observation level. The fund-level QE shock is expressed in percentage points of a fund's total net assets. In the figure, the measure is scaled for an approximately $1 billion shock purchase of a Treasury (in sample, this magnitude represents approximately 0.01% of the total amount outstanding of all Treasury coupons).

In Table B.3, I provide descriptive statistics on the fund-level QE shock. Table B.4 describes the average serial correlations of the fund QE shock for a given fund. For a given fund, the QE shocks it experiences are essentially uncorrelated across months.

	Mean	St.Dev.	p10	p25	p50	p75	p90	N
QE Shock	0.6044	7.2962	-2.3726	-0.4053	0.0000	0.4159	3.4619	37477

Table B.3: This table presents summary statistics for the fund QE shock in the sample. The QE shock is expressed in percentage points of a fund's total net assets. In the table, the measure is scaled for an approximately \$1 billion shock purchase of a Treasury (in sample, this magnitude represents approximately 0.01% of the total amount outstanding of all Treasury coupons).

	t
t-1	0.009
t-2	-0.007
t-3	-0.047
t-4	-0.044
t-5	0.013
t-6	0.040
t-7	-0.020
t-8	-0.001
t-9	-0.038
t-10	-0.019
t-11	-0.006
t-12	0.010

Table B.4: This table shows the correlation for a fund of its QE shock in month t and in month $t - \tau$, for $\tau = (1, ..., 12)$.

B.8 Rebalancing into Other Asset Classes

I estimate Equation 9 for the following other asset classes: agency bonds, non-agency commercial MBS, CMOs, agency MBS, municipal bonds, and non-agency residential MBS. The estimated coefficients β_{ell} are shown in Figures B.8, B.9, B.10, B.11, B.12, and B.13 respectively. I find that in addition to corporate bonds, more shocked funds also rebalance more into non-agency RMBS and CMBS, and CMOs following a QE shock. I find no evidence that more shocked funds rebalance any differently into agency bonds, CMOs, agency MBS or municipal bonds.

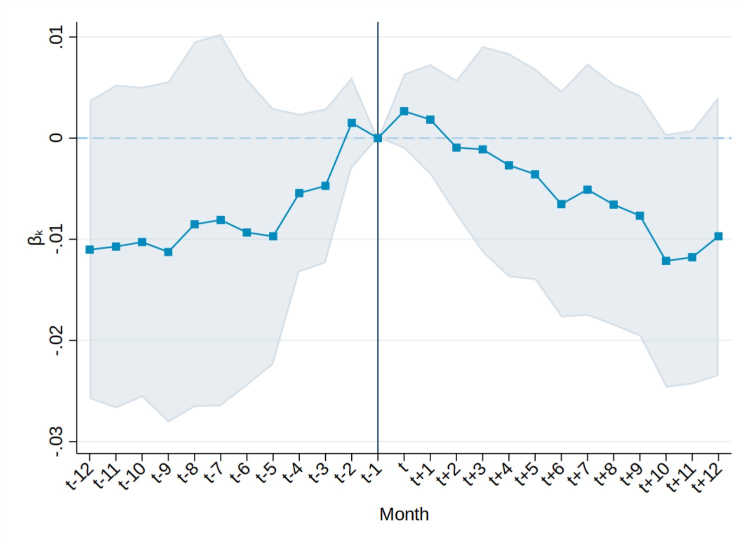

Figure B.8: Active rebalancing into agency bonds.

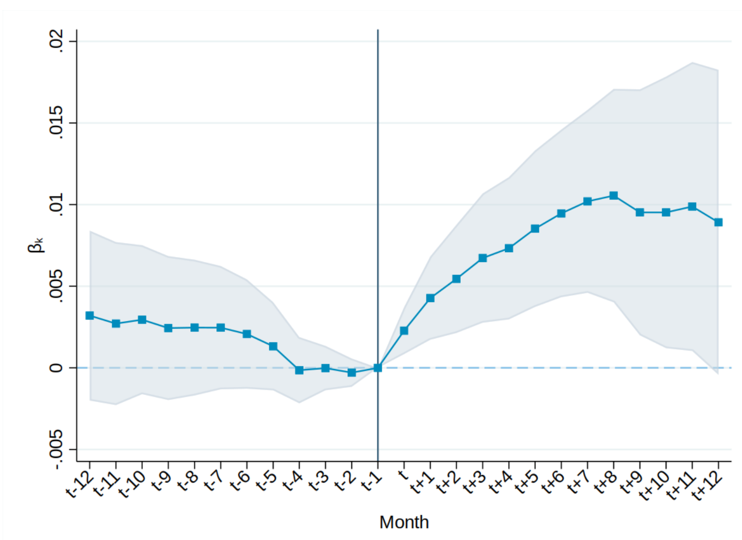

Figure B.9: Active rebalancing into non-agency commercial MBS

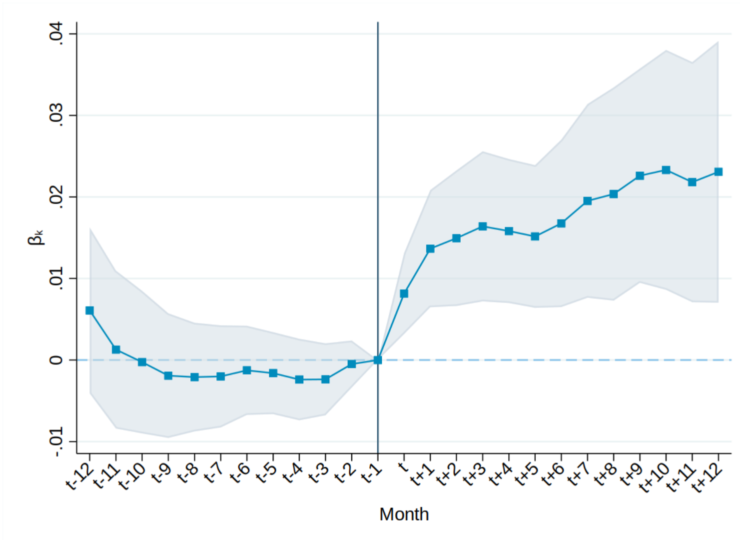

Figure B.10: Active rebalancing into collaterlized mortgage obligations

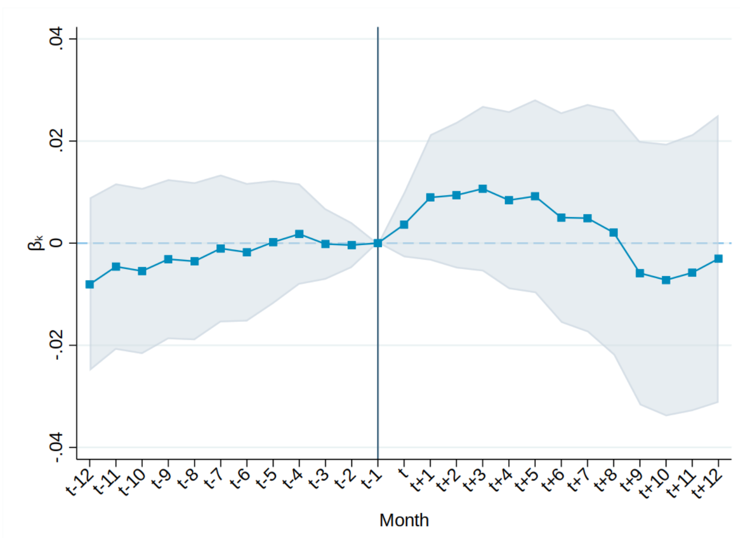

Figure B.11: Active rebalancing into agency MBS

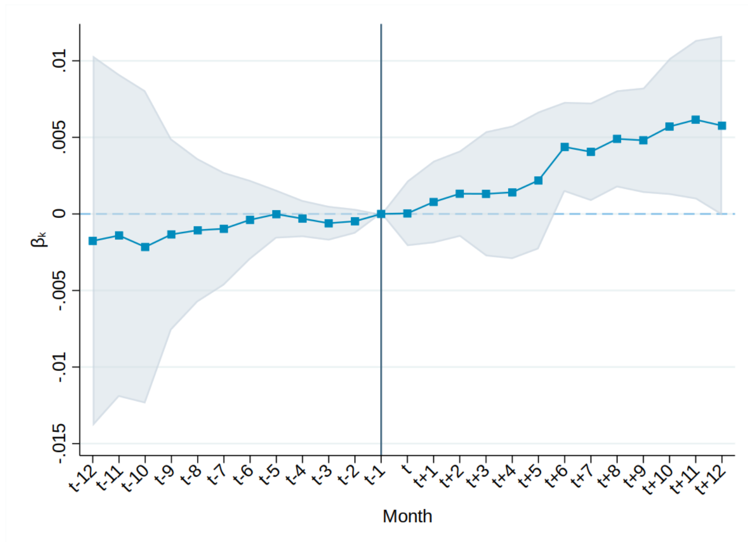

Figure B.12: Active rebalancing into municipal bonds

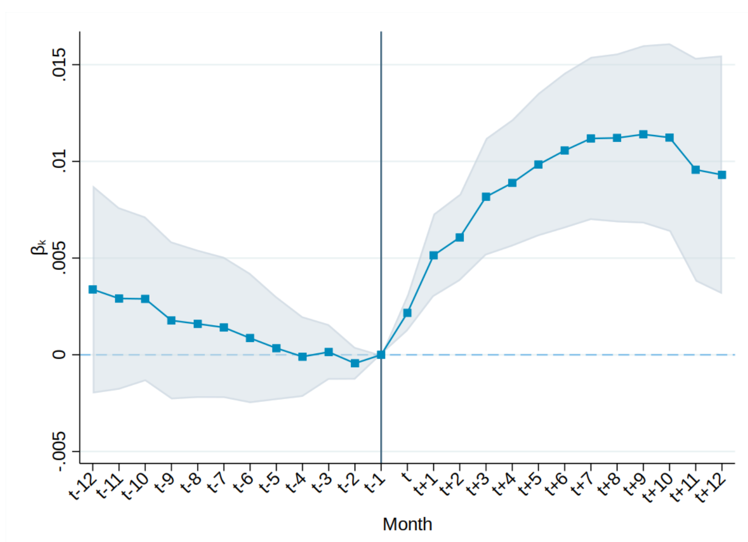

Figure B.13: Active rebalancing into non-agency residential MBS

B.9 Effect of Expected Fed Purchases on Rebalancing

I investigate whether there are any differences in the rebalancing of funds in response to Fed purchases that are expected, given what market participants know about the Fed's decision rule. Given that pressure to rebalance occurs once the Fed actively reduces the publicly available supply of Treasurys from the market, we should expect to see funds rebalance in response to predicted Fed purchases also only from the month that the QE purchases occur and on. To test this hypothesis, I estimate the following specification:

$$\begin{aligned}\Delta Holdings_{f,t-1\to t+\tau} = &\sum_{\ell=-12}^{12} \beta_\ell QEPred_{f,t} \times \mathbb{1}\{\tau = \ell\} \\ &+ \sum_{\ell=-12}^{12} \gamma_\ell \mathbb{1}\{\tau = \ell\} + \lambda_f + \lambda_t + \epsilon_{f,t,\tau} \end{aligned} \tag{50}$$

$QEPred_{f,t}$ captures how much the fund held at the end of month $t-1$ of Treasurys that the Fed is expected to purchase in month t: $QEPred_{f,t} = \sum_i w_{i,f,t-1} \times QEPred_{i,t}$. $\Delta Holdings_{f,t-1\to t+\tau}$ is active rebalancing by fund f either into Treasurys or corporate bonds, between the end of the month $t-1$ and τ months later. Tables B.5 and B.6 displays the results of the estimation for Treasurys and corporate bonds respectively.

Table B.5 shows the results for active rebalancing into Treasurys. The coefficients β_ℓ turn negative at $\tau = 0$ and remain so for the following 12 months, suggesting that funds that previously held more Treasurys that the Fed was expected to purchase more of during a month also rebalance more out of Treasurys in the months that follow. Table B.6 shows the results for active rebalancing into corporate bonds. The coefficients β_ℓ turn positive at $\tau = 0$ and remain so for the following 12 months, suggesting that funds that previously held more Treasurys that the Fed was expected to purchase during a month rebalance more into corporate bonds in the months that follow. The magnitudes are similar to those estimated in Tables 5 and 7. This suggests that funds respond similarly to expected and unexpected purchases by the Fed in terms of their rebalancing.

B.10 Effect of Expected Fed Purchases on Corporate Bond Yields

I also investigate whether expected purchases by the Fed induce any changes in corporate bond yields following the QE operations. Given that funds' holdings are available publicly (with a slight lag of a month or two), and given that a fund's holdings are relatively stable month-to-month, then it is predictable which issuers' bonds any given fund would rebal-

	(1) Cumulative Change in Treasury Holdings
$QEPred \times \mathbb{1}\{\tau = -3\}$	0.003
	(0.007)
$QEPred \times \mathbb{1}\{\tau = -2\}$	-0.001
	(0.005)
$QEPred \times \mathbb{1}\{\tau = 0\}$	-0.043***
	(0.009)
$QEPred \times \mathbb{1}\{\tau = 1\}$	-0.083***
	(0.011)
$QEPred \times \mathbb{1}\{\tau = 2\}$	-0.093***
	(0.013)
$QEPred \times \mathbb{1}\{\tau = 3\}$	-0.107***
	(0.015)
$QEPred \times \mathbb{1}\{\tau = 4\}$	-0.110***
	(0.017)
$QEPred \times \mathbb{1}\{\tau = 5\}$	-0.113***
	(0.019)
$QEPred \times \mathbb{1}\{\tau = 6\}$	-0.116***
	(0.021)
$QEPred \times \mathbb{1}\{\tau = 7\}$	-0.126***
	(0.023)
$QEPred \times \mathbb{1}\{\tau = 8\}$	-0.124***
	(0.024)
$Exposure \times \mathbb{1}\{\tau = 9\}$	-0.116***
	(0.025)
$QEPred \times \mathbb{1}\{\tau = 10\}$	-0.107***
	(0.026)
$QEPred \times \mathbb{1}\{\tau = 11\}$	-0.108***
	(0.027)
$QEPred \times \mathbb{1}\{\tau = 12\}$	-0.106***
	(0.028)
Event Time FEs	✓
Calendar Time FEs	✓
Fund FEs	✓
R^2	0.188
N	462,717

Table B.5: This table presents the estimates for the regression equation:

$$\Delta Holdings_{f,t-1\to t+\tau} = \sum_{\ell=-12}^{12} \beta_\ell QEPred_{f,t} \times \mathbb{1}\{\tau = \ell\} + \sum_{\ell=-12}^{12} \gamma_\ell \mathbb{1}\{\tau = \ell\} + \lambda_f + \lambda_t + \epsilon_{f,t,\tau} \tag{51}$$

$QEPred_{f,t}$ captures how much the fund previously held in month $t-1$ of Treasurys that the Fed is expected to purchase in month t. $\Delta Holdings_{f,t-1\to t+\tau}$ is active rebalancing by fund f into Treasurys, between the end of the month $t-1$ and τ months later. Standard errors are provided in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively.

	(1)
	Cumulative Change in Corporate Bond Holdings
$QEPred \times \mathbb{1}\{\tau = -3\}$	-0.004
	(0.007)
$QEPred \times \mathbb{1}\{\tau = -2\}$	-0.004
	(0.003)
$QEPred \times \mathbb{1}\{\tau = 0\}$	0.020***
	(0.005)
$QEPred \times \mathbb{1}\{\tau = 1\}$	0.039***
	(0.008)
$QEPred \times \mathbb{1}\{\tau = 2\}$	0.050***
	(0.010)
$QEPred \times \mathbb{1}\{\tau = 3\}$	0.059***
	(0.012)
$QEPred \times \mathbb{1}\{\tau = 4\}$	0.063***
	(0.014)
$QEPred \times \mathbb{1}\{\tau = 5\}$	0.063***
	(0.016)
$QEPred \times \mathbb{1}\{\tau = 6\}$	0.060***
	(0.018)
$QEPred \times \mathbb{1}\{\tau = 7\}$	0.064***
	(0.020)
$QEPred \times \mathbb{1}\{\tau = 8\}$	0.070***
	(0.021)
$Exposure \times \mathbb{1}\{\tau = 9\}$	0.070***
	(0.022)
$QEPred \times \mathbb{1}\{\tau = 10\}$	0.067***
	(0.024)
$QEPred \times \mathbb{1}\{\tau = 11\}$	0.062**
	(0.025)
$QEPred \times \mathbb{1}\{\tau = 12\}$	0.058**
	(0.026)
Event Time FEs	✓
Calendar Time FEs	✓
Fund FEs	✓
R^2	0.115
N	462,717

Table B.6: This table presents the estimates for the regression equation:

$$\Delta Holdings_{f,t-1\to t+\tau} = \sum_{\ell=-12}^{12} \beta_\ell QEPred_{f,t} \times \mathbb{1}\{\tau = \ell\} + \sum_{\ell=-12}^{12} \gamma_\ell \mathbb{1}\{\tau = \ell\} + \lambda_f + \lambda_t + \epsilon_{f,t,\tau} \tag{52}$$

$QEPred_{f,t}$ captures how much the fund previously held in month $t-1$ of Treasurys that the Fed is expected to purchase in month t. $\Delta Holdings_{f,t-1\to t+\tau}$ is active rebalancing by fund f into corporate bonds, between the end of the month $t-1$ and τ months later. Standard errors are provided in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively.

ance into if they held Treasurys that are purchased by the Fed. It is also predictable which funds hold the Treasurys that the Fed is expected to purchase in a month. Therefore, it is predictable which issuers' bonds will be rebalanced into by funds following expected Fed purchases. As a result, we would not expect to see a change in yields for these corporate bonds following the QE operations, as information on expected rebalancing by funds should have been incorporated into the price beforehand.

To investigate this, I estimate the following specification:

$$\begin{aligned}\Delta y_{b,t-1\to t+\tau} &= \sum_{\ell=-12}^{12} \beta_\ell QEPred_{i(b),t} \times \mathbb{1}\{\tau=\ell\} \\ &\quad + \sum_{\ell=-12}^{12} \gamma_\ell \mathbb{1}\{\tau=\ell\} + \lambda_b + \lambda_t + \epsilon_{b,t,\tau} \end{aligned} \tag{53}$$

$\Delta y_{b,t-1\to t+\tau}$ is the change in the yield of corporate bond b between end of month $t-1$ and τ months later. $QEPred_{i(b),t}$ captures how much of an issuer i's bonds are held by funds that also hold Treasurys that the Fed is expected to purchase. It is formally defined as follows:

$$QEPred_{i,t} = \sum_{f\in F} \frac{Holdings_{f,I(b),t-1}}{AmountOutstanding_{I(b),t-1}} \times QEPred_{f,t} \tag{54}$$

The results of the estimation are shown in Table B.7. From $\tau = 0$ on, the coefficients do not provide any evidence that corporate bonds of issuers that are expected to be rebalanced into following QE operations in a month experience any difference in yield changes in the months afterward. This suggests that any information on expected fund rebalancing into corporate bonds has already been incorporated by the market into corporate bond prices before the month of the QE operations.

	(1)
	Δy
$QEPred \times \mathbb{1}\{\tau = -3\}$	-0.262*
	(0.148)
$QEPred \times \mathbb{1}\{\tau = -2\}$	-0.165
	(0.101)
$QEPred \times \mathbb{1}\{\tau = 0\}$	-0.177
	(0.121)
$QEPred \times \mathbb{1}\{\tau = 1\}$	-0.106
	(0.131)
$QEPred \times \mathbb{1}\{\tau = 2\}$	0.050
	(0.107)
$QEPred \times \mathbb{1}\{\tau = 3\}$	0.156
	(0.136)
$QEPred \times \mathbb{1}\{\tau = 4\}$	0.086
	(0.113)
$QEPred \times \mathbb{1}\{\tau = 5\}$	0.242*
	(0.126)
$QEPred \times \mathbb{1}\{\tau = 6\}$	0.305
	(0.233)
$QEPred \times \mathbb{1}\{\tau = 7\}$	0.299
	(0.247)
$QEPred \times \mathbb{1}\{\tau = 8\}$	0.375*
	(0.219)
$QEPred \times \mathbb{1}\{\tau = 9\}$	0.288
	(0.213)
$QEPred \times \mathbb{1}\{\tau = 10\}$	0.305
	(0.229)
$QEPred \times \mathbb{1}\{\tau = 11\}$	0.231
	(0.224)
$QEPred \times \mathbb{1}\{\tau = 12\}$	0.197
	(0.215)
R^2	0.124
N	1620175

Table B.7: This table presents the estimates for the regression equation:

$$\Delta y_{i,t-1\to t+\tau} = \sum_{\ell=-12}^{12} \beta_\ell QEPred_{i,t} \times \mathbb{1}\{\tau = \ell\} + \sum_{\ell=-12}^{12} \gamma_\ell \mathbb{1}\{\tau = \ell\} + \lambda_i + \lambda_t + \epsilon_{f,t,\tau} \tag{55}$$

$\Delta y_{b,t-1\to t+\tau}$ is the change in the yield of corporate bond b between end of month $t-1$ and τ months later. $QEPred_{i(b),t}$ captures how much of an issuer i's bonds are held by funds that also hold Treasurys that the Fed is expected to purchase. Standard errors are provided in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively.

C Solving the Model

C.1 Asset Prices and Returns

We posit that asset prices take the form

$$-logP_t^{(\tau)} = A(\tau)' s_t + C(\tau) \tag{56}$$
$$-log\tilde{P}_t^{(\tau)} = \tilde{A}(\tau)' s_t + \tilde{C}(\tau) \tag{57}$$

Then by Ito's lemma and 22, it follows that:

$$\frac{dP_t^{(\tau)}}{P_t^{(\tau)}} = \mu_t^{(\tau)} dt - A(\tau)' \Sigma dB_t \tag{58}$$
$$\frac{d\tilde{P}_t^{(\tau)}}{\tilde{P}_t^{(\tau)}} = \tilde{\mu}_t^{(\tau)} dt - \tilde{A}(\tau)' \Sigma dB_t \tag{59}$$

where

$$\mu_t^{(\tau)} = \frac{\partial A(\tau)'}{\partial t} s_t + \frac{\partial C(\tau)}{\partial t} + A(\tau)' \Gamma (s_t - \overline{s}) + \frac{1}{2} A(\tau)' \Sigma \Sigma' A(\tau) \tag{60}$$
$$= \frac{\partial A_i(\tau)}{\partial t} i_t + \frac{\partial A_d(\tau)}{\partial t} d_t + \frac{\partial A_{f_s}(\tau)}{\partial t} f_{st} + \frac{\partial A_{f_l}(\tau)}{\partial t} f_{lt} + \frac{\partial A_{QE}(\tau)}{\partial t} QE_t + \frac{\partial C(\tau)}{\partial t} \tag{61}$$
$$+ A_i(\tau)\kappa_i(i_t - \overline{i}) + A_d(\tau)\kappa_d(d_t - \overline{d}) + A_{f_s}(\tau)\kappa_{f_s}(f_{st} - \overline{f_s}) + A_{f_l}(\tau)\kappa_{f_l}(f_{lt} - \overline{f_l}) + A_{QE}(\tau)\kappa_{QE}(QE_t - \overline{QE}) \tag{62}$$
$$+ \frac{1}{2} A_i(\tau)^2 \sigma_i^2 + \frac{1}{2} A_d(\tau)^2 \sigma_d^2 + \frac{1}{2} A_{f_s}(\tau)^2 \sigma_{f_s}^2 + \frac{1}{2} A_{f_l}(\tau)^2 \sigma_{f_l}^2 + \frac{1}{2} A_{QE}(\tau)^2 \sigma_{QE}^2 \tag{63}$$

and similarly for $\tilde{\mu}_t^{(\tau)}$ (just replace $A(\tau)$ and $C(\tau)$ with $\tilde{A}(\tau)$ and $\tilde{C}(\tau)$).

C.2 FOC for the Arbitrageur's Problem

We can rewrite the arbitrageur's optimisation problem by substituting the budget constraint into the maximization object and using 58:

$$\underset{(X_t^{(\tau)}}{max} W_t i_t + \int_0^T \{X_t^{(\tau)}(\mu_t^{(\tau)} - i_t)d\tau - \frac{a}{2}[\int_0^T \{X_t^{(\tau)} A(\tau)'\Sigma\}]^2 \tag{64}$$

The FOC w.r.t. $X_t^{(\tau)}$ is:

$$\mu_t^{(\tau)} - i_t = a[\int_0^T \{X_t^{(\tau)} A(\tau)\} d\tau]\Sigma\Sigma A(\tau)' \tag{65}$$

C.3 Market Clearing Condition

The market clears when $Z_t^{(\tau)} + X_t^{(\tau)} + V_t^{(\tau)} = \theta_0(\tau)$. So for riskless assets:

$$\begin{aligned} X_t^{(\tau)} &= -Z_t^{(\tau)} - V_t(\tau) + \theta_0(\tau) \\ &= \alpha(\tau) log P_t^{(\tau)} - \beta(\tau) log \tilde{P}_t^{(\tau)} - \mathbb{1}\{\tau < L\} w_s(\tau) f_{st} - (1 - \mathbb{1}\{\tau < L\}) w_l(\tau) f_{lt} + \theta_0(\tau) \end{aligned} \tag{66}$$

For risky assets:

$$\begin{aligned} \tilde{X}_t^{(\tau)} &= -\tilde{Z}_t^{(\tau)} - \tilde{V}_t^{(\tau)} + \tilde{\theta}_0(\tau) \\ &= \tilde{\alpha}(\tau) log \tilde{P}_t^{(\tau)} - \tilde{\beta}(\tau) log P_t^{(\tau)} - \mathbb{1}\{\tau < L\}(1 - w_s(\tau)) f_{st} - (1 - \mathbb{1}\{\tau < L\})(1 - w_l(\tau)) f_{lt} + \tilde{\gamma}(\tau) log \tilde{P}_t^{(\tau)} + \tilde{\theta}_0(\tau) \end{aligned} \tag{67}$$

As arbitrageurs do not engage in the risky asset market, $\tilde{X}_t^{(\tau)} = 0$. It follows from 67 that:

$$
\begin{aligned}
0 &= (\tilde{\alpha}(\tau) + \tilde{\gamma}(\tau))[-\tilde{A}(\tau)' s_t - \tilde{C}(\tau)] - \tilde{\beta}(\tau)[-A(\tau)' s_t - C(\tau)] - \mathbb{1}\{\tau < L\}(1 - w_s(\tau)) f_{st} - (1 - \mathbb{1}\{\tau < L\})(1 - w_l(\tau)) f_{lt} + \tilde{\theta}_0(\tau) \\
&= (\tilde{\alpha}(\tau) + \tilde{\gamma}(\tau))[-\tilde{A}_i(\tau) i_t - \tilde{A}_d(\tau) d_t - \tilde{A}_{f_s}(\tau) f_{st} - \tilde{A}_{f_l}(\tau) f_{lt} - \tilde{A}_{QE}(\tau) QE_t - \tilde{C}(\tau)] \qquad (68) \\
&- \tilde{\beta}(\tau)[-A_i(\tau) i_t - A_d(\tau) d_t - A_{f_s}(\tau) f_{st} - A_{f_l}(\tau) f_{lt} - A_{QE}(\tau) QE_t - C(\tau)] \\
&- \mathbb{1}\{\tau < L\}(1 - w_s(\tau)) f_{st} - (1 - \mathbb{1}\{\tau < L\})(1 - w_l(\tau)) f_{lt} + \tilde{\theta}_0(\tau)
\end{aligned}
$$

C.4 Solving the Arbitrageur's Problem

Substituting the market clearing condition 66 into the FOC 65 yields:

$$
\begin{aligned}
\mu_t - i_t &= a\Big[\int_0^T \big\{[\alpha(\tau) log P_t^{(\tau)} - \beta(\tau) log \tilde{P}_t^{(\tau)} - \mathbb{1}\{\tau < L\} w_s(\tau) f_{st} - \mathbb{1}\{\tau \geq L\} w_l(\tau) f_{lt} + \theta_0(\tau)] A(\tau)'\big\} d\tau\Big] \Sigma\Sigma A(\tau) \\
&= a\Big[\int_0^T \big\{[\alpha(\tau)(-A(\tau)' s_t - C(\tau)) - \beta(\tau)(-\tilde{A}(\tau)' s_t - \tilde{C}(\tau)) - \mathbb{1}\{\tau < L\} w_s(\tau) f_{st} - \mathbb{1}\{\tau \geq L\} w_l(\tau) f_{lt} + \theta_0(\tau)] A(\tau)'\big\} d\tau\Big] \Sigma\Sigma A(\tau) \\
&= A_i(\tau)\lambda_{i,t} + A_d(\tau)\lambda_{d,t} + A_{f_s}(\tau)\lambda_{f_s,t} + A_{f_l}(\tau)\lambda_{f_l,t} + A_{QE}(\tau)\lambda_{QE,t} \qquad (69)
\end{aligned}
$$

where

$$
\begin{aligned}
\lambda_{s,t} = a\sigma_s^2 \int_0^T \Big\{ &- \alpha(\tau)[A_i(\tau) i_t + A_d(\tau) d_t + A_{f_s}(\tau) f_{st} + A_{f_l}(\tau) f_{lt} + A_{QE}(\tau) QE_t + C(\tau)] A_s(\tau) \\
&+ \beta(\tau)[\tilde{A}_i(\tau) i_t + \tilde{A}_d(\tau) d_t + \tilde{A}_{f_s}(\tau) f_{st} + \tilde{A}_{f_l}(\tau) f_{lt} + \tilde{A}_{QE}(\tau) QE_t + \tilde{C}(\tau)] A_s(\tau) \\
&- \mathbb{1}\{\tau < L\} w_s(\tau) f_{st} A_s(\tau) - (1 - \mathbb{1}\{\tau < L\}) w_l(\tau) f_{lt} A_s(\tau) \\
&+ \theta_0(\tau) A_s(\tau) \Big\} d\tau
\end{aligned}
$$

C.5 Matching Coefficients

To solve, collect the terms that are linear in each state variable s_t and the constant terms. This results in a system of ODEs that can be solved numerically.

C.5.1 Risky Market Clearing Condition

It follows from matching coefficients for each state variable in 67 that for the state variables i_t, d_t, QE_t:

$$\begin{aligned} 0 &= -\tilde{\alpha}(\tau)\tilde{A}_s(\tau) - \tilde{\gamma}(\tau)\tilde{A}_s(\tau) + \tilde{\beta}(\tau)A_s(\tau) \\ \tilde{A}_s(\tau) &= \frac{\tilde{\beta}(\tau)}{\tilde{\alpha}(\tau) + \tilde{\gamma}(\tau)} A_s(\tau) \end{aligned} \tag{70}$$

and that for state variables $f_{s,t}$:

$$\begin{aligned} 0 &= -\tilde{\alpha}(\tau)\tilde{A}_{f_s}(\tau) - \tilde{\gamma}(\tau)\tilde{A}_{f_s}(\tau) + \tilde{\beta}(\tau)A_{f_s}(\tau) - \mathbb{1}\{\tau < L\}(1 - w_s(\tau)) \\ \tilde{A}_{f_s}(\tau) &= \frac{\tilde{\beta}(\tau)A_{f_s}(\tau) - \mathbb{1}\{\tau < L\}(1 - w_s(\tau))}{\tilde{\alpha}(\tau) + \tilde{\gamma}(\tau)} \end{aligned} \tag{71}$$

and for $f_{l,t}$:

$$\begin{aligned} 0 &= -\tilde{\alpha}(\tau)\tilde{A}_{f_l}(\tau) - \tilde{\gamma}(\tau)\tilde{A}_{f_l}(\tau) + \tilde{\beta}(\tau)A_{f_l}(\tau) - (1 - \mathbb{1}\{\tau < L\})(1 - w_l(\tau)) \\ \tilde{A}_{f_l}(\tau) &= \frac{\tilde{\beta}(\tau)A_{f_l}(\tau) - (1 - \mathbb{1}\{\tau < L\})(1 - w_l(\tau))}{\tilde{\alpha}(\tau) + \tilde{\gamma}(\tau)} \end{aligned} \tag{72}$$

Also, from matching the constant terms in 67, it follows that:

$$\begin{aligned} 0 &= -\tilde{\alpha}(\tau)\tilde{C}(\tau) - \tilde{\gamma}(\tau)\tilde{C}(\tau) + \tilde{\beta}(\tau)C(\tau) + \tilde{\theta}_0(\tau) \\ \tilde{C}(\tau) &= \frac{\tilde{\beta}(\tau)C(\tau) + \tilde{\theta}_0(\tau)}{\tilde{\alpha}(\tau) + \tilde{\gamma}(\tau)} \end{aligned} \tag{73}$$

C.5.2 Substituting in Risky Market Clearing Conditions to Arbitrageur's FOC

Substituting 70, 71, 72, 73 into 69 yields:

$$\mu_t - i_t = A_i(\tau)\lambda_{i,t} + A_d(\tau)\lambda_{d,t} + A_{f_s}(\tau)\lambda_{f_s,t} + A_{f_l}(\tau)\lambda_{f_l,t} + A_{QE}(\tau)\lambda_{QE,t} \tag{74}$$

where

$$\begin{aligned}
\lambda_{s,t} = a\sigma_s^2 \int_0^T \Big\{ & - \alpha(\tau)[A_i(\tau)i_t + A_d(\tau)d_t + A_{f_s}(\tau)f_{st} + A_{f_l}(\tau)f_{lt} + A_{QE}(\tau)QE_t + C(\tau)]A_s(\tau) \\
& + \beta(\tau)\frac{\tilde{\beta}(\tau)}{\tilde{\alpha}(\tau)+\tilde{\gamma}(\tau)}[A_i(\tau)i_t + A_d(\tau)d_t + A_{QE}(\tau)QE_t \\
& + \beta(\tau)\frac{\tilde{\beta}(\tau)A_{f_s}(\tau) - \mathbb{1}\{\tau < L\}(1-w_s(\tau))}{\tilde{\alpha}(\tau)+\tilde{\gamma}(\tau)} f_{st}A_s(\tau) \\
& + \beta(\tau)\frac{\tilde{\beta}(\tau)A_{f_l}(\tau) - (1-\mathbb{1}\{\tau < L\})(1-w_l(\tau))}{\tilde{\alpha}(\tau)+\tilde{\gamma}(\tau)} f_{lt}A_s(\tau) \\
& + \beta(\tau)\frac{\tilde{\beta}(\tau)C(\tau) + \tilde{\theta}_0(\tau)}{\tilde{\alpha}(\tau)+\tilde{\gamma}(\tau)}A_s(\tau) \\
& - \mathbb{1}\{\tau < L\}w_s(\tau)f_{st}A_s(\tau) - (1-\mathbb{1}\{\tau < L\})w_l(\tau)f_{lt}A_s(\tau) \\
& + \theta_0(\tau)A_s(\tau)\Big\} d\tau
\end{aligned}$$

Now we can match coefficients, and will end up with a system of 6 ODEs in 6 unknowns, $A(\tau)$ and $C(\tau)$. Once we solve this system, we can then find $\tilde{A}(\tau)$ and $\tilde{C}(\tau)$ using 70, 71, 72, and 73 above. Matching coefficients on each of the state variables and the constant term yields:

C.5.3 i_t

$$\begin{aligned}
\frac{\partial A_i(\tau)}{\partial t} + A_i(\tau)\kappa_i - 1 = & A_i(\tau)a\sigma_i^2 \int_0^T \Big\{ (\frac{\beta(\tau)\tilde{\beta}(\tau)}{\tilde{\alpha}(\tau)+\tilde{\gamma}(\tau)} - \alpha(\tau))A_i(\tau)A_i(\tau) \Big\} d\tau \\
& + A_d(\tau)a\sigma_d^2 \int_0^T \Big\{ (\frac{\beta(\tau)\tilde{\beta}(\tau)}{\tilde{\alpha}(\tau)+\tilde{\gamma}(\tau)} - \alpha(\tau))A_i(\tau)A_d(\tau) \Big\} d\tau \\
& + A_{f_s}(\tau)a\sigma_{f,s}^2 \int_0^T \Big\{ (\frac{\beta(\tau)\tilde{\beta}(\tau)}{\tilde{\alpha}(\tau)+\tilde{\gamma}(\tau)} - \alpha(\tau))A_i(\tau)A_{f_s}(\tau) \Big\} d\tau \\
& + A_{f_l}(\tau)a\sigma_{f,l}^2 \int_0^T \Big\{ (\frac{\beta(\tau)\tilde{\beta}(\tau)}{\tilde{\alpha}(\tau)+\tilde{\gamma}(\tau)} - \alpha(\tau))A_i(\tau)A_{f_l}(\tau) \Big\} d\tau \\
& + A_{QE}(\tau)a\sigma_{QE}^2 \int_0^T \Big\{ (\frac{\beta(\tau)\tilde{\beta}(\tau)}{\tilde{\alpha}(\tau)+\tilde{\gamma}(\tau)} - \alpha(\tau))A_i(\tau)A_{QE}(\tau) \Big\} d\tau
\end{aligned}$$

C.5.4 d_t

$$\begin{aligned}
\frac{\partial A_d(\tau)}{\partial t} + A_d(\tau)\kappa_d = & A_i(\tau)a\sigma_i^2 \int_0^T \Big\{ (\frac{\beta(\tau)\tilde{\beta}(\tau)}{\tilde{\alpha}(\tau)+\tilde{\gamma}(\tau)} - \alpha(\tau))A_d(\tau)A_i(\tau) \Big\} d\tau \\
& + A_d(\tau)a\sigma_d^2 \int_0^T \Big\{ (\frac{\beta(\tau)\tilde{\beta}(\tau)}{\tilde{\alpha}(\tau)+\tilde{\gamma}(\tau)} - \alpha(\tau))A_d(\tau)A_d(\tau) \Big\} d\tau \\
& + A_{f_s}(\tau)a\sigma_{f_s}^2 \int_0^T \Big\{ (\frac{\beta(\tau)\tilde{\beta}(\tau)}{\tilde{\alpha}(\tau)+\tilde{\gamma}(\tau)} - \alpha(\tau))A_d(\tau)A_{f_s}(\tau) \Big\} d\tau \\
& + A_{f_l}(\tau)a\sigma_{f_l}^2 \int_0^T \Big\{ (\frac{\beta(\tau)\tilde{\beta}(\tau)}{\tilde{\alpha}(\tau)+\tilde{\gamma}(\tau)} - \alpha(\tau))A_d(\tau)A_{f_l}(\tau) \Big\} d\tau \\
& + A_{QE}(\tau)a\sigma_{QE}^2 \int_0^T \Big\{ (\frac{\beta(\tau)\tilde{\beta}(\tau)}{\tilde{\alpha}(\tau)+\tilde{\gamma}(\tau)} - \alpha(\tau))A_d(\tau)A_{QE}(\tau) \Big\} d\tau
\end{aligned}$$

C.5.5 $f_{s,t}$

$$
\begin{aligned}
&\frac{\partial A_{f_s}(\tau)}{\partial t} + A_{f_s}(\tau)\kappa_{f_s} \\
&= A_i(\tau)a\sigma_i^2 \int_0^T \Big\{ -\alpha(\tau)A_{f_s}(\tau)A_i(\tau) + \beta(\tau)\frac{\tilde{\beta}(\tau)A_{f_s}(\tau) - \mathbb{1}\{\tau < L\}(1 - w_s(\tau))}{\tilde{\alpha}(\tau) + \tilde{\gamma}(\tau)} A_i(\tau) - \mathbb{1}\{\tau < L\}w_s(\tau)A_i(\tau) \Big\} d\tau \\
&+ A_d(\tau)a\sigma_d^2 \int_0^T \Big\{ -\alpha(\tau)A_{f_s}(\tau)A_d(\tau) + \beta(\tau)\frac{\tilde{\beta}(\tau)A_{f_s}(\tau) - \mathbb{1}\{\tau < L\}(1 - w_s(\tau))}{\tilde{\alpha}(\tau) + \tilde{\gamma}(\tau)} A_d(\tau) - \mathbb{1}\{\tau < L\}w_s(\tau)A_d(\tau) \Big\} d\tau \\
&+ A_{f_s}(\tau)a\sigma_{f_s}^2 \int_0^T \Big\{ -\alpha(\tau)A_{f_s}(\tau)A_{f_s}(\tau) + \beta(\tau)\frac{\tilde{\beta}(\tau)A_{f_s}(\tau) - \mathbb{1}\{\tau < L\}(1 - w_s(\tau))}{\tilde{\alpha}(\tau) + \tilde{\gamma}(\tau)} A_{f_s}(\tau) - \mathbb{1}\{\tau < L\}w_s(\tau)A_{f_s}(\tau) \Big\} d\tau \\
&+ A_{f_l}(\tau)a\sigma_{f_l}^2 \int_0^T \Big\{ -\alpha(\tau)A_{f_s}(\tau)A_{f_l}(\tau) + \beta(\tau)\frac{\tilde{\beta}(\tau)A_{f_s}(\tau) - \mathbb{1}\{\tau < L\}(1 - w_s(\tau))}{\tilde{\alpha}(\tau) + \tilde{\gamma}(\tau)} A_{f_l}(\tau) - \mathbb{1}\{\tau < L\}w_s(\tau)A_{f_l}(\tau) \Big\} d\tau \\
&+ A_{QE}(\tau)a\sigma_{QE}^2 \int_0^T \Big\{ -\alpha(\tau)A_{f_s}(\tau)A_{QE}(\tau) + \beta(\tau)\frac{\tilde{\beta}(\tau)A_{f_s}(\tau) - \mathbb{1}\{\tau < L\}(1 - w_s(\tau))}{\tilde{\alpha}(\tau) + \tilde{\gamma}(\tau)} A_{QE}(\tau) - \mathbb{1}\{\tau < L\}w_s(\tau)A_{QE}\tau) \Big\} d\tau
\end{aligned}
$$

C.5.6 $f_{l,t}$

$$
\begin{aligned}
&\frac{\partial A_{f_l}(\tau)}{\partial t} + A_{f_l}(\tau)\kappa_{f_l} = \\
&A_i(\tau)a\sigma_i^2 \int_0^T \Big\{-\alpha(\tau)A_{f_l}(\tau)A_i(\tau) + \beta(\tau)\frac{\tilde{\beta}(\tau)A_{f_l}(\tau) - (1-\mathbb{1}\{\tau < L\})(1-w_l(\tau))}{\tilde{\alpha}(\tau)+\tilde{\gamma}(\tau)}A_i(\tau) - (1-\mathbb{1}\{\tau < L\})w_l(\tau)A_i(\tau)\Big\}d\tau \\
&+ A_d(\tau)a\sigma_d^2 \int_0^T \Big\{-\alpha(\tau)A_{f_l}(\tau)A_d(\tau) + \beta(\tau)\frac{\tilde{\beta}(\tau)A_{f_l}(\tau) - (1-\mathbb{1}\{\tau < L\})(1-w_l(\tau))}{\tilde{\alpha}(\tau)+\tilde{\gamma}(\tau)}A_d(\tau) - (1-\mathbb{1}\{\tau < L\})w_l(\tau)A_d(\tau)\Big\}d\tau \\
&+ A_{f_s}(\tau)a\sigma_{f_s}^2 \int_0^T \Big\{-\alpha(\tau)A_{f_l}(\tau)A_{f_s}(\tau) + \beta(\tau)\frac{\tilde{\beta}(\tau)A_{f_l}(\tau) - (1-\mathbb{1}\{\tau < L\})(1-w_l(\tau))}{\tilde{\alpha}(\tau)+\tilde{\gamma}(\tau)}A_{f_s}(\tau) - (1-\mathbb{1}\{\tau < L\})w_l(\tau)A_{f_s}(\tau)\Big\}d\tau \\
&+ A_{f_l}(\tau)a\sigma_{f_l}^2 \int_0^T \Big\{-\alpha(\tau)A_{f_l}(\tau)A_{f_l}(\tau) + \beta(\tau)\frac{\tilde{\beta}(\tau)A_{f_l}(\tau) - (1-\mathbb{1}\{\tau < L\})(1-w_l(\tau))}{\tilde{\alpha}(\tau)+\tilde{\gamma}(\tau)}A_{f_l}(\tau) - (1-\mathbb{1}\{\tau < L\})w_l(\tau)A_{f_l}(\tau)\Big\}d\tau \\
&+ A_{QE}(\tau)a\sigma_{QE}^2 \int_0^T \Big\{-\alpha(\tau)A_{f_l}(\tau)A_{QE}(\tau) + \beta(\tau)\frac{\tilde{\beta}(\tau)A_{f_l}(\tau) - (1-\mathbb{1}\{\tau < L\})(1-w_l(\tau))}{\tilde{\alpha}(\tau)+\tilde{\gamma}(\tau)}A_{QE}(\tau) - (1-\mathbb{1}\{\tau < L\})w_l(\tau)A_{QE}(\tau)\Big\}d\tau
\end{aligned}
$$

C.5.7 $QE(\tau)$ terms

$$
\begin{aligned}
\frac{\partial A_{QE}(\tau)}{\partial t} + A_{QE}(\tau)\kappa_{QE} = {} & A_i(\tau) a\sigma_i^2 \int_0^T \Big\{ (\frac{\beta(\tau)\tilde{\beta}(\tau)}{\tilde{\alpha}(\tau)+\tilde{\gamma}(\tau)} - \alpha(\tau)) A_{QE}(\tau) A_i(\tau) - A_i(\tau) \Big\} d\tau \\
& + A_d(\tau) a\sigma_d^2 \int_0^T \Big\{ (\frac{\beta(\tau)\tilde{\beta}(\tau)}{\tilde{\alpha}(\tau)+\tilde{\gamma}(\tau)} - \alpha(\tau)) A_{QE}(\tau) A_d(\tau) - A_d(\tau) \Big\} d\tau \\
& + A_{f_s}(\tau) a\sigma_{f_s}^2 \int_0^T \Big\{ (\frac{\beta(\tau)\tilde{\beta}(\tau)}{\tilde{\alpha}(\tau)+\tilde{\gamma}(\tau)} - \alpha(\tau)) A_{QE}(\tau) A_{f_s}(\tau) - A_{f_s}(\tau) \Big\} d\tau \\
& + A_{f_l}(\tau) a\sigma_{f_l}^2 \int_0^T \Big\{ (\frac{\beta(\tau)\tilde{\beta}(\tau)}{\tilde{\alpha}(\tau)+\tilde{\gamma}(\tau)} - \alpha(\tau)) A_{QE}(\tau) A_{f_l}(\tau) - A_{f_l}(\tau) \Big\} d\tau \\
& + A_{QE}(\tau) a\sigma_{QE}^2 \int_0^T \Big\{ (\frac{\beta(\tau)\tilde{\beta}(\tau)}{\tilde{\alpha}(\tau)+\tilde{\gamma}(\tau)} - \alpha(\tau)) A_{QE}(\tau) A_{QE}(\tau) - A_{QE}(\tau) \Big\} d\tau
\end{aligned}
$$

C.5.8 Constant Terms

$$
\begin{aligned}
\frac{\partial C(\tau)}{\partial t} = {} & A_i(\tau)\kappa_i \bar{i} + A_d(\tau)\kappa_d \bar{d} + A_{f_s}(\tau)\kappa_{f_s}\overline{f_s} + A_{f_l}(\tau)\kappa_{f_l}\overline{f_l} + A_{QE}(\tau)\kappa_{QE}\overline{QE} \\
& - \frac{1}{2}A_i(\tau)^2\sigma_i^2 - \frac{1}{2}A_d(\tau)^2\sigma_d^2 - \frac{1}{2}A_{f_s}(\tau)^2\sigma_{f_s}^2 - \frac{1}{2}A_{f_l}(\tau)^2\sigma_{f_l}^2 - \frac{1}{2}A_{QE}(\tau)^2\sigma_{QE}^2 \\
& + A_i(\tau) a\sigma_i^2 \int_0^T \Big\{ [\beta(\tau)\frac{\tilde{\beta}(\tau)C(\tau)+\tilde{\theta}_0(\tau)}{\tilde{\alpha}(\tau)+\tilde{\gamma}(\tau)} - \alpha(\tau)C(\tau)] A_i(\tau) + \theta_0(\tau) A_i(\tau) \Big\} d\tau \\
& + A_d(\tau) a\sigma_d^2 \int_0^T \Big\{ [\beta(\tau)\frac{\tilde{\beta}(\tau)C(\tau)+\tilde{\theta}_0(\tau)}{\tilde{\alpha}(\tau)+\tilde{\gamma}(\tau)} - \alpha(\tau)C(\tau)] A_d(\tau) + \theta_0(\tau) A_d(\tau) \Big\} d\tau \\
& + A_{f_s}(\tau) a\sigma_{f_s}^2 \int_0^T \Big\{ [\beta(\tau)\frac{\tilde{\beta}(\tau)C(\tau)+\tilde{\theta}_0(\tau)}{\tilde{\alpha}(\tau)+\tilde{\gamma}(\tau)} - \alpha(\tau)C(\tau)] A_{f_s}(\tau) + \theta_0(\tau) A_{f_s}(\tau) \Big\} d\tau \\
& + A_{f_l}(\tau) a\sigma_{f_l}^2 \int_0^T \Big\{ [\beta(\tau)\frac{\tilde{\beta}(\tau)C(\tau)+\tilde{\theta}_0(\tau)}{\tilde{\alpha}(\tau)+\tilde{\gamma}(\tau)} - \alpha(\tau)C(\tau)] A_{f_l}(\tau) + \theta_0(\tau) A_{f_l}(\tau) \Big\} d\tau \\
& + A_{QE}(\tau) a\sigma_{QE}^2 \int_0^T \Big\{ [\beta(\tau)\frac{\tilde{\beta}(\tau)C(\tau)+\tilde{\theta}_0(\tau)}{\tilde{\alpha}(\tau)+\tilde{\gamma}(\tau)} - \alpha(\tau)C(\tau)] A_{QE}(\tau) + \theta_0(\tau) A_{QE}(\tau) \Big\} d\tau
\end{aligned}
$$

D Model Calibration

D.1 Short-Rate

For the short-rate process i_t, I use monthly series of one-year zero-coupon yields from Gurkaynak, Sack, and Wright (2006) between 2008 and 2021. The following AR(1) process is estimated using this series of short-rates:

$$s_t = \alpha + \beta_s s_{t-1} + \epsilon_{s_t} \tag{75}$$

The parameters governing the Ornstein-Uhlenbeck processes are recovered as follows:

$$\kappa_s = \frac{1 - \hat{\beta}_s}{\delta_t} \tag{76}$$

$$\sigma_s = \sqrt{\frac{\sigma^2_{\epsilon_s}}{\delta_t}} \tag{77}$$

where δ_t is 1/12 as the short-rate data is monthly. The long-term average for the short-rate $\bar{i}$ is found by taking the average of the one-year zero-coupon yield between 1961-2022.

D.2 Preferred-Habitat Idiosyncratic Demand Shock Processes

For the quantitative analysis using the model, I assume that there are two shocks: $f_{s,t}$, which affects only the demand of short-maturity investors, and $f_{l,t}$, which affects only the demand of long-maturity investors. The cutoff maturity L denotes the maturity habitat after which an investor is considered a long-term investor. So the idiosyncratic shock that a τ-habitat investor faces takes the following functional form: $f_t(\tau) = \mathbb{1}\{\tau < L\} f_{st} + \mathbb{1}\{\tau \geq L\}) f_{lt}$.

For the short-term and long-term preferred-habitat investor idiosyncratic demand shocks $f_{s,t}$ and $f_{l,t}$, I define a short-term investor as investing in maturities of less than 10 years, and a long-term investor as investing in 10 years or more, so $L = 10$. To estimate the parameters governing these shock processes, I first construct flows for a fund f at time t as follows:

$$Flow_{f,t} = \frac{TNA_{f,t} - TNA_{f,t-1} \times (1 + R_{f,t})}{TNA_{f,t-1}} \tag{78}$$

where $TNA_{f,t}$ is fund f's total net assets at the end of month t, and $R_{f,t}$ is the fund f's return during month t.

For the baseline analysis, I estimate equation 75 across all funds in my sample using these series, so assuming that $\kappa_{f_s} = \kappa_{f_l}$ and $\sigma_{f_s} = \sigma_{f_l}$, i.e. that the persistence and volatility of fund flows is the same for short and long-horizon funds. The parameters governing the Ornstein-Uhlenbeck processes are recovered using equation 76, where δ_t is 1/12 as fund reports are observed at the monthly frequency. The average of flows across all funds is calculated for 2008-2021. In the baseline analysis, I assume that this is split proportionally between short-term and long-term funds based on total amount outstanding Treasurys in short-term maturities versus long-term maturities.

$w(\tau)$ signifies how much of the fund flows are allocated to riskless bonds in a τ-maturity fund. For the baseline analysis, I assume that short-term aggregate flows are distributed across short-term maturity funds in proportion to the maturity distribution of Treasurys outstanding, and that long-term aggregate flows are similarly distributed across long-term maturity funds. For the distribution into risky versus riskless bonds within each τ-maturity fund, I use the average ratio of mutual fund portfolio allocations into Treasurys versus corporate bonds in my sample, which is 0.313. So:

$$w(\tau) = \frac{TSYOut(\tau)}{\mathbb{1}\{\tau < L\} \times TSYOut(\tau < L) + \mathbb{1}\{\tau \geq L\} \times TSYOut(\tau \geq L)} \times 0.313 \tag{79}$$

where $TSYOut(\tau)$ refers the face value of outstanding Treasurys of maturity τ.

D.3 Own-Price Elasticities of Demand

Abstracting from differences in the relative base supply of different maturities, preferred-habitat investors' demand elasticity for riskless bonds with respect to log prices is assumed to take the functional form $\alpha(\tau) = \frac{\alpha_0}{\tau}$. This implies a constant elasticity of demand with respect to yields across all τ-habitat investors. The same functional form is assumed for preferred-habitat investors' demand elasticity for risky bonds $\tilde{\alpha}(\tau)$.

From Equation 17, it follows directly that $\frac{\partial Z_t^{(\tau)}}{\partial log P_t^{(\tau)}} = -\alpha(\tau)$. Given that $\frac{-log P_t^{(\tau)}}{\tau} = y_t^{(\tau)}$, it follows that $\frac{\partial Z_t^{(\tau)}}{\partial y_t^{(\tau)}} = \tau\alpha(\tau)$. I obtain a direct empirical estimate of the average $\frac{\partial Z_t^{(\tau)}}{\partial y_t^{(\tau)}}$ across all maturities $\tau \in (0, 30)$ in Table 6:

$$\overline{\frac{\partial Z_t^{(\tau)}}{\partial y_t^{(\tau)}}} = \overline{\tau\alpha(\tau)} = \tau\overline{\frac{\alpha_0}{\tau}} = \overline{\alpha_0} = \alpha_0 \tag{80}$$

Under the assumed functional form, the empirical estimate is equal to the average value of α_0 across all maturities. Assuming that α_0 is constant across maturities (i.e. a constant elasticity of demand with respect to yields across all investors), the average is equal to its actual value. To convert quantities to the scale used in the model, namely fractions of the total amount outstanding of all Treasury coupons, I multiply the empirical estimate by the average of $\frac{AmountOutstandingTSY(\tau)}{AmountOutstandingTSYCoupons}$.

D.4 Base Supply of Riskless and Risky Bonds

The publicly available level supply of riskless bonds $\theta_0(\tau)$ is found by taking the average across 2008-2021 of the total amount outstanding of Treasury coupons with remaining time to maturity of 0-1 year, 1-2 years, ..., 29-30 years, divided by the total amount outstanding of all Treasury coupons. I assume that the maturity composition of risky bonds outstanding is the same as for riskless bonds. To obtain the base level supply of risky bonds $\tilde{\theta}_0(\tau)$, I scale $\theta_0(\tau)$ by the ratio of total amount outstanding of corporate bonds to Treasury coupon bonds. On average, between 2008-2021, this ratio is 0.7902, so $\tilde{\theta}_0(\tau) = 0.7902 \times \theta_0(\tau)$.

D.5 Derivation of Model-Implied Moments

Table 13 provides estimates of the magnitude of the change in yield of a corporate bond that occurs for a given change in demand by investors for that corporate bond following a QE shock, over various horizons. Formally, we have n estimates of the average at various horizons h of:

$$\frac{\partial \tilde{y}_{t+h}^{(\tau)}/\partial QE_t}{\partial \tilde{Z}_{t+h}^{(\tau)}/\partial QE_t} = \frac{d\{\frac{\tilde{A}_h(\tau)}{\tau}s_t + \frac{\tilde{C}_h(\tau)}{\tau}\}}{d\{\tilde{\alpha}(\tau)(\tilde{A}_h(\tau)s_t + \tilde{C}_h(\tau)) - \tilde{\beta}(\tau)(A_h(\tau)s_t + C_h(\tau))\}} \tag{81}$$

To convert quantities to the scale used in the model, namely fractions of the total amount outstanding of all Treasury coupons, I multiply the empirical estimates by the average of $1/\frac{AmountOutstandingCB(\tau)}{AmountOutstandingTSYCoupons}$.

The empirical analysis on the rebalancing over various horizons across asset classes of funds that are relatively more exposed to this shock provides an additional moment to match. For example, 12 months following a QE shock, more shocked investors that on average sell 0.107% more of their TNA in Treasurys the Fed purchases rebalance 0.065% more of their TNA into corporate bonds. This implies that shocked investors rebalance 60.8% of the capital received from Treasury sales into corporate bonds. For the parameter calibration, I input an unexpected Fed purchase of Treasurys of maturity $\tau = 7$ of size 0.01% of all Treasury coupons into the model. This is the same magnitude shock as that to which the empirical estimates are scaled. The weighted average maturity of all unexpected Fed Treasury purchases in the sample is approximately 7 years. Denoting by τ^* the directly shocked maturity, and by τ all other maturities, we have an empirical estimate of:

$$
\begin{aligned}
\frac{\overline{\frac{\partial \tilde{Z}_t^{(\tau^*)}}{\partial QE_t}} - \overline{\frac{\partial \tilde{Z}_t^{(\tau)}}{\partial QE_t}}}{\overline{\frac{\partial Z_t^{(\tau^*)}}{\partial QE_t}} - \overline{\frac{\partial Z_t^{(\tau)}}{\partial QE_t}}}
&= \frac{\overline{d(-\tilde{\alpha}(\tau^*)log\tilde{P}_t^{(\tau^*)} + \tilde{\beta}(\tau^*)logP_t^{(\tau^*)})} - \overline{d(-\tilde{\alpha}(\tau)log\tilde{P}_t^{(\tau)} + \tilde{\beta}(\tau)logP_t^{(\tau)})}}{\overline{d(-\alpha(\tau^*)logP_t^{(\tau^*)} + \beta(\tau^*)log\tilde{P}_t^{(\tau^*)})} - \overline{d(-\alpha(\tau)logP_t^{(\tau)} + \beta(\tau)log\tilde{P}_t^{(\tau)})}} \\
&= \frac{\begin{array}{l}\overline{d(-\tilde{\alpha}(\tau^*)(-\tilde{A}(\tau^*)s_t - \tilde{C}(\tau^*)) + \tilde{\beta}(\tau^*)(-A(\tau^*)s_t - C(\tau^*)))} \\ \quad - \overline{d(-\tilde{\alpha}(\tau)(-\tilde{A}(\tau^*)s_t - \tilde{C}(\tau^*)) + \tilde{\beta}(\tau)(-A(\tau^*)s_t - C(\tau^*)))}\end{array}}{\begin{array}{l}\overline{d(-\alpha(\tau^*)(-A(\tau^*)s_t - C(\tau^*)) + \beta(\tau^*)(-\tilde{A}(\tau^*)s_t - \tilde{C}(\tau^*)))} \\ \quad - \overline{d(-\alpha(\tau)(-A(\tau^*)s_t - C(\tau^*)) + \beta(\tau)(-\tilde{A}(\tau^*)s_t - \tilde{C}(\tau^*)))}\end{array}}
\end{aligned}
$$

From the system of ODEs that determine $A(\tau)$, $\tilde{A}(\tau)$, $C(\tau)$ and $\tilde{C}(\tau)$ derived in Appendix C, it follows that $A(\tau)$, $\tilde{A}(\tau)$, $C(\tau)$ and $\tilde{C}(\tau)$ depend on the unknown parameters $\tilde{\gamma}(\tau)$ and dos. Therefore, the empirical estimates provide us with $n+1$ moments to match which can pin down $\tilde{\gamma}(\tau)$ over n horizons, and dos. In Table 18, I report the empirical and model-implied moments, together with the calibrated parameters $\gamma_{0,h}$ and dos. The model is able to match the empirically observed moments well.