STOCKHOLM SCHOOL OF ECONOMICS

Master Thesis in Finance

Anticipated Shocks and their Impact on Expectations

An event study of the impact of TIPS auctions on ZCIIS

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ABSTRACT

This thesis has the purpose to empirically investigate how anticipated shocks that result into recurrent supply shocks are subsumed by change in expectations. More precisely, we study the price impact of Treasury Inflation Protected Securities (TIPS) auctions on the Zero-Coupon Inflation-Indexed Swap (ZCIIS) rates using an event study methodology for each of the 60 auctions of 5-, 10-, 20- and 30-year TIPS during the period 2004-2011. In our results we observe that TIPS auctions impose a significant pressure on the ZCIIS markets during the 3 to 5 days prior to and up to 10 days post the auctions in question. We find that ZCIIS rates are characterized by a decline and a following increase around auction dates giving the ZCIIS rates a rather distinctive V-shape around these dates. This pattern is consistent with other academic literature that documents a similar price pressure around Treasury auctions.

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1.0 INTRODUCTION

The aim of this paper is to empirically investigate how anticipated shocks that result into recurrent supply shocks are subsumed by change in expectations. More precisely, we study the price impact of Treasury Inflation Protected Securities (TIPS) auctions on the Zero-Coupon Inflation-Indexed Swap (ZCIIS) rates. Given the fact that the US Treasury is pretty transparent with regard to the amounts auctioned and the specific dates, it is plausible to assume that there will be no substantial impact on prices from expected supply shocks. On the contrary, the results we reach indicate that there are significant effects on the ZCIIS rates.

In particular, we observe that TIPS auctions impose a significant pressure on ZCIIS markets during the 3 to 5 days prior to and up to 10 days post the auctions in question. An effective procedure in discovering the pattern in ZCIIS rates characterized by a decline and following increase is to look into the returns on these rates around TIPS auctions. Specifically, the time-series average of the cumulative difference of the ZCIIS three days before and ten days after all auctions of TIPS is 7.16(t=3.00) and 7.90(t=2.81) basis points for the 10- and 20-year ZCIIS. For the 5- and 30-year maturity it comes to 5.51(t=1.87) and 5.67(t=2.30) basis points respectively. In effect, this implies that even almost identical substitutes, as the TIPS and ZCIIS are not immune capital immobility and consequently cannot integrate instantaneously recurrent supply shocks.

The results have significant economic implications. Firstly, the results also imply, in accord with previous research, Lou et al. (2011), Elsasser and Sack (2004), to name a couple, that the price pressure exerted around TIPS auctions is spilled over to the ZCIIS. With the latter failing to take on the additional price pressure, it follows closely the pattern deployed by the TIPS – with the fixed rate of the swap falling noticeably. In effect, the Treasury bears much higher additional issuance costs which are exactly down to the inability of ZCIIS to act as a good substitute.

Secondly, the findings imply that even in a tailored over-the-counter market such as the ZCIIS, there are frictions of first-order importance as the response to demand/supply shocks on behalf of investors is rather slow. A straightforward way to capitalize on the repeated swings in the ZCIIS rates delivers a Sharpe ratio of 0.24 and 0.20 for 5- and 10-year rates respectively. More precisely, one can enter in a swap agreement three days prior to the auction by paying the fixed rate of the ZCIIS and afterwards taking the opposite side in a matching agreement paying the inflation-linked side of the derivative thus pocketing the difference in fixed rates.

The documented pattern is consistent with the interpretation that price pressure is exerted around TIPS auctions on ZCIIS rates. First, the notion that ZCIIS and TIPS can be perfect substitutes is challenged substantially suggesting a higher degree of internal dependence. Second, primary dealers due to their limited risk-bearing capacity have to hedge their positions and further exacerbate the pressure on ZCIIS. However, if there was enough capital in the system to supply the required liquidity the shocks would have limited impact on the derivative rates. Thus, finally, the slow-moving capital of end-investors comes in play. In essence, about half of the outstanding Treasury securities are held either by the Federal Government accounts and the Federal Reserve. The latter is unlikely to exploit the temporary price discrepancies bearing in mind its mandate. Thus, the rest of the outstanding securities are held by private investors which are comprised of mutual funds, insurance companies, foreign investors, and local and state governments. Some of these investors most probably do not have the resources and/or intention to harness the transient price movements, while others due to their different trading strategies are likely to postpone capitalizing on the observed pattern since they prefer to minimize their tracking error.

The remainder of the study is arranged as follows: Section 2 describes the general concept of inflation, TIPS and ZCIIS and the markets for the latter two; Section 3 explains the methodology and our data; Section 4 reports our results; Section 5 concludes the paper.

2.0 BACKGROUND

2.1 INFLATION

Both TIPS and ZCIIS are instruments linked to the alteration of inflation over time and can therefore be used to hedge future liabilities and claims against inflation risk. We will therefore in the following paragraphs outline the general characteristics of inflation, first we will describe the general methodology of inflation calculation and describe the CPI-U (Consumer Price Index for All Urban Consumers All City Average) index to whom both ZCIIS and TIPS are linked to, lastly we describe the seemingly stable development of the index from the year 2000 until present.

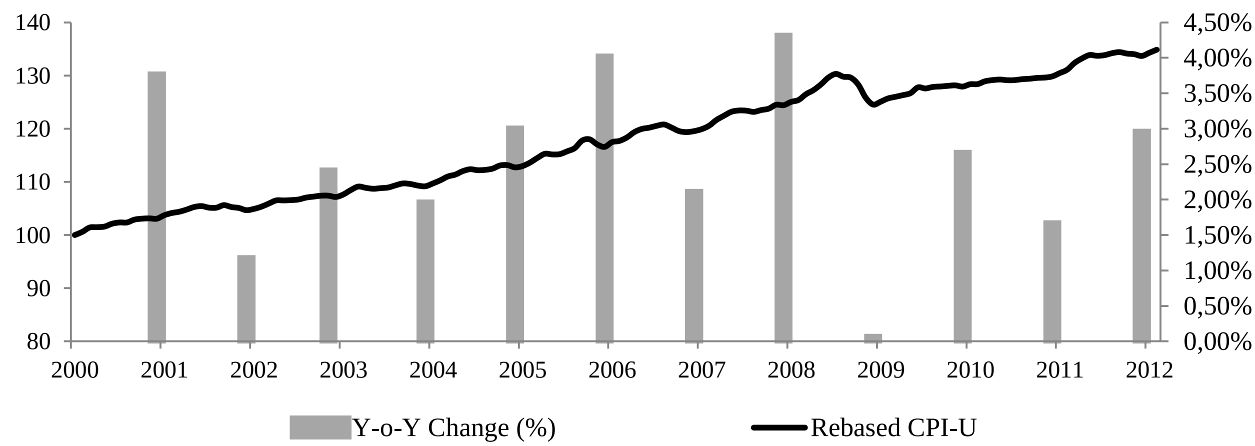
As we examine the effect of TIPS auction on the ZCIIS rate we herein concentrate on CPI-U (all items). This inflation measurement is prepared by the U.S. Bureau of Labor Statistics (BLS) and represents changes in prices of all goods and services purchased for consumption by urban households (includes approximately 87 percent of the U.S population). User fees, such as water and sewer service, and sales and excise taxes paid by the consumer are included in the index while income taxes and investment items (like stocks, bonds, and life insurance) are not (BLS, 2012). [1]

The common practice when measuring intra-month inflation is either by linear interpolation or by using the value for the last publication date (Waldenberger, 2011). To depict the evolvement of inflation we below, in Graph 1.0, illustrate the rebased CPI-U index from January 2000 until February 2012 with the Year-over-Year (Y-o-Y) change.

Graph 1.0

CPI-U rebased index and Y-o-Y (%) from January 2000 until February 2012

The black line represents the rebased Consumer Price Index - All Urban Consumers with January 2000 as the base date, 100, until February 2012. The grey bars displays the Year-on-Year changes measured as the simple return on the CPI-U index between January (t) and January (t-1). The data is collected from the Bureau of Labor statistics which also have constructed the underlying index.



In Graph 1.0 it is worth noticing the seemingly stable trend in the index. We calculate the average Y-o-Y changes of the index to 2.45 percent over the period with a standard deviation of 1.39 percent. This stable drift is not very surprising as the government in the US as well in the rest of the developed world have inflation targets. The motivation for such inflation targets can be explained by the global recognition of the negative repercussions on economies with high rates of inflation and recurring boom-bust cycles (Freedman and Laxton, 2009). That the reported average inflation of approximately 2.45 percent is close to the 2 percent inflation target

[1] See BLS's homepage for more details: www.bls.gov

determined by the US Federal Reserve[2] gives the inflation return series some stationary features due to it arguably constant mean. Further, the inflation target provides everyone trying to anticipate/model future inflation over the short/medium horizon with a credible benchmark.

However, there is a wide debate on whether inflation series in fact is best treated as a stationary or non-stationary process and a conclusion on that debate has not yet been reached. On one side we have academics like Rose (1988) and Culver and Papell (1997) which apply time series unit root and stationarity tests to 13 OECD countries and find overwhelming evidence in favor for inflation following a stationary process, while we have, on the other hand, papers by Johansen (1992) and Ng and Parron (2001) whom do not find any conclusive evidence for the hypothesis for inflation being in fact being stationary. This uncertainty about how the inflation-process should be treated introduces severe problems when modeling long-term series data. One would also suspect if inflation follows a stationary process then also the ZCIIS would display the same features which we examine in section 4.1.

We would also point to the fact that the variance in the CPI-U measurement is often lower than the underlying commodities themselves. This is in order as CPI-U measures the price of goods at the consumer level and not the price level at the producing or wholesaler level. The goods/services may themselves be subject to variability but it is not certain that the consumer prices are subject to the same degree of variability, that is the consumer price of gas/diesel/electricity changes daily while the day-to-day consumer price changes in milk/toilet-paper/insurances is negligible.

Lastly we would like to raise the point, that like in GDP, there is a high degree of seasonality in the CPI-U measurements. Theses periodic patterns in the CPI-U index can partly be explained by events like Christmas shopping, holiday season or season of the year.[3] BLS adjusts for this in their series but if one would try to model inflation, seasonality must be accounted for.

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[2] The 2 percent target was decided in January 2012, prior to that decision the Federal Reserve did not explicitly communicated a inflation goal but adjusted it accordingly to its 3 goals of (i) stable prices (measured by CPI-U), (ii) low unemployment and (iii) stable interest rates. However as Ben Bernanke, Chairman of the Federal Reserve, have been one of the strong advocate for the 2 percent goal we therefore argue that the FED have aimed at the 2 percent level ever since he was elected Chairman in 2006.

[3] See Waldenberger (2011) and Pericoli (2012) for a more thorough discussion of this topic.

All of the above-mentioned characteristics of inflation (i) lagged publication of data (ii) the debate on its stationarity or nonstationarity (iii) its lower variance than underlying commodities, (iv) its seasonal patterns would induce any modeling of daily/monthly inflation changes cumbersome as one has to correct for each of these characteristics. Therefore inflation modeling is most often applied in macroeconomic settings, modeling long-term inflation expectation rather than day-to-day changes, as these are arguably constant over a short period of time (Stock and Watson, 1996).

$$E_t\left(\frac{CPI_T}{CPI_t}-1\right)=E_{t+\omega}\left(\frac{CPI_{T+\omega}}{CPI_{t+\omega}}-1\right) \qquad [1.0]$$

Where the LHS is the expected inflation growth from *t* to *T* at time *t* and the RHS is the expected inflation after a short incremental time change, denoted by ω. One would expect that the LHS and RHS equals if the incremental time change, $\omega,$ is sufficiently small. In their paper, Stock and Watson also question the precision of several of the most often used methods as their accuracy seems to vary with chosen sample period and forecast horizon.

2.2 TIPS Market structure and Auctions

The United States Treasury issued the first lot of Treasury Inflation Protected Securities (TIPS) in January 1997. By and large the TIPS are similar to the nominal Treasury securities, with the key difference being that the cash flow from TIPS's is adjusted over time to reflect the changes in inflation, the latter being measured by the CPI-U, see previous section 2.1. As the coupon rate of the TIPS is fixed over time, the semi-annual coupon varies over time due to the above-discussed modification, which could be both inflationary and deflationary, of the principal amount. The final principal payment to the holder of the security corresponds to the maximum between the inflation-adjusted principal amount and the original principal amount. In essence, the TIPS protect investors' principal against deflation, which however, is not the case for the coupon payments.

The construction of TIPS is fundamental to their prospective success or failure, as is identified by Roll (1996). The insightful analysis reveals six major features in the design of TIPS: choice of index, indexation lag, maturity composition, ability to strip, tax treatment, and cash flow structure. It has been argued that an asset class that diminishes the inflation risk by safeguarding against unexpected spikes would preserve the real purchasing power, which is not the case with nominal securities, would be highly sought-after on behalf of investors. What is more, there is silver lining to TIPS – they offer a potentially useful measure for monetary policymakers as they would gauge what compensation investors require to offset inflation as well as the associated risks. This compensation is by market participants, policymakers and academics alike called the break-even-inflation ("BEI") and is calculated by subtracting the yield of the TIPS from a Nominal bond with the same maturity and cash flow. For example the last observation in our sample, the 21 November 2011, the generic 5-year nominal bond had a yield of 0.90 percent and the generic 5-year TIPS – a negative yield of -0.80 resulting in a 5 year BEI of 1.7 percent. If the actual inflation 5 years from the 21 November 2011 is above this BEI an investor would have been better of investing in the TIPS than the nominal bond. If the average 5 year inflation however would have been below 1.7 percent, in hindsight, the nominal security would have been the better option.

For the Federal Reserve and the US government the reasoning behind the introduction of TIPS was that this type of securities would bring down the financing costs of the Treasury department due to a lower risk premium required by investors as they would be able to lock in a real-rate return Fleckenstein et al. (2010) and Roll (2003). However, in order to make it attractive for investors, the instruments need to offer a broad range of maturities and liquidity as argued by Haubrich (2001) and Fleckenstein et al. (2010), among others. On the other hand, the introduction of broad range of maturities is sure to increase the interest on behalf of investors but due to the inflation indexing it would inevitably, under normal inflationary conditions, backload the cash flows, with the effect exacerbated for longer maturities.

In effect, as Sack and Elsasser (2004) point out, TIPS in reality impose additional costs on the Treasury in the short-term and on taxpayers in the long-term. This issue has been investigated in academia and recent discussions and empirical research have been leading to the conclusion that around Treasury auctions the yields increase in the period prior to the auction just to "normalize" in the period after it, in effect taking an inverted V-shaped form. One study (Fleckenstein et al., 2010) estimates that in 2007 alone, the Treasury incurs additional issuance costs for its notes amounting to over half a billion dollars.

Bearing in mind that the market is relatively new it has been growing faster than the United States' total public debt. Looking at the Monthly Statement of the Public Debt of the United

States by December 2004 the amount of TIPS outstanding added up to approximately $246 billion, with TIPS representing approximately 3.24 percent of the Total Outstanding Public Debt of the US (TOPD). By December 2011 the outstanding TIPS had grown to nearly $739 billion, a threefold increase since 2004 to a proportion of the TOPD of 4.85 percent.

In the following two sections we will describe the general characteristics on both the primary market and the secondary market.

2.2.1 PRIMARY MARKET

Currently the US-Treasury only issues TIPS with original maturities of 5, 10, and 30 years. These are sold in the primary market via single price auctions, and can be purchased at auction by domestic investment accounts and professional investors alike. However, as one may suspect, the main proportion of issued securities are acquired by the primary dealers appointed by the Federal Reserve[4]. Fleming (2007) calculates on the behalf of the Federal Reserve that the primary dealers alone purchased 70.9 percent of the issued securities (all issued securities including Nominal and TIPS) and an additional 21.6 percent on behalf of their institutional clients during July 30, 2001 to December 28, 2005. The primary dealers play an important role as they are anticipated to participate in every auction and take an active role in the secondary market in order to provide liquidity and act as market makers. In return the nomination as primary dealer has some signaling value in terms of creditworthiness but also add some tangible benefits as some central banks and certain pension and endowment funds will only do business with banks that are classified as primary dealer (Martin, 2009), (Arnone and Iden, 2003).

The auction process for U.S. Treasury securities follows a formal and rigid structure. The Treasury Department first releases data on its auctions through a number of announcements and disclosures through the use of advertising in major newspapers, press releases and information on the website tresurydirect.gov. The auctions are therefore arguable well known in advance by all relevant parties[5]. Some days, normally 7, prior to the auction a press release is distributed by the

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[4] The Federal Reserve list 21 dealers as primary dealers at the 18th of April 2012: Bank of Nova Scotia, New York Agency, BMO Capital Markets Corp., BNP Paribas Securities Corp.. Barclays Capital Inc., Cantor Fitzgerald & Co., Citigroup Global Markets Inc., Credit Suisse Securities (USA) LLC, Daiwa Capital Markets America Inc., Deutsche Bank Securities Inc., Goldman, Sachs & Co., HSBC Securities (USA) Inc., Jefferies & Company, Inc., J.P. Morgan Securities LLC, Merrill Lynch, Pierce, Fenner & Smith Incorporated, Mizuho Securities USA Inc., Morgan Stanley & Co. LLC, Nomura Securities International, Inc., RBC Capital Markets, LLC, RBS Securities Inc.. SG Americas Securities, LLC. UBS Securities LLC.

[5] In the 10th of May the next Auction 10 year TIPS is scheduled for the 17th of May

Treasury Department with detail about the general characteristics of the upcoming auction, including information about:

(i) Amount of the security being offered
(ii) Auction date
(iii) Issue date
(iv) Maturity date
(v) Terms and conditions of the offering
(vi) Noncompetitive and competitive bidding close time
(vii) Other pertinent information

Once the auction is announced, any participant may submit a bid for the security. The Treasury Department employs a Dutch auction[6] to sell its offerings and consequently two bidding options are available to investors, competitive and noncompetitive.

(i) Competitive bidding, investors specify the rate or yield which is acceptable. Any individual investor may maximally be awarded 35 percent of the total offering through competitive bids.
(ii) With a noncompetitive bid, a bidder agrees to accept the rate or yield determined at auction. Noncompetitive bidding is limited to purchases of $5 million per auction.

At the close of an auction, the Treasury department accepts all noncompetitive bids that comply with the auction rules and then accepts competitive bids in ascending order in terms of their rate or yield until the quantity of accepted bids reaches the offering amount. All bidders will receive the same rate or yield at the highest accepted bid. The results are then released within a few minutes of the 1 p.m. auction close[7]. The auction results and the market quoted yield doesn´t per see have to be equal but one obviously expects them to be closely correlated. Jegadeesh (1993)

[6] Two auction mechanisms have been employed in Treasury auctions: multiple-price and single-price auctions. Under both mechanisms, the clearing price is identified by equating the aggregate demand submitted by competitive bidders to the total issue amount minus the total demand from noncompetitive bidders (i.e., those who submit market orders). The difference between the two mechanisms lies in that, while in multiple-price auctions, competitive bidders pay for their allocated shares at their submitted rates, in single-price auctions, all winning bidders pay the same price. While almost all Treasury auctions in the 1980s were multiple-price auctions, the single-price mechanism is the dominant form in the more recent two decades (Sack and Elsasser, 2004).

[7] Please see http://www.treasurydirect.gov/ for more details.

study this by taking the average difference in auction yield and market quoted yield of maturity-matched nominal instrument, finding a small average difference of 4 basis points.

By analyzing Treasury Department data, Fleming (2007) finds that investment funds (which include mutual funds and hedge funds) account for 30.2 percent of TIPS sold at auction, but only 11.5 percent of nominal notes and bonds. In contrast, primary dealers and brokers account for 56.3 percent of TIPS sold at auction versus 63.6 percent of nominal notes and bonds and foreign and international investors account for 8.2 percent of TIPS sold at auction versus 21.1 percent of nominal notes and bonds. The higher proportion bought by institutional investors may act as an indicator that the end-user are the larger instructional clients and not retail investors or central banks which often deal through the primary dealers.

Another indication that TIPS in a larger proportion is bought by end-users can be shown through the categorization of clients that Goldman Sachs does. They divide the market into (i) natural payers of inflation (wants to short inflation protected securities) and (ii) natural receivers of inflation (wants to go long in inflation protected securities)

(i) Some companies' revenues are strongly positively correlated with inflation, thus called natural payers of inflation. Companies, which are in a monopoly situation such as utility or infrastructure companies often have their revenues linked to inflation. Further, retail companies are indirectly exposed to inflation as they adjust their prices accordingly. Lastly, central and local governments which collect taxes which in turn rise in inflation.

(ii) On the other hand, companies with revenues, which are strongly negatively correlated to inflation, are defined as natural receivers of inflation. Insurance companies and pension funds are prime examples as part of their liabilities are linked to inflation. In addition, some financial institutions are sensitive to inflation as well as industrial companies in the commodities industry whose costs are further exacerbated by inflation.

From two of the biggest market makers we also obtain further information that inflation is predominantly purchased for the purpose of hedging inflation and not for speculative reasons (JP Morgan (2009), Goldman Sachs (2010)). The difference in end-users is also presented by Fleming and Krishnan (2009) who present supporting evidence that the TIPS market is driven by low-frequency institutional trading (buy-and-hold) as opposed to higher-frequency hedging and speculative demands.

2.2.2 SECONDARY MARKET

The secondary market structure for TIPS is also similar to that for nominal Treasury securities where the trading for both asset classes predominately takes place through multiple-dealer over-the-counter (OTC) relations. The principal market makers the so-called primary dealers trade with the Fed, their customers, and one another and stand for most of the market activity.

A large share of TIPS activity also occurs via breakeven inflation trades, whereby a particular inflation-indexed security is traded against a proportionate quantity of a particular nominal security. Some TIPS are also traded via issue-for-issue switch trades, whereby a particular inflation-indexed security is traded against a proportionate quantity of another inflation-indexed security. In contrast to the nominal market, there is no organized futures market in TIPS (Fleming and Krishnan, 2009).

However, there also exists a market for forward contracts on the soon-to-be-issued treasury securities. This so called when-issue market normally starts at the announcement of an auction. However this market is relatively small and underdeveloped for TIPS compared to that of nominal bonds where the total value of forward contracts often exceeds the value of the soon-to-be issued bonds (Bikhchandani, 2000).

Fleming and Krishnan (2009) study the microstructure of the TIPS market and find that the liquidity of newly issued securities, often denoted on-the-run, is considerable higher compared to the off-the-run securities. They find that the daily trading volume is on average 6.6 times higher when the security is on-the-run compared when it is of the off-the-run[8]. This is line with the general findings of Fleming (2002), Goldreich et al. (2005) and Barclay et al. (2006) that the demand curve is higher for newly issues securities.

All in all, even if the US TIPS market has a total value outstanding of approximately $739 billion, liquidity can be seen not as an absolute but rather a relative measurement. The market is only worth about 1/10 of the nominal market and we therefore assume that TIPS securities in general have lower liquidity than its nominal counterpart.

[8] See Fleming and Krishnan (2009) for additional results from their study.

2.3 Characteristics of the ZCIIS market

In order to hedge away the floating inflation that a TIPS security still includes, market participants, as early as the first auction of TIPS back in 1997, started trading in inflation swaps, trading floating inflation against a predetermined fixed rate. Since then the markets for inflation-linked securities as well as the one for the respective derivative products, such as swaps among others, have grown significantly and liquidity has been improving considerably with the US and UK showing the highest level of active trading. Fleckenstein (2010) and Kerkhof (2005) estimate the notional size of the swap market to be in the range of 1-2 percent of the size of the entire interest rate swap market. Taking the above into consideration along with the Bank of International Settlements approximation of the interest rate swap market, this would translate that the inflation swap market is approaching $4 trillion in 2005. As it has been established in Fleckenstein (2010) also concludes through discussion with inflation swap traders, that these instruments are fairly liquid with transaction costs in the order of five basis points.

However, when examining the market it is not only the size and the liquidity that are of interest but the supply and demand for such products. By and large the clientele of TIPS and ZCIIS are similar as we will argue in section 2.3.2 that they are close substitute. Furthermore compared with other similar derivatives, such as year-on-year inflation-indexed swaps, real annuity swaps, and inflation caps to name a few, the ZCIIS is, according to market participants, the most traded derivative and allows for an easier maturity matching. The demand is primarily driven by market participants with inflation-linked liabilities such as pension funds. On the other side, there are many groups, such as central and local governments and retail companies, whose income/taxes are indexed to inflation and are in the position to sell this protection. Thus, in effect, through inflation-indexed derivatives companies are presented with the easiest way to obtain and manage their desired level of inflation exposure (Dodgson and Kainth, 2006).

2.3.1 ZCIIS Construction

When it comes to the inflation-indexed derivative securities, the prevailing derivatives are the ZCIIS, which are becoming more easily obtainable[9]. The execution of the ZCIIS follows the classical paradigm of swaps with two specific adjustments. First, (i) there is only one cash flow

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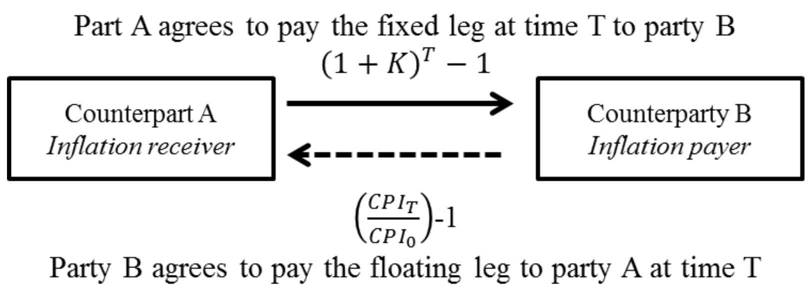
[9]Royal Bank of Scotland now offers electronic trading of inflation swaps (UKRPI with maturities from two to fifty years, FCPI-x and MUICP-x with maturities from one to thirty years).

occurring, namely on the maturity date, typical for any zero-coupon instrument. Second, (ii) the principal is adjusted accordingly for the inflation during the relevant period. For a more vivid representation, consider a world where at time 0 there are no cash flows and a 5-year ZCIIS is executed at a swap rate (K, fixed leg) of 250 basis points. At maturity the cash flow that the counterparties need to exchange is computed as follows: $(1 + .0250)^5 - \pi_t$, where π_t is the inflation adjustment factor. Consequently, if over the five-year period the realized inflation comes to 200 basis points, then the net cash flow from the swap would come to $(1 + .025)^5 - 1.020^5$= $0.027327 per notional dollar of the swap.



Hence, as a zero-coupon swap consists of agreeing to pay the fixed amount in T years of $(1 + K)^T - 1$ in exchange for receiving the relative increase of the CPI-U, $\left(\frac{CPI_T}{CPI_0}\right) - 1$, the below relationship must hold as a swap is a zero sum security:

$$(1+K)^T = \frac{E[CPI_T]}{CPI_0} \qquad [2.0]$$

Where K is the quoted fixed swap rate and the one quoted on data providers in the like of Bloomberg, Datastream and FactSet. $E[CPI_T]$ is the expected CPI-U index level at time *T*.

2.3.2 Relationship between Expected Inflation and ZCIIS.

As seen in the section above the general mechanics of a ZCIIS is pretty straightforward and easily comprehensible. However, as expected inflation is not known, we would in order to price the asset be required to use a model to form an expectation of the CPI-U from time 0 to *T*. There exist two main paradigms in forming such expectation, (i) macro-economic based models and (ii) market based models. The former preferred by academics and the latter of market participants (Benhamou, 2012). The market based approach takes the dynamics of inflation for granted and aim of providing derivative prices based on its assumed dynamics (Benhamou, 2012). One of the common market practices is to extract the break-even inflation rate to price any derivative (Benhamou, 2012). As the BEI and ZCIIS display a high level of correlation and are used to price each other we argue in the section that TIPS and ZCIIS can act as close to perfect substitute for protecting ones liabilities and claims against inflation.

TIPS allow, like nominal bonds, to both go long and short in the security and can therefore can be used in order to hedge ones liabilities and claims (Siegel and Warting, 2004). The procedure is somewhat straightforward and focuses on matching ones expected liabilities inflation duration with the one derived from the available TIPS. However, the yield of any given TIPS is dependent on the required real rate of return which introduces in addition to the inflation duration interest rate duration. It is therefore common to isolate the inflation duration by going long in a nominal bond and short in a TIPS with the same cash flow-characteristics and maturity. By the construction itself and the Fischer theorem investors can thereby isolate the inflation duration effect.

While using TIPS for the purpose of hedging inflation risk one can also use a strategy involving ZCIIS to hedge oneself against the inflation risk. As ZCIIS is a derivative it can be tailor-made to fit any liability structure and therefore easy to adapt for any inflation duration. We show in Appendix 1.0 that TIPS and ZCIIS can be deemed as close substitutes as both can be used to transform floating inflation rate risk into fixed inflation risk or vice versa. We therefore expect that nominal securities, TIPS and ZCIIS not only to be internally closely correlated but also displaying close correlation with other measures of expected inflation such as the Survey of Consumer Attitudes and Cleveland Fund Measure.

The Blue Chip Survey and Survey of Consumer Attitudes and Behavior, conducted by the University of Michigan, try to gauge what the prevailing inflation expectations are amongst participants through a monthly survey.

The Cleveland Fund Measure is developed by Haubrich et al. (2008) and Haubrich (2009) for the Cleveland Federal Reserve. They have developed a paradigm that model inflation expectations using different measures and argues that they have managed to estimate the inflation risk premium embedded in expectations of inflation. As it is illustrated by Graph 2.0 on the following page, the expected inflation from the above-discussed models (the dark grey series) is much more persistent than the market-based measure of expected inflation (the black and the red series).

Haubrich et al. (2008) and Haubrich (2009) also identify two different drivers behind changes in the risk premium – either inflation becomes much more volatile with greater swings from top to bottom and vice-a-versa, or investors change their risk tolerance. Regardless of which driver affects the risk premium, e.g. people might not want to avoid gambling on inflation if they are expecting a lengthy recession, then inflation measures are either going to under- or overestimate the actual expected inflation. Hence, the main difference between the BEI and the inflation risk premium is that the former includes a risk premium which is not related to inflation expectations. In their paper Haubrich et al. (2008) estimate that the inflation risk premium in 27 years is on average around 50 bps, and fluctuations are not stark and ranging between 29 and 61 basis points. In essence, the stability and low level of the risk premium lead to a conclusion that the dominant portion of BEI is in fact inflation expectations, and not the premium. Therefore, using the BEI, derived from the financial measure is a good proxy of expected inflation. We plot the measures for the constant maturity of 5 year over the period of 2004-2011 Graph 2.0 and the correlation coefficients in Table 1.0 on the following page.

Graph 2.0

5 Year Expected Inflation Over Time: Comparison of Measurements

This graph represents 4 different measures of expected average inflation over the next 5 years during the years from 2004 to the end of 2011 measured on a monthly basis. The four measurements displayed are (i) The Cleveland Expected Inflation: derived from ZCIIS rate but corrected for the liquidity premium and changes in real rate, (ii) ZCIIS rate: market quoted fixed rate (iii) Break-Even-Inflation: measured as the difference between a Nominal Treasury Security and a maturity-matched TIPS at the beginning of the month (iv) The Michigan State University Consumer Survey: using the mean value of consumer responses.

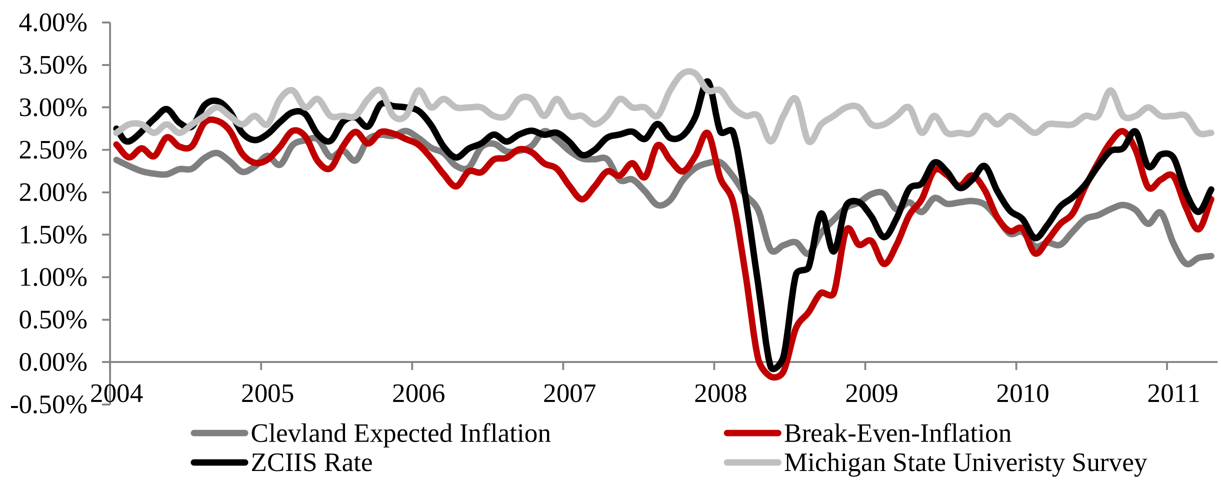


Table 1.0

Correlation Coefficients for 4 measures of 5 year expected inflation from 2004 to 2011

The four measurements displayed are (i) Cleveland: The Cleveland Expected Inflation, (ii) ZCIIS rate (iii) BEI: Break-Even-Inflation (iv) Michigan: The Michigan State University Consumer Survey

	ZCIIS	BEI	Cleveland	Michigan
ZCIIS	*1.00*			
BEI	*0.95*	*1.00*		
Cleveland	*0.75*	*0.67*	*1.00*	
Michigan	*0.40*	*0.31*	*0.41*	*1.00*

2.4. RELATED LITERATURE

Proposing an event study methodology we fall back on the classical framework of the EMH, originally put forward by Fama (1970), which was then followed by Scholes's (1972) postulation that demand curves for stocks should be flat based on the former. However, Shleifer (1986) shook the foundations of these statements, and since then the research investigating how the supposedly information-free events such as index re-compositions impact stock prices has mushroomed. With one of the emphases of the paper being the price impact of demand and supply shocks, we have considered other related papers such as Kaul et al. (2000), Wurgler and Zhuravskaya (2002), Mitchell et al. (2004), Greenwood (2005).

Lou (2011), Frazzini and Lamont (2008), and Coval and Stafford (2007) have conducted related studies exploring the price impact of institutional capital flows. In a related paper, Fleming and Rosenberg (2007) show that prior to Treasury auctions dealers reduce their positions in order to be able to absorb the newly issued securities, and explain that dealers' inventory changes associated risk is compensated for by the augmentation of the price during the subsequent week.

The main inspiration for our study comes from the investigation of Lou et al. (2011) of nominal Treasury securities, in essence, the researchers investigate the impact of primary markets on secondary ones. In effect, their paper builds up on the above-discussed research by looking into the effect of anticipated and repeated shocks in liquid markets, interpreting the results as evidence of dealers' limited risk-bearing capacity and investors' imperfect capital mobility. What Lou et al (2011) underscore is that even in the most liquid financial market capital mobility plays a key part. The contribution of our paper is aimed at building upon the studies on anticipated and frequently repeated shocks in liquid markets. In contrast to previous research we investigate the impact of primary market on the underlying derivatives one. In essence, the emphasis falls on the first-order significance of frictions to our comprehension of financial markets.

Fleckenstein et al. (2010) have discovered that the relative mispricing between Treasury bonds and TIPS presents the largest arbitrage ever documented in the related literature. In accord with them, our paper focuses not only on whether the capital immobility further exacerbates the already documented mispricing and how this is reflected in the underlying derivatives market but also whether these can be exploited with a trading strategy. Our study contributes to the literature focused on inflation-indexed bonds, e.g. Roll (1996, 2004), Barr and Campbell (1997), Evans (2003), Seppälä (2004), Bardong and Lehnert (2004), Buraschi and Jiltsov (2005), Campbell et al. (2009), Adrian and Wu (2009), Gurkaynak et al. (2010), among others.

3.0 METHODOLOGY

We aim to study the effect from TIPS auction on ZCIIS rates using the event study approach, chosen both due to its robustness and empirical acceptance. In order to further add robustness to our test we not only consider ZCIIS rates but also examine any possible effect on the implied expected inflation rate derived from ZCIIS rates. In the following section we will discuss our methodology divided into five subsections. First, we present the general event methodology; second, we discuss the calculation of abnormal return, variance and the test statistics. Third, we display how we derived the implied expected inflation rate from ZCIIS rates and motivate its use, fourth we introduce our sub-sample definition and fifth and finally we put forward two possibly confounding effects.

3.1 GENERAL METHODOLOGY

The general event study methodology is one of the most common methodologies of modern finance. It is often used both for firm-specific and economy-wide events and was formalized by MacKinlay in his famous 1997 paper, "*Event studies in economics and finance*". In this paper he outlines that the main power of the event study over other similar methodologies is that an event study joins two attractive features, namely that (i) it imposes a difference in difference-like identification and (ii) that the study summarize the event impact into one sufficient and easily understandable statistic (t-stat).

We adopt a methodology inspired by Lou et al. (2011) who suggest a constant mean return (CMR) method to study the impact from the anticipated and arguably information-free Treasury auctions. This approach differs from the market model approach as it does not measure abnormal returns as the predication error from any predefined model, for example the CAPM or Fama-French 3-factor model, but measures abnormal return as the difference from a benchmark rate, often the rate/price at/around the event date. Apart from the ones already mentioned this methodology is also employed in Milonas (1987), Schroeder et al., (1990), Mann and Dowen (1997), and McKenzie and Thomsen (2001). All papers use a methodology, very similar to the one employed in this investigation, but with minor modifications to fit the specific derivative examined. Similar to the market model the CMR methodology for event studies relies on three main assumptions.

(i) The model for normal prices is well-specified (CTA)

- ♣ In the absence of the event, price of event firm would be close to "normal" price after the event. We follow, as previously mentioned, the methodology of Lou et al. and uses raw returns. It is noteworthy to mention that studies of Brown and Warner (1980, 1985) find that CMR models yields results similar to those of using a simple market models since the variance of abnormal returns is not reduced much by selecting a specific market model.

(ii) No Anticipation Assumption (NAA)

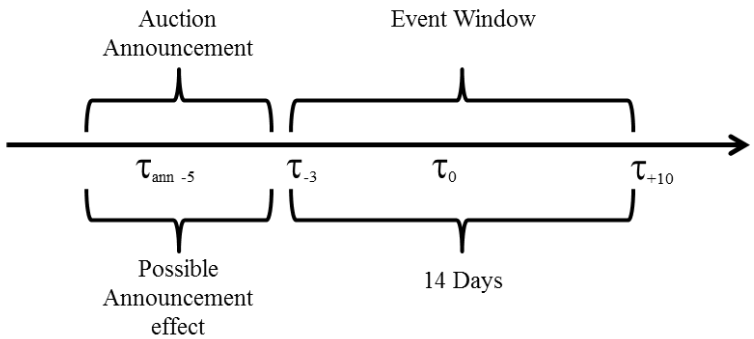
- ♣ Relevant information on the event is not transmitted into prices before official event, to correct for such effect we include up to 3 days before the event(auction) in the event window.

(iii) Market Efficiency (EMH)

- ♣ Relevant information is instantaneously transmitted to asset prices after official event. Nevertheless, to add robustness we use an event window of up till 10 days.

3.2 EVENT STUDY

As formalized by MacKinlay (1997) we measure the cumulative abnormal return over an event period where the event dates (τ_0) are the 60 TIPS issue auctions from July 2004 to November 2011. As described in section 2.2.1 these auctions usually occur in the middle of the month and are announced approximately 1 week (5 trading days) before the auction itself. Due to the fact that the announcement of the auction takes place only a short time period before the event date we define an asymmetrical event window that in its maximum is 14 days, 3 days before and 10 days after the event itself (see figure below)



During the event window we will measure the abnormal returns, defined in section 3.2.1, to capture any prevailing effect. The practice of expanding the event window to a few days before the actual the event date is common in order to adjust for any violation of the NAA and EMH assumptions. Violations of the EMH that new information is not always immediately incorporated in prices have been documented by many studies, Ball and Brown (1968), Chan et al. (1996), Fama (1998), among others, and it has come to be the standard to adjust for this.

3.2.1 Measuring Abnormal Return

When measuring the impact of the auction on the ZCIIS, we need to calculate the abnormal returns for the swap rate and implied yield which is assumed to follow an efficient market pricing process (McWilliams & Siegel, 1997). Further, in order to define abnormal return ($AR_\tau = R_\tau - R_\tau|X_\tau$) we have followed a methodology inspired by Lou et al. (2011), using the swap rate and implied inflation rate at the event date as the benchmark rate. Hence, we measure the abnormal return around each auction as:

$$AR_\tau = ZCIIS_\tau - ZCIIS_{\tau_0} \qquad [3.0]$$

Where AR_τ is the abnormal return for the swap rate at time τ and $ZCIIS_{\tau_0}$is the prevailing swap rate at the event date τ_0. Measuring abnormal returns as the difference in level between day τ and the event date, CMR approach, is motivated by several factors both academic and practical.

- ZCIIS rate is driven by expected inflation over the whole maturity of the swap. To model day-over-day changes of these expectations is not only impractical[10] but it also lacks a clear consensus amongst market participants and academics which of the models that are market standard. We therefore deem that the expected gain is lower than the expected damage of using a wrongly calibrated market model.
- Inflation is measured and mostly modeled on monthly basis while we measure price impact on daily level.
- Following the same methodology leads to a higher degree of consistency and the results are directly comparable with the findings of Lou et al. (2011)
- Most financial time series indicate unit root behavior which, if present, would potentially bias modeling results (Dieckmann and Planck, 2011)

3.2.2 TEST STATISTICS

In order to test the significance of the event over proposed time series we use MacKinlay's notation of cumulative abnormal return that we uses the sum of the abnormal return over the event period:

$$CAR_i = \sum_{\tau=\tau_1}^{\tau_2} AR_{i,\tau} \qquad [4.0]$$

Where CAR_i is the sum of the abnormal return over the period from $\tau_1$to τ_2 for each event i in our sample. In order to examine whether the CAR_i are significantly different from zero during the event window we follow Lou et al. (2011). Thus, we look at the cumulative abnormal return over all auctions treated as a group and averaging both cumulative abnormal return and the variance of the same across all events. We derive the test statistic using the equation below wherein one sets equal weights to the individual cumulative abnormal returns.

$$tstat = \frac{\overline{CAR}_{\tau_1,\tau_2}}{\sigma\left(\overline{CAR}_{\tau_1,\tau_2}\right)} \sim N(0,1) \qquad [5.0]$$

[10] The event window we use is only 1/73 of the length of the shortest maturity.

The test statistic is adjusted to the number of events, N, in the chosen sample period. As N becomes larger, this test statistic converges to the unit normal distribution under the central limit theorem.

3.2.3 CALCULATION OF IMPLIED INFLATION CURVE

As there are different TIPS auctions depending on the maturity any impact might be more profoundly pronounced in the implied expected inflation rate from the swap rates. Thus in order to investigate whether this is the case, using swap rates for ZCIIS, we back out the inflation curve from the swap curve. Knowing that the swap rate is defined by:

$$c_\tau(M) = \frac{1 - Z_\tau(M)}{\sum_{j=1}^{n} Z_\tau(M_j)} \qquad [6.0]$$

where $c_\tau(M)$ is the swap rate at time τ with maturity M, and $Z_\tau(M)$ defines the respective discount factors for each maturity from τ to M. Once we arrive at the discount factors for each maturity we compute the implied expected inflation. The reasoning behind exploring the latter is that the ZCIIS rate is not only dependent on the expected inflation for the respective maturity but also taking account of the changes in the one for the prior maturities.

3.2.4 SUB-SAMPLE TEST

We have data for 8 years (2004-2011) in our sample and it is safe to say that we have experienced several paradigm shifts during this period of time. For this thesis a inflation cut-off date was the financial crisis starting point in 2008. During the crisis most financial markets displayed increased volatility and widening spreads. This was also true for the spread between the inflation swap rate (ZCIIS) and the BEI derived from TIPS which is partly consistent of a liquidity premium. As shown in Graph 3.0 this spread was somewhat constant up till the crash to Lehman where it suddenly spiked to return to pre-crisis levels after mid-2010. This increase in liquidity premium demanded by actors in the inflation market arguably introduces additional effects, Andersen (2011), Campbell et al. (2009). One could expect that a security with a high liquidity premium would be more sensitive to shocks in supply that is new issues of TIPS. Therefore, we split our data set into two sub-samples with the cut-off date of September 15, 2008 which was the date when Lehman Brothers filed for Chapter 11 bankruptcy protection.

3.2.5 CONFOUNDING EFFECTS

What could prove to be troublesome when conducting and event study is the event window itself. Selecting the right length of the window is not always a clear-cut case – a long event window is sure to capture the full magnitude of the event but could also include non-direct effects. Still, using a shorter window limits the impact of side effects but could also understate extent to which the event has influence.

In our data the announcement date may introduce a confounding effect if announcement of the auction causes a drift in the swap rate and implied expected inflation rate. We therefore test the effect by using an event study, presented in section 3.0, to study if such effect could be isolated. In our tests we did not come across any significant such effects and we therefore argue that our proposed event window, 3 days before the event and 10 days after, is free of significant confounding effects from the announcement.

Another important issue is related to event clustering (the occurrence of one event shortly after another, documented 23 times in our data, see section 4.3). Event clustering can lead to inefficient estimates and incorrect test statistics. This inefficacy comes from the fact that if the event periods for two or more events overlap then estimates of the normal returns are not independent and this induces serial correlation in the abnormal returns. However as the auctions are somewhat evenly distributed, albeit overlapping of our event window is present on a couple occasions, our test statistic is computed under the normal assumption of independency among events.

4.0 DATA

In the following the section we will present the general characteristics of the data used in the event studies. First we present the data for ZCIIS, second we present the data for the implied expected inflation rate, and finally the data for the 60 auctions in our sample. The data used throughout the paper was obtained from Bloomberg and Datastream.

4.1 ZCIIS

Our general data is the swap rate for ZCIIS from the period of July 2004 until November 2011 for maturities of 5,10,20, and 30 years. We use the quoted swap rate which is an index, meaning that the quoted swap rate C is the fixed swap rate for the given maturity *M* (5-, 10-, 20- and 30-

year). The quoted data is hence not for individual contracts but is the (mid) fixed-rate of reported entered contracts. Further, as previously mentioned in section 2.2.2, the inflation derivative market is not yet electronically quoted but an OTC market. This introduces the possibility problems of the existence of a grey market. The existence of a grey market may result in delays in the reporting entered contracts or that some entered agreements are not reported at all (Jones, 2009). Still, we deem such problems in the ZCIIS market as negligible.

Below in Table 2.0 we present the summary statistics for the ZCIIS. What we observe is that the term structure is upward sloping and the standard deviation decreases with the increase in maturity, in line with previous research.

Table 2.0

Summary Statistics of Zero Coupon Inflation Indexed Swaps from 2004-2011

The table below outlines the general statistics for ZCIIS from the beginning of 2004 to the end of 2011. The yield represents the market quoted fixed swap rate measured as percentage. Excess Kurtosis is measured by subtracting 3 from the sample kurtosis. AC(1) and AC(2) display the autocorrelation for 1 and 2 lags respectively.

Summary Statistics of Zero Coupon Indexed Swaps (2004-2011)											
Variables	Mean	Standard Deviation	25th	Median	75th	Skewness	Excess Kurtosis	Max	Min	AC(1)	AC(2)
Summary Statistics of Zero Coupon Indexed Swap rates (percentage %)											
Yield (5-year)	2.39	0.50	2.06	2.53	2.74	-0.84	3.16	3.31	0.57	0.98	0.97
Yield (10-year)	2.63	0.30	2.54	2.71	2.82	-1.75	7.15	3.15	1.15	0.98	0.96
Yield (20-year)	2.81	0.30	2.73	2.88	2.99	-1.78	7.52	3.36	1.07	0.97	0.94
Yield (30-year)	2.93	0.30	2.82	2.98	3.11	-1.37	6.05	3.50	1.45	0.96	0.94

One can also observe that the ZCIIS displays a leptokurtic distribution as the excess kurtosis for all maturities is different from zero indicating that the distributions are peaked and fat tailed. Further, it is noteworthy that the skewness is negative and different from zero, indicating that in addition to being leptokurtic the distribution is also skewed to the right. If the series does not follow a normal distribution, as indicated by the relatively high skewness and kurtosis, the small sample distribution following a Student-t distribution may no longer hold and a normal t-test would be biased. However, we observe that on a year-to-year basis the effect of both skewness and kurtosis are less severe depicted in Table 3.0 on the following page. Examining the daily ZCIIS returns however paints a slightly different picture where in 2008 both skewness and excess kurtosis, see table 5.0, reach their peaks during 2008. Therefore we ascribe most of the high kurtosis and skewness to originate from the market turbulence around the crash of Lehman which is in line with the general observations of Lee (2009). Further, it can be shown that in large samples (N>30), that a given process approximately follows a standard normal distribution as result of the Central Limit Theorem.

Table 3.0

Year by Year Skewness and Excess Kurtosis for daily returns of 5 year ZCIIS

The panel below displays the yearly skewness and excess kurtosis for the daily simple return of the 5 year ZCIIS over the year from 2004-2011. Excess kurtosis is measured by subtracting 3 from the yearly sample kurtosis.

Panel: Skewness and Excess Kurtosis Year by Year for 5-year ZCIIS

Variables	Skewness	Excess Kurtosis
2004	-0.15	-1.26
2005	0.19	-0.98
2006	-0.27	-1.32
2007	-0.59	0.47
2008	-1.41	0.91
2009	-1.08	1.21
2010	-0.38	-0.94
2011	-0.39	-0.69

We test for autocorrelation on the ZCIIS level and evaluate it according to the Portmanteau (Q) statistics find evidence of autocorrelation. Testing the general level of the ZCIIS for all maturities we reject the null hypothesis that all lags (12) are not jointly correlated.

When testing whether the ZCIIS rates are stationary or not, using the Dickey-Fuller (DF) test for the existence of unit roots, we arrive at mixed results – some rejecting the null hypothesis of unit root, while others do not, see Table 6.0 for results. All maturities, with the exception of the 5-year ZCIIS exert stationarity since the DF test statistic is significant even at the 5% level up to 5 lags. However DF lacks power when autocorrelation is present. Thus concluding that a CMR approach is indeed a preferable choice considering the characteristics of the data.

4.2 The Implied Expected Inflation Curve

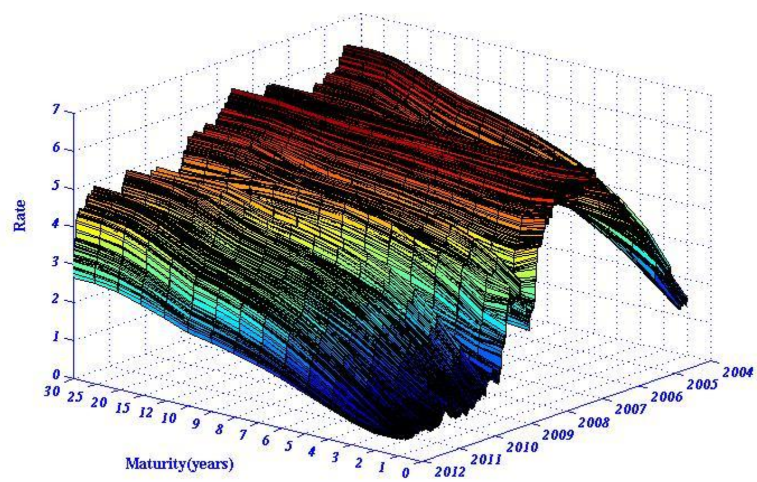
The implied expected inflation rate curve derived through the methodology described in section 4.2 yields results in line with our hypothesis of providing a rate very similar to that from the ZCIIS. We exhibit the results in Table 7.0. It is worth noticing that the standard deviation is higher for the expected inflation rates compared to ZCIIS over similar maturities, and contrary to ZCIIS the standard deviation varies over maturities. Furthermore, we do not observe the same pattern for kurtosis and skewness that is present for the ZCIIS.

From the implied expected inflation rate we plot the implied expected inflation surface in Graph 3.0. We can from this figure see that the market in 2012 expects a near zero inflation environment for the next 1-2 years going forward. We can also see that the long-term inflation (greater than 15 years) is at an all-time low for our sample period. The current level of the 30-year expected inflation is less than 3 percent while compared to the economic upheaval in 2006 where the 30-year average expected inflation was approximately twice as much – close to 6 percent. However we also observe that the evolution of the process is somewhat steady, that is we do not observe any clear outliners that would indicate high variance. We also plot the expected inflation curve for 2 randomly chosen dates with the swap rates for the corresponding dates in Graph 5.0. From this graph we can observe that even though the overall levels are close to similar there exists some discrepancy between the two measures.

Graph 3.0

Implied Expected Inflation Surface for the period from 2004 to 2012

This graph displays the implied expected inflation rate prevailing in the market from 2004 to 2012. The calculated maturities considered in this graph are the maturities from year 1-10 and the 15, 20, 25 and 30 year maturity. The surface is derived from ZCIIS following the methodology in section 3.2.3.



4.3 TIPS Auctions

As discussed above the Treasury started issuing TIPS since 1997, but data for ZCIIS is available only since July 2004 which limits the number of events of interest. Further it must be noted that the Treasury stopped issuing TIPS with maturity of 20 years (with the last auction of such securities held in July 2009). Instead the Treasury has decided to start issuing TIPS with maturities of 30 years motivating the switch as an attempt to improve the liquidity in the market, augment the average maturity of the portfolio, and capture the inflation-associated risk premium more appropriately.[11] This limits the usefulness and accuracy of the 20- and 30-year auctions as events.

Historically, the auctions of TIPS have been spread out in such a way that there are no overlapping ones over the course of a calendar year, which makes the event, not only information-free but also makes sure that there is no breach of the internal consistency relations in bond prices. TIPS with 5-year maturity are often issued in April and October[12], 10-year maturities in January, April, July and November and 20-year maturities were issued in January and July while the 30-year TIPS is preferably issued in October and February. One notes that the months of April and July is the preferred month of issuance for more than 1 maturity. In our data there are several occasions where we have two or more auction during the same month. April is the preferred month for both the issuance of 5- and 10-year TIPS, while July for 10- and 30-year TIPS. During our whole sample period (2004-2011) there are 23 months in which there are 2 auctions in the same month. In such months the issuance of the TIPS with the longer maturity lays at the end of the month and the TIPS with the shorter maturity is issued at the beginning of the month in order to minimize the interference of the auctions. During the above-mentioned 23 months with more than one auction the average time-span between the auctions in the same month is 15 days with 10 days being the minimum time-span. By using a short event window of maximums 14 days (3 days before and 10 days after the auction) we minimize the interference of such events on the studied effect. The table below summarizes the issuing months for each maturity in the sample.

Maturity	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5-year				X				X				X
10-year	X		X		X		X		X		X	
30-year		X				X				X		

The announcement date, see section 2.2.1 is in most cases a week (or 5 trading days) before the auction itself. The median day between announcement and event date is 4.5 with a mean of 4.61 and a minimum and a maximum of respectively 2 and 7 days. Using our event window we aim to minimize the possibility that the announcement biases or distorts the results from the auction itself.

[11] http://explorebonds.com/treasury-to-replace-20-year-tips-with-30-year-tips

[12] In 14 of 15 configuration, however the last auction was in the August 2011 and thus broke the pattern.

As discussed above we compute the reported auction yield against the average yield prevailing in the market 5 days before and 5 days after the auction itself for the TIPS with 10 year maturity. Our results are in line with those of Lou et al. (2011) that the auction yield is considerably lower than the prevailing market rate. We find an average difference of 7 basis points for the whole sample and a 5 vs. 10 basis points difference pre- and post-Lehman respectively. Further, we also applied our methodology, section 3.1, of ZCIIS rates on TIPS yield around TIPS auctions. These results presented in Graph 14.0 clearly display Lou et al.'s inverted V-shape, supporting the hypothesis that the TIPS auctions in fact extort a negative price pressure in the market.

5.0 RESULTS

5.1 IMPACT ON ZCIIS

To investigate the impact of TIPS auctions on the ZCIIS we examine how the rates of the derivative are affected, comparing each maturity only with the auctions for that relevant maturity. However, as already discussed the data for ZCIIS is only available since July 2004 thus the already limited amount of TIPS auctions was further decreased. Hence, we are also examining how each maturity ZCIIS is impacted by the amalgamation of TIPS auctions. It is also noteworthy to mention that there are cases in which there is some overlapping between TIPS auctions event windows and auctions of nominal securities but we are unable to completely isolate the effect of the latter due to the close proximity of the events.

When examining an information-free event, ipso facto it should not emit any signals that would cause a change in the market. This in essence would translate to there being no change in the either the ZCIIS rates as well as the TIPS yields. Still, based on the conclusions Lou et al. (2011) reach in their research of Treasury securities, albeit not inflation-protected, we expect our results to conform them. After estimating the time series average yield during the event window, it clearly depicted that TIPS yields adhere to the inverted V-shaped pattern. In effect, for the entire event window around each auction the yield difference is negative. The inverted-V shape of the yield confirms that the yield is prone to go up prior to the auction and decline during the following days. Coming back to the issue of main interest in the study, Graph 8.0 illustrates the pattern observed there. At first the V-shaped pattern depicted by the graphs comes as a surprise at first but it is actually in conformity with the behavior observed by the TIPS. As discussed in the

Appendix, a stripped TIPS, apart from the principal, is the equivalent of a ZCIIS, thus both instruments are deemed as substitutes when it comes to managing exposure towards inflation. Following that logic the higher the yield on TIPS (i.e. the cheaper the TIPS become), ceteris paribus, the lower the ZCIIS rate would have to be.

A more precise picture of the swap rate and return pattern can be obtained by Table 4.0 on the following page which documents the ZCIIS rates around all TIPS auctions. The statistically significant results are predominantly found for the 10-year ZCIIS, which does not come as a complete surprise since the 10-year TIPS auctions represent half of all the observations in the tested sample. Three days prior to the auction the ZCIIS rate drops by 2.00 basis points (statistically significant from zero), with the decline slowing down and reversing the trend after the auction increasing by 5.16 basis points by the tenth day. Similar decrease is observed for 5-, 20- and 30-year maturities with respectively 1.33, 2.82 and 1.70 basis points respectively on the third day before the auction, and by the tenth day after the auction they have respectively increased by 4.18, 5.08 and 3.97 basis points. The results are also illustrated in Graph 4.0 on the following page, allowing for a more vivid representation of the observed pattern. Similar results were achieved when ZCIIS maturities were matched against auctions of the same maturities but with lower statistical significance and are therefore omitted for brevity.

Table 4.0
ZCIIS Return Pattern Around All TIPS Auctions

The first table displays the Mean and corresponding t-stat in parenthesis for the ZCIIS with maturities of 5,10 and 30 years around all auction dates. Abnormal return is calculated as AR=Y(t) –Y(0) where Y(0) is the benchmark rate i.e. the rate prevailing at each auction date and Y(t) the rate at day t. The second table displays the Mean and corresponding t-stat in parenthesis for the implied expected inflation with maturities of 5,10 and 30 years around all auction dates. All returns are expressed in basis points. T-statistics are based on robust standard errors and are reported in parentheses. ***, **, and * indicate significance levels of 1%, 5% and 10%, respectively.

ZCIIS Behavior around all TIPS Auction dates: Y(t)-Y(0)						
	5 year ZCIIS		10 year ZCIIS		30 year ZCIIS	
t	Mean	*t*-value	Mean	*t*-value	Mean	*t*-value
-5	3,37	(1,71)	2.92**	(2,25)	3.16**	(2,18)
-4	3,11	(1,94)	1,97	(1,64)	2.77**	(2,01)
-3	1,33	(0,92)	2.00**	(2,14)	1,70	(1,24)
-2	1,82	(1,53)	1,46	(1,63)	1,94	(1,68)
-1	1,43	(1,68)	0,50	(0,67)	1,10	(1,18)
1	1,37	(1,78)	1.77**	(2,27)	0,76	(1,04)
2	0,46	(0,47)	2.76**	(2,37)	0,31	(0,40)
3	1,58	(1,22)	2.80**	(2,32)	1,63	(1,30)
4	2,48	(1,88)	3.08***	(2,87)	2.62**	(2,40)
5	2,36	(1,53)	3.61***	(2,98)	2.63**	(2,03)
6	2,65	(1,31)	3.11**	(2,10)	1,96	(1,51)
7	3,22	(1,58)	3.34**	(2,01)	3,28	(1,97)
8	2,79	(1,41)	2,98	(1,70)	1,39	(0,75)
9	3,62	(1,51)	4.08**	(2,16)	3,43	(1,92)
10	4,18	(1,57)	5.16**	(2,55)	3.97**	(2,18)
No. Obs.	60		60		60	

** p<0.10, ** p<0.05, *** p<0.01*

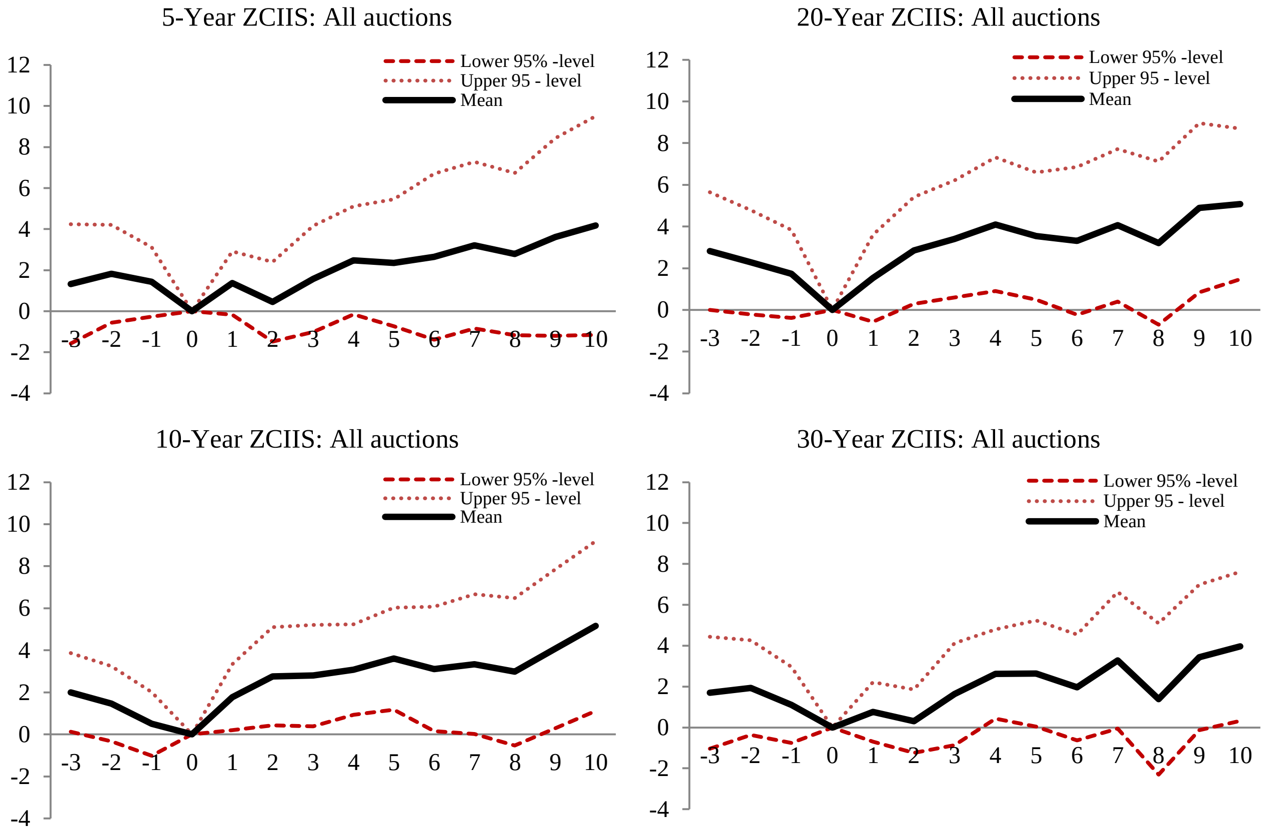
Implied Expected Inflation Behavior around all TIPS Auction dates: Y(t)-Y(0)						
	5 year ZCIIS		10 year ZCIIS		30 year ZCIIS	
t	Mean	*t*-value	Mean	*t*-value	Mean	*t*-value
-5	3,54	(1,77)	3.08**	(2,20)	3.98***	(2,84)
-4	3.31**	(2,04)	2,31	(1,80)	3.49**	(2,49)
-3	1,56	(1,07)	2.26**	(2,24)	1,92	(1,24)
-2	1,84	(1,54)	1.59*	(1,67)	2,28	(1,78)
-1	1,44	(1,70)	0,62	(0,76)	1,31	(1,23)
1	1,49	(1,95)	2.00**	(2,43)	0,852	(0,98)
2	0,51	(0,52)	2.97**	(2,47)	0,148	(0,16)
3	1,69	(1,31)	2.90**	(2,36)	1,57	(1,08)
4	2,18	(1,66)	2.70**	(2,41)	1,95	(1,77)
5	2,33	(1,46)	3.07**	(2,43)	2,21	(1,73)
6	2,54	(1,19)	2,57	(1,62)	1,28	(1,05)
7	3,05	(1,45)	2,82	(1,61)	2,7	(1,62)
8	2,80	(1,38)	2,48	(1,39)	0,508	(0,27)
9	3,23	(1,30)	3.33*	(1,73)	2,9	(1,71)
10	3,80	(1,37)	4.56**	(2,16)	3,46	(1,94)
No. Obs.	60		60		60	

** p<0.10, ** p<0.05, *** p<0.01*

Graph 4.0

Graphical Display of Abnormal Return Pattern for ZCIIS and Implied Expected Inflation Around All Auction

The graphs below display the Abnormal Return for ZCIIS around all auction dates. The abnormal return for each point in time t is Y(t) –Y(0) where Y(0) is the benchmark rate i.e. the rate prevailing at each auction date. The X-axis represents the distance, no. of days, from the auction and the Y-axis the change in rate measured in basis points



In addition, Table 8.0 provides the time-series average of the cumulative difference of the ZCIIS three days before and ten days after all auctions of TIPS is 7.16(t=3.00) and 7.90(t=2.81) basis points for the 10- and 20-year ZCIIS. For the 5- and 30-year maturity it comes to 5.51(t=1.87) and 5.67(t=2.30) basis points respectively. Further discussion about exploiting this possibility is to follow shortly.

5.2 ECONOMIC SIGNIFICANCE

The observed movements in TIPS yields and ZCIIS rates, albeit temporary, suggest a number of significant implications. Firstly, as documented by Lou et al. (2011) for nominal notes and bonds, the pattern of the yield lead to profoundly higher issuance cost for the Treasury. This, in essence, means that the ZCIIS market even though a very close substitute to the TIPS is unable to take on the additionally exerted price pressure and also follows the pattern by decreasing the fixed side of the swap rate.

Secondly, bearing in mind the persistent pattern in ZCIIS rates around auctions of TIPS this implies a potentially, stable over time trading profit. In order to exploit the opportunity one can enter in a swap agreement three days prior to the auction by paying the fixed rate of the ZCIIS and afterwards taking the opposite side in the agreement paying the inflation-linked side of the derivative. In other words, one sells a ZCIIS prior to the auction and then reverses the trade, locking in the difference between the fixed rates since the inflation-indexed streams offset each other. The strategy does not require entering into trades which would expose to bid-ask spreads and there is only one exchange of cash flows at the maturity of the contract. Still, the cash flow matching might not always be a perfect one, which introduces an element of uncertainty in the whole execution process.

Finally, the swings in average returns deliver practical guidance for future asset-pricing and derivatives paradigms. Calculating the returns for our proposed strategy for the whole sample period the Sharpe ratio for 5- and 10-year ZCIIS rates, focusing in particular as Haubrich et al. (2012) argue that these maturities would be the most traded as the fluctuations in inflation would be greatest in those maturities rather than 20- or 30-year ones[13], ranged between 0.13-.018. In order to measure the relative performance of the trading strategy, we use the United States Government Inflation-Linked All maturities USD Total Return Index. We believe that it is the most applicable one since gauges the performance of all maturities, and since we are measuring across auctions of multiple maturities. It is noteworthy to mention that since there is some overlapping of the event window in which one should execute the strategy we sample different variations but only in one occasion, namely 10-year ZCIIS with event window of 3 days before and 5 days after the auction, the Sharpe ratio is superior to the original proposition. We also tested how the strategy would perform once the auctions were far enough so that there is no overlapping whatsoever, which is after the 5-year TIPS auction in October 2008. In that setting, for the original proposed trading strategy the Sharpe ratio came to 0.24 and 0.20 for 5- and 10-year ZCIIS rate respective[14]. Acknowledging that compared to other documenting pricing

[13] In our sample we have only five auctions for 30-year TIPS, while the 20-year TIPS issuance has been suspended.

[14] For all holding periods across maturities see Table 11.0

anomalies[15], ours does not produce significantly high Sharpe ratio, still offers a potentially profitable trading strategy. Perhaps, more precisely what could abstain arbitrageurs from capitalizing on this possibility would be the feasibility of achieving a perfect maturity match and/or more probable locating counterparties willing to enter into the agreement in the first place.

5.3 ROBUSTNESS

As discussed above due to the limited amount of auction for our sample period, we emphasize more on the results which examined each ZCIIS maturity against auctions for all maturities. Were the results to be examined by matching maturities the statistical significance of the results would be weakened, albeit the pattern is still consistent. In order to reassure the robustness of our results, we divide our sample in two subsamples: one before Lehman Brothers files for Chapter 11 (15 September 2008) and one after. This splits our sample almost exactly in half, and the main results still hold. It is noteworthy to mention that prior to Lehman the lower volatility facilitates a very stable and slightly less pronounced pattern. However, after Lehman the increased uncertainty in markets acts as a catalyst to for the bigger swings observed in ZCIIS rates. In addition, we check whether each of the two maturities with most auctions, namely the 5- and 10-year maturities, contradicts the above-described results when the auction sample is reduced by the 20- and 30-year maturities. The results conform to the results achieved above. Finally, we back out the implied expected inflation rate from the ZCIIS rates for each maturity to investigate whether it would yield any different results. By and large the results remain unchanged with respect to Tables 5.0 and 6.0, and Graph 8.0 hence they are omitted for brevity.

5.4 INTERPRETATION AND DISCUSSION

It seems only intuitive to identify the observed phenomenon with the information revealed in auctions. Even though the general information concerning all Treasury auctions, such as size and date, are perfectly foreseen the actual outcome, in terms of the yield and the bid-to-cover ratio, is plausible to emanate additional information about the general economic conditions, TIPS markets and, in effect, expectations about inflation. Were the possibility that the prior to the auction the gradually released information is analysed accordingly, one would not expect that there would be significant change in the ZCIIS rate. Still, the data seems to point to the contrary.

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[15] See Lou et al. (2011) , Brunnermeir et al.(2009), Lustig et al. (2009) and Asness et al. (2008) for strategies yielding higher Sharpe ratios.

A more tenable explanation of the observed occurrence is the momentous price pressure impact exerted by the TIPS auctions. The reasoning behind this logic is the fact that before the auction the rate goes down and afterwards it experiences a reversal. We believe that there are three stories that play out simultaneously and in effect precipitate the documented pattern.

First of all, as discussed in Section 2.3.2 the ZCIIS and TIPS can be deemed to be close to perfect substitutes. Furthermore, it is also worth noting that the TIPS market has been growing reaching almost 5% of the whole Treasury market. Following that line of thought along with Haubrich et al. (2012), it is rather plausible to deduce that the additional supply of TIPS exerts price pressure on the ZCIIS thus resulting in the witnessed pattern. More precisely, as the TIPS yield spikes on the auction date it translates in a lower price for the TIPS. In order for parties seeking inflation protection to be interested to enter into ZCIIS they would be demanding a lower fixed rate, since otherwise they could simply go to the TIPS market and use Treasury instruments to achieve their desired exposure to inflation. However, the price impact should not be significant if there is enough capital liquidity since TIPS and ZCIIS are deemed to be close to perfect substitutes.

Second, primary dealers are presumed to participate by submitting relevant bids in all auctions. In other words, it is expected of primary dealers that they absorb large portions of the auctioned securities. However, they have limited risk-bearing capacity (Lou et al., 2011) and in effect have to offset the positions they will be obtaining by either shorting TIPS in both the when-issued and secondary markets. In addition, due to the above-discussed resemblance between TIPS and ZCIIS they could also use the derivatives to hedge their positions thereby further exacerbating the price pressure on the swap rates.

The underlying driving factors for the limited risk-bearing capacity can be split up in two main reasons. For one, when the risk exposure of primary dealers is higher either due to economic conditions and higher return volatility, or due to the size of the auction, the price impact would be more profound. In the discussion about the robustness of our results, we divided the data into two subsamples – one prior to Lehman and one after it. The results suggested precisely that, in accord with Haubrich et al. (2012), in a period with high economic uncertainty the price pressure exerted by primary dealers offsetting their positions the ZCIIS rates are affect more profoundly than in a period of economic stability. With regard to the impact of the auction size we perform a simple time-series regression of returns on the defined trading strategy on auction size and bid-to-cover ratios for each auction. The results imply no statistical significance and have little to none explanatory power. When the auction yield is regressed on the same independent variables, both of which are statistically significant and the resulting equation explains more than half of the observations.

For another, the pattern as described in our results is consistent for all maturities both only matched against the specific auctions and against all auctions. In essence, this suggests that the spillover across maturities further augments the price pressure on TIPS yields which in turn passes the effect of the shock onto the ZCIIS rates. Moreover, we also examined whether this spillover effect is stronger when maturities are closer together, further apart or surrounding the particular maturity. In all cases but one, namely the 10-year rates against 20- and 30-year TIPS auctions, the pattern has been confirmed as well as the notion found by Lou et al. (2011) that the effects of auctions are more pronounced when maturities are closer together. In the case of the exception, we observe that the ZCIIS rate is following an upward trend before and after the auction. However, the results fail to achieve statistical significance, thus not contradicting the overall conclusions.

Finally, we shall briefly discuss the slow-moving capital of end-investors as the last driving factor of the pressure exercised on ZCIIS rates. According to several studies, Lou et al. (2011), D'Amico (2010), to name a couple, about half of the outstanding Treasury securities are held either by the Federal Government accounts and the Federal Reserve. The latter is unlikely to exploit of the temporary price discrepancies bearing in mind its mandate. Thus, the rest of the outstanding securities are held by private investors which are comprised of mutual funds, insurance companies, foreign investors, and local and state governments. In their study, Lou et al. (2011) estimate that insurance companies trade very irregularly, and even though bond mutual funds do not share that trait, portfolio managers are likely to postpone capitalizing on the phenomenon since they prefer to minimize their tracking error with respect to the index they try to replicate. The rest of the investors most probably do not have the resources and/or intention to harness the transient price movements.

6.0 CONCLUSION

Overall, the results we achieved point to the fact that anticipated TIPS auctions that result into recurrent supply shocks have first-order price impact on the ZCIIS market, with the latter failing to take on the additionally exerted pressure. The results imply that the spillover effect across TIPS and ZCIIS markets is specifically pronounced around TIPS auctions. Although the patterns we observed are consistent over time, a larger sample size would most certainly enhance the quality of the results.

In our paper we focus on the US Treasury market since it is the most developed and liquid one in the world. A logical extension of this study could be to investigate other sovereign bond markets, some with longer history of inflation-indexed issuance. Future research in such countries like the UK (1981)[16], Sweden (1994), France (1998) and Germany (2006), could yield further interesting results with respect to the price pressure exerted by anticipated supply shocks of auctions of inflation-linked securities on the underlying securities and the respective ZCIIS rates.

Furthermore, our findings suggest that additional research is necessary to produce paradigms that are able to account for the slow-moving capital of end investors as well as the limitations primary dealers experience due to finite risk-bearing capacity. Finally, a possible area for fruitful future research lies in the inherent characteristics of the ZCIIS market and its relations with the TIPS one.

[16] Year of first issue of inflation-indexed securities.

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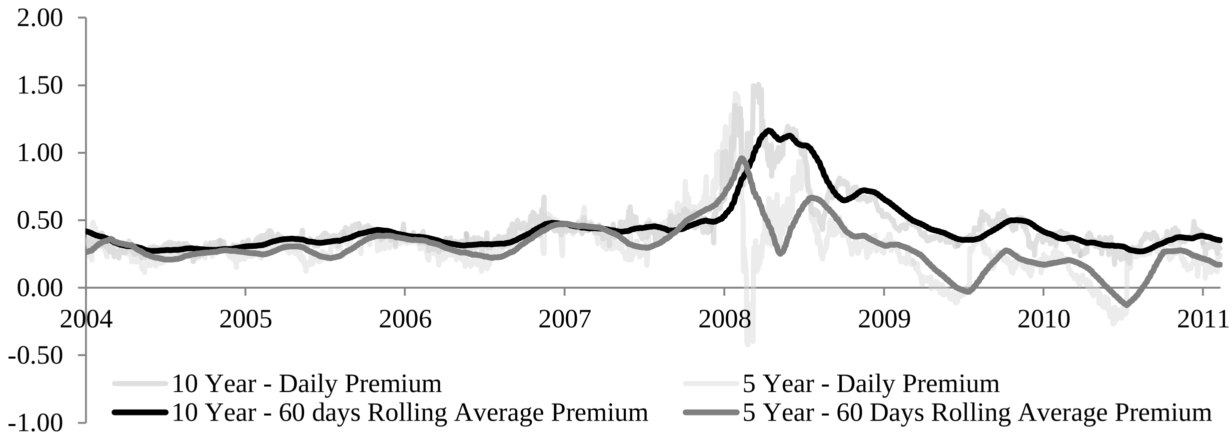
TABLES AND GRAPHS

GRAPHS

Graph 5.0

Liquidity Premium for 5- and 10-Year maturity over time

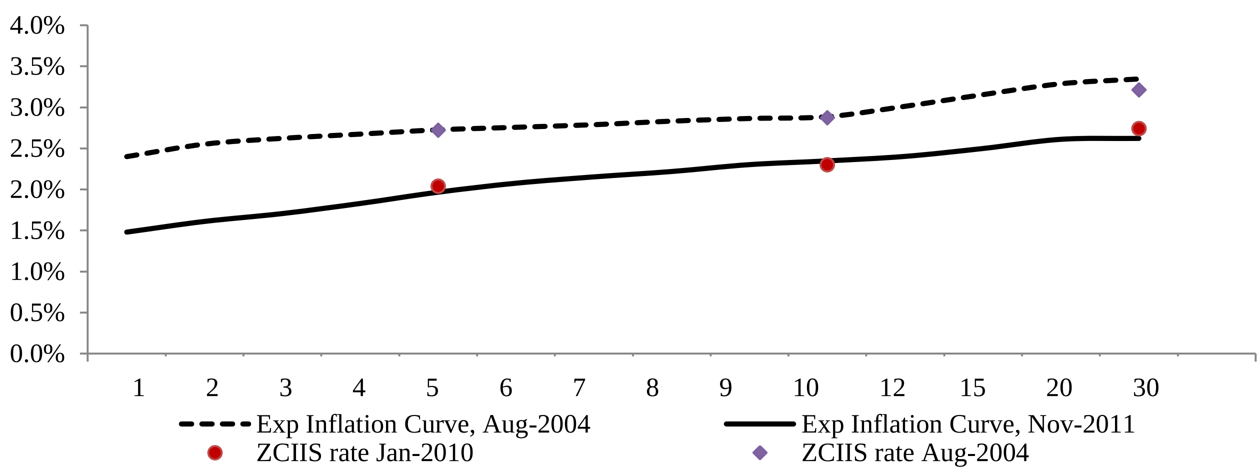
This graph display the liquidity premium, measured as the difference of the ZCIIS rate over the BEI rate, for the assets maturing in 5 year and 10 years. The bolded grey and black line represents the 60 day rolling average daily premium from 2004 to November 2011 for the 5 year and 10 year maturity respectively. The faded grey line visible behind each bolded line represents the daily measured premium over which the 60 days rolling average calculated. Days with no data for either ZCIIS, TIPS or Nominal Bond have been excluded and total of 1829 observations have been used.



Graph 6.0

Implied Expected Inflation Curve with plotted ZCIIS rate

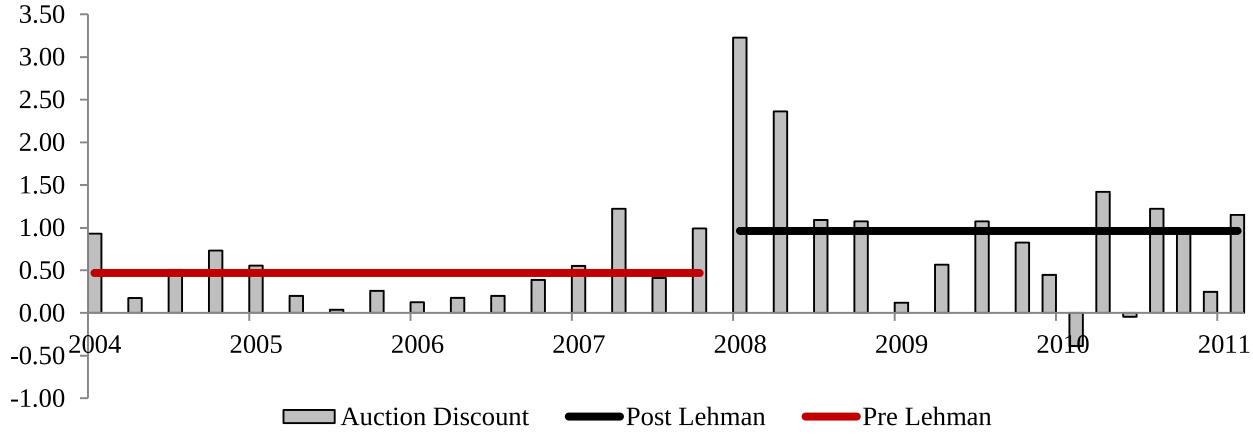
This graph display the implied expected inflation yield curve and the corresponding market quoted fixed led rate for ZCIIS with maturities of 5-,10- and 30-year. The solid line represents the expected inflation curve at our last observation, 21th of November 2011 and the dotted black line represent the curve at the 16th of August 2004. The methodology for deriving the expected inflation curve is described in the methodology section, see 3.2.3. The X-axis represents the forecasting horizon measured in numbers of years. Please, note that we plot on a yearly basis upto the 10th year when the time span is 2-,3-,5- and 10-year respectively.



Graph 7.0

Auction Discounts for 10-Year TIPS compared to 10 day average yield around auction date

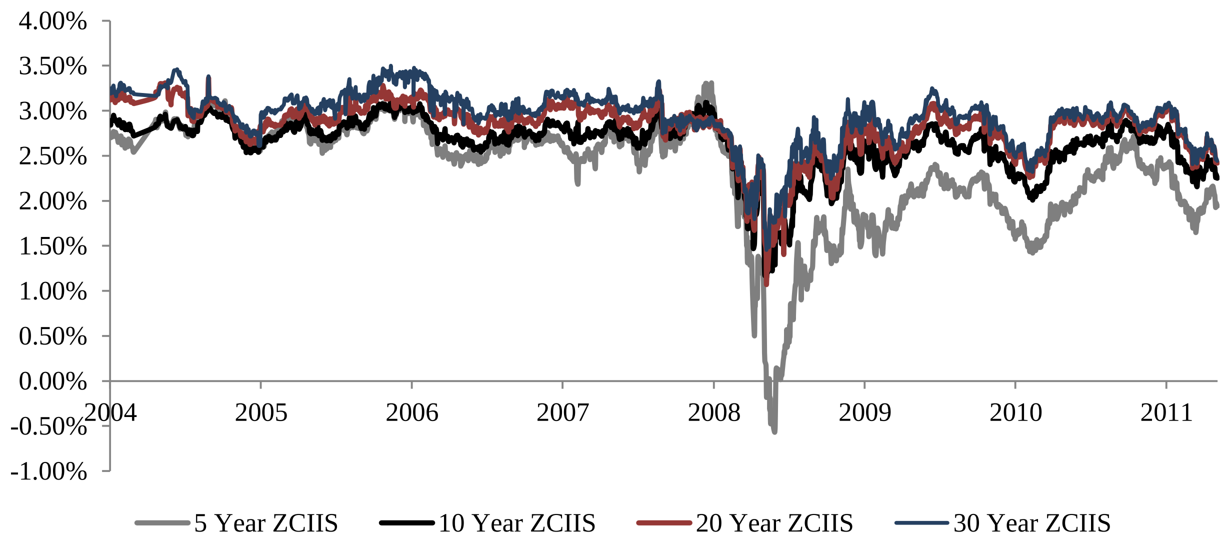
This figure displays the discount for each of the 32 TIPS auction in our sample. The discount, inspired by Lou et al, is the difference from the reported auction yield, reported by the Federal Reserve, and the average market yield calculated over a -5 to +5 window with the auction in the middle. The black line represents the average discount for the 16 auction occurring after Lehman and the red line is the average discount for the 16 auction occurring before the crash of Lehman Brothers. 2 auctions displays a premium and not a discount when comparing to the 10 day average, the auction at the 24th of May 2011 and the auction at the 4th of November 2010, otherwise all auction displays a discount



Graph 8.0

5-, 10-, 20- and 30-Year maturity ZCIIS rate over time

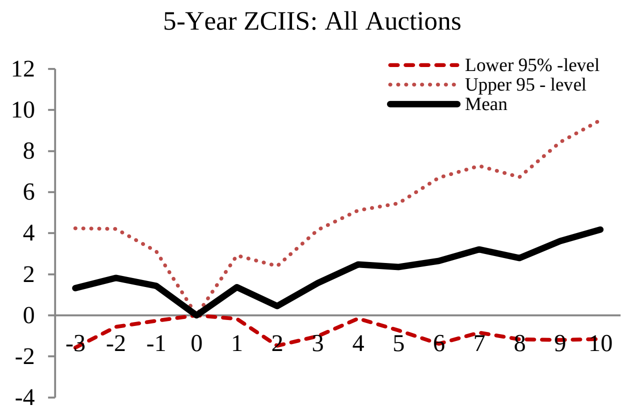
This figure outline the market quoted fixed rate for all maturities in our sample on a daily basis. The grey line represents the 5-Year ZCIIS, the black line the 10-Year ZCIIS, the maroon line the 20-Year ZCIIS and the blue line the 30-Year ZCIIS

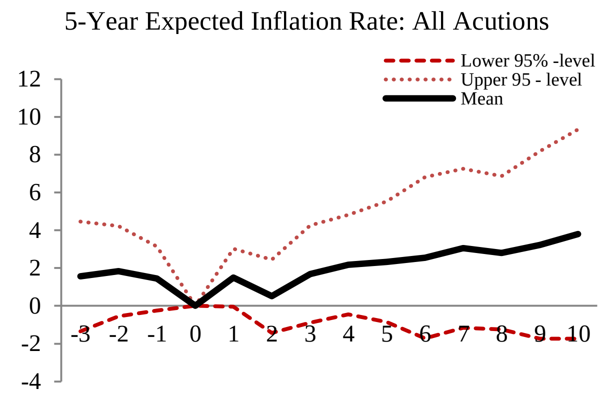


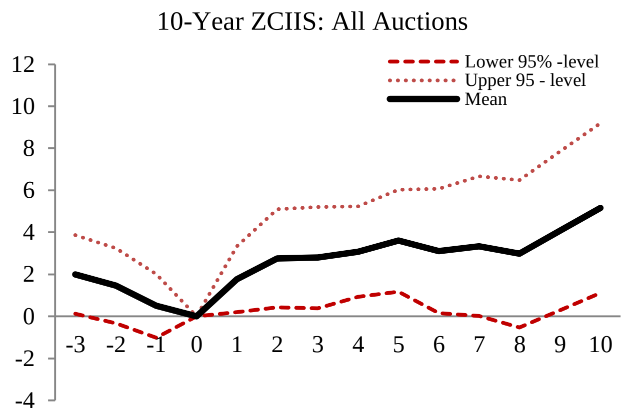
Graph 9.0

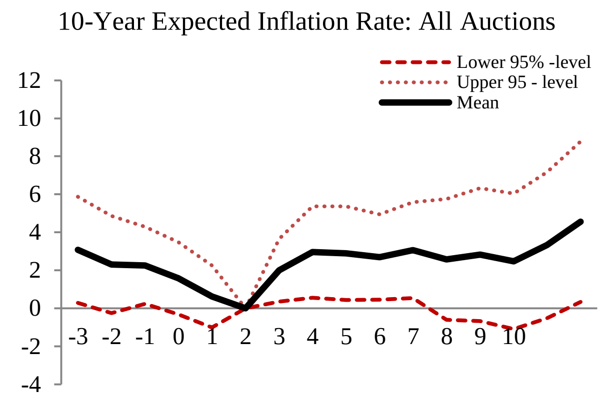
Graphical Display of Abnormal Return for ZCIIS and Implied Expected Inflation Around all Auction Dates

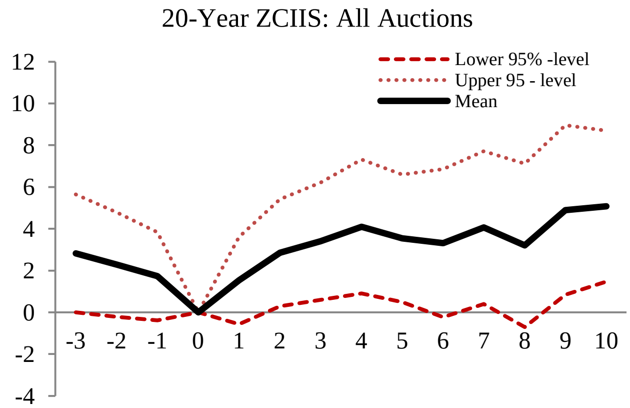
The graphs below displays the Abnormal Return for ZCIIS and Implied expected inflation around all auction dates. Observe that no graph is displayed for the implied expected inflation e 20-year, this due to shortage of data. The abnormal return for each point in time t is Y(t) –Y(0) where Y(0) is the benchmark rate i.e. the rate prevailing at each auction date. The X-axis represents the distance, no. of days, from the auction and the Y-axis the change in rate measured in basis points

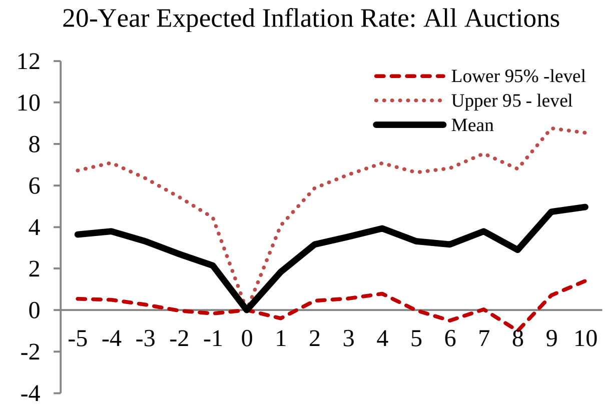




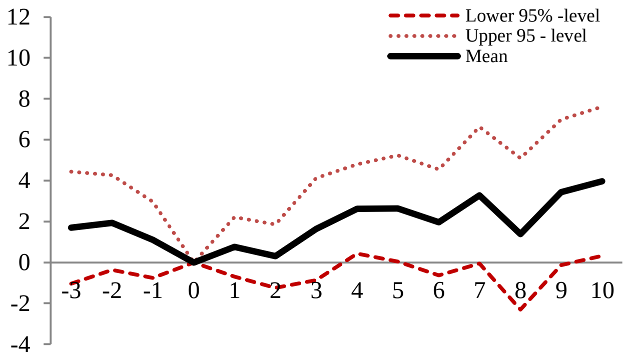




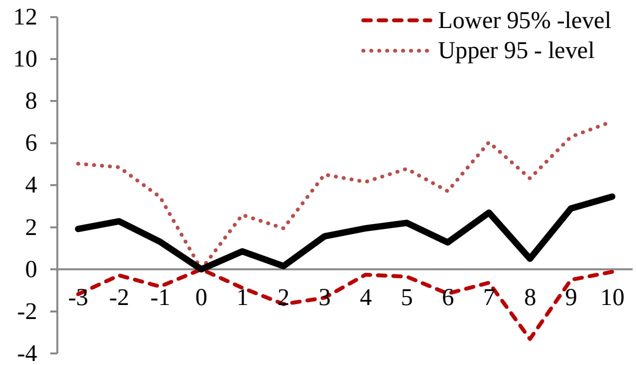




30-Year ZCIIS: All auctions



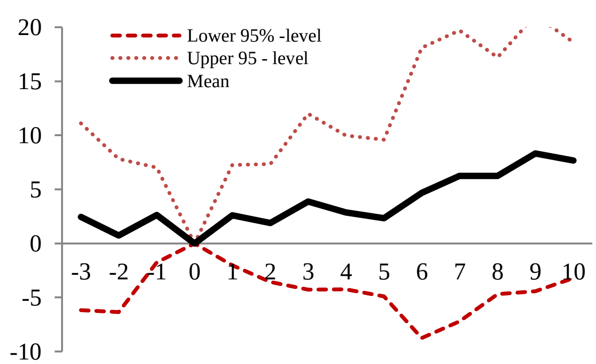
30-Year Expected Inflation Rate: All Auctions



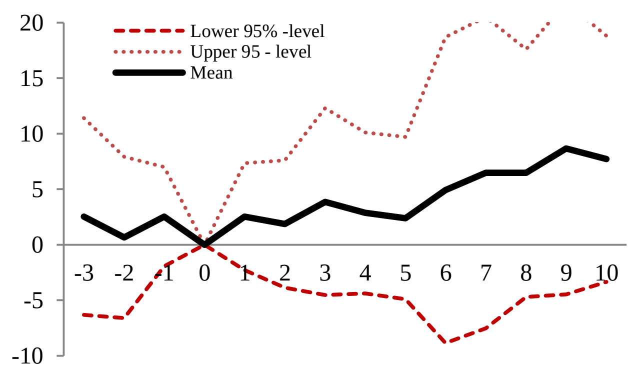
Graph 10.0
Graphical Display of Abnormal Return for ZCIIS and Implied Expected Inflation Around Matched Auction Dates

The graphs below displays the Abnormal Return for ZCIIS and implied expected inflation around auction dates of TIPS with same Maturity (Matched). For example for the 5-year derivative we only consider the auction of TIPS with a corresponding maturity of 5 years. Observe that no graph is displayed for the implied expected inflation 20-year, this due to shortage of data. The abnormal return for each point in time t is Y(t) –Y(0) where Y(0) is the benchmark rate i.e. the rate prevailing at each auction date. The X-axis represents the distance, no. of days, from the auction and the Y-axis the change in rate measured in basis points

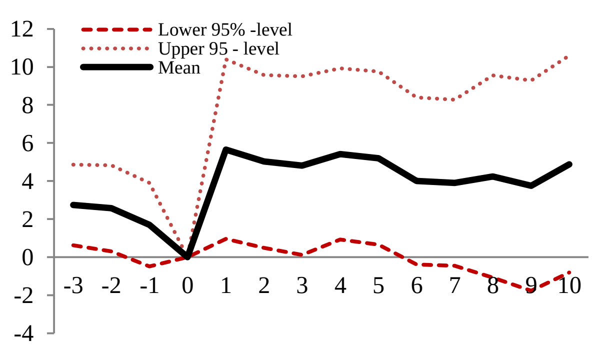
5-Year ZCIIS: Matched Auctions



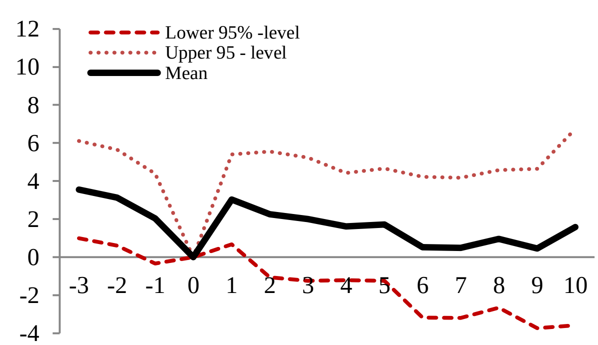
5-Year Expected Inflation Rate: Matched Auctions

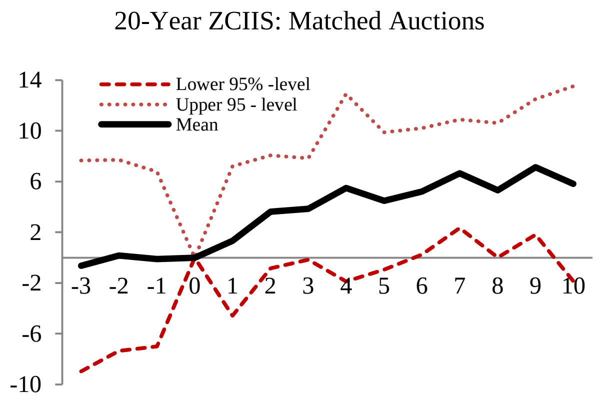


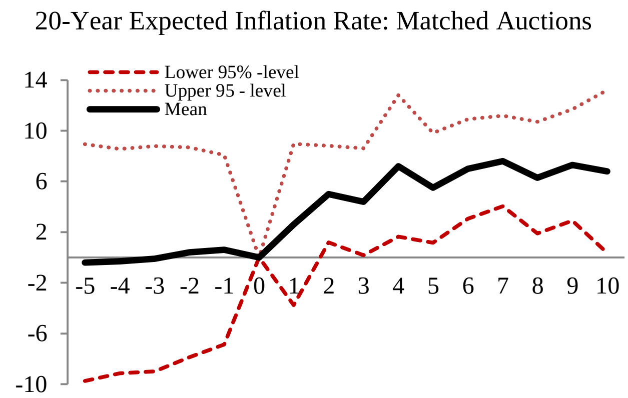
10-Year ZCIIS: Matched Auctions

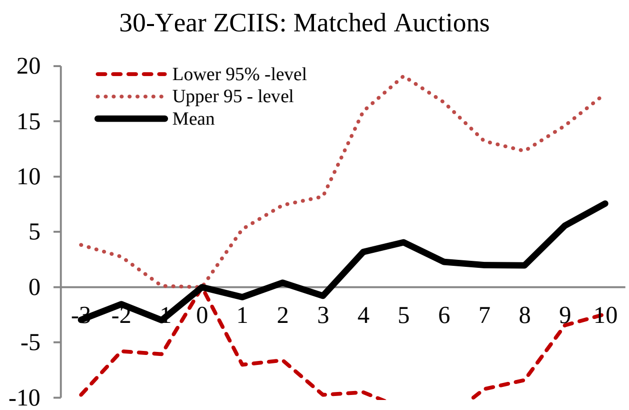


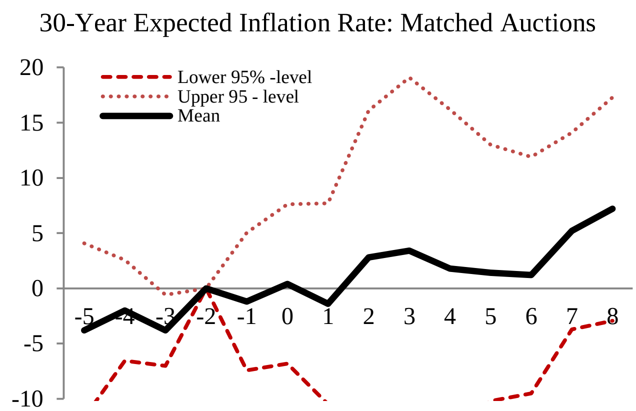
10-Year Expected Inflation Rate: Matched Auctions




20-Year ZCIIS: Matched Auctions
Lower 95% -level
Upper 95 - level
Mean


20-Year Expected Inflation Rate: Matched Auctions
Lower 95% -level
Upper 95 - level
Mean


30-Year ZCIIS: Matched Auctions
Lower 95% -level
Upper 95 - level
Mean

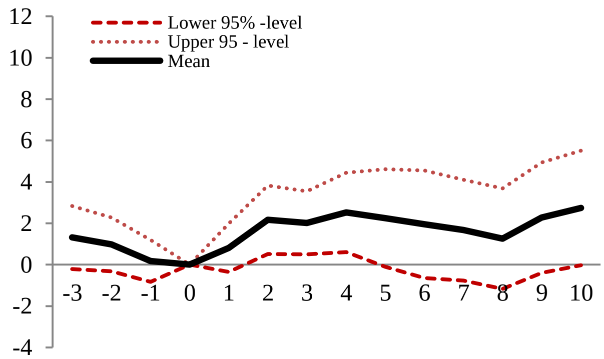

30-Year Expected Inflation Rate: Matched Auctions
Lower 95% -level
Upper 95 - level
Mean

Graph 11.0

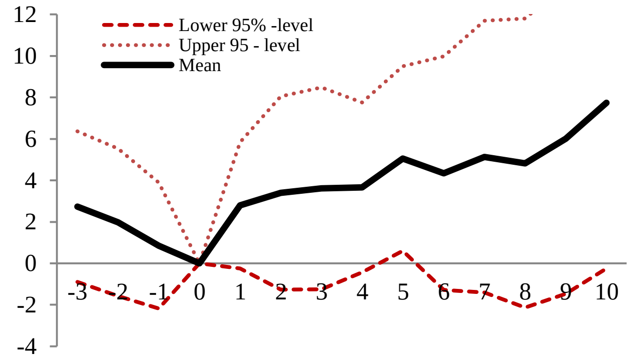
Graphical Display of Abnormal Return for 10-Year ZCIIS and Implied Expected Inflation Around all Auctions dates: Sub-samples based whether or not auction was Pre or Post the crash of Lehman Brothers

The graphs below displays the Abnormal Return for ZCIIS and implied expected inflation around all auction dates. The observations is divided into 2 sub-samples whether or not the event occurred before or after the crash of Lehman Brothers in September 2008 (cutoff-date). The abnormal return for each point in time t is calculated as AR=Y(t) – Y(0) where Y(0) is the benchmark rate i.e. the rate prevailing at each auction date and Y(t) the rate at day t.

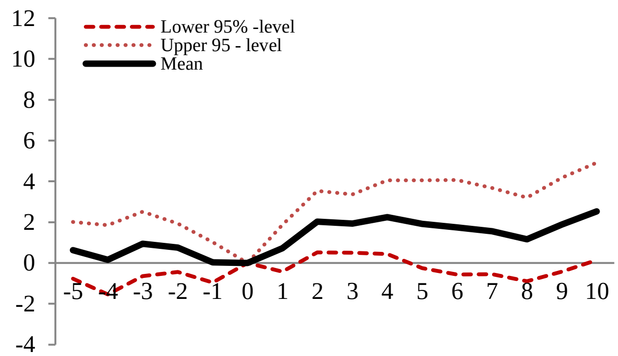
10-Year ZCIIS: Pre-Lehman



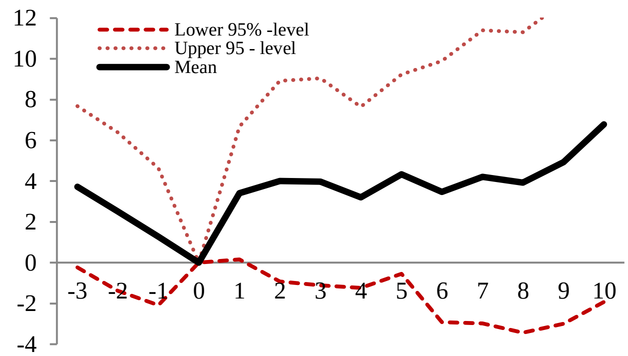
10-Year ZCIIS: Post-Lehman



10-Year Expected Inflation Rate: Pre-Lehman



10-Year Expected Inflation Rate: Post-Lehman

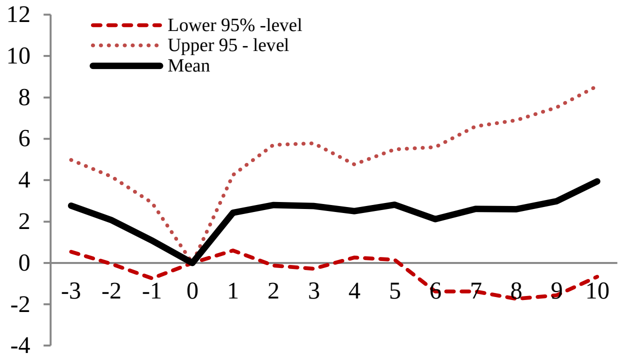


Graph 12.0

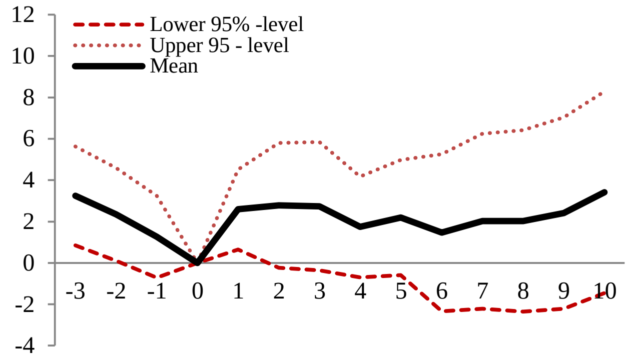
Robustness Test for 10-year ZCIIS and Implied Expected Inflation Around Various Auction Dates

The graphs below displays the Abnormal Return for ZCIIS and implied expected inflation around various auction dates. The abnormal return for each point in time t is calculated as AR=Y(t) –Y(0) where Y(0) is the benchmark rate i.e. the rate prevailing at each auction date and Y(t) the rate at day t.

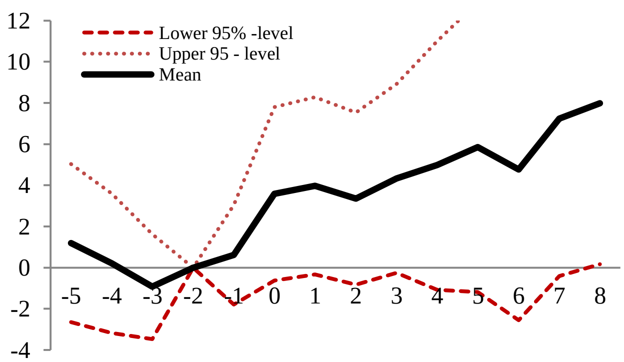
10-Year ZCIIS: 5 & 10yr TIPS auctions



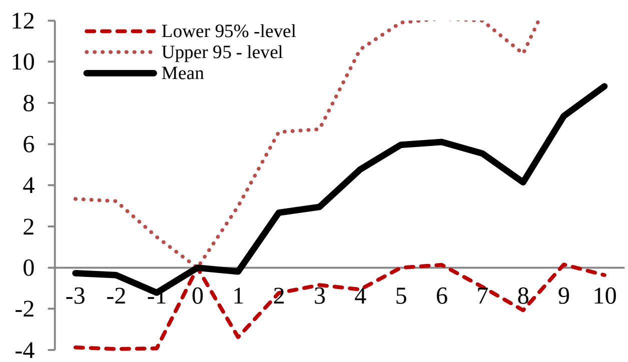
10-Year Expected Inflation Rate: 5 & 10yr TIPS



10-Year ZCIIS: 5 & 20yr TIPS auctions



10-Year Expected Inflation Rate: 5 & 20yr TIPS

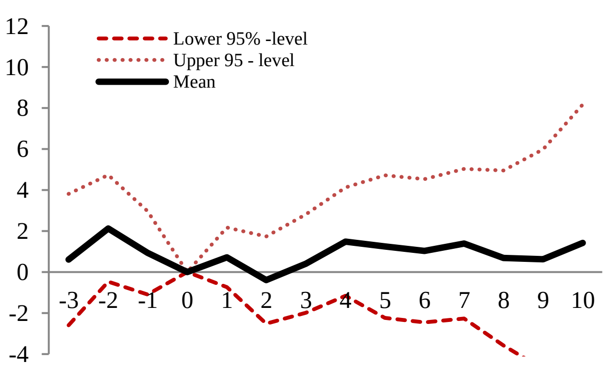


Graph 13.0

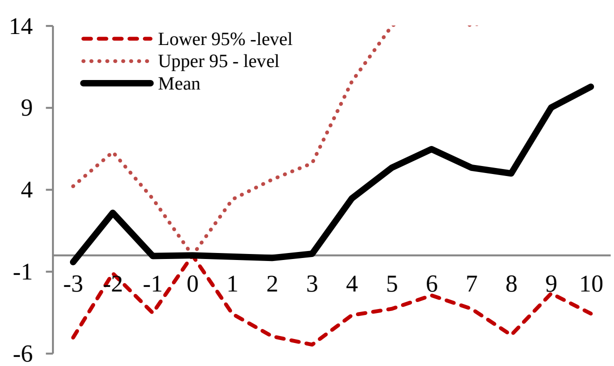
Robustness Test for 5-, 10- and 30-year ZCIIS and Implied Expected Inflation

The graphs below display the Abnormal Return for ZCIIS and implied expected inflation around auction dates of TIPS with various time to maturity. The abnormal return for each point in time t is calculated as AR=Y(t) –Y(0) where Y(0) is the benchmark rate i.e. the rate prevailing at each auction date and Y(t) the rate at day t.

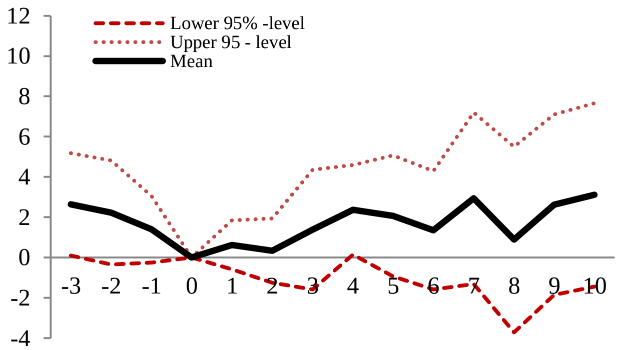
5-Year ZCIIS: 10- & 20-Year TIPS auctions



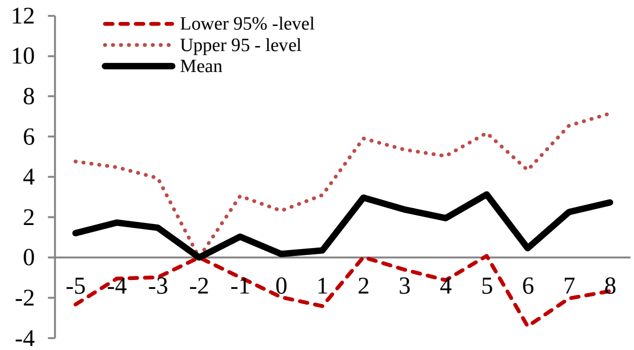
10-Year ZCIIS: 20- & 30-Year TIPS auctions



30-Year ZCIIS: 5- & 20-Year TIPS auctions



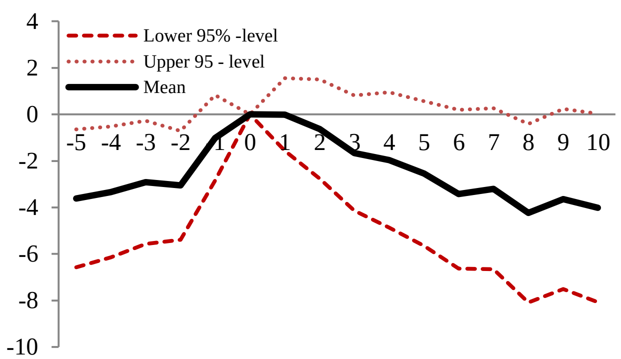
30-Year ZCIIS: 10- & 20-Year TIPS auctions



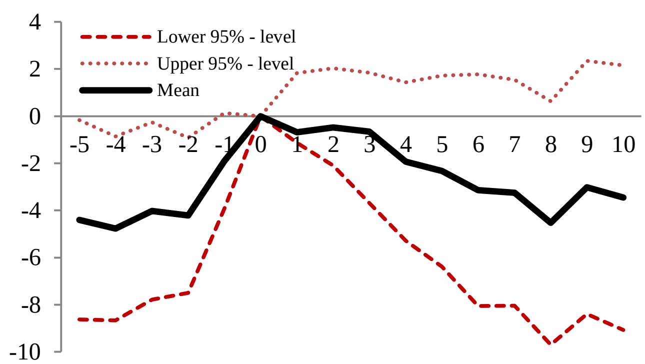
Graph 14.0
TIPS yields around all TIPS Auctions

The graphs below display the Abnormal Return for TIPS yield around auctions of TIPS. The method used is the same as the methodology used for ZCIIS.

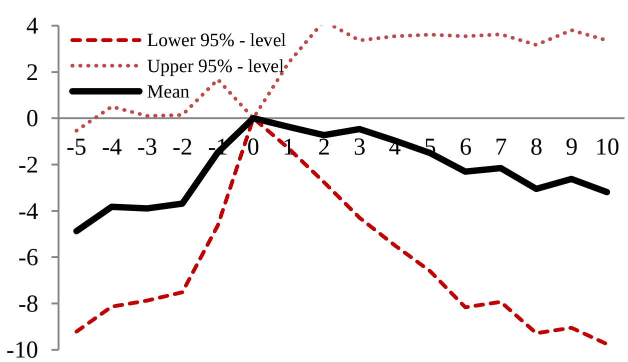
10-Year TIPS: All Auctions



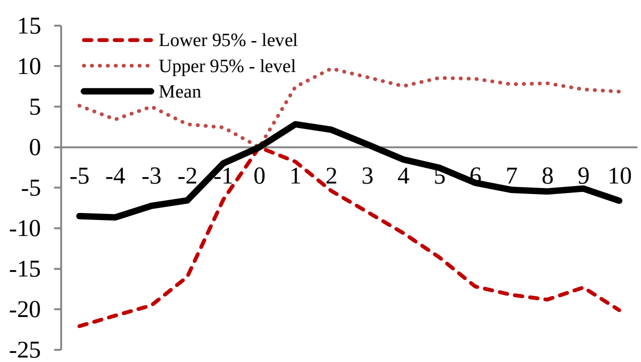
5-Year TIPS: All Auctions



10-Year TIPS: Matched Auctions



5-Year TIPS: Matched Auctions



TABLES

Table 5.0

Year by Year Skewness and Excess Kurtosis for daily returns of 5 year ZCIIS

The panel below displays the yearly skewness and excess kurtosis for the 5 year ZCIIS daily returns over the year from 2004-2011. Excess kurtosis is measured by subtracting 3 from the yearly sample kurtosis.

Panel: Skewness and Excess Kurtosis Year by Year for 5 year ZCIS

Variables	Skewness	Excess Kurtosis
2004	-0,048	0,526
2005	-0,068	0,749
2006	-0,215	1,105
2007	0,205	7,385
2008	2,002	17,564
2009	-0,237	6,408
2010	-0,052	0,936
2011	-0,241	2,438

Table 6.0

Dickey-Fuller Test Statistic for Stationarity

	No of lags used:			
Variable	5	7	10	12
Dickey-Fuller Test Statistics of ZCIIS rate				
5 year ZCIIS	-2.177	-2.057	-2,06	-2.147
10 year ZCIIS	-3.074 **	-2.833*	-2,624*	-2.479
20 year ZCIIS	-3.316**	-3.168**	-2,754*	-2.960 *
30 year ZCIIS	-2.898**	-2.218**	-1,86	-1.541

Table 7.0

Summary Statistics of Zero-Coupon Inflation-Indexed Swaps from July 2004 to November 2011

The table below outlines the general statistics for ZCIIS from the beginning of 2004 to the end of 2011. The yield represents the market quoted fixed rate measured as percentage. Kurtosis is measured by subtracting 3 from the sample kurtosis. AC(1) and AC(2) display the autocorrelation for 1 and 2 lags respectively.

Panel 3: Summary Statistics Implied Expected Inflation Yield (2004-2011)											
Variables	Mean	Standard Deviation	25th	Median	75th	Skewness	Kurtosis	Max	Min	AC(1)	AC(2)
Summary Statistics of Implied Expected Inflation Yield (percentage %)											
Yield (5-year)	2.30	0.56	1.89	2.45	2.71	-0.69	-0.10	3.34	0.10	0.97	0.96
Yield (10-year)	2.64	0.25	2.53	2.68	2.81	-0.91	0.98	3.16	1.41	0.96	0.94
Yield (20-year)	3.48	1.39	2.23	3.69	4.85	-0.15	-1.34	5.76	0.84	1.00	1.00
Yield (30-year)	4.87	0.78	4.36	5.07	5.46	-0.72	-0.07	6.31	2.42	1.00	1.00

Table 8.0

ZCIIS Cumulative Difference Around All TIPS Auctions: Event Window [-3:10]

This table reports the average cumulative difference of n-year (n=5,10,20,30) ZCIIS rates for entering in a contract 3 days before and 10 days after the auction, locking in the spread difference of the fixed rate. The sample period is from July 2004 to November 2011. All returns are expressed in basis points. T-statistics are based on robust standard errors and are reported in parentheses. ***, **, and * indicate significance levels of 1%, 5% and 10%, respectively.

ZCIIS Behavior: All TIPS Auction dates:EW				
Maturity	**Mean**	***t*-value**	**Lower CI**	**Upper CI**
5	5.51*	1,87	-0,40	11,40
10	7.16***	3,00	2,38	11,90
20	7.90***	2,81	2,28	13,50
30	5.67**	2,30	0,74	10,60
No. Obs.	60			

** p<0.10, ** p<0.05, *** p<0.01*

Imp. E(Inflation) behavior: All TIPS Auction dates:EW				
Maturity	**Mean**	***t*-value**	**Lower CI**	**Upper CI**
5	5.36*	1,78	-0,67	11,40
10	6.82***	2,75	1,85	11,80
20	8.28***	2,92	2,60	14,00
30	5.38**	2,11	0,28	10,50
No. Obs.	60			

** p<0.10, ** p<0.05, *** p<0.01*

Table 9.0

ZCIIS Abnormal Returns Around All TIPS Auctions

The first table displays the Mean and corresponding t-stat in parenthesis for the ZCIIS with maturities of 5-,10- and 30-years around all auction dates. Abnormal return is calculated as AR=Y(t) –Y(0) where Y(0) is the benchmark rate i.e. the rate prevailing at each auction date and Y(t) the rate at day t. The second table displays the Mean and corresponding t-stat in parenthesis for the implied expected inflation with maturities of 5-,10- and 30-years around all auction dates. All returns are expressed in basis points. T-statistics are based on robust standard errors and are reported in parentheses. ***, **, and * indicate significance levels of 1%, 5% and 10%, respectively.

ZCIIS Behavior around all TIPS Auction dates: Y(t)-Y(0)						
	5 year ZCIIS		10 year ZCIIS		30 year ZCIIS	
t	Mean	*t*-value	Mean	*t*-value	Mean	*t*-value
-5	3,37	(1,71)	2.92**	(2,25)	3.16**	(2,18)
-4	3,11	(1,94)	1,97	(1,64)	2.77**	(2,01)
-3	1,33	(0,92)	2.00**	(2,14)	1,70	(1,24)
-2	1,82	(1,53)	1,46	(1,63)	1,94	(1,68)
-1	1,43	(1,68)	0,50	(0,67)	1,10	(1,18)
1	1,37	(1,78)	1.77**	(2,27)	0,76	(1,04)
2	0,46	(0,47)	2.76**	(2,37)	0,31	(0,40)
3	1,58	(1,22)	2.80**	(2,32)	1,63	(1,30)
4	2,48	(1,88)	3.08***	(2,87)	2.62**	(2,40)
5	2,36	(1,53)	3.61***	(2,98)	2.63**	(2,03)
6	2,65	(1,31)	3.11**	(2,10)	1,96	(1,51)
7	3,22	(1,58)	3.34**	(2,01)	3,28	(1,97)
8	2,79	(1,41)	2,98	(1,70)	1,39	(0,75)
9	3,62	(1,51)	4.08**	(2,16)	3,43	(1,92)
10	4,18	(1,57)	5.16**	(2,55)	3.97**	(2,18)
No. Obs.	60		60		60	

** p<0.10, ** p<0.05, *** p<0.01*

Implied Expected Inflation Behavior around all TIPS Auction dates: Y(t)-Y(0)						
	5 year ZCIIS		10 year ZCIIS		30 year ZCIIS	
t	Mean	*t*-value	Mean	*t*-value	Mean	*t*-value
-5	3,54	(1,77)	3.08**	(2,20)	3.98***	(2,84)
-4	3.31**	(2,04)	2,31	(1,80)	3.49**	(2,49)
-3	1,56	(1,07)	2.26**	(2,24)	1,92	(1,24)
-2	1,84	(1,54)	1.59*	(1,67)	2,28	(1,78)
-1	1,44	(1,70)	0,62	(0,76)	1,31	(1,23)
1	1,49	(1,95)	2.00**	(2,43)	0,852	(0,98)
2	0,51	(0,52)	2.97**	(2,47)	0,148	(0,16)
3	1,69	(1,31)	2.90**	(2,36)	1,57	(1,08)
4	2,18	(1,66)	2.70**	(2,41)	1,95	(1,77)
5	2,33	(1,46)	3.07**	(2,43)	2,21	(1,73)
6	2,54	(1,19)	2,57	(1,62)	1,28	(1,05)
7	3,05	(1,45)	2,82	(1,61)	2,7	(1,62)
8	2,80	(1,38)	2,48	(1,39)	0,508	(0,27)
9	3,23	(1,30)	3.33*	(1,73)	2,9	(1,71)
10	3,80	(1,37)	4.56**	(2,16)	3,46	(1,94)
No. Obs.	60		60		60	

** p<0.10, ** p<0.05, *** p<0.01*

Table 10.0

ZCIIS Abnormal Returns Around Matched TIPS Auctions

The first table displays the mean and corresponding t-stat in parenthesis () for the ZCIIS with maturities of 5-,10- and 30-years around all auctions of matching maturity. For example is 5-year ZCIIS only calculated against the auction of TIPS with a matching maturity i.e. 5-year TIPS. Abnormal return is calculated as AR=Y(t) –Y(0) where Y(0) is the benchmark rate i.e. the rate prevailing at each auction date and Y(t) the rate at day t. The second table displays the mean and corresponding t-stat in parenthesis () for the implied expected inflation with maturities of 5-,10- and 30-years around all auctions of matching maturity. All returns are expressed in basis points. T-statistics are based on robust standard errors and are reported in parentheses. ***, **, and * indicate significance levels of 1%, 5% and 10%, respectively.

ZCIIS Behavior around each TIPS Auction dates: Y(t)-Y(0)

	5 year ZCIIS		10 year ZCIIS		30 year ZCIIS	
t	Mean	T-value	Mean	T-value	Mean	T-value
-5	8,23	(1,38)	2,90	(2,04)	-2,57	(-1,00)
-4	7,39	(1,53)	1,94	(1,39)	-2,36	(-1,05)
-3	2,45	(0,61)	2.74**	(2,65)	-2,97	(-1,21)
-2	0,74	(0,22)	2.57**	(2,33)	-1,53	(-0,99)
-1	2,63	(1,29)	1,70	(1,59)	-2,98	(-2,68)
1	2,60	(1,20)	2.77**	(2,53)	-0,89	(-0,40)
2	1,89	(0,74)	2,14	(1,36)	0,40	(0,16)
3	3,87	(1,02)	1,92	(1,23)	-0,78	(-0,24)
4	2,86	(0,86)	2.53**	(2,22)	3,19	(0,70)
5	2,34	(0,69)	2,30	(1,82)	4,04	(0,74)
6	4,66	(0,74)	1,11	(0,82)	2,29	(0,44)
7	6,25	(1,00)	1,01	(0,68)	1,98	(0,49)
8	6,25	(1,23)	1,35	(0,78)	1,96	(0,53)
9	8,33	(1,40)	0,86	(0,44)	5,56	(1,71)
10	7,68	(1,51)	1,98	(0,86)	7,55	(2,10)
No. Obs.	15		30		5	

** p<0.10, ** p<0.05, *** p<0.01*

Implied Expected Inflation Behavior around each TIPS Auction dates: Y(t)-Y(0)

	5 year ZCIIS		10 year ZCIIS		30 year ZCIIS	
t	Mean	t-value	Mean	*t*-value	Mean	*t*-value
-5	8,47	(1,38)	3.87**	(2,22)	-3,00	(-1.02)
-4	7,47	(1,51)	2,90	(1,79)	-3,20	(-1.21)
-3	2,53	(0,61)	3.55***	(2,84)	-3,80	(-1.34)
-2	0,67	(0,20)	3.13**	(2,53)	-2,00	(-1.22)
-1	2,53	(1,21)	2,03	(1,76)	3.80**	(-3.28)
1	2,53	(1,13)	3.03**	(2,62)	-1,20	(-0.53)
2	1,87	(0,70)	2,26	(1,40)	0,40	(0,15)
3	3,87	(0,99)	2,00	(1,26)	-1,40	(-0.43)
4	2,87	(0,85)	1,61	(1,17)	2,80	(0,58)
5	2,4	(0,71)	1,71	(1,19)	3,40	(0,60)
6	4,93	(0,77)	0,52	(0,28)	1,80	(0,35)
7	6,47	(0,99)	0,48	(0,27)	1,40	(0,34)
8	6,47	(1,24)	0,97	(0,55)	1,20	(0,31)
9	8,67	(1,41)	0,45	(0,22)	5,20	(1,62)
10	7,73	(1,50)	1,58	(0,63)	7,20	(1,97)
No. Obs.	15		30		5	

** p<0.10, ** p<0.05, *** p<0.01*

Table 11.0

Sharpe Ratio for 5-, 10-, 20- and 30-Year ZCIIS over all auction with varying holding period

This table displays the Sharpe Ratio for all maturities of ZCIIS in our sample. Abnormal return is calculated as AR=Y(t) –Y(0) where Y(0) is the benchmark rate i.e. the rate prevailing at each auction date and Y(t) the rate at day t. The holding period is stated within brackets and should read as [Start:End]. Starting date is the number of days before each auction one enters into a long position in the corresponding ZCIIS. The end date represents the number of days after the actual auction date were one liquidate the position. The gain is calculated over the market return of the return of the MSCI Linked Bond Total Return Index quoted in USD

Sharpe Ratio for All Maturities of ZCIIS

Sharpe Ratio Calculation for 5 Year ZCIIS

	Around All Auctions			Around All Auctions Post November 2008		
Holding Period	Gain	Std.dev	Sharpe	Gain	Std.dev	Sharpe
[-3:10]	19,02%	1,23	0,16	43,18%	1,81	0,24
[-3:5]	15,49%	1,10	0,14	35,33%	1,64	0,22
[-3:4]	10,78%	0,76	0,14	0,70%	1,12	0,01
[-3:3]	9,69%	0,72	0,13	21,59%	1,08	0,20

Sharpe Ratio Calculation for 10 Year ZCIIS

	Around All Auctions			Around All Auctions Post November 2008		
Holding Period	Gain	Std.dev	Sharpe	Gain	Std.dev	Sharpe
[-3:10]	1,28%	0,08	0,16	1,95%	0,10	0,20
[-3:5]	0,84%	0,05	0,18	1,10%	0,06	0,19
[-3:4]	0,71%	0,04	0,18	0,70%	0,06	0,12
[-3:3]	0,64%	0,05	0,14	0,93%	0,05	0,18

Sharpe Ratio Calculation for 20 Year ZCIIS

	Around All Auctions			Around All Auctions Post November 2008		
Holding Period	Gain	Std.dev	Sharpe	Gain	Std.dev	Sharpe
[-3:10]	0,75%	0,05	0,15	1,16%	0,06	0,20
[-3:5]	0,26%	0,04	0,07	0,30%	0,05	0,06
[-3:4]	0,64%	0,04	0,16	0,68%	0,05	0,13
[-3:3]	0,34%	0,03	0,10	0,48%	0,03	0,14

Sharpe Ratio Calculation for 30 Year ZCIIS

	Around All Auctions			Around All Auctions Post November 2008		
Holding Period	Gain	Std.dev	Sharpe	Gain	Std.dev	Sharpe
[-3:10]	0,62%	0,06	0,11	1,57%	0,07	0,23
[-3:5]	0,41%	0,04	0,10	0,39%	0,05	0,07
[-3:4]	0,40%	0,04	0,10	0,55%	0,05	0,12
[-3:3]	0,37%	0,04	0,09	0,71%	0,05	0,15

APPENDIX

EXAMPLE OF LIABILITY HEDGING USING TIPS AND ZCIIS

We assumes a liability with semiannual coupon payments of C and a principal of K, which both grow with CPI-U. Further assume that there in the market exists 1 Nominal and 1 TIPS note with the same face value F, coupon C and maturity $T - T_0$. We further assume that inflation grows in the function I(CPI-U). In this assumed and fortunate setting the floating inflation risk can easily be transformed into a fixed price similar to the fixed leg in a swap. In order to neutralize the floating leg of inflation an investor can then enter into strategy involving selling 1 nominal bond to the price P(Nom) and buying 1 TIPS bond with the price P(TIPS) at time 0. Thereby the cash flows during from time 0 to T is:

Time	0	τ	T
Original liability cash flow	n.a.	$-\left(C * F * \frac{CPI_{\tau}}{CPI_0}\right)$	$-\left(C * F * \frac{CPI_T}{CPI_0} + F * \frac{CPI_T}{CPI_0}\right)$
Shorts 1 Nominal Bond	$+P(Nom)$	$-(C * F)$	$-(C * F + F)$
Buys 1 TIPS Bond CF	$-P(Tips)$	$+\left(C * F * \frac{CPI_{\tau}}{CPI_0}\right)$	$+\left(C * F * \frac{CPI_T}{CPI_0} + F * \frac{CPI_T}{CPI_0}\right)$
Hedged Liability (A=	$= P(nom) - P(tips)$	$-(C * F)$	$-(C * F + F)$

We see that through this operation that we have transformed a floating interest rate risk into a fixed cost of P(Nom) – P(Tips). Instead of using this replicating strategy one could contact your local friendly investment bank to purchase ZCIIS with the same maturity and face values as the individual liabilities. One would agree to pay the fixed rate K in exchange for paying the floating rate CPI-U with a face value F. Using this strategy the cash flow from 0-T would have the following characteristics:

Time	0	τ	T
Liability cash flow	n.a.	$-\left(C * F * \frac{CPI_{\tau}}{CPI_0}\right)$	$-\left(C * F * \frac{CPI_T}{CPI_0} + F * \frac{CPI_T}{CPI_0}\right)$
Payoff ZCIIS(0,τ)	0	$-(C * F) * (1 + K)^{\tau} + \frac{CPI_{\tau}}{CPI_0} * (C * F)$	
Payoff ZCIIS(0,T)	0		$-(C * F) * (1 + K)^{T} + \frac{CPI_T}{CPI_0} * (C * F) - F * (1 + K)^{\tau} + F * \frac{CPI_T}{CPI}$
Hedged Liability (B)	0	$-(C * F) * (1 + K)^{\tau}$	$-(C * F) * (1 + K)^{T} + F * (1 + K)^{\tau}$

We observe that none of the hedged liabilities includes any unknown variable (P(Nom),P(TIPS) and K is marked to market).Therefore we see that in order for no arbitrage to be present the present value, PV, of the two hedging strategies must be equal:

$\mathrm{PV(A)} = \mathrm{PV(B)}$

Solving for PV(A) and PV(B) we see that in order for this to hold must:

$$\mathrm{P(Nom)} - \mathrm{P(TIPS)} \sim \mathrm{K} \rightarrow \mathrm{BEI} \sim \mathrm{K}$$

That the LHS and RHS are not strictly equal is due to the compounding of coupons. There exists a spread between the BEI and the Swap rate K due to the time value of money. We expect that this spread is stationary over time and decrease in Time to Maturity as the duration decreases. Using the above setting we have simulated the spread to be in the area of 20bp -50bp in the most common settings and maturities, which is consistent with the empirical evidence see graph below. We conclude that in order to hedge inflation linked liabilities using TIPS and ZCIIS yields approx. the same results to the approx. the same cost and therefore determine that they are next to perfect substitutes.

Figure Appendix 1.0

Spread between BEI and ZCIIS for 5 and 10 year maturities

This graph displays the difference between the break-even-inflation rate and the quoted market fix rate for ZCIIS. The daily difference is calculated as ZCIIS – BEI over the whole period. The vertical green line represents the geometrical average over the whole period for the instruments with a constant maturity of 5 year. The vertical red line represents the geometrical average over the whole period for the instruments with a constant maturity of 5 year.