Preferred Habitats and Timing in the World's Safe Asset*

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Abstract

We build the first-ever comprehensive security-level dataset on the size, flows, coupon payments and returns of foreign and U.S. investors' Treasury portfolios. Portfolio *composition* is such that private investors, whether U.S. or foreign, should all else equal earn higher returns than foreign governments; private investors hold longer-duration higher-return Treasuries, whereas foreign governments hold shorter-duration lower-return Treasuries. But all else is not equal. Foreign governments earn higher returns because U.S. and foreign private investors' *poor timing* substantially reduces their returns. Moreover, we find that foreigners beat the (non-Fed) market or, to put it another way, that there is no convenience yield attributable to foreigners paying (through poor returns) for non-pecuniary benefits. U.S. investors earn a small and insignificant 19 basis points less than market returns. One simple but far-reaching implication: When assessing U.S. Treasuries it might be useful to differentiate by the investor's type (private or government) but not by country (U.S. or foreign).

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1 Introduction

As the world transitions from quantitative easing and central banks reduce their sizeable bond portfolios, it would be useful to understand investors' behavior in the world's safe asset, U.S. Treasury bonds. Investors' actions help determine Treasury yields, which impact loan prices, not only in the United States (mortgages, corporate bonds, etc.) but all over the world (e.g., dollar bonds issued by foreign entities); how U.S. monetary policy is transmitted domestically and to the rest of the world; and the U.S. government's fiscal space (if investors have unlimited demand for Treasuries, the government could run larger budget deficits for longer, as price insensitive investors might willingly fund budget shortfalls). Moreover, if *foreign* investors have unlimited demand for Treasuries, the country's international budget constraint is also relaxed; the U.S. would not have to worry that its net foreign asset position is negative $18 trillion - a level that for many countries would suggest a coming currency crisis - knowing that foreigners would continue to fund it at any price.

While investors' behavior in the world's safe asset determines monetary policy transmission, fiscal policy space, loan pricing, and international vulnerabilities, we know little about it for two main reasons. One, aggregate data are often used, but the *composition* of different investors' Treasury bond portfolios differ: Investors have preferred habitats (Figure 1, top graph).[1] Over the period from 2003 to 2021 - the time span of most analysis in this paper - the duration of U.S. investors' Treasury bond portfolio fluctuated between 7 and 8 years, whereas foreigners' duration was shorter at 4 to 5 years. All else equal (although we will show that it is not), these preferred habitats translate directly into differential returns in the world's safe asset. For example, over the past two decades, average annual returns on 3-, 5- and 7-year Treasuries (computed using information from the Federal Reserve's H.15

[1]We are pleased to have inserted in annual Treasury Department surveys a similar graph showing the remaining maturity of foreigners' (but not U.S. investors') Treasury portfolios, starting with the 2021 survey. See Exhibit 15 in https://ticdata.treasury.gov/resource-center/data-chart-center/tic/Documents/shla2021r.pdf.

release) were 2.0, 2.6 and 3.2 percent, respectively. That is, over the past two decades, a Treasury of 7-year maturity earned on average 120 basis points more per year than a 3-year Treasury. Since investor behavior is often inferred from an assessment of returns, not taking into account preferred habitats can lead to incorrect inference.

Two, researchers have not had accurate information on the *timing and magnitude* of purchases of Treasuries. For example, the oft-used TIC S capital flow data (Figure 1, bottom graph) indicate that the bulk of foreign purchases of Treasuries have been by private foreign investors: in the TIC S data, every year from 2005 to 2019 private foreign investors purchased substantially more U.S. Treasuries than foreign governments, and the 15-year cumulative gap is substantial, amounting to $3.5 trillion. In reality, each year in the decade starting 2005 foreign governments purchased more Treasuries than private foreign investors. And the gap is not $3.5 trillion more purchases by private foreign investors, but $1 trillion more by foreign governments. Researchers have not had an accurate picture of the timing and magnitude of the purchases and sales of Treasuries.[2]

Our study addresses these two issues by building the first-ever comprehensive security-level dataset of the positions, flows, and income streams associated with the Treasury bond portfolios of four investor types that span the entire market: U.S. investors, private foreign investors, foreign governments, and the Federal Reserve. Our results are both simple (there is nothing complicated in this paper) and striking. We find, perhaps not surprisingly once one thinks about it, that investors' preferred habitats determine the mean and volatility of annual buy-and-hold returns. U.S investors had long-duration high-return high-volatility portfolios, foreign governments had the opposite (short duration, low returns, low volatility),

[2]Inaccuracies with now-discontinued TIC S flow data pre-date our main sample period. For example, Griever, Lee and Warnock (2001) and Warnock and Cleaver (2003) showed that TIC S reported foreign flows into Treasuries were $179 billion (or 44 percent) too high over the period January 1995 - March 2000. TIC S, which formed the basis for *any analysis* of U.S. flows prior to 2000, was discontinued in February 2023; see https://home.treasury.gov/data/treasury-international-capital-tic-system-homepage/tic-forms-instructions/tic-s-form-and-instructions.

and for most of the past two decades private foreign investors were somewhere in between. Perhaps more surprisingly, volatility-adjusted returns (i.e., Sharpe ratios) show that the portfolios of foreigners - both governments and private investors - performed better than the high-return high-volatility portfolios of U.S. investors (although these differences, while interesting, are not statistically significant).

Here is where all else is not equal. Yes, portfolio composition is important. But no one, not even the market, earns the buy-and-hold rate of return (RoR). To do so one of two conditions should hold: returns would have to be constant throughout the entire period under consideration or all purchases would have to have been made prior to the initial period and no others through the end of the sample. If either of those conditions hold, buy-and-hold returns would be ensured. The same is true for index returns; if returns are non-constant, to ensure earning index returns no new net purchases should occur during the period under consideration.

Typically, however, neither condition holds. Returns vary through time and buying and selling occur. So to compute the returns actually earned by different investor types, we calculate internal rates of returns (IRRs) that take into account both the composition of portfolios and the market, plus the timing and magnitude of purchases (and, for the market, of issuance). Our security-level dataset has the four components needed to compute IRRs: the market value of initial positions (the initial outlay), flows (interim outlays), face value of positions (to which we apply security-specific coupon rates to calculate interim payouts), and the market value of terminal positions (the final payout). We do this for all four investor types, which allows for a direct comparison of the returns earned by foreign and U.S. investors. Moreover, our IRR computations embed the composition effect, as they are built from the security-level portfolios. Finally, for each investor type, a comparison of its IRR and RoR is a measure of timing; if actual returns (IRR) are lower than the investor's

own benchmark (its RoR), timing is poor because it reduces returns.[3]

Taking into account both investors' preferred habitats and the timing and magnitude of purchases, we find that the Treasury bond market does not earn market returns, as aggregate returns (the market IRR) are 77 basis points less per year than buy-and-hold returns (the market RoR).[4] Moreover, this difference is much larger for private investors, whether U.S. (who earn 199 basis points less than buy-and-hold returns) or foreign (135 basis points less). In contrast, foreign officials' returns are only 36 basis points lower than their buy-and-hold returns.

In summary, investors' actual Treasuries returns differ materially from buy-and-hold returns, and this difference is quite large (and negative) for private investors. In fact, taking into account the composition of portfolios as well as the timing and magnitude of purchases, we find that foreign investors, whether private or official, earn no less on their Treasury portfolios than U.S. investors. And foreign governments earn significantly more than U.S. investors.

In a later portion of the paper we venture away from the pristine world of security-level data and bring monthly estimates of flows into the analysis. We view everything in the first portion of the paper as rock solid, whereas the analysis with monthly flows estimates is more speculative. We include it because it is useful for at least starting to ask whether different investors' demand can be described as inelastic. That question might seem narrow but is not: As the spectre of higher Treasury yields for longer looms, and one large entity (the Federal Reserve) reduces the size of its Treasury portfolio, which investors will step

[3]As always with an assessment of timing and performance, an appropriate benchmark is needed. We, following Barber and Odean (2000) and many others, use an 'own benchmark' that is determined by each investor type's portfolio composition. To do otherwise would be akin to gauging insurance companies' long-dated Treasury portfolio by comparing it with a 3-month bill, or grading a growth fund's performance by comparing with a portfolio of value stocks.

[4]This is another way of saying that after the Treasury Department bond issuance increases, Treasury returns tend to be lower. A similar effect is evident in equities. For example, IPO issuance is elevated prior to equity market peaks (Ritter 1991, Pastor and Veronosi 2005)).

in and buy Treasuries? In this descriptive portion of the paper we find evidence that is suggestive of private foreigners - who are behind the bulk of foreign purchases the past 5-10 years - and U.S. investors have elastic demand for Treasuries, but foreign governments do not. More specifically, using the higher frequency (monthly) dataset we show that U.S. and private foreign investors, but not foreign officials, increase their flows into U.S. Treasuries when CIP deviations (the synthetic sovereign dollar yield minus the Treasury yield) are low or have fallen.[5] The analysis of monthly flows suggests that private investors, whether U.S. or foreign, who together were behind 90 percent of net purchases in the 6-year pre-pandemic period (2014-2019), have elastic demand for Treasuries. Additional analysis of the historical data suggests that as the Fed reduces the size of its balance sheet, private investors - especially U.S. investors - will be the counterparty.

Related Literature

We contribute to the literature on convenience yields, the non-pecuniary benefit of holding safe and liquid assets that can serve as substitute for money. In a closed-economy setting, Bansal and Coleman (1996) showed the importance of bond supply on convenience yields, while Krishnamurthy and Vissing-Jorgensen (2012) showed that the convenience yield on U.S. Treasuries - relative to other U.S. debt such as corporate debt bonds - is an important component of bond yields. Subsequent work - notably Engel (2016) and Du et al. (2018) - brought the notion to an open economy setting. There are important differences within this large and growing literature, as some, such as Engel and Wu (forthcoming), do not posit that U.S. Treasuries are particularly special and instead focus more generally on all governments' bonds, whereas others, such as Krishnamurthy and Lustig (2019) and Jiang et al. (2021), emphasize the specialness of the dollar and Treasuries (and that foreign investors are different). And many if not all papers in this literature embed assumptions about investor

[5]For the flow analysis we rely on survey-consistent monthly estimates of foreign flows based on Bertaut and Tryon (2007), Bertaut and Judson (2014) and our own calculations, coupled with data on monthly flows for the entire market and the Fed.

behavior in safe assets. For example, demand for safe assets is at the heart of Kekre and Lenel (2021), Bianchi et al. (2022), Valchev (2020), and Choi et al. (2022). Our study of investors' Treasuries portfolios can inform this literature.

Our paper is related to any work that differentiates between foreign and domestic investors. Some of this has focused on whether foreign demand for Treasuries is elastic.[6] For example, in the model of Greenwood et al. (2022), foreign demand is elastic - a decrease in foreign bond yields prompts foreigners to purchase U.S. Treasuries - whereas central to the model of Jiang et al. (2021) is that foreign demand is inelastic. In the literature, at times the elasticity of demand is inferred from an analysis of performance and timing; if foreigners have poor timing in Treasuries (buying prior to price declines) or, relatedly, exhibit poor performance over time (earning below market returns), it is inferred that their demand is inelastic (e.g., Krishnamurthy and Lustig 2019). Our work can directly assess whether there is a meaningful difference in the performance of domestic and foreign investors, something not yet done in the literature, and thus can speak to timing and the elasticity of demand, issues that remain unsettled in the literature. More generally, our assessment of data quality informs any study using capital flows data. For example, our assessment indicates that the flow data that undelies IRR calculations in Krishnamurthy and Lustig (2019) and subsequent papers through Jiang et al. (2022) are not up to the task (and have indeed been discontinued).

Our paper is also related to the broad set of research that differentiate bonds by maturity, such as the long literature on preferred habitats and the shorter but growing literature on the effects of quantitative easing (QE). On preferred habitats, the seminal papers are Culbertson (1957) and Modigliani and Sutch (1966). More recently, Vayanos and Vila (2021)

[6] Our work is also tangentially related to literature on the effects of foreign investment on Treasury yields. In the theoretical model of Caballero, Farhi, and Gourinchas (2008), emerging market demand for Treasuries depresses U.S. long rates. Empirical estimates of foreigners' impact on Treasury yields are in Warnock and Warnock (2009), Beltran et al. (2013), and Wolcott (2020), among others.

deviate from a frictionless asset pricing model by assuming investors have preferred habitats;[7] Krishnamurthy and Vissing-Jorgensen (2011) note that, when using that model to think about the effects of QE, it is an open question as to whether there are preferred habitats within an asset class (such as Treasuries). In a similar vein, our paper is related to QE analysis on how one large market participant - the central bank - affects the slope of the yield curve; see Swanson (2011), Greenwood and Vayanos (2014), and many others. Of course, that Philippon (2011, page 275) had to state that "[t]here was a time when macroeconomic textbooks used only one interest rate" indicates, as we all know, that the assumption of a single interest rate is common in papers ranging from single-country closed economy models to multi-country international finance models that assume interest rates are equalized across countries (e.g., Caballero et al. 2021).

Methodologically, our focus on IRRs follows the Dichev (2007) seminal work on the equity premium and Krishnamurthy and Lustig (2019), which applied IRR analysis to Treasuries. Dichev (2007), focusing on large U.S. equities, found that investors earned 130 basis points less per year than buy-and-hold returns. Our findings for the Treasury portfolios of private investors, whether U.S. or foreign, are similar in magnitude. Krishnamurthy and Lustig (2019), which helped propel an important part of the convenience yield literature (including but not limited to Jiang et al. (2021)), has eye-opening results and conclusions that support the notion that there is a large convenience yield that is due to foreigners. For example, in Krishnamurthy and Lustig (2019) foreigners accept returns that are 500 basis points per year lower than Treasury returns, and this finding becomes the heart of the theoretical model of Jiang et al. (2021). Such results are worth revisiting as they rely on since-discontinued inaccurate TIC S data, and those inaccuracies are mirrored in U.S. investors' flows that are calculated as a residual.[8] We find that revisiting this analysis with better, more com-

[7] Kekre et al. (2022) incorporate preferred habitats to study the effects of monetary policy.

[8] Any U.S. portfolio flows data prior to 2000, including the Bureau of Economic Analysis' (BEA) International Investment Position of the United States (IIP) and the Federal Reserve's Financial Accounts of the

prehensive data produces quite different results. Computing the convenience yield as the difference between investors' actual returns and the non-Fed market's actual returns - that is, an apples-to-apples comparison of IRRs - the convenience yield is not positive for foreigners and a paltry and insignificant 19 basis points for U.S. investors. There are other reasonable ways of computing convenience yields, for example (among many others) the van Binsbergen et al. (2022) focus on risky assets. We show that attributing convenience yield to foreigners' non-pecuniary benefits is not supported by the evidence. By measuring whose demand is (not) driving the Treasury convenience yield, our work can help inform theories of its deeper source and future.

Finally, our work informs literatures on the U.S. government and international budget constraints. For both, if investors - especially foreign investors - have inelastic demand for Treasuries, the budget constraint might be relaxed.

Caveats and Constraints

Our main dataset is constrained by the availability of confidential and mandatory security-level surveys on *foreigners'* U.S. Treasury portfolios. The so-called SHL surveys have been conducted as of each June 30 since 2003 through the U.S. Treasury International Capital (TIC) System, so our main sample is annual (as of June 30) from 2003 to 2021.[9] While it would be desirable to have a longer time series, we will show that data that pre-date our sample period are problematic.

That our observations are just once per year presents a few constraints. One, it precludes the inclusion of Treasury bills - Treasury securities with less than one year original maturity, which prior to the pandemic were only 15 percent of outstanding Treasuries - from much of our analysis. Thus, other than in Section 3.2.3 where we explicitly include Treasury bills,

United States (known as Flow of Funds, or FOF), are based on TIC S flows.

[9]See https://www.treasury.gov/resource-center/data-chart-center/tic/Pages/shlreports.aspx for the SHL reports. As TIC survey data are the primary input for BEA's IIP, when summed our security-level holdings data add up to the official U.S. IIP data as reported by the BEA. The Fed's FOF relies on BEA's presentation, so our holdings data also sum to FOF.

when we refer to Treasuries, we mean Treasuries of greater than one year original maturity.[10] Two, annual data preclude the analysis of trading during the year. We address limitations arising from the annual frequency of surveys in the following ways. In ancillary analyses we (i) include, at an aggregate (i.e., not security) level, Treasury bills and (ii) use aggregate quarterly estimates of flows and positions. Both extensions are presented in Section 3.2; neither changes the main assessment.

Another limitation of the SHL data is that among foreign investors the identification of the ultimate investor's country is not accurate if the investor uses a third-country custodian. More specifically, data are reported on a resident basis; that is, we observe the direct owner of these investments as reported by the custodians, but not necessarily the ultimate owner. This has two practical implications. One, while the survey data allow us to distinguish between holdings of foreign official institutions (e.g., central bank reserve managers) and holdings of private foreign investors, the distinction is not perfect because in some cases a central bank might use a custodian in a third country and, if so, some official holdings may be reported as private. In our opinion, informed by twenty years working with these surveys, this blurring of official and private is not severe, but just in case we run a number of robustness checks. Two, a bigger issue is that because country attributions are subject to the nationality vs. residency issue studied in Warnock and Cleaver (2003), Bertaut, Bressler, and Curcuru (2019), and Coppola et al. (2021), country attribution can be problematic (as with any liabilities-based survey). To avoid the country-attribution problem we aggregate across foreign countries rather than assess country-level data.

The reader should be aware that while we use the term *investors*, we fully recognize that two Treasury market participants - the Fed and foreign governments - have motiva-

[10] Our dataset is of holdings. We do not have information on derivatives positions or repo activity. We exclude, unless otherwise noted, FRNs and TIPs, in part because duration cannot be computed for these securities, which are a small share (15 percent as of mid-2019) of outstanding Treasuries. In an online appendix we show that including these securities wherever possible does not alter our results.

tions that differ from private investors'. The Fed does not attempt to maximize returns on Treasuries. As noted by the Federal Reserve Bank of New York System Open Market Account (SOMA) desk (https://www.newyorkfed.org/markets/treasury-reinvestments-purchases-faq): "In general, the Desk seeks to operate in a manner that is relatively neutral to the securities available for purchase and in a way that limits the potential for operations to affect normal market functioning, unless otherwise appropriate for efficient and effective implementation under the directive. As such, purchases of Treasury securities are conducted across a range of maturities and security types in rough proportion to the universe of Treasury securities outstanding." In one period - Operation Twist from September 2011 until June 2012 - the Fed deviated from this by purchasing the long end and selling the short end. Similarly, foreign governments have broad objective functions that typically do not include maximizing returns on their Treasury portfolios. Foreign governments' demand for Treasuries are due to the world's main reserve asset's role in countries' reserve management and FX interventions, with motivations often divided into precautionary (building up defenses to reduce the probability of a future crisis), mercantilist (managing the exchange rate), and those that are natural by-products of other goals (e.g., managing inflation, smoothing business cycle fluctuations); see Arslan and Cantu (2019) for a useful discussion.

The paper proceeds as follows. In the next section we create survey-consistent flows and assess the many different sources of data on foreigners' flows into and positions in U.S. Treasury bonds; the heavy lifting on this public service portion of our paper is relegated to an appendix. In Section 3 we calculate the returns on Treasuries earned by different investors, differentiating between the composition and timing effects, and compare with market returns. In addtion, we implement a series of robustness checks with quarterly data (to determine if our annual data are too limiting; they are not), using data from the 1990s that pre-dates our survey data (to see if it is wise to include older non-survey data; it is not), and including

Treasury bills, which were excluded from our main analysis because annual surveys are ill-suited for examining securities with less than one year original maturity (results change in nuanced ways but not materially). In Section 4 we incorporate higher frequency flow data to examine two issues of current interest: how investors' flows adjust to changes in the spread between non-U.S. sovereign yields and Treasury yields and, when the Fed pares back its Treasury portfolio, who buys. Section 5 discusses how the literature might be informed by our results. Section 6 concludes. An online appendix includes much robustness analysis.

2 U.S. Treasury Portfolios: Stylized Facts

Security-level information on the overall Treasury bond market and the Fed's portfolio is readily available.[11] More difficult, even at the aggregate level, are data on foreigners' Treasuries portfolios, in part because there are multiple sources of data on foreigners' purchases of and positions in U.S. Treasury securities that, as we discussed with respect to Figure 1, can provide conflicting information.

Our study is based on data from the best source, annual security-level TIC SHL surveys on foreigners' positions. From that we can observe security-level positions and can construct flows and coupon payments. Briefly - and please see the appendix for complete details - the security-level holdings data, collected annually (as of each June 30) since 2003, are mandatory, represent the universe to the extent it is known, and include a general security description and identifier, issue and maturity dates, coupon rate, and amount held reported at both face (which excludes price change effects) and market value. To confirm that we have included all bonds, for each annual survey from June 2003 through June 2021 we sum the holdings and compare to the surveys' published aggregate amounts. They match

[11] See the U.S. Treasury Monthly Statement of the Public Debt on the TreasuryDirect website (https://www.treasurydirect.gov) and the Federal Reserve Bank of New York SOMA site (https://www.newyorkfed.org/markets/soma-holdings).

exactly. Confident we have all Treasury bond holdings, we use the security-level survey data to accurately calculate security-level flows as the change in the face value of holdings. With comprehensive data on foreigners' and the Fed's positions and flows and knowing the universe of all marketable Treasury bonds outstanding, we construct U.S. investors' portfolios as a residual: total outstanding less foreign and Fed holdings. The data are a primary input for U.S. official statistics; while the security-level data are confidential, various aggregations of *positions* are made publicly available in annual survey reports and those aggregations inform the BEA's IIP as well as the U.S. current account (via income streams computed using the aggregate positions estimates).

The novel dataset enables us to provide a public service by creating survey-consistent series that can be used to check the quality of publicly available data on foreigners' positions in and net purchases of U.S. Treasuries. For *positions*, this assessment is straightforward. We find that since 2003 positions reported by other sources line up with the survey data. But to check data on *flows* requires another step: creating survey-consistent flows. From the survey data we directly, and therefore accurately, compute the security-level flow (i.e., net purchases). Summing the security-level flow produces a survey-consistent aggregate flow measure that can help assess reported flow data, and based on that we show which publicly available data on foreigners' flows should (and should not) be used. While we relegate much to an appendix, we briefly summarize here: Researchers should not use TIC S transactions data, which have been so problematic that they were discontinued in 2023. This warning applies to other sources that prior to 2000 were based on TIC S data, such as the BEA's BOP and the Fed's FOF data. Since 2000 and, especially, 2003, data sources have improved in part because they have become more based on the SHL survey positions data rather than TIC S transactions data.

Some basic facts on positions and flows emerge from the dataset. On positions, for much of the past two decades, foreigners as a group have had the largest Treasury bond

holdings (Figure 2, top graph). Their holdings, as a share of all marketable Treasury bonds outstanding, has mostly fluctuated between 40 and 50 percent, reaching a high of 58 percent in 2008. Over this period Fed holdings were often roughly 15 percent of the market, with noticeable sharp shifts during QE1 and the pandemic. U.S. investors' holdings, which we calculate as the residual, have fluctuated between 30 and 40 percent of the Treasury market over the past two decades. Within the set of foreign investors (Figure 2, bottom graph), foreign officials' Treasury holdings have been consistently larger than private foreigners'. That said, since 2012 foreign officials' holdings have been largely flat, mimicking global international reserves (which peaked in 2014Q2 and did not reach that level again until 2020Q3), while foreign private positions have been steadily increasing. As a result, as a percent of the expanding Treasury market, the relative size of foreign official positions has steadily fallen and foreign private positions have increased a bit.

For flows, which for readability we depict in Figure 3 as 3-year moving sums, foreigners were the largest source of flows until 2016, when U.S. investors' flows began increasing and exceeding foreign flows. Fed purchases peaked 2011-2013 with the initial QE programs and by 2017 were zero or negative until large purchases resumed during the pandemic. Within foreign flows (Figure 3, bottom graph), every year since 2014 private foreign purchases of Treasuries have exceeded officials' purchases. Foreign governments, arguably the most important group early in our sample, have had zero net purchases for a full decade.

3 Portfolio Performance

In this section we present the actual returns earned by private U.S. and private foreign investors, as well as the Fed and foreign governments. We then assess two factors behind the observed returns - portfolio composition and timing - and discuss some robustness checks that use higher frequency data, include Treasury bills, and extend the analysis back to the

1990s.

3.1 Actual Returns

We assess investors' actual returns by calculating the internal rate of return (IRR); see Fabozzi (2014) for a textbook exposition, Dichev (2007) for an application to equities, and Krishnamurthy and Lustig (2019) for an application to Treasuries. Security-level data on each bond's market value, face value, and coupon yield, as well as flows that we compute from the security-level data, allow us to compute IRRs for a sample period of mid-2003 through mid-2021 using the following components:

- the initial investment is the sum of the market value of an investor type's holdings of each Treasury bond at the end of June 2003 (assumed to all be purchased at that time),
- intermediate contributions are our computed bond-by-bond net purchases from mid-2003 through mid-2021,
- intermediate distributions are coupon payments each period from mid-2004 through mid-2021, computed at the security-level from the bond's coupon yield and face value, and
- the final payout is equal to the sum of the market value of holdings of each Treasury bond as of end-2021.

Column 1 of Table 1 presents IRRs for foreigners (separating out private and official foreign investors), U.S. investors, and the Fed over the period from mid-2003 to mid-2021. We also show market and float (i.e., non-Fed) IRRs computed in the same manner as the other IRRs.

Result 1: Foreign governments have better returns than U.S. investors. The first striking result is that foreign governments earn higher returns (2.66%) than private U.S. investors (2.27%). Based on bootstrapped standard errors in which the order of flows is shuffled 1000 times, the difference is statistically significant at the 1% level.[12]

We next delve into the portfolios and flows to understand the returns each investor-type earned. We do this in two steps. First, we compute average annual returns (RoR, or rate of return), which are based solely on portfolio composition; these are presented in Column 2. Then we examine the difference, by investor, of IRR and RoR (column 4). An IRR that is less than the corresponding RoR is indicative of poor timing (i.e., relatively more purchases prior to low returns).

3.1.1 The Effect of Portfolio Composition

Figure 1 (top graph) foreshadowed this section: Investors have reasonably well defined preferred habitats in Treasury bonds. The differences in duration naturally produce differences in average annual returns.

Figure 4 shows the duration of the portfolios of private and official foreign investors, U.S. investors, the Fed and the overall market. Over the period 2003-2021, market duration was between 5 and 6.5 years (with an average of 5.78). Among investor types, U.S. investors had the longest duration for most of the period and in general stayed between 7 and 8.5 years (average 7.33). The duration of foreign private investors (average 6.60) fluctuated between 6 and 7, but since 2014 has trended up. Foreign governments had by far the shortest duration (mostly between 3.5 and 4.5 years, average 4.09). The Fed's duration extended in the 2012-2014 period (following Operation Twist) and averages 6.05 years.

The different durations preferred by the different investor groups mean that, all else

[12] In the rest of column 1, only the Fed's returns is statistically different from the return on the float (i.e. non-Fed) portfolio. Note that the Fed remits any excess profits on its security holdings to the U.S. Treasury and does not attempt to maximize returns on Treasuries.

equal, average annual returns will differ. For the period from mid-2003 until mid-2021, average annual returns for 3-, 5- and 7-year constant maturity Treasury bonds were 2.01, 2.63 and 3.17 percent. Thus, based on preferred habitats, without doing any complicated calculations we could guess that U.S. investors have substantially higher average annual returns - perhaps 100 basis points more per year - than foreign governments.

But we can be more precise by using the security-level data to calculate returns using standard returns index construction methodology and assuming investors reallocate on June 30th of each year (the day we observe foreign portfolios). In index construction, the returns of each bond are typically weighted by the relative size of the bond. Analogously, we weight the return on each Treasury bond by its size in each investor type's portfolio. That is, the weighted average rate of return on investor type i's portfolio of U.S. Treasury securities from year t to year *t+1*, $\text{RoR}_{i,t+1}$, is calculated as follows:

$$\text{RoR}_{i,t+1} = \sum_{b=1}^{n} \omega_{b,i,t} \text{RoR}_{b,t+1} \tag{1}$$

where i denotes foreign official, foreign private, U.S., or the entire market. $\text{RoR}_{b,t+1}$ is bond b's annual total rate of return (price changes plus interest) from year t to year *t+1*. The weight $\omega_{b,i,t}$ is investor i time t holdings of particular bond $\text{H}_{b,i,t}$ relative to her total holdings:[13]

$$\omega_{b,i,t} = \frac{\text{H}_{b,i,t}}{\sum_{b=1}^{n} \text{H}_{b,i,t}} \tag{2}$$

Results are in column 2 of Table 1. It is immediately apparent that the ordering of returns is very similar to that of the durations. That is, the composition of investors' Treasury portfolios are such that the Treasuries held by U.S. investors, who have the longest duration

[13]Our weights being at time t means that the bond must exist at time t to be included in our returns calculations. This is similar to standard bond index inclusion rules that require the bond to have been issued prior to index rebalancings.

portfolio, had high average annual returns (4.25 percent). Foreign officials' Treasuries portfolio, with the shortest duration, had the lowest returns, 3.02 percent, while private foreign investors' Treasuries produced returns of 3.76 percent per annum.[14] The returns orderings are in line with what we would expect from the preferred habitats, and the differences (for example, the portfolios of foreign officials earning 123 basis points less than U.S. investors) are in line with returns from the various constant maturity Treasury series.

The preferred habitats also determine volatility: The higher returns earned by U.S. and foreign private investors came with higher volatility. In fact, abstracting from the Fed, the ordering of Sharpe ratios (column 3) is reversed. Foreign officials' low-duration portfolios delivered the highest Sharpe ratio, while private investors' (both U.S. and foreign) higher-duration portfolios had lower Sharpe ratios.

Result 2: The composition of Treasury portfolios is such that U.S. investors' high duration portfolios produce high returns with high volatility average annual returns, while foreign officials' low duration portfolios have lower returns and lower volatility.

To get the highest return, private U.S. and foreign investors hold long-duration portfolios that had the most volatility and hence low Sharpe ratios, while the short-duration foreign official portfolio had a high Sharpe ratio. That said, preferred habitats notwithstanding, returns are volatile enough that no RoR or Sharpe ratio is statistically different from the market's.

3.1.2 The Effect of Timing

That U.S. investors have the highest RoR but lowest IRR suggests that they have poor timing. Their portfolio composition (long duration bonds) would provide high (and volatile) returns, but their timing of purchases reduced those returns. More specifically, a comparison

[14]We perform two robustness checks for the return calculations. First, we shift Belgium's private holdings of Treasuries to the official investors' portfolio; and second, we shift Cayman Islands' holdings from the foreign to the U.S. portfolio. The results are very similar.

of actual and average annual returns provides a measure of timing. An IRR that is lower than the corresponding RoR indicates poor timing due to, for example, purchases made prior to low returns. Column 4 shows the IRR minues RoR. A number of striking results emerge.

Result 3: The market does not earn market returns. The market IRR is 77 basis points lower than the market RoR. This is comparable to the Dichev (2007) finding that equity index returns are higher than IRRs - 130 basis points for large cap stocks – and hence the equity premium is lower than previously thought. Our result indicates that actual Treasury bond returns are lower than index returns. Another way to put this: Treasury tends to issue more bonds just prior to low returns.[15]

Result 4: Investors' timing is such that foreign governments' returns are reduced only slightly by timing, while U.S. investors lose almost 200 bps per year to poor timing. Investors' returns are reduced by poor timing: In all non-Fed rows in Table 1 the difference between IRR and RoR is negative and significant. Private investors have particularly poor timing, with the IRRs of U.S. and foreign private investors being 199 and 135 basis points, respectively, lower than their RoRs. The timing of foreign officials, in contrast, lowers their returns only 36 basis points. And, abstracting from the Fed, as with Sharpe ratios, the ordering of IRRs is foreign official, foreign private, and U.S. private, the exact opposite ordering of RoRs. U.S. and private foreign investors have volatile high duration portfolios that should produce high returns, but poor timing substantially (and significantly) reduces their actual returns.

3.2 Robustness Checks

3.2.1 Quarterly Data

The estimates in Table 1 are precise, as every component is built using security-level data. But a limitation is that they are built from annual data and so cannot capture trading that

[15] An equity analogy is that IPOs tend the be high just prior to low retuns (Ritter 1991, Pastor and Veronosi 2005).

occurs within the year. To ascertain the extent to which within-year trading impacts our IRR results, we proceed in three steps. One, to make our data more comparable to publicly available aggregate series we include FRNs and TIPs because they are included in aggregate series (which cannot differentiate them from other long-term Treasury securities). Those IRRs are in Table 2 (column 1). Two, we discard the security-level coupon streams and instead compute streams by applying the coupon yields from an index (BoAML) to market values.[16] This, still using annual data, is shown in column (2). Three, in column (3) we switch to quarterly observations by using quarterly 'benchmark consistent' data; please see the appendix for details on this dataset. While there is a material difference when moving from annual security-level data and best methodologies (column 1) to using index coupon yields for all and applying those yields to market value (column 2), moving to quarterly data (column 3) has very little effect on the estimates.

3.2.2 Using Data from the 1990s

While it is tempting to find datasets that include longer time series, columns (4) and (5) of Table 2 illustrate why reported flow data that pre-date the advent of annual holdings surveys should not be used to create IRRs. Griever, Lee and Warnock (2001) and Warnock and Cleaver (2003) pointed out that TIC S flows - which for decades were the primary source for BEA and FOF flows - vastly overstated foreigners' purchases of U.S. bonds. Over the period January 1995 - March 2000, a period that spans two holdings surveys (when they were conducted every five years), cumulative TIC S flows were $179 billion (or 44 percent) too high. For that period, column 5 shows IRRs using benchmark-consistent flows analagous to those in Griever, Lee and Warnock (2001) and Warnock and Cleaver (2003). In column 4 IRRs are computed using FOF flows, which prior to 2000 were identical to TIC S flows. The inaccurate flows in column 4 produce a foreign IRR that is 312 bps lower than the column

[16]For the market's market value, we subtract FOF Table L.210 line 58 (the discrepancy) from line 4 (other Treasury notes, bonds and TIPS).

5 IRR that uses better quality flow data. Data prior to 2000 produce erroneous results.

3.2.3 Including Treasury Bills

We have omitted Treasury bills for the simple reason that annual surveys are ill-suited to shed light on holdings of securities that have less than one year original maturity. A 30-day bill bought between survey dates will usually fall out of the portfolio by the next survey. So, while Treasury bills are included in the survey data, because surveys are annual we do not include them in preceding sections.

In this subsection we include bills. We first note that they are small (Figure 5), both in terms of outstanding Treasuries (14 percent in 2019) and in investors' holdings. That said, during crises they have increased importance, with their share peaking around the GFC - when they were 30 percent of all Treasuries outstanding, 43 percent of U.S. investors' Treasuries portfolio, and 36 percent of foreign private investors' - and increasing again during the pandemic.

Including bills alters the duration pictures a bit (Figure 6). Not surprisingly, including short-dated securities reduces duration. And, while foreign investors' portfolios still have lower duration than U.S. investors', for much of the period private foreign and U.S. investors had very similar durations. This was true, even for bond and notes, at the end of our sample - see the last observation of Figure 4 - but is true throughout the sample once bills are included. The takeaway is that foreign private investors (15 percent of holdings) are similar to U.S. investors, a point that comes through in our analysis of bonds and notes and even more strongly when bills are included.

Table 3 replicates the Table 1 RoR and IRR calculations but includes bills. We cannot include bills at the security level in these annual calculations, so they enter in aggregate weighted by their by-investor-type shares.[17] RoRs are lower than in Table 1, but the RoR

[17]Specifically, RoR is security-level from Table 1 column 2 times the long-term share plus a bills return

and Sharpe ratio orders are unchanged and IRRs are pretty similar. As in Table 1, U.S. and foreign private timing erodes their returns by substantial amounts of 136 and 97 basis points, respectively.

Overall, including bills alters duration pictures a bit - private investors, whether U.S. or foreign, have similar durations - but does not materially affect the returns and timing analysis.

Summary of Robustness Checks. Using annual data does not appear to affect the quality of our estimates, but assuming a representative Treasury bond (e.g., by using an index) would.[18] Once we move to less precise data, switching to a quarterly frequency has very little effect, suggesting that within-year trading does not materially impact returns estimates. Including Treasury bills does not materially alter our main findings. IRRs computed using data that pre-date the advent of annual holdings surveys should be handled with care.

4 Addressing Two Timely Questions with Higher Frequency Data

In this section we step away from our annual security-level data and use higher frequency data to address two timely questions. One, our main analysis is entirely U.S.-based as it examines investors' performance in the U.S. Treasury market. We do not have the data necessary to do such careful analysis of foreign markets, but here we ask a basic question: What is the relationship between investor flows and past spreads between foreign and U.S. yields? Two, in periods when the Fed reduced the size of its Treasury portfolio, as it has

times the bills share. IRR cash flows are as in Table 1 column 1, with bills added (initial and ending positions, interim purchases, and "streams" computed as lagged face value times a bills return).

[18]The assumption of a representative bond is common, even in official U.S. statistics. For example, when computing income streams for the U.S. current account balance, BEA applies the yield from an index to the market value of holdings. While more work is warranted, our data suggest that those estimates might currently run about $10 billion too high.

recently started to do, who steps in and buys?

4.1 Flows and Yields

Does the volume of investors' flows into Treasuries react to changes in the spread between non-U.S. sovereign yields and Treasury yields? Answering this requires data at a higher frequency than annual, so we turn to monthly benchmark-consistent flows; see the appendix for details. In the monthly flows dataset, all long-term Treasuries are included (i.e., including FRNs and TIPs, as aggregate data does not permit excluding them). We follow the Krishnamurthy and Lustig (2019) analysis of foreign flows but use benchmark-consistent flows and expand the analysis to include U.S. investors. Specifically, we run separate regressions for each investor type i (foreign official, foreign private, and U.S. private) flows and for each lag k of the CIP deviation - synthetic dollar sovereign yield minus U.S. Treasury yield - as follows:[19]

$$\text{Flow}_t/\text{Position}_{t-1} = \alpha + \beta(\text{CIP}_t - \text{CIP}_{t-k}) + \epsilon_t \tag{3}$$

$$\text{Flow}_t/\text{Position}_{t-1} = \alpha + \beta\text{CIP}_{t-k} + \epsilon_t \tag{4}$$

In Figure 7 we plot the β coefficients from each time series regression we run for each lag k. Each plot in Figure 7 shows, from 13 time series regressions of flows regressed on lagged 10-year G10 CIP deviation (CIP) and a constant, the β coefficients of CIP deviation lags from 0 to 12 months. Lags are cumulative changes (left column, corresponding to eq. (5)) or simple levels (right column, corresponding to eq. (6)). Flows, scaled by lagged positions, are private foreign (top row), foreign official (middle), or U.S. private (bottom). The sample

[19]Data on CIP deviations, also called the synthetic yield difference, are from Du and Schreger (2016) and Du, Im, and Schreger (2018). We use 10yr SynDiff, country j's synthetic yield difference where the synthetic dollar sovereign yield (10yrSynSov) is constructed using Du, Im and Schreger's data on the forward premium.

period is January 1999 through December 2019.[20] CIP deviation is computed as a weighted average of G10 CIP deviations, with the weights coming from each country's holdings of Treasuries. Plotted are coefficients (the dot in each graph), two standard deviation error bands (the vertical lines), and the statistical significance at the 1, 5 or 10 percent level (the stars).

The evidence indicates that private investors, whether foreign or U.S., purchase Treasuries after the CIP deviation is low or falling, that is when the synthetic dollar yield is low (or has fallen) relative to the Treasury yield. For private foreigners (top row), this relationship holds at 0-4-month lags of levels (right column) and cumulative lags of changes starting at a lag of 6 months (left column), while for U.S. investors (bottom row) the relationship is evident for all lag lengths (right column). In contrast to private U.S. and foreign investors, foreign officials (middle row) do not seem to adjust their net purchases based on the levels of or changes in CIP deviations.

Overall, the evidence in Figure 7 indicates that private foreign and U.S. investors, but not foreign governments, react to changes in CIP deviations. Specifically, when Treasury yields are high relative to the synthetic sovereign yield, private investors, both U.S. and foreign, purchase more Treasury bonds. To put this another way, when U.S. Treasuries are inexpensive relative to synthetic sovereign yields, private investors increase their Treasury purchases.[21]

[20]The CIP deviation data, available at https://sites.google.com/view/jschreger/CIP, begin in 1997, but data for the euro area do not start until the euro's inception, so our analysis starts in January 1999. The CIP data end in 2020, so we could extend the sample one more year; we hesitate to because of a structural change in the estimated flows data.

[21]In untabulated results, we find similare results for duration. That is, private investors alter the duration of their portfolios when sovereign spreads change, foreign governments do not.

4.2 Who Buys from Whom?

A timely question as central banks unwind QE policies and hence reduce the size of their bond portfolios is who will step in and buy. We cannot answer this question definitively, but our comprehensive data and analysis of investor behavior help shed light on this question.

First, we can learn from a graphical representation of positions and flows by investor type, shown in Figure 8 (best viewed in color) using quarterly flow data for foreigners and our computed U.S. investor series. The top panel shows positions, which remind us of relative sizes in the Treasury market. Foreign officials are quite large, but their positions have plateaued since 2012; foreign governments have not been actively adding to their Treasury portfolio for about a decade because they have not been accumulating international reserves. On the other hand, private holdings, both U.S. and foreign, have grown substantially. Foreign private holdings, quite small until about 2010, are now sizeable but still much smaller than the largest holder, private U.S. investors. This evolution of Treasury holdings suggests that when thinking about who might step in as the Fed reduces its bond portfolio, the focus should be on private investors, whether U.S. or foreign.

Flows data and analysis add to our understanding. First, Figure 8 (bottom panel) shows that foreign governments (red bars) provided the majority of Treasury purchases until the GFC and still had sizeable purchases until 2012. More recently, however, foreign governments' purchases and sales have offset through time and private (both U.S. and foreign) investors' purchases have become more important: between 2014 and 2019 private investors were behind 90 percent of net purchases. The graph also shows the Fed's flows and highlights that periods of negative Fed flows are limited, with the QT period from October 2017 until September 2019 being most prominent. Note that in this period the Fed did not actively sell Treasuries but allowed maturing securities to roll off their balance sheet (which is a negative flow). Second, Table 4 provides correlations that are embedded in the flows data. From these correlations, the most obvious counterparts to the Fed are private investors, whose flows are

significantly negatively correlated with Fed flows whether the Fed is expanding or reducing its portfolio.[22]

Our earlier findings on preferred habitats in the Treasury market can further support the point that private investors, both U.S. or foreign, are most likely to step in as the Fed reduces its Treasury holdings. The Fed's Treasury portfolio has a long duration, a portion of the yield curve favored by private investors (Figure 4). One large group - foreign governments - has not purchased Treasuries in meaningful amounts for about a decade and focus on the shorter end, so they are not likely to step in and buy in a meaningful way when the Fed reduces its balance sheet.

5 Relation to the Existing Literature

Our study of investors' behavior in the world's safe asset revealed a number of stylized facts - facts that just emerge from inspection of data - and results that will inform future work. Some are surprising given existing results. In this section we briefly recap our main findings and help the reader understand differences with the existing literature.

Our paper extends and complements the Dichev (2007) use of the difference between RoRs and IRRs as a measure of timing. In that paper, in large cap equities (NYSE and Amex, specifically) investors' trading reduced returns by 130 basis points a year, substantially reducing previously computed estimates of the equity premium and the equity cost of capital. Some of our results are similar to Dichev (2007). For example, we find that actual market returns on Treasury bonds are 77 basis points lower than index returns. Our by-investor-type analysis yields additional insights; for example, the timing of private investors, whether U.S. or foreign, appears to be even worse, with the gap between RoR and IRR being around

[22]The flows in Table 4 are monthly. Quarterly flows provide similar conclusions but with the correlation between U.S. private and foreign private flows becoming positive and weakly significant and that between U.S. private and foreign official increasing in significance (and still negative). For either monthly or quarterly flows, results excluding the 2017-2019 QT period are similar but moderately weaker in significance.

130-200 basis points.

Our findings are quite different than prominent findings in the convenience yield literature. In a series of papers, Krishnamurthy and Lustig (2019) and Jiang et al. (2021, 2022) have argued that the convenience yield on U.S. Treasuries is quite large, from 500 basis points in early estimates to a still sizeable 200 basis points in later work. Moreover, the argument is that the large convenience yield is due to the non-pecuniary benefits *foreigners* receive from Treasuries. In those papers, evidence that foreigners must receive sizeable non-pecuniary benefits come from results that indicate that foreigners have poor timing, poor performance, and buy Treasuries when they are expensive. In contrast, we find that foreign governments do not have poor timing and, while private foreign investors do, their timing is no worse than U.S. investors. And we find that both U.S. and foreign private investors buy Treasuries when they are inexpensive (i.e., when their yields are high relative to the synthetic sovereign yield), precisely opposite existing results.

The reader can understand the stark difference between our results and those in Krishnamurthy and Lustig (2019) and Jiang et al. (2021, 2022) as follows. One, existing results are based on the now-discontinued TIC S data for foreign flows. If foreign flows are mismeasured then the residual (U.S. investors) is mismeasured in the exact opposite way. As it turns out, IRR estimates based on TIC S (or, prior to 2000, BOP or FOF, because they were based on TIC S) are far too low for foreigners and thus far too high for U.S. investors. This, all else equal, would errouneously indicate that foreigners have very poor performance. Two, the existing literature effectively assumes one bond. That is, it does not take into account the composition effect that is due to the preferred habitats. This can influence results for foreign governments (relative to U.S. investors) by more than 100 basis points. Three, at times comparisons in the literature have been of market index returns and foreigners' IRRs, but we show, like Dichev (2007), that the not even the market earns market index returns. Existing estimates are based on erroneus (and since discontinued) data, do not incorporate the fact

that investors have preferred habitats, and at times compare apples with oranges. When put on equal footing and assessing all investor types using similar techniques, we find that foreign governments, while they do not alter their purchases when sovereign spreads change, have relatively good timing and performance. Private foreign investors are very much like U.S. investors, in that they operate in a similar part of the yield curve, respond to changes in sovereign spreads but have poor timing and poor performance. This is consistent with the finding in Krishnamurthy and Vissing-Jorgensen (2007) that private foreign investors are more price elastic than official investors and with the model of Greenwood et al. (2022) in which foreigners respond to changes in yields, but is inconsistent with the Krishnamurthy and Lustig (2019) and Jiang et al. (2021, 2022).

6 Conclusion

Investors' behavior in the U.S. Treasury bond market - the nature and evolution of Treasury portfolios - is important but has been inferred from aggregate statistics that can be less than pristine. We directly observe Treasury portfolios at the security level and find that preferred habitats determine buy-and-hold returns - average annual returns are a function of duration and hence risk - while the timing and magnitude of purchases substantially reduces the actual returns earned by *private* investors. Specifically, U.S. investors have long duration Treasury portfolios that produce high returns with high volatility, but the timing of their purchases reduces their actual returns by about 200 basis points a year. Foreign governments are at the other end of the spectrum, with short duration portfolios that produce lower returns with less volatility (so that their Sharpe ratios are no lower than U.S. investors), and their timing is substantially better. Private foreign investors are in between when analysis is based on Treasury bonds and notes, and much more like U.S. investors when bills are included. Moreover, private foreign investors, like U.S. investors, appear to be sensitive to sovereign

spreads, whereas foreign governments are not.

Our results have implications for a pressing question as we transition to a post-QE world: Who will buy Treasuries as the Fed reduces the size of its portfolio? Perhaps foreign governments, but they have not materially added to their Treasury portfolios in almost a decade. Moreover, they tend to hold shorter duration bonds, while the Fed's portfolio is tilted more towards longer durations. More likely it will be private investors, whether U.S. or foreign, whose purchases react to yields and whose portfolios are tilted towards longer duration bonds.

Our results have implications for many literatures. The most obvious connection is the blossoming convenience yield literature which, while well entrenched since Krishnamurthy and Vissing-Jorgensen (2007, 2012), is still evolving. A straightforward takeaway is that the convenience yield literature should not rely on foreigners being different. Private investors, whether U.S. or private, behave differently and have different preferred habitats than governments. A stronger statement is that differential investors within the Treasury market is not the source of the convenience yield: From our analysis, no investor-type earns significantly less than the (non-Fed) Treasury market. Rather than relying on investor differentiation, our results point to notions (and calculations) of convenience yields that apply to all investors, such as van Binsbergen, Diamond, and Grotteria (2022), Engel and Wu (2022), Piazzesi, Rogers, and Schneider (2021), and Krishnamurthy and Vissing-Jorgensen (2012). Similarly, the Du, Im, and Schreger (2018) CIP deviations apply to all investors. There may well be a convenience yield, but our evidence questions whether it applies differentially.

Our paper also has important implications for anyone using data on international flows and positions. There are multiple data sources, some that we show should not be used (and, in fact, have recently been discontinued), others that are more accurate but can still be confusing (see, for example, data discussions in Meng and van Wincoop (2020) and Chari, Dilts Stedman, and Lundblad (2021)). Our advice for anyone using data on international

flows and positions is straightforward: Check data quality, if possible, and know what the series represent.

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Appendix: Security-level Data on U.S. Treasury Portfolios

Two components of Treasury portfolios are easily obtained. The "market" - that is, security-level data on the every Treasury bond - is available at https://www.treasurydirect.gov. And security-level data on the Fed's Treasury portfolio - both the portfolio at different points in time and the new purchases or sales - are publicly available at https://www.newyorkfed.org/markets/soma-holdings.

An important third component - foreigners' portfolios - is more difficult to obtain. We start with the gold standard, security-level data from annual surveys that started in 2003 and are the basis for much of the analysis in this paper. Then, because there are multiple additional sources of data on foreigners' purchases of and positions in U.S. Treasury securities and no clear way for researchers to ascertain data quality, we present and assess the various sources.

With those components - the market and holdings by the Fed and foreigners (split between governments and private foreign investors) - private U.S. investors' security-level portfolios can be calculated as the residual.

Security-Level Portfolio Data on Foreigners' Treasury Portfolios

Since 2003, security-by-security data on foreigners' Treasury portfolios - the amount foreigners hold of each and every Treasury security - are collected annually by the U.S.

Department of the Treasury as part of the TIC reporting system.[23] The security-level data underlie the annual U.S. TIC reports (the so-called SHL reports) of foreign holdings of U.S. securities and feed into official BEA data on the U.S. international investment position (and thus the Fed's FOF data). The main reporters are U.S.-resident custodians (including brokers and dealers), which must report all U.S. securities they hold on behalf of foreign residents (including in their own foreign subsidiaries and affiliates). Given the mandatory reporting, the holdings data are comprehensive; they capture the entire foreign portfolio of U.S. Treasuries at the individual security level.

The security-level data are annual since 2003, reported as of June 30 of each year for each foreign country's holdings of each security. The survey data distinguish between holdings of foreign official institutions (e.g., central bank reserve managers) and holdings of private investors. Survey data are reported on a resident basis; that is, on the direct owner of these investments as reported by the custodians, but not the ultimate owner.

We conduct a number of checks. We use security identifiers to match the TIC holdings to security-level information on outstanding amounts from other sources. We use ICE BofA Merrill Lynch U.S. Treasury indices and TreasuryDirect for data on Treasury bond amounts issued and outstanding. We cross check the data on outstanding amounts from these different data sources to make sure we correctly capture security re-openings (when the U.S. Treasury issues additional amounts of a previously issued security; the reopened security has the same

[23] Griever, Lee, and Warnock (2001) discuss the origins of the TIC system. Briefly, in the early 1970s public concern about the rise in European and Japanese investors' U.S. investments, as well as about the substantial investable sums accumulated by oil-producing countries, prompted the first modern benchmark survey to measure foreign holdings of U.S. long-term securities as of year-end 1974. It was recognized that without benchmark surveys, the TIC system could not accurately identify the countries that were holding U.S. securities or provide much information on the actual securities being purchased. To address these shortcomings, Congress passed the Foreign Investment Study Act of 1974 (Public Law 93-479), which evolved into the International Investment and Trade in Services Survey Act (22 U.S.C. 3101 et seq.). The latter act stipulates, among other things, that a comprehensive benchmark survey of foreign portfolio investment in the United States be conducted at least once every five years and that information collected under the authority of the act be published for use by the general public and by U.S. government agencies. Such surveys were conducted every 5 years from 1974 through 1999 (with the 1999 survey being conducted in March 2000 to avoid possible Y2K complications). Since 2003 the surveys have been conducted annually.

maturity date and coupon interest rate). We do this for each annual survey from June 2003 through June 2021. To confirm that we have included all bonds, we first sum the holdings and compare to the surveys' published aggregate amounts. They match exactly. We also, from the surveys' prices and payment terms, calculate each bonds' total return, yield-to-maturity, and duration at each end-June date. The prices and payment terms are the same or very close to the ones reported per security in the constituent files of the BofA Merrill Lynch index. The security-level data we use represent the universe, to the extent it is known.

Non-Security Level Data on Positions

We separate this discussion into pre- and post-2003, as there was a fundamental shift in data quality once security-level surveys (henceforth TIC SHL) became annual.

Since 2003 the end-June TIC SHL data have been the primary input for BEA's International Investment Position, or IIP, data.[24] As Figure A1 (top panel) shows, since the SHL surveys became annual (in 2003), for *positions* there are no discrepancies between these series. These sources also provide a split between foreign official and private foreign investors, and are in agreement not only on the overall amount of foreign holdings, but also on the split between official and private investors (Figure A1, bottom panel). There are minor differences - BEA puts a little more in private holdings, because it moves holdings of international and regional organizations to private - but data on foreigners' holdings of U.S. Treasuries are pretty similar regardless of the source. This makes sense because aggregations from the annual security-level TIC SHL are the primary inputs into other sources, so minor differences arising only when a source creates estimates at a frequency higher than annual or when a source publishes data prior to the release of the annual survey data. But, because each source recognizes that the TIC SHL is the most comprehensive and accurate measure of foreign holdings of U.S. securities, differences tend to be small and short-lived.

[24]BEA's IIP data is at https://www.bea.gov/data/intl-trade-investment/international-investment-position. FOF, which follows from BEA's data, is at https://www.federalreserve.gov/releases/z1/.

Prior to 2003, benchmark surveys were less frequent (every 5 years through 2000) and BEA's IIP data, based on the since-discontinued TIC S flow data, could deviate substantially from the surveys. By 2000 BEA tended to revise IIP estimates to be in line with the surveys.

Flow Data Since 2003

The distinction between pre- and post-2003 is even more important for flow data. The TIC SHL *holdings* surveys obtain positions data from global custodians, but there is no equivalent for data on transactions (i.e., flows). That is, there is no comprehensive security-level *transactions* survey, so each source must decide how to compute flows. One way - directly collect flow data through the TIC S monthly transactions reports - has been so inaccurate that it was discontinued in 2023. Since 2013 BEA, recognizing issues with the TIC S transactions data, imputes transactions from the reported TIC positions. *However, prior to 2013, TIC S flows were the main source for BEA and, hence, FOF transactions data.*[25]

Figure A2 (top panel) shows that since 2012 TIC S flows differ substantially from BEA's BOP flows. For some years prior to the GFC, TIC S flows exceed BOP-reported flows, but since 2012 TIC S flows have been far below. Moreover, the split between official and private foreign flows is dramatically different. BEA BOP data (Figure A2, bottom left) show that through 2012 the bulk of foreign flows into U.S. Treasury bonds were from official investors, whereas TIC S (Figure A2, bottom right) suggests that private flows have exceeded official flows every year. The difference between TIC S and the other sources is vast. Over the period from 2005 through 2014, TIC S reported that private foreign flows into Treasury bonds were $3.5 trillion greater than official flows, while for the same period BEA's BOP reported that official flows were $1 trillion greater. Overall, since 2003 private foreign flows

[25]For more details on the relationship between BEA and TIC S flows, see Bureau of Economic Analysis (2019). BEA's presentation is, in turn, the official source for FOF. Note that in FOF tables all flow series are seasonally adjusted, but unadjusted series are also available. BEA does not seasonally adjust portfolio flows, nor do we.

into Treasury bonds are $1.6 trillion greater in TIC S than in BEA's BOP data.

An Assessment

Researchers are confronted with a number of series on what is ostensibly the same thing - foreigners' purchases of Treasury bonds - and have no obvious way to discern which is most accurate. While there are official descriptions of each measure, an outsider might find it difficult to judge how to use the data.[26] But there is a direct way to ascertain which series should be used, albeit one that is only available since 2003. The comprehensive security-level annual surveys of foreigners' holdings is the single most accurate source. The problem for the researcher is that annual holdings data do not easily translate into flow series.

We can assess flows data sources by creating implied flows from the TIC SHL surveys. The confidential security-level data from the comprehensive annual surveys include various security characteristics, such as a general security description and identifier, issue and maturity dates, coupon rate, and amount held. The data also include both the face (which excludes price change effects) and market values of holdings. With face values, we can compute a direct measure of flow as the change in face value of holdings.[27]

We do this for each annual survey from June 2003 through June 2021. To confirm that we have included all bonds, we first sum the holdings and compare to the surveys' published aggregate amounts. They match exactly. Confident that we have every bond, we then sum the flows; we will call the flows calculated from the security-level holdings and calculated valuation changes *implied flows*. As Figure A3 (top panel) shows, our implied flows differ greatly from TIC S flows and are closest to the BEA flow series, although in certain years, such as 2005 and 2018, the gap is sizeable. The evidence suggests that *since 2003* researchers

[26] See, for example, the TIC FAQ page (https://www.treasury.gov/resource-center/data-chart-center/tic/Pages/ticfaq1.aspx), as well as Bertaut and Judson (2014).

[27] We can also calculate flows an alternative way. Because we can accurately calculate the valuation change on each and every U.S. Treasury bond, security-level flow can be computed as the change in the position (which is observed) less the valuation adjustment (which is directly computed). Because survey information is complete and consistent, the two methods produce identical flow series.

should use BEA data (or FOF, which are identical).

A difficulty for flow analysis using data from the 1980s and 1990s is that TIC S was the primary source for BEA and FOF flows. Figure A4 shows that FOF and TIC S flows were almost identical in those decades; BEA flows (not shown) were very similar. *In the 1980s and 1990s, any problem with TIC S flows fed directly into BEA BOP flows and the Fed's FOF series.* And problems were substantial. Griever, Lee, and Warnock (2001) and Warnock and Cleaver (2003) showed for the period January 1995 - March 2000 that TIC S reported foreign flows into U.S. bonds were $179 billion (or 44 percent) too high. TIC S was discontinued in February 2023 (https://home.treasury.gov/data/treasury-international-capital-tic-system-home-page/tic-forms-instructions/tic-s-form-and-instructions).

Turning to the split of foreign holdings into those by governments (i.e., foreign official holdings) and those by private foreign investors (Figure A3, bottom panel), since 2003 the BEA series and our implied flows are very similar for the foreign official and foreign private flows. The only material deviation was in 2016, when the BEA series has more official and less private flows (but the same total). TIC S flows differ substantially from our implied flows and BEA-reported flows.

Figure A5 brings in another source. Since 2001 the Federal Reserve's International Finance Division has used the high-quality but infrequent positions surveys to improve flow data and create internally consistent monthly dataset on positions, flows, and valuation adjustments (Thomas, Warnock, and Wongswan (2004), Bertaut and Tryon (2007)).[28] More recently, since 2012 a new monthly holdings series, the TIC SLT, became available and forms the basis for another internally consistent monthly dataset on positions, flows, and valuation adjustments; see Bertaut and Judson (2014).[29] We call the spliced series - Bertaut and

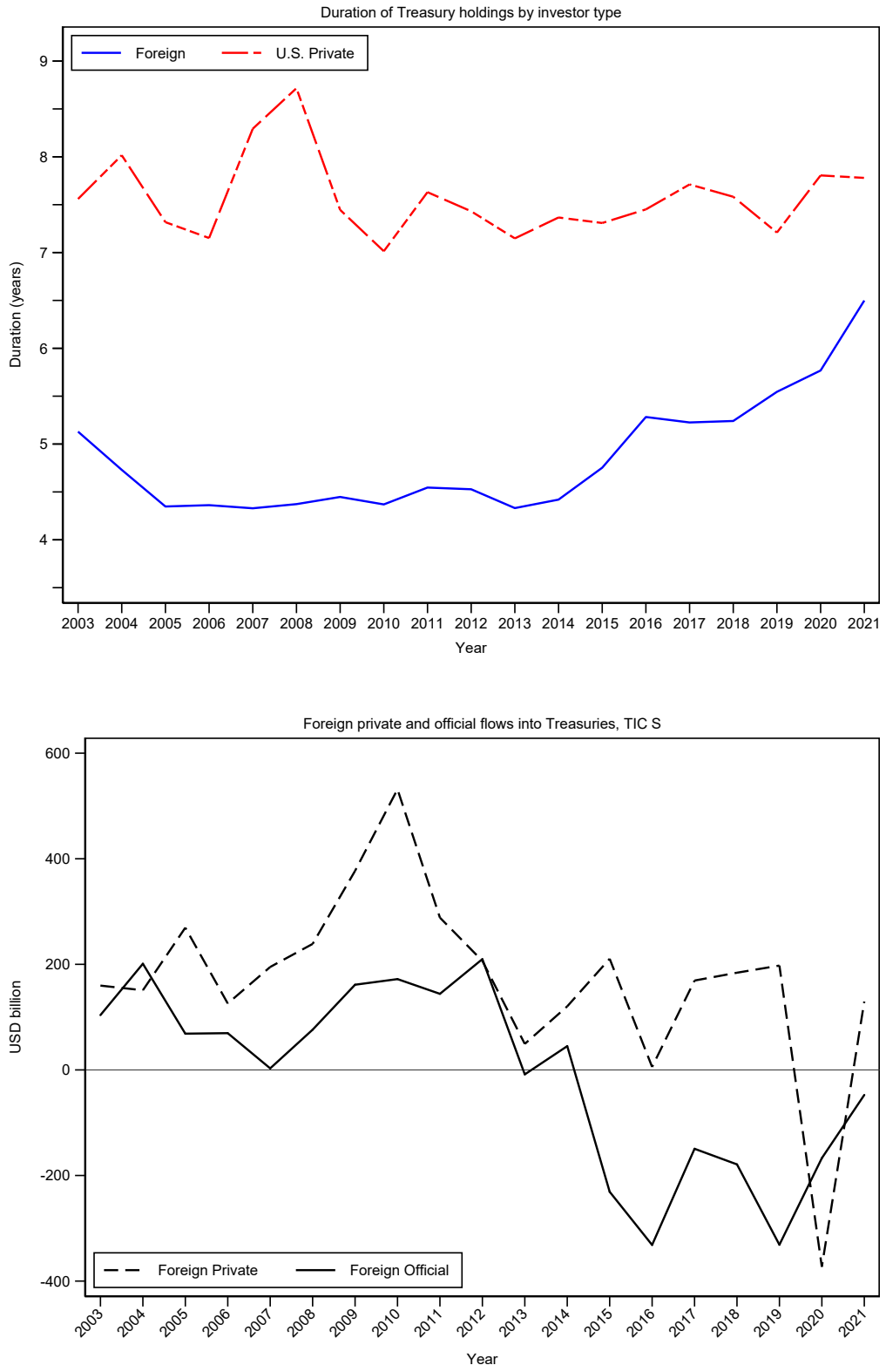
[28]Internally consistent in this context means that flows plus valuation changes equal the change in positions or, equivalently, that so-called *other adjustments* are zero. For more on this point, see Curcuru et al. (2008).

[29]The new SLT data, collected at an aggregate level, are similar (but not identical) to the aggregated security-level SHL annual data and are an additional input to the BEA IIP and FOF published data.

Tryon (2007) data through 2011, Bertaut and Judson (2014) starting in 2012, and since 2021 series that we construct following the technique of Bertaut and Tryon (2007) - *benchmark consistent* series. For Treasuries, the benchmark consistent series for private and official foreign investors start December 1979. Note though that the quality of benchmark consistent data may well vary through time, as quality is a function of the frequency of the underlying security-level surveys that provide the methodology's important fixed points for the positions. That is, when security-level surveys were conducted approximately every five years (1974 - 2000) the benchmark consistent data, while the best available for that time period, are likely lower quality than when the surveys have been conducted more frequently (annually since 2003). As Figure A5 shows, since the advent of annual holdings survey benchmark consistent positions are identical to SHL positions (top panel) and benchmark consistent flows are nearly identical to survey implied flows (bottom panel). For historical data series available at the monthly frequency, the benchmark-consistent data provide an internally consistent series on positions, flows, and valuation adjustments.

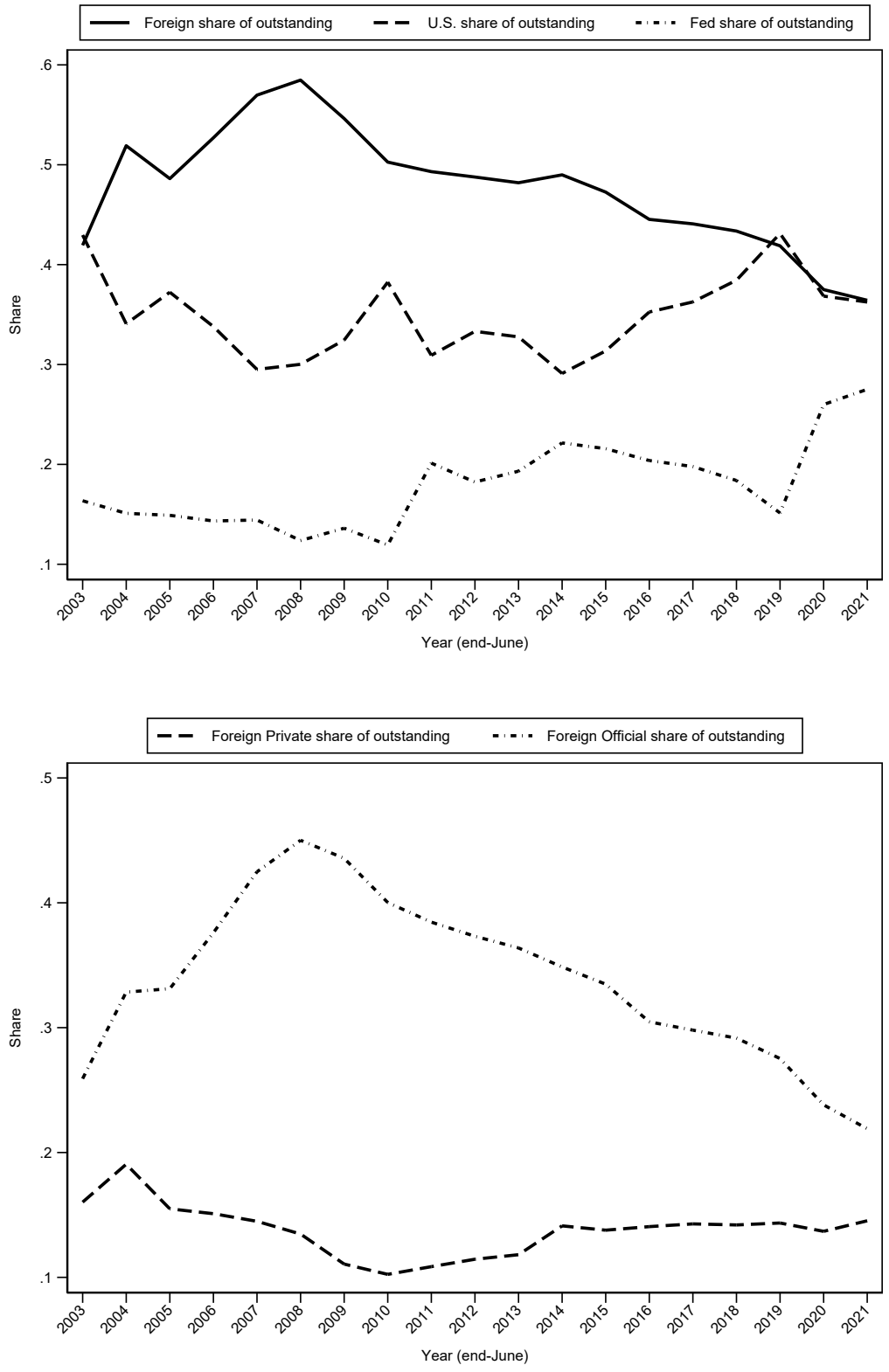
To summarize, holdings data are very similar across all data sources, but flow data can vary substantially. For current flows estimates, researchers should not use TIC S data and instead should turn to the quarterly BEA data (or unadjusted FOF data). For historical (monthly) time series, researchers should use benchmark-consistent series that have been formed by Thomas, Warnock, and Wongswan (2004), Bertaut and Tryon (2007), Bertaut and Judson (2014), and us, while recognizing that data quality substantially improved in 2003 with the advent of annual holdings surveys.

Figure 1: Duration and Flows



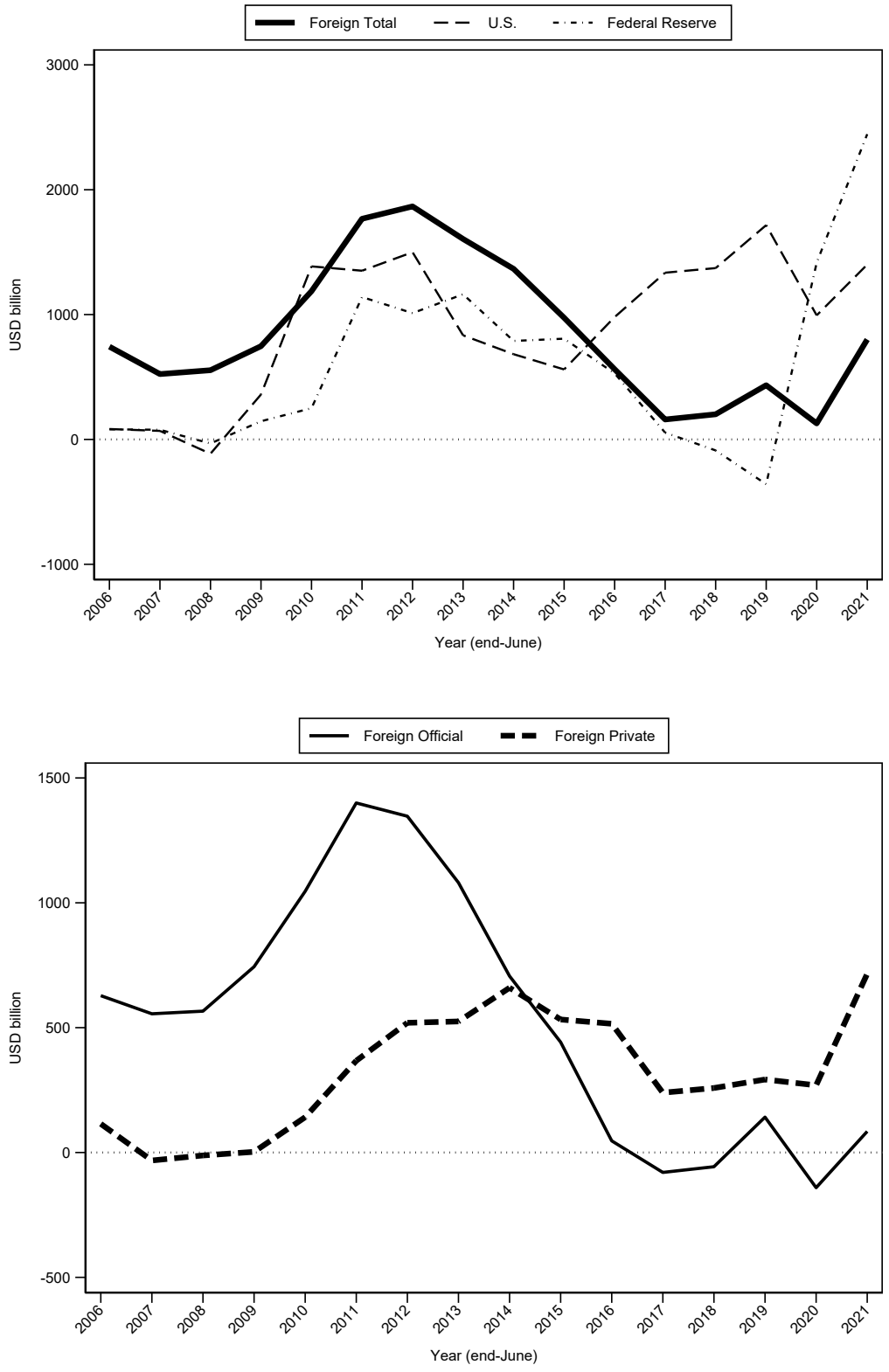
The top figure plots weighted averages of duration for U.S. private and foreign investors. Sample excludes floating rate notes (FRN), Treasury inflation protected securities (TIPS), and securities maturing within one year. The bottom figure shows, using data from the TIC S, the evolution of foreign private and foreign official flows into U.S. Treasury bonds and notes.

Figure 2: U.S. Treasury Holdings by Investor Type



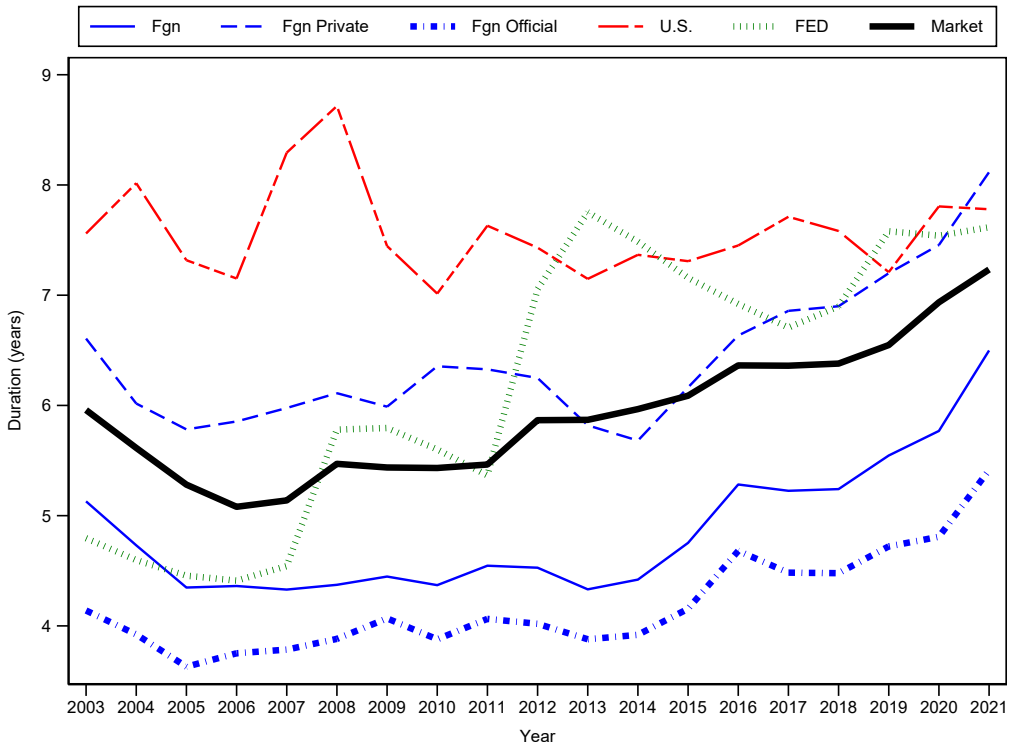
The figures show the share of long-term Treasuries held by U.S. investors, the Fed, and foreigners (split between foreign private and foreign official in the bottom graph).

Figure 3: U.S. Treasury Flows by Investor Type: 3-year rolling sum



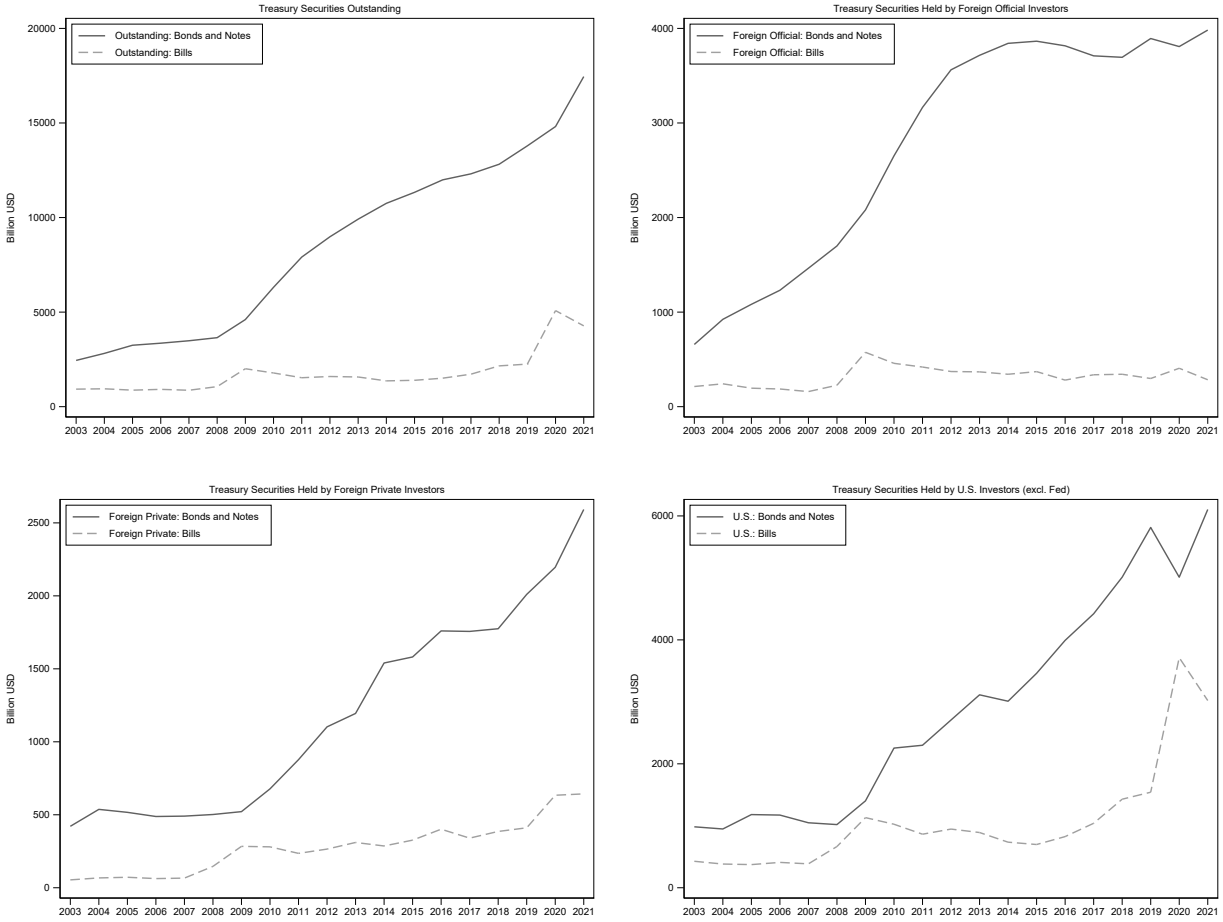
The figures show net purchases (3-year rolling sum using annual end-June to end-June data, in billions of U.S. dollars) of long-term Treasuries by U.S. investors, the Fed, and foreigners (total and, in the bottom graph, foreign private and foreign official).

Figure 4: Duration of Treasury Holdings by Investor Type



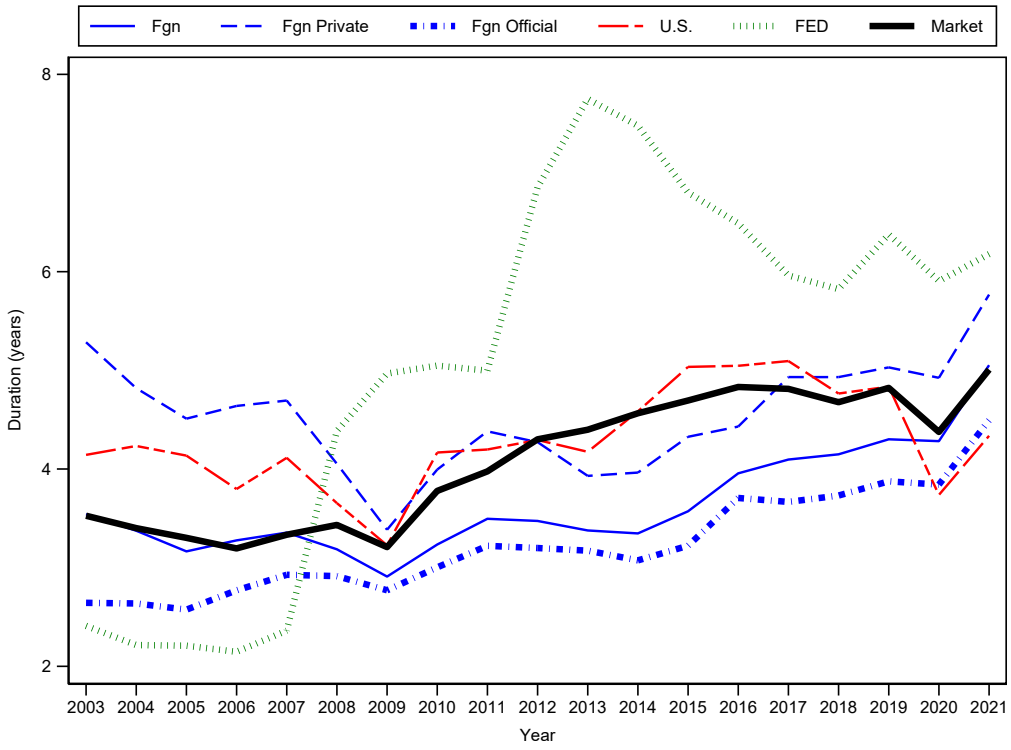
The figure plots weighted averages of duration by investor type. Market refers to all outstanding marketable Treasuries as reported by Treasury Direct. Sample excludes floating rate notes (FRN), Treasury inflation protected securities (TIPS), and securities maturing within one year.

Figure 5: U.S. Treasury Bonds, Notes, Bills: Outstandings and Holdings per Investor Type



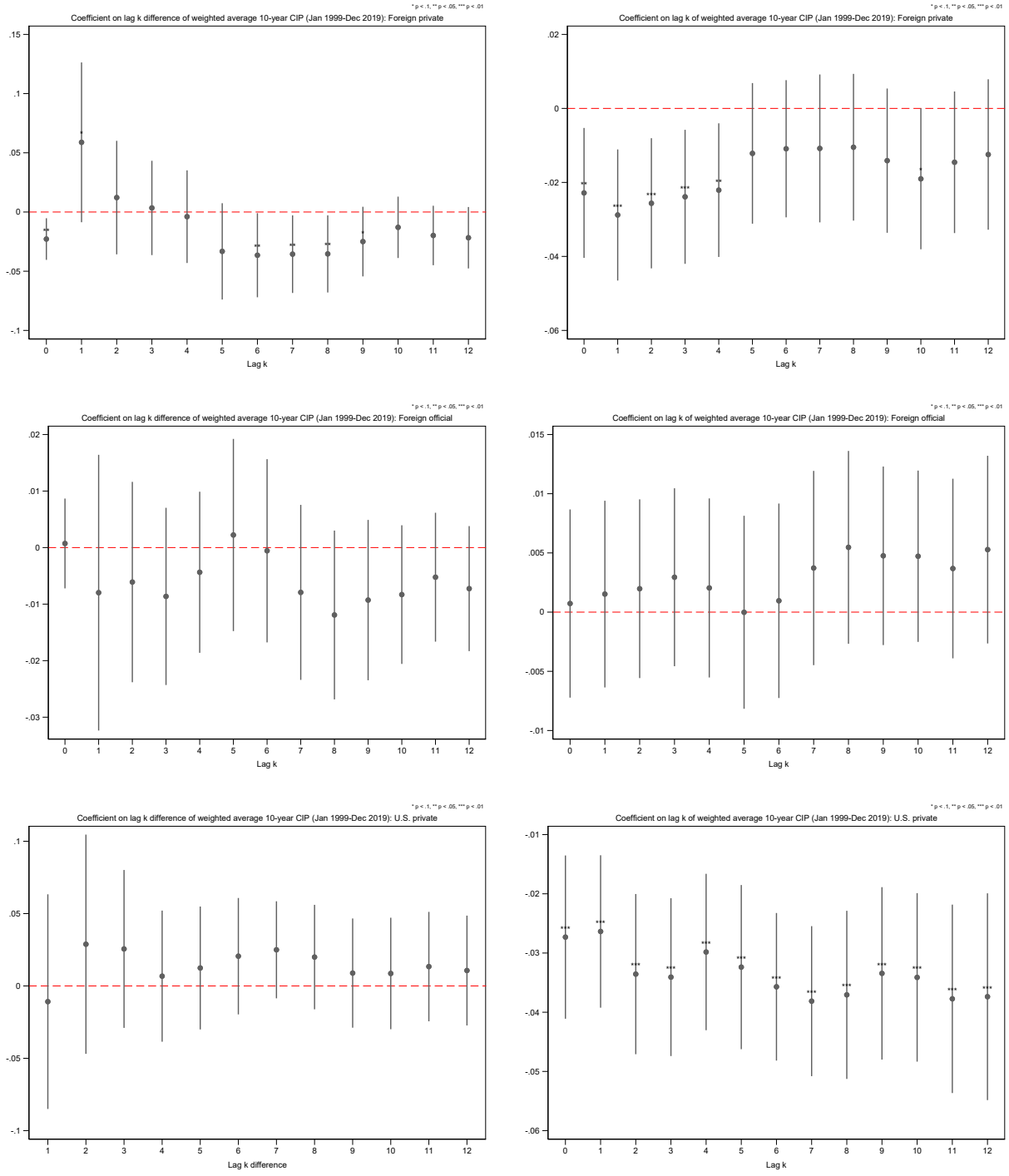
The figure plots amounts outstanding and holdings of marketable Treasury securities with original maturity greater than one year (bonds and notes) and less than one year (bills). The bonds and notes sample includes floating rate notes (FRN) and Treasury inflation protected securities (TIPS).

Figure 6: Duration of Treasury Holdings, Including Bills, by Investor Type



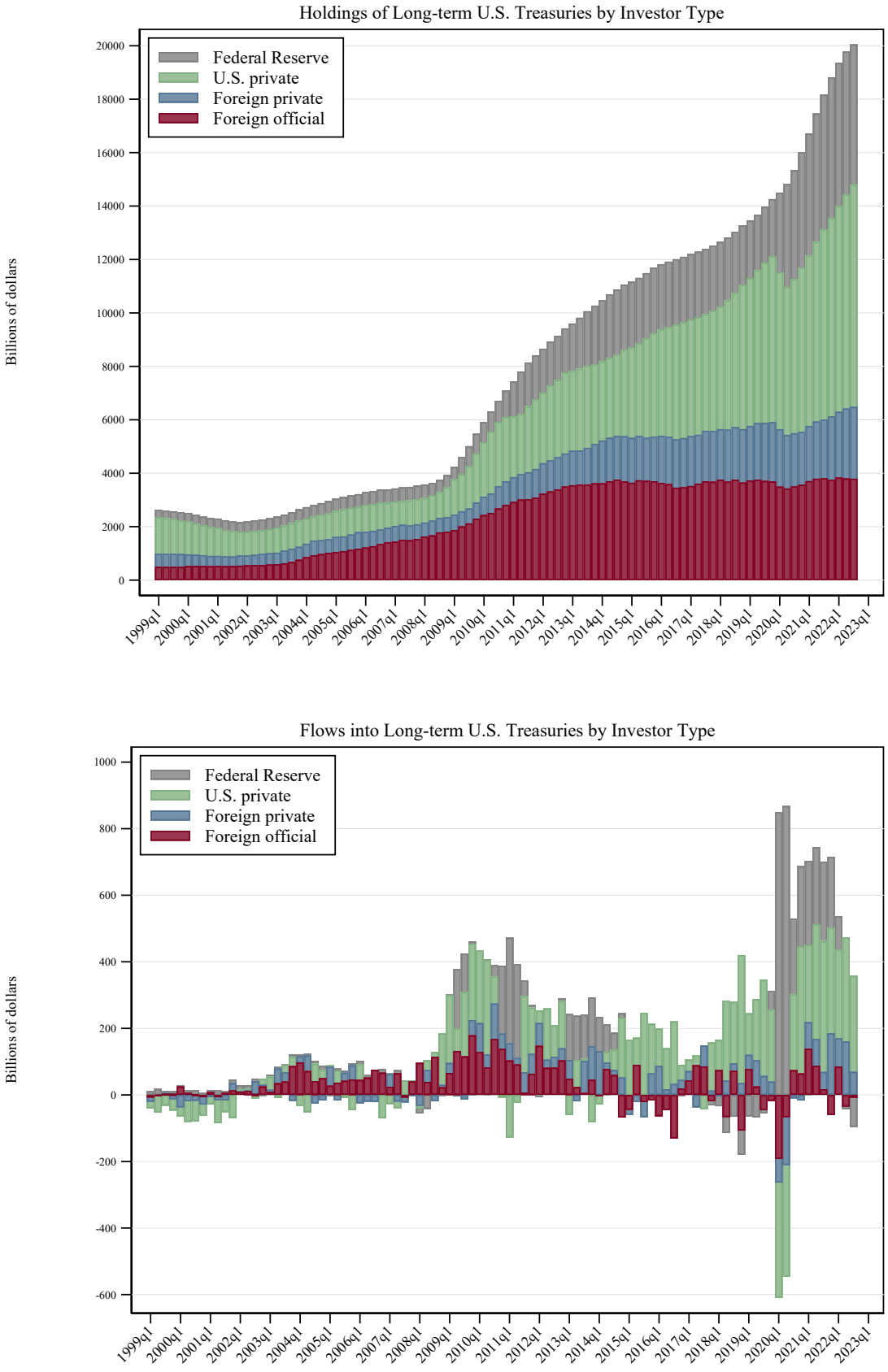
The figure plots weighted averages of duration by investor type. Market refers to all outstanding marketable Treasuries as reported by Treasury Direct. Sample excludes floating rate notes (FRN) and Treasury inflation protected securities (TIPS).

Figure 7: CIP Deviations and Flows into Treasuries



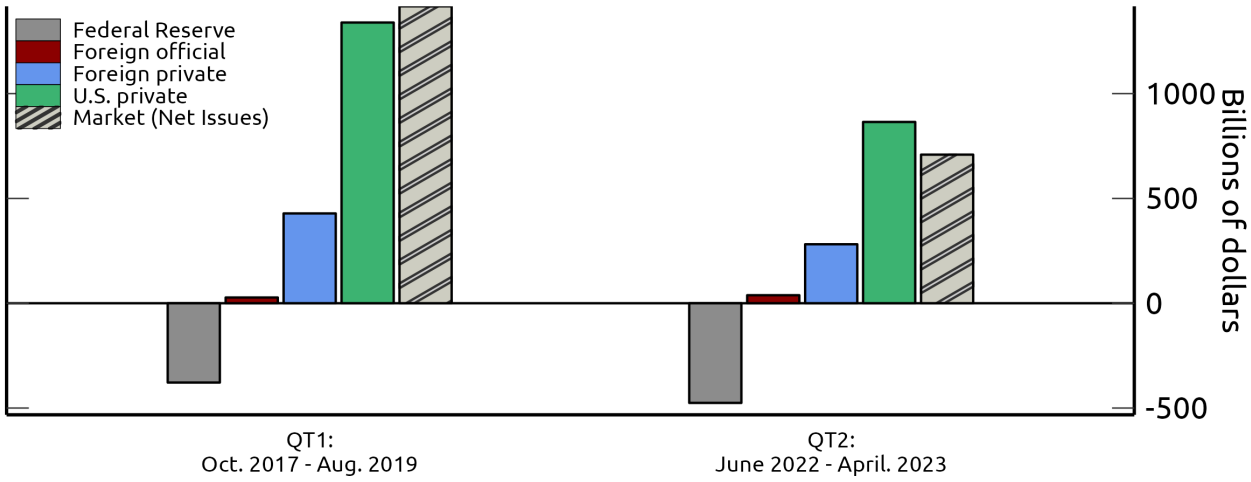
The left figures plot the coefficients on the lag k difference of the G10 10-year CIP deviation from equation 3 in the text for foreign private flows (top panel), foreign official flows (middle panel), and U.S. private flows (bottom panel). The right figures plot the coefficients on the lag k G10 10-year CIP deviation from equation 4 in the text for foreign private flows (top panel), foreign official flows (middle panel), and U.S. private flows (bottom panel). The x-axes denote k used for the lag k differences (left panels) or lag k levels (right panels) of the CIP deviation. The G10 CIP deviation is the weighted average of the G10 currencies using the respective countries' Treasury positions. Sample period: January 1999 - December 2019.

Figure 8: Treasuries Positions and Flows by Investor Type



The figure plots quarterly data on holdings (top) and flows (bottom) into long-term Treasury securities (notes and bonds) by investor type for the period 1999q1-2022q3. Source data: benchmark-consistent data for foreign flows and positions, SOMA data for the Federal Reserve. U.S. private investors are calculated as a residual using MSPD for Treasury outstanding amounts.

Figure 9: Quantitative Tightening: flows into Treasuries by investor type



The figure plots for QT1 and QT2, the sum of flows into Treasury bonds and notes per investor type. The quantitative tightening periods are defined as follows: QT1: October 2017 - August 2019; QT2: June 2022 - April 2023.

Table 1: Returns on Treasury Bonds and Notes (2003-2021), in percent

	IRR	**RoR**	*Sharpe*	**IRR - RoR**
Market	2.80	3.57	*0.84*	-0.77†
Fed	4.16	3.72	*0.85*	0.44†
Float (Market-Fed)	2.46	3.53	*0.83*	-1.07†
Foreign	2.59***	3.21	*0.88*	-0.63†
Official	2.66***	3.02	*0.93*	-0.36†
Private	2.42	3.76	*0.79*	-1.35†
U.S. Private	2.27***	4.25	*0.75*	-1.99†

The table shows, for the market (calculated using data on outstanding marketable Treasuries as reported by Treasury Direct) and by investor type, the internal rate of return (IRR), the geometric mean returns (rate of return, or RoR), Sharpe ratios (calculated as geometric mean divided by standard deviation), and the difference between the RoR and the IRR. Sample excludes floating rate notes (FRN), Treasury inflation protected securities (TIPS), and Treasury bills. *** denotes that Foreign and Foreign Official are different from U.S. Private at the 1% significance level. † denotes that IRR-RoR is different from zero at the 1% significance level.

Table 2: Internal Rate of Return (IRR) on U.S. Treasury Purchases, in percent

Period	2003q2-2021q2			1994q4-2000q1	
Data source	TIC Survey		Benchmark-cons.	FOF	Benchmark-cons.
	market & face value	market value	market value	market value	market value
	security-level	aggregate	aggregate	aggregate	aggregate
	(1)	(2)	(3)	(4)	(5)
Market	2.74	3.14	3.10	6.88	6.88
Fed	4.21	3.97	3.90	7.24	7.24
Foreign Investors	2.54	3.24	3.31	4.76	7.88
Official	2.60	3.31	3.35		
Private	2.39	3.08	3.20		
U.S. Private	2.21	2.41	2.25	7.92	6.31

The table shows the internal rate of return (IRR) results for two periods: 2003q2-2021q2 in columns (1)-(3) and 1994q4-2000q1 in columns (4)-(5). Column (1) uses the security-level TIC survey (SHL) data for the market value of initial and terminal positions, the face value of initial and interim positions (in order to calculate the interim coupon payments), and our survey-implied flows. For each period the coupon payments are calculated using the security-level information on coupon yields and face value. In column (2) we again use the TIC survey data for foreign and U.S. private investors but coupon payments are now calculated by multiplying coupon yields from the ICE BoA Merrill Lynch Treasury index by the aggregate market value of positions. Market and Fed positions and flows are from the Flow of Funds and their coupon payments are similarly calculated by multiplying the index coupon yield by the position. In columns (3) and (5) we use quarterly benchmark-consistent data for positions and flows for foreign investors; Market and Fed positions and flows are from the Flow of Funds. Column (4) uses only quarterly Flow of Funds data. All rates are annualized. Sample excludes Treasury bills.

Table 3: Returns on Treasury Bonds, Notes, and Bills (2003-2021), in percent

	IRR	**RoR**	*Sharpe*	**IRR - RoR**
Market	2.52	3.09	*0.91*	-0.56†
Fed	3.26	3.73	*0.92*	-0.47*
Float (Market-Fed)	2.65	2.97	*0.90*	-0.32†
Foreign	2.36***	2.89	*0.93*	-0.53†
Official	2.46***	2.80	*0.97*	-0.33‡
Private	2.11	3.09	*0.82*	-0.97†
U.S. Private	1.91***	3.27	*0.83*	-1.36†

The table shows, for the market (calculated using data on outstanding marketable Treasuries as reported by Treasury Direct) and by investor type, the geometric mean returns (rate of return, or RoR), Sharpe ratios (calculated as geometric mean divided by standard deviation), the internal rate of return (IRR), and the difference between the RoR and the IRR. Sample includes Treasury Bills. Sample excludes floating rate notes (FRN) and Treasury inflation protected securities (TIPS). *** denotes that Foreign and Foreign Official are different from U.S. Private at the 1% significance level. †, ‡, * denote that IRR-RoR is different from zero at the 1%, 5% or 10% significance level, respectively.

Table 4: Correlations of flows into long-term Treasuries

(a) When the Fed reduces its Treasury portfolio

	Fed	U.S. Private	Foreign Private	Foreign Official
Fed	1.000			
U.S. Private	-0.349**	1.000		
Foreign Private	-0.293*	-0.039	1.000	
Foreign Official	0.304*	-0.659***	0.000	1.000

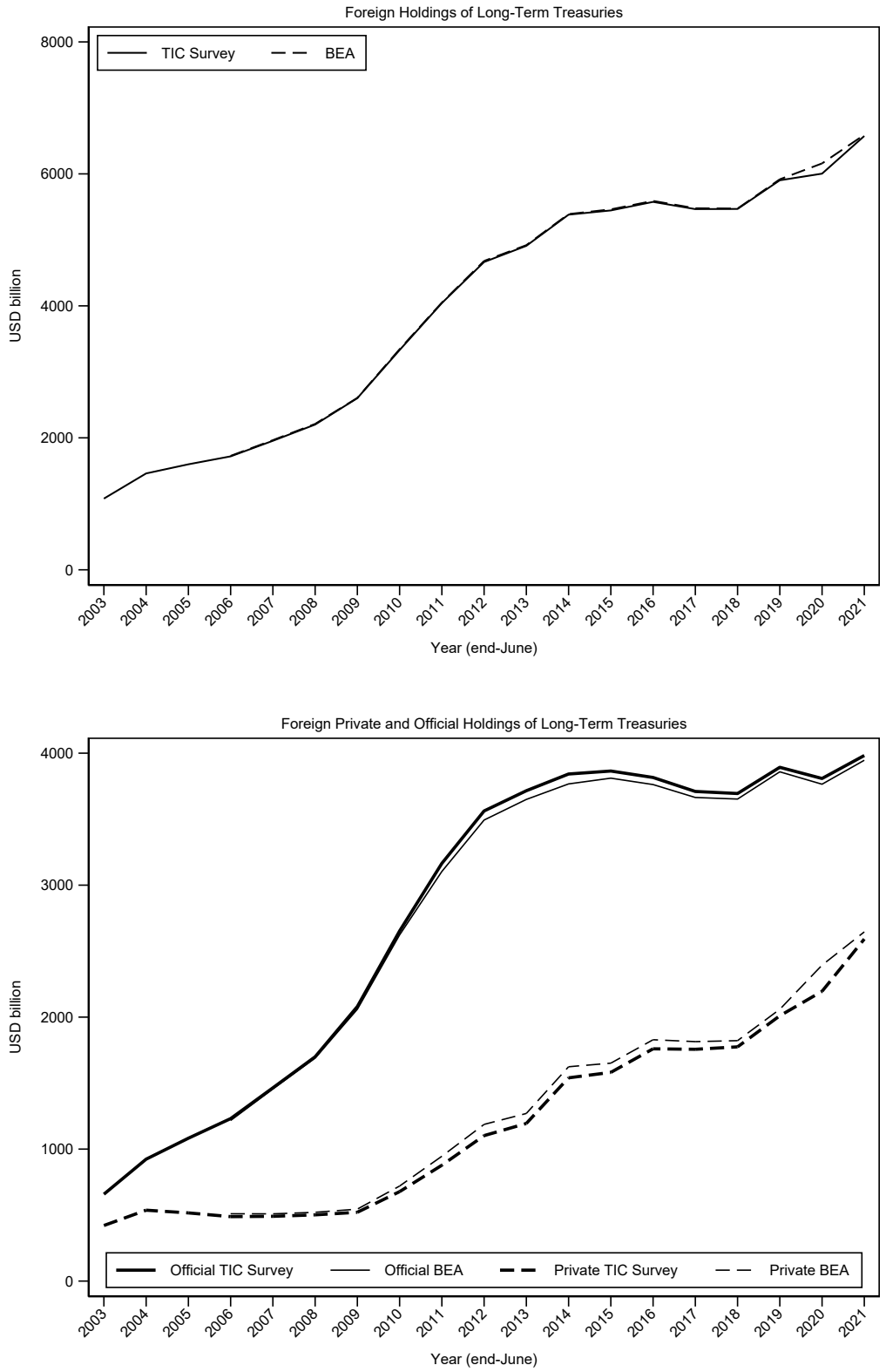
The table shows the paiwise correlations of flows into long-term Treasuries when the Fed reduces its Treasury portfolio, using monthly data for all investor types. Sample period: 1999m1-2022m11. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

(b) When the Fed buys Treasuries

	Fed	U.S. Private	Foreign Private	Foreign Official
Fed	1.000			
U.S. Private	-0.368***	1.000		
Foreign Private	-0.499***	0.129	1.000	
Foreign Official	-0.578***	0.295***	0.372***	1.000

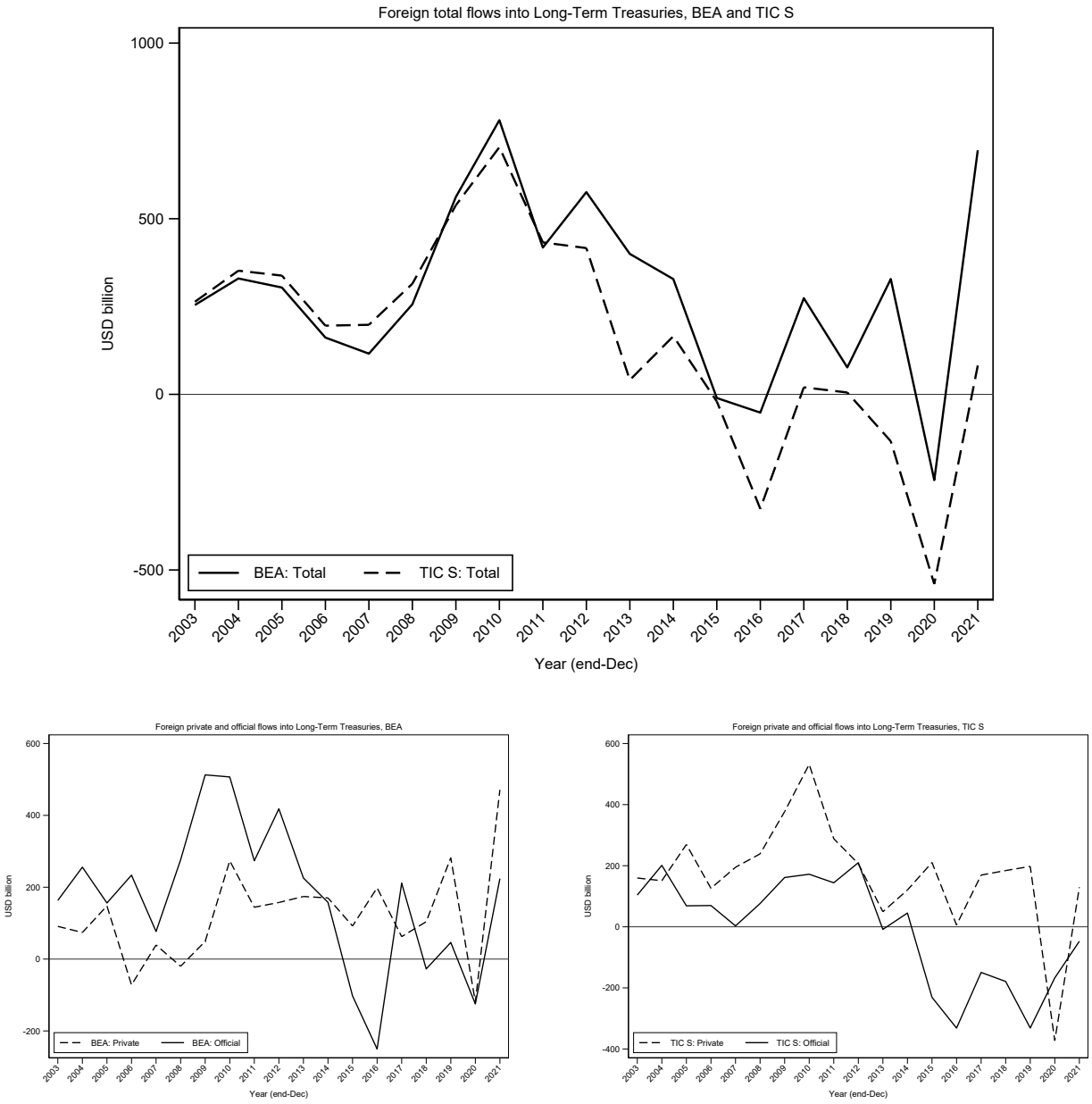
The table shows the paiwise correlations of flows into long-term Treasuries when the Fed purchases Treasuries, using monthly data for all investor types. Sample period: 1999m1-2022m11. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Figure A1: Foreign Holdings of Long-Term Treasuries



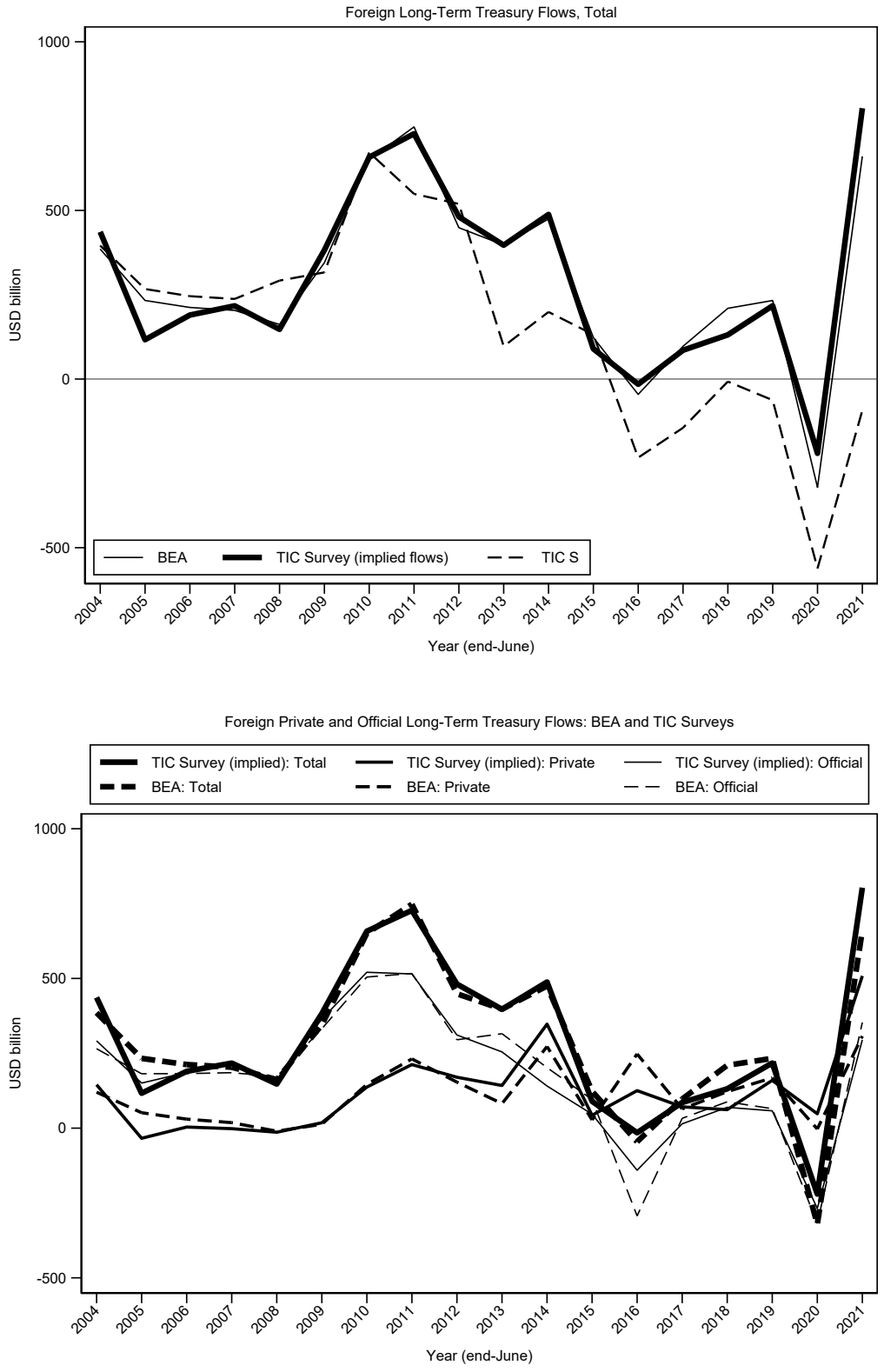
The figure shows, using data from the BEA and TIC surveys, the evolution of foreigners' holdings of U.S. Treasury bonds and notes (annual, in billions of U.S. dollars). The lower graph shows foreign private and foreign official holdings.

Figure A2: Foreigners' Net Purchases of Long-Term Treasuries



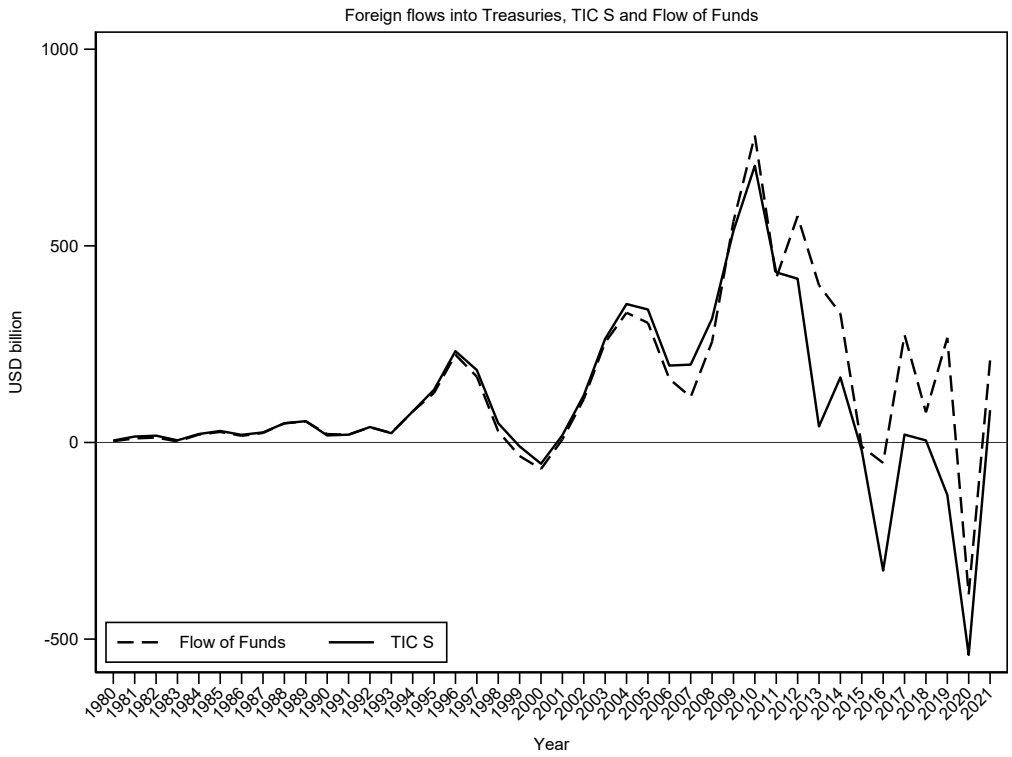
The figure shows, using data from the BEA and TIC S, the evolution of foreign flows into U.S. Treasury bonds and notes (annual, in billions of U.S. dollars). The lower graphs show foreign private and foreign official flows.

Figure A3: Foreigners' Net Purchases of Long-Term Treasuries



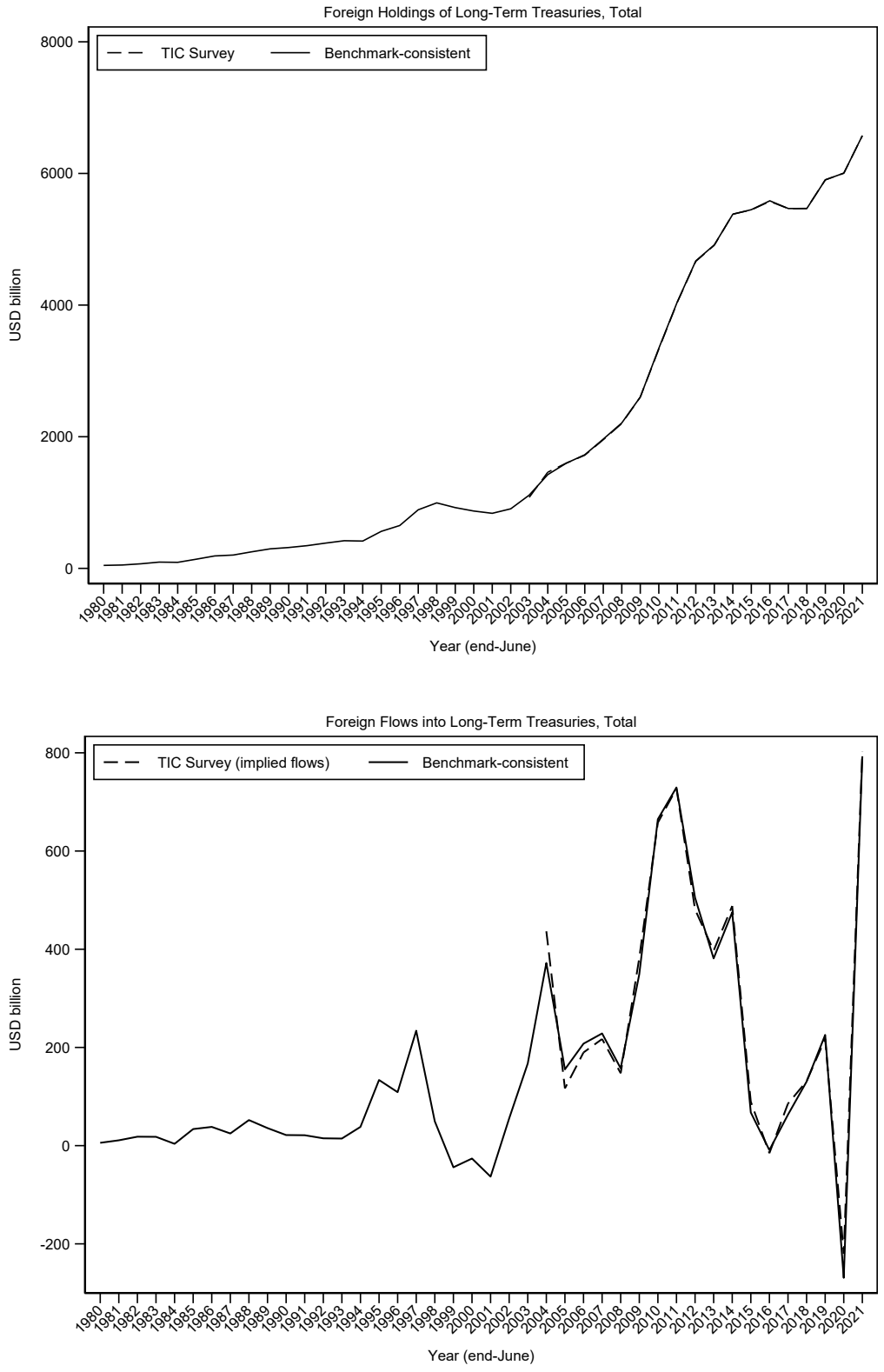
The figure shows, using data from three sources - BEA, TIC annual surveys, and TIC S - the evolution of foreign flows into U.S. Treasury bonds and notes (annual end-June to end-June, in billions of U.S. dollars). The lower graph shows foreign private and foreign official flows.

Figure A4: Foreigners' Net Purchases of Long-Term Treasuries: TIC S and Flow of Funds



The figure shows, using data from TIC S and Flow of Funds, the evolution of foreign flows into U.S. Treasury bonds and notes (annual, in billions of U.S. dollars).

Figure A5: Foreigners' Holdings and Net Purchases of Long-Term Treasuries



The figure shows, using data from TIC surveys and benchmark-consistent data on flows and positions, the evolution of foreign holdings of and flows into U.S. Treasury bonds and notes (annual end-June to end-June, in billions of U.S. dollars).