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

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Abstract

Investors' behavior in U.S. Treasuries - the world's safe asset - affects monetary policy transmission mechanisms, fiscal policy space, loan pricing, and international vulnerabilities. Yet it is not well understood for a simple reason: researchers, not having a clear picture of the Treasury portfolios of the largest participants in the market (foreigners and U.S. private investors), often infer behavior from aggregate statistics that can be less than pristine. We address this by building, from confidential security-level surveys, a comprehensive dataset on the size, flows, coupon payments, and returns of foreign and U.S. investors' Treasury portfolios. We find that investors do not view Treasuries as homogenous but have preferred habitats that determine returns: U.S. private investors hold a long-duration Treasury portfolio that delivers high average annual returns with high volatility, while foreigners have shorter-duration lower-volatility portfolios. Further, when taking into account the timing and magnitude of purchases, the actual returns earned by foreigners are higher. We also find that while foreign governments have inelastic demand, private U.S. and foreign investors, behind the bulk of Treasury purchases over the past decade, have elastic demand, increasing purchases of Treasuries and the duration of their Treasury portfolios when non-U.S. sovereign yields are low or decrease relative to Treasury yields. Our results shed light on the question of who will buy Treasuries as the Fed reduces the size of its portfolio and suggest that it will more likely be private investors, whether U.S. or foreign, not foreign governments. Finally, our comprehensive security-level data also enable a critical assessment of publicly available data on foreigners' flows.

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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 inelastic 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 inelastic 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, for various reasons we know little about it. Behavior is at times inferred from returns - for example, a group of investors that accepts below market returns might be assumed to receive non-pecuniary benefits and have inelastic demand. Other times data on portfolio adjustments is brought to the analysis; then behavior might be inferred from the relationship between flows of one type of investor and subsequent or past returns. But the literature has been plagued by partial analysis (e.g., drawing conclusions from one group's portfolios without applying similar methodologies to others' portfolios) and, more pervasively, data problems. The calculation and assessment of returns - and even flows - crucially depends on the quality of the data used.

We, too, examine flows and infer behavior from returns, but a number of features dis-

tinguish our study from others. We use best-quality security-level data that provide a clear picture of the positions, flows, income streams, and returns associated with the Treasury bond portfolios of U.S. investors, private foreign investors, foreign governments, and the Federal Reserve. We note the importance that such analysis includes foreigners, who have held roughly one-half of the Treasury bond market over the past two decades, and assess domestic (i.e., U.S.) investors, often omitted from studies of capital flows, using similar methodologies.

We also challenge two common assumptions: that the composition of investors' Treasury portfolios is limited to a single representative Treasury bond and that the timing and magnitude of different investors' flows into and out of Treasuries is known. These assumptions, while common, are not supported by evidence.

On the composition of Treasury bond portfolios, investors do not view Treasuries as homogenous but have preferred habitats (Figure 1, top graph). The difference in the Treasuries portfolios of U.S. and foreign investors is striking. Over the period from 2003 to 2019, 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, preferred habitats will 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 release) were 2.3, 2.9 and 3.5 percent, respectively. That is, over the past 20 years, 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.

On the second common assumption - that we know the timing and magnitude of investors' purchases - we note that foreign holders of Treasuries are actually two distinct groups: private foreign investors and foreign governments (which we will at times refer to as foreign officials). The oft-used TIC S capital flow data (Figure 1, bottom graph) indicate that the bulk of

foreign purchases of Treasuries are 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. However, we will show that 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 for private foreign, but $1 trillion in favor of foreign governments. Not only have researchers not had an understanding of investors' preferred habitats, but they also have not had an accurate picture of the timing and magnitude of the purchases and sales of Treasuries.[1]

Our study is enabled by a comprehensive security-level dataset of investors' Treasuries holdings. The dataset has three important features: it (i) forms internally consistent series on positions, flows, coupon payments, and returns, (ii) is built from security-level data, and (iii) represents the universe, to the extent we know it. Given that at the security level both the universe of Treasury bonds and the Fed's portfolio are publicly available, with accurate security-level information on foreigners' Treasury portfolios we also know (as the residual) U.S. investors' security-level portfolio. Overall, the dataset enables a first-ever apples-to-apples analysis of the security-level portfolios of four main groups - U.S. investors, private foreign investors, foreign governments, and the Fed - that cannot be done with any other dataset because a comprehensive security-level dataset on foreigners' portfolios has not been available.[2]

[1]We will be more specific about the exact nature of the problem with TIC S flow data, but note here that it persists in 2022. TIC S indicates that for the calendar year through July foreign governments sold $89 billion in Treasury bonds, whereas a more accurate measure indicates $65 billion in net purchases.

[2]The dataset has some limitations. A main one is that observations are just once per year. This precludes the inclusion of Treasury bills - Treasury securities with less than one year original maturity, which are currently only 15 percent of outstanding Treasuries - from much of our analysis. Thus, other than in Section 5 where we explicitly include Treasury bills, when we refer to Treasuries, we mean Treasuries of greater than one year original maturity. Moreover, 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 analysis we (i) include, at an aggregate (i.e., not security) level, Treasury bills and (ii) use aggregate quarterly data on flows and positions. Both extensions are presented in the paper; neither changes the main assessment. A second limitation is among foreign investors the identification of the ultimate investor's country is not

The confidential and mandatory security-level surveys on foreigners' U.S. Treasury portfolios that enable our study are conducted as of each June 30 from 2003 to 2019 through the U.S. Treasury International Capital (TIC) System. 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 (SHL reports) and those aggregations inform the Bureau of Economic Analysis' (BEA) International Investment Position of the United States (IIP) as well as the U.S. current account (via income streams computed using the aggregate positions estimates).[3] The confidential security-level data include various security characteristics, such as a general security description and identifier, issue and maturity dates, coupon rate, and amount held, but also include both the face (which excludes price change effects) and market values of holdings. In all, our dataset enables security-level analysis and the first-ever direct comparison of foreign and U.S. investors' Treasury portfolios, while also producing the first-ever survey-consistent aggregate measures of flows, coupon payments and returns.

Equipped with the novel dataset, we first 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. The survey data allow for a straightforward comparison with other sources of *positions* and 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

accurate if the investor uses a third-country custodian. Thus, in most of our analysis we aggregate across foreign countries.

[3]See https://www.treasury.gov/resource-center/data-chart-center/tic/Pages/shlreports.aspx for the 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 Federal Reserve's Financial Accounts of the United States (known as Flow of Funds, or FOF) relies on BEA's presentation, so our holdings data also sum to FOF. Note that there are mid-2020 and mid-2021 surveys that post-date our sample; the processing of those more recent data for use in research is in progress.

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.

We then focus on questions our data on holdings, net purchases and income streams are particularly suited to address. Taking into account both the composition of Treasury portfolios - important because investor groups have reasonably well defined preferred habitats - and the timing and magnitudes of purchases, what returns are earned by each group? And, based on the returns earned, as well as focusing on the timing of purchases, can we describe different investors' demand as inelastic? That question might seem narrow but is not: As the spectre of higher Treasury yields looms, and one large entity (the Federal Reserve) reduces the size of its Treasury portfolio, which investors will step in and buy Treasuries?

We investigate the impact of portfolio composition on returns by constructing annual cross-sectional returns for the four types of Treasury market participants - foreign private and foreign official investors, private U.S. investors, and the Federal Reserve - for the period June 2003 - June 2019.[4] These can be thought of as buy-and-hold returns in which the index composition changes year to year but fluctuations in the timing and magnitude of purchases are not considered. We find that investors' preferred habitats determine the mean

[4]We note that two Treasury market participants - the Fed and foreign governments - have motivations 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. 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.

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), and private foreign investors were somewhere in between. In fact, 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.

Peering into the portfolios to compute average annual returns and understand drivers of any differences is useful but does not adequately capture the timing and magnitude of participants' flows into and out of the Treasury market. To capture how variation in the timing of purchases - along with differences in portfolio composition - affect the actual returns investors earn, we compute dollar-weighted returns as given by internal rates of returns (IRRs). No study has investigated the effects of timing and composition using a Treasuries dataset that is high quality, internally consistent, comprehensive, and spans the entire market. We, in contrast, use the security-level dataset to build all four components needed to compute investors' Treasury market IRRs: the market value of initial positions (the initial outlay), flows (interim outlays), face value (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 the first-ever direct comparison of the returns earned by foreign and U.S. investors.

Our IRR analysis is analogous to the Dichev (2007) seminal work on the equity premium, which found that buy-and-hold returns - which assume investors buy at the start of the sample period and make no subsequent transactions until they sell everything at the end of the sample - differed from investors' actual returns. Dichev (2007) found, focusing on large U.S. equities, that investors earned 130 basis points less per year than buy-and-hold returns. Taking into account both investors' preferred habitats - that is, observing their actual holdings of Treasury securities - and the timing and magnitude of purchases, we find

a similar result for the Treasury bond market: investors earn 77 basis points less than buy-and-hold returns. Moreover, this difference is much higher for private investors, whether U.S. (198 basis points less than buy-and-hold returns) or foreign (130 basis points less). In contrast, foreign officials' returns are only 35 basis points lower than buy-and-hold returns. Thus, our first conclusion is that, as with equities, for Treasuries investors' actual returns differ materially from buy-and-hold returns, and this difference is quite large 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.

Finally, we explore the demand elasticity for Treasuries by assessing how and if investors alter their Treasury portfolios. We find that 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. We do this in two ways: one focuses on changes in the composition of foreigners' Treasury portfolios, the other on the timing of investors' flows. We first use the security-level foreign holdings data and show, using country-level regressions of weighted-average duration, that private foreign investors, but not foreign official investors, lengthen the duration of their Treasury portfolios when CIP deviations (the synthetic sovereign dollar yield minus the Treasury yield, which is the opposite of the Treasury basis) decrease. We then turn to a higher frequency (monthly) dataset and show that U.S. and private foreign investors, but not foreign officials, increase their flows into U.S. Treasuries when CIP deviations are low or have fallen.[5] Overall, the analyses of flows and duration provide evidence that private investors, whether U.S. or foreign, who together were behind 90 percent of net purchases the past 6 years (2014-2019), have elastic demand for Treasuries. Additional analysis of the historical data suggests that as the Fed reduces the size of its

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

balance sheet, private investors - especially U.S. investors - will be the counterparty.

Related Literature

Our paper is directly related to the Dichev (2007) analysis of the difference between index and actual returns. That paper showed that investors' behavior substantially reduced actual returns, which implies that the equity premium and cost of equity capital had been overestimated. We too focus on the difference between average annual and actual returns while in addition taking into account the composition of investors' holdings.

The Dichev (2007) technique allows us to meaningfully 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 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 also 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

[6]Our work is also tangentially related to literature on the effects of foreign investment on Treasury yields.

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.

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) 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

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.

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

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).

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.

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 focus on the composition of Treasury portfolios and how it impacts the average annual returns of foreigners and U.S. investors. In Section 4 we continue to allow for different portfolio compositions while assessing the effects of the timing and magnitude of purchases; demonstrate how and if investors alter their Treasury portfolios in response to changes in yields; and explore the question of who will likely buy as the Fed reduces the size of its portfolio. Section 5 brings in Treasury bills, excluded from preceding sections because annual surveys are ill-suited for examining securities with less than one year original maturity, and shows that results change in nuanced ways but not materially. Section 6 discusses how the literature might be informed by our results. Section 7 concludes. An online appendix will include 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.[8] More difficult, even at the aggregate level, are data on foreigners' Trea-

[8]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).

suries 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, sometimes provide conflicting information. It would be difficult for researchers to know which sources are appropriate for addressing a particular question. We relegate to the appendix a lengthy but important discussion and assessment of the various sources on foreigners' portfolios.

Here we use the best sources: annual security-level TIC SHL annual surveys for foreigners' positions and, from the same source, flows that we construct. 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 2019 we sum the holdings and compare to the surveys' published aggregate amounts. They match 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.[9] 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.

[9]A few things to note. We focus on Treasury bonds and notes - that is, Treasury securities with one year or more original maturity - and the data are of holdings (i.e., we do not have information on derivatives positions or repo activity). Moreover, 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); for this reason we focus on aggregates rather than country-level analysis.

The data show that 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 just below 20 percent of the market, with a noticeable sharp deviation from that during QE1 (when the Fed shifted its portfolio toward other securities like mortgage-backed securities) and a slow decline between 2015 and 2019. 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, foreign officials' Treasury holdings are about twice as large as private foreigners (Figure 2, bottom graph). 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.

Turning to the associated 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. Within foreign flows (Figure 3, bottom graph), every year since 2014 private foreign purchases of Treasuries have exceeded officials' purchases.[10]

[10]In Section 4.2.3 we present another graphical representation of positions and flows by investor-type.

3 The Composition of Security-Level Portfolios

In the rest of the paper we attempt to understand investors' behavior in the world's safe asset. We start in this section by peering into the portfolios to assess any differences in composition and how those differences impact portfolio returns.

Figure 1 (top graph) foreshadowed this section: Investors have reasonably well defined preferred habitats in Treasury bonds. Figure 4 shows the same information but separates foreign investors into private and official and includes the Fed and the overall market. Over the period 2003-2019, market duration was between 5 and 6.5 years (with an average of 5.78).[11] 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 equal, average annual returns will differ. For the period from mid-2003 until mid-2019, average annual returns for 3-, 5- and 7-year constant maturity Treasury bonds were 2.01, 2.66 and 3.23 percent. Thus, just based on preferred habitats we expect U.S. investors to have substantially higher returns - perhaps 100 basis points more per year - than foreign governments.

We use the security-level data to precisely 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

[11] Note that because we focus on duration, for the rest of the paper we exclude, unless otherwise noted, FRNs and TIPs, for which duration cannot be computed. These securities 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.

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:[12]

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

Results are in column 1 of Table 1.[13] 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 U.S. investors, who have the longest duration portfolio, had high average annual returns (4.34 percent). Foreign officials, with the shortest duration portfolio, had the lowest returns, 3.02 percent, while private foreign investors earned 3.77 percent per annum.[14] The returns orderings are in line with what we would expect from the preferred habitats, and the differences (for example, foreign official earning 132 basis points less than U.S. investors) are in line with returns from the various constant maturity Treasury

[12]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.

[13]The Fed, which remits any excess profits on its security holdings to the U.S. Treasury, does not attempt to maximize returns on Treasuries and its motivation in buying Treasury securities is quite different from other investors'.

[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.

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 2) is reversed. Foreign official's low-duration portfolios delivered the highest Sharpe ratio, while private investors' (both U.S. and foreign) higher-duration portfolios had lower Sharpe ratios.

To summarize, careful examination of the composition of Treasury portfolios indicates that time-weighted average annual returns differentials are a direct function of risk. 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.[15]

4 Investors' Behavior in the Treasury Market

The previous section showed that preferred habitats determine the mean and volatility of annual returns. We might be tempted to infer behavior from those results, but other metrics are better suited for that. In this section we aim to increase our understanding of behavior by exploring investors' timing in the Treasury market as well as what prompts portfolio changes.

4.1 The Magnitude and Timing of Purchases

Average annual returns are informative but do not take the magnitude and timing of purchases and hence, if the magnitude of purchases vary through time (as they do), do not translate into the returns actually earned by investors. In this subsection we continue to

[15] An interesting question that we cannot address with our annual data is if foreign officials' returns are boosted by selling during crises, when Treasury prices are high. The case against this is implied in Vissing-Jorgensen (2021), which notes, using quarterly BEA data, that foreign officials' behavior varies across crises, as they purchased Treasuries in 2008Q4 and sold in 2020Q1.

take into account security-by-security data on portfolio composition (as in the last section) and add in security-level data on the timing and magnitude of purchases.

The metric best suited to assess whether an investor type's purchases led to higher returns is internal rate of returns (IRR); see Fabozzi (2014) for a textbook exposition and Dichev (2007) for an application to equities. Security-level data on each bond's market value, face value, and coupon yield, as well as flows we compute from the security-level data, allow us to compute IRRs for a sample period of mid-2003 through mid-2019 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-2019,
- intermediate distributions are coupon payments each period from mid-2004 through mid-2019, 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-2019.

Column 3 of Table 1 presents IRRs, based entirely on security-level data, for foreigners (separating out private and official foreign investors), U.S. investors, and the Fed over the period from mid-2003 to mid-2019. We also show a market IRR computed in the same manner as the other IRRs. Column 4 shows the difference between RoRs and IRRs. Where RoR is higher than IRR (i.e., a positive entry in column 4), the timing and magnitude of flows reduced actual returns.

We note first that 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.

By investor-type analysis indicates that private investors have poor timing, with the IRRs of U.S. and foreign private investors being 198 and 130 basis points, respectively, lower than their RoRs. The timing of foreign officials, in contrast, lowers their returns only 35 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. Private U.S. and foreign investors have volatile high duration portfolios and, in addition, poor timing materially reduces their actual returns.

The estimates in Table 1 are precise, as every component is built using security-level data. But they have the limitation that they are built from annual data and so cannot capture trading that 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 data from Bertaut and Tryon (2007) and Bertaut and Judson (2014), which we refer to as BTBJ data; please see the appendix for details. 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

[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).

yields to market value (column 2), moving to quarterly data (column 3) has near-zero effect on the estimates. This exercise suggests that while using annual data does not appear to affect the quality of our estimates, assuming a representative Treasury bond (e.g., by using an index) would.[17] Once we move to less precise data, switching to a quarterly frequency has no effect, suggesting that within-year trading does not materially impact returns estimates.

4.2 How Investors Alter Their Treasury Portfolios

Data limitations have impeded the ability to gauge how foreigners alter their Treasury portfolios. We cannot definitively address this, but can make some progress in two ways. First, similar to the analysis in Section 3 we can use the annual security-level survey data to focus on portfolio composition - specifically, how foreigners change the duration of their Treasury portfolios when spreads change. Second, analogous to the analysis in the previous subsection, we can examine the evolution of flows, specifically how flows respond to changes in spreads. On the latter, we recognize that the annual SHL data, while detailed and the best quality, have limitations. For example, if investors have sizeable net purchases, then contemporaneous annual regressions will be hindered by price pressure: Is it that Treasuries are bought when they are expensive or that the purchases make Treasuries expensive? Lagging yields could help, but a full year lag is a bit extreme. All this suggests turning to flows from the higher frequency (monthly) aggregate flows of BTBJ, which are better suited to capture leads and lags in the relationship between flows and yields.

In both analyses in this subsection we make use of data on CIP deviations from Du and Schreger (2016) and Du, Im, and Schreger (2018). Briefly, we will use 10yr SynDiff, country j's synthetic yield difference - synthetic dollar sovereign yield minus U.S. Treasury yield -

[17] 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. Our data suggest that those estimates might currently run about $10 billion too high.

where the synthetic dollar sovereign yield (10yrSynSov) is constructed using Du, Im and Schreger's data on the forward premium. Note that the synthetic yield difference is also called the CIP deviation.

4.2.1 Duration

We can use the security-level data to gauge how the composition of foreigners' U.S. Treasury bond portfolios - specifically, how the duration of those portfolios - changes with changes in the sovereign rate, the synthetic (i.e., CIP-adjusted) sovereign rate and the Treasury rate. The panel regressions we run are as follows:

$$\text{Dur}_{j,t} = \alpha + \beta \Delta \text{10yr SynDiff}_{j,t} + c_j + \eta_t + \epsilon_{j,t} \tag{3}$$

$$\text{Dur}_{j,t} = \alpha + \beta \Delta \text{Y}_{j,t} + \Delta \text{Y}_t^{\text{US 10yr}} + c_j + \epsilon_{j,t} \tag{4}$$

The dependent variable ($\text{Dur}_{j,t}$) is the weighted average duration of country j's portfolio of U.S. Treasury securities in year t; that is, it is built from the security-level holdings and security characteristics, with duration being aggregated to the country-year using bond size-based weights. In equation (3) the explanatory variable, 10yr SynDiff, is country j's synthetic yield difference (synthetic sovereign yield minus U.S. Treasury yield). In equation (4), in addition to the 10-year U.S. Treasury yield (US 10yr) we also include the components of the synthetic yield difference: variable $\text{Y}_{j,t}$ is either country j's sovereign local currency 10-year bond yield (Sov10y) or country j's synthetic dollar sovereign yield (10yr SynSov). All explanatory variables are in changes. In Table 3 we report the results separately for foreign private and foreign official investors. Since the focus is on sovereign rates and the Treasury basis, the sample excludes Belgium, Ireland, and Luxembourg, because these coun-

tries house custodians that primarily serve investors from other countries.[18] All specifications include country fixed effects (c_j); time fixed effects (η_t), are included in columns 1 and 5 (corresponding to equation (3)); and standard errors are clustered on country.

Results indicate that private foreign investors extend the duration of their Treasury portfolios when their country's synthetic yield difference (the CIP deviation or negative of the Treasury basis) becomes more negative (columns 1 and 2). Unpacking the components of the synthetic difference, private foreigners appear to be reacting to changes in their countries' synthetic dollar yield (column 3), not to changes in U.S. Treasury yields or their sovereign local currency rates (column 4). Foreign officials (columns 5-8) seem different. The only significant coefficient, although only marginally so, in the foreign officials regressions is on changes in their own sovereign yield: When the sovereign yield increases, foreign officials extend the duration of their Treasury portfolios (although as a group their portfolios have the lowest duration of any investor group).

We note that included in foreign private are insurance companies and pension funds (ICPF) who might match the duration of their liabilities. To check if these investors influence our results, we control for the size of each country's ICPF sector (measured as the size of the sector's assets relative to total domestic assets) by using a dummy variable of high versus low based on the sample median. This ICPF size dummy, constant over time within a country, does not appear to be a significant determinant in foreign investors' behavior (Table 4).

Overall, results in Tables 3 and 4 indicate that foreign private investors lengthen the duration of their Treasury portfolios when the Treasury basis increases (i.e., CIP deviation decreases), but foreign officials do not.

[18] Our sample also excludes the Caribbean banking centers because these countries do not have significant sovereign debt outstanding and therefore lack reliable data on sovereign rates. Moreover, their investments are predominantly held on behalf of a diverse group of non-residents, for whom the interest rate to use is ambiguous.

4.2.2 Flows and Yields

Does the volume of investors' flows into Treasuries react to changes in Treasury yields? Answering this requires data at a higher frequency than annual, so we create monthly flows for U.S. investors and for foreign flows we use the aggregate (i.e., not security-level) BTBJ data of Bertaut and Tryon (2007) and Bertaut and Judson (2014). In the BTBJ dataset, all long-term Treasuries are included (i.e., including FRNs and TIPs) and the by-country private/official split is confidential, so in this subsection the analysis is aggregated (i.e., not at the country level) and FRNs and TIPs are included. 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 as follows:

$$\text{Flow}_t/\text{Position}_{t-1} = \alpha + \beta(\text{CIP}_t - \text{CIP}_{t-k}) + \epsilon_t \tag{5}$$

$$\text{Flow}_t/\text{Position}_{t-1} = \alpha + \beta\text{CIP}_{t-k} + \epsilon_t \tag{6}$$

In Figure 5 we plot the β coefficients from each time series regression we run for each lag k. Each plot in Figure 5 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 period is January 1999 through December 2019.[19] 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

[19]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 will start in January 1999.

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 5 indicates that private foreign and U.S. investors react to changes in CIP deviations, while foreign officials can be characterized as having inelastic demand.

4.2.3 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 6 (best viewed in color) using quarterly BTBJ 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 6 (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 maturity securities to roll off their balance sheet (which is a negative flow). Second, Table 5 provides correlations that are embedded in the flows data. From these correlations, the most obvious counterparts to the Fed are private U.S. investors, whose flows are significantly negatively correlated with Fed flows.[20]

Our earlier findings on preferred habitats in the Treasury market and differences in demand elasticities among investors 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), who seem to have elastic demand (Tables 3 and 4, Figure 5), so price and hence expected returns will influence decisions. The one large group with inelastic demand - foreign governments - have 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

[20]The flows in Table 5 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.

meaningful way when the Fed reduces its balance sheet.

5 Including Treasury Bills

The analysis in the preceding sections 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 section we include bills. We first note that they are small (Figure 7), both in terms of outstanding Treasuries (14 percent in 2019) and in investors' holdings. That said, early in our sample period they were more important, 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'. (Interestingly, they were still a small portion of foreign governments' Treasuries portfolio at only 22 percent.)

Including bills alters the duration pictures a bit (Figure 8). Not surprisingly, including short-dated securities reduces duration. And, while foreign investors' portfolios still have lower duration than U.S. investors' (top graph), for much of the period private foreign and U.S. investors had very similar durations (lower graph). 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 6 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.[21] RoRs are lower than in Table 1, but with the ordering preserved, Sharpe ratio order is unchanged, and IRRs are pretty similar. As in Table 1, U.S. and foreign private timing erodes their returns by substantial amounts of 144 and 99 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.

6 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 will briefly recap our main findings and help the reader understand differences with the existing literature.

Our paper extends and complements existing work in Dichev (2007) on the difference between RoRs and IRRs. 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. Our study complements Dichev (2007) in that it is the first, as far as we know, that takes this point seriously for Treasury bonds and explores not only for the market but by investor type. 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

[21] Specifically, RoR is security-level from Table 1 column 1 times the long-term share plus a bills return times the bills share. IRR cash flows are as in Table 1 column 3, with bills added (initial and ending positions, interim purchases, and "streams" computed as lagged face value times a bills return).

130-200 basis points.

Our findings add clarity to a notion that appears in the convenience yield literature that foreigners have poor timing, poor performance, and inelastic demand in their Treasury portfolios. Those characteristics, by extension, imply a Treasury convenience yield that is much larger for foreigners than U.S. investors. We provide the following clarity. One, there are two distinct groups of foreign investors: private and government. Two, we assess U.S. investors using identical techniques. Three, comparisons in the literature have been of market index returns and foreigners' IRRs, but we show, like Dichev (2007), that not even the market earns market index returns. When put on equal footing and assessing all investor types using similar techniques, we find that foreign governments have inelastic demand, but their timing and performance are relatively good. Private foreign investors are very much like U.S. investors, in that they operate in a similar part of the yield curve and have elastic demand, 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), but inconsistent with the Krishnamurthy and Lustig (2019) and Jiang et al. (2021, 2022) findings that foreigners have inelastic demand.[22] Going forward, the literature should focus on the distinction between private (both U.S. and foreign) and official investors, not U.S. versus foreign.

[22]The reader might be familiar with estimates of a large convenience yield 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, Krishnamurthy, and Lustig (2021). Those large differentials are primarily due to a comparison of foreigners' IRRs and the market RoR (comparing IRRs with IRRs reduces the differential by 130 basis points) and incorrect index returns data from 1980 to 1986 (see Figure A1 of Jiang et al. (2022), which shows an erroneous 52 percent return in 1980q2; using correct index series would reduce the IRR by 250 basis points).

7 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 degrades the actual returns earned by *private* investors. Specifically, by investor group, U.S. investors have long duration Treasury portfolios that produce high returns with high volatility, but the timing of their purchases reduces 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 Treasury bonds and notes are considered and much more like U.S. investors when bills are included in the analysis. Moreover, private foreign investors, like U.S. investors, appear to be price sensitive, 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 demand is elastic and is 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. Our results are consistent with all non-governmental investors placing similar convenience yields on Treasuries, suggesting that the literature should focus on notions (and calculations) of convenience yields that do not rely on foreigners being different. Work in that direction includes 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, will soon be discontinued), others that are more accurate but can still be confusing (see, for example, discussions about BTBJ data 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.

Board of Governors of the Federal Reserve System

Darden Business School, University of Virginia; and National Bureau of Economic Research

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

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. Data on the overall Treasury bond market are available at the security-level at https://www.treasurydirect.gov.

The primary impediment to getting a clear picture of different investor groups' Treasury portfolios has been data on foreigners' portfolios. Moreover, there are multiple sources of data on foreigners' purchases of and positions in U.S. Treasury securities and no clear way for researchers to ascertain data quality. In this appendix we present and assess the various sources.

Data Sources on Foreigners' Treasury Portfolios

The main sources for data on foreigners' holdings are reports by the Treasury Department and BEA. Another source, the Fed's FOF data, follows BEA's data, so we will mention FOF data only parenthetically. We first discuss the annual security-level holdings data, then higher frequency data on positions and flows.

Security-Level Portfolio Data

The highest quality data are, not surprisingly, reported at the lowest frequency: annual. 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

[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

annual U.S. TIC surveys 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, 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. 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. In practical terms this means that the foreign official amount is a lower bound with some official holdings bleeding into the foreign private numbers (for example, if a central bank uses a custodian in, say, Belgium).[24]

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

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.

[24]That said, reporters can indicate that the holdings are on behalf of a government. A bigger issue is with country attribution, which is subject to the nationality vs. residency issue studied in Warnock and Cleaver (2003), Bertaut, Bressler, and Curcuru (2019), and Coppola et al. (2021).

maturity date and coupon interest rate). We do this for each annual survey from June 2003 through June 2019. 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.

Other Data on Positions

The now annual security-level TIC survey (henceforth TIC SHL), conducted each year as of end-June, is the primary input for BEA's International Investment Position, or IIP, data (quarterly since 2006, prior to that year-end).[25] 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.

[25]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/.

Flow Data

While sources of holdings data are in agreement, data on foreigners' net purchases of Treasuries can vary substantially by source for one simple reason: There is no comprehensive security-level *transactions* survey. The TIC SHL *holdings* surveys obtain positions data from global custodians, but there is no equivalent for data on transactions (i.e., flows). TIC S monthly transactions reports survey broker dealers and banks, but it has long been recognized that there are issues with the TIC S transactions data. Thus, each source must decide how to estimate net foreign purchases. Since 2013 BEA imputes transactions from the reported TIC positions; prior to 2013, TIC S flows were the main source for BEA transactions data.[26]

Figure A2 (top panel) shows that TIC S flows differ substantially from BEA's BOP flows. For some years 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 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

[26]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.

accurate. While there are official descriptions of each measure, an outsider might find it difficult to judge how to use the data.[27] 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.[28]

We do this for each annual survey from June 2003 through June 2019. 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 researchers should use BEA data (or FOF, which are identical).[29]

[27]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).

[28]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.

[29]That the TIC S flow data, soon to be discontinued (Federal Register Vol.86, No.104, 2021: https://ticdata.treasury.gov/resource-center/data-chart-center/tic/Documents/frnslt2022(6-2021).pdf), should not be used has been recognized for at least two decades; see Griever, Lee, and Warnock (2001). Warnock and Cleaver (2003) noted significant problems with the TIC data on U.S. bonds. Many of TIC S problems pertain to country attribution and, hence, bilateral flows, but there have also been substantial issues with aggregate flows.

We then turn 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). The BEA series and our implied flows are very similar for the foreign official and foreign private flows, with a material deviation only 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 A4 brings in another source. Starting in 2001 the Federal Reserve's International Finance Division began to use 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)). More recently, since 2012 a new monthly holdings series, the TIC SLT, is available and forms the basis for another internally consistent monthly dataset on positions, flows, and valuation adjustments; see Bertaut and Judson (2014).[30] We call the spliced series - Bertaut and Tryon (2007) data through 2011 and Bertaut and Judson (2014) starting in 2012 - BTBJ (for Bertaut Tryon, Bertaut Judson). For Treasuries the aggregate BTBJ series for private and official foreign investors are currently available starting December 1979; country-level estimates are available starting December 1984. As Figure A4 shows, BTBJ positions are identical to SHL positions (top panel), and BTBJ flows are nearly identical to survey implied flows (bottom panel). For historical data series available at the monthly frequency, the BTBJ data provide a publicly available internally consistent series on positions, flows, and valuation adjustments.[31]

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

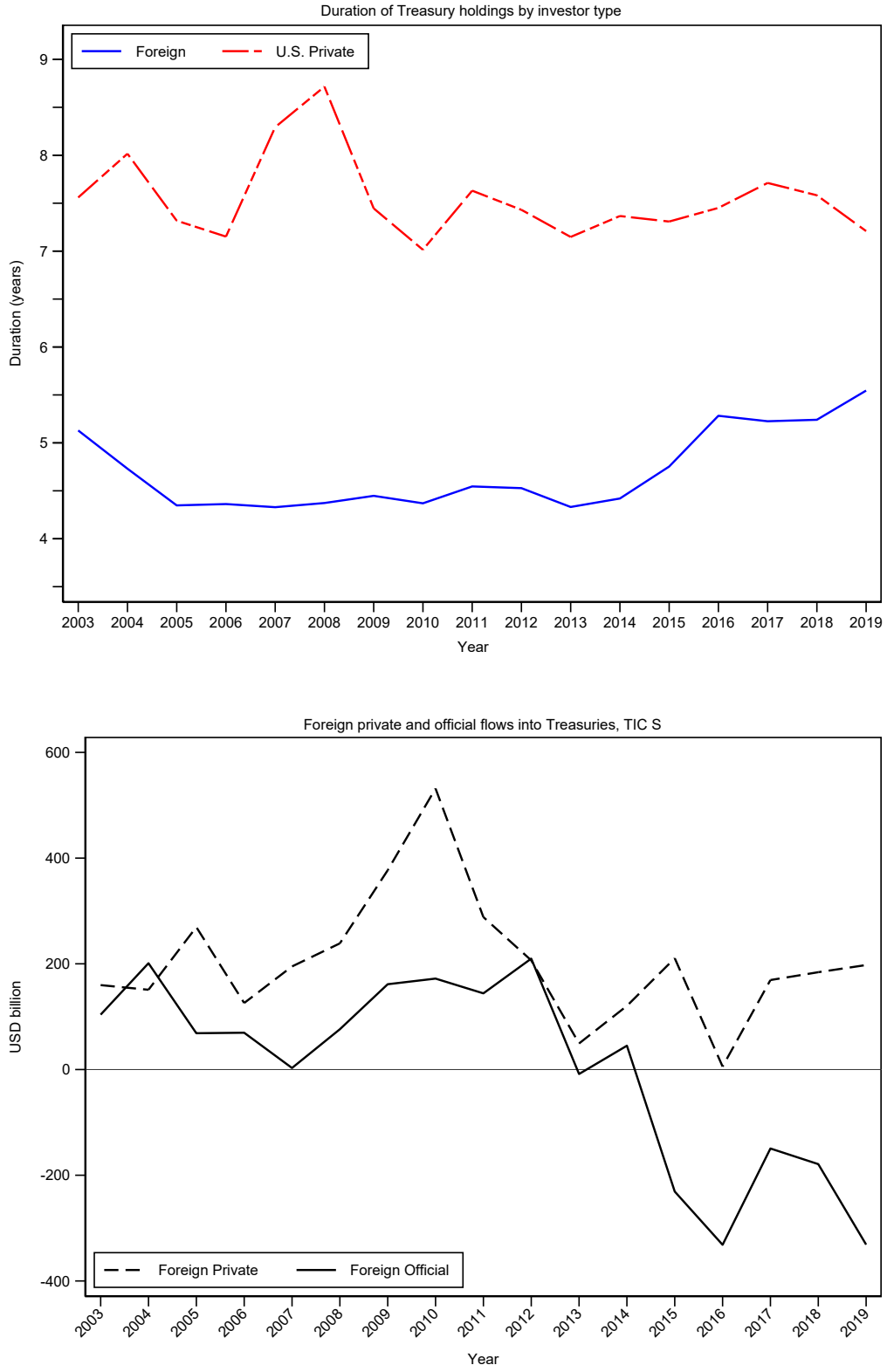
[30]The new SLT data, collected at an aggregate level, are similar (but not identical) to the aggregated security-level SHL annual data and are an additional input to the BEA IIP and FOF published data.

[31]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).

instead should turn to the quarterly BEA data (or unadjusted FOF data). For historical (monthly) time series, researchers should use the Bertaut and Tryon (2007) and Bertaut and Judson (2014) BTBJ data.

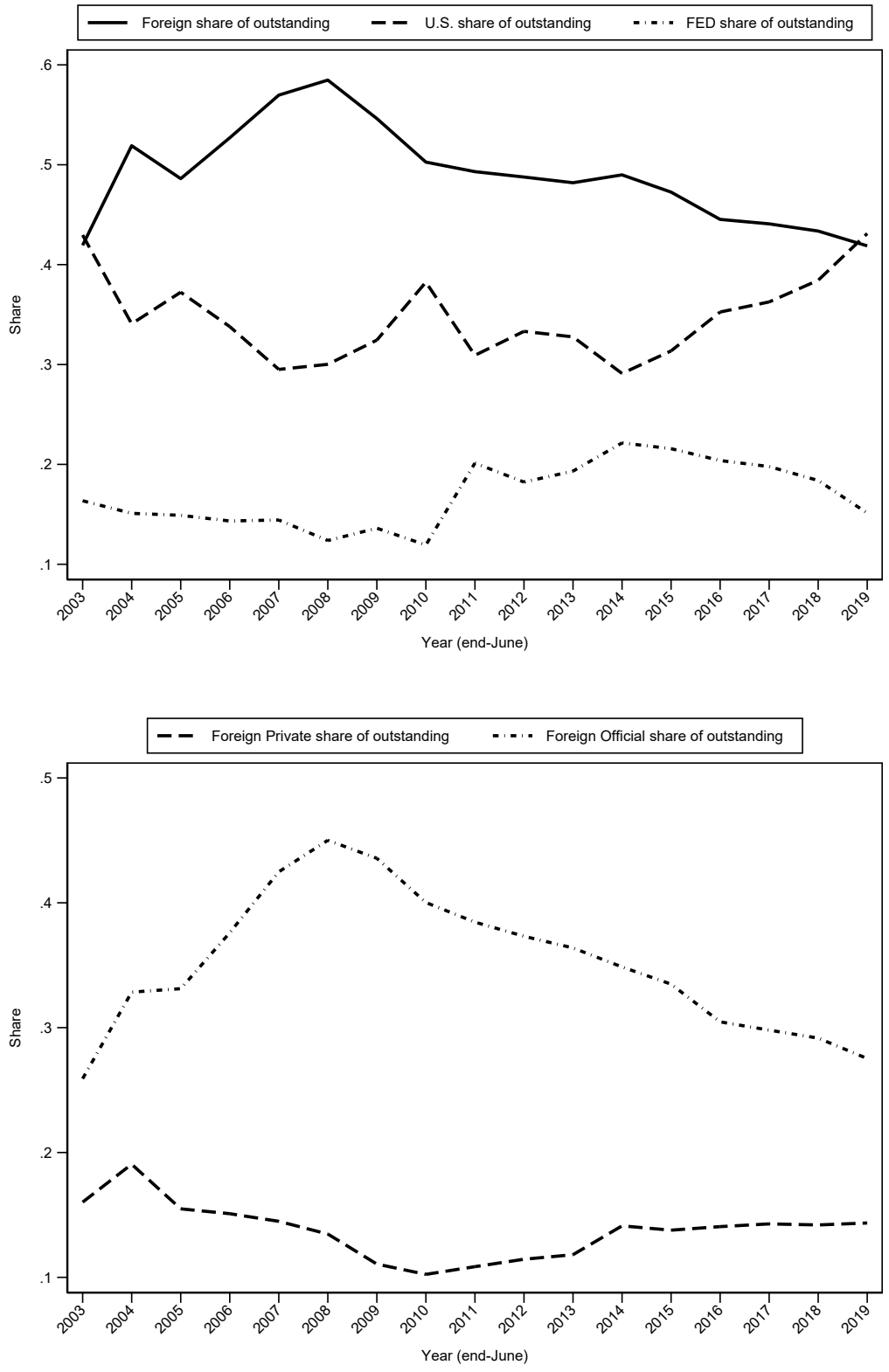
Note though that the quality of BTBJ data may well vary through time, as it is a function of the frequency of the underlying security-level surveys that provide the methodology's important fixed points for the positions. That is, when security-level surveys were conducted approximately every five years (1974 - 2000) the BTBJ 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). In addition, the monthly SLT data (since 2012) might further increase data quality.

Figure 1: Duration and Flows



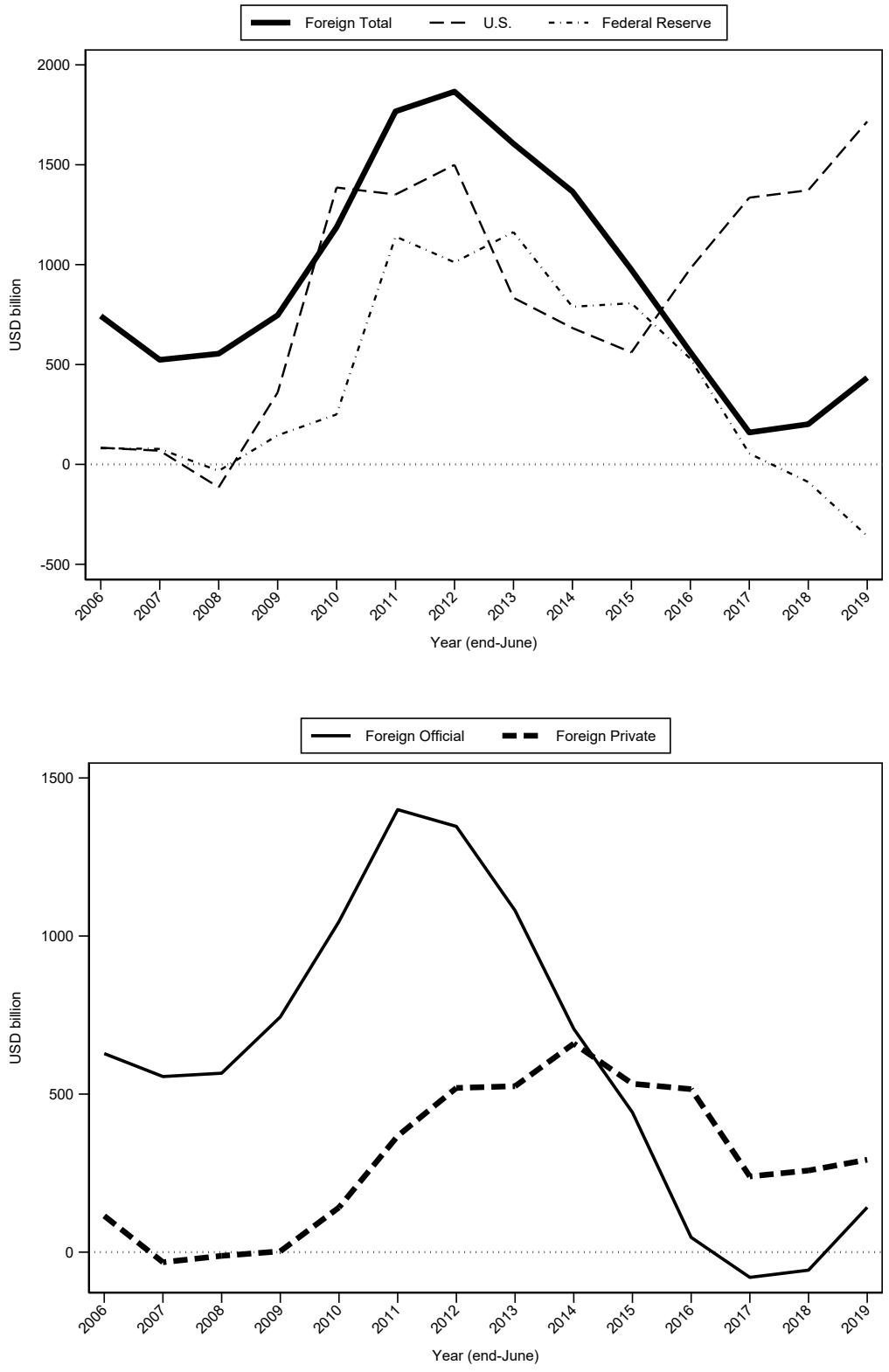
The top figure plots weighted averages of duration for U.S. private and foreign investors. Sample excludes floating rate notes (FRN), Treasury inflation protected securities (TIPS), and securities maturing within one year. The bottom figure shows, using data from the TIC S, the evolution of foreign private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

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



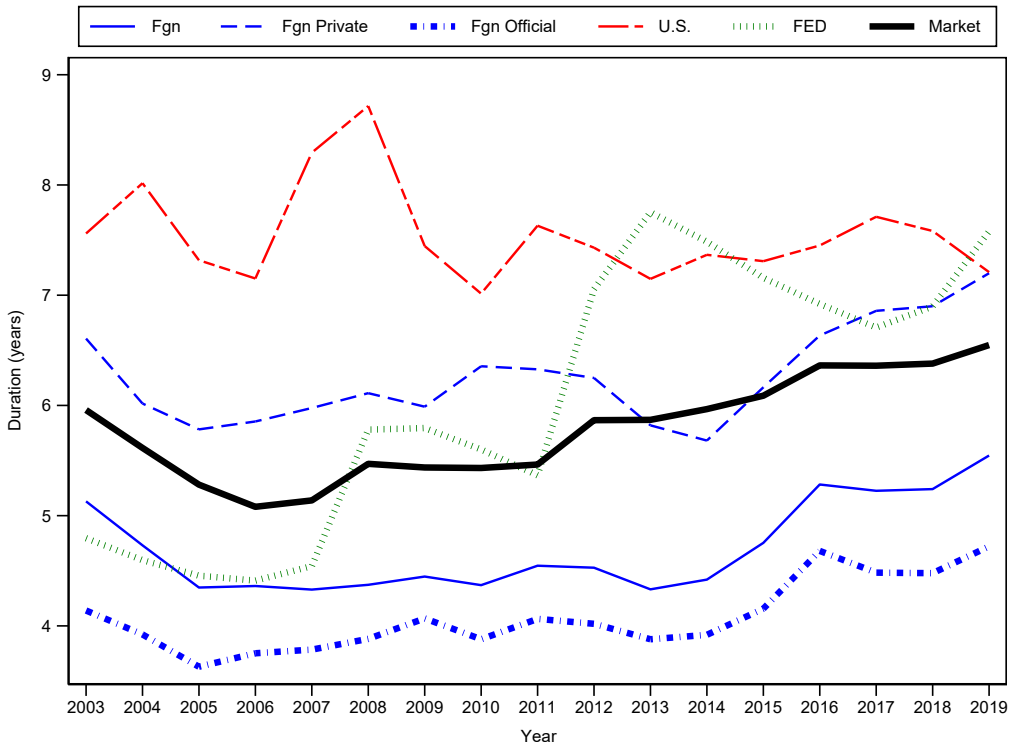
The figures show the share of long-term Treasuries held by U.S. investors, the Fed, and foreigners (split between foreign private and foreign official in the bottom graph).

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



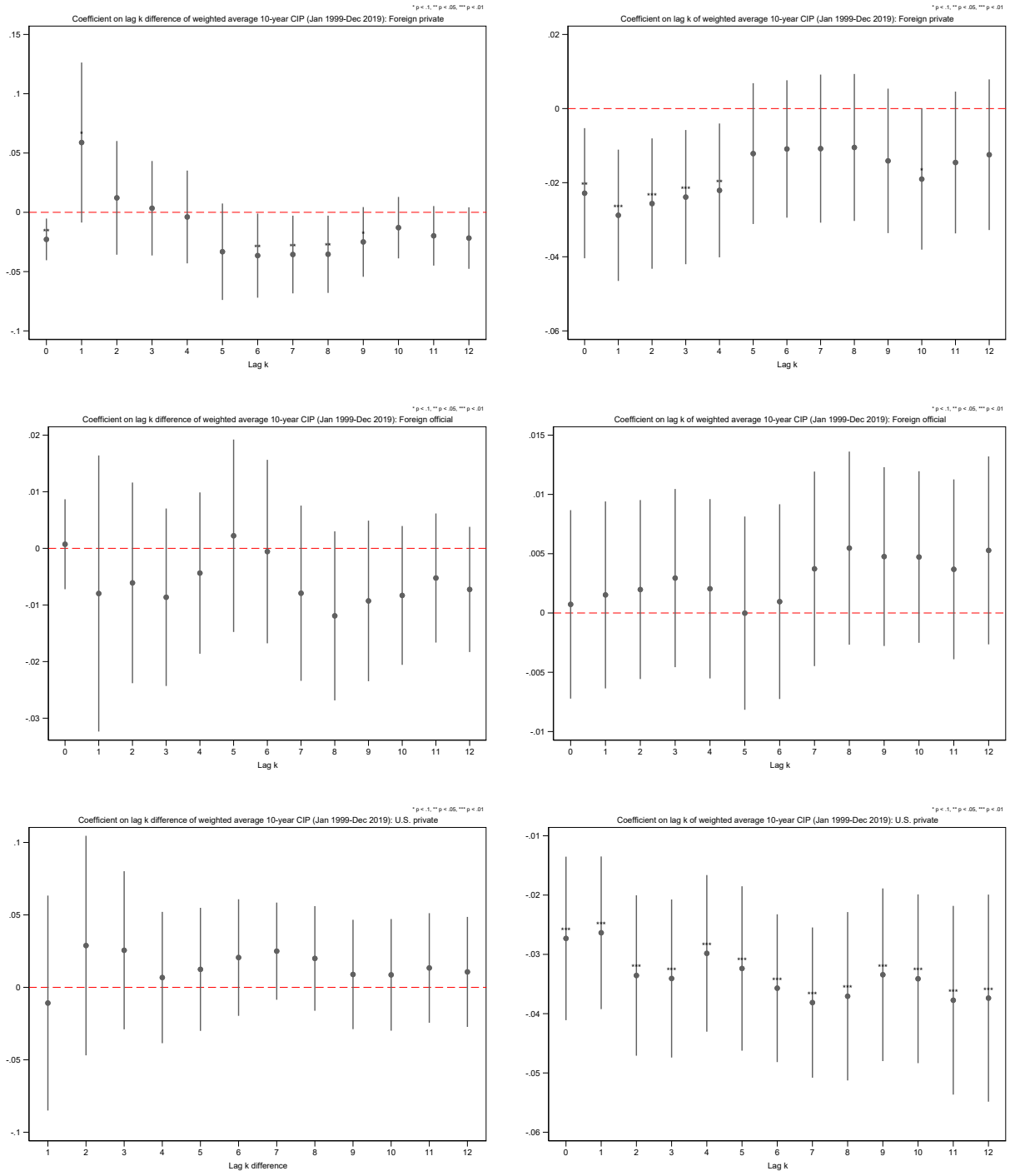
The figures show net purchases (3-year rolling sum using annual end-June to end-June data, in billions of U.S. dollars) of long-term Treasuries by U.S. investors, the Fed, and foreigners (total and, in the bottom graph, foreign private and foreign official).

Figure 4: Duration of Treasury Holdings by Investor Type



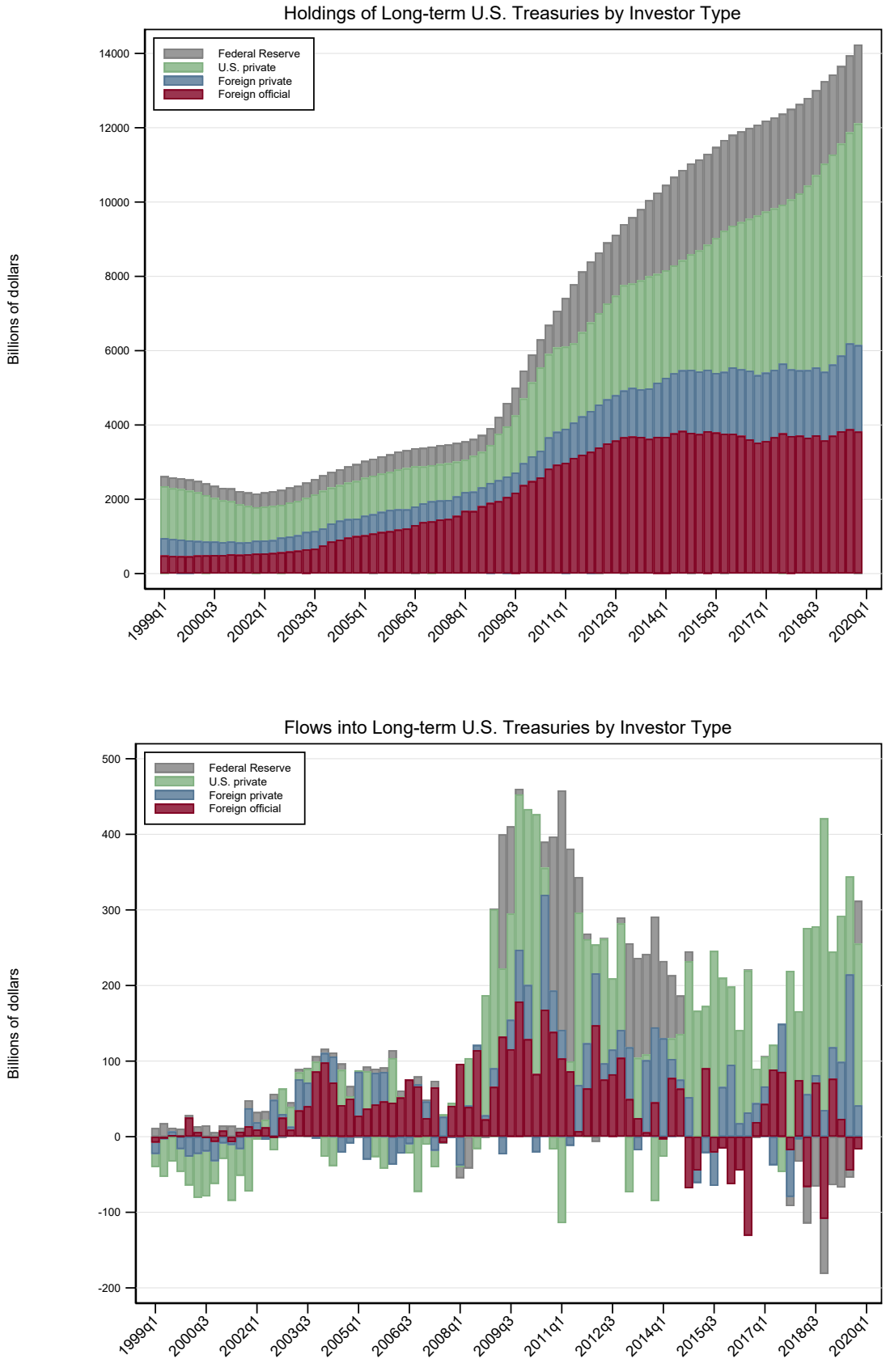
The figure plots weighted averages of duration by investor type. Market refers to all outstanding marketable Treasuries as reported by Treasury Direct. Sample excludes floating rate notes (FRN), Treasury inflation protected securities (TIPS), and securities maturing within one year.

Figure 5: CIP Deviations and Flows into Treasuries



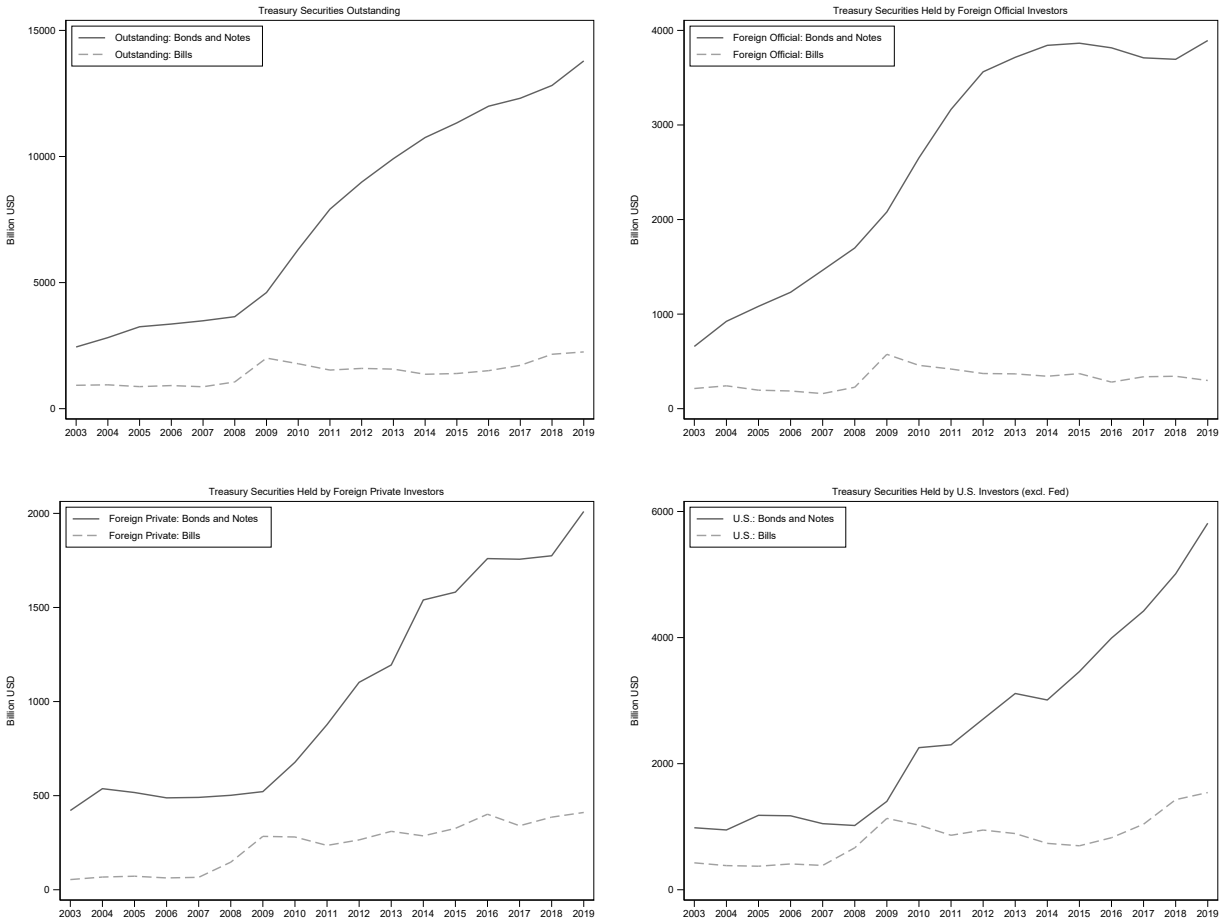
The left figures plot the coefficients on the lag k difference of the G10 10-year CIP deviation from equation 5 in the text for foreign private flows (top panel), foreign official flows (middle panel), and U.S. private flows (bottom panel). The right figures plot the coefficients on the lag k G10 10-year CIP deviation from equation 6 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 6: Treasuries Positions and Flows by Investor Type (1999q1-2019q4)



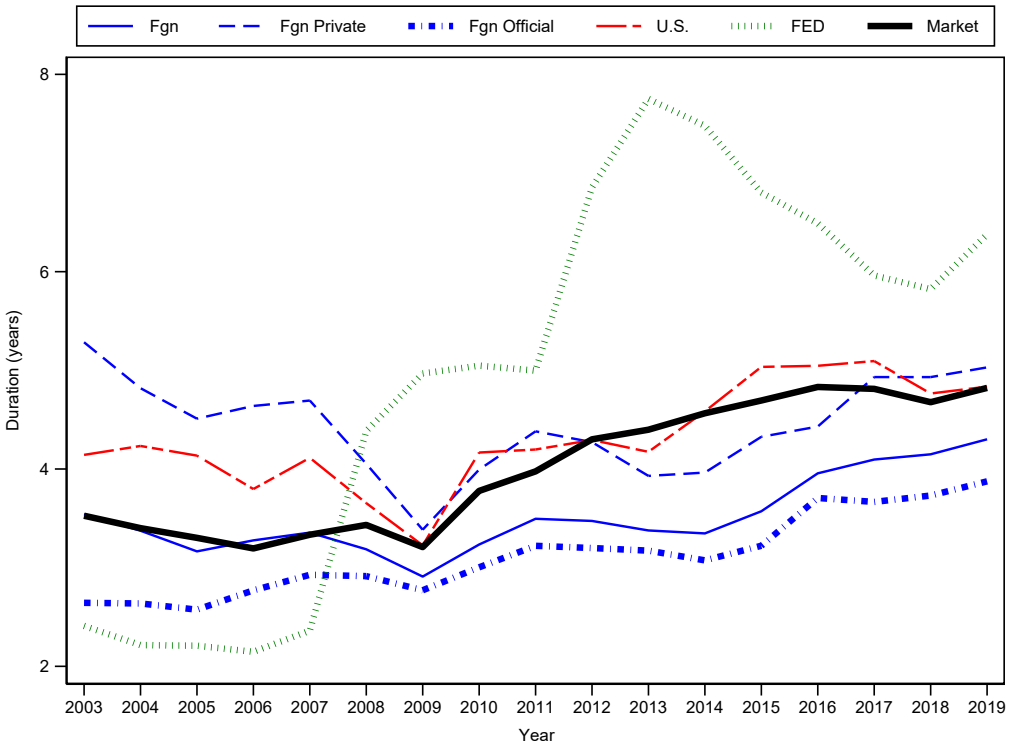
The figure plots quarterly data on holdings (top) and flows (bottom) into long-term Treasury securities (notes and bonds) by investor type for the period 1999q1-2019q4. Source data: BTBJ for foreign flows and positions, SOMA data for the Federal Reserve. U.S. private investors are calculated as a residual using MSPD for Treasury outstanding amounts.

Figure 7: 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 8: 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).

Table 1: Returns on Treasury Bonds and Notes (2003-2019), in percent

	RoR	*Sharpe*	**IRR**	**RoR - IRR**
Market	3.59	*0.86*	2.82	0.77
Fed	3.70	*0.91*	3.97	-0.27
Foreign	3.21	*0.90*	2.62	0.59
Official	3.02	*0.94*	2.67	0.35
Private	3.77	*0.80*	2.47	1.30
U.S. Private	4.34	*0.74*	2.36	1.98

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 excludes floating rate notes (FRN), Treasury inflation protected securities (TIPS), and Treasury bills.

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

Data source	TIC Survey		BTBJ
	market & face value	market value	market value
	security-level	aggregate	aggregate
	(1)	(2)	(3)
Market	2.71	3.15	3.14
Fed	3.93	3.92	3.91
Foreign Investors	2.52	3.22	3.24
Official	2.58	3.29	3.34
Private	2.36	3.05	3.02
U.S. Private	2.23	2.61	2.58

The table shows the internal rate of return (IRR) results for 2003q2-2019q2. 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. Column (2) is identical except coupon payments are calculated by multiplying coupon yields from the ICE BoA Merrill Lynch Treasury index by the aggregate market value of positions. In column (3) we use quarterly BTBJ data for positions and flows. All rates are annualized. Sample excludes Treasury bills.

Table 3: **The Duration of Foreign Investors' Treasury Holdings and Interest Rates**
The table shows panel (country-year) regression results. The dependent variable is the weighted average duration of Treasury bond holdings by foreign private (columns 1-4) and foreign official (columns 5-8) investors. Independent variables include sovereign local currency 10-year bond yields (Sov10y), synthetic dollar sovereign yields (10yrSynSov), and the Synthetic Difference (10yr SynDiff, synthetic sovereign yield minus U.S. Treasury yield). All yields are in changes. Sample excludes Belgium, Ireland, and Luxembourg (BIL). All specifications include country fixed effects. Time fixed effects are included in columns 1 and 5. Standard errors are clustered on country.

	Foreign Private				Foreign Official			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
D.10yr SynDiff	-0.157***	-0.139***			0.005	0.016		
	(0.047)	(0.044)			(0.029)	(0.029)		
D.10yr SynSov			-0.139***				0.012	
			(0.043)				(0.026)	
D.US 10yr			0.142	0.010			-0.043	-0.121
			(0.127)	(0.122)			(0.088)	(0.078)
D.Sov10y				-0.088				0.097*
				(0.080)				(0.055)
Observations	451	451	451	547	445	445	445	532
Adj R-sq	0.35	0.35	0.34	0.34	0.41	0.41	0.41	0.44
Time FE	Yes				Yes			

Table 4: **The Duration of Foreign Investors' Treasury Holdings, Interest Rates, and the Insurance and Pension Fund Sectors**

The table shows panel (country-year) regression results. The dependent variable is the weighted average duration of Treasury bond holdings by foreign private (columns 1-4) and foreign official (columns 5-8) investors. Independent variables include sovereign local currency 10-year bond yields (Sov10y), synthetic dollar sovereign yields (10yrSynSov), the Synthetic Difference (10yr SynDiff, synthetic sovereign yield minus U.S. Treasury yield), and ICPF (an indicator variable that equals one if the size of a country's insurance companies and pension funds sector, measured as the size of the sectors assets relative to total domestic assets, is higher than the sample median). All yields are in changes. Sample excludes Belgium, Ireland, and Luxembourg (BIL). Time fixed effects are included in columns 1 and 5. Standard errors are clustered on country.

	Foreign Private				Foreign Official			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
D.10yr SynDiff	-0.168***	-0.160***			-0.021	0.003		
	(0.029)	(0.020)			(0.027)	(0.020)		
High ICPF=1	0.481	0.467	0.433	1.073*	-0.280	-0.319	-0.322	-0.195
	(0.612)	(0.596)	(0.606)	(0.640)	(0.354)	(0.356)	(0.357)	(0.334)
High ICPF=1 × D.10yr SynDiff	0.162	0.221			0.231	0.226		
	(0.569)	(0.375)			(0.368)	(0.277)		
D.10yr SynSov			-0.149***				-0.004	
			(0.014)				(0.020)	
High ICPF=1 × D.10yr SynSov			0.188				0.223	
			(0.355)				(0.247)	
D.US 10yr			0.262	0.013			-0.080	-0.117
			(0.181)	(0.212)			(0.095)	(0.109)
High ICPF=1 × D.US 10yr			-0.543	-0.184			-0.251	-0.445
			(0.399)	(0.223)			(0.279)	(0.355)
D.Sov10y				-0.184***				0.045
				(0.017)				(0.050)
High ICPF=1 × D.Sov10y				0.078				0.616*
				(0.104)				(0.331)
Observations	254	254	254	288	246	246	246	282
R-sq	0.08	0.02	0.03	0.06	0.07	0.01	0.01	0.03
Time FE	Yes				Yes			

Table 5: Correlations of flows into long-term Treasuries (1999-2019)

	Fed	U.S. Private	Foreign Private	Foreign Official
Fed	1.000			
U.S. Private	-0.220***	1.000		
Foreign Private	0.026	-0.241***	1.000	
Foreign Official	0.201***	-0.155	-0.002	1.000

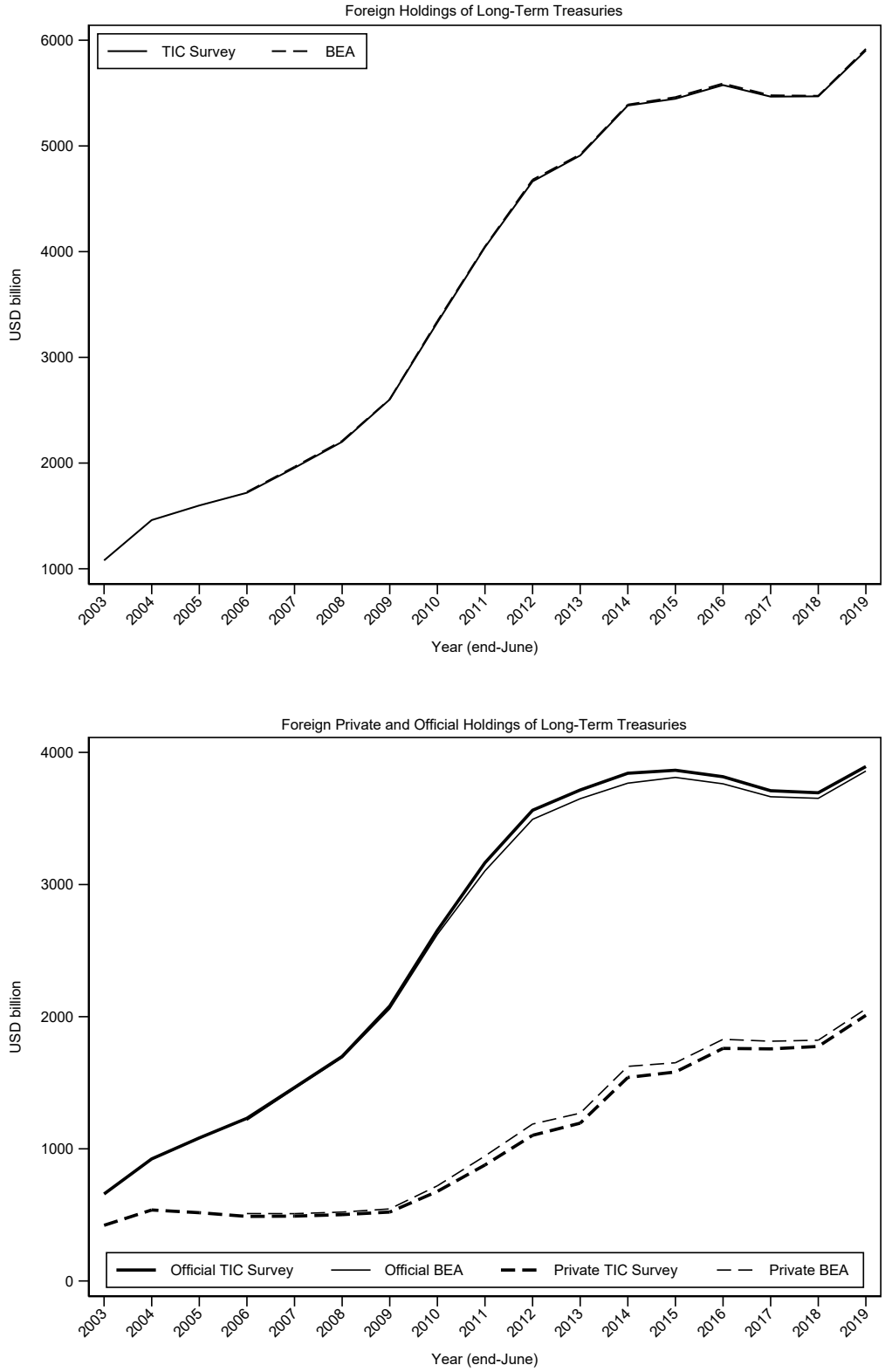
The table shows the paiwise correlations of flows into long-term Treasuries, using monthly data for all investor types.

Table 6: Returns on Treasury Bonds, Notes, and Bills (2003-2019), in percent

	RoR	*Sharpe*	**IRR**	**RoR - IRR**
Market	3.16	*0.94*	2.51	0.65
Fed	3.75	*0.99*	3.89	-0.14
Foreign	2.91	*0.95*	2.37	0.54
Official	2.81	*0.99*	2.46	0.35
Private	3.12	*0.84*	2.13	0.99
U.S. Private	3.43	*0.83*	1.99	1.44

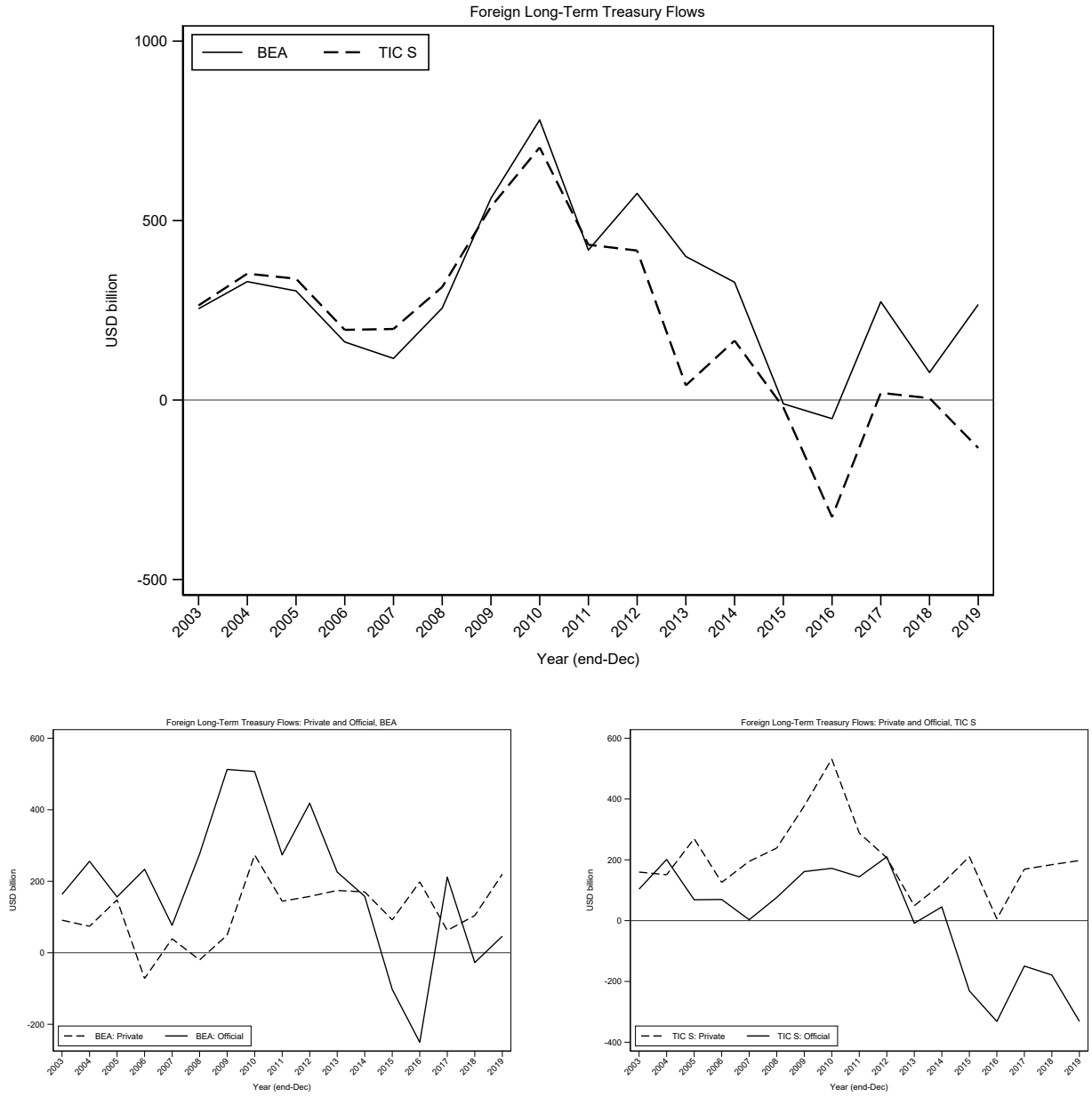
The table shows, for the market (calculated using data on outstanding marketable Treasuries as reported by Treasury Direct) and by investor type, the geometric mean returns (rate of return, or RoR), Sharpe ratios (calculated as geometric mean divided by standard deviation), the internal rate of return (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).

Figure A1: Foreign Holdings of Long-Term Treasuries



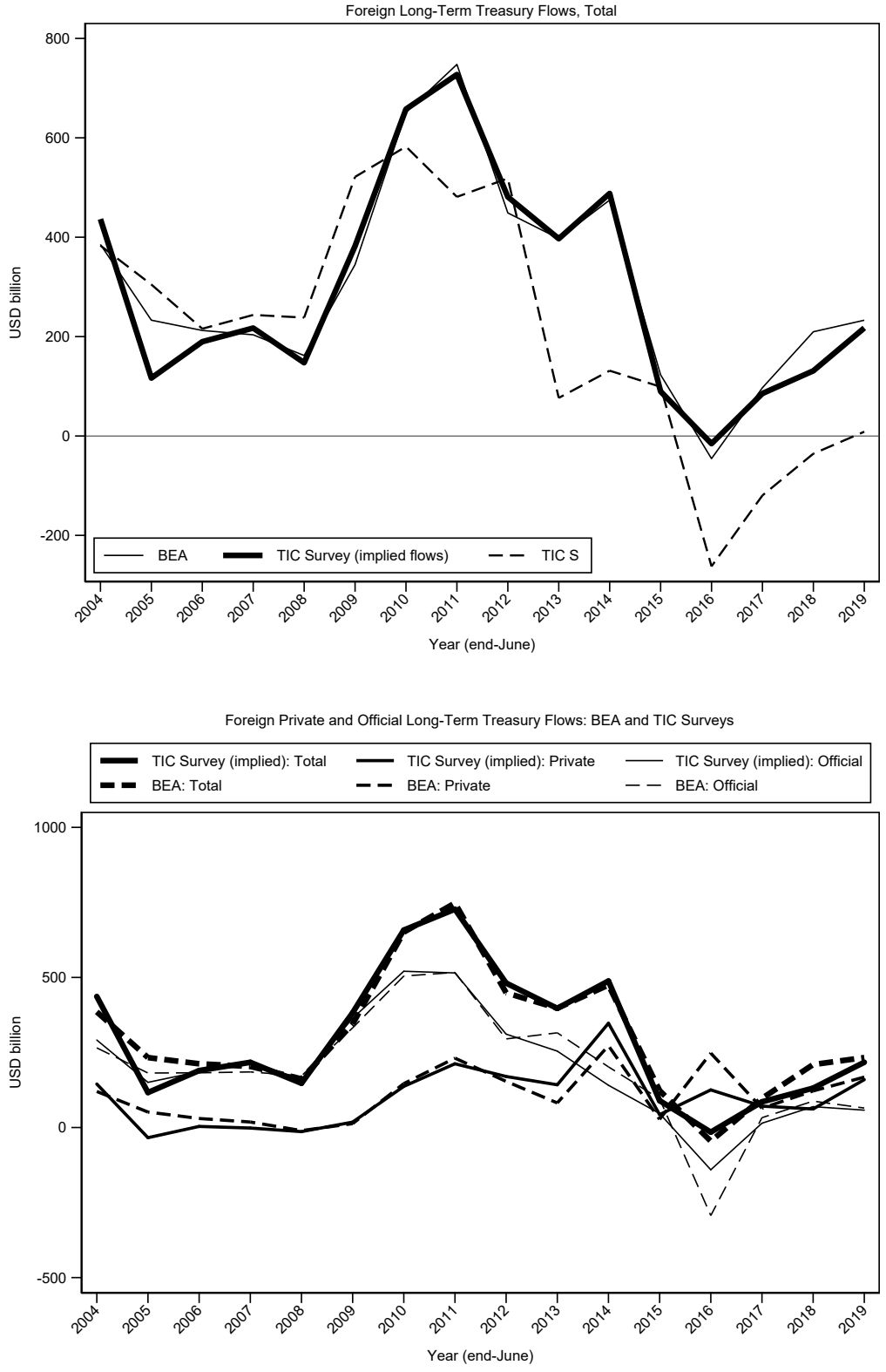
The figure shows, using data from the BEA and TIC surveys, the evolution of foreigners' holdings of U.S. Treasury bonds and notes (annual, in billions of U.S. dollars). The lower graph shows foreign private and foreign official holdings.

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



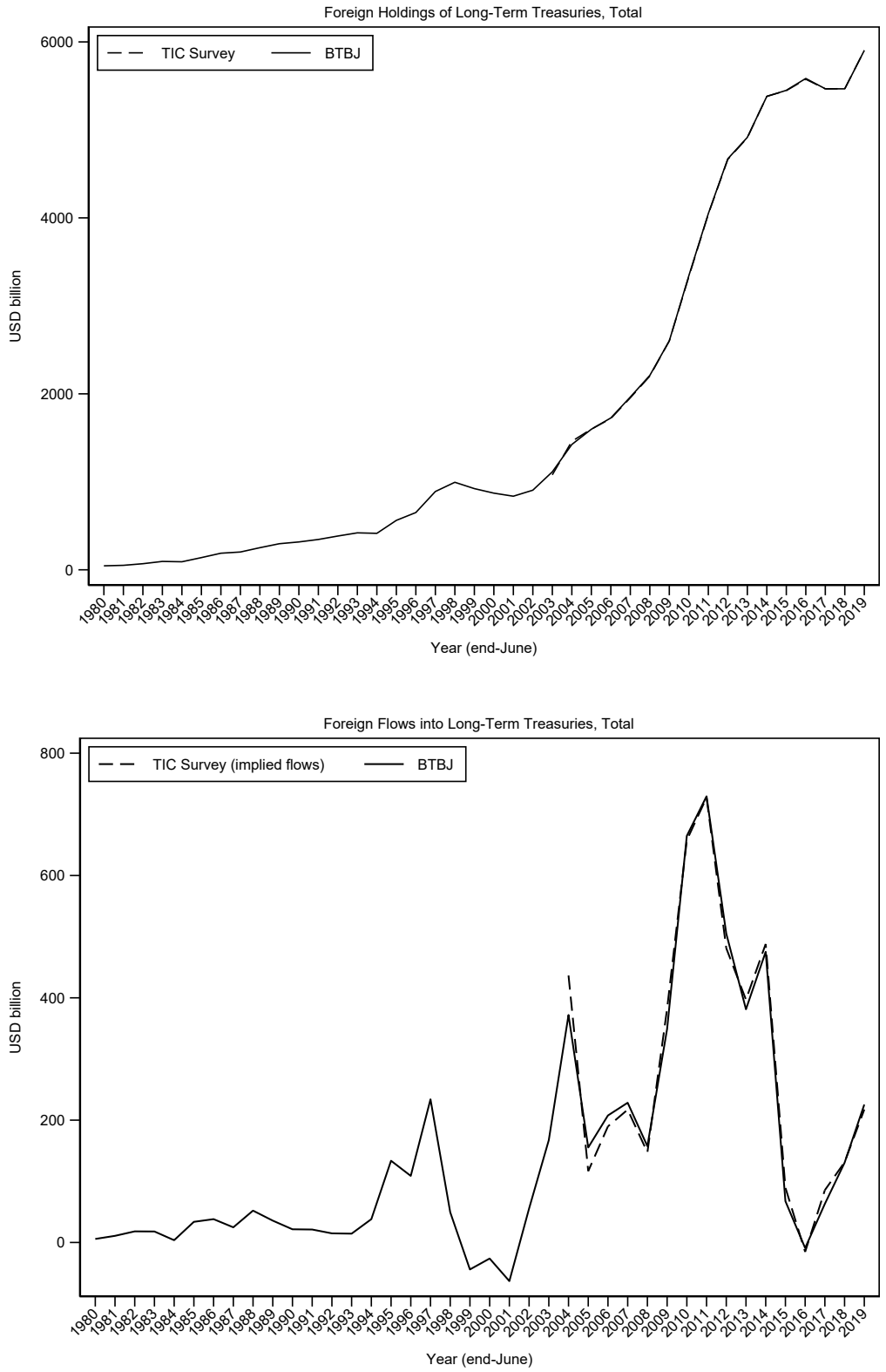
The figure shows, using data from the BEA and TIC S, the evolution of foreign flows into U.S. Treasury bonds and notes (annual, in billions of U.S. dollars). The lower graphs show foreign private and foreign official flows.

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' Holdings and Net Purchases of Long-Term Treasuries



The figure shows, using data from TIC surveys and BTBJ, 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).