US Treasury Auctions and Inflation Swap Market Dynamics*

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Abstract

We document the presence of a V-shaped pattern in the quoted rate of inflation swaps around the days leading to and after the auction on Treasury Inflation Protected Securities (TIPS). We robustly establish the presence of this auction cycle and find that on average the quoted rate on inflation swaps drops by about 3.35 basis points in the days leading up to the auction and reverts afterwards. Contrary to previous literature, we look at the demand side of these securities and find the role of institutional investors that can explain this particular pattern. Our work has implications for regulations that can be enacted by central banks to borrow money in a more efficient manner.

EFM Classification Codes: 340, 350, 360

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1 Introduction

Market frictions can sometimes lead to inefficiencies that can provide seemingly large risk-less profit-making opportunities. One of such findings is related around the auctions of Treasury bonds. More broadly, such abnormalities can be found in markets where there is an element of sequential trading (Ito et al. 2016). Technically, since the auction is anticipated (time and size of an auction are known in advance), there should not be any change in the price of a security when that auction occurs. But Lou, Yan and Zhang (2013) document the presence of an inverted V-shaped pattern of yields in the secondary market around the auction of US Treasury bonds, i.e. the price of the secondary securities decreases leading up to the auction of the new securities. The authors estimate that this translates to a cost of about 9 to 18 basis points to the treasury or over half a billion dollars of the issuance size in 2007.

This particular inverted V-shaped pattern has been termed as "Auction Cycle" in the literature (Beetsma et al. 2016). The explanation for this auction cycle, as by Lou, Yan and Zhang (2013), is two folds. First, it is attributed to the limited risk bearing capacity of the primary dealers and second, because of an end investor's imperfect capital mobility. Basically, because the primary dealers have to participate in the treasury auctions and they have a limited risk bearing capacity, so they short-sell in the secondary market to try to hedge their risk. With short-selling, we observe a decrease in price (or increase in yield) in the secondary market and thus a temporary inverted V-shaped pattern for treasury yields. But the authors argue that the end-investor is not able to meet this liquidity demand quickly, so because of the restraints we observe the particular pattern. This idea relates to the slow-moving capital theory as pointed out by Duffie (2010).

But we see a particular pattern in the recent data for Treasury Inflation Protected Securities (TIPS) auctions. The US treasury has been providing details about the auctions results highlighting the amount that is actually tenured by the primary dealers and the amount that is allocated to them.[1] From here we see that Primary Dealers' contribution in the auction

[1]Since 2008, the US Treasury details the auctions results in terms of the amount allocated to Direct

process has been steadily decreasing (both in the amount tenured as a percentage of total amount tenured, and the amount allocated to them). The amount allocated to primary dealers in 2017 was around 20% of the total auction size down from 60% in 2008. So, if primary dealers are the major contributors to this auction cycle, we would expect that a decrease in their participation should actually reduce the severity of the auction cycle.

Motivated by these empirical observations, our first objective is to see whether there's an auction cycle present in the TIPS. And second, if there is indeed an auction cycle then how consistent it is over time when participation level of primary dealers is varying. Additionally, as our main analysis, we also check if there is an auction cycle present in the Inflation Swap market. The idea behind checking the inflation swap market is that if primary dealers are the main culprits in producing the auction cycle, then the inflation swap market should only be inhabited by arbitrageurs and there shouldn't be anything extra going on in this market.[2]

In the first part of our analysis, we conduct an event study analysis in accordance with Lou et al. (2013) and find the presence of an auction cycle in TIPS market consistent with the literature. For a 10-year TIPS, we find that in our data spanning the years 2005 till 2017, on average the severity of this auction cycle is about 6.17 basis points (i.e. about 3.1 basis points increase in yield till the date of the auction and the reversal afterwards). Moreover, we find the presence of an auction cycle in the Zero-Coupon Inflation Swap (ZCIS) market. We observe a V-shaped pattern for the swap, and for a 10-year swap we find that on average the severity of the auction cycle is about 6.83 basis points (i.e. the quoted swap rate decreases about 3.40 basis points in the days leading up to the auction and reversal afterwards). This particular pattern means that there is short-selling in this particular market. Since we look

Bidders, Indirect Bidders and Primary Dealers. The results explicitly highlight the amount that is tendered and allocated by each of these players. The data is available online at Treasury Direct website.

[2]We can take any other security that can be considered a substitute to the TIPS for our analysis, but we take the inflation swap since they are one of the simplest substitutes for TIPS, their popularity has sharply increased over the years (trading volume increased from $100 million per day in 2010 to $350 million per day in 2012 (Fleming and Sporn 2013)) and they are widely used in the literature either as a market based measure of inflation expectations or used to create a synthetic nominal or TIPS bond (Beechey, Johannsen and Levin (2011), Christensen and Gillan (2011), Haubrich, Pennacchi and Ritchken (2012) and Fleckenstein Longstaff and Lustig (2014) among others)

at the change in the quoted swap rate of ZCIS leading up to the auction and afterwards, it means that sellers of the swap are willing to accept a lower rate before the auction. This implies that there must be more supply than demand of the swap till the date of the auction and then reversal afterwards.

In the second part, we check the consistency of this auction cycle by doing a sub-sample analysis (i.e. we divide our sample in two halves and see how the severity of the auction cycle changes in those two halves)[3]. For TIPS, we see that the severity of the auction cycle doesn't decrease in the second half where the contribution of Primary Dealers is relatively less than before. Our results imply that the theory attributing primary dealers as the main contributors of this auction cycle should not hold because first the auction cycle in TIPS market remains unchanged and second the pattern in the ZCIS market is not intuitively explained by the existence of limited risk bearing capacity of primary dealers. Additionally, we exploit the data pertaining to primary dealers weekly net positions in TIPS. And we see that in the days leading up to the auction, on average primary dealers have a net increase in TIPS. But selling before the auction would imply that there should be a net decrease in positions before the auction. That we do not observe.

To find an explanation for this persistent auction cycle in the swap market, we focus on the demand side of Lou et al. (2013) explanation. Since there is selling in the secondary market before auction, then it means there is a demand for these securities. We propose that inflation-seeking investors find it cheaper to invest in TIPS in the days leading up to the auction, since the yield of TIPS is increasing. So, they would sell in the ZCIS market and buy TIPS with a higher yield. This would generate the required pattern in the inflation swap and TIPS markets. Additionally, we also check the change in the spread between the ZCIS and Break-even Inflation in the days before and after the auction relative to the auction day itself. There should be a lagged response in one of the markets if inflation-seeking investors are selling in one market and then going to the other.

[3]We divide the auctions in our sample starting from 2010 as we want to exclude any effects related to the financial crisis of 2008. So, the two samples that we have then are from 2010-2013 and from 2014-2017

Further, in order to check the validity of our proposition, we look at the net flows of mutual funds that invest in inflation-linked bonds. Here our intuition is that these funds should experience inflows in the days leading up to the auction and outflows afterwards. Theoretically, if there is a net inflow in the fund then it would create demand for the particular security the fund invests in. Our results indicate that in our sample from 2010-2017 indeed on average the mutual funds experience an inflow of about 0.15% of the size of the fund in the 10 days leading to the auction and an outflow of about 0.99% of the size of the fund on the auction day and in the 10 days after that. Similarly, we observe that the spread between the ZCIS and Break-even Inflation changes before and after the auction as compared to the day of the auction itself.

So, our main goal in this paper has been to highlight the major players involved in the auction process of US Treasury. It is important because the US Treasury incurs huge costs because of auction under pricing. It is vital to identify the proper channels because of whom this under pricing occurs as it would serve as a guideline for US Treasury on how to improve its auction process and to raise money more efficiently.

Our work adds to the literature by looking at the demand side of the securities that are being auctioned and tries to identify the players involved in the auction process. Previous studies look at only the supply side of the auction process. Lou, Yan and Zhang (2013) document the price pressure before the auction and attribute it to the limited risk-bearing capacity of primary dealers. The primary dealers have a limited risk-bearing capacity and since they have to participate in the auction process, they short-sell before in the secondary market. But in addition to their short-selling, the end investor is not able to fully take in that supply shock. This explanation is a two part explanation involving the limited risk-bearing capacity and the slow moving capital (as highlighted by Duffie (2010)). Beetsma et al. (2016) find a similar auction cycle present in the Italian Treasury market and Forest (2007) documents that with a higher-than-expected auction demand (as proxied by the bid-to-cover ratio), the interest rate on Treasuries decline.

In addition to the empirical work in documenting the auction cycle, there is a large amount of literature that tries to theoretically motivate the emergence of this cycle. As mentioned above, Duffie (2010) documents the slow moving capital where traders trade infrequently and at any given time only a certain proportion of those traders are present. Because of that, when there is a supply shock, the traders are not able to absorb the full shock and thus the price decreases because of the liquidity shock. But with infrequent trading, the price actually rises before and then it decreases afterwards till the date of the shock[4]. Sigaux (2018) tries to explain the price decrease in the days leading up to the auction using a three period portfolio management model shows that this particular pattern is because of the hedging demand that primary dealers have. The model in Sigaux (2018) is based on an imperfectly anticipated shock and is along similar lines as the asymmetric model in Vayanos and Wang (2011) and the symmetric case in Vayanos and Woolley (2013).[5]

Still all of the contemporary literature looks at the supply side of the auction process. Supply side in the sense that when there is going to be an auction on the US treasury, the explanation for the pattern show that there is an increased supply before the auction date and thus a decreasing price pattern. This explanation is not complete in the sense that if there is short-selling going on in the market, then there's another side that is willing to buy treasuries at a higher price than at the price at which they could buy at the auction date. And also the supply side explanation doesn't explain the pattern in the inflation swap market. We show that at least in the inflation-indexed market, there are inflation-seeking investors that short-sell in the swap market since they find it cheaper to invest through TIPS that have an increasing yield. And thus the emergence of the pattern in the inflation swap market and also they provide the demand in the secondary TIPS market.

[4]For further details regarding the Slow-Moving Capital Theory, we refer the readers to Mitchell, Pedersen and Pulvino (2007), Acharya, Shin and Yorulmazer (2009), Buss and Dumas (2015) and Fuchs, Green and Papanikolaou (2016)

[5]In addition to the mentioned literature above, there are other papers that document the dynamics of the market before a large anticipated liquidity shock. But the idea in these papers revolves around strategic trading. For details see Admati and Pfleiderer (1991), Brunnermeier and Pedersen (2005) and Bessembinder, Carrion, Tuttle and Venkataraman (2016)

Moreover, since we look at the ZCIS and its reaction around TIPS auctions, we try to infer the properties of the ZCIS market from that event. There is not much literature concerning the liquidity of the ZCIS market and literature about the TIPS market suggest that there are liquidity concerns within that market. Fleming and Krishnan (2012) study the liquidity of the TIPS market. Pflueger and Viceira (2011) find that the liquidity premium on TIPS is quite high, and during their issuance and the crisis of 2008-09 it became even larger. Thus investors demand a huge liquidity premium from TIPS. And thus using TIPS as a measure to calculate Break-even inflation can be problematic. And since the ZCIS can also be used to calculate Break-even inflation, if the ZCIS market is more liquid then its measure might be better.

Still there is not much evidence regarding the liquidity in the ZCIS market. Fleming and Sporn (2013), use transaction data on the ZCIS in the period from July till August 2010, and try to infer the liquidity concerns within the ZCIS market. The authors use the data set to check price transparency within the market. They compare the trading prices with the quoted prices and find them to be within a few basis points of each other. Similarly, they also calculate the Bid-Ask spread within the market and find it to be within a modest range. Thus they conclude that despite being an OTC market, it is still quite liquid.

We infer about the liquidity characteristics of the ZCIS market by looking at the impact of the auction cycle. Despite low daily transaction volumes (Fleming and Sporn, 2013), we find that the auction cycle is quite comparable to the TIPS market. And it is within range (the size impact of auctions) of the US Treasury Notes auction cycle, as documented by Fleming and Rosenberg (2007). Additionally, when we see the fluctuation of the spread between ZCIS and BEI, we see that it increases around the auction. And this increase points out that the increase in TIPS yield around the auction is not fully matched by a decrease in ZCIS quoted rate. This points to higher liquidity constraints in the TIPS market.

The rest of the paper proceeds as follows; **Section 2** gives a brief overview of the Inflation Swap Market and how the Zero-Coupon Inflation Swap works. Also it provides some details regarding US Treasury Auctions. **Section 3** describes details regarding the data, our sample period and which securities are used in the analysis. **Section 4** proceeds with our first main analysis. It first conducts an event-study then proceeds with the regression analysis and as a robustness we perform a cross-sectional auction study, before looking at the spill-over effects of different maturity TIPS auctions. **Section 5** proceeds with our second main analysis. It looks at the declining contribution of primary dealers over our sample period and then checks the validity of our explanations by looking at the net flows of mutual funds. Finally **Section 6** concludes the paper, also highlighting future directions the research can proceed.

2 Inflation Swap Market and Treasury Auction Mechanism

In the following sub-sections, we first provide a brief introduction to the inflation derivatives market in general and the swap market in particular. Also a brief account of Treasury Auction mechanism follows afterwards.

2.1 Inflation Derivatives Market

The inflation derivatives market debut in the US in early 2000's (Kerkhof, 2005), shortly after the inception of Treasury Inflation Protected Securities in the late 90's (Source: Treasury Direct). These derivatives hedge an investor against inflation by transferring the inflation risk from one party to another. And since its inception, the growth of the inflation derivatives market has been quite rapid. The figure below shows the size of inflation derivatives market over the years.

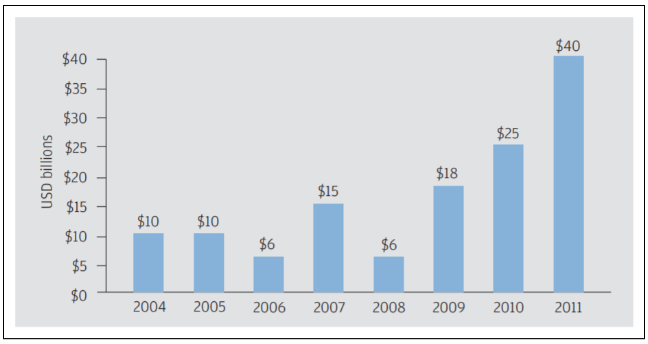

Figure 1: CPI Trading Volume, in USD billions

Source: Barclays Capital and J.P. Morgan Asset Management.

The most common and the most liquid among the inflation derivatives is a Zero-Coupon Inflation Swap (from here on referred to as ZCIS). With a ZCIS the buyer receives the actual inflation (the CPI rate) that prevailed during the particular maturity period, and in return pays a fixed rate based on present inflation expectations. So, the one who enters the contract receives a floating rate and pays a fixed rate. The fixed rate (also called the swap rate)is negotiated such that the initial value of entering the swap is zero, thus there is no cash outflow at the beginning. The net payment, in the case of a Zero-Coupon Swap as the name implies, is settled at the maturity.

The fixed and the floating legs of a ZCIS can be better described in terms of the following figure.

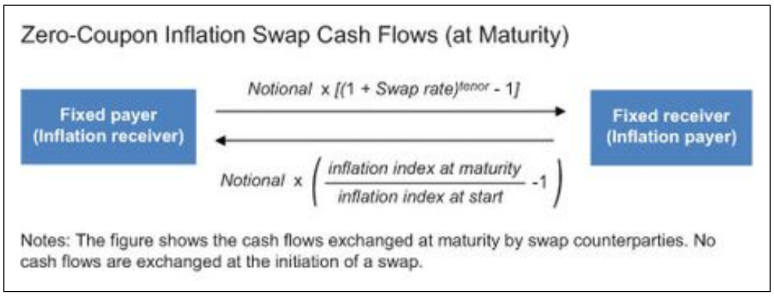

Figure 2: Workings of a Zero-Coupon Inflation Swap

Source: Fleming and Sporn, 2013

The ZCIS are quoted in terms of the fixed swap rate, and they are traded in a dealer based over-the-counter market. The market-makers of this particular OTC market are mostly G14 dealers and their customers include mostly Mutual and Pension Funds and Asset-Liability. Investors see these swaps as a good way to hedge against the inflation risk, and preferable to other instruments (such as TIPS), since these are available in a range of maturities (ranging from 1-year to 30-years) and thus can be customized to fulfill their particular needs.

Fleming and Sporn (2013), investigate the liquidity characteristics of the ZCIS market by looking at the daily transactions done and volumes traded during a particular period of time. Regarding the average volumes traded based on the data provided from BGC Partners, the authors find that from 2010 till 2012 there's been an increase in the average total volume of ZCIS being traded per day. Within the inter-dealer market, the authors see a roughly average of about $100 million per day in 2010, to about $190 million per day during the first half of 2012. With the highest activity in the 10-year maturity spectrum.

2.2 Treasury Auctions Mechanism[6]

US Treasury offers various types of securities (Bills, Notes, Bonds, TIPS and FRNs) with varying maturities over a particular year through public auctions. The auction mechanism is a single-price auction and the process involves three steps namely;

1. Announcement
2. Bidding
3. Issuance

The announcement is usually done a week before the auction and it includes the size of the offering, the auction, issue and maturity dates along with other characteristics of the particular maturity auction. So, it is an anticipated sale and a known liquidity shock within the Treasury market.

For the bidding process, there are competitive and non-competitive bids. In competitive bids, the participants specify the rate or yield acceptable to them and submit their bids

[6]Source: Treasury Direct and New York Fed Websites

to the Treasury before the closing time specified in the announcement. It is limited to 35% of the offering amount per each bidder and the competitive bidders, direct and indirect, usually include institutional investors, banks, governments and individuals. Primary dealers, included in direct bidders, are expected to participate in the auction process. Currently there are 23 primary dealers (Include investment banks including Goldman Sachs and JP Morgan with others) on the New York Fed's list that are expected to participate in the auction process.

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. Non-competitive bidders usually include small investors.

Since it is a single-price auction, all bidders receive the same yield at the highest accepted bid. For issuance, the Treasury delivers the securities to the bidders who were awarded those securities during the auction day, and in exchange charges their respective accounts.

For our analysis, we are interested in TIPS Auctions. They follow the same mechanism described above. For our sample ranging from 2005-2017, we see auctions on four different maturities of TIPS (5, 10, 20 and 30-years). Auctions on 20-year maturity are done till 2009, then they are replaced by 30-year maturity TIPS. More details regarding the TIPS auctions are provided in Section IV, describing the data and providing summary statistics.

3 Data Description and Methodology

The first part of our analysis revolves around the change in ZCIS quoted rate when there is an auction on TIPS (same maturity and cross-maturity impact). More precisely, for each n-year TIPS auction ($n = 5, 10, 20, 30$), we take the average quoted rate of ZCIS t^{th} day before the auction and t^{th} day after the auction ("t" ranges from 1 to 10) and we plot $Y(t) - Y(0)$. Where $Y(t)$ is the rate of specific maturity ZCIS t^{th} day before or after the auction, and $Y(0)$ is the rate at the auction day. Our first analysis is similar to that of Lou et al. (2013)

as they try to check for the presence of an auction cycle among treasury securities, 10 days before and after.

Additionally, we do a regression analysis where we check the presence of the auction cycle removed from the confounding effects of other variables. Like some auctions could be auctioned around nearby dates. So, we try to capture the effects of a specific maturity TIPS auction on a particular maturity ZCIS. In this part, we also reaffirm our first analysis by looking at the effects of all maturities TIPS auctions together on varying maturities of ZCIS. This particular part is similar to the study conducted in Beetsma et al. (2016) where the authors check for the presence of an auction cycle in German and Italian securities and compare the two.

Our analysis period ranges from 2005 to 2017. We use Bloomberg to get daily quotes on the Swap Rate. Additionally, we again use Bloomberg to get daily yields on TIPS and Nominal Bonds, that we use in our supplementary analysis. For the Swap, we have maturities ranging from 1-year to 30-years, and for the TIPS and Nominal our maturities are 5, 10 and 30-year.

For TIPS Auctions, we get data from Treasury Direct website. The website details the dates of the announcement and commencement of the auction, also it provides the announcement and results details (mentioning the size of the auction, and the amount of competitive and non-competitive bids tendered and accepted). Over our sample period we have a total of 133 auctions of all the TIPS maturities combined (5, 10, 20 and 30-year). The summary statistics of both the auctions and inflation swap rates are given in Tables 1 and 2 respectively.

Table 1(a) gives the average summary per auction of the respective maturities, and table 1(n) gives the number of auctions per year of a specific maturity.x As mentioned before, for 20-years TIPS, we have auctions till 2009. Then 2010 onward, we see auctions on 30-years TIPS and 20-years is discontinued. Still for our analysis we include the 20-years auctions and see their impact on different maturities of the Inflation Swap.

Table 1 (a)
Summary Statistics

Summary Statistics of TIPS Auctions

Maturity	Auction Type	No. of Issues	Amount ($ Millions)		Bid-to-Cover Ratio	
			Mean	Standard Deviation	Mean	Standard Deviation
5	Single	33	12,944	3,613	2.48	0.39
10	Single	67	11,528	2,613	2.40	0.36
20	Single	10	8,326	1,950	1.88	0.31
30	Single	23	7,408	1,289	2.57	0.25

Table 1 (b)
Number of TIPS Auctions per Year

	Maturity (in Years)			
Year	**5**	**10**	**20**	**30**
2005	2	4	2	0
2006	2	4	2	0
2007	2	4	2	0
2008	2	4	2	0
2009	2	4	2	0
2010	2	5	0	2
2011	3	6	0	3
2012	3	6	0	3
2013	3	6	0	3
2014	3	6	0	3
2015	3	6	0	3
2016	3	6	0	3
2017	2	6	0	3

Table 1: Summary Statistics for TIPS Auction

Table 2
Zero-Coupon Inflation Swap Summary Statistics

Summary Statistics for all Maturities of Zero-Coupon Inflation Swaps

Maturity (in Years)	Mean*	Standard Deviation	Percentiles			Skewness	Kurtosis	Max	Min
			25th	50th	75th				
1	1.65	1.16	1.17	1.73	2.44	-1.79	8.64	3.80	-4.55
2	1.84	0.91	1.46	1.84	2.45	-1.80	9.74	3.46	-3.61
3	1.98	0.73	1.62	1.97	2.52	-1.41	7.73	3.35	-2.05
4	2.10	0.61	1.74	2.11	2.57	-1.08	6.15	3.34	-1.23
5	2.20	0.54	1.85	2.23	2.60	-0.98	5.38	3.31	-0.57
7	2.33	0.45	2.07	2.41	2.66	-0.87	3.88	3.23	0.40
10	2.49	0.37	2.29	2.59	2.75	-0.89	3.04	3.15	1.15
20	2.66	0.38	2.47	2.78	2.93	-0.94	3.06	3.36	1.07
30	2.74	0.40	2.54	2.83	3.02	-0.78	2.82	3.50	1.45

*The mean gives the average quoted swap rate in percentage over our sample period [2005-2017]

Table 2: Summary Statistics for ZCIS

Further we obtain data about auction characteristics (size and bid-to-cover) and the amount tendered and allocated to primary dealers by looking at the announcements and the results of the auction available on treasury direct website. In addition, the list of primary dealers, and their weekly net positions in TIPS is obtained from New York Fed's website.

Mutual Funds data is obtained from Morningstar. We take Estimated Net Flows and Comprehensive Size variables available on a daily basis. And use them in our analysis. For our sample, we obtain a total of 72 mutual funds that invest in inflation-linked bonds. These include funds that are still working and others that haven't survived. A summary of these funds by year is presented later in the section 6.

4 Empirical Analysis

4.1 Event-Study

This section provides our main empirical analysis. We first conduct a simple constant return model where we take the rate difference of a particular maturity ZCIS around the auction dates, then we do a regression analysis to remove the effects of nearby auctions on a different maturity. Lastly, to see how the auction cycle we document varies with auction characteristics, we take into account the size and demand (we proxy it by the bid-to-cover ratio) of each auction and conduct a cross-sectional study.

4.1.1 Constant Return Model

This section presents the results of our event-study analysis. We conduct an event-study in line with Lou et al. (2013), where we take the auction date quoted rate of the Swap as the base rate, $Y(0)$ and we do a $Y(t) - Y(0)$ analysis with "t" days before and after the auction. Since most of the auctions are conducted about a week after the announcement, we check the auction cycle 10 days before and after the auction.

Lou et al. (2013) find that the yields on treasury bonds increase from the announcement date till the auction, and then there is a reversal after the auction date. So, they find an inverted V-shaped pattern. Before doing our analysis with the inflation swap, we check whether we find the presence of the particular inverted-V shape in secondary market of TIPS when there is an auction of the same or different maturity TIPS. We also plot the 95% confidence intervals, where the standard errors used are Newey-West adjusted. Figure 3 captures the result of our first analysis.

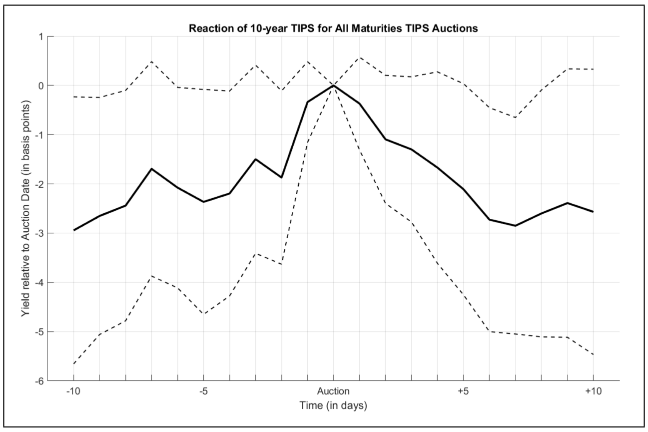

Figure 3: Reaction of 10-Year TIPS around all TIPS Auctions

From the figure, we see that the results are in line with that of Lou et al. (2013). We do observe an inverted V-shaped pattern for TIPS yields around the auction date. We do the same analysis for 5 and 30-years maturities and get the same results.

For the ZCIS, if we follow the theory about primary dealers short-selling in the market should not be applicable here. Still, since the ZCIS is almost equivalent to the Break-Even Inflation (BEI), if BEI moves in a particular pattern, it should be manifested in ZCIS. As else it would be an arbitrage opportunity. So, if there's a V-shaped pattern in the ZCIS, then it means there is more short-selling in this market till the auction date and reversal afterwards. As if investors are selling the swap, it means they would be willing to accept even a lower quoted rate. If it is an inverted V-shaped pattern, the opposite would apply.

Figure 4 shows the results for the reaction of the same maturity ZCIS as the TIPS auctioned. Later, Figure 5 shows results for reaction of a particular maturity ZCIS (5, 10 and 30 years) for all TIPS auctions.

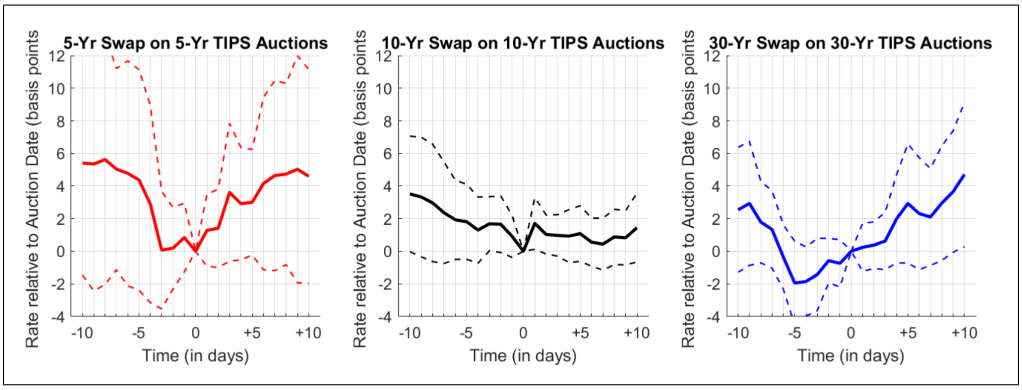

Figure 4: Reaction of ZCIS around same Maturity TIPS Auctions

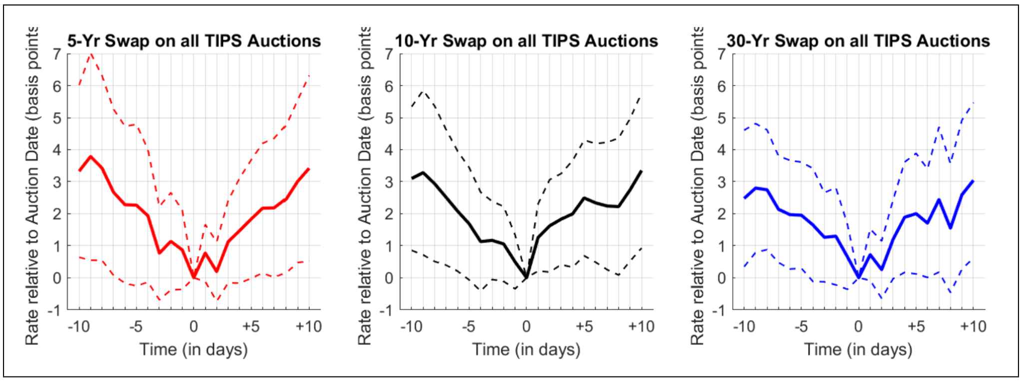

Figure 5: Reaction of ZCIS around all TIPS Auctions

Again with the figures above, we plot the 95% confidence intervals. The first thing to notice is that we see a gradual decrease in the quoted ZCIS rate that starts 10 days before the auction in all 5, 10 and 30-Year maturities. And we see a gradual reversal after the auction date. This scenario is more evident in the case of Figure 5 where our sample size is much greater, as it takes the effects of all auctions on a specific maturity swap.

Looking more closely at Figure 5, we see that the shorter the maturity the higher is the presence of the auction cycle. That is we see a decrease from about 4 basis points in the case of 5-Year ZCIS, a bit above 3 basis points in case of 10-Year and closer to 2 basis points in the case of 30-Year ZCIS maturity. In the same line, the confidence intervals at the top end (97.5^{th} percentile) are higher, the shorter the maturity. The explanation for this particular phenomenon could be either that there are higher liquidity constraints in the short-term maturities, or it could be that there is higher activity in the short-term maturities when there is an auction on any maturity TIPS. The second explanation could be more plausible, since if we consider TIPS and ZCIS as substitutes, then when there is an auction on a higher maturity TIPS (lets say 30-Year), then speculators or inflation seekers can substitute that particular TIPS on a roll-over basis with shorter-maturities (like 5, 10 or any other maturity spectrum). We look into this particular aspect in detail in the cross-maturity spill-over analysis.

The results of Figure 4 and 5 are respectively translated into numbers in Tables 3 and 4.

Table 3
ZCIS Abnormal Returns around same Maturity TIPS Auctions

ZCIS around same Maturity TIPS Auctions: *Y(t) - Y(0)*

	5-Year		10-Year		30-Year	
t	**Mean**	***t*-stat**	**Mean**	***t*-stat**	**Mean**	***t*-stat**
-10	5.41*	(1.64)	3.51**	(2.07)	2.54	(1.38)
-9	5.35	(1.43)	3.32*	(1.89)	2.94	(1.61)
-8	5.62	(1.53)	2.96*	(1.72)	1.79	(1.49)
-7	5.04*	(1.70)	2.36	(1.58)	1.33	(1.17)
-6	4.78	(1.44)	1.93*	(1.66)	-0.37	-(0.39)
-5	4.37	(1.35)	1.81*	(1.64)	-1.95	-(1.58)
-4	2.89	(1.00)	1.30	(1.34)	-1.86*	-(1.83)
-3	0.07	(0.04)	1.68**	(2.12)	-1.42	-(1.34)
-2	0.19	(0.15)	1.66	(1.99)	-0.58	-(0.88)
-1	0.84	(0.83)	0.91	(1.47)	-0.74	-(1.07)
1	1.28	(1.20)	1.71**	(2.24)	0.24	(0.34)
2	1.41	(1.23)	1.03*	(1.80)	0.37	(0.55)
3	3.61*	(1.78)	0.97	(1.59)	0.63	(0.75)
4	2.92*	(1.77)	0.93	(1.20)	1.99	(1.53)
5	3.00**	(1.94)	1.08	(1.32)	2.93*	(1.67)
6	4.16*	(1.64)	0.56	(0.79)	2.31	(1.40)
7	4.64*	(1.66)	0.43	(0.57)	2.10	(1.48)
8	4.74*	(1.78)	0.88	(1.08)	2.95*	(1.75)
9	5.03	(1.51)	0.83	(1.04)	3.65**	(2.05)
10	4.59	(1.46)	1.45	(1.43)	4.71**	(2.22)

This table follows the same pattern of Lou et al. (2013). It reports the time-series average of Y(t) -Y(0), where Y(t) in this particular case is the quoted rate of the *n-year* ZCIS relative to the auction date (where n = 5, 10 and 30-years). The t-stats reported are based on Newey-West adjusted standard errors. ***, ** and * indicate significance levels of 1%, 5% and 10% respectively.

Table 3: Reaction of ZCIS around same maturity TIPS Auctions

Table 4
ZCIS Abnormal Returns around all TIPS Auctions

ZCIS around all TIPS Auctions: *Y(t) - Y(0)*

	5-Year		10-Year		30-Year	
t	**Mean**	***t*-stat**	**Mean**	***t*-stat**	**Mean**	***t*-stat**
-10	3.33***	(2.58)	3.10***	(2.88)	2.48***	(2.42)
-9	3.79***	(2.44)	3.28***	(2.66)	2.80***	(2.90)
-8	3.42***	(2.48)	2.94***	(2.52)	2.75***	(3.07)
-7	2.67**	(2.15)	2.51***	(2.47)	2.14***	(2.68)
-6	2.28*	(1.94)	2.08**	(2.31)	1.97***	(2.42)
-5	2.27*	(1.87)	1.69**	(2.01)	1.95***	(2.46)
-4	1.94*	(1.95)	1.13	(1.53)	1.65*	(1.95)
-3	0.77	(1.10)	1.17**	(2.00)	1.26*	(1.90)
-2	1.14	(1.56)	1.06*	(1.88)	1.30*	(1.78)
-1	0.87	(1.47)	0.49	(1.23)	0.66	(1.35)
1	0.77*	(1.81)	1.26***	(2.51)	0.72*	(1.87)
2	0.19	(0.43)	1.62***	(2.34)	0.25	(0.59)
3	1.12*	(1.83)	1.83***	(2.68)	1.20**	(2.04)
4	1.47*	(1.87)	1.99***	(2.50)	1.89**	(2.29)
5	1.83**	(2.07)	2.49***	(2.88)	2.00**	(2.22)
6	2.17**	(2.24)	2.34***	(2.63)	1.70**	(2.10)
7	2.18**	(2.10)	2.24***	(2.35)	2.44**	(2.25)
8	2.45**	(2.22)	2.22**	(2.17)	1.55	(1.61)
9	3.01***	(2.48)	2.74***	(2.57)	2.59***	(2.33)
10	3.42***	(2.46)	3.35***	(2.89)	3.04***	(2.61)

This table follows the same pattern of Lou et al. (2013). It reports the time-series average of Y(t) -Y(0), where Y(t) in this particular case is the quoted rate of the *n-year* ZCIS relative to the auction date (where n = 5, 10 and 30-years). The t-stats reported are based on Newey-West adjusted standard errors. ***, ** and * indicate significance levels of 1%, 5% and 10% respectively.

Table 4: Reaction of ZCIS around all TIPS Auctions

One limitation in our analysis is the number of TIPS auctions we have in our sample. if we look at the specific maturity ZCIS rate change when there is an auction on the specific maturity TIPS, our sample size reduces quite significantly. As an example, overall we have 133 TIPS auctions of varying maturities, but looking at the impact of 5-Year TIPS auctions on 5-Year ZCIS reduces our sample to a total of 32 auctions. The results of this limitation are visible in the Tables. Because we get much higher significance, and thus a strong indicator of the presence of the auction cycle, in Table 4 where our sample size is comparatively quite large.

Overall, the results of our analysis indicate that there is a presence of an auction cycle in the Inflation Swap market. Our results are different form the literature in the sense that first, we detect the presence of an auction cycle (inverted V-shaped pattern) in the secondary

TIPS market and second, we find the presence of a similar auction cycle (V-shaped pattern) in the market of an instrument that is not actually auctioned, but can be considered as a substitute of the original one being auctioned.

Additionally we also run the same analysis on Break-even Inflation (BEI), i.e. we check the behavior of a (Nominal - TIPS) security where both the Nominal and TIPS have the same maturities). Since BEI is a direct comparison of the inflation-swaps. The results are very similar to the ZCIS pattern. Still we see a delayed reaction in the 5-year swap market. These results are shown in figure 6.

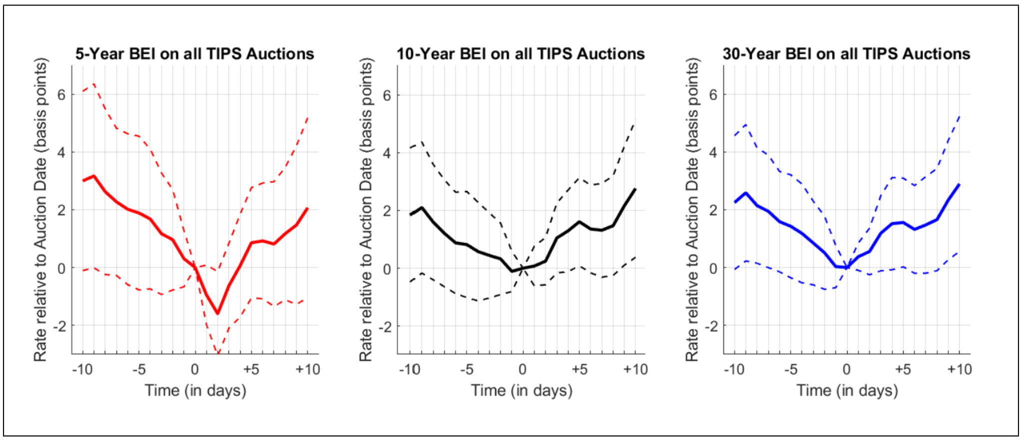

Figure 6: Reaction of BEI around all TIPS Auctions

4.1.2 Regression Analysis

With a regression analysis, we try to excluding confounding factors like there could be different maturity auctions taking place at or around the same date. The analysis performed here is very similar to Beetsma et al. (2016) where the authors use this analysis to check the presence of auction cycle in Italian and German bonds. Basically we run the following regression;

$$\Delta ZCIS_t^m = c_0^t + \sum_{l=10}^{-10} \alpha_l AUC_{t+l}^m + \sum_{l=10}^{-10} \beta_l AUC_{t+l}^{n \neq m} + \epsilon_t^m$$

Where $\Delta ZCIS_t^m$ is the change in the swap rate of "m'' maturity swap at time "t", and

"AUC'' is a dummy variable that indicates whether on the specific date there is an auction or not. "$n \neq m''$ indicates all maturities other than "m''. So, with "$t + l''$, we can check the presence of the auction cycle 10 days before and after the auction, and the impact of a particular maturity TIPS auction on the swap rate.

To check the presence of the auction cycle, we do a F-test, in line with Beetsma et al. (2016), with the following hypothesis:

$$H_0 : \left(\sum_{l=-1}^{-10} \alpha_l \right) - \left(\sum_{l=9}^{0} \alpha_l \right) = 0$$

We perform the same test on the β co-efficients. To get the same results as the constant return model, we expect $\left(\sum_{l=-1}^{-10} \alpha_l \right) > 0$ and $\left(\sum_{l=9}^{0} \alpha_l \right) < 0$. 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). So, we expect that coefficients with $l < 0$ will have a positive value and coefficients with $l > 0$ (in anticipation of the upcoming auction) will see a negative value.

In this section, in addition to running the regression on change in the rate of ZCIS, we also check the change in TIPS yield with the same auction, and perform the same test statistics. In this way, we compare the impact or severity of the auction cycle in the ZCIS market and the TIPS secondary market. In a way, it can give us the sense to compare liquidity within the two markets. Our intuition is that if the auction cycle is deeper, then that particular market might have more liquidity concerns. Since the auction cycle in TIPS is an inverted V-shape, we expect $\left(\sum_{l=-1}^{-10} \alpha_l \right) < 0$ and $\left(\sum_{l=9}^{0} \alpha_l \right) > 0$. Also, we report the sum of coefficients so that it represents the absolute change in yield value. So, the regression done is:

$$\Delta TIPS_t^m = d_0^t + \sum_{l=10}^{-10} \alpha_l AUC_{t+l}^m + \sum_{l=10}^{-10} \beta_l AUC_{t+l}^{n \neq m} + \nu_t^m$$

Similarly, the F-test performed for TIPS yield change is on the following hypothesis:

$$H_0 : \left(\sum_{l=9}^{0} \alpha_l\right) - \left(\sum_{l=-1}^{-10} \alpha_l\right) = 0$$

The results are shown in Table 5.

Table 5
Estimates of TIPS Auction Effects on Swap Rates and Secondary TIPS Yields of Different Maturities

Auction Cycle of 21 days (-10 to +10)

	Inflation Swap Rate			TIPS Yields		
	5-year	10-year	30-year	5-year	10-year	30-year
Dummy own	9.76**	5.45**	7.25*	5.05	5.71**	7.68*
Dummy 5-year	-	7.28**	6.63*	-	3.28	2.77
Dummy own	9.55**	5.03**	7.2*	5.08	5.74**	7.74*
Dummy 10-year	4.31	-	4.77*	5.1*	-	6.20**
Dummy own	9.76**	4.67**	7.25*	5.05	6.01**	7.69*
Dummy 20-year	5.09	3.41	1.75	10.93	6.97	8.85
Dummy own	9.76**	4.91**	7.24*	5.05	6.03**	7.69*
Dummy 30-year	11.70**	9.72**	-	11.49**	9.01*	-
Dummy own	9.71**	4.66**	7.17*	5.12	6.42**	7.77*
Dummy 5-year	-	7.42**	6.49*	-	3.16	2.71
Dummy 10-year	4.26	-	5.81**	6.35**	-	6.98***
Dummy 20-year	4.72	4.32	0.47	10.77	6.45	8.22
Dummy 30-year	11.68**	9.68**	-	11.38**	9.06*	-
Dummy own	10.31***	5.29**	7.24*	5.49	6.29**	7.64*
Dummy $n \neq m$	6.38***	7.94***	5.51***	7.68***	5.89**	5.74***
Dummy All	7.39***	6.83***	5.87***	6.71***	6.17***	6.03***

This table implemets regressions similar to Beetsma et al. (2016). The regression checks the effect of Auction dummies, 10 days before and after the auction, for different maturity TIPS on a the change in quoted rate of a specific maturity Inflation Swap. As an example, "Dummy own" checks the effect of the same maturity Auction on the same maturity Swap, and "Dummy n ≠ m" represents the auction on all maturities TIPS different from the maturity of the swap. "Dummy All" is basically the same as the Constant Return model event-study conducted in the previous section and it just checks the presence of the auction cycle. All the numbers in the table represent change in basis points. The sample in this period spans our original period of 2005-2017. ***, ** and * represent the significance levels at 1%, 5% and 10% respectively

Table 5: Reaction of ZCIS and Secondary TIPS around TIPS Auctions

In Table 5, first if we look at the variable "*Dummy All*", it actually can be thought of as being very similar to the Constant Return Model that we did above. Because this particular variable contains the auction dates of all TIPS maturities, so the differentiation between particular maturities of TIPS is not made. Thus the results should be in line with the constant return model. And we see for the inflation swap, we have the same result of presence of an auction cycle. And the severity of this auction cycle decreases with an increase in maturity of the swap. For 5-year ZCIS, we observe an auction cycle of about 7.4 basis points, and for 30-year we observe an auction cycle of about 5.90 basis points.

Overall, just by looking at Table 5, it indicates the presence of the auction cycle in 5, 10 and 30-year maturities of the inflation swap, when there is an auction on the same maturity TIPS.

Another important thing this table highlights, is the effect of cross-maturity auctions spill-over effects. We will expound more on the details of this particular part in the next sub-section. But on a glance, we see that the effect of 30-year TIPS auction spreads through the 5 and 10-year maturities inflation swaps. Meaning that, when there is an auction on 30-year TIPS, investors indulge in a roll-over basis by taking on shorter maturities.

The right hand side of Table 5 shows the impact on already issued TIPS when there is an auction on new TIPS of varying maturities. Except for 5-years, we find the presence of the auction cycle in the secondary market of TIPS also. The 5-year maturity TIPS has an auction cycle when there is an auction on higher maturities TIPS (this is indicated by a change of 5.10 and 11.49 basis points during the auction of 10 and 30-year TIPS). Concerning the severity of the auction cycle along different maturity spectrum, we see the same trend as that present in inflation swaps, i.e. we see that given auction on all maturities TIPS, we see that the auction cycle becomes less severe on increasing maturity already issued TIPS.

Lastly, the table gives us an opportunity to compare the secondary TIPS market and ZCIS market. Our results suggest that, on average, the auction cycle is a bit more pronounced in the ZCIS market. This suggests that there could be more liquidity concerns present in the Inflation Swaps market, though it is considered more liquid than the TIPS. To find out more in detail about this issue and check whether the auctions during the recession period might be affecting the results in some way, we divide our sample to a post-recession period (Auctions after July 2009[7]). The results are shown in Table 6.

[7]The official date of regression is taken from NBER's Recession classification

Table 6
Estimates of TIPS Auction Effects on Swap Rates and Secondary TIPS Yields of Different Maturities

Auction Cycle of 21 days (Post-Recsession Period, mid 2009-2017)

	Inflation Swap Rate			TIPS Yields		
	5-year	10-year	30-year	5-year	10-year	30-year
Dummy own	4.71	4.01*	7.29*	5.14	3.58	7.77*
Dummy 5-year	-	3.7	5.25	-	5.3	1.81
Dummy 10-year	4.59	-	4.37	4.48	-	4.35
Dummy 30-year	12.09**	9.93***	-	11.77**	9.14*	-
Dummy own	4.66	4.82*	7.45*	5.23	3.85	7.64*
Dummy $n \neq m$	7.27***	6.34**	5.65*	6.77**	7.13**	3.67*
Dummy All	6.54***	5.56***	5.34**	6.44**	5.44**	4.58**

This table implemets regressions similar to Beetsma et al. (2016). The regression checks the effect of Auction dummies, 10 days before and after the auction, for different maturity TIPS on a the change in quoted rate of a specific maturity Inflation Swap. As an example, "Dummy own" checks the effect of the same maturity Auction on the same maturity Swap, and "Dummy n ≠ m" represents the auction on all maturities TIPS different from the maturity of the swap. "Dummy All" is basically the same as the Constant Return model event-study conducted in the previous section and it just checks the presence of the auction cycle. All the numbers in the table represent change in basis points. The sample in this period spans the post-recession period of mid 2009-2017. ***, ** and * represent the significance levels at 1%, 5% and 10% respectively

Table 6: Reaction of ZCIS and Secondary TIPS around TIPS Auctions

By excluding the Pre and During-Recession period, we loose 37 auctions from our sample, and now the total auctions of 5, 10 and 30-year TIPS maturities are 96 (also the 20-year TIPS auctions are automatically excluded from our analysis since there aren't any in the post-recession period). Again if we look at the "*Dummy All*" variable, we see that the severity of the auction cycle in both TIPS and ZCIS is about the same. Though it is still a bit higher in the ZCIS market.

4.2 Cross-Sectional Analysis

In this section we conduct analysis based on the characteristics of the auction. In particular, we look at the size of a particular auction and how it impacts the change in the swap rate and secondary TIPS yield. Our initial intuition says that if we look at the primary dealers and slow moving capital theories, we should see a positive relationship between the size and total change in TIPS yields. Since, the higher the size of a particular auction, the more a primary dealer needs to hedge itself and thus there should be a deepening of the auction cycle at least in the TIPS market. For ZCIS, since we observe short-selling before the auction date, a similar reasoning might apply, where we should expect a positive relationship with the size of the auction and also with the demand.

Similar to what we did before, we follow Beetsma et al. (2016) and conduct the following regressions for both ZCIS and TIPS:

$$\Delta ZCIS_t^m = c_0^t + \sum_{l=9}^{-10} \alpha_l SIZE_{t+l}^m + \sum_{l=9}^{-10} \beta_l SIZE_{t+l}^{n \neq m} + \epsilon_t^m$$

$$\Delta TIPS_t^m = d_0^t + \sum_{l=9}^{-10} \alpha_l SIZE_{t+l}^m + \sum_{l=9}^{-10} \beta_l SIZE_{t+l}^{n \neq m} + \nu_t^m$$

So, we replace the auction dummies, with the size of the particular auction either to be conducted ($l > 0$) or already conducted ($l < 0$). The size of an auction is represented in billions, and the results are shown in Table 7.

Table 7
Estimates of TIPS Auction Size Effects on Swap Rates and Secondary TIPS Yields of Different Maturities

Auction Cycle of 21 days (Full Sample Analysis, 2005-2017)

	Inflation Swap Rate			TIPS Yields		
	5-year	10-year	30-year	5-year	10-year	30-year
Size own	0.55*	0.41**	0.96	0.33	0.33	1.13*
Size 5-year	-	0.41*	0.45	-	0.29	0.17
Size own	0.54*	0.39**	0.95	0.34	0.35	1.13*
Size 10-year	0.37*	-	0.39*	0.38	-	0.44**
Size own	0.55*	0.36*	0.96	0.34	0.36	1.13*
Size 20-year	0.83	0.65	0.36	1.35	0.86	1.16
Size own	0.55*	0.37*	0.96	0.33	0.38*	1.13*
Size 30-year	1.58**	1.31**	-	1.67**	1.32**	-
Size own	0.55*	0.34*	0.94*	0.33	0.39*	1.14*
Size 5-year	-	0.41*	0.44	-	0.28	0.16
Size 10-year	0.35	-	0.46**	0.46*	-	0.47**
Size 20-year	0.78	0.68	0.21	1.37	0.79	1.13
Size 30-year	1.59**	1.30**	-	1.65**	1.32**	-
Size own	0.55*	0.41**	0.96	0.35	0.36	1.11*
Size n ≠ m	0.54**	0.58***	0.42**	0.61**	0.49*	0.36**
Size All	0.55***	0.49***	0.47***	0.51**	0.42**	0.41**

This table implemets regressions similar to Beetsma et al. (2016). The regression checks the effect of Auction size, 10 days before and after the auction, for different maturity TIPS on a the change in quoted rate of a specific maturity Inflation Swap. The size is in billions and the results of coefficients are in basis points. For the variables, as an example, "Size own" checks the effect of size of same same maturity Auction on the same maturity Swap, and "Size n ≠ m" represents the size of auction on all maturities TIPS different from the maturity of the swap. The sample in this period spans our original period of 2005-2017. ***, ** and * represent the significance levels at 1%, 5% and 10% respectively

Table 7: Reaction of ZCIS and TIPS around Different Sizes of TIPS Auctions

Table 8 provides similar estimates to that of Table 5 and 6, i.e. it reports the coefficients $\left(\sum_{l=-1}^{-10}\alpha_l\right) - \left(\sum_{l=9}^{0}\alpha_l\right)$ for the ZCIS rates and $\left(\sum_{l=9}^{0}\alpha_l\right) - \left(\sum_{l=-1}^{-10}\alpha_l\right)$ for TIPS yields. First looking at the Inflation-swap market, we see that for an increase of \$1 billion in the size of any auction ("*Size All*" variable) is associated with about 0.5 basis points increase in the severity of the auction cycle. The most severe is the case of the shorter 5-year maturity and it reduces with the increase in maturity of the swap, again in line with our previous results.

For TIPS yield change we observe a very similar trend, though again the severity of the cycle is less. Our results are very similar to those documented by Fleming and Rosenberg (2007). The authors show that for each increase of about 1 billion dollars in auction size, there is an increase in yield of about 0.3 - 0.5 basis points of 5-year US Treasury Notes.

4.2.1 A Note on the Liquidity Comparison of ZCIS and TIPS

Now coming back to the question of ZCIS and TIPS liquidity. Liquidity is an important question relating to ZCIS and TIPS, as TIPS are usually assumed to demand a higher liquidity premium than the Nominal Treasury market (Pflueger and Viceira (2011) and Andreasen et al. (2018) among others), and both ZCIS and TIPS can be used to determine Break-even inflation, it remains a question whether ZCIS might actually be a better measure. We see from Tables 5 and 7 that the effect of auction cycle appears to be less severe in TIPS market than in the ZCIS market. This suggests that simply by looking at these measures we can conclude that TIPS market is slightly more liquid. Still, table 6 points out that the differential isn't too much (There's only a difference of 0.09 basis points in the severity of the auction cycle among ZCIS and TIPS 5-year maturities)

But to get a better understanding of this question, we look at the literature for guidance as to which measure is more liquid than the other. There isn't much evidence on the liquidity of the ZCIS market. Haubrich et al. (2012) develop a model of nominal and real yield curves using different data set for inflation expectations. The authors find that the TIPS market has more liquidity constraints and thus the inflation swap is a better measure of inflation expectations.

The first study that really tackles this particular question is Fleming and Sporn (2013). The authors use electronically matched inflation swap transactions between June 1 and August 31, 2010. The data is obtained from MarketSERV, that only supports zero-coupon inflation swaps. So, their data is comprised of only ZCIS. Within their sample data, the authors find that overall the transaction volume is quite low in the ZCIS market (an average of about 2 transactions per day during their sample period). Given the low level of transaction volumes in the inflation swap market, our results should have shown that the auction cycle should be more severe. Still, we obtain measures that are quite close to the TIPS and the

Nominal Treasury market. Additionally the authors find that the bid-ask spreads are quite modest in ZCIS market and price transparency (differential between traded and quoted prices) is quite high. So, from this we conclude that the Inflation Swap market, though having low transaction volumes has still got comparable severity of the auction cycle, has less frictions and thus more liquid.

4.3 Effect of Auction Demand

This section studies how the demand of the auction impacts the V-shaped pattern in the ZCIS market and the inverted-V pattern in TIPS market. The auction demand here is proxied by the Bid-to-Cover ratio, the statistic released by the Treasury in the announcement of its Auction results. Forest (2018) investigates the effect of Bid-to-Cover ratio (as a proxy for auction demand) on US Treasury interest rates. He finds that a higher than expected auction demand tends to push the yield of 5 and 10 years treasury notes down. Our analysis is similar in the sense that we use Bid-to-Cover ratio as a proxy for auction demand. But then we see how it impacts the auction cycle itself.

Going along with Lou et al. (2013), primary dealers will sell more in the secondary market if they have a higher demand for the auctioned securities, since they will be buying or bidding more in the auction itself. So, based on this we expect that the auction cycle should be more severe if the auction demand is higher in TIPS. The results are shown below in Table 8.

Table 8
Estimates of TIPS Auction-Demand (Bid-to-Cover Ratio) on Swap Rates and Secondary TIPS Yields

Auction Cycle of 21 days (Full Sample Analysis, 2005-2017)

	Inflation Swap Rate			TIPS Yields		
	5-year	10-year	30-year	5-year	10-year	30-year
Dummy own	3.25**	2.34**	2.77	2.60	2.06*	2.88*
Dummy 5-year	-	2.38*	2.23	-	1.60	1.15
Dummy own	3.25**	2.22**	2.77	2.67	2.08*	2.89*
Dummy 10-year	1.9	-	2.13**	1.94		2.28**
Dummy own	3.25**	2.1**	2.77	2.60	2.07*	2.88*
Dummy 20-year	2.42	1.92	0.72	5.87	3.63	4.48
Dummy own	3.25**	2.16**	2.77	2.60	2.21**	2.88*
Dummy 30-year	4.6**	3.8**	-	4.47**	3.46*	
Dummy own	3.31**	2.06**	2.75	2.66	2.21*	2.88*
Dummy 5-year	-	2.43*	2.24	-	1.55	1.12
Dummy 10-year	1.81	-	2.4**	2.17	-	2.40**
Dummy 20-year	2.4	2.13	0.46	5.99	3.48	4.24
Dummy 30-year	4.66**	3.78**	-	4.44**	3.47*	-
Dummy own	3.46**	2.31**	2.82*	2.78	2.23*	2.85*
Dummy $n \neq m$	2.72***	2.96***	2.21**	2.96***	2.51**	2.08**
Dummy All	2.91***	2.69***	2.35***	2.83***	2.39***	2.22***

This table implemets regressions similar to Beetsma et al. (2016). The regression checks the effect of Auction Demand (proxied by the Bid-to-Cover Ratio), 10 days before and after the auction, for different maturity TIPS on a the change in quoted rate of a specific maturity Inflation Swap and the Secondary TIPS. As an example, "Dummy own" checks the effect of the same maturity Auction on the same maturity Swap, and "Dummy n ≠ m" represents the auction on all maturities TIPS different from the maturity of the swap. "Dummy All" is basically the same as the Constant Return model event-study conducted in the previous section and it just checks the presence of the auction cycle. All the numbers in the table represent change in basis points. The sample in this period spans our original period of 2005-2017. ***, ** and * represent the significance levels at 1%, 5% and 10% respectively

Table 8: Reaction of ZCIS and TIPS around Different Demand of TIPS Auctions

The results for both the TIPS market and the ZCIS market are very similar. We are mostly interested in the ”Dummy All” variable, since it gives the results by combining all auctions (5, 10 and 30 years TIPS) and checks the impact on 5, 10 and 30 years inflation swap and TIPS. And we observe that for all maturities of TIPS and the respective maturities of the Inflation Swap, an increase in auction demand (an increase in Bid-to-Cover ratio) is associated with an increase in the severity of the auction cycle. So, the results for the TIPS auctions are in line with the explanation of Lou et al. (2013). And similarly for the ZCIS market, the higher the demand of the auction means that the higher will be the price pressure in the TIPS secondary market, so the higher is the activity in the inflation swap market.

4.4 Spill-Over Effects on Other Maturities

A deeper look at tables 5, 6 and 7 show the spill-over effects of cross-maturity auctions. That is what happens to the quoted swap rate (in the case of ZCIS) of a particular maturity when there is an auction on a different maturity TIPS. In this section we look at this spill-over effects in more details and see how different maturities of ZCIS react to TIPS auctions. This gives us an idea about the substitutes relation inherent within the ZCIS and TIPS.

Looking at Table 5 (auctions for the full sample), we see that when there is an auction on 30-year TIPS, we see the presence of an auction cycle on 5 and 10-year ZCIS maturities. Similarly, when there is an auction on either 5 or 10-year TIPS maturities, we see the presence of an auction cycle in 30-year ZCIS. This reflects that investors hedge there risks using different maturities of ZCIS across the spectrum. Lastly, the same thing is shown in Table 5 again with the dummy variable "$Dummy\ n \neq m''$, since it is significant across all maturities of inflation swap. So it reflects that when thre is an auction on a "n-year" TIPS maturity, we see an activity in the "m-year" inflation swap, with "$n \neq m''$ as mentioned before.

To look whether this effect is also present in other maturities of the inflation swap, we do the same analysis as done in Table 5 and Table 7 on all maturities of ZCIS. But this time we only do for the Dummy Variable "$Dummy\ n \neq m''$ and the Size Variable "$Size\ n \neq m''$, since both these variables include all auctions. The results are shown in Table 9.

Table 9
Cross-Maturity Spill-Over effects

ZCIS Maturity	Auction Impact	Auction Size Impact
1	5.28	0.45
2	6.72**	0.47*
3	7.91***	0.56**
4	7.26***	0.55***
5	7.39***	0.55***
10	6.83***	0.49***
20	6.75***	0.47***
30	5.87***	0.47***

This table reports the auction cycle severity in column 2 and the impact of the size of the auction in column 3. The Auction Impact and Auction Size Impact reported numbers are in basis points, whereas ZCIS Maturity is in years. The sample period is 2005-2017 and includes all TIPS auctions. ***, ** and * indicate significance levels of 1%, 5% and 10% respectively.

Table 9: Reaction of All ZCIS Maturities around TIPS Auctions

The results indicate a presence of auction cycle on all maturities of ZCIS, except for the 1-year maturity. The severeness of the auction cycle for maturities 3, 4 and 5-years is quite high comparatively, but then it reduces with increasing maturity. This results is the same as can be done with the Constant Return Model by simply taking the rate differentials and looking at the pattern around the auction. This is shown in Figure 7.

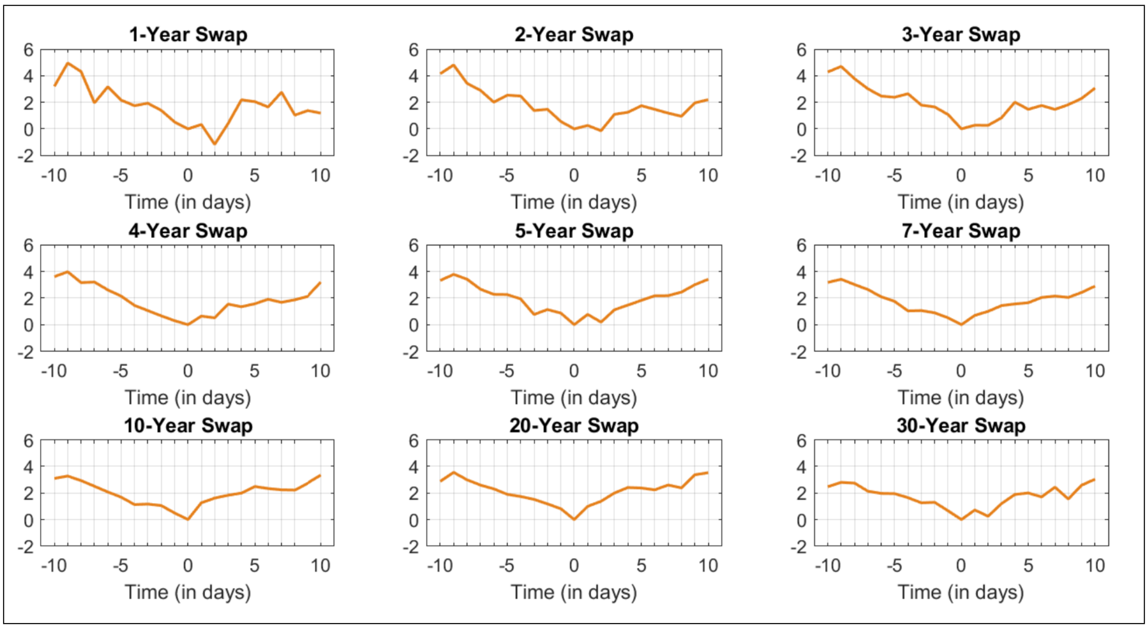

Figure 7: All Maturities ZCIS Reactions

The y-axis in the figure represents the rate relative to the auction day rate. We see the emergence of the same V-shape pattern. We also do the same analysis for particular maturities of TIPS auctions (5, 10 and 30-years), and we observe the same pattern emerging in all the different maturities. The pattern is most prominent when there is an auction on the 30-year ZCIS maturity.

Overall the results in this section show that before the auction day, there is an increased activity in the Inflation Swap markets, irrespective of the maturities. We don't have transaction level data to confirm that or to find out which maturity is traded the most, still the results here quite interestingly show the inner dynamics of an OTC market during the auction of a different security.

5 Explanation of Auction Cycle in ZCIS Market

Up till this point we have established the presence of a strong auction cycle in the ZCIS market. In this section we document a declining contribution of primary dealers in the TIPS auction process and see its impact on the auction cycle of ZCIS and TIPS. Further, by looking at the flows of mutual funds around the same time period, we document the changing role of market participants during the auction process.

5.1 Primary Dealers Declining Contribution

Since April of 2008, the US Treasury provides more details about the participants contributions in the tendered and accepted bids in its results announcements. From here we see the contribution of primary dealers, the amount they tendered and the amount that eventually got accepted. And for all maturity TIPS auctions, we observe that there is a declining trend both for the amount that is tendered by the dealers and in the actual share of bids accepted in the end. It is more clearly shown in the figure below:

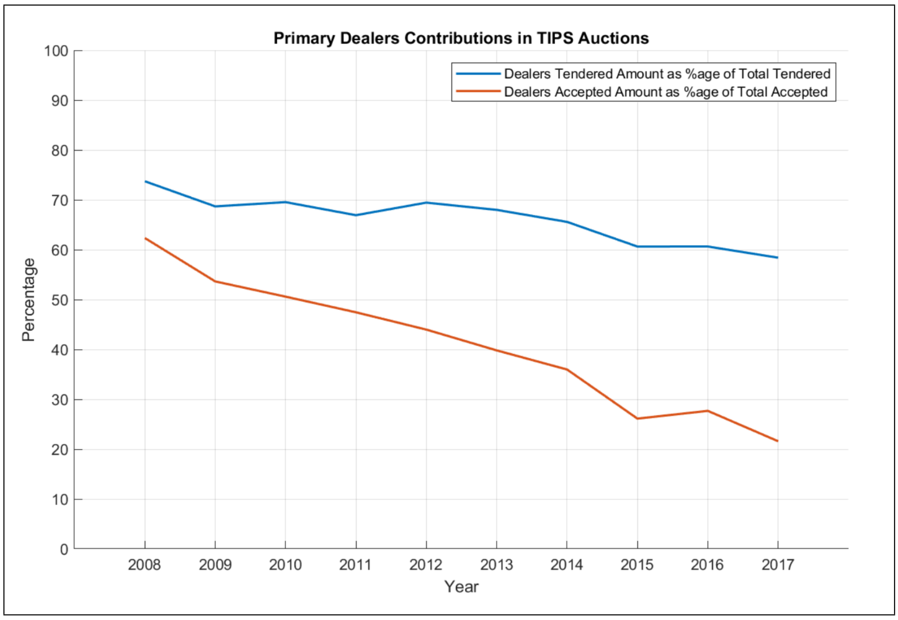

Figure 8: Primary Dealers Contribution

In Figure 8 the lower line shows the accepted bids of Primary Dealers as a percentage of total competitive bids accepted for 10-year maturity TIPS auctions. We see that there is a declining trend and we observe the same trend for 5 and 30-year maturity TIPS. So, overall there is a declining trend in terms of the contribution by primary dealers. So, again going with Lou et al. (2013) explanation, if primary dealers are one of the main factors because of which we observe the auction cycle, we should see that over the years the severity of the auction cycle should decline in both the inflation swap and TIPS markets.

Table 10 shows how severe the auction cycle is in the Swaps and TIPS markets during the period starting from 2010 and ending in 2017. For our analysis in this part, we have data about details of primary dealers starting from 2008. But we didn't include the crisis period so not to bias our results during that abnormal period. So, we start from 2010. Also we couldn't do a year-by-year analysis, as that would make our sample size very small for a particular year. So, we divide the period from 2010 to 2017 included into two sub-periods and see the severity of the auction cycle during these two periods. There are 45 auctions in the first sub-period and 47 auctions in the second one.

The results in Table 10 indicate that at least for the 10-year inflation swap, we see that the severity of the auction cycle declined quite a lot. It dropped by almost half when compared during the first sub-period. For 5 and 30-years maturities, we see similar results but the results aren't significant enough to make a useful conclusion. Comparatively in the TIPS market, the results indicate that the severity of the auction cycle actually increased during the second sub-period. And the results are all significant in both samples for the TIPS market.

The results are quite interesting in both markets. Since, coming from our earlier intuition we should have observed a less severe auction cycle in both markets. But for TIPS, this is not the case. There can be two implications for the TIPS market; first, it could be that there are structural friction in this market so the number or the amount of transactions being conducted doesn't have an impact on the liquidity of the market. Second, it could be that the primary dealers aren't the main players in TIPS market.

Table 10
Severity of Auction Cycle for Inflation Swap and TIPS

Auction Cycle of 21 days

	Maturities		
	5-year	10-year	30-year
Inflation Swaps			
Auction Cycle (2010-2013)	7.69**	6.09**	6.01*
Auction Cycle (2014-2017)	4.31	3.47*	4.04
TIPS			
Auction Cycle (2010-2013)	6.13**	4.97**	4.46**
Auction Cycle (2014-2017)	6.15*	5.43*	5.40*

The regressions in this table are very similar to the ones conducted earlier. Here just we divide our sample starting from 2010 till 2017 into two sub-periods. The variable "Auction Cycle" represents the change in the rate (yield) of a particular maturity Swap (TIPS) when there is an auction on a 5, 10 or 30-year TIPS. All the numbers in the table represent change in basis points. The sample in this period spans our original period of 2005-2017. ***, ** and * represent the significance levels at 1%, 5% and 10% respectively

Table 10: Severity of Auction Cycle

To probe further into the behavior of primary dealers, we exploit more data sources available to us to have a better understanding of the functioning of the market. From New York Fed's website, we have weekly net positions in TIPS of Primary Dealers. The data is available every 5 days and it is published every Wednesday with a one week lag. For our analysis, we don't have symmetrical data points available (not symmetrical in the sense that mostly the data is 1 business day before the auction and 4 business days after.For all auctions included in our sample, figure 9 shows the available data points around that particular auction date.

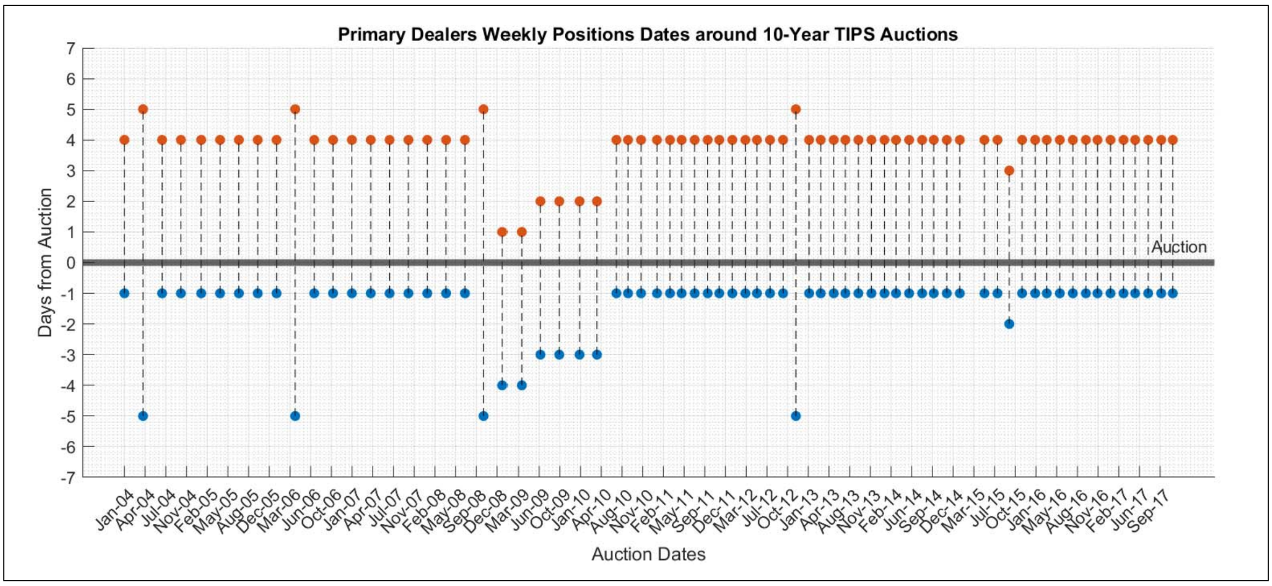

Figure 9: Primary Dealers' Net Positions Data Dates

From figure 9, it is quite clear that the weekly positions data for most of the auctions is about 1 day before the auction and 4 days after. So, we exclude other auctions where the data points don't fall on the above mentioned days around the auction and do an empirical analysis. Table 11 below reports the positions of primary dealers 't' business days around the auction ($t = -6, -1, 4, 9$).

Before looking at the results, we intuitively suspect that there should be decrease in net positions before an auction and an increase afterwards, since primary dealers are short-selling secondary securities before and buying them at auction.

Table 11
Primary Dealers Positions in TIPS Market

Maturity of TIPS being Auctioned	# of Auctions	Positions in Millions $			
		Days Around Auction			
5-Year		-6	-1	4	9
All auctions excluding Recessions	31	2853.3	5149.7	4511.4	4149.1
During Recession	3	2793.3	4971.7	4047.3	3715.3
Pre-Recession	7	1894.3	3278.9	2866.1	2909.1
Post-Recession	24	3133.0	5695.4	4991.3	4510.8
10-Year					
All auctions excluding Recessions	65	2404.8	4387.8	3887.2	3657.9
During Recession	6	1707.2	3416.8	3725.3	3774.7
Pre-Recession	16	277.4	1585.3	2197.5	2032.2
Post-Recession	49	3099.5	5302.9	4438.9	4188.8
30-Year					
Post-Recession	23	3953.3	4638.9	4444.4	4281.3
All Maturities					
All auctions excluding Recessions	125	2749.0	4496.4	4050.9	3769.1
During Recession	12	1992.8	4008.8	3741.3	3893.7
Pre-Recession	29	946.1	2098.0	2301.5	2147.8
Post-Recession	96	3293.6	5220.9	4579.4	4258.9

This table shows the positions in millions of $ of Primary dealers in the TIPS market. The sample spans from 2005 - 2017

Table 11: Primary Dealers Weekly Positions around TIPS Auctions

The results in table 11 go against our intuition. We see that there is an actual increase in net position leading up to the auction date and a slight decrease after. The results are consistent for all maturities of TIPS around auctions during different time periods. Though the data available to us is weekly, still it holds against the theory that primary dealers are short-selling before the auction.

In summary, the two analysis we perform above show that at least for the TIPS market, primary dealers don't seem to be the major players in making the auction cycle. Identification of the parties involved in making the auction cycle in TIPS market is outside the scope of the paper, for our current work we limit ourselves to the V-shaped pattern in ZCIS market. We just exploited the data sources we had to and found interesting patterns that challenge contemporary theories.

For the ZCIS market, we do have a less severe auction cycle as documented in table 10. If we go by the theory that investors who hedge themselves against inflation find it cheaper to hedge with TIPS before an auction, they won't have much securities to buy from the dealers. Since there's a decreasing share of primary dealers. And thus also there will be less short-selling in the ZCIS market. The results are consistent with this theory, and to dig more into it we look at the behavior of mutual funds around TIPS auctions that invest in inflation-linked bonds in the next sub-section.

5.2 Proposed Explanations for ZCIS Pattern

In this sub-section, we propose explanations for the V-shaped pattern in the ZCIS market around TIPS auctions. Since, this is a pattern observed in a substitute market, we look at the possible participants who would invest in the ZCIS market.

As our first explanation, we propose that investors who deal in the inflation swap market and need to hedge against inflation, may find it cheaper to hedge through TIPS than through ZCIS. The reasoning goes in the line that since there is short-selling in the TIPS market, so there is an increase in yield (decrease in price) leading up to the auction. So, inflation-seeking investors would then short-sell in the ZCIS market and go long in higher yield TIPS. One way to test this approach could be to look at the treasury positions of those particular investors during treasury auctions.

To test our intuition, we look at the estimated daily net flows of mutual funds that invest in inflation-linked securities. This is not a direct method to test our theory for the presence of an auction cycle in ZCIS market for one main reason. Because, we are not looking at the positions in treasury securities of these mutual funds because of non-availability of data. Still, if our intuition holds correct, then there should be an increase in net flows in the days leading to the auction date, and we should observe outflows after the auction date. This will establish a V-shaped pattern in the ZCIS market as it would mean that those investors short-sell in ZCIS to buy TIPS and after auction they reverse their positions.

We collect mutual funds data from Morningstar. We only include those mutual funds that invest in inflation-linked securities. We take estimated net flows and daily size variables. Both of these variables are estimated by Morningstar as they aren't directly reported by the funds themselves. We provide definitions of these variables and the names of the funds in the Appendix. Table 12 below gives summary statistics for the funds we study.

Table 12
Mutual Funds Summary Statistics

Year	# of Funds	Minimum Size	Average Size (in millions)	Maximum Size (in millions)
2005	38	182,570	194.74	1,145.08
2006	45	79,908	239.13	1,472.88
2007	45	3,485,836	280.55	2,831.80
2008	46	11,749,355	336.76	1,662.55
2009	46	13,503,551	353.13	2,366.74
2010	48	14,415,096	506.03	3,614.48
2011	50	22,982,568	629.61	4,200.17
2012	53	47,555	682.75	5,262.43
2013	51	593,324	665.68	4,620.51
2014	51	1,242,051	579.11	3,199.26
2015	51	317,207	595.12	3,023.51
2016	52	1,057,246	739.77	7,398.41
2017	49	5,515,880	929.47	8,194.14
2018	50	3,421,332	995.00	8,373.85

This table provides year-by-year summary statistics for the mutual funds used in our analysis. The size of the funds are represented in US dollars

Table 12: Mutual Funds Summary Statistics

We were able to identify 72 unique US funds in total from Morningstar that invest in inflation-linked securities. Some of the funds appeared during our sample period and some didn't survive. From table 11 we can see that the average fund size has been increasing over the years.

To conduct our empirical analysis, we take the daily estimated net flows divided by the daily estimated size of each fund, so we can look how much percentage of the total size of the fund is the net flow. Mostly we will be interested in looking at the average sign of the Net Flow per Size since it will tell us whether there was an inflow (positive sign) or an outflow (negative sign). Our empirical analysis for mutual funds begins from 2010. Mostly because we have data limitations before that period. Table 13 gives a snapshot of results, and 't' represents the specific day around the auction.

Table 13
Mutual Funds daily Net Flows per Size

	Sample Period			
t	**2010-2017**	**2012 - 2017**	**2013 - 2017**	**2014 - 2017**
-10	-0.12	-0.19	-0.22	-0.26
-9	-0.09	-0.14	-0.17	-0.21
-8	0.02	0.01	0.02	0.07
-7	0.04	0.02	0.03	0.05
-6	0.19	0.20	0.20	0.24
-5	-0.39	-0.52	-0.40	-0.55
-4	0.02	0.01	0.01	0.03
-3	0.15	0.11	0.07	0.11
-2	0.17	0.17	0.08	0.11
-1	0.16	0.18	0.16	0.22
0	-0.52	-0.63	-0.80	-0.96
1	0.01	0.03	0.01	0.02
2	0.05	0.03	0.02	0.04
3	0.00	-0.02	-0.03	-0.04
4	-0.03	-0.06	-0.09	-0.10
5	0.07	0.08	0.10	0.13
6	0.07	0.05	-0.03	-0.01
7	-0.07	-0.12	-0.04	-0.06
8	-0.26	-0.36	-0.43	-0.54
9	-0.17	-0.26	-0.35	-0.39
10	-0.14	-0.20	-0.24	-0.29
# of Auctions	92	71	59	47

This table reports the estimated daily net flow of a mutual fund as a percentage of the size of the particular fund. The figures in this table are to be interpreted as percentage of the size of the fund, with negative values indicating an outflow and positive values indicating an inflow.

Table 13: Mutual Funds daily Net Flows per Size

The results in table 13 indicate that on average there are net outflows from a mutual fund at and after the TIPS auction. For our whole sample (2010 till 2017), we see that starting 10 days before the auction and going 10 days after, there are about 6 days of outflows on and after the auction date. While there are mostly inflows before the auction. We get stronger and stronger results as we move through the years and get farther away from recession period.

We also divide our mutual fund sample in quartiles based on the size of the fund. Here we want to single out the impact of larger funds compared to the smaller ones. Table 14 gives the results for the sample starting in 2010 and ending in 2017.

Table 14
Mutual Funds daily Net Flows per Size (in Quartiles)

t	Quartiles 25th	50th	75th	100th
-10	-0.54	0.01	0.00	0.02
-9	0.14	0.03	0.02	0.02
-8	0.06	-0.04	0.04	0.02
-7	0.10	0.06	0.00	0.03
-6	0.68	0.13	0.02	0.02
-5	-1.75	0.06	-0.02	0.02
-4	0.04	0.02	0.05	0.05
-3	0.38	0.04	-0.03	0.08
-2	0.47	0.16	-0.04	0.04
-1	0.64	0.07	0.02	0.05
0	-2.26	0.09	0.01	-0.02
1	0.03	-0.03	0.00	0.03
2	0.10	0.11	-0.02	-0.03
3	0.02	0.00	-0.11	0.06
4	-0.16	-0.06	0.02	0.04
5	0.37	0.03	-0.02	-0.02
6	0.29	0.01	-0.13	0.01
7	-0.12	-0.24	-0.02	0.04
8	-0.34	-0.80	-0.08	0.07
9	0.05	0.01	-0.08	0.06
10	-0.60	0.05	0.04	-0.02
# of Auctions	92	92	92	92

This table reports the estimated daily net flow of a mutual fund as a percentage of the size of the particular fund. Based on the size of the funds, they are divided into quartiles. The figures in this table are to be interpreted as percentage of the size of the fund, with negative values indicating an outflow and positive values indicating an inflow.

Table 14: Mutual Funds daily Net Flows per Size

The results in table 14 show that on average all funds experience outflows at and after the auction date. And there are more inflows before the auction.

Tables 13 and 14 provide credence to our theory that inflation-seeking investors buy inflation-linked bonds before an auction and they sell it afterwards. Since they find it cheaper to invest in TIPS rather than ZCIS. The funds in the top half generally experience inflows before the auction and outflows afterwards during our sample period.

Additionally, we also look at the evolution of the spread between ZCIS and BEI during TIPS auctions. We do the same analysis as we did in the Constant Return model to identify the V-shaped pattern in the inflation-swap market. The idea behind this exercise goes along the line that if inflation-seeking investors are buying TIPS as they find it easier to finance and they are short-selling in the ZCIS market, then the spread between ZCIS and BEI

(Break-Even Inflation) should change also. As the spill-over of TIPS auction on ZCIS would be a little lagged. The results for this analysis are shown in table 15.

Table 15
ZCIS-BEI Spread around all TIPS Auctions

ZCIS around all TIPS Auctions: *Y(t) - Y(0)*

	5-Year		10-Year		30-Year	
t	**Mean**	***t*-stat**	**Mean**	***t*-stat**	**Mean**	***t*-stat**
-10	0.33	(0.33)	1.26*	(1.89)	0.23	(0.32)
-9	0.62	(0.62)	1.18*	(1.84)	0.21	(0.30)
-8	0.80	(0.80)	1.34*	(1.87)	0.60	(0.94)
-7	0.40	(0.40)	1.30**	(2.07)	0.19	(0.37)
-6	0.26	(0.26)	1.20**	(2.06)	0.38	(1.03)
-5	0.38	(0.38)	0.87*	(1.71)	0.53	(1.07)
-4	0.25	(0.25)	0.55	(1.26)	0.47	(1.26)
-3	-0.40	-(0.40)	0.72	(1.62)	0.42	(1.13)
-2	0.18	(0.18)	0.73*	(1.87)	0.79**	(2.15)
-1	0.56	(0.56)	0.60*	(1.83)	0.63**	(1.98)
1	1.72*	(1.72)	1.19***	(2.84)	0.35	(1.12)
2	1.79*	(1.79)	1.38***	(2.96)	-0.30	-(0.76)
3	1.75*	(1.75)	0.78**	(2.31)	0.02	(0.03)
4	1.40	(1.40)	0.70*	(1.92)	0.37	(0.68)
5	0.97	(0.97)	0.88**	(2.14)	0.44	(0.91)
6	1.25	(1.25)	0.98**	(2.09)	0.39	(0.74)
7	1.37	(1.37)	0.93*	(1.92)	0.97*	(1.66)
8	1.28	(1.28)	0.75	(1.48)	-0.11	-(0.19)
9	1.54	(1.54)	0.59	(1.26)	0.26	(0.44)
10	1.35	(1.35)	0.59	(1.23)	0.15	(0.29)

This table follows the same pattern of Lou et al. (2013). It reports the time-series average of Y(t) -Y(0), where Y(t) in this particular case is the spread between the Breakeven Inflation and the ZCIS relative to the auction date (where n = 5, 10 and 30-years). The t-stats reported are based on Newey-West adjusted standard errors. ***, ** and * indicate significance levels of 1%, 5% and 10% respectively.

Table 15: Reaction of ZCIS, BEI Spread around all TIPS Auctions

From table 15, we see that in the 10-year maturity spectrum, the spread between ZCIS and BEI is not constant. In the days leading to the auction date, the spread is greater relative to that of at the auction date. And the same holds true after the auction date. To have a better understanding, we can view the spread as ZCIS rate - Nominal yield + TIPS yield (since $Spread = ZCIS - BEI$). We ignore the reaction of Nominal yields during this period since we checked their behavior around TIPS auctions, and they are not different from zero around the auction date. So, we only include TIPS and ZCIS in our analysis.

So it means that if spread is increasing in the days around the auction, then the ZCIS rate doesn't decrease enough to compensate the increase in TIPS yields. So, the results, at least in the 10-year maturity spectrum, are in line with our intuition.

Apart from the above explanation of the ZCIS pattern, we propose our second explanation which is based on an increase in speculative positions in the market. Since Break-even inflation (Nominal - TIPS) and inflation swaps basically are the same thing (apart from the risk-premia present in the spread), then according to the law of one price, if there's a price pressure in one market then there should be similar pattern in the other market.

So, seeing that the Break-even inflation also has a V-shaped pattern, a pre-auction strategy can be to go long in break-even inflation (Nominal - TIPS) and short the ZCIS (as mentioned earlier). To break in part, an investor needs to go long in Nominal, and short in TIPS and ZCIS. Through reverse-repo transactions, primary dealers go short in TIPS (Lou et al. (2013)), to go long in Nominal, they can do the same reverse-repo transaction and hold the Nominal. So, both in the case of hedging (TIPS market auction cycle) and speculating (ZCIS auction cycle), we see that there should be a pronounced effect on the damping of the repo rates. Thus, one way to infer this could be to see how the repo rates are being depressed because of the hedging and because of speculating. And then inferring about the amount of speculation during TIPS auctions. We feel this can be a potent explanation for the pattern. But since we don't have a way to separate the depression of repo rates owing to different effects, we are not able to test this theory for now.

6 Conclusion

The main focus of this paper has been to investigate the workings of the Inflation Swap (ZCIS) and TIPS markets while seeing through the lens of a particular market event, i.e. the auction on TIPS securities. The main theme of the paper is very closely tied with that of Lou et al. (2013) and the methodology resembles Beetsma et al. (2016). First, we show that the auction cycle that has been documented in the literature is also prevalent in an

OTC market of a product that can be considered as a substitute of the one being auctioned. We started with the intuition that there might be a price impact on the quoted rate of the Zero-Coupon Inflation Swap when there is an auction on TIPS since, both of them can be considered as substitutes. We tested our intuition and found that indeed there is a presence of an auction cycle in the ZCIS market. We observe the presence of a V-shaped pattern in ZCIS around TIPS auctions.

Second, we try get some intuition about why we observe the particular auction cycle in ZCIS market. We exploit an interesting pattern in our data regarding the contribution of primary dealers in the auction process. We see that over the years, the relative contribution of primary dealers has been declining. And since primary dealers limited risk bearing capacity theory is one of the leading ones in explaining the auction cycle, we test for that prediction that if primary dealers have a higher contribution then there should be a more severe auction cycle. The results for the inflation swap market are in line with that but that is not the case for TIPS market, hinting at difference in the workings of both markets.

To explore this further, we propose that the auction cycle in ZCIS is due to the demand side explanation of Lou et al. (2013). That is the investors who are actually buying before the auction date find it cheaper to invest in TIPS and they might be the ones actually short-selling in the ZCIS market. We take inflation-linked mutual funds and see, on average, inflows before the auction date and outflows afterwards. Indicating that they are on the demand side. Indicating that they might be selling in the ZCIS market and hence generating the pattern.

So, through our empirical analyses, we try to shed new light in the inner workings of TIPS and ZCIS markets. This understanding of market functioning is very important as around auctions, because of this particular pattern, it is costly for the US Treasury to raise money. And our results imply that it is important to look at the demand side of these securities. If primary dealers are selling off-the-run TIPS then who are the players buying those securities. Yes there is an excess supply before the auction, but there could also be strategic behavior on the demand side by the investors ho want to invest in those securities. So, in further research it would be interesting to explore this reasoning behind imperfect capital mobility, where an anticipated shock has a temporary, yet predictable, price impact. And whether better regulations can be enacted to prevent it.

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