The Changing Landscape of Treasury Auctions *

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Abstract

Contemporary literature attributes the temporary drop in secondary prices before a Treasury auction to primary dealers' limited risk-bearing capacity and slow-moving capital. We attribute the temporary price pressure to slow-moving capital, but not primary dealer's limited risk-bearing capacity. We document a decline of more than 45% in the Treasury Inflation-Protected Securities (TIPS) auction amount allocated to primary dealers over the years and uncover empirical evidence inconsistent with dealers being the main contributor to the auction cycle. In contrast, our results suggest strategic trading behavior whereby some direct and indirect bidders deliberately reduce their demand in the days leading to the auction. More specifically, we find that, on average, inflows into inflation-indexed mutual funds before the auction days do not translate into increased demand for the underlying, as opposed to inflows on other days. Our results imply an issuance cost to the US Treasury of over $300 million for issuing TIPS in 2019 alone.

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1. Introduction

Anticipated and repeated shocks (auctions) in the US Treasury market lead to temporary price pressure in the secondary market. Lou et al. (2013) document an inverted V-shaped pattern for secondary Treasury yields around US Treasury auctions. Similarly, related literature documents this pattern in the Euro area and dubs it the "auction cycle" (Beetsma et al., 2016). These results imply an issuance cost to the Treasury on the order of millions of dollars. Therefore, identifying the right cause is an essential first step to tackling this problem. The literature attributes this pattern mainly to the limited risk-bearing capacity of primary dealers[1] and the end investors' imperfect capital mobility. Our evidence for the TIPS market identifies slow-moving capital as the main culprit. We show that this slow-moving capital is likely caused by strategic trading on behalf of a group of investment funds (that are separate from the primary dealers) involved in the auction process. Conceptually, our paper is very similar to Lou et al. (2013) in that we both argue that the auction cycle is caused by different players involved in the Treasury market and slow-moving capital. Our paper can be seen as a more refined explanation of Lou et al. (2013), where we cite the role of Investment Funds involved in the auction process.

We start by documenting the presence of an inverted V-shaped pattern in the TIPS market, and then we proceed by documenting a fact that is self-evident from the data. We document a declining contribution of primary dealers and an increasing contribution of investment funds in TIPS auctions.[2] We find that in 2008, primary dealers (investment funds) alone accounted for about 60.13% (20%) of TIPS sold to the public, whereas they

[1]For a detailed description of limited risk-bearing capacity theory, we encourage the reader to see Lou et al. (2013). To describe briefly, as primary dealers are expected to participate actively in the auction process, they tend to hedge the risk they are about to take in the Treasury auctions by short-selling similar securities in the secondary market.

[2]To check the investors involved in the auction process, we look at the auction allotment data for different investor classes. This data and the respective description of each investor class are available on the US Treasury official website. The description of each asset class can be downloaded from https://home.treasury.gov/data/investor-class-auction-allotments.

accounted for only 15.05% (about 75%) in 2019.[3] Figure 1 shows this decreasing (increasing) contribution of primary dealers (investment funds). Observing this decline, we hypothesize that there should be a decreasing severity of the auction cycle over the years if the dealers' limited risk-bearing capacity theory was the valid one.[4] However, our results reveal no significant decline in the severity of the TIPS auction cycle during this period. To the contrary, for 10-year TIPS, we see that in the latter half of our sample, the magnitude of the auction cycle is 5.75 basis points compared to 5.20 basis points in the earlier sample.

On the other hand, since primary dealers account for more than 50% of the TIPS sold to the public in the earlier part of our sample (2005–2010), how do they hedge themselves against the risk of acquiring Treasury securities at auction? Collin-Dufresne and Goldstein (2002) argue that volatility risk cannot be hedged by Treasury bonds and thus investors go to the derivatives market. We find evidence that dealers are indeed active in the derivatives market, where they short-sell instruments that are similar to TIPS before the auction. More precisely, we find evidence of an auction cycle in the zero-coupon inflation swap (ZCIS) market in the earlier part of our sample that disappears in the latter part. We can see in Table 1 that the auction cycle in the ZCIS (TIPS) market is about 3.99 (6.71) basis points in the full sample and it declines (persists) in significance and magnitude as we move towards the latter part of our sample.

If primary dealers are indeed not responsible for the auction cycle in the TIPS market, then how can we explain its persistence over the years? To answer this question, we look at the demand side of the Lou et al. (2013) explanation: that is, the end investor's imperfect capital mobility. This explanation relates to the idea of slow-moving capital, as highlighted by Duffie (2010).[5] The underlying mechanism in our explanation is that inflation-seeking

[3]Fleming and Rosenberg (2008) document that primary dealers account for 70.9% of Treasury securities sold to the public, on average, by taking data from 576 US Treasury auctions between May 5, 2003, and December 28, 2005.

[4]By "severity" of the auction cycle we mean the difference between the amounts of temporary up and down movements of secondary Treasury yields before and after the auction.

[5]That is, there is slow-moving capital in the financial markets because the investors are not actively trading in the market at all times (Duffie, 2010), there is not enough capital to absorb a large supply shock

investors tend to absorb a large number of TIPS at auction (especially in the latter half of our sample), so it is in their interest to buy the newly issued securities at the highest yield (lowest price) possible.[6] Since the auction is an anticipated event, these investors reduce their demand for the secondary securities before the auction, and thus they drive down prices and hence generate the observed pattern.

Our interpretation of the auction cycle in the TIPS market has several further predictions. First, it implies that if there is a high demand from inflation-seeking investors at auction, then the severity of the auction cycle should decrease. It is because if, to begin with, these investors have a higher demand for TIPS, they will not be able to reduce their demand (in the days leading up to the auction) as much as they would be able to if their demand were low. So, we proceed to check the sensitivity of secondary TIPS yields to the demand by dealers and funds. Our results suggest that the change in the auction day yield is entirely insensitive to the demand by the primary dealers. However, consistent with our prediction, a bid-to-cover ratio one unit higher than the average, of the investment funds, decreases the auction day yield of 5-year (10-year) secondary TIPS by 8.86 (7.70) basis points.

Second, if investors are indeed limiting their demand, this behavior should be apparent either through their net positions or net flows surrounding the auction. To dig more deeply into this implication, we look at the net flows (normalized by fund size) of open-ended inflation-indexed mutual funds before and after the auction. Our results suggest that the 2^{nd} and 3^{rd} terciles of mutual funds experience inflows of 0.42% and 0.23% of the total fund size in the days leading up to the auction. These inflows should create a demand for the underlying (see, for example, Edelen and Warner, 2001; Ben-Rephael et al., 2011). In turn, this demand should lead to a decrease in the severity of the cycle.[7] We find no relationship

(Lou et al., 2013), or the capital might flow out of the illiquid market (Dow et al., 2018).

[6]These investors generally include investment funds, a category which then includes mutual funds, money market funds, hedge funds, and others.

[7]We claim that a positive net flow to the fund should create demand for the underlying. This demand should lead to an increase in price for the underlying and thus should lead to a decrease in yield. Thus decreasing the severity of the auction cycle. Section 6.2.3 provides empirical evidence for this price pressure hypothesis.

between these fund inflows and the auction cycle in the TIPS market. As these inflows do not lead to an increase in demand (capital) in the secondary market, our results hint to the idea that these investors deliberately reduce their demand before the auction.[8]

Our results have public finance implications; though TIPS account for about 10% of total marketable securities, the associated issuing costs are comparable to those of nominal securities.[9] Moreover, Fleckenstein et al. (2014) argue that the Treasury could have saved billions of dollars by issuing nominal securities instead of TIPS. Our results show an additional hidden cost to TIPS. So, the benefit of issuing TIPS should be carefully evaluated. Additionally, our results have future research implications. First, to find out the actual cause of a lack of demand in the TIPS market as the auction cycle is extremely sensitive to the demand by investors. Second, to further investigate this plunge in demand before the auction and study its welfare effects. The insights from this research can help better understand the role of market participants and the way they affect the market during particular events.

In terms of methodology, our paper is closely related to Fleming and Rosenberg (2008), Lou et al. (2013), and Beetsma et al. (2016). In terms of findings, we relate to two main strands of literature. First is the growing literature that studies the price impact of anticipated and predictable trades. We relate most closely to Lou et al. (2013), Beetsma et al. (2016), Bessembinder et al. (2016), Beetsma et al. (2018), and Sigaux (2018). Our paper is consistent with the literature in documenting the presence of an auction cycle in the TIPS secondary market and confirms that indeed capital moves slowly even in the Treasury market. We add to this literature by empirically suggesting that the auction cycle is caused by the strategic trading of investment funds. Regarding the dealers, they have increasingly become mostly active in the derivatives market rather than the secondary Treasury market.[10]

As for the second strand of literature, our findings are closely related to the literature

[8]Simutin (2014) finds that actively managed equity funds with high abnormal cash holdings outperform their low abnormal cash peers by more than 2% per year. This hints to the idea that mutual funds hold cash and try to time the market to reap out the desired returns.

[9]Lou et al. (2013) document a hidden cost of over half a billion dollars for issuing Treasury notes in 2007.

[10]Throughout this paper, we use the terms "primary dealers" and "dealers" interchangeably.

on slow-moving capital. Important papers in this literature include Mitchell et al. (2007), Duffie (2010), Buss et al. (2015), Fuchs et al. (2016), Getmansky et al. (2017), Dow et al. (2018), and Bogousslavsky et al. (2020). This literature mostly gives reasons for the existence of slow-moving capital. We add to this literature by providing empirical evidence for the existence of slow-moving capital in the secondary Treasury market around auctions. The novelty of our results relate to the persistence of slow-moving capital. We empirically suggest the presence of strategic trading whereby investors deliberately limit their demand in the days leading to the auction. Other important papers related to strategic trading include Admanti and Pfleiderer (1991), Brunnermeier and Pedersen (2005), Garcia and Sangiorgi (2011), and Bessembinder et al. (2016).

The rest of the paper is organized as follows. Section 2 provides a brief introduction to the TIPS market and the inflation swap market and gives a primer on the US Treasury auction mechanism. Section 3 describes the data. Section 4 conducts an event study similar to Lou et al. (2013) and documents the presence of the auction cycle in TIPS secondary market. Section 5 provides evidence that primary dealers are not involved in generating the auction cycle. We establish this by verifying three different hypotheses. First, we look at how the auction cycle changes over the years with a decreasing contribution of primary dealers. Second, we look at primary dealers' net weekly positions in TIPS surrounding auction days. And third, we look at the sensitivity of the auction day yield to a change in the demand by primary dealers. Section 6 looks at the auction cycle from the point of view of the slow-moving capital theory. Section 6.2.3 does robustness tests. Section 7 gives implications of our results. Lastly, section 8 summarizes our results and gives concluding remarks. A supplemental appendix available from authors' web pages contains additional material including further robustness checks on our findings.

2. Basic Inflation-Hedging Security Markets

In this section, we provide a brief introduction and a review of the literature for the TIPS market and the inflation-swap market. Furthermore, we describe the mechanism with which the US Treasury conducts TIPS auctions. An informed reader can skip this section and go directly to Section 3, where we list the sources of our data and provide summary statistics.

2.1. TIPS Market and Treasury Auction Mechanism

TIPS are marketable Treasury securities first introduced in the US in 1997. These securities hedge an investor against inflation and are issued for the maturities of 5, 10, and 30 years. TIPS protect against inflation by adjusting the principal with changes in the Consumer Price Index (CPI). That is, with inflation (i.e., a rise in the general price level), their principal increases. They pay semi-annual interest payments, and since that fixed interest rate is tied to the principal, the interest payment adjusts with the changes in inflation. Additionally, at maturity, a TIPS either pays the adjusted principal or the original principal, whichever is greater. So, a TIPS provides investors with some protection against deflation.[11]

There are several arguments in favor of TIPS, particularly in asset allocation where the literature highlights the welfare improvement effects they could entail (see Campbell and Viceira, 2001; Brennan and Xia, 2002; Wachter, 2003; Kothari and Shanken, 2004). Moreover, Campbell et al. (2009) argue inflation-indexed bonds to be a relatively cheap form of debt. Still over the years, we observe that the true benefits of TIPS have not been realized as recent literature documents the presence of illiquidity in the market (Fleming and Krishnan, 2012; Fleckenstein et al., 2014; D'Amico et al., 2018), which is closely associated with the low demand we see in the data. A potential explanation for this low demand is given by Lioui and Tarelli (2019) in the form of an investor who suffers from money illusions.

Regarding public debt, the US Treasury offers various types of securities (Bills, Notes,

[11]Figure D.1 of the Internet Appendix plots the total amount of TIPS outstanding over the years since their issuance. The total amount of TIPS outstanding as of December 2019 is about $1500 billion. Still, this translates to approximately 10% of the total US marketable debt outstanding—a relatively low proportion.

Bonds, TIPS and FRNs) with varying maturities over a particular year through public auctions. For TIPS, the Treasury currently offers maturities of 5, 10, and 30 years. For 5-year TIPS the original issue is in April and October. For 10-year TIPS it is January and July, while for 30-year TIPS it is in February. The 5-year TIPS is auctioned as a reopening in June and December; the 10-year TIPS is auctioned in March, May, September and November, while the 30-year TIPS is auctioned as a reopening in August. So, as a whole, the US Treasury conducts 12 TIPS auctions in a given year.

The US Treasury auction mechanism is single-price auction, which means that the treasury first accepts all the bids at the lowest yield. Once the lowest bids are covered, the Treasury goes to the second lowest yield and accepts all the bids at that yield. This process continues until the full amount of securities needed to be issued is fully covered by all bids. Then, the highest bid is charged to all participants. The participants involved in Treasury auctions include primary dealers, investment funds, foreign and international monetary authorities, among others.

There are two types of bids in US Treasury auctions: competitive and non-competitive. In competitive bids, the participants specify the rate or yield acceptable to them and submit their bids to the Treasury before the closing time specified in the announcement. It is limited to 35% of the offering amount per bidder. Primary dealers, included in the category competitive bidders, are expected to participate in the auction process. Currently there are 24 primary dealers on the Federal Reserve Bank of New York's (hereafter, the Fed) list that are expected to participate in the auction process.[12] In non-competitive bids, the bidder agrees to accept the rate or yield determined at the auction date, and the bids are limited to purchases of $5 million per auction.

Further, the auction process itself involves four stages. The first stage is the announcement where the Treasury lists out the characteristics of the security to be auctioned, the amount to be auctioned and other particularities. Second stage is the bidding, where in-

[12]The names of the registered dealers as of May 2019 are provided in the Internet Appendix.

vestors submit their competitive and non-competitive bids. Third stage is the auction itself and soon after the results of that auction. The final stage is the issuance where the Treasury delivers securities to the winning bidders and charges the price for these securities.[13]

For our analysis, we are mainly interested in TIPS auctions. They follow the same mechanism described above. From January 2005 to December 2019, we see auctions on four different maturities of TIPS (5, 10, 20, and 30 years). Auctions on 20-year maturity TIPS are done until 2009, and then they are replaced by TIPS of 30-year maturity.

2.2. Zero-Coupon Inflation Swap Market

The inflation derivatives market started in the US in the early 2000s, shortly after the inception of TIPS in the late 90s (Kerkhof, 2005). These derivatives hedge an investor against inflation by transferring the inflation risk from one party to another. Since its inception, the growth of the inflation derivatives market has been quite rapid. The annual trading volume for inflation-linked derivatives and swaps has increased from $10 billion in 2004 to more than $40 billion in 2011.[14]

One of the simplest among these inflation-derivatives—and one that is widely used in the literature to infer about market-based measures of inflation expectations—is the zero-coupon inflation swap. With a swap, the "buyer" receives the actual realized inflation (the CPI rate) during the period (the floating rate) and in return pays a fixed rate based on present inflation expectations. This fixed rate (also called the quoted swap rate) is negotiated such that the initial value of entering the swap is zero, and hence there is no cash net flow at the beginning. The net payment is settled at the maturity. The ZCIS market is an OTC market where the market makers are the G14 dealers (Fleming and Sporn, 2013).[15] Fleming and

[13]For information regarding the auction process see the US Department of the Treasury website, Garbade and Ingber (2005) and Gorodnichenko and Ray (2018).
[14]Figure D.2 of the Internet Appendix shows the Annual Trading Volume of Inflation Linked Derivatives over the years.
[15]The G14 dealers are the largest derivatives dealers and include Bank of America, Barclays, BNP Paribas, Citigroup, Credit Suisse, Deutsche Bank, Goldman Sachs, HSBC, JP Morgan Chase, Morgan Stanley, Royal Bank of Scotland, Société Générale, UBS, and Wells Fargo.

Sporn (2013) study the ZCIS market and try to infer its liquidity characteristics by looking at daily transactions completed and volumes traded over the three-month sample period of June 1 to August 31, 2010. Over this sample period, the authors find a low level of activity in the swap market. Still, the authors conclude that the swap market is reasonably liquid. They find that transaction prices are quite close to end-of-day quoted prices.[16]

3. Data and Summary Statistics

We take TIPS auction data from the US Department of Treasury website. For each TIPS auction of 5-, 10-, 20-, and 30-year maturity we meticulously look at its result and take the auction date, the issue date, maturity date, total size of the auction, amount of competitive bids submitted by primary dealers and by direct and indirect bidders, amounts of bids that actually got accepted, the bid-to-cover ratio, and so on.[17]

For 5-year maturity TIPS we have 40 auctions; there are 80 for 10-year, 10 for 20-year, and 28 for 30-year TIPS for our sample starting in January 2005 and ending in December 2019. So, we have 158 auctions in total. The issuing frequency for these TIPS have varied over the years. The 5-year TIPS was issued twice yearly from 2005 till 2010. Since 2011, it has been issued three times a year. Recently, it has been issued four times every year. A better idea is given by looking at the summary statistics in Panel A of Table 2 which gives a clear picture of the frequency of these auctions over our sample period. In addition, Figure 2 provides a visual for the number of auctions in our sample by year.

We get the data for auction allotment by investor class also from the US Department of Treasury website. We take primary dealers' data and their weekly net positions in TIPS from the Federal Reserve Bank of New York website. Again, the sample period is from January 2005 to December 2019. We obtain daily zero-coupon inflation swap rates from

[16]Haubrich et al. (2012) argue that inflation swap rates provide more reliable information on real yields than do inflation-indexed bonds, and these derived yields are more prone to liquidity shocks.

[17]To our knowledge, previous literature has not utilized the data for primary dealers' tendered amount and the auction amount allocated to them.

Bloomberg. The traded maturities are from 1 to 10 years, as well as 12, 15, 20, 25, and 30 years. For our analysis, we mostly use 5, 10, 20, and 30 year swaps. But to check spill-overs in the swap market, we use additional short-term and long-term maturities. We use daily data on US Nominal Treasury yields and US Treasury Inflation-Protected Yields. We use nominal yields and TIPS yields together to test the auction cycle in break-even inflation.[18] Zero-coupon yields and par yields on nominal Treasury bonds and TIPS are constructed by Gürkaynak et al. (2010). Both yield curves are constructed assuming that the instantaneous forward rates follow a Nelson-Siegel-Svensson functional form. The fitting errors are very small, and thus we assume that these yields correspond to the actual yields. In addition to these constructed yields, we also obtain raw TIPS yields from Bloomberg. Again, our sample starts from January 2005 and ends on December 2019. Panel B of Table 2 shows the summary statistics for swap rates, TIPS yields, and break-even inflation rates.

It is clear from Table 2 that the term structures of ZCIS, break-even inflation and TIPS are all upward sloping. Additionally, we see that, on average, the quoted swap rate is always greater than the break-even inflation rate in our data sample. This is attributed to TIPS mispricing (see, for example, Fleckenstein et al., 2014). Moreover, the break-even inflation is more negatively skewed and more leptokurtic in our data as compared with the ZCIS. Furthermore, looking at the distributive properties of TIPS yields obtained from Bloomberg and those constructed through Gürkaynak et al. (2010), it is clear that they are very similar. As an example, the 10-year TIPS yields obtained from Bloomberg (Gürkaynak et al., 2010) have a mean of 0.94% (1.02%) with a standard deviation of 0.88% (0.89%) and a skewness and kurtosis of 0.18 (0.21) and 2.24 (2.37), respectively.

Data for inflation-indexed open-ended mutual funds are obtained from Morningstar. For daily returns, our data set contains 353 surviving and non-surviving mutual funds. For estimated net flows and size data, we have data that are aggregated across asset classes.

[18]The results for this analysis are not shown in the main body of the paper. These are included in the Internet Appendix.

So, we are able to identify 71 unique open-ended mutual funds in this case. Again, to be consistent, we start our data from January 2005 and end on December 2019.

4. Auction Cycle in TIPS Market

In this section, we document the presence of an auction cycle in the TIPS market. To show that there is an inverted V-shaped pattern, as documented for Notes in earlier literature, we proceed by conducting an event-study in the style of Lou et al. (2013). That is, we check whether, on average, the yield on t^{th} day before the auction and t^{th} day after the auction is below or above the average yield on the auction day, with t ranging from 1 to 10. We denote the TIPS yield on the day of auction as $Y(0)$, and the yield on t^{th} day as $Y(t)$. For the sample starting from January 2005 to December 2019, there are 158 auctions on 5-, 10-, 20-, and 30-year TIPS maturities. We conduct our event-study of the impact of an n-year TIPS auction on an n-year TIPS maturity. The results shown in Figure 3 for 10-year TIPS are consistent with the literature. That is, we see an inverted V-shaped pattern in on-the-run (soon-to-be off-the-run) TIPS yields. The yields start to increase on the 10^{th} day before the auction, reach a peak on the auction day, and decline afterwards.

The inverted V-shaped pattern is also consistent with 5- and 30-year maturity TIPS and implies huge costs to the US Treasury.[19] Table 3 gives an estimate of these costs. The setup is almost identical to Lou et al. (2013). We look at the average $\bar{Y}(t)$ of the yields of an n-year TIPS t days before and after an auction, relative to the yield $Y(0)$ at the auction

[19]To check if the price decline before the TIPS auction is indeed correlated with the price bounce back, we did two empirical analyses. Our results show that the price decline and the reversion afterwards are definitely correlated. For the first empirical analysis, we find a correlation among all maturities of TIPS' auctions, and for the second, the methodology and results have been added in the Table E.8. of the Online Appendix. We thank an anonymous reviewer for pointing out this concern and now the analyses give more credence to our theory.

day. Then we check the average $Y(0) - \bar{Y}(t)$ over all TIPS auctions in our sample.[20,21] The results from Panel A of Table 3 suggest that, on average, the yield at the day of the auction is higher than the yields before or after the auction. Our results imply, based on the yield difference at $t = 5$, a cost of about \$300 million for TIPS issued in 2019 alone. This cost is comparable to what Lou et al. (2013) find for Treasury notes, where the Treasury incurred a cost of around \$690 million for all notes issued in 2007. So, the US Treasury incurs a huge cost while issuing Treasury securities, and thus identifying proper actors is vital if a solution is to be found to control this auction cycle.

5. Primary Dealers and TIPS Auction Cycle

In this section, we provide empirical evidence that primary dealers are not responsible for the presence of the TIPS auction cycle. We show this in three different ways. First, we see a declining participation of primary dealers in the TIPS auctions associated with no significant decline in the TIPS auction cycle. Second, we look at dealers' weekly net positions in TIPS before and after the auction and find no significant change in those positions. Lastly, we look at the demand of primary dealers (proxied by their bid-to-cover ratio) and see no correlation with the auction cycle. After providing empirical evidence that primary dealers may not be contributing to the auction cycle, we show that they are primarily active in the OTC derivatives market.

[20] In addition to this analysis, we also check the average over only auctions on the same maturity TIPS, in order to see the effect of auctions of a given n-year TIPS on the same n-year on-the-run (soon-to-be off-the-run) TIPS yields (where n = 5, 10, and 30). We find that the yield difference is higher and significant. So, here we report conservative estimates of the issuance cost. The results for the effect of an n-year TIPS auction on TIPS yields of the same maturity are shown in the Internet Appendix. We report the analysis of the effect of any TIPS auction on a specific n-year maturity TIPS yields, first to increase our sample size. Next, we find spill-over effects of an n-year maturity TIPS auction on TIPS yields for other maturities, so our estimates are justified by including all TIPS auctions.

[21] The analysis in Table 3 is performed using the par equivalent yields based on Gürkaynak et al. (2010). We also perform the same analysis using raw yields taken from Bloomberg. Our results are consistent.

5.1. Declining Contribution in Auctions

The US Treasury provides results of each auction soon after the auction has been conducted. These results include the amounts that are tendered by as well as allocated to primary dealers, direct bidders, and indirect bidders. This particular breakdown has been provided within the auctions' results since 2008. Before 2008, this breakdown of amount allocated to different bidders was provided separately. We take the results for each maturity of TIPS auctions from the years 2005 to 2019 and meticulously take out the amounts that are tendered by and allocated to the primary dealers. Then we sum those amounts by year and plot the results in Figure 4.[22]

The line at the top in Figure 4 shows how much (by percentage) of the total tendered amount for an auction is tendered by the dealers. Similarly, the line below represents how much of the entire auction amount is allocated to those dealers. The results show a declining contribution of primary dealers, both in the amount they tender and in the amount that is allocated to them.[23] More specifically, we see that primary dealers went from absorbing about 60% of the total auction amount in 2008 to almost 15% at the end of 2019. Similarly, their bidding also declined from a height of 72% in 2008 to about 55% at the end of 2019.[24]

On the other hand, if primary dealers are the main culprits in generating the auction cycle, then, over the years, there should be an associated impact on the TIPS auction cycle. To see if we observe this in the data, we take the post-recession period and divide our sample in two sub-samples. The first sample spans over the period 2010–2014 and the second spans

[22] In addition to summing the primary dealers' amounts tendered and allocated for all maturities, we analyze the trend for each particular maturity of TIPS auction, and the results are very similar—meaning that we get a declining contribution in terms of amounts tendered and allocated for all 5-, 10- and 30-year TIPS maturities.

[23] This particular declining trend may be a result of regulations put in place after the Great Recession to furnish banks with adequate capital buffer. See Adrian et al. (2017)

[24] Till 2008, our results are similar to Fleming and Rosenberg (2008). Using data available from 2003 to 2007 the author shows that on average primary dealers acquire an average 71% share of Treasury issues sold at auction for their own account. But after 2008, at least for TIPS, our results point in a different direction.

over the period 2015–2019. Then, we run the following regression:[25]

$$\Delta TIPS_t^m = d_0 + \sum_{l=9}^{-10} \alpha_l AUC_{t+l} + controls + \nu_t, \tag{1}$$

where $\Delta TIPS_t^m$ is the change in the m-year maturity TIPS yield at time t, AUC_{t+l} is a dummy variable that indicates whether or not, on the specific date $t+l$, there is a TIPS auction (maturity of 5, 10, or 30 years), and where l represents the lead or lag relative to the auction date. Meanwhile, $l < 0$ represents l days after the auction and $l \geq 0$ represents l days before the auction. The variable *controls* contains dummies for Nominal Treasury Auctions for maturities ranging from 1 month to 30-year. Lastly, d_0 is the drift coefficient, and ν_t is the error term.

In equation (1), we expect that $\sum_{l=9}^{0} \alpha_l > 0$ and $\sum_{l=-1}^{-10} \alpha_l < 0$ as the literature documents the presence of an inverted V-shaped pattern in yields surrounding the auction. Therefore, we define $S^{TIPS}(\alpha) = \left(\sum_{l=9}^{0} \alpha_l\right) - \left(\sum_{l=-1}^{-10} \alpha_l\right)$ to be the severity of the auction cycle in TIPS market. So, to check for the presence of the auction cycle, we do an F-test with the following hypothesis:

$$H_0 : S^{TIPS}(\alpha) = 0.$$

As we expect that coefficients with $l < 0$ will have a negative value and coefficients with $l > 0$ (in anticipation of the upcoming auction) will have a positive value, by checking if the above hypothesis holds, we are testing the presence of a full cycle of temporary up and down movements in yields.

The higher the magnitude of $S^{TIPS}(\alpha)$, the more severe the cycle is, since a high magnitude indicates a more pronounced inverted V-shaped pattern. For our analysis, we look at the 5- and 10-year TIPS in the right-hand-side of equation (1) since these are traded more frequently (Fleming and Krishnan, 2012), and we include the auctions from 2010 to 2019.

[25]This regression is in the fashion of Beetsma et al. (2016), where the authors use this analysis to check the presence of an auction cycle in Italian and German bond markets.

We do this for two main reasons. First, because we see that primary dealers' contribution in the auction starts declining after 2010. Second, because we want to divide our sample equally with about 60 auctions in both sample periods. The results are shown in Table 4.

The results from Table 4 indicate that the cycle is less pronounced in the 5-year maturity TIPS (decreases from 7.33 bps in the earlier part to 6.02 bps in the latter part) but actually increases in severity in the 10-year maturity TIPS (increases from 5.20 bps in the earlier part to 5.75 bps in the latter part). If primary dealers are short-selling in the secondary market before an auction, then we would expect that with their decreasing participation there would be less short-selling and thus a less severe auction cycle. The results from 10-year TIPS auctions seem to contradict this point. Additionally, the decrease in 5-year TIPS is not as significant as the decrease in dealers' participation over the years.[26]

5.2. Weekly Positions in TIPS

To further probe into the role of primary dealers during TIPS auctions, we look at their weekly change in net positions in TIPS surrounding auction days. Our main motivation for looking into the change in net positions of primary dealers around auctions is to check whether their net positions increase or decrease surrounding the days of the auction. An increasing (decreasing) position before the auction would indicate that primary dealers are buying (selling) government securities before the auction day. The weekly net positions data are available from the New York Fed's website and are provided with a one-week lag.

To better visualize how the weekly data are distributed around auctions, we plot Figure 5, which shows the distribution of data around 10-year maturity TIPS auctions. Figure 5 plots the number of business days between the available data of weekly net positions and TIPS auctions. The horizontal line represents the day of the auction, and the vertical dots represent the primary dealers' weekly data dates. The distance between the horizontal line and the dots captures the number of business days when the weekly net positions data are

[26]This point is further explored in Section 5.4.

available with respect to the auction.

From Figure 5 it is clear that most of the positions data are available one business day prior and four business days after the auction.[27] Using this information, we first provide summary statistics of dealers' net positions surrounding auctions in Table 5. Since positions data are available on a weekly basis, we report dealers' net positions one and six business days before the auction and four and nine business days after the auction. Second, we run regressions to check the effects of TIPS issuance on dealers' net positions in Table 6.

Overall, the results from Table 5 suggest that, on average, primary dealers increase their positions in TIPS in the days leading up to the auction day. For 10-year TIPS, we see that dealers' net positions in TIPS increase from about \$3.87 Billion six days before to the auction to almost \$5.68 Billion one day before the auction. In all of our samples, this pattern holds true. After the auction, in general, we see a decreasing trend in net positions. In other words, the statistics seem to imply that primary dealers have a higher demand for TIPS before the auction and a decreasing demand afterwards.

To check more robustly that it is indeed the issuance of TIPS (the auction) that is making the primary dealers increase their net positions, we regress weekly changes in the net positions of primary dealers on the size of TIPS issuance with several control variables.[28] We run the following regression:

$$\begin{aligned} \Delta WNP_t = \alpha_0 + \beta_1(AUC_{t-1} \times Size_{t-1}) + \beta_2(AUC_t \times Size_t) \\ + \beta_3(AUC_{t+1} \times Size_{t+1}) + controls + \epsilon_t, \end{aligned} \tag{2}$$

where ΔWNP_t is the change in dealers' net positions in TIPS in week t, AUC_t is an indicator variable that takes the value 1 if there is an auction in week t, in which case $Size_t$ corresponds to the size of that particular auction, and AUC_t takes the value 0 otherwise, in which case

[27] We plot the same figure for 5-year and 30-year TIPS auctions and find the same pattern.

[28] This analysis is very similar to the regression of Fleming and Rosenberg (2008), wherein the authors regress weekly changes in dealers' net positions in Treasury Bills and Coupons on Treasury issuance and redemption. The authors' results, especially for coupon positions, are similar to ours. But in our analysis, the variable Effect of same week's issuance includes the change in net positions of primary dealers one day before the auction from a week before. It is explained in detail in Table 6.

$Size_t$ is equal to zero. So, if AUC_t indicates if there is an auction in the same week then AUC_{t-1} indicates if there is an auction a week before, and AUC_{t+1} indicates if there is an auction a week ahead of the net positions data.

Notice that the dependent variable in the regression (2) is not the total exposure to TIPS, since primary dealers can have a synthetic exposure to TIPS by combining Nominal securities and inflation swaps. As we do not have data for dealers' positions in the inflation swap market, we just run regression with a partial exposure to TIPS.[29]

As reported in Table 6, if there is an auction on TIPS, then primary dealers' net positions increase substantially in response to that auction. The coefficients with the issuance variables are interpreted as the average change in dealers' net position in relation to the size of the auction. For the full sample, we see that for a $1 billion issuance of TIPS (irrespective of maturity), primary dealers increase their positions by $158 million.[30] And this explains more than a quarter of the total change in dealers' net positions.[31] We find similar results for the issuance variables in our sub-sample that starts from 2012, but there, the percentage of change explained is more than one-third. Since primary dealers are buying before the auction, it seems that they are absorbing part of the supply as they are the market makers and one of their duties is to create reasonable market for their customers.[32]

Additionally, looking at the control variables suggest that for the full sample we do not have anything significant, but for the later sample, we see a positive and significant relationship of primary dealers' change in net position with change in Federal Reserve Holdings. The coefficient implies that for a $1 billion increase (decrease) in Federal Reserve Holdings we see an increase (decrease) of $439 million in primary dealers' net positions. Fleming

[29]We thank the anonymous referee for highlighting this point.

[30]In addition to starting our sample from 2012, we also start from 2010, 2011, 2013, and so on. The results show a declining trend in TIPS net positions for the same week TIPS issuance.

[31]We also estimate the models without control variables, and then the percentage of explained variation for the full sample is 18%, while that for the sample starting in 2012 is about 38%.

[32]The charter for the Administration of Relationships with primary dealers posted on the Federal Reserve Bank of New York states, "Primary dealers are required to participate in all auctions of U.S. government debt and to make reasonable markets for the New York Fed when it transacts on behalf of its foreign official account-holders," posted at https://www.newyorkfed.org/markets/pridealers˙policies.html

and Rosenberg (2008) find a similar result in relation to dealers' Treasury Bills and Coupon Bonds positions. The result is somewhat counter-intuitive, since we would expect that if there is an increase in Federal Reserve Holdings, there should be a decrease in dealers' net positions, as they would make the market for Fed. Apart from that, we find no other control variable significant:

From this particular analysis we conclude that primary dealers are not short-selling in the TIPS secondary market before an auction. Rather, their positions in TIPS are increasing leading up to the auction day. Combining these results with the fact that primary dealers have a decreasing participation in TIPS auctions over the years with no significant drop in the auction cycle tells us that primary dealers are not the major contributor in the auction cycle. In the next sub-section, we find evidence that dealers are mainly active in the OTC derivatives market.

5.3. Impact of Dealers' Demand

Beetsma et al. (2018) show that a more successful auction (as captured by higher bid-to-cover ratio) of Euro area public debt has the opposite effect from that of the auction on secondary market yields. That is, as an upcoming auction leads to an increase in yield, a more successful auction leads to a decrease in yield in the secondary market. Therefore, the effect is dampened, and so is the implied issuance cost associated with it. The authors associate this effect with the limited risk-bearing capacity of dealers. Since they have a higher demand for to-be-auctioned securities, they have the ability to absorb more, thus leading to less short-selling in the secondary market and hence a less severe auction cycle.

One potential concern with this approach is that the bid-to-cover ratio includes all the tendered bids by primary dealers, direct bidders, and indirect bidders. To overcome this problem, we look only at primary dealers' demand for the auctioned securities. Since the US Treasury details the amount that is tendered by dealers separately, we are able to disentangle their particular demand. More specifically, we look at the total amount dealers tender relative to the size of each auction in our sample period. A higher bid-to-size, relative to the sample average, would imply a higher demand by the dealers. The regression we run has the following specification:

$$\Delta TIPS_t^m = \beta_0 + AUC_t(\beta_1 + \beta_2 \widetilde{BC}_t) + controls + \epsilon_t, \tag{3}$$

where $\Delta TIPS_t^m$ is the change in the m-year maturity TIPS yield on day t, AUC_t is a dummy variable indicating whether there is an auction on the specified date, *controls* contains dummies for Nominal Treasury Auctions for maturities ranging from 1 month to 30-year, and $\widetilde{BC}_t$ is the bid-to-cover ratio of primary dealers relative to the sample average. We look at daily changes in yield to be consistent with the literature (See Beetsma et al., 2018).

Table 7 clearly shows that generally the coefficients on the Auction Dummy variable are positive and significant, implying that an upcoming auction leads to an increase in yield in the secondary market. As an example, when there is an auction on any maturity TIPS, the yield of 5-year TIPS increase, on average, by 1.38 basis points on the auction day. But the coefficients on the bid-to-cover ratio for primary dealers are insignificant throughout our sample. The results show that a higher-than-average (lower-than-average) demand for TIPS securities (over our sample period) by the primary dealers has no impact on TIPS yields in the secondary market. Our above empirical analysis indicates that primary dealers are not short-selling on net in the secondary TIPS market before the auction, or if they are, then it is not significant enough to have an impact on the price of these securities.[33]

5.4. Primary Dealers and the Derivatives Market

Our previous results do not validate the theory that primary dealers significantly short-sell securities before an auction and hence contribute to the appearance of the auction cycle.

[33]The analysis in Table 7 is done by checking the effect of a TIPS auction of any maturity on a TIPS of a specific maturity in the secondary market. So, here our analysis assumes spill-over effects. As for robustness, we also analyze the effect of an auction of an n-year maturity TIPS on an n-year TIPS in the secondary market. The results remain consistent with no significance on the bid-to-cover ratio variable of the dealers. In addition, we also do the same analysis using raw TIPS yields from Bloomberg, and again we find no impact of dealers' demand, as proxied by their bid-to-cover ratio.

On the other hand, since primary dealers are obligated to participate in the auction—and until 2008 they took almost 60% of the total auction amount for their own accounts—they take pure inventory risk (see, for example, Stoll, 1979; Ho and Stoll, 1981; O'Hara and Oldfield, 1986). To hedge this risk, dealers can sell TIPS prior to the auction, sell after the auction in the secondary market, or take off-setting positions in the derivatives market (Fleming and Rosenberg, 2008).[34] Since our results do not show evidence for the first two scenarios, we postulate that primary dealers must be active in the derivatives market.

To show that primary dealers are indeed active in the derivatives market, we take one of the simplest derivatives that can be substituted for TIPS to hedge the same underlying risk (i.e. uncertainty regarding future inflation). We use the ZCIS, and in the two sub-sections that follow, we first establish the presence of an auction cycle in the swap market, and then show that this auction cycle decreases in severity, over the years, with the decrease in the participation rate of primary dealers in the TIPS auctions.[35]

5.4.1. Auction Cycle in the Swap Market

To show that there is an auction cycle in the inflation swap market, we proceed by conducting an event-study like Lou et al. (2013). That is, we check whether, on average, the quoted rates t^{th} day before the auction and t^{th} day after the auction are below or above the average quoted rate on the auction day, with t ranging from -10 to +10. Let us denote the swap rate at the auction day as $Y(0)$ and the rate on the t^{th} day relative to the auction day as $Y(t)$. For the sample starting from January 2005 to December 2019, there are 158 auctions on which we conduct our event study. Panel A of Figure 6 shows the results of this event-study where a V-shaped pattern in the inflation swap market can easily be seen. We see that for an n-year swap, the quoted rate on average drops starting 10 days before the auction, reaches the lowest level on the auction day, and recovers thereafter.

[34] For theoretical explanations, see Sigaux (2018) and Vayanos and Woolley (2013).

[35] We use ZCIS, as it is used as a market-based measure of expected inflation and because of its use in the literature (Haubrich et al., 2012; Fleckenstein et al., 2014).

These results suggest that, on average, all TIPS auctions impact temporarily the quoted rate on a given n-year maturity swap.[36] In other words, this pattern in the swap market implies that there is an excess supply in the days leading up to the auction. This is consistent with the the idea that there is excess short-selling in this particular market, as excess short-selling would imply that investors taking short positions are willing to accept a lower quoted rate to be able to take such a position. Table 8 shows that the quoted return on the 10-year swap decreases by 2.50 basis points in the 10 days before the auction with a t-statistic of 2.66. As is clear from Table 8, this documented quoted rate pattern is not unique for 10-year swaps: it is also prevalent in 5- and 30-year maturity swaps.

In addition to conducting an event-study around auction days, we also do a regression analysis by using auction dummies. We implement a similar reaction as the one implemented in Section 5.1. Still, in this section, in addition to analyzing the impact of all TIPS auctions on a given m-year maturity inflation swap rate, we also analyze the impact of the specific m-year maturity TIPS auction on the m-year maturity swap rate. The regression equation is given by:[37]

$$\Delta ZCIS_t^m = c_0 + \sum_{l=9}^{-10} \alpha_l AUC_{t+l}^m + \sum_{l=9}^{-10} \beta_l AUC_{t+l}^{\neq m} + controls + \epsilon_t, \tag{4}$$

where $\Delta ZCIS_t^m$ is the change in the quoted rate of the m-year maturity inflation swap at time t (where m = 5, 10, 20 for the inflation swap), AUC^m is a dummy variable that indicates whether or not, on the specific date, there is a m-year maturity TIPS auction, and $AUC^{\neq m}$ is a dummy variable that indicates whether or not, on the specific date, there is an auction on TIPS of a maturity other than m. We can check the presence of the auction cycle 10 days before and after the auction and hence determine the impact of TIPS auctions on the swap rate. The variable *controls* contains dummies for Nominal Treasury Auctions for

[36]We also analyze the impact of an n-year TIPS auction on an n-year Inflation Swap and find similar results. Additionally, since we have data for a wider array of maturities of inflation swaps (i.e. $n = 1, 2, 3, \ldots, 30$), we check for maturity spill-over effects. The results are provided in the Internet Appendix.

[37]The regression equation is similar to eq 1 in Section 5.1. Results are provided in Table 9.

maturities ranging from one month to 30-year.[38]

Since, $l < 0$ represents specific days after the auction, and from the event study we see that after the auction, the quoted rate on the swap starts to increase (V-shaped pattern), we expect that coefficients with $l < 0$ will have a positive value and coefficients with $l > 0$ (in anticipation of the upcoming auction) will have a negative value. Therefore, we define the severity of the auction cycle in the ZCIS market as $S^{ZCIS}(\alpha) = \left(\sum_{l=-1}^{-10} \alpha_l\right) - \left(\sum_{l=9}^{0} \alpha_l\right)$. Similar to TIPS, we check for the presence of an auction cycle in the ZCIS market around TIPS auctions, using a F-test with the following hypothesis:

$$H_0 : S^{ZCIS}(\alpha) = 0.$$

We perform the same test on the β coefficients using the analogue statistic $S^{ZCIS}(\beta)$.

Results from Table 9 suggest that when there is an auction of 10-year TIPS, we see a temporary movement in the quoted rate of 10-year inflation swap that has an overall magnitude of 3.43 basis points (shown in Panel E of Table 9). We get similar results for 5- and 20-year inflation swaps.[39] Interestingly, we see that when there is an auction on a 30-year TIPS, the magnitude of the auction cycle in all maturities of swaps is quite amplified (as is shown in Panels D and E of Table 9) and this magnitude of the auction cycle decreases with maturity. As we can see, when there is an auction on 30-year TIPS, the total change in the quoted rate of a 5-year swap is 8.32 basis points compared to a change of 6.34 basis points for a 20-year swap. These results imply that there are cross-maturity spill-over effects and primary dealers may hedge their positions by short-selling swaps of lower maturities.

Overall, the results in Panel G of Table 9 show the presence of an auction cycle in the swap market in the sample period, January 2005 to December 2019. Additionally, combining

[38] Conducting this regression analysis helps to remove confounding effects if there are TIPS auctions of different maturities that are overlapping or occur very close to each other. Additionally, we are able to quantify the whole magnitude of the auction cycle—that is, we are able to capture the full temporary up and down movements of the quoted rate of ZCIS surrounding a TIPS auction.

[39] Doing analysis on a 30-year swap gives us the same results.

these results with those obtained from the event-study, we establish that in our sample period starting in January 2005 and ending in December 2019 there is an auction cycle in the inflation swap market. The severity of this cycle is more than four basis points for 5-, 10-, and 20-year inflation swaps.

5.4.2. Primary Dealers and the Swap Market

The results above establish the presence of an auction cycle in the inflation swap market. Now to show that primary dealers are indeed active in the swap market rather than the TIPS market, we look at how the severity of the auction cycle changes with the decreasing contribution of the dealers over the years. For this purpose, first, we look at the second half of our sample that starts from January 2012 and ends in December 2019 and see the reaction in the inflation swap market 10 days before and after a TIPS auction. The results are plotted in Panel B of Figure 6.

As is obvious from Panel B of Figure 6, the auction cycle in the swap market is not recognizable in the latter half of our sample. 0 is well within both the 95% confidence interval and the bootstrapped 95% confidence interval bounds for all maturities of the inflation swap and the V-shaped pattern, documented earlier, disappears. Moreover, as is clear from Table 1, to the contrary of the TIPS auction cycle, the severity of the ZCIS auction cycle decreases as the amount of TIPS auction allocated to primary dealers decreases.[40]

Starting from 2008, we see a consistent decline in the amount allocated to dealers. In 2005, the dealers absorb 55.73% of the auction amount, but in 2016, they absorb 27.68% of the amount auctioned.[41] This pattern is almost mirrored by the auction cycle in the inflation swap market. One of the most noticeable declines in the severity of the ZCIS cycle is from 2008 to 2009. We see that the magnitude of the auction cycle decreases from 3.73 bps in the 2008–19 sample to 3.44 bps in the 2009–19 sample. This corresponds to a decrease of about

[40]The same exercise is done for 5- and 30-year swap and 5- and 30-year TIPS. The results are consistent across maturities.

[41]This allocated amount drops to 15.05% in 2019, but we restrict our analysis to 2016–2019 as otherwise the sample size gets too small.

7% in the auction amount allocated to primary dealers from 2008 to 2009.

For the full sample period, the auction cycle has a significant severity of 3.99 bps for the 10-year swap. But starting from 2012, we see a disappearance of significance of this cycle in the swap market altogether. On the other hand, the cycle remains positive and significant throughout different sample periods in the TIPS market. It is 6.71 bps for the full sample and becomes even more severe for the period 2016–19 with an overall magnitude of 6.98 bps.

As a whole, from the above results, we suggest that, before a TIPS auction, primary dealers may be short-selling on net in the OTC derivatives market. They hedge against the risk of having a large inventory of TIPS—which they take on by absorbing a huge amount of those securities in the auction—by taking offsetting positions in the swap market and thus they drive the auction cycle in the swap market. When they expect that they will take on a lesser amount during the auction, their activity in the derivatives market declines and thus the auction cycle disappears.

6. TIPS Auction Cycle from the Demand Side

The results from Section 5 indicate that primary dealers might not be the major players involved in generating the auction cycle. Additionally, the explanation based on primary dealers invokes the supply side explanation of the auction cycle. That is, if primary dealers are the ones short-selling before the auction then it means there is an excess supply of Treasury securities in the secondary market and there are not enough end investors to absorb that excess supply. Thus, a temporary price pressure is exerted in the secondary market. In this section, we look at the demand side of that story and try to identify the investors who have a demand for TIPS and are thus participating in the auction process and contributing in the formation of the cycle.

To check the investors involved in the auction process, we look at the auction allotment data for different investor classes. This data and the respective description of each investor class are available on the US Treasury official website.[42] Based on the historical data starting from January 2000 and ending in January 2020, we look at the TIPS auction amounts allocated to different investor classes. More specifically, we look at the amount allocated to two investor classes ("Dealers and Brokers" and "Investment Funds"), since over the years they have been absorbing more than 80% of the total auction size. Figure 1 plots the results and shows a very interesting pattern. We see that investment funds absorb more and more of the TIPS auction amount starting from 2010, and the amount allocated to primary dealers starts to decline starting in mid-2011.[43] The amount absorbed by investment funds goes from an average of about 30% in 2005 to more than 70% at the end of 2019. For primary dealers, the reverse trend is shown. Especially, from 2012, we see that the investment funds and primary dealers start to reverse their roles in the TIPS auction market.

As it is evident from Figure 1 that investment funds increasingly take huge positions in TIPS during auctions, in the sub-sections that follow, we try to establish a link between the auction cycle and the increasing demand from investment funds. To establish this, we first show that the severity of the auction cycle depends on the demand from investors other than primary dealers. Second, we look at a particular class of investment funds—that is, mutual funds that invest in inflation-linked bonds—and we see how their daily net flows and daily returns change surrounding the days of the auction.

Looking at the demand side of the auction necessarily invokes the idea of slow-moving capital as a plausible explanation for the cycle (Mitchell et al., 2007; Duffie, 2010). The analysis that follows in this section provides more credence to this theory. It does not identify the causes of slow-moving capital, as this is not within the scope of this paper. It identifies the end investors that are involved and provides empirical evidence for the existence of slow-moving capital.

[42] The description of each asset class can be downloaded from `https://home.treasury.gov/data/investor-class-auction-allotments`.

[43] The amounts allocated shown in Figure 1 are based on a ten-auction moving average. We also plot these contributions based on the amount allocated at each particular auction and get similar results. The only difference is that the latter are more volatile.

6.1. Direct and Indirect Bidders' Demand during Auctions

To check how the demand of investors other than primary dealers impacts the TIPS auction cycle, we do a similar analysis as done in Section 5.3. We divide the bid-to-cover ratio of an auction into the bid-to-cover ratio of primary dealers and other investors (direct and indirect bidders). The idea is that if the amount tendered by direct and indirect bidders as a ratio of the total size of the auction is higher than the sample average ex-post, then their ex-ante demand for the to-be-auctioned securities is high. The regression specification is:

$$\Delta TIPS_t^m = \beta_0 + AUC_t(\beta_1 + \beta_2 \widetilde{BC}_t^{di} + \beta_3 \widetilde{BC}_t^{pd}) + controls + \epsilon_t, \tag{5}$$

where $\Delta TIPS_t^m$ is the change in the m-year maturity TIPS yield on day t, AUC_t is a dummy variable indicating whether there is an auction on the specified date t, *controls* contains dummies for Nominal Treasury Auctions for maturities ranging from 1 month to 30-year, $\widetilde{BC}_t^{di}$ is the bid-to-cover ratio of direct and indirect bidders relative to the sample average, and $\widetilde{BC}_t^{pd}$ is the bid-to-cover ratio of primary dealers relative to the sample average.

Looking at Table 10, first, we see that the Auction Dummy variable is both positive and significant for all TIPS maturities. For 5-year (10-year) maturity, this implies that, on average, the yield increases by 1.37 (0.72) basis points in the secondary market when there is an auction on any 5-, 10-, 20- or 30-year maturity TIPS. Second, we see that the coefficients on bid-to-cover ratio of direct and indirect bidders are negative and highly significant. It says that if direct and indirect bidders' bid-to-cover is higher than the sample average by one unit leading up to the day of TIPS auction of any maturity, the yield in the secondary market, on average, decreases by 8.86 (7.60) basis points for 5-year (10-year) TIPS. For the bid-to-cover of primary dealers, there is no significance, as before.

Overall, the results in Table 10 imply that the changes in TIPS yields are very sensitive to the change in demand of investment funds but are not sensitive at all to the change in demand of primary dealers.[44] The results are easily explained in light of slow-moving capital theory. That is, since the auction is an anticipated event, investment funds decrease their demand for the security that is going to be auctioned in the days leading up to the auction. This decrease in demand in turn leads to a decrease in capital in the TIPS secondary market, and thus the price decreases in the days leading up to an auction. However, if these funds have a higher demand to begin with, then they are not able to decrease the demand as much in the days before the auction. Thus, the severity of the auction cycle decreases when the demand from direct and indirect bidders is high.[45]

6.2. Investment Funds' Daily Returns and Net Flows

After showing that the auction cycle is sensitive to the demand of direct and indirect bidders, we now take a deeper look at the "Investment Funds" investor class. This particular investor class, as defined by the US Treasury, comprises mutual funds, money market funds, hedge funds, money managers, and investment advisers. As described above, we focus on a sub-category of this investment funds: that is, open-ended inflation-indexed mutual funds.[46]

The analysis then proceeds in two steps: first, again, we document the presence of a TIPS auction cycle, but this time by analyzing the daily returns of mutual funds around TIPS auctions. Second, we provide empirical evidence for slow-moving capital theory by looking

[44] We assume investment funds are in the category of direct and indirect bidders, as these funds have been absorbing more and more TIPS at auctions and the amount that is accepted for direct and indirect bidders has been increasing in a similar fashion over our sample period.

[45] Following the advice of the anonymous reviewer, we also checked the effect of the Bid-to-Cover ratio of the primary dealers and Direct and Indirect Bidders during the days not immediately surrounding the auction days. We carried out an empirical analysis to provide support to this particular claim. The methodology (we thank the Reviewer for providing us with a solution) and the results of that particular analysis are provided in table E.11. of the Online Appendix.

[46] Money market funds mainly invest in highly liquid and short-term securities so, we exclude them from our analysis. For the money manager and investment adviser sub-classes, we look at the United States Code of Federal Regulations (see section §356.15), as it lists rules for bidding through investment advisers. The investment advisers can bid either for a controlled account or for an individual. So, we assume that the bids by these sub-classes must be quite small when compared to mutual funds, and we exclude them also from our analysis (the electronic version of the United States Code of Financial Regulations can be accessed via the link: `https://gov.ecfr.io/`). Lastly, we take mutual funds to conduct our analysis as they are better regulated than hedge funds and the data are more readily available to us. Additionally, we are better able to interpret our results by comparing them to the extensive literature that exists on mutual funds.

at the estimated daily net flows of these funds ten days before and after the auction.

6.2.1. Mutual Funds' Daily Returns around TIPS Auctions

We analyze the daily returns of mutual funds before and after the TIPS auction, and from there we again establish the presence of a TIPS auction cycle. If mutual funds are one of the groups that absorb a large amount of TIPS at auction, then we should see negative returns in the days leading up to the auction and positive returns afterwards. This would imply that the price on those securities falls in the days leading to the auction and then recovers afterwards. Morningstar provides data for Total Return Index (TRI) of inflation-indexed open-ended mutual funds. We have 353 surviving and non-surviving mutual funds in the period 2005 to 2019. From Morningstar documentation,[47] TRI is defined as:

$$TRI_t = TRI_{t-1} \times (1 + R_t), \tag{6}$$

where R_t is the total return on date t expressed in decimals. From equation (6) we calculate the daily returns. Then, we check the average of equally weighted returns on all mutual funds surrounding auction days. As shown in Table 11, for the full sample, an average mutual fund experiences negative returns in the days leading to the auction day and positive returns afterwards. The pattern also holds for the later sample (2012–2019), where we see that on the 7^{th} day before the auction day an average fund has a negative return of -4.93 basis points. Mostly, the returns are negative, and we see no positive and significant return before the auction. Immediately after the auction, we see that an average fund experience a positive and significant return of 7.12 basis points. Overall, the results imply the presence of an auction cycle in the full sample period and also in the two sub-samples.

[47] The Morningstar methodology paper on Total Return Index can be downloaded from `https://www.morningstar.com/content/dam/marketing/shared/research/methodology/823664_TotalReturnIndex.pdf`

6.2.2. Mutual Funds' Net Flows around TIPS Auctions

After establishing the presence of a TIPS auction cycle by looking at mutual funds' returns, we now focus our attention on the Estimated Net Flows of mutual funds around auctions. The aim of this exercise is to analyze the net flows before, during, and after the auction to get a sense of how the demand is changing and what impact it has, if any, on the auction cycle. A positive net flow would signal an increase in demand for the underlying and a negative net flow would indicate a decrease.

We look at the daily Estimated Net Flows of Inflation-Indexed Mutual Funds as a percentage of the size of the fund since the data are easily available to us through Morningstar.[48] Since the Estimated Net Flows and Estimated Size data are aggregated across asset classes, we are able to identify 71 unique open-ended mutual funds (both surviving and non-surviving) that invest in inflation-indexed securities.[49] In our data sample, in 2005, the maximum size of an inflation-indexed mutual fund is \$1.29 billion. This maximum size increases to \$33.04 billion in 2019.

To see how the Estimated Net Flows behave surrounding an auction, we divide our sample into three groups depending on the size. So, the 1^{st} tercile represents the lowest 33% and the 3^{rd} tercile represents the largest 33% of mutual funds. Then we see, on average, what the pattern of net flows is per size of the fund ten days before and after the auction day. Table 12 formulates these results, and immediately, we can see a very interesting pattern. Panel A of Table 12 shows that, on average, from the smallest to the largest funds there are positive net flows in the funds. As an example, we see that on the 4^{th} day before the auction, a mutual fund in the 3^{rd} tercile would experience a significant inflow of 0.06% of the fund size. Though we lose significance, still the pattern shows that there are almost all positive

[48] The Morningstar methodology paper to calculate estimated net cash flows can be downloaded at `https://www.morningstar.com/content/dam/marketing/shared/research/methodology/765555_Estimated_Net_Cash_Flow_Methodology.pdf`.

[49] We look at the open-ended United States Mutual Funds that have the Morningstar category "Inflation-Protected Bond." According to Morningstar, these funds have over 80% of their Net Assets invested in inflation-indexed bonds.

net flows leading up to the day of the auction and outflows afterwards.

In Panel B of Table 12, the results are presented as the sum of estimated net flows per size from ten days before to the auction day, and for the ten days after. From the results, we do not see any inflow in the days leading up to the auction in the lowest 33% of the funds. For the the 3^{rd} tercile, we see that an average mutual fund experiences a significant inflow representing about 0.23% of the fund size. As an example, in 2019 the 75^{th}-largest mutual fund in our sample has an estimated size of $8.7 billion. So, the net flow in that fund would be about $20 million in the days leading up to the auction day. This inflow should create a demand for the underlying (in the case of inflation-indexed mutual funds, the underlying is the inflation-indexed bond). But as is clear from Table 1, there is no apparent decline in the severity of the cycle. Looking at the 2^{nd} tercile, we see an even higher percentage of inflows. An average mutual fund in the 2^{nd} tercile faces a significant inflow representing about 0.42% of the fund size in the days leading up to the auction. Since the funds in the 2^{nd} tercile also receive inflows before the day of the auction, this indicates a general trend whereby capital is flowing into the mutual funds leading up to the day of the auction.[50]

Thus, the results in this section indicate that even though there is capital flowing in the funds in the days before an auction, the severity of the TIPS auction cycle remains unchanged. This result suggests that the capital flow to the funds before the auction might not be passed on in the secondary TIPS market.

6.2.3. Simulation with Fictitious Auction Dates

We argued that, since positive net flows are associated with negative returns on a mutual fund in the days leading to the auction, this means that mutual funds are deliberately reducing their demand. Since they reduce their demand for the underlying security, it leads

[50]Furthermore, by combining the results of Table 11 and Table 12, we see that on average inflation-indexed mutual funds experience negative returns in the days leading up to the auction associated with positive net flows during those days. Here, our results relate to a growing literature on the determinants of mutual funds flows and the relationship between fund flows and fund returns (Warther, 1995; Edelen and Warner, 2001; Ben-Rephael et al., 2011; Ellul et al., 2011; Chen and Qin, 2017). Our results do not suggest the existence of temporary price pressure in the inflation bond mutual funds before the auction day.

to a drop in prices. Thus, they generate the price pattern (increasing yields before the auction). This argument is based on the temporary price pressure hypothesis, which implies that flows in a mutual fund are positively correlated with market returns (see, for example, Edelen and Warner, 2001 and Ben-Rephael et al., 2011). If this indeed is the case, then the days surrounding the auction day must be an oddity rather than the norm. In other words, we need to see evidence of a temporary price pressure in days other than the auction days.

To proceed with this analysis, we take 139 random days between 2007 and 2019, and we conduct a similar analysis as presented in Tables 11 and 12.[51] That is, we consider the random day as the auction day and we check the average net flows and returns of mutual funds around that particular day (for the sake of convenience, we shall call this random day the "fictitious auction day"). Then, we take the sum of net flows in the ten days leading to our "fictitious auction day" and take the ones that are positive and significant. Afterwards, we count the number of positively and negatively significant daily returns in those ten days leading up to the fictitious auction day. We repeat this exercise 100 times.

Figure 7 plots the results of this exercise for the 2^{nd} tercile of mutual funds. As can be clearly seen from the figure, there are considerably more positive returns (represented by dots) than negative ones (represented by crosses). Out of the 100 times that we do this exercise, we have 32 positive and significant net flows for the 2^{nd} tercile of mutual funds. Almost all of these inflows are associated with more positive and significant positive returns than negative ones. We find 24 cases where the positive flows are associated with positive daily contemporaneous returns.[52]

These results point towards the presence of a price pressure in the inflation-indexed mutual funds. A positive net flow to a fund leads to an increase in demand for the underlying and hence an increase in price as well as a positive contemporaneous return. However, for

[51] We take random days from the year 2007 to 2019 because our analysis in Table 12 is based on this sample period, and the number of auctions that we have during that period is 139.

[52] We do the same analysis for the 3^{rd} tercile of mutual funds and obtain similar results. The results for that exercise are shown in the Internet Appendix.

the days surrounding the auction day, these positive net flows are instead associated with negative returns. Hence, during the auction days, these positive net flows do not lead to an increase in demand in the underlying. Thus, the days surrounding the auction days are more of an oddity than the norm.

7. Implications

Lou et al. (2013) report that for nominal notes and bonds, in 2007 alone, the U.S. Treasury incurred a cost of over half a billion dollars because of the auction cycle. Our results imply a similar issuance cost for TIPS. On average, we find that the US Treasury incurred a cost of over $300 million in 2019 alone.[53] Thus, the Treasury bears considerable cost issuing notes and bonds, no matter the security type. Therefore, identifying the right participants is an essential first step to tackling this problem.

Our results imply that the TIPS auction cycle is sensitive to the demand by direct and indirect bidders. So, to decrease this temporary price pressure, one possible step is to increase the demand for TIPS securities. In this regard, our results point to the importance of identifying the lack of demand in the TIPS market. Lioui and Tarelli (2019) put forward money illusion as one possible explanation. If an investor suffers from money illusion, then this causes significant portfolio shifts from inflation-indexed toward nominal bonds. This shift, in turn, entails utility loss to the investor. So, tackling the problem of money illusion is one possible way to go about tackling this temporary price pressure.

Moreover, our results hint towards a strategic decrease in demand by investment funds in the days leading up to the auction. For future research, modeling this plunge in demand before the auction and studying its welfare effects can lead to further insights about the role of market participants and how they affect market efficiency during particular events.

[53] 2019 is the last year in our sample period, and this $300 million is based on an estimate of a 5-day auction cycle.

8. Conclusion

In this paper, we study how the TIPS auctions lead to an increase in yield in the secondary market. First, we show that in the TIPS market, which is much smaller than the Nominal Treasury market, the implied issuance cost associated with an auction is the same as documented earlier in the literature for nominal notes.

Second, we try to identify the major players involved, and we show, in contrast to previous literature, that primary dealers are likely not the ones responsible for this temporary price pressure. We document a decrease of over 45% (as a percentage of auction size), over the years, in the amount allocated to primary dealers with no significant reduction in the TIPS auction cycle. Additionally, we find strong empirical support to reject the idea that primary dealers are the main contributors to this auction cycle.

Lastly, we identify slow-moving capital as the main culprit for this price pressure. We find support for this explanation first by documenting the sensitivity of the cycle to the demand by investment funds, and second by looking at the returns and flows of investment funds around auction days. Our results point to an issuance cost to the treasury for issuing TIPS that is comparable to the one for issuing nominal notes. Moreover, we try to identify the actors involved in generating this auction cycle, thus providing useful background for future research about how the auction cycle might be mitigated.

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Table 1. Auction Cycle Severity in ZCIS and TIPS markets. The table presents the results of the regression $\Delta Y_t^m = d_0 + \sum_{l=9}^{-10} \alpha_l AUC_{t+l} + controls + \nu_t$. Where $\Delta Y_t^m = \Delta ZCIS_t^m$ for ZCIS and $\Delta Y_t^m = \Delta TIPS_t^m$ for TIPS. For ZCIS, entries are the quantity $S^{ZCIS}(\alpha) = \left(\sum_{l=-1}^{-10} \alpha_l\right) - \left(\sum_{l=9}^{0} \alpha_l\right)$. For TIPS, entries are the quantity $S^{TIPS}(\alpha) = \left(\sum_{l=9}^{0} \alpha_l\right) - \left(\sum_{l=-1}^{-10} \alpha_l\right)$. $\Delta ZCIS_t^m$ and $\Delta TIPS_t^m$ are the variables denoting changes in the m-year maturity Swap Quoted Rate and TIPS yield, respectively, at time t. AUC is a dummy variable that indicates whether or not, on the specific date $t+l$, there is an auction of TIPS (maturities 5, 10 and 30-year). The variable $controls$ contains dummies for Nominal Treasury Auctions for maturities ranging from 1 month to 30-year. The column Auction Proceedings allocated to dealers represents the percentage of the auction size that was absorbed by primary dealers. The figures in that column are the end of the year figures for the starting year of the subsample. As an example, 55.73% in 2005–19 means that in 2005 primary dealers absorbed about 55.73% of the total amount of TIPS auctioned. The values for the severity of the auction cycle are in basis points. The full sample period includes all TIPS auctions conducted by the Treasury from the start of 2005 till the end of 2019. The sample excludes 10 auctions of 20-year maturity TIPS but includes all auctions during recession times. The recession period is based on daily NBER recession classification. Estimation method is Ordinary Least Squares (OLS). ***, ** and * indicate the significance levels at 1%, 5% and 10%, respectively.

Sample Period	Number of Auctions	Auction Proceedings allocated to Dealers	Severity of Auction Cycle	
			Inflation Swap	TIPS
			10-Year	10-Year
2005-19	147	55.73%	3.99***	6.71***
2006-19	141	50.41%	4.10***	6.43***
2007-19	135	54.13%	4.00**	6.21***
2008-19	129	60.13%	3.73**	5.43**
2009-19	123	53.64%	3.44**	5.94***
2010-19	117	50.58%	1.97	5.23***
2011-19	108	47.45%	2.39*	5.93***
2012-19	96	43.98%	1.01	6.18***
2013-19	84	39.81%	0.94	6.22***
2014-19	72	35.97%	0.53	6.24***
2015-19	60	26.13%	0.32	5.75***
2016-19	48	27.68%	-0.67	6.98***

Table 2. Summary Statistics of TIPS auctions. Panel A provides summary statistics for the auctions in our sample that starts from January 2005 and ends at December 2019. Maturity is the number of years left to maturity (we record the maturity of an n-year maturity TIPS reopening as n, still technically it is one or 2 months less). Auction Type is the type of auction. In our sample, all of the TIPS auctions are single price auctions. No. of Issues are the number of auctions conducted in our sample. Amount represents the total face value of the TIPS auctioned and Bid-to-Cover Ratio is the number of competitive bids tendered divided by the amount of those bids accepted. Panel B gives the distribution properties of inflation swaps, TIPS and break-even inflation. The sample period is from January 2005 to December 2019. Maturity is in number of years till the security matures. TIPS data is taken from Bloomberg and the par yields and zero-coupon yields are based on Gürkaynak et al. (2010). To calculate the Break-even Inflation, the nominal yields are constructed according to Gürkaynak et al. (2007).

Panel A: Summary Statistics of TIPS Auctions

Maturity	Auction Type	No. of Issues	Amount ($ Millions)		Bid-to-Cover Ratio	
			Mean	Std. Dev.	Mean	Std. Dev.
5	Single	40	13540	3593	2.51	0.37
10	Single	80	11694	2488	2.41	0.34
20	Single	10	8327	1950	1.88	0.31
30	Single	28	7303	1370	2.56	0.23

Panel B: Summary Statistics of ZCIS, TIPS and Break-Even Inflation

Maturity	Mean	Std. Dev.	Percentiles 25th	50th	75th	Skewness	Kurtosis	Max	Min
Zero-Coupon Inflation Swap Quoted Rates (in %)									
5	2.19	0.51	1.87	2.20	2.56	-0.82	5.66	3.37	-0.57
10	2.45	0.37	2.17	2.52	2.76	-0.47	2.41	3.19	1.15
20	2.61	0.40	2.27	2.73	2.94	-0.43	2.14	3.42	1.08
30	2.67	0.44	2.29	2.77	3.02	-0.28	1.99	3.56	1.47
Treasury Inflation Protected Securities Yields (in %)									
5	0.42	1.06	-0.30	0.25	1.11	0.30	2.51	3.20	-1.78
10	0.94	0.88	0.35	0.73	1.67	0.18	2.24	3.13	-0.92
30	1.42	0.63	0.90	1.32	2.00	0.12	1.81	3.23	0.23
Treasury Inflation Protected Securities Par Yields based on Gürkaynak et al. (2010) (in %)									
5	0.51	1.08	-0.22	0.33	1.21	0.36	2.68	4.01	-1.70
10	1.02	0.89	0.43	0.79	1.74	0.21	2.37	3.84	-0.83
20	1.41	0.72	0.82	1.21	2.10	0.16	1.74	3.41	0.05
Treasury Inflation Protected Securities Zero-Coupon Yields based on Gürkaynak et al. (2010) (in %)									
5	0.51	1.08	-0.23	0.33	1.22	0.33	2.63	3.91	-1.71
10	1.02	0.89	0.44	0.80	1.77	0.16	2.32	3.75	-0.85
20	1.44	0.72	0.84	1.25	2.14	0.10	1.66	3.32	0.05
Break-Even Inflation Rates based on Gürkaynak et al. (2010) (in %)									
5	1.85	0.60	1.62	1.94	2.19	-2.31	12.18	2.90	-1.78
10	2.13	0.42	1.84	2.21	2.46	-0.88	4.08	2.86	0.17
20	2.28	0.44	1.92	2.37	2.63	-0.49	2.50	3.11	0.82

Table 3. Implied Issuance Cost of TIPS. Panel A reports the time series average of $Y(0) - \bar{Y}(t)$. Where $Y(0)$ is the yield at the day of the auction and $\bar{Y}(t)$ is the average yield of an on-the-run (soon-to-be off-the-run) TIPS t days before and after the auction with t ranging from 1 to 10. Since the yield difference is positive throughout, it implies that the yield at the auction day is the maximum yield. The sample period is from January 2005 to December 2019 and contains 158 auctions. All yields are expressed in basis points. The last column represents the implied issuance cost in millions of dollars for the year 2019. The t^{th} day implied issuance cost is calculated by taking the yield at auction day and then subtracting from this yield, the on average decrease implied by the table. Then the hypothetical price is calculated at which the Treasury could have issued TIPS and this hypothetical price is on average greater than the price at the auction day. We calculate the Issuance cost based on the percentage the hypothetical price is greater than the actual price and multiplying it with the total size of the auction. Panel B presents the same results but the sample period is from January 2012 to December 2019, and contains 95 auctions. The t-stats reported are based on Heteroskedasticiy and Autocorrelation consistent (Newey-West) standard errors. All values are in basis points. ***, ** and * indicate significance levels of 1%, 5% and 10%, respectively.

Panel A: Yield Difference Y(0) - $\bar{Y}$(t) for sample 2005-2019							
	5-Year		10-Year		20-Year		Implied Issuance Cost
t	Mean	*t*-stat	Mean	*t*-stat	Mean	*t*-stat	
1	0.93***	(2.63)	0.82***	(2.54)	0.89***	(2.75)	125
2	1.63***	(2.83)	1.68***	(3.25)	1.53***	(3.10)	236
3	1.81***	(2.70)	1.75***	(3.09)	1.52***	(2.70)	247
4	2.52***	(3.03)	2.31***	(3.28)	2.03***	(2.84)	330
5	2.84***	(3.13)	2.47***	(3.25)	2.17***	(2.75)	359
6	3.09***	(3.33)	2.69***	(3.47)	2.46***	(3.18)	394
7	2.93***	(3.08)	2.60***	(3.23)	2.33***	(2.89)	377
8	3.30***	(3.20)	2.94***	(3.37)	2.62***	(2.98)	425
9	3.34***	(3.22)	2.90***	(3.23)	2.60***	(2.87)	423
10	3.65***	(3.19)	3.10***	(3.21)	2.65***	(2.76)	450
No. Obs.	158		158		158		
Panel B: Yield Difference Y(0) - $\bar{Y}$(t) for sample 2012-2019							
	5-Year		10-Year		20-Year		Implied Issuance Cost
t	Mean	*t*-stat	Mean	*t*-stat	Mean	*t*-stat	
1	0.49	(1.49)	0.55	(1.57)	0.69*	(1.90)	83
2	0.62	(1.23)	0.98*	(1.80)	0.98**	(1.96)	130
3	0.70	(1.33)	0.95*	(1.71)	0.93*	(1.73)	129
4	1.33**	(2.02)	1.56**	(2.31)	1.57**	(2.30)	219
5	1.72**	(2.25)	1.69**	(2.28)	1.57**	(2.10)	242
6	1.93***	(2.46)	1.73***	(2.35)	1.63**	(2.24)	253
7	1.76**	(2.07)	1.69**	(2.16)	1.55**	(2.07)	241
8	2.06**	(2.28)	1.91**	(2.19)	1.64**	(1.96)	271
9	2.33***	(2.36)	2.12**	(2.22)	1.82**	(2.02)	302
10	2.92***	(2.67)	2.55***	(2.55)	2.06**	(2.30)	363
No. Obs.	95		95		95		

Table 4. TIPS Auctions Cycle Severity. The table presents the results of the regression $\Delta TIPS_t^m = d_0 + \sum_{l=9}^{-10} \alpha_l AUC_{t+l} + controls + \nu_t$ where $\Delta TIPS_t^m$ is the variable denoting changes in the m-year maturity TIPS yield. Entries are the quantity $S^{TIPS}(\alpha) = \left(\sum_{l=9}^{0} \alpha_l\right) - \left(\sum_{l=-1}^{-10} \alpha_l\right)$. AUC is a dummy variable that indicates whether or not, on the specific date $t+l$, there is an auction of TIPS (maturities 5, 10 and 30-year). The variable $controls$ contains dummies for Nominal Treasury Auctions for maturities ranging from 1 month to 30-year. The yields are par yields constructed by Gürkaynak et al. (2010). The magnitude of the numbers is represented in basis points. The first sample period includes all auctions conducted by the Treasury from the start of 2010 till the end of 2014. Similarly the second sample includes all auctions conducted by the Treasury from the start of 2015 till the end of 2019. Estimation method is Ordinary Least Squares (OLS). ***, ** and * indicate the significance levels at 1%, 5% and 10%, respectively.

Sample Period	Number of Auctions	Severity of TIPS Auction Cycle	
		Maturities	
		5-Year	10-Year
2010-14	57	7.33**	5.20*
2015-19	60	6.02***	5.75***

Table 5. Summary Statistics of Dealers' Net Positions in TIPS. Entries in the Table report the average net positions of primary dealers in TIPS. $t = -6, -1, 4$ and 9 represent the t^{th} business day before or after the auction. Panel A reports dealers' average net positions during auctions of 5-year maturity TIPS at four different time periods. Panel B and C provide the same statistics for 10- and 30-year maturity TIPS, whereas Panel D includes all maturities of TIPS auctions. The entries in the are in billions of dollars (except for the number of auctions) and are based on the market price of TIPS at the time of analysis. The full sample covers the period 2004-2019. Recession period is NBER classified regression that starts from the 1st of January, 2008 and ends on the 31st of June 2009.

Sample Period	Number of Auctions	Net Positions in Billions $			
		Business Days Around Auction			
Panel A: (5-Year TIPS)		-6	-1	4	9
All auctions (No Recession)	38	4.49	6.46	6.04	5.74
During Recession	3	2.79	4.97	4.05	3.72
Pre-Recession	7	1.89	3.28	2.87	2.91
Post-Recession	31	5.08	7.18	6.75	6.38
Panel B: (10-Year)					
All auctions (No Recession)	77	3.87	5.68	5.25	5.03
During Recession	6	1.71	3.42	3.73	3.77
Pre-Recession	16	0.28	1.59	2.20	2.03
Post-Recession	61	4.81	6.76	6.05	5.81
Panel C: (30-Year)					
Post-Recession	28	5.38	6.16	5.87	5.57
Panel D: (All Maturities)					
All auctions (No Recession)	149	4.21	5.81	5.43	5.15
During Recession	12	1.99	4.01	3.74	3.89
Pre-Recession	29	0.95	2.10	2.30	2.15
Post-Recession	120	5.00	6.71	6.19	5.87

Table 6. Determinants of Primary Dealers' TIPS Positions. Entries in this table are the slope coefficients of the regression $\Delta WNP_t = \alpha_0 + \beta_1(AUC_{t-1} \times Size_{t-1}) + \beta_2(AUC_t \times Size_t) + \beta_3(AUC_{t+1} \times Size_{t+1}) + controls + \epsilon_t$. Where ΔWNP_t is the change in dealers' net positions in TIPS, AUC_t is an indicator variable that takes the value 1 if the auction is in the same week as the week when the net positions of dealers is reported, and is 0 otherwise. The variable $Size_t$ corresponds to the size of that particular auction. The subscript t is in weeks. So, if AUC_t represents the auction in the same week then AUC_{t-1} represents the auction that happened a week before and AUC_{t+1} represents the auction that will happen a week ahead of the net positions data. All variables are in billions of dollars. Coefficients are reported with heteroskedasticity and autocorrelation consistent (Newey-West) standard errors in parentheses. All variables are in billions of dollars. ***, ** and * indicate significance levels of 1%, 5% and 10%, respectively.

	Dependent Variable: Weekly Net Positions Change	
Independent Variable	All TIPS Issuance (2005-2019)	All TIPS Issuance (2012 - 2019)
Constant	-0.441**	-0.561**
	(0.202)	(0.242)
Effect of previous week's issuance	0.008	0.008
	(0.019)	(0.021)
Effect of same week's issuance	0.158***	0.189***
	(0.022)	(0.026)
Effect of next week's issuance	0.011	-0.003
	(0.019)	(0.019)
MBS Positions	0.006	0.021
	(0.014)	(0.020)
Corporate Debt Positions	0.002	0.022
	(0.017)	(0.021)
T-Bills Positions	0.002	0.000
	(0.007)	(0.009)
Coupon Bonds Positions	0.021	0.005
	(0.007)	(0.010)
Agency Debt Positions (Discount)	-0.010	-0.010
	(0.017)	(0.028)
Agency Debt Positions (Coupon)	0.011	0.084*
	(0.024)	(0.044)
Federal Reserve Holdings	0.128	0.439***
	(0.116)	(0.167)
Adjusted R^2	28.7%	39.4%
Number of Observations	451	288

Table 7. Dealers' Bid-to-Cover ratio and TIPS Yields around Auctions. Entries are the slope coefficients of the regression $\Delta TIPS_t^m = \beta_0 + AUC_t(\beta_1 + \beta_2 \widetilde{BC}_t) + controls + \epsilon_t$ where $\Delta TIPS_t^m$ is the one day change in TIPS yields of a specific maturity TIPS. AUC_t is a dummy variable representing whether there is an auction an any TIPS maturity. The variable $controls$ contains dummies for Nominal Treasury Auctions for maturities ranging from 1 month to 30-year. $\widetilde{BC}_t$ is the Bid-to-Cover ratio of primary dealers relative to the sample average. Numbers in parentheses represent the Heteroskedasticity and Auto-correlation adjusted (Newey-West) standard errors. Numbers in square brackets show the t-statistics. The means of coefficients are expressed in basis points. The sample period is from January 2005 to December 2019 and covers 158 TIPS auctions. Estimation method is Ordinary Least Squares (OLS). ***, ** and * indicate significance levels of 1%, 5% and 10%, respectively.

	Dependent Variable: Change in TIPS Yield		
Independent Variable	5-year	10-year	20-year
Constant	-0.16	-0.14	-0.15
	(0.12)	(0.11)	(0.09)
	[-1.34]	[-1.29]	[-1.59]
Auction Dummy	1.38***	0.73*	0.84**
	(0.50)	(0.43)	(0.38)
	[2.75]	[1.70]	[2.22]
Bid-to-Cover (Primary Dealers)	-1.33	-1.41	-1.02
	(1.33)	(1.35)	(1.35)
	[-1.00]	[-1.04]	[-0.75]
Controls (Nominal Auctions)	0.15	0.13	0.15
	(0.16)	(0.15)	(0.14)
	[0.93]	[0.89]	[1.09]

Table 8. Quoted Swap Rates around TIPS Auctions. Entries are the time-series average of $Y(t)$ -$Y(0)$, where $Y(t)$ is the quoted swap rate of an n-year zero-coupon inflation swap (n = 5, 10, 30) on day t with t ranging from -10 to + 10 with 0 (the day of the auction) included. But since the table reports quoted swap rates relative to the auction day, it doesn't include results for t=0. The t-stats reported are based on Heteroskedasticiy and Autocorrelation consistent (Newey-West) standard errors. The sample period is from January 2005 to December 2019 and contains 158 TIPS auctions. All values are in basis points. ***, ** and * indicate significance levels of 1%, 5% and 10%, respectively.

	5-Year		10-Year		30-Year	
t	Mean	*t*-stat	Mean	*t*-stat	Mean	*t*-stat
-10	2.58**	(2.28)	2.50***	(2.66)	2.02**	(2.26)
-9	3.10**	(2.32)	2.71***	(2.55)	2.41***	(2.86)
-8	2.72**	(2.29)	2.51***	(2.48)	2.28***	(2.97)
-7	2.10**	(1.97)	2.16***	(2.40)	1.80***	(2.53)
-6	1.80*	(1.79)	1.66**	(2.08)	1.67**	(2.32)
-5	1.67	(1.61)	1.30*	(1.76)	1.58**	(2.25)
-4	1.55*	(1.79)	0.91	(1.39)	1.32*	(1.78)
-3	0.62	(0.99)	0.84	(1.61)	0.99*	(1.67)
-2	0.83	(1.31)	0.79	(1.59)	0.98	(1.55)
-1	0.65	(1.35)	0.20	(0.62)	0.46	(1.06)
1	0.69*	(1.87)	1.04***	(2.37)	0.56*	(1.67)
2	0.11	(0.28)	1.25**	(2.10)	0.19	(0.51)
3	0.71	(1.30)	1.48***	(2.44)	0.98*	(1.87)
4	1.04	(1.48)	1.56**	(2.18)	1.52**	(2.14)
5	1.27	(1.60)	1.92***	(2.52)	1.58**	(1.98)
6	1.52*	(1.75)	1.69**	(2.19)	1.21*	(1.72)
7	1.61*	(1.74)	1.62**	(2.01)	1.66*	(1.84)
8	1.63*	(1.66)	1.57*	(1.75)	1.07	(1.27)
9	2.15**	(2.01)	2.04**	(2.18)	1.92*	(1.96)
10	2.39*	(1.94)	2.49***	(2.42)	2.27**	(2.21)

Table 9. Change in Quoted Swap Rates around TIPS Auctions. The table presents the results of the regression $\Delta ZCIS_t^m = c_0 + \sum_{l=9}^{-10} \alpha_l AUC_{t+l}^m + \sum_{l=9}^{-10} \beta_l AUC_{t+l}^{\neq m} + controls + \epsilon_t$ where $\Delta ZCIS_t^m$ is the variable denoting changes in the m-year maturity Swap Quoted Rate. Entries are the quantity $S^{ZCIS}(\alpha) = \left(\sum_{l=-1}^{-10} \alpha_l\right) - \left(\sum_{l=9}^{0} \alpha_l\right)$. AUC is a dummy variable that indicates whether or not, on the specific date $t+l$, there is an auction of m maturity TIPS. The variable $controls$ contains dummies for Nominal Treasury Auctions for maturities ranging from 1 month to 30-year. $\neq m$ indicates all maturities of TIPS auctions other than m. With variable *Dummy own* we analyze the impact of TIPS auction of specific maturity on the quoted rate of the swap with the same maturity. With variable *Dummy All*, we analyze the impact of a TIPS auction, regardless of a specific maturity, on the ZCIS quoted rate of a specific maturity. Panels A, B, C and D present results of the impact on an m-year ZCIS quoted rate when there is an auction on an m-year TIPS and auction on a TIPS with maturity other than m. Panel E presents results for the full regression where all m-year maturity TIPS auctions are taken separately. Panel F presents results with the same maturity TIPS and Swap and TIPS auctions of all other maturities. Panel G presents results for the *Dummy All* variable. The magnitude of the numbers is represented in basis points. The sample period is from January 2005 to December 2019 and contains 158 TIPS auctions. Estimation method is Ordinary Least Squares (OLS). ***, ** and * indicate significance levels of 1%, 5% and 10%, respectively.

	Change in Inflation Swap Rate		
	5-year	10-year	20-year
Panel A:			
Dummy own	5.75*	3.86**	1.64
Dummy 5-year	-	4.23*	5.02*
Panel B:			
Dummy own	5.22	3.62**	-12.71
Dummy 10-year	1.19	-	4.30**
Panel C:			
Dummy own	5.76*	3.52*	1.64
Dummy 20-year	6.31	-8.53	-
Panel D:			
Dummy own	6.03*	3.57**	1.64
Dummy 30-year	8.51**	7.95***	6.68**
Panel E:			
Dummy own	5.76*	3.43*	0.06
Dummy 5-year	-	4.09*	4.45*
Dummy 10-year	1.3	-	4.13**
Dummy 20-year	5.2	2.63	-
Dummy 30-year	8.32**	7.70***	6.34**
Panel F:			
Dummy own	6.06*	3.66**	1.3
Dummy n $\neq$ m	3.66*	5.65***	4.79***
Panel G:			
Dummy All	4.27**	4.21***	4.77***

Table 10. Investors' Bid-to-Cover ratio and TIPS Yields around Auctions. Entries are the slope coefficients of the regression $\Delta TIPS_t^m = \beta_0 + AUC_t(\beta_1 + \beta_2 \widetilde{BC}_t^{di} + \beta_3 \widetilde{BC}_t^{pd}) + controls + \epsilon_t$ where $\Delta TIPS_t^m$ is the one day change in TIPS yields of a specific maturity TIPS. AUC_t is a dummy variable representing whether there is an auction an any TIPS maturity. The variable *controls* contains dummies for Nominal Treasury Auctions for maturities ranging from 1 month to 30-year. $\widetilde{BC}_t^{di}$ is the Bid-to-Cover ratio of direct and indirect bidders relative to the sample average and $\widetilde{BC}_t^{pd}$ is the Bid-to-Cover ratio of primary dealers relative to the sample average. Numbers in parentheses represent the Heteroskedasticity and Auto-Correlation adjusted (Newey-West) standard errors. Numbers in square brackets show the t-statistics. The means of coefficients are expressed in basis points. The sample period is from January 2005 to December 2019 and covers 158 TIPS auctions. Estimation method is Ordinary Least Squares (OLS). ***, ** and * indicate significance levels of 1%, 5% and 10%, respectively.

	Dependent Variable: Change in TIPS Yield		
Independent Variable	5-year	10-year	20-year
Constant	-0.16	-0.14	-0.15
	(0.12)	(0.11)	(0.09)
	[-1.36]	[-1.31]	[-1.62]
Auction Dummy	1.37***	0.72*	0.83***
	(0.47)	(0.40)	(0.35)
	[2.90]	[1.79]	[2.35]
Bid-to-Cover (Direct/Indirect Bidders)	-8.86***	-7.70***	-7.03***
	(2.24)	(1.44)	(1.30)
	[-3.96]	[-5.34]	[-5.41]
Bid-to-Cover (Primary Dealers)	-1.17	-1.26	-0.89
	(1.26)	(1.26)	(1.23)
	[-0.93]	[-1.00]	[-0.72]
Controls (Nominal Auctions)	0.15	0.14	0.16
	(0.16)	(0.15)	(0.14)
	[0.98]	[0.93]	[1.13]

Table 11. Mutual Funds Daily Returns around TIPS Auctions. Entries in the table provide average t^{th} day return of an inflation-indexed open-ended mutual fund before and after a TIPS auction (t = -10 to 10, where $t = 0$ represents the day of the auction). The t-stats reported are based on Heteroskedasticiy and Autocorrelation consistent (Newey-West) standard errors. The full sample period is from January 2005 to November 2019 and contains 157 TIPS auctions. All values are in basis points. ***, ** and * indicate significance levels of 1%, 5% and 10%, respectively.

	Sample Periods					
	2005-2019		2005-2011		2012-2019	
t	Mean	*t*-stat	Mean	*t*-stat	Mean	*t*-stat
-10	3.53*	(1.81)	8.21**	(2.08)	0.34	(0.16)
-9	0.07	(0.03)	6.64	(1.34)	-4.39*	(-1.84)
-8	-1.06	(-0.50)	2.25	(0.55)	-3.32	(-1.55)
-7	-4.35***	(-2.42)	-3.49	(-1.02)	-4.93***	(-2.51)
-6	2.81	(1.28)	6.72	(1.70)	0.15	(0.06)
-5	2.00	(0.85)	1.69	(0.37)	2.20	(0.94)
-4	1.78	(1.02)	2.32	(0.69)	1.42	(0.69)
-3	-4.66**	(-2.03)	-5.12	(-1.14)	-4.34**	(-2.07)
-2	1.41	(0.54)	2.26	(0.42)	0.84	(0.38)
-1	-5.57*	(-1.69)	-10.72	(-1.57)	-2.07	(-0.64)
0	-6.21*	(-1.92)	-14.55**	(-2.17)	-0.54	(-0.19)
1	6.43***	(2.33)	5.41	(0.95)	7.12***	(2.71)
2	3.22*	(1.93)	6.12*	(1.77)	1.24	(0.93)
3	3.85*	(1.85)	7.67*	(1.74)	1.25	(0.68)
4	3.92*	(1.75)	4.83	(1.18)	3.31	(1.34)
5	4.03*	(1.88)	4.09	(0.86)	3.99**	(2.10)
6	4.22**	(2.04)	6.12	(1.50)	2.93	(1.32)
7	0.64	(0.29)	0.78	(0.18)	0.55	(0.26)
8	0.97	(0.34)	7.27	(1.36)	-3.32	(-1.13)
9	-0.81	(-0.42)	-1.75	(-0.55)	-0.17	(-0.07)
10	2.55	(0.92)	3.20	(0.55)	2.10	(0.82)
Number of Auctions	157		64		93	

Table 12. Mutual Funds' Net Flows per Size around TIPS Auctions. Entries in the table report the average estimated net flow as a percentage of the total size of the mutual fund. The magnitude of the numbers is represented in percentage, so a mean value of 0.11 would indicate a positive inflow of 0.11% of the size of the fund. The sample period is from January 2007 to November 2019 and contains 139 TIPS auctions and the mutual funds are divided into terciles based on the size of the fund. Panel A reports the average t^{th} day return before or after a TIPS auction (t = -10 to 10, where t = 0 represents the day of the auction). Panel B reports the avergage cummulative net flow starting at the t^{th} day and ending at the auction day, and starting a day after auction and going till the t^{th} day. Estimation method is Ordinary Least Squares (OLS) and the t-statistics reported in parentheses are based on Heteroskedasticity and Auto-correlation adjusted (Newey-West) Standard Errors. ***, ** and * indicate significance levels of 1%, 5% and 10%, respectively.

Panel A: Estimated Comprehensive Net Flows per Size around TIPS Auctions

	Terciles					
	1st		2nd		3rd	
t	Mean	*t*-stat	Mean	*t*-stat	Mean	*t*-stat
-10	-0.27	(-0.87)	0.02	(0.80)	0.00	(0.04)
-9	0.11**	(2.26)	0.01	(0.20)	0.01	(0.93)
-8	0.05	(1.01)	0.08	(1.20)	0.05	(1.01)
-7	0.08	(1.42)	0.03	(0.79)	0.02	(1.59)
-6	0.64***	(2.54)	0.07	(1.43)	0.00	(0.12)
-5	-0.82	(-1.19)	0.01	(0.47)	0.02	(0.90)
-4	0.11	(1.16)	0.06*	(1.83)	0.06***	(2.35)
-3	0.23*	(1.71)	0.01	(0.29)	0.05*	(1.93)
-2	0.24	(1.44)	0.05	(1.58)	0.03	(1.33)
-1	0.33*	(1.76)	0.07*	(1.76)	0.02	(1.40)
0	-1.22	(-1.43)	0.04*	(1.85)	-0.01	(-0.57)
1	0.11	(1.03)	0.01	(0.21)	-0.06	(-1.10)
2	0.16***	(2.47)	0.06	(0.75)	-0.02	(-0.38)
3	0.07	(0.81)	-0.01	(-0.24)	0.03	(0.76)
4	-0.09	(-1.14)	0.02	(0.88)	-0.11	(-0.84)
5	0.21	(0.84)	0.01	(0.20)	-0.02	(-1.39)
6	0.18	(1.28)	-0.06	(-1.06)	0.03	(1.59)
7	-0.17	(-1.52)	-0.20	(-1.62)	0.05***	(2.71)
8	-0.12	(-0.96)	-0.46	(-1.07)	0.02	(0.86)
9	0.02	(0.29)	0.01	(0.24)	0.04**	(2.30)
10	-0.26	(-0.89)	0.05*	(1.76)	0.02	(0.82)

Panel B: Cummulative Estimated Net Flows per Size around TIPS Auctions

	Terciles					
	1st		2nd		3rd	
t	Mean	*t*-stat	Mean	*t*-stat	Mean	*t*-stat
-10 to 0	-0.49	(-0.44)	0.42*	(1.89)	0.23**	(1.97)
1 to +10	0.11	(-0.17)	-0.50	(-0.96)	-0.03	(-0.17)

Figure 1. Percentage of TIPS Auction Allocated to Different Investor Classes. The dotted line represents the amount of TIPS auction that is allocated to Dealers and Brokers, the dashed line represents the amount that is allocated to Investment Funds and the solid line represents the amount that is allocated to both Dealers and Brokers and Investment Funds. All three lines are 10 auctions moving averages. The X-axis corresponds to the TIPS auctions held on different dates during the sample period. The sample period is from January 2000 to January 2020 and contains 175 TIPS auctions on 5, 10, 20 and 30-year maturities.

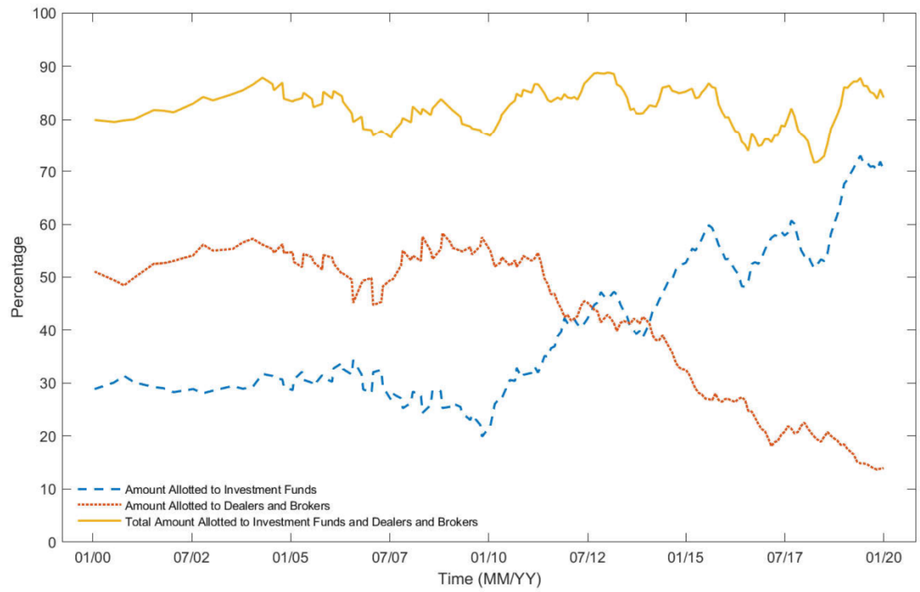

Figure 2. Number of TIPS auctions by year. A full bar in the figure represents the total number of TIPS auctions in our sample that starts from January 2005 and ends in December 2019. From 2005 till 2009, the lowest segment represents the number of 5-year TIPS auctioned, the middle segment represents the number of 10-year TIPS and the top segment represents the number of 20-year TIPS auctioned during a particular year. Starting from 2011, the 20-year TIPS is replaced by the 30-year TIPS and the top segment represents the number of 30-year TIPS auctioned during a particular year.

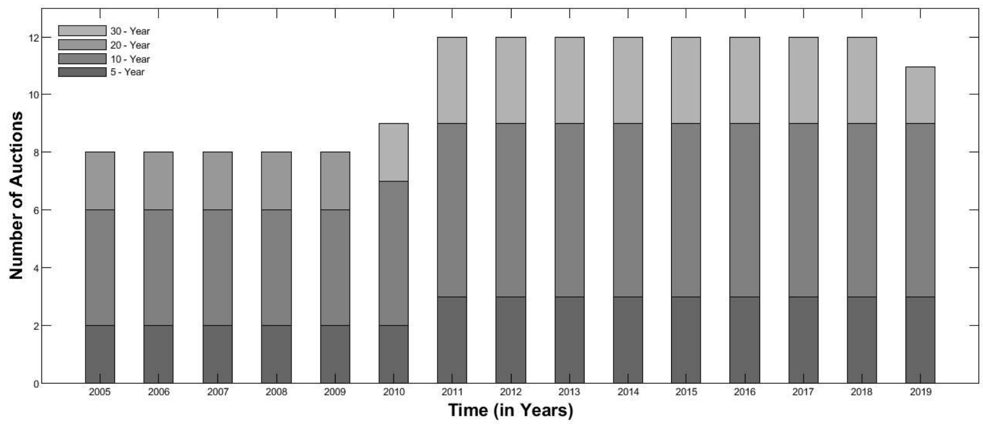

Figure 3. Tips yields around Auctions. The solid line represents the time series average of $Y(t)$ - $Y(0)$, where $Y(t)$ is the yield of a 10-year TIPS on day t with t ranging from -10 to + 10. The dotted lines represent the 95% confidence interval bounds and the dotted-dashed lines represent the 95% bootstrapped confidence interval bounds. The confidence interval bounds are based on Newey-West Adjusted standard errors. The sample period is from January 2005 to December 2019 and contains 83 10-year TIPS auctions. All yields are expressed in basis points.

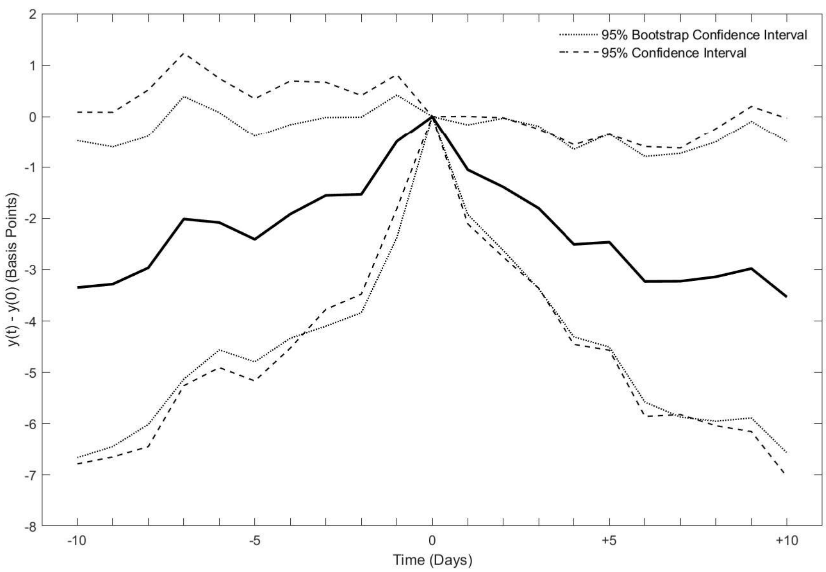

Figure 4. Primary Dealers' Contribution in TIPS Auctions. The solid line shows how much percentage of the total amount tendered during the auction was tendered by primary dealers. While the dashed line shows how much, in percentage, of the total auction amount was allocated to primary dealers. For each year, we sum the totals of each auction and calculate the percentages. Each point on the horizontal axis denotes the data summed up over that year and presented at the end of that particular year. The sample period is from 2005 to 2019.

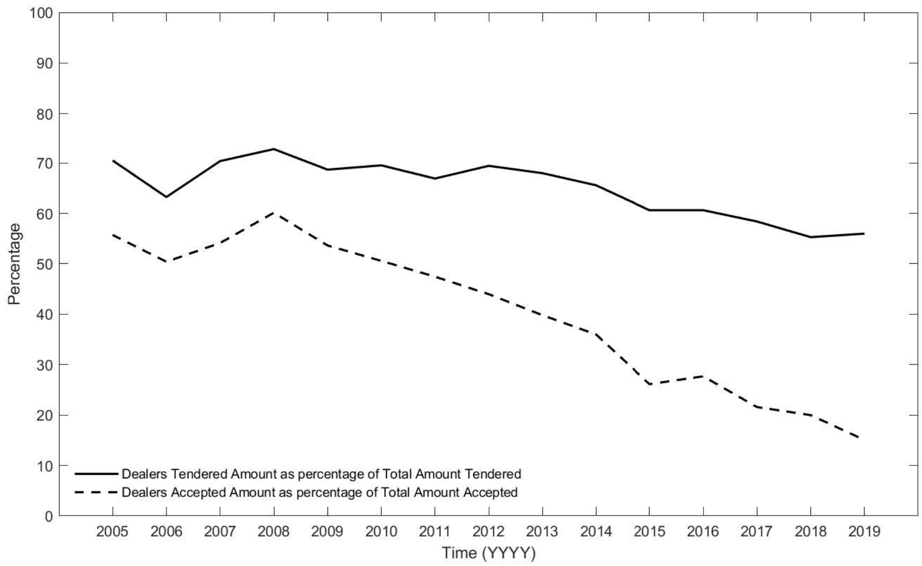

Figure 5. Primary Dealers' Weekly Net Positions Data Dates. The horizontal line in the middle of the Figure represents the day of the auction. It is also denoted by 0 on the y-axis. The numbers on the y-axis represent the number of business days either before (below zero) or after (above zero) the auction on 10-year maturity TIPS. As an example, for the auction held in January 2004, we have primary dealers' net positions data 4 business days after the auction (represented by the first dot above horizontal line) and 1 business day before the auction (represented by the dot below the horizontal line). In total there are 83 auctions from the sample period 2004 to 2019.

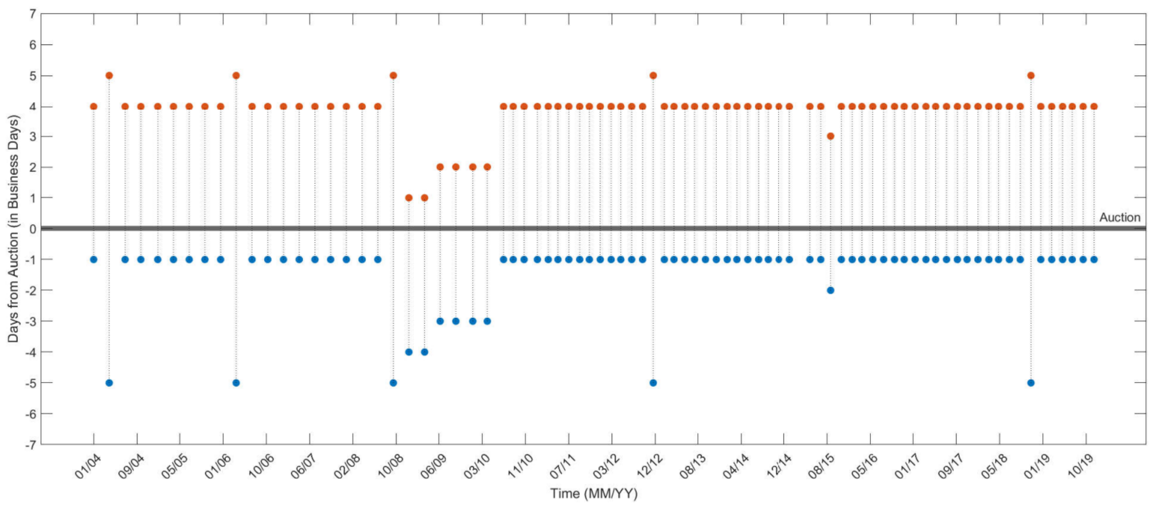

Figure 6. Swap Rates around All TIPS Auctions. The solid lines represent the time series average of $Y(t)$ - $Y(0)$, where $Y(t)$ is the quoted swap rate of an n-year zero-coupon inflation swap (n = 5, 10, 30) on day t with t ranging from -10 to + 10. The dotted lines represent the 95% confidence interval bounds and the dotted-dashed lines represent the 95% bootstrapped confidence interval bounds. In Panel A, the sample period is from January 2005 to December 2019 and contains 157 auctions. In Panel B, the sample period is from January 2012 to December 2019 and contains 95 auctions. All quoted rates are expressed in basis points.

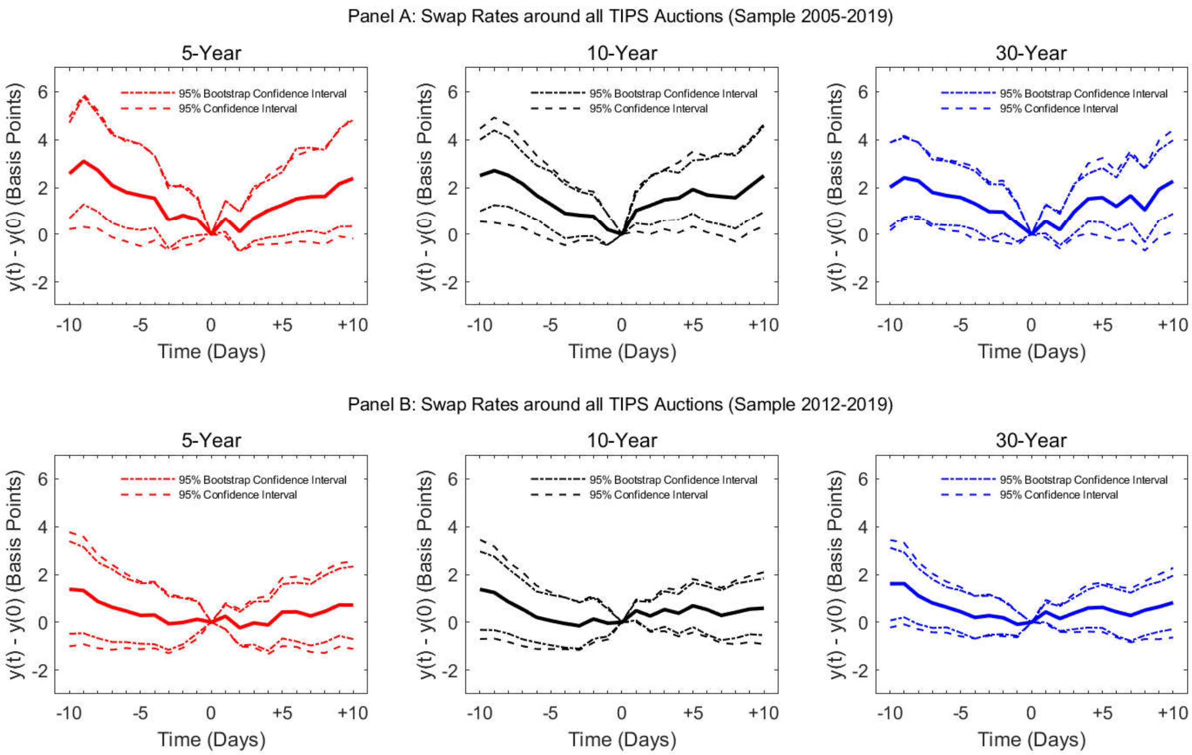

Figure 7. 2^{nd} Tercile Mutual Funds Net Flows and Returns. The dots (crosses) in the figure represent the number of daily positive (negative) and significant return on the mutual fund in a total of 10 days before the fictitious auction date. The results are based on an exercise of 100 randomly generated fictitious auction date data, where each data set contains 139 random fictitious auction dates from the period January 2007 to December 2019. The significance of net flows and daily returns is based on Heteroskedasticity and Auto-Correlation adjusted (Newey-West) standard errors.