WHY DOES THE TREASURY ISSUE TIPS?

THE TIPS–TREASURY BOND PUZZLE

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Abstract. We show that the price of a Treasury bond and an inflation-swapped TIPS issue exactly replicating the cash flows of the Treasury bond can differ by more than $20 per $100 notional. Treasury bonds are almost always overvalued relative to TIPS. Total TIPS–Treasury mispricing has exceeded $56 billion, representing nearly eight percent of the total amount of TIPS outstanding. TIPS–Treasury mispricing is strongly related to supply factors such as Treasury debt issuance and the availability of collateral in the financial markets, and is correlated with other types of fixed-income arbitrages, These results pose a major puzzle to classical asset pricing theory. In addition, they raise the issue of why the Treasury issues TIPS, since in so doing it both gives up a valuable fiscal hedging option and leaves large amounts of money on the table.

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1. INTRODUCTION

The Treasury bond and the Treasury inflation-protected securities (TIPS) markets are two of the largest and most-actively-traded fixed-income markets in the world. Despite this, we find that there are persistent arbitrage opportunities on a massive scale across these two markets. Furthermore, these arbitrages are almost invariable in one direction; Treasury bonds are consistently overpriced relative to TIPS. For example, we show that the price of a Treasury bond can exceed that of an inflation-swapped TIPS issue exactly matching the cash flows of the Treasury bond by more than $20 per $100 notional amount. To the best of our knowledge, the relative mispricing of TIPS and Treasury bonds represents the largest arbitrage ever documented in the financial economics literature. The TIPS–Treasury arbitrage poses a major puzzle to classical asset pricing theory.

The U.S. Treasury has two distinct technologies at its disposal for financing primary government deficits. It can issue either nominal debt or inflation-indexed debt of various maturities. For most of its history, the Treasury has relied exclusively on the first technology. More recently, however, the Treasury has relied increasingly on the second technology.[1] These technologies are very different. Nominal debt allows for state contingency in real returns by creating inflation. In response to an adverse fiscal shock, the government can exploit this state contingency to smooth taxes either through surprise inflation or the announcement of inflation at some point in the future before the current nominal debt matures. In contrast, indexed debt does not allow for this type of state contingency. Thus, by issuing indexed debt, the government clearly gives up a valuable fiscal hedging option.

These considerations imply that the Treasury has strong disincentives to issue TIPS. In particular, our results indicate that the Treasury could have saved up to $56 billion by buying back TIPS, entering into inflation swaps, and issuing Treasury bonds with the same maturity instead. Hence, from a public finance perspective, nominal debt unambiguously dominates indexed debt. Whenever the government issues indexed debt, it gives up a valuable option and leaves money on the table at the same time. On average, the U.S. government has to levy $2.92 more in taxes, in present discounted value, to repay $100 of debt issued if the debt is indexed rather than nominal. This leaves us with the perplexing question: Why does the Treasury issue TIPS?

Furthermore, our findings of persistent arbitrage in these markets also imply that the Treasury–TIPS price differentials cannot be used to back out the mar-

[1] On January 29, 1997, the Treasury auctioned $7 billion of 10-year TIPS. Prior to that auction, all U.S. debt was nominal debt.

ket's inflation expectations, a common practice. In fact, the implied measure is biased downwards and, moreover, the bias worsens in times of increased volatility in financial markets.

In this paper, we proceed by first describing the TIPS–Treasury arbitrage strategy. The intuition behind this simple strategy is that the inflation-linked cash flows from a TIPS issue can be converted into fixed cash flows using inflation swaps. The resulting cash flows can be structured to match exactly the cash flows from a Treasury bond with the same maturity date as the TIPS issue. Thus, price differences between the inflation-swapped TIPS issue and the Treasury bond represent straightforward arbitrage opportunities. The data set includes daily prices for 29 matched-maturity pairs of TIPS issues and Treasury bonds for the 64-month period from July 2004 to November 2009.

We show that there is persistent arbitrage across all 29 pairs of TIPS and Treasury bonds. For individual pairs, the mispricing often exceeds $10 to $20.[2] Translated into yields, the average size of the arbitrage is 54.5 basis points, but can exceed 200 basis points for some pairs. The average size of this mispricing is orders of magnitude larger than the transaction costs of executing the arbitrage strategy. We also consider an extensive list of alternative factors that might mitigate the ability of an arbitrageur to profit from this strategy. In particular, we consider the potential impact of transaction costs, differential taxation, credit risk, institutional and foreign ownership of Treasury bonds and TIPS, collateralization, the ability to short Treasury bonds, market liquidity, and other factors. None of these factors are able to provide a fully satisfactory explanation for the existence of these arbitrage opportunities.

While the TIPS–Treasury arbitrage is important in its own right, there are deeper reasons why the study of significant arbitrages in the market may provide key asset-pricing insights. In particular, the value of an arbitrage strategy is unambiguously zero in any classical asset-pricing model. This means that we can study arbitrages without having to invoke a specific asset-pricing model first. Thus, by studying arbitrages, we can completely filter out the "noise" of asset-pricing models and directly identify forces driving prices in security markets which may lie outside of classical asset-pricing theory.

To explore the forces that might be driving the arbitrage, we regress changes in TIPS–Treasury mispricing on variables proxying for changes in systemic risk, credit risk, investor sentiment, the supply of Treasury debt, market liquidity, and the availability of Treasury collateral in the financing markets. The results clearly

[2]For simplicity, all bond prices and dollar mispricing values will be expressed in terms of dollars per $100 notional or par amount throughout the remainder of the paper.

indicate that the size of the arbitrage is strongly influenced by supply factors. In particular, the size of the arbitrage narrows significantly when the Treasury issues either Treasury bonds or TIPS. Furthermore, the size of the arbitrage is strongly positively related to the amount of repo failures in the primary dealer market. Since repo failures are a result of the inability of investors to provide or deliver Treasury bonds, they reflect disruptions in the supply of Treasury bonds in the market. There is also some anecdotal evidence that the Federal Reserve's program to purchase up to $300 billion of longer-maturity Treasury bonds via a series of competitive auctions beginning in April 2009 may have helped to reduce the size of the arbitrage.

Recent theory such as Duffie (2010), Ashcraft, Gârleanu, and Pedersen (2010), Brunnermeier and Pedersen (2009), and others stresses the role that frictions such as slow-moving capital or funding constraints may play in propagating mispricing in financial markets. An important implication of this literature is that these types of frictions may induce correlation across various types of arbitrages. We explore this by regressing changes in TIPS–Treasury mispricing on changes in the corporate bond/CDS arbitrage described by Duffie and on the CDX index/component arbitrage. Although these arbitrages occur in very different markets, we find that there is strong commonality across these arbitrages. Furthermore, we examine whether changes in mispricing are related to the returns on hedge funds that focus on different types of arbitrage strategies. Again, we find evidence of significant correlation. These results provide strong support for the implications of these friction-based theories.

This paper contributes to the literature on the pricing of inflation-linked bonds. Other important papers on real bonds include Roll (1996, 2004), Barr and Campbell (1997), Evans (2003), Seppälä (2004), Bardong and Lehnert (2004), Buraschi and Jiltsov (2005), Campbell, Shiller, and Viceira (2009), Adrian and Wu (2009), Gürkaynak, Sack, and Wright (2010), and many others. This paper differs from the previous literature by being the first to formally study the no-arbitrage relation between TIPS and Treasury bonds and explore the determinants of the mispricing.

Our paper also contributes to the emerging literature on government finance by questioning the wisdom of issuing TIPS. In earlier work on government finance, Campbell (1995) argues that a cost-minimizing government should respond to a steeply sloped nominal yield curve by shortening the maturity structure since high yield spreads tend to predict high expected bond returns in the future. In related work, Barro (1997) asserts that governments can reduce their risk exposure and better smooth taxes by shortening the maturity structure when the inflation process becomes more volatile and persistent. However, Lustig, Sleet and Yeltekin (2008) argue for the almost exclusive use of long-term nominal debt, because such debt mitigates the distortions associated with hedging fiscal shocks by allowing the government to allocate them efficiently across multiple states and periods.

The remainder of this paper is organized as follows. Section 2 provides a brief introduction to the TIPS and inflation swap markets and describes the TIPS–Treasury arbitrage strategy. Section 3 describes the data. Section 4 examines the size of the TIPS–Treasury mispricing. Section 5 considers additional factors that might drive a wedge between the pricing of TIPS and Treasury bonds. Section 6 explores the determinants of TIPS–Treasury mispricing. Section 7 examines the relation between TIPS–Treasury mispricing and other types of arbitrages and fixed-income arbitrage hedge fund returns. Section 8 discusses the TIPS issuance puzzle. Section 9 summarizes the results and presents concluding remarks.

2. TIPS–TREASURY ARBITRAGE

In this section, we provide brief introductions to the TIPS and inflation swap markets. We then describe the arbitrage strategy that links the theoretical prices of Treasury bonds, TIPS, and inflation swaps.

2.1 The TIPS Market

TIPS are direct obligations of the U.S. Treasury and are similar in most respects to Treasury bonds.[3] The key difference is that the principal amount of a TIPS issue is adjusted over time to reflect changes in the CPI. Since the fixed coupon rate for the TIPS issue is applied to its principal amount, the actual semiannual coupon received varies over time as the principal amount changes in response to the realized inflation or deflation rate. Similarly, the final principal amount paid to the bondholder equals the maximum of the original principal amount or the inflation-adjusted principal amount. Thus, TIPS investors' principal is protected against deflation (although the same is not true for coupon payments).

The principal amount of a TIPS issue is adjusted daily based on the Consumer Price Index for All Urban Consumers, known as CPI-U. Let I_t denote the inflation adjustment for a TIPS issue as of date t. The inflation adjustment is computed as the ratio of the reference CPI at the valuation date t divided by the reference CPI at the issuance date which we designate as time zero. The reference CPI for a particular date during a month is linearly interpolated from the CPI reference index for the beginning of that month and the CPI reference index for the beginning of the subsequent month. The CPI reference index for the first day of any calendar month is the CPI-U index for third preceding calendar month. Thus, the reference CPI for April 1 would be the CPI-U index for the month of January, which is reported by

[3]For expositional convenience, we will generally refer to all nominal debt obligations of the Treasury (including Treasury bills and Treasury notes) simply as Treasury bonds throughout the paper.

the Bureau of Labor Statistics during February. The details of how the principal amount of a TIPS issue is adjusted for inflation are described on the U.S. Treasury's website.[4]

The current total principal amount of all TIPS outstanding is in excess of $550 billion. The Treasury first began auctioning TIPS in January 1997. Since then, 34 separate TIPS issues have been auctioned. Currently, the Treasury issues 5-year, 10-year, and 30-year TIPS on a regular cycle.

2.2 The Inflation Swap Market

Beginning with the first TIPS auction in 1997, market participants began making markets in inflation swaps as a way of hedging inflation risk. As the TIPS market has grown, the inflation swaps market has become very liquid and actively traded, particularly in the U.S. and the U.K.[5] The notional size of the inflation swap market is estimated by Kerkhof (2005) to be about one to two percent of the size of the interest swap market. Based on estimates provided by the Bank for International Settlements, this would imply a size of the inflation swap market on the order of $4 trillion. Conversations with inflation swap traders confirm that these instruments are fairly liquid with transaction costs on the order of five basis points.

In this paper, we focus on the most-basic and widely-used type of inflation swap which is designated a zero-coupon swap. This swap is executed between two counterparties at time zero and has only one cash flow which occurs at the maturity date of the swap. For example, imagine that at time zero, the five-year zero-coupon inflation swap rate is 200 basis points. As is standard with swaps, there are no cash flows at time zero when the swap is executed. At the maturity date of the swap in five years, the counterparties to the inflation swap exchange a cash flow of $(1 + .0200)^5 - I_t$, where I_t is again the inflation adjustment factor. Thus, if the realized inflation rate was 1.50 percent per year over the five year horizon of the swap, $I_t = 1.015^5 = 1.077284$. In this case, the net cash flow from the swap would be $(1+.0200)^5 - 1.077284 = \$0.026797$ per dollar notional of the swap. The timing and index lag construction of the index I_t used in an inflation swap are chosen to match precisely the definitions applied to TIPS issues.

2.3 The Arbitrage Strategy

The idea behind the TIPS–Treasury arbitrage strategy is very simple. Imagine that an investor buys a TIPS issue at par which has a coupon rate of s per semiannual

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[4]See http://www.treasurydirect.gov/instit/statreg/auctreg/auctreg_gsr31cfr356.pdf.

[5]Kerkhof (2005) provides an excellent introduction to the inflation swap market. Also see Jarrow and Yildirim (2003) and Hinnerich (2008).

period. Because of the inflation adjustment, the coupon paid at time t will be sI_t. Now imagine that the investor executes a zero-coupon inflation swap with a maturity date and notional amount matching that of coupon payment for the TIPS issue. At date t, the inflation swap pays a cash flow of $s(1+f)^t - sI_t$, where f is the fixed inflation swap rate. The sum of the two cash flows is now just $sI_t + s(1+f)^t - sI_t = s(1+f)^t$ which is a constant. Similarly, by executing zero-coupon inflation swaps with maturities and notional amounts matching the indexed cash flows from the TIPS issue, the investor can convert all of these indexed cash flows into fixed cash flows.

To make the mechanics of this arbitrage strategy more clear, Table 1 shows the various components of the strategy and their associated cash flows. The first part of the table shows the cash flows associated with a Treasury bond purchased at price P and with a coupon rate of c. The Treasury bond pays a semiannual coupon of c per period, and then makes a principal payment of 100 at maturity date T.

The second part of the Table shows how the cash flows from the Treasury bond can be replicated exactly from a TIPS position. First, the arbitrageur purchases a TIPS issue with a coupon rate of s and the same maturity date as the Treasury bond for a price of V. The TIPS bond pays coupons of sI_t each period, and then makes a principal payment of $100I_T$ at maturity. The arbitrageur then enters into an inflation swap for each coupon payment date with a notional amount of s (or $s + 100$ for the final principal payment date). This converts all of the indexed cash flows from the TIPS into fixed cash flows. To match exactly the cash flows from the Treasury bond, however, the arbitrageur also needs to go long or short a small amount of Treasury STRIPS for each coupon payment date. As shown at the bottom of the second part of the Table, the net result is a portfolio that exactly replicates the cash flows from the Treasury bond in the first part of the table.

To provide a specific example, Table 2 shows the actual cash flows that would result from applying the arbitrage strategy on December 30, 2008 to replicate the 7.625 percent coupon Treasury bond maturing on February 15, 2025. As shown, the price of the Treasury bond is \$169.479. To replicate the Treasury bond's cash flows, the arbitrageur buys a 2.375 percent coupon TIPS issue with the same maturity date for a price of \$101.225. Since there are 33 semiannual coupon payment dates, 33 inflation swaps are executed with the indicated notional amounts. Finally, positions in Treasury STRIPS of varying small notional amounts are also taken by the arbitrageur. The net cash flows from the replicating strategy exactly match those from the Treasury bond, but at a cost of only \$146.379. Thus, the cash flows from the Treasury bond can be replicated at a cost that is \$23.10 less than that of the Treasury bond. The transaction costs associated with the creation of the replicating strategy would likely only be on the order of \$0.40. Even with very liberal assumptions about the size of bid-ask spreads for the various components of the strategy. total transaction costs for implementing the arbitrage would not exceed \$1.00 to \$1.50. Thus, transaction costs cannot begin to account for arbitrages of this magnitude.

3. THE DATA

The data for the study consist of daily closing prices for U.S. Treasury bonds, TIPS, STRIPS, and inflation swaps for the period from July 23, 2004 to November 19, 2009. All data are obtained from the Bloomberg system. The TIPS and Treasury pairs in the dataset have maturities ranging from 2007 to 2032. Daily closing prices for TIPS and Treasury bonds are adjusted for accrued interest following standard market conventions.

Inflation swaps are quoted in terms of the constant rate on the contract's fixed leg. The traded maturities are 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 15, 20, 25, and 30 years. To obtain swap rates for intermediate maturities, we use cubic spline interpolation. For maturities that include fractional years (e.g. 2.3 years), seasonal patterns in inflation must be taken into account. To do this, we first estimate seasonal weightings for the CPI-U for each month of the year by regressing the CPI-U index values for January 1980 to October 2009 period on monthly indicator variables. The estimated weights are normalized to ensure than there is no seasonal effect for full-year swaps and then used to adjust the interpolated inflation swap curve (seasonal adjustments are not used for maturities less than one year). The details about the algorithm used to compute synthetic Treasury bond prices are provided in the Appendix.

For our analysis, we match TIPS and Treasury bonds based on their respective maturities. We define maturity mismatch as the number of days between the maturity of a TIPS issue and that of a Treasury bond with the closest maturity to that of the TIPS issue. We only include pairs of TIPS and Treasury bonds in the sample if the maturity mismatch is less than or equal to 31 days. This leads to a total of 29 TIPS–Treasury bond pairs.[6] In particular, there are 7 exact matches, 9 mismatches of 15 days, and 13 mismatches of 31 days. The 31-day mismatches occur only for maturities of February 2015 or later. Thus, these mismatches represent a very small percentage mismatch in the maturities of the TIPS and Treasury bonds. To adjust for the maturity mismatches, we calculate the yield to maturity on the synthetic fixed rate bond formed from the TIPS issue and the inflation swaps, and then apply this yield to calculate the price of a synthetic bond that would exactly match the

[6]Specifically, the Treasury has issued 34 TIPS bonds to date. One of these issues had matured by the beginning of the sample period. Four issues had maturity mismatches in excess of 31 days.

maturity of the Treasury bond in the pair.

4. HOW LARGE IS THE ARBITRAGE?

Table 3 provides summary statistics for the arbitrages for each of the 29 pairs of TIPS and Treasury bonds in the sample. The first two columns show the maturity date and coupon rate for the TIPS issue in each pair. The next two columns show the maturity date and coupon rate for the Treasury bond in each pair. The column labeled Days denotes the maturity mismatch between the two bonds. The central panel of the table reports summary statistics for the arbitrages. The rightmost panel of the table reports summary statistics for the arbitrages measured as the basis point difference between the yield of the synthetic Treasury bond and the actual Treasury bond for each pair.

The arbitrages reported in Table 3 are stunning in magnitude and likely the largest ever documented in any fixed income market.[7] For example, many of the arbitrages for the TIPS–Treasury pairs with maturities of 2015 or later reach values in excess of $10. In fact, the arbitrage for the TIPS–Treasury pair maturing in 2025 reaches a level in excess of $23. What makes these findings even more dramatic is that the TIPS and Treasury markets are two of the largest and most-liquid financial markets in the world. In almost every case, the value of the Treasury bond is larger than its synthetic equivalent constructed from the matching TIPS issue and the inflation swap. Thus, Treasury bonds appear to be almost uniformly "rich" relative to the portfolios of Treasury securities that replicate their cash flows.

The average sizes of the arbitrages shown in Table 3 are equally astonishing. For example, the average size of the arbitrage between the TIPS and Treasury bonds maturing in January 2029 and February 2029, respectively, is $6.84. Similarly, the average basis-point size of the arbitrage between the TIPS and Treasury bonds maturing in January 2014 and December 2013, respectively, is 103.66 basis points.

To illustrate the average size of the TIPS–Treasury mispricing, we compute the TIPS-notional-weighted mispricing for each date during the sample period, where the average is taken over all TIPS–Treasury pairs in the sample on that date. Figure 1 plots the weighted-average dollar mispricing for the TIPS–Treasury pairs. Figure 2 plots the corresponding weighted-average basis-point arbitrages for these pairs. As

[7] Examples of fixed-income arbitrages reported in the literature include Cornell and Shapiro (1990), Amihud and Mendelson (1991), Boudoukh and Whitelaw (1991), Longstaff (1992, 2004), Daves and Ehrhard (1993), Kamara (1994), Jordan, Jorgensen, and Kuipers (2000), Grinblatt and Longstaff (2000), Longstaff, Santa Clara, and Schwartz (2001), Yu (2006), Duarte, Longstaff, and Yu (2007) and many others.

can be seen, the mispricing is evident throughout the entire sample period, not just during the crisis period of 2008–2009. In particular, while the amount of mispricing peaked at \$9.60 or 175 basis points around the time of the Lehman bankruptcy in the Fall of 2008, there were clearly earlier periods when the average mispricing was in excess of \$3 or about 60 basis points. In addition, Figures 1 and 2 show that there is significant time series variation in TIPS–Treasury mispricing throughout the sample period. The overall average size of the arbitrages is \$2.92. The overall average basis-point size of the arbitrages is 54.5 basis points.

As discussed earlier, the total notional amount of TIPS outstanding has increased significantly over time. In particular, the total amount of TIPS outstanding at the beginning of the sample period in July 2004 was \$222.60 billion, but increased to \$567.51 billion by the end of the sample period in November 2009. At the end of the sample period, TIPS accounted for 7.91 percent of the total notional value of marketable U.S. Treasury debt.

From the Treasury's perspective, TIPS–Treasury mispricing represents a potential opportunity for reducing Treasury debt. For example, if Treasury bonds have a higher market valuation than the equivalent inflation-swapped TIPS issues, then the Treasury could potentially generate significant savings by buying back all the outstanding TIPS issues, issuing Treasury bonds with the same maturity, and hedging out the inflation risk in the inflation swap market. The evidence in Han, Longstaff, and Merrill (2007) suggests that the Treasury is able to buy back large quantities of its debt with only minor market impact costs. To evaluate the potential savings from this type of a debt exchange, we multiply the TIPS–Treasury mispricing by the notional amount of TIPS outstanding and total this value over all pairs of bonds available during the sample period (include the four with maturity mismatches in excess of 31 days).

The total savings from the debt exchange are graphed in Figure 3. As shown, the total savings increases secularly over the sample because of the increase in the issuance of TIPS. Moreover, it spikes towards the end of 2008 in the wake of the global financial crisis and reaches a peak of \$56.4 billion on December 30, 2008. By the end of the sample period, the total savings is \$11.2 billion.

Another perspective on this issue is given by computing the cost to the Treasury of issuing TIPS rather than Treasury bonds. This is perhaps a more realistic measure of the costs incurred, because the Treasury could clearly have simply issued Treasury bonds rather than TIPS. Figure 4 plots the total cost to the Treasury of the 27 TIPS issuances during the sample period. The total costs of new issuances during the sample period is \$9.6 billion.[8]

[8]This number does not include the 0.875 percent TIPS issue with maturity April 15, 2010 issued on October 29, 2004 because there is not a good match with a Treasury

On January 30, 2009, the Treasury issued $14.01 billion of 20-year TIPS at a cost of $12.00 per $100 notional. This issuance alone cost the Treasury $1.68 billion. The Treasury has so far successfully auctioned $38.07 billion TIPS in 2010, and is expected to auction $80 billion total during 2010, up from $58 billion in 2009. Clearly, issuing these TIPS during periods characterized by increased volatility in the financial markets and flights to nominal Treasury bonds implies that large new TIPS issuance can be very costly from the taxpayers' vantage point.

5. TIPS AND TREASURY BONDS

In the previous sections, we have shown that a simple no-arbitrage argument imposes a strong restriction on the relative prices of Treasury bonds and TIPS and that this no-arbitrage restriction is frequently violated in the market. Before exploring the determinants of the mispricing, however, is it useful to first consider whether there are any additional institutional or economic factors that might drive a wedge between the market prices of Treasury bonds and TIPS. In this section, we consider a list of possibilities and briefly evaluate their potential impact on the analysis. A number of these factors will be addressed in the subsequent section exploring the determinants of TIPS–Treasury mispricing.

5.1 Tax Differences

The Federal and State income taxation of Treasury bonds is identical to that of TIPS in all but one small aspect. Specifically, since the notional amount of TIPS accretes over time with realized inflation, taxable investors must treat this "phantom income" as if they were interest income for Federal tax purposes. In contrast, taxable investors holding Treasury bonds only include coupons as interest income (abstracting from original issue discount (OID) and premium amortization issues). Interest income from both Treasury bonds and TIPS (including any accreted notional amounts) is exempt from State income taxation.

Although we do not have specific information about the ownership of TIPS, discussions with market participants suggest that a large portion of outstanding TIPS issues are held either directly or indirectly by tax-sheltered entities such as pension plans and retirement funds. Thus, the phantom income provision is likely to be somewhat irrelevant for many of these investors. This view is consistent with a survey by the Bond Market Association in which 79 percent of respondents indicated that the current tax status of TIPS is not a deterrent to buying TIPS, some indicating that this was because of the tax-free status of their funds.[9] Finally,

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bond for the first part of the sample period.

[9] See http://archives1.sifma.org/research/tips_survey.pdf.

it is important to observe that if the taxation of phantom income were to affect the valuation of TIPS, it should do so uniformly across all issues since the accretion rate is the same for all TIPS.

5.2 Credit Risk

In recent years, it has become clear that the market attaches some positive probability to the event that the U.S. Treasury defaults on its debt. For example, Euro-denominated CDS contracts on the U.S. Treasury traded at spreads as high as 100 basis points during early 2009. There is an extensive literature on sovereign default risk including Duffie, Pederson, and Singleton (2003), Pan and Singleton (2008), and Longstaff, Pan, Pedersen, and Singleton (2010), and many others. A key point often made in this literature is that default risk for foreign-currency-denominated sovereign debt may differ from that for local-currency-denominated debt.

This foreign vs. local distinction is relevant for Treasury bonds and TIPS since one can imagine scenarios in which the U.S. might be able to honor its nominal debt by simply “printing more money,” but then not be able to pay off its inflation-linked debt. In essence, inflation-linked TIPS can be viewed as equivalent to foreign-currency-denominated debt from a sovereign default-risk perspective. If the market views the default risk of Treasury bonds as being lower than that of TIPS, then TIPS might trade at prices lower than those implied by the no-arbitrage model.

5.3 Bid-Ask Spreads

Another possible difference between Treasury bonds and TIPS might be in the costs of trading. In reality, however, the costs of trading Treasury bonds and TIPS are both very small. Conversations with Treasury bond and TIPS traders indicate that on average, a large financial institution would typically face a bid-ask spread for Treasury bonds on the order of a quarter of a basis point in yield. In terms of price, this would translate into a two or three cent bid-ask spread for a ten-year Treasury note. The same financial institution would generally face a bid-ask spread for a TIPS issue of about one basis point in yield during much of the study period. Bid-ask spreads for TIPS, however, roughly doubled with the onset of the financial crisis in 2008 and 2009 and are now about two basis points in yield. This would translate into roughly a 15 cent bid-ask spread for a 10-year TIPS issue. Note also that the bid-ask spreads for Treasury STRIPS would be on the same order of magnitude as that of TIPS. Finally, the bid-ask spread on inflation swaps is on the order of five basis points. Taken together, these values imply that TIPS–Treasury mispricing greater than say, eight basis points, cannot be explained in terms of transaction costs; the transaction costs are very small relative to the typical size of the pricing differences between Treasury bonds and TIPS.

5.4 The Deflation Floor

As discussed earlier, the principal amount of a TIPS issue is protected against deflation since the principal amount received by a TIPS holder at maturity cannot be less than par. Thus, there is an embedded option or deflation floor incorporated into the TIPS issues. Because of this, the value of a TIPS issue may be somewhat higher than it would be if there was no protection against deflation.

The analysis in the previous sections abstracts from the value of the deflation option. It is clear, however, that if we were to adjust observed TIPS prices by subtracting out the value of the deflation option, then the estimated TIPS–Treasury mispricing would be even larger than reported. Thus, the deflation floor in TIPS prices goes in the wrong direction to explain TIPS–Treasury mispricing.

5.5 Repo Financing

A difference in an investor's ability to obtain repo financing for TIPS relative to that of Treasury bonds might induce pricing differences between the two types of Treasury debt. Discussions with market participants, however, indicate that both types of debt are treated similarly by repo dealers. In particular, both Treasury bonds and TIPS can be financed at government repo rates with similar levels of haircuts. Currently, a typical haircut applied to Treasury bonds or TIPS issues by large institutional participants in the repo market would be on the order of two to three percent. There is no material difference between the two types of debt in terms of an investor's ability to obtain repo financing.

5.6 Collateral Value

Since the principal and interest from both Treasury bonds and TIPS is fully guaranteed by the U.S. Treasury, both types of debt are acceptable collateral for almost all forms of public, private, and banking obligations. To provide some examples, TIPS are equally acceptable as collateral for the Treasury Tax and Loan Program and the Treasury Term Investment Option (see 31 CFR Parts 202 and 203), as acceptable collateral for bonds secured by government obligations in lieu of bonds with sureties (see 31 CFR Part 225), and as acceptable collateral for uninsured deposits (see 12 CFR 550.320). Similarly, Treasury bonds and TIPS are equally acceptable as collateral for virtually all State and local government purposes.

5.7 Eligibility for the Treasury STRIPS Program

Both Treasury bonds and TIPS are eligible for stripping under the Treasury's STRIPS program. The key difference is that stripped coupon from different TIPS issues is not fungible since each issue has its own CPI reference level. The U.S Treasury's Statement of the Public Debt reports that on December 31, 2009, 21.22 percent of the notional amount of all Treasury bonds, 4.99 percent of the notional amount of all Treasury notes, and 0.03 percent of the notional amount of all TIPS were held in stripped form.

5.8 Futures Contracts

Futures contracts on 2-year, 3-year, 5-year, 10-year, and 30-year Treasury notes and bonds are traded at the Chicago Board of Trade. Each of these contracts specifies a list of Treasury notes and bonds that are deliverable in settlement of futures positions. In contrast, futures contracts on TIPS are not currently traded on any futures exchange. This distinction likely has little impact on the relative pricing of most Treasury bonds and TIPS. This is because forward purchases or sales of both Treasury bonds and TIPS can be readily executed by institutional participants in the over-the-counter market. The key exception might be the case of a cheapest-to-deliver bond at or near the expiration of a futures contract. Market participants, however, indicate that any cheapest-to-deliver effect on Treasury bond prices would typically be very small in magnitude since the Treasury bond/futures basis is actively traded and arbitraged by many financial institutions.

5.9 Foreign Ownership

We attempted to obtain data on whether Treasury bonds and TIPS differ in terms of the foreign ownership of these securities. Unfortunately, only aggregate foreign ownership data for Treasury bonds and TIPS are available. As of November 2009, the largest foreign holders of U.S. Treasury bonds and TIPS are Mainland China and Japan, with holdings of $789.6 billion and $757.3 billion, respectively. We note, however, that an August 2008 report by the Office of Debt Management of the U.S. Treasury Department provides a graph indicating that during the 2000-2008 period, roughly 60 percent of TIPS were auctioned to dealers and brokers, 30 percent to investment firms, and 10 percent to foreign entities. Similarly, Gongloff (2010) reports that foreign demand at TIPS auctions averages about 39 percent.

5.10 Institutional Ownership

To explore whether there are differences in the pattern of institutional ownership between Treasury bonds and TIPS, we note that some data on institutional ownership is available via SEC Form 13F filings. In particular, Section 13(f) of the Securities Exchange Act of 1934 requires that institutional investment managers using the U.S mail (or any other means or instrumentality of interstate commerce) in the course of their business and exercising investment discretion over $100 million or more in Section 13(f) securities must file Form 13F. In making these filings, many of these institutional investors provide information about their holdings of Treasury and TIPS bonds.

The information about institutional holdings of Treasury bonds and TIPS included in these Form 13F filings is compiled by Bloomberg and is summarized in their system for each bond or TIPS issue. We collected data on the TIPS issues in the sample from the Bloomberg system and then collected data for a sample of

Treasury bonds with maturities closely matching those of the TIPS issues. We then compared the percentages of the notional amount held by the institutions filing Form 13F. In doing this, however, it is important to provide the caveat that the coverage of Treasury bonds and TIPS issues provided by these Form 13F filings and tabulated by the Bloomberg system may not necessarily be comprehensive.

On average, 31.58 percent of the notional amount of the TIPS bonds in the sample are reported on Form 13F. The corresponding value for a set of maturity-matched Treasury bonds is 25.02 percent. Thus, the total percentage amounts reported are similar. A more detailed analysis, however, indicates that there are some intriguing differences in the institutional ownership patterns. In particular, investment firms (mutual funds, investment advisors, etc.) hold 20.69 percent of the TIPS, but only 4.71 percent of the matching Treasury bonds. In contrast, the Federal Reserve Bank of New York holds 8.41 percent of the TIPS, but 17.35 percent of the matching Treasury bonds. Thus, while the total reported institutional ownership of TIPS and Treasury bonds is similar, the data indicate that investment funds hold a much larger fraction of the TIPS than the Federal Reserve Bank of New York, while the reverse is true for Treasury bonds. Insurance companies hold 2.48 percent of the TIPS and 2.96 percent of Treasury bonds.

5.11 Bond Dealers and Market Microstructure

We also investigated whether there are differences between Treasury bonds and TIPS in the number and types of institutions functioning as bond dealers. The Federal Reserve Bank of New York maintains a list of primary government securities dealers. This list currently includes BNP Paribas, Banc of America, Barclay's Capital, Cantor Fitzgerald, Citigroup, Credit Suisse, Daiwa, Deutsche Bank, Goldman Sachs, HSBC, Jefferies, J.P. Morgan, Mizuho, Morgan Stanley, Nomura, RBC, RBS, and UBS.

The Federal Reserve Bank of New York also lists the standards expected of primary dealers. For example, primary dealers are expected to meet a $150 million minimum net capital requirement. Furthermore, primary dealers are expected to participate consistently as a counterparty to the New York Fed in its execution of open market operations. Primary dealers are also required to participate in all auctions of U.S. Government debt and to make reasonable markets in these securities. These rules make clear that there is no difference between Treasury bonds and TIPS in how these primary dealers are expected to conduct their operations. This is also confirmed by discussions with Treasury bond and TIPS traders who indicate that there is little difference in how bond dealers make markets in the two types of securities. The OTC market microstructure is very similar across the Treasury bond and TIPS markets.

5.12 Supply Considerations

One clear distinction between Treasury bonds and TIPS issues is in terms of the supply of these securities to the financial markets. To provide some background on the relative size of the TIPS market to the total Treasury bond market, we refer to Table FD-2 of the March 2010 Federal Reserve Bulletin. The ratio of TIPS notional debt outstanding to the total amount of Treasury debt held by the public was 6.67 percent at the end of 2005, 8.17 percent at the end of 2006, 9.05 percent at the end of 2007, 9.02 percent at the end of 2008, and 7.30 percent at the end of 2009. Thus, the notional amount of TIPS was less that ten percent of the total amount of Treasury debt held by the public during recent years. The ratio increased significantly during the 2005–2007 period, but has declined during the recent financial crisis as total Treasury debt issuance has accelerated.

5.13 TIPS Liquidity

As one measure of the relative liquidity of TIPS and Treasury bonds, we can examine the average trading volume of the two types of securities by primary dealers. This information is tabulated and reported online by the Federal Reserve Bank of New York. Focusing on 2009, the total average daily trading volume in Treasury bonds with maturities of three years or more by primary dealers was about $207 billion. In contrast, the same measure for TIPS bonds was roughly $5 billion. Recall, however, that TIPS bonds represent less that ten percent of the total amount of Treasury debt held by the public. Thus, while TIPS may not be as intensively traded as Treasury bonds, these results suggest that the average daily trading volume for TIPS is still very substantial.

We also interviewed Treasury bond and TIPS traders who confirmed this assessment of the relative liquidity of the two markets. In particular, one trader told us that there are roughly 15 dealers who were competitive in providing quotes and would be able to quickly execute purchases and sales of Treasury bonds. In contrast, the same trader indicated that there were only about 5 dealers who would be able to provide the same level of liquidity for TIPS. Despite this, however, the trader felt that TIPS were liquid and that trades could be executed rapidly.

5.14 Costs of Shorting Treasury Bonds

To short a Treasury bond, an investor must first borrow the bond through a reverse repo arrangement. In return, the investor allows the owner of the bond to borrow funds at some market determined rate. Typically, this rate is slightly below the market rate and the difference represents the borrowing cost of the bond. Discussions with traders indicates that it was always possible to short Treasury bonds throughout the sample period.

In extreme situations, however, this spread could widen. For example, during the depths of the financial crisis in the Fall of 2008, an arbitrageur wishing to short a bond might have needed to allow the owner of the bond to borrow at a cost of zero. Since short term repo rates were only on the order of 25 basis points during this period, however, the effective cost to the arbitrageur of allowing the owner of the bond to borrow at zero was relatively minor.

In mid-2009, the Security Industry and Financial Markets Association (SIFMA) mandated that repo failures result in the security lender being able to borrow at a annual rate of −300 basis points. This change increased the maximum potential cost to an arbitrageur of short selling Treasury issues in the extreme situation in which the arbitrageur was not able to find a repo dealer willing to lend him the security. Given the timing of this provision, however, it is unlikely to have had much impact on the results reported in this paper.

5.15 Mispricing in the Inflation Swaps Market

Could the large TIPS–Treasury mispricing documented in the previous section be explained by massive mispricing in the inflation swaps market? To explore this, we solve for the size of the parallel shift in the inflation swap curve that would be required to eliminate the mispricing. The results argue strongly against the mispricing being due entirely to inflation swap mispricing. In particular, inflation swap rates (already viewed by many as anomalously low) would actually need to be significantly lower to explain the TIPS–Treasury mispricing. For example, Figure 5 plots the term structure of inflation swap prices that would be needed to reconcile the December 30, 2008 mispricing between the Treasury bond and TIPS issue shown in Table 2. As illustrated, the market would need to be anticipating significant deflation for ten years to reconcile the mispricing. Furthermore, the maximum inflation swap rate over the entire horizon of the strategy would only be 0.28 percent. Thus, it is very implausible that TIPS–Treasury mispricing could be explained by mispricing in inflation swaps of this magnitude and in this direction. Furthermore, inflation swap rates would need to be 51.5 basis points lower on average to explain TIPS–Treasury mispricing during the sample period. Note that this is roughly ten times as large as the bid-ask spread for inflation swaps. Furthermore, 51.5 basis points represents an average error of more than 21 percent of the average level of the five-year inflation swap during the sample period. Again, inflation swap pricing errors of this nature seem very implausible.

5.16 Counterparty Credit Risk

The financial crisis has focused significant attention on the role of counterparty credit risk in swap contracts. Since the arbitrage strategy involves the use of inflation swaps, it is important to consider whether counterparty credit risk could account for some portion of TIPS–Treasury mispricing.

In a recent paper, Arora, Gandhi, and Longstaff (2010) study the effect of counterparty credit risk on the pricing of CDS contracts. They document that differences in the credit risk of dealers selling credit protection have only a very small effect on pricing of CDS contracts. They argue that the market practice of requiring full collateralization of swap liabilities results in counterparty credit risk having only a tiny effect on the pricing of swap contracts. Their evidence is also consistent with theoretical models of the effect of counterparty credit risk on swap contracts such as Duffie and Huang (1996) and others. In light of these results, it is unlikely that counterparty credit risk has much of an effect on the pricing on inflation swaps.

6. WHAT DRIVES THE MISPRICING?

The evidence of significant and persistent mispricing between TIPS and Treasury bonds presents a major puzzle to our understanding of how these markets function. In this section, we explore whether variation in the mispricing is linked to a number of economic and financial variables suggested by the literature or motivated by the discussion in the previous section. By doing this, we hope to shed light on the underlying reasons for the mispricing via the identification of factors that may drive the mispricing.

6.1 The Variables

There are a number of possible factors that might influence the size of TIPS–Treasury arbitrage over time. We discuss each of these in turn and describe the specific variables to be used in the regression analysis.

6.1.1 Systemic risk

The recent financial crisis has highlighted the role that systemic risk may play in the financial markets. If investors fear that a major economic shock could propagate through all investment asset classes, then Treasury security prices might be affected in anticipation of a potential flight to quality or a flight to liquidity. Recent research on the effects of flights on security markets include Longstaff (2004), Vayanos (2004), Vayanos and Weill (2008), Beber, Brandt, and Kavajecz (2008), and many others.

We use two different measures to capture the degree of systemic risk in the financial markets. The first is the VIX index of implied volatility from S&P 500 index options. This well-known index is widely viewed as a measure of the level of "fear" in the financial markets and has been extensively used in the literature as a proxy for the level of systemic risk. The VIX data is obtained from the Bloomberg system.

The second measure is the credit spread on super senior CDO tranches.[10] Specifically, we use the credit spread for the 15–30 percent synthetic CDO tranche on the CDX investment grade index. The CDX index consists of an equally-weighted average of the CDS quotes for a basket of 125 corporate debt issuers. The spread for the 15–30 percent tranche on this index represents the market spread that an investor would receive in exchange for absorbing credit losses on the CDX index in excess of 15 percent of the notional amount. Thus, assuming that creditors recover about 50 percent of the notional amount of their debt if a firm in the CDX index were to default, then an investor in the 15–30 percent tranche would only begin to suffer losses if 30 percent or more of the firms in the CDX index were to default. As shown by Giesecke, Longstaff, Schaefer, and Strebulaev (2010), however, an economic event in which more than 30 percent of corporate bond issuers in the U.S. were to default is very unlikely, and has only occurred once during the past 150 years in the U.S. (during the 1873–1875 railroad crisis). Thus, the spread on the 15–30 percent CDX tranche should reflect the market's assessment of the risk that this type of a devastating systemic shock of the financial markets may occur. The tranche spread data are provided to us by a large fixed income institutional investor.

6.1.2 Credit Risk

As discussed earlier, another possibility might be that the market perceives the credit risk of TIPS as being slightly higher than that of Treasury bonds. In this situation, TIPS might appear to be underpriced relative to Treasury bonds. On the other hand, even if the market viewed the credit risk of TIPS and Treasury bonds as equivalent, changes in aggregate credit risk in other markets might influence the relative pricing of TIPS and Treasury bonds. This is because TIPS and Treasury bonds might not be viewed as equally attractive safe havens in the event of a credit-induced flight to quality in the financial markets.

To explore the effects of credit risk on TIPS–Treasury mispricing, we use three credit-related variables. First, we use the 10-year swap spread. Swap spreads are one of the most important indicators of the credit risk of the banking system, and have been widely used as measures of aggregate credit risk.[11] We obtained data on the ten-year swap spread from the Bloomberg system. The second measure is the CDX index described above. This index reflects the weighted-average CDS spread for a portfolio of 125 U.S. investment grade firms. We obtained the CDX index data from the same source as the CDX super senior tranche data. The third measure is the spread for a CDS contract on the U.S. Treasury. This contract is denominated

[10]For a description of the pricing of CDOs, see Longstaff and Rajan (2008).

[11]For example, see Duffie and Singleton (1997), Liu, Longstaff, and Mandell (2006), and others.

in Euros and reflects the market's assessment of the credit risk of the United States. One difficulty with this measure, however, is that it is only available since January 2008. Thus, there is only a partial time series of this data available.

6.1.3 Confidence

Previous work on mispricing in Treasury markets has emphasized the role that consumer confidence and portfolio behavior may play in financial markets.[12] In this analysis, we use two measures of the level of confidence. The first is the Consumer Confidence Index reported monthly by the Conference Board. This survey measure directly reflects the level of reported confidence by a broad cross section of U.S. consumers. The second is the monthly change in the total amount of assets in money market mutual funds as reported by the Investment Company Institute. Intuitively, this measure should reflect changes in investors' perceptions of the investment environment. In particular, investors may tend to place more of their wealth in safer money market funds when they are less comfortable with the risk of other investment opportunities, and vice versa. Thus, changes in the assets of these funds may signal changes in aggregate market sentiment. The data are available from the respective websites of these organizations.

6.1.4 Supply

The supply of Treasury securities available in the financial markets may also be a key factor affecting the ability of arbitrageurs to exploit pricing differences between the TIPS and Treasury bond markets. In particular, it may be easier to execute arbitrage strategies in a market when there is an increase in the supply of on-the-run or recently-auctioned bonds. This follows from Kamara (1988), Cammack (1991), Boudoukh and Whitelaw (1991), Amihud and Mendelson (1991), Kamara (1994), Krishnamurthy (2002), Han, Longstaff, and Merrill (2007), and others who document that on-the-run bonds differ in terms of their trading and pricing characteristics. To explore the effects of supply on TIPS–Treasury mispricing, we include the total notional amount of all TIPS and all Treasury bonds auctioned each month during the sample period. These data are obtained from the Treasury website.

6.1.5 Liquidity

There is an extensive literature documenting that liquidity patterns can have significant effects on the valuation of securities. For example, see Boudoukh and Whitelaw (1993), Vayanos and Vila (1999), Acharya and Pedersen (2005), Amihud, Mendelson, and Pedersen (2005), Huang and Wang (2008), Brunnermeier and Pedersen

[12]For example, Longstaff (2004) examines the effect of changes in these factors on the spread between Treasury yields and yields on REFCORP bonds that are explicitly guaranteed by the U.S. Treasury.

(2009), Longstaff (2009), and many others.

To study the effects of changes in liquidity on the TIPS–Treasury mispricing, we include two variables in the analysis. The first is the ratio of total TIPS trading volume by U.S. primary dealers to total coupon-bearing Treasury note and bond trading volume by U.S. primary dealers. Intuitively, changes in this ratio may capture variation in the liquidity of TIPS relative to that of Treasury bonds. Information on trading activity by primary bond dealers is reported by the Federal Reserve Bank of New York.

The second measure is the total notional amount of repo fails experienced by primary bond dealers. Repo fails represent a measure of market disruption caused by investors' inability to find specific Treasury securities in the markets, and directly reflects a breakdown in market liquidity. Specifically, a repo fail occurs when a primary dealer is not able to deliver a Treasury security that the dealer had previously committed to deliver as part of a securities repurchase agreement. Alternatively, a repo fail occurs when the primary dealer does not receive back a Treasury security pledged as collateral on a repurchase agreement. In either case, the failure indicates that market participants are not able to locate specific Treasury securities. Thus, repo fails should increase during stressed periods in which liquidity and available supply of Treasury securities in the markets dries up. Information on repo fails is also reported by the Federal Reserve Bank of New York.[13]

6.1.6 Asset Purchases by the Federal Reserve

Finally, there is some strong but anecdotal evidence that permanent open market operations by the Federal Reserve during the mortgage crisis have had a major impact on the size of the arbitrage.[14] On March 18, 2009, the Federal Open Market Committee announced an unprecedented program to purchase up to $300 billion of longer-dated Treasury bonds through a series of competitive auctions. Over the course of the program the Federal Reserve's Open Market Trading Desk purchased $11 billion in nominal Treasury securities maturing in 1 to 2 years, $242 billion maturing in 2 to 10 years, $42 billion maturing in 10 to 30 years, and $5 billion

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[13]In addition to the variables described in this section, we also examined whether changes in TIPS–Treasury mispricing were related to Federal Reserve open market purchases of Treasury bonds and TIPS, Federal Reserve securities lending, or the amount of Treasury and TIPS trading by primary bond dealers. None of these variables have explanatory power for changes in TIPS–Treasury mispricing.

[14]Permanent open market operations include purchases or sales of securities on an outright basis that add to or diminish reserves. These are different from temporary open market operations that consist of short-term repurchases or reverse repurchase agreements.

in TIPS. In spite of the relatively small size of the TIPS purchases, relative to the Treasury bonds, this program appears to have dramatically reduced the mispricing gap between TIPS and Treasury bonds. On March 18, 2009, the average amount of mispricing was \$8.69. Figure 6 plots the time series of mispricing after the announcement. This number declined to \$6.49 by April 19, the date of the first outright TIPS purchase. The total amount tendered to the Treasury was \$15.56 billion, and the total amount accepted was \$1.50 billion. The mispricing then declined to \$2.08 on May 26 when a second TIPS purchase took place. The total amount accepted at this second purchase was \$1.55 billion. This represents an overall decline of 76 percent in the potential savings to the Treasury during the first six weeks since the program was announced. As of July 14, 2010, the Federal Reserve holds \$46.55 billion of TIPS (out of a total of \$564 billion outstanding). This compares to holdings of \$712 billion of Treasury notes and bonds, out of \$5.75 billion outstanding.

6.2 Regression Analysis

To explore the relation between these variables and TIPS–Treasury mispricing, we regress monthly changes in the mispricing on the corresponding changes or values of these variables. Rather than doing this at the level of individual TIPS and Treasury pairs, however, we focus on the average yield mispricing across all pairs, where the average is weighted by the outstanding notional amount of the TIPS issue (taking into account the accretion in the notional amount). Specifically, we regress the monthly changes in the average mispricing value on the monthly changes in the VIX index, the super senior CDX tranche spread, the ten-year swap spread, the CDX investment grade spread, the Consumer Confidence Index, and the total assets in money market mutual funds, and on the total notional amounts of TIPS and coupon-bearing Treasury bonds issued each month, the ratio of monthly TIPS trading to Treasury bond trading by primary dealers, and the notional amount of all repo fails reported each month by primary dealers.

Since the two systemic variables are strongly related to each other, we estimate a number of specifications in which only one of these two variables is included at a time. We use the same approach for the two credit variables which are also strongly correlated, and for the two confidence measures. The regression results from these alternative specifications are reported in Table 4.

The results provide a number of important insights into the determinants of the mispricing. First, they show that systemic risk, as measured by changes in the VIX index, has some relation to changes in this mispricing for some of the specifications. In particular, changes in the VIX are significant at the ten-percent level for the first two specifications reported. In contrast, the super senior spread is never significant in any of the specifications.

Turning to the credit variables, Table 4 shows that neither changes in the ten-year swap spread nor changes in the CDX index are significant in any of the specifications. Although not shown, we also estimate the regression using changes in the spread of the Euro-denominated CDS contract on the United States. This data is only available for the last 23 months of the study period. As with the other credit variables, the U.S. CDS spread is not significant in any of the regressions. The results for the confidence variables are similar to those for the credit variables. In particular, neither of the confidence variables are significant in any of the regressions.

The results for the supply variables are very different in nature. In particular, the results indicate that there is a significant relation between changes in mispricing and the notional amount of both TIPS and Treasury bonds issued each month. The amount of TIPS issuance is significant at the ten-percent level in six of the specifications. The amount of Treasury issuance is significant at the ten-percent level for seven of the specifications, and significant at the five-percent level for three of the specifications. All of the coefficients for the supply variables are negative in sign. Figure 2 shows that the weighted-average mispricing variable is always positive. Thus, the negative sign for TIPS and Treasury issuance has the clear implication that as more TIPS and Treasury bonds are issued, the size of the arbitrage shrinks. It is important to note that this result holds even though the TIPS-Treasury arbitrage involves taking a short position in the Treasury bond. Thus, the effect of TIPS and Treasury issuance on the arbitrage is not merely the result of an on-the-run pricing effect on Treasury bonds.

The strongest results in Table 4 are for the repo fail variable in the liquidity category. The amount of repo fails is highly significant in all of the eight specifications, often with t-statistics in excess of 4.00. All of the coefficients for the amount of repo fails are positive, indicating that as repo fails become more prevalent in the market, the size of the arbitrage widens. Since repo fails are the result of market participants experiencing difficulty in acquiring specific Treasury collateral, these results provide clear evidence that the supply or liquidity of the securities involved in the arbitrage is directly linked to the size of the arbitrage. As far as we are aware, this is the first time that such a result has been documented in the literature.

7. CORRELATED ARBITRAGE

A number of important recent papers have put forward potential explanations for the existence of persistent mispricing in financial markets. Mitchell, Pedersen, and Pulvino (2007) and Duffie (2010) discuss the role that slow-moving capital may play in allowing arbitrage opportunities to exist for extended periods of time. Shleifer and Vishny (1997), Liu and Longstaff (2004), Fostel and Geanakoplos (2008), Gorton and Metrick (2008), and Ashcraft, Gârleanu, and Pederson (2010) argue that margins, haircuts, and other collateral-related frictions may permit arbitrage or deviations from the law of one price to occur. Brunnermeier and Pedersen (2009) emphasize the role that the availability of funding may play in allowing liquidity effects on security prices.

A key implication of this literature is that arbitrage in different markets could be driven by common factors. For example, if capital returns slowly to the fixed-income arbitrage hedge fund sector after periods of flat performance, then arbitrages arising in various types of fixed income markets could display significant commonality. Motivated by this, we explore the extent to which TIPS–Treasury mispricing is correlated with other types of fixed-income arbitrages as well as hedge fund returns.

7.1 Fixed-Income Arbitrage

We focus on two well-known and widely-followed types of fixed-income arbitrage strategies in this section. The first is the CDS-Corporate bond basis strategy discussed by Duffie (2010). In this strategy, the spread for a CDS contract on a firm is compared with the spread on corporate bonds issued by that firm. In theory, the two spreads should be very similar. In reality, there is often a significant difference between the two spreads, which is termed the CDS/corporate-bond basis.[15] Duffie argues that this basis may be a result of slow-moving capital. In particular, entering into a CDS contract requires little capital, while purchasing a corporate bond requires the use of significant capital. Thus, if arbitrage capital in the market is relatively scarce, then the CDS/corporate-bond basis may be able to persist. We were given access to a proprietary time series by a major investment management firm of the CDS/corporate-bond basis for the firms included in the CDX index for the period from January 2005 to November 2009. We average the basis across these firms and compute the monthly changes in the average basis. For simplicity, we refer to this arbitrage as the CDS arbitrage.

The second arbitrage strategy is based on the difference between the CDX index and the average CDX spreads for the 125 firms included in the CDX index. Since contracts on the CDX index trade separately, the market price for a contract on the CDX need not always equal the average value of the CDS spreads in the index. This failure of the index to equal the sum of its parts is similar in concept to the difference between the price of an ETF and the value of the ETF's holdings.[16] We were also given access to this data for the same time period as that for the CDS/corporate-bond basis strategy described above. We designate this arbitrage as the CDX arbitrage.

[15] Also see Longstaff, Mithal, and Neis (2005).

[16] For example, see Tucker and Laipply (2010).

It is important to stress that these two arbitrage strategies are fundamentally different in terms of their use of capital. To implement the CDS/corporate-bond basis strategy requires an investment in the underlying corporate bond and the use of the arbitrageur's capital. In contrast, the CDX index arbitrage strategy only requires taking long and short positions in CDS contracts, involving little or no capital. Note also that neither of these two arbitrage strategies involves Treasury bonds or TIPS. Thus, finding that these strategies and TIPS–Treasury mispricing are correlated would provide evidence in support of the implications of the literature described above.

Table 5 reports the results from the regression of the monthly change in the absolute value of the TIPS–Treasury mispricing index on lagged, contemporaneous, and leading changes in the absolute values of these two fixed-income arbitrages. By using the change in the absolute value, a positive regression coefficient has the clear interpretation that the arbitrage and TIPS–Treasury mispricing are widening and narrowing together.

Table 5 shows that there is a significant relation between changes in TIPS–Treasury mispricing and changes in the other two arbitrages. For the CDS arbitrage, the contemporaneous change is highly significant with a t-statistic of 3.64. The coefficient value of 0.3270 implies that the TIPS–Treasury arbitrage widens by about a third of a basis point as the CDS arbitrage widens by a basis point. The adjusted R^2 for this regression is 0.386. For the CDX arbitrage regression, the first and second lagged changes as well as the contemporaneous change are significant (at the ten-percent level) in explaining changes in the TIPS-Treasury arbitrage. The adjusted R^2 for the regression is 0.289.

These results have several important implications. First, they demonstrate that the forces that allow arbitrages to exist in the CDS/corporate-bond markets may also be at work in the TIPS–Treasury market. Second, finding that both the CDX and CDS arbitrages are related to the TIPS–Treasury arbitrage argues against the view that arbitrages are due exclusively to slow-moving capital. This follows from the fact that the CDX arbitrage requires relatively little capital to implement, while the opposite is true for the CDS arbitrage. Third, the evidence that lagged CDX arbitrages are predictive for subsequent TIPS–Treasury arbitrages raises the interesting possibility of cross-momentum in different types of arbitrages.

7.2 Hedge Fund Returns

To provide an alternative perspective, we also explore whether TIPS–Treasury mispricing is related to the returns for hedge funds that specialize in arbitrage strategies. In particular, we obtain the monthly returns for the CS/Tremont fixed-income arbitrage, convertible-bond arbitrage, and merger arbitrage indexes. We regress changes in the TIPS–Treasury mispricing on lagged, contemporaneous, and leading returns for these hedge funds.

Table 6 reports the results from the regressions. The contemporaneous returns for both the fixed-income and convertible bond arbitrage hedge funds are both highly statistically significant. In addition, the second lagged returns for these hedge funds are significant at the ten-percent level. We note that the correlation of the fixed-income and convertible bond arbitrage hedge fund returns is 91 percent, which may explain why their relation with TIPS–Treasury mispricing is similar. Although there is no significant contemporaneous relation between the merger arbitrage hedge fund returns and the TIPS–Treasury mispricing, the first lagged value of the merger arbitrage returns is significant at the ten-percent level. Thus, all three of these hedge fund return series has some degree of correlation with changes in TIPS–Treasury mispricing.

Table 6 also shows that all three of these types of hedge funds have negative coefficients for the contemporaneous returns (although only the first two are significantly negative), indicating that the TIPS–Treasury arbitrage tends to narrow as arbitrage hedge funds experience positive returns. There are two possible interpretations of this result. First, the negative coefficients are consistent with a scenario in which positive hedge fund performance increases the amount of capital available to these hedge funds to arbitrage away mispricing. Thus, TIPS–Treasury mispricing decreases as the assets under management of these hedge funds increase. Second, the negative coefficient could also be consistent with a scenario in which arbitrage-related hedge funds profit as arbitrages converge towards zero, and vice versa.

8. THE TIPS ISSUANCE PUZZLE

We have shown that Treasury bonds are almost invariably too expensive in relation to TIPS. Our findings have important government finance implications. The Treasury could reduce the dollar market value of outstanding debt by buying back TIPS and issuing nominal Treasury bonds instead. To make this a risk-free proposition would involve a large transaction in the inflation-swap market. This transaction might not be feasible. Without the inflation swap leg of the transaction, the Treasury is exposed to deflation risk: unanticipated deflation increases the real debt burden faced by the Treasury. However, if one takes the view that the Federal Reserve can avoid deflation, then the Treasury does not bear any risk of unanticipated deflation.

The upside of this swap of TIPS for Treasury bonds, even without the inflation swap, is that it restores the option of reducing the real value of its outstanding debt. Bohn (1988), for example, argues that nominal debt provides valuable insurance against the budgetary effects of economic fluctuations. Nominal debt may be a desirable form of funding because of the covariance of inflation with government spending: high government spending tends to go with high inflation. Since nominal bonds pay poorly in real terms when inflation is unexpectedly high, nominal debt has some of the characteristics of government-issued contingent debt. In their seminal paper, Lucas and Stokey (1983) point out that tax smoothing through the issuance of state-contingent debt is desirable from a welfare point of view.[17]

Historically, these considerations seem much more relevant. Figure 7, which plots U.S. inflation rates during the 20th Century, shows that U.S. seems to have used the inflation option repeatedly, mainly to help finance war expenditures. These war episodes are informative because the triggers are truly exogenous fiscal shocks. During World War I, there was a substantial run-up in the rate of inflation. It peaked at an annualized rate of 20.4 percent in 1918. Similarly, towards the end of World War II, inflation increased dramatically and it peaked in 1946 at an annualized rate of 18.1 percent. Finally, there was another run-up in inflation during the Korean War when inflation reached 6 percent in 1951.

So, overall, our finding that Treasury bonds provide much cheaper financing for U.S. Federal deficits than TIPS is remarkable. Treasury bonds include an option to reduce the real value of outstanding debt. Obviously, the Treasury would be willing to pay extra for this option to inflate debt away. Instead, the Treasury gets this option for free in financial markets. Moreover, when it issues TIPS, it gives up this free option.

9. CONCLUSION

In this paper, we study the relative pricing of TIPS and Treasury bonds. A simple no-arbitrage argument places a strong restriction on the relation between the prices of these securities. We show that this no-arbitrage relation is frequently violated in the markets. To our knowledge, this arbitrage, which can exceed $20 per $100 notional amount, represents the largest arbitrage ever documented in the literature. Furthermore, the sheer magnitude of this mispricing in markets as deep and actively traded as the Treasury bond and TIPS markets presents a serious challenge to conventional asset pricing theory.

Using a regression framework, we explore the determinants of TIPS–Treasury

[17]Clearly, indexed debt does not allow for this type of state contingency, except by trying to span the fiscal shocks through large long and short positions in indexed debt of various maturities (Angeletos, 2002). Buera and Niccolini (2004) point out that this seems to involve implausible trading strategies.

mispricing. The results strongly point to supply-related factors as key drivers of the mispricing. In particular, we find that TIPS–Treasury mispricing narrows significantly whenever the Treasury auctions either Treasury bonds or TIPS. In contrast, the mispricing widens significantly when primary dealers have difficulties in obtaining Treasury securities and experience increased levels of repo failures. These results argue that the supply of securities in the market may play a much greater role in determining prices than classical asset pricing models indicate.

Recent theoretical work suggests that slow-moving capital or funding frictions may represent a common denominator in explaining the deviation of market prices from fundamentals. Motivated by this, we examine whether there is evidence of commonality in a variety of fixed-income arbitrages. We find that TIPS–Treasury mispricing and several major CDS-related arbitrages are strongly correlated. Furthermore, we find that fixed income arbitrage hedge fund returns are significantly related to TIPS–Treasury mispricing. These results provide empirical support for the implications of this recent theoretical work.

Finally, our results point out that the ongoing issuance of TIPS by the Treasury is in itself a puzzle. This is because the Treasury not only gives up a fiscal hedging option by issuing TIPS, it also leaves billions of dollars on the table by issuing securities that are not as highly valued by the market as nominal Treasury bonds.

APPENDIX

This appendix describes the details about how we compute the size of the TIPS–Treasury arbitrage. In addition to the pricing data for TIPS, Treasury bonds, and STRIPS issues, we also download daily closing prices of inflation swaps with maturities of 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 15, 20, 25 and 30 years for the period from July 23, 2004 to November 19, 2009 from the Bloomberg terminal. Inflation swaps are identified on the Bloomberg system by the ticker USSWITn, where n denotes the maturity of the swap. For a few of these swaps, inflation swap data are missing for several days. In these cases, we replace missing data points by the last available observation.

To implement the arbitrage strategy, we set the notional amount of each inflation swap to match the corresponding semiannual coupon payment (before inflation adjustment) on the TIPS issue which we designate s. At date t, the inflation swap pays a cash flow of $s\,(1+f_t)^t - sI_t$, where I_t is the indexed leg and f_t is the fixed inflation swap rate for maturity t.

Implementing the arbitrage strategy requires interpolating the quoted inflation swap rates for all maturities ranging from 0 to 30 years. Furthermore, seasonal patterns in inflation must be taken into account for swap maturities that include fractional years (e.g. 2.3 years). To interpolate the inflation swap rate curve, we first fit a standard cubic spline through the quoted maturities using a grid size of one month. Let the interpolated swap rates be denoted by $f_{i,j},\ i = 1, 2, \ldots, 30,\ j = 1, 2, \ldots, 12$, where the first index refers to the year and the second to the month.

We then estimate seasonal components in inflation from the monthly non-seasonally adjusted U.S. CPI index (CPI-U NSA) series between January 1980 and October 2009 by estimating an OLS regression of monthly log changes in the CPI index on month dummies. More specifically,

$$\Delta \text{CPI}_t \equiv \log\left(\frac{\text{CPI}_t}{\text{CPI}_{t-1}}\right) = \sum_{i=1}^{12} \beta_i \; d_i \; + \; \varepsilon_i, \tag{A1}$$

where t is measured in months. The month dummies d_i, $i = 1, 2, \ldots, 12$ are defined as

$$d_i = \begin{cases} 1, & \text{for month } i, \\ 0, & \text{otherwise.} \end{cases} \tag{A2}$$

and d_1 =January, d_2 =February, … , d_{12} =December. We obtain an estimate of the seasonal effect in month i by subtracting the average of the coefficients $\bar{\beta} = \frac{1}{12}\sum \hat{\beta}_i$

from the estimated coefficients $\hat{\beta}_i,\ i = 1, 2, \ldots, 12$. Let this estimate be denoted by $\hat{b}_i = \hat{\beta}_i - \bar{\beta},\ i = 1, 2, \ldots, 12$.

Next, we construct monthly forward rates $H_{i,j},\ i = 1, 2, \ldots, 30,\ j = 1, 2, \ldots, 12$ from the interpolated swap rate rates $f_{i,j}$. Then, we normalize the seasonal factors $\hat{b}_i$ so that their product is unity. Let the normalized monthly adjustment factors be denoted by $\hat{m}_i,\ i = 1, 2, \ldots, 12$, where $\prod_{i=1}^{12} \hat{m}_i = 1$. We then multiply the forward rates $H_{i,j}$ by the corresponding adjustment factor $\hat{m}_j,\ j = 1, 2, \ldots, 12$ to obtain seasonally adjusted forward rates $\tilde{H}_{i,j},\ i = 1, 2, \ldots, 12,\ j = 1, 2, \ldots, 12$. By construction, there will be no seasonal effects for full-year swaps. In the last step, we obtain the seasonally adjusted inflation swap curve by converting the forward rates $\tilde{H}_{i,j}$ into inflation swap rates $\tilde{f}_{i,j},\ i = 1, 2, \ldots, 30,\ j = 1, 2, \ldots, 12$. We do not interpolate or adjust maturities smaller than one year, but use the one-year swap rate instead, because the interpolated rates are sensitive to short-term inflation assumptions in that case. We set $\tilde{f}_{0j} = f_1,\ j = 1, 2, \ldots, 12$.

With the inflation swap curve, we can now implement the TIPS–Treasury arbitrage strategy and compute the size of the mispricing in the following way. First, we take a position in a TIPS issue with a coupon rate of s and maturity T for a price of V. Each period, the TIPS issue pays coupons of sI_t and makes a principal payment of $100I_T$ at maturity.

Next, we enter into an inflation swap for each coupon payment date $t = 1, 2, \ldots, T$ with notional amount of s for $t < T$ and $s + 100$ for the final principal payment at time T. Let f_t denote the fixed rate on the inflation swap for date $t = 1, 2, \ldots, T$ obtained from the interpolated inflation swap curve. At each coupon payment date t, the inflation swap pays a cash flow of $s\,(1 + f_t)^t - sI_t$ and $(s + 100)\,(1 + f_T)^T - (s + 100)\,I_T$ at maturity T. The sum of the cash flows at date t from the TIPS issue and the inflation swap is constant, since $sI_t + s\,(1 + f_t)^t - sI_t = s\,(1 + f_t)^t$. Similarly, at maturity $(s + 100)\,I_T + (s + 100)\,(1 + f_T)^T - (s + 100)\,I_T = (s + 100)\,(1 + f_T)^T$. This converts all of the indexed cash flows from the TIPS bond into fixed cash flows.

Let P and c denote the price and the semiannual coupon payment for the Treasury bond, respectively. To match the cash flows c from the Treasury bond exactly, the replicating portfolio must include a small long or short position in Treasury STRIPS for each coupon payment date t and the maturity date T, such that $s\,(1 + f_t)^t + x_t = c$ and $(s + 100)\,(1 + f_T)^T + x_T = c + 100$, where x_t denotes the notional amount of STRIPS for date $t = 1, 2, \ldots, T$. This step converts the indexed bond into a synthetic security with fixed cash flows that exactly replicate the magnitude of the cash flows from the Treasury bond. Given the fixed cash flows and the value of the replicating portfolio, we then calculate the yield to maturity for the replicating portfolio.

In the last step, we use the yield to maturity for the replicating portfolio to determine the price of a synthetic Treasury bond with the same maturity, coupon rate, and cash flows as the matched Treasury bond. The difference between the prices of the synthetic Treasury bond and the matched Treasury bond represents the TIPS–Treasury mispricing.

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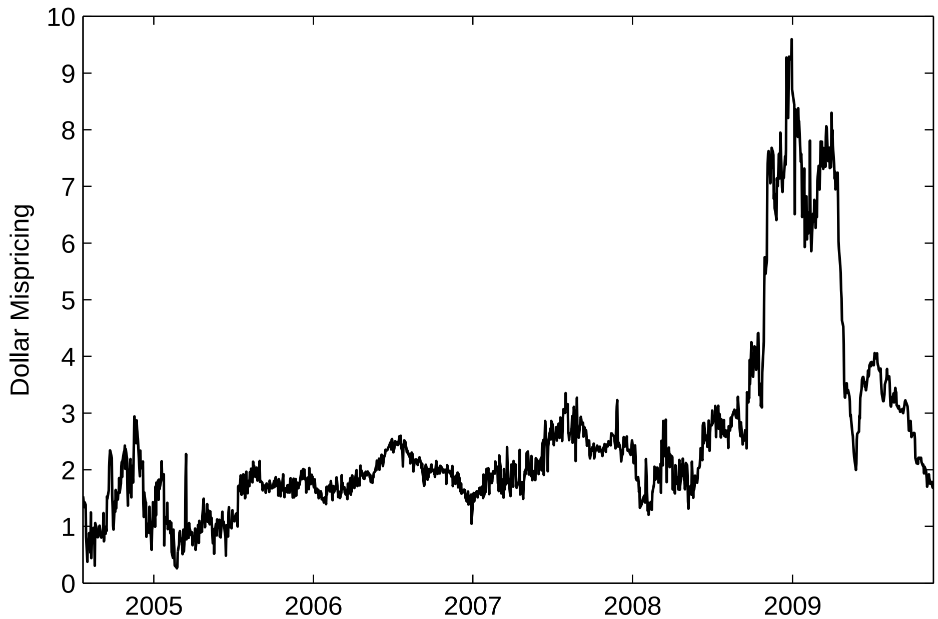

Figure 1. TIPS–Treasury Mispricing. This figure plots the time series of the weighted-average TIPS–Treasury mispricing, expressed in units of dollars per $100 notional, across the pairs included in the sample, where the average is weighted by the notional amount of the TIPS issue.

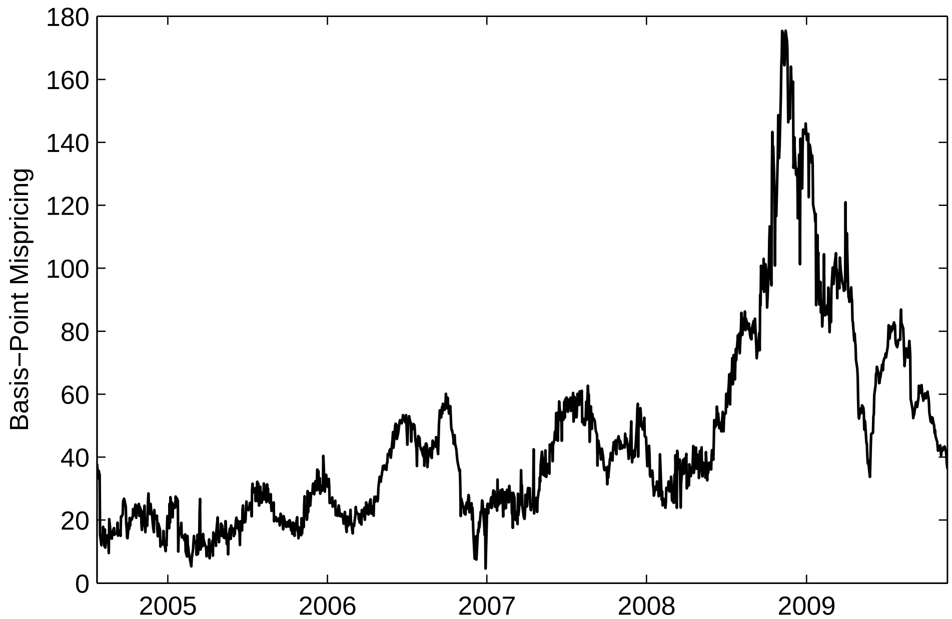

Figure 2. Weighted Average TIPS–Treasury Mispricing in Basis Points. This figure plots the time series of the average TIPS–Treasury mispricing, measured in basis points, across the pairs included in the sample, where the average is weighted by the notional amount of the TIPS issue.

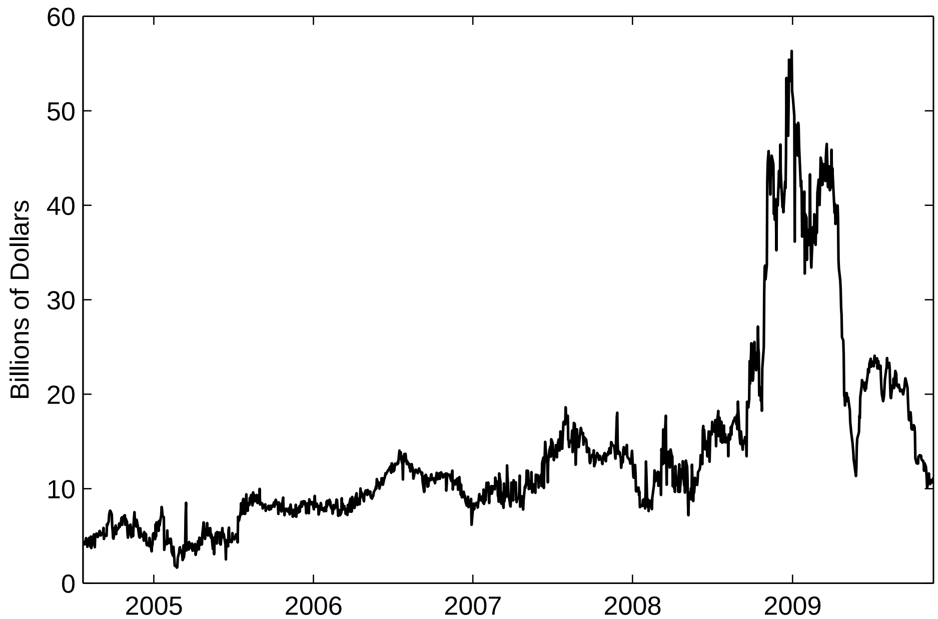

Figure 3. Total Dollar Amount of TIPS–Treasury Mispricing. This figure plots the total dollar amount in billions of TIPS–Treasury mispricing, where the total is calculated using all 33 pairs of TIPS issues outstanding during some portion of the sample period and the corresponding matching-maturity Treasury bonds.

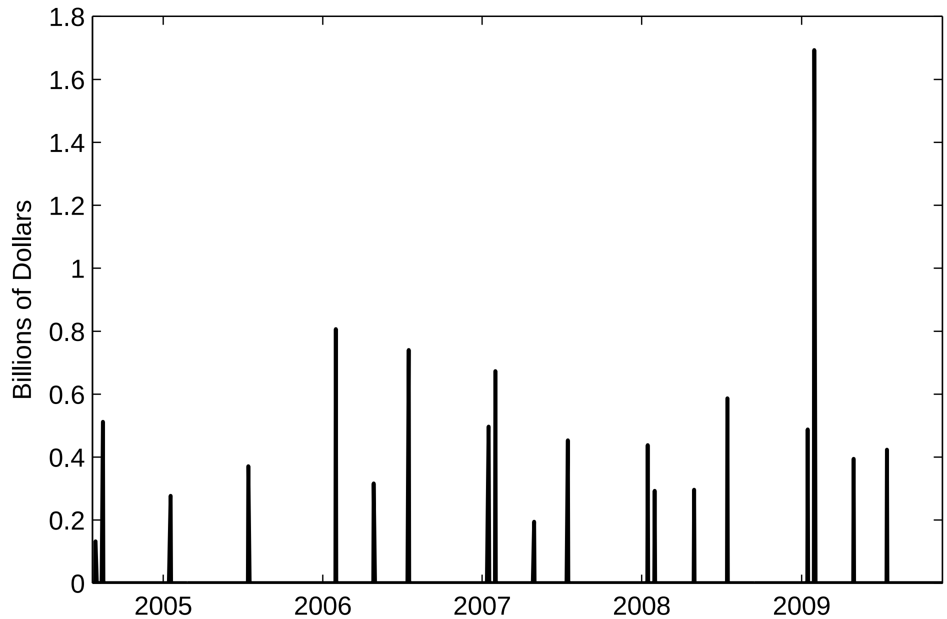

Figure 4. Total Cost to the Treasury from Issuing TIPS Rather than Treasury Bonds. This figure plots the total cost to the Treasury (measured in billions of dollars) of issuing TIPS rather Treasury bonds for each of the TIPS auctions during the sample period.

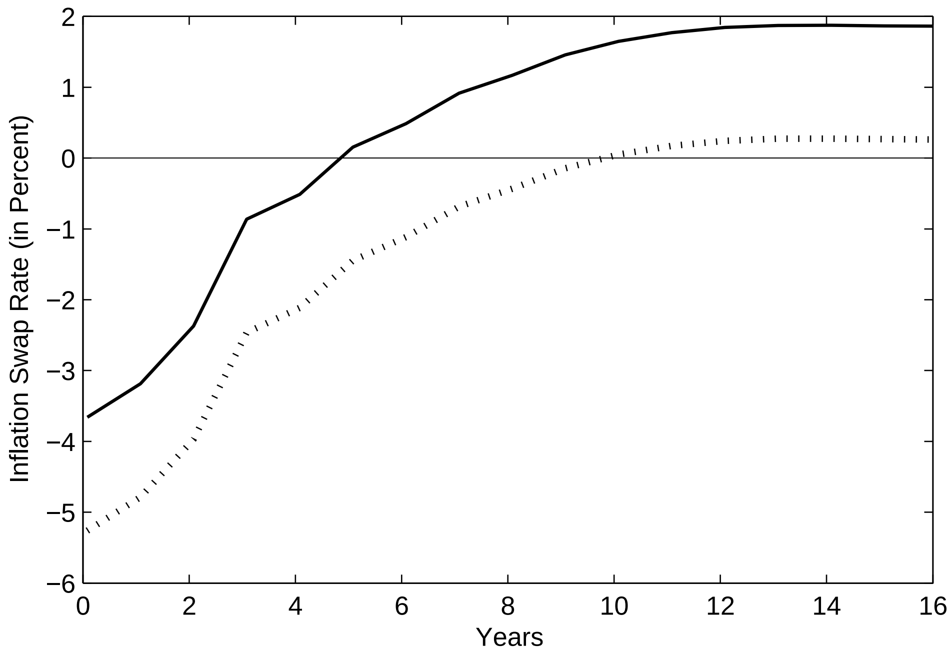

Figure 5. Implied Inflation Swap Curve that Reconciles TIPS–Treasury Mispricing. This figure plots the actual inflation swap curve for December 30, 2008 (solid curve) and the implied inflation swap curve (dotted curve) for the same date that would reconcile the pricing of the Treasury bond with maturity date February 15, 2025 and the corresponding TIPS issue.

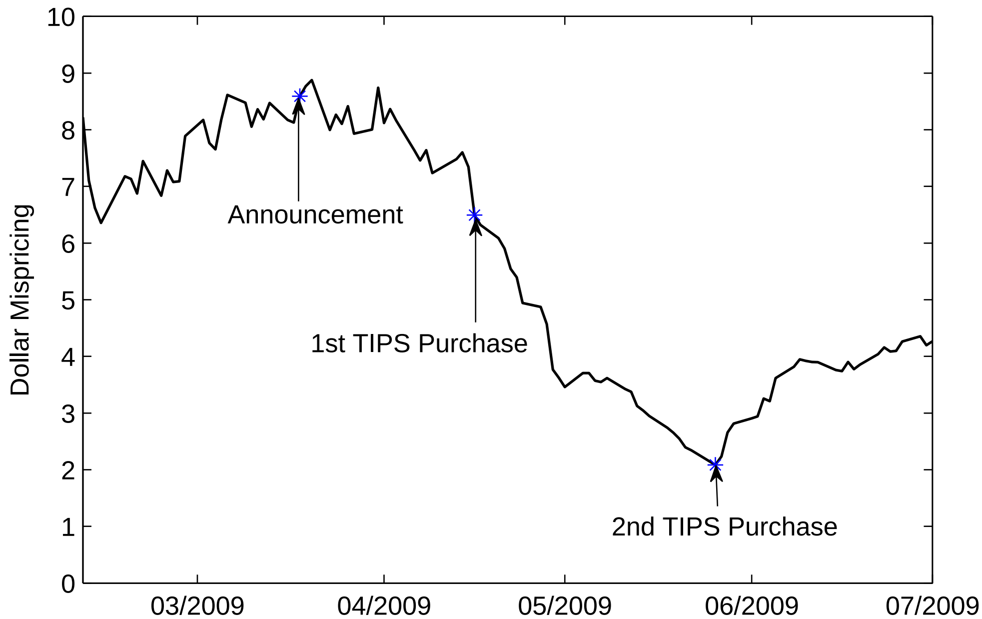

Figure 6. Treasury Purchase Program and TIPS–Treasury Mispricing. This figure plots key dates in the Treasury Purchase Program along with the weighted-average TIPS–Treasury mispricing measured in units of dollars per $100 notional.

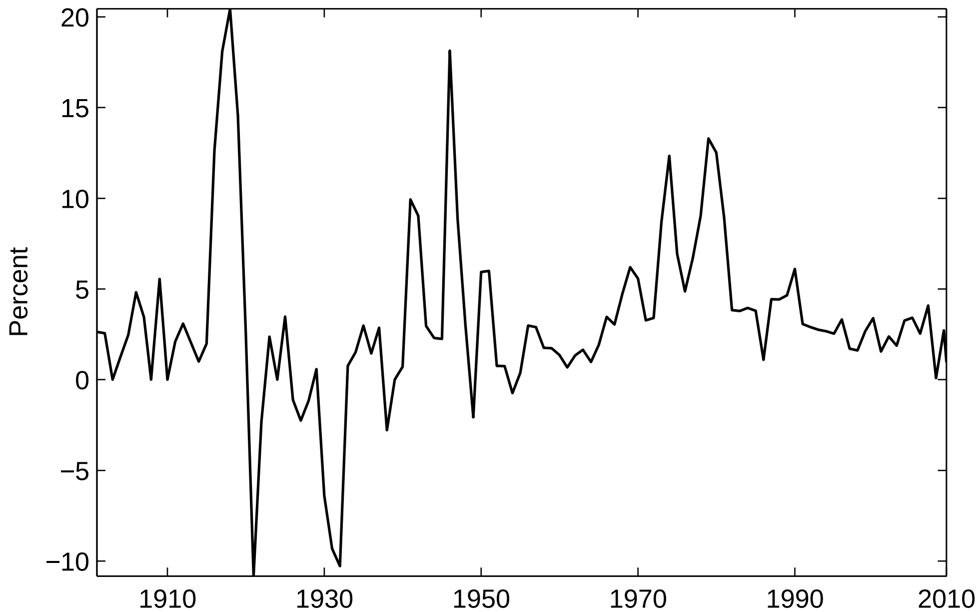

Figure 7. Annualized Inflation Rate from 1900 to 2010. This figure plots the annualized inflation rate from 1900 to 2010 as reported by the Bureau of Labor Statistics.

Table 1

Cash Flows from the Treasury Bond and the Synthetic Treasury Bond Replicating Strategy. This table shows the cash flow generated each period from the indicated positions. P denotes the price of the Treasury bond with coupon c, V denotes the price of the TIPS bond with the same maturity date as the Treasury bond and a coupon rate of s, and $D(t)$ denotes the price of a Treasury STRIP with a maturity of t. F_t denotes the fixed payment on a zero-coupon inflation swap of maturity t (calculated as $(1+f)^t$, where f is the corresponding inflation swap rate). The inflation index I_t denotes the ratio of the CPI-U index at time t divided by the CPI-U index at time zero.

Strategy	0	1	2	3	...	T
Buy Treasury	$-P$	c	c	c	...	$c+100$
Buy TIPS	$-V$	sI_1	sI_2	sI_3	...	$(s+100)I_T$
Inflation Swap$_1$	0	$s(F_1-I_1)$	0	0	...	0
Inflation Swap$_2$	0	0	$s(F_2-I_2)$	0	...	0
Inflation Swap$_3$	0	0	0	$s(F_3-I_3)$	...	0
⋮	⋮	⋮	⋮	⋮		⋮
Inflation Swap$_T$	0	0	0	0	...	$(s+100)(F_T-I_T)$
STRIPS$_1$	$(c-sF_1)D(1)$	$c-sF_1$	0	0	...	0
STRIPS$_2$	$(c-sF_2)D(2)$	0	$c-sF_2$	0	...	0
STRIPS$_3$	$(c-sF_3)D(3)$	0	0	$c-sF_3$	...	0
⋮	⋮	⋮	⋮	⋮		⋮
STRIPS$_T$	$(c+100)D(T)-$ $(s+100)F_TD(T)$	0	0	0	...	$(c+100)-$ $(s+100)F_T$
Total Cash Flow	$\sum_{i=1}^{T}(c-sF_i)\ D(i)\ +$ $100(1-F_T)D(T)-V$	c	c	c	...	$c+100$

Table 2

A Specific Example of the Synthetic Treasury Bond Replicating Strategy. This table shows the cash flows associated with the 7.625 percent Treasury bond with maturity date February 15, 2025 and the cash flows from the replicating strategy using the 2.375 percent TIPS issue with the same maturity date that replicates the cash flows of the Treasury bond. The example is based on market prices for December 30, 2008. Cash flows are in dollars per $100 notional. I_t denotes the realized percentage change in the CPI index from the inception of the strategy to the cash flow date. Date designates the number of the semiannual period in which the corresponding cash flows are paid.

Date	Treasury	TIPS	Inflation Swaps	STRIPS	Total
0	−169.4793	−101.2249	0	−45.6367	−146.3786
1	3.8125	$1.1875\ I_1$	$1.1856 - 1.1875\ I_1$	2.6269	3.8125
2	3.8125	$1.1875\ I_2$	$1.1638 - 1.1875\ I_2$	2.6487	3.8125
3	3.8125	$1.1875\ I_3$	$1.1480 - 1.1875\ I_3$	2.6645	3.8125
4	3.8125	$1.1875\ I_4$	$1.1467 - 1.1875\ I_4$	2.6658	3.8125
5	3.8125	$1.1875\ I_5$	$1.1307 - 1.1875\ I_5$	2.6818	3.8125
6	3.8125	$1.1875\ I_6$	$1.1376 - 1.1875\ I_6$	2.6749	3.8125
7	3.8125	$1.1875\ I_7$	$1.1566 - 1.1875\ I_7$	2.6559	3.8125
8	3.8125	$1.1875\ I_8$	$1.1616 - 1.1875\ I_8$	2.6509	3.8125
9	3.8125	$1.1875\ I_9$	$1.1630 - 1.1875\ I_9$	2.6495	3.8125
10	3.8125	$1.1875\ I_{10}$	$1.1773 - 1.1875\ I_{10}$	2.6352	3.8125
11	3.8125	$1.1875\ I_{11}$	$1.1967 - 1.1875\ I_{11}$	2.6158	3.8125
12	3.8125	$1.1875\ I_{12}$	$1.2095 - 1.1875\ I_{12}$	2.6030	3.8125
13	3.8125	$1.1875\ I_{13}$	$1.2248 - 1.1875\ I_{13}$	2.5877	3.8125
14	3.8125	$1.1875\ I_{14}$	$1.2466 - 1.1875\ I_{14}$	2.5659	3.8125
15	3.8125	$1.1875\ I_{15}$	$1.2683 - 1.1875\ I_{15}$	2.5442	3.8125
16	3.8125	$1.1875\ I_{16}$	$1.2866 - 1.1875\ I_{16}$	2.5259	3.8125
17	3.8125	$1.1875\ I_{17}$	$1.3058 - 1.1875\ I_{17}$	2.5067	3.8125
18	3.8125	$1.1875\ I_{18}$	$1.3304 - 1.1875\ I_{18}$	2.4821	3.8125
19	3.8125	$1.1875\ I_{19}$	$1.3556 - 1.1875\ I_{19}$	2.4569	3.8125
20	3.8125	$1.1875\ I_{20}$	$1.3792 - 1.1875\ I_{20}$	2.4333	3.8125
21	3.8125	$1.1875\ I_{21}$	$1.4009 - 1.1875\ I_{21}$	2.4116	3.8125
22	3.8125	$1.1875\ I_{22}$	$1.4225 - 1.1875\ I_{22}$	2.3900	3.8125
23	3.8125	$1.1875\ I_{23}$	$1.4427 - 1.1875\ I_{23}$	2.3698	3.8125
24	3.8125	$1.1875\ I_{24}$	$1.4635 - 1.1875\ I_{24}$	2.3490	3.8125
25	3.8125	$1.1875\ I_{25}$	$1.4806 - 1.1875\ I_{25}$	2.3319	3.8125
26	3.8125	$1.1875\ I_{26}$	$1.4979 - 1.1875\ I_{26}$	2.3146	3.8125
27	3.8125	$1.1875\ I_{27}$	$1.5126 - 1.1875\ I_{27}$	2.2999	3.8125
28	3.8125	$1.1875\ I_{28}$	$1.5277 - 1.1875\ I_{28}$	2.2848	3.8125
29	3.8125	$1.1875\ I_{29}$	$1.5407 - 1.1875\ I_{29}$	2.2718	3.8125
30	3.8125	$1.1875\ I_{30}$	$1.5548 - 1.1875\ I_{30}$	2.2577	3.8125
31	3.8125	$1.1875\ I_{31}$	$1.5676 - 1.1875\ I_{31}$	2.2449	3.8125
32	3.8125	$1.1875\ I_{32}$	$1.5823 - 1.1875\ I_{32}$	2.2302	3.8125
33	103.8125	$1.1875\ I_{33}$	$135.9861 - 1.1875\ I_{33}$	−32.1736	103.8125

Table 3

Summary Statistics for TIPS–Treasury Mispricing. This table reports summary statistics for TIPS–Treasury mispricing for the 29 pairs of TIPS and Treasury bonds shown. Days denotes the maturity mismatch of the pair. The left central panel reports summary statistics for the mispricing measured in dollars per $100. The right central panel reports summary statistics for the mispricing measured in basis points. The sample period is from July 23, 2004 to November 19, 2009.

TIPS		Trsy		Days	Mean	SDev	Min	Max	ρ	Mean	SDev	Min	Max	ρ	N
Jan-15-07	3.375	Dec-31-06	3.000	15	0.18	0.39	−0.76	1.10	0.97	34.57	92.03	−255.56	357.23	0.98	506
Jan-15-08	3.625	Dec-31-07	4.375	15	0.34	0.34	−0.25	1.26	0.96	53.82	66.57	−80.99	270.41	0.96	502
Jan-15-09	3.875	Jan-15-09	3.250	0	0.67	0.46	−0.34	2.56	0.95	72.54	135.34	−25.55	723.29	0.98	1109
Jan-15-10	4.250	Jan-15-10	3.625	0	0.85	0.59	−1.05	4.69	0.91	55.14	71.91	−64.47	420.39	0.97	1215
Apr-15-10	0.875	Apr-15-10	4.000	0	1.09	0.65	−1.18	4.51	0.93	58.25	57.84	−69.20	316.69	0.96	1161
Jan-15-11	3.500	Jan-15-11	4.250	0	1.32	0.71	−0.03	4.94	0.92	50.24	33.67	−1.07	231.07	0.94	971
Apr-15-11	2.375	Mar-31-11	4.750	15	1.67	0.70	−0.37	5.03	0.91	56.13	33.04	−15.24	213.25	0.94	736
Jan-15-12	3.375	Jan-15-12	1.125	0	1.84	0.75	0.79	4.64	0.96	72.32	24.20	31.10	163.04	0.95	215
Apr-15-12	2.000	Apr-15-12	1.375	0	1.42	0.41	0.62	2.32	0.91	54.11	14.90	21.83	90.97	0.90	154
Jul-15-12	3.000	Jul-15-12	1.500	0	1.66	0.37	0.94	2.89	0.86	60.25	12.44	35.72	104.19	0.83	91
Apr-15-13	0.625	Mar-31-12	2.500	15	2.19	1.18	−1.07	6.37	0.95	55.44	28.02	−24.54	156.69	0.95	395
Jul-15-13	1.875	Jun-30-13	3.375	15	4.02	1.83	1.77	9.36	0.98	96.27	39.99	49.04	212.92	0.97	353
Jan-15-14	2.000	Dec-31-13	1.500	15	4.38	1.50	2.30	7.86	0.98	103.66	30.32	59.34	173.67	0.97	225
Apr-15-14	1.250	Mar-31-14	1.750	15	1.76	0.30	1.07	2.58	0.85	41.24	6.97	23.77	56.82	0.85	143
Jul-15-14	2.000	Jun-30-14	2.625	15	3.01	0.48	2.04	4.04	0.95	67.20	9.76	46.45	88.47	0.93	101
Jan-15-15	1.625	Feb-15-15	4.000	31	3.36	2.04	1.22	12.52	0.99	55.48	37.53	15.62	214.11	0.99	1204
Jul-15-15	1.875	Aug-15-15	4.250	31	3.61	2.18	1.54	13.24	0.99	56.39	36.45	22.68	207.57	0.99	1079
Jan-15-16	2.000	Feb-15-16	4.500	31	4.01	2.29	1.63	13.14	0.99	59.66	35.41	22.46	206.56	0.99	950
Jul-15-16	2.500	Jun-30-16	3.250	15	3.76	0.59	2.46	4.99	0.98	62.34	9.63	40.75	82.58	0.98	101
Jan-15-17	2.375	Feb-15-17	4.625	31	4.27	2.35	1.51	12.56	0.98	58.22	31.97	18.92	166.06	0.98	698
Jul-15-17	2.625	Aug-15-17	4.750	31	4.43	2.34	1.70	11.20	0.97	57.29	29.83	20.51	143.82	0.97	573
Jan-15-18	1.625	Feb-25-18	3.500	31	5.00	2.51	2.13	12.05	0.98	65.33	31.57	26.99	147.04	0.97	446
Jul-15-18	1.375	Aug-15-18	4.000	31	5.38	2.62	1.78	12.31	0.98	65.78	29.84	21.72	137.22	0.97	320
Jan-15-19	2.125	Feb-15-19	2.750	31	5.32	2.08	2.56	10.14	0.99	68.36	24.60	33.66	123.37	0.99	194
Jul-15-19	1.875	Aug-15-19	3.625	31	3.94	0.78	2.40	5.09	0.99	47.98	9.44	29.05	62.51	0.99	68
Jan-15-25	2.375	Feb-15-25	7.625	31	4.27	3.57	−0.89	23.06	0.98	29.40	23.45	−5.51	138.97	0.98	1342
Jan-15-26	2.000	Feb-15-26	6.000	31	4.90	3.16	−0.06	18.49	0.97	36.85	21.96	−0.50	118.59	0.96	961
Jan-15-27	2.375	Feb-15-27	6.625	31	5.30	3.46	0.54	18.53	0.97	36.42	22.03	3.70	108.12	0.96	709
Jan-15-29	2.500	Feb-15-29	5.250	31	6.84	3.49	1.68	15.22	0.98	48.43	23.69	12.22	103.74	0.98	205

Table 4

Results from Regression of Monthly Changes in Average Basis-Point Mispricing on Systemic, Credit, Confidence, Supply, and Liquidity Factors. This table reports the Newey-West t-statistics for the coefficients in the indicated regressions. VIX denotes the change in the VIX index. Super Senior denotes the change in the spread of the on-the-run 15–30 CDX index tranche. CDX denotes the change in the on-the-run CDX Investment Grade Index. Conf denotes the change in the Consumer Confidence Index. Flows denotes the change in the total assets held by money market mutual funds. TIPS Issue denotes the total notional amount of TIPS issued during the month. Trsy Issue denotes the total notional amount of Treasury notes and bonds issued during the month. Trade Ratio denotes the ratio of total monthly TIPS trading volume by primary dealers to total monthly Treasury note and bond trading volume by primary dealers. Fails denotes the total notional amount of repo failures reported by primary dealers. The superscript ** denotes significance at the five-percent level; the superscript * denotes significance at the ten-percent level. The sample period is June 2004 to November 2009.

Systemic		Credit		Confidence		Supply		Liquidity		
VIX	Super Senior	Swap Spread	CDX	Conf	Flows	TIPS Issue	Trsy Issue	Trade Ratio	Fails	$\bar{R}^2$
1.97*		0.95		−0.16		−1.86*	−1.80*	0.33	2.86**	0.135
1.78*		0.95			−0.83	−1.86*	−1.93*	0.37	4.02**	0.138
0.95			0.30	−0.32		−1.90*	−2.00**	0.38	2.05**	0.124
0.84			0.42		−0.59	−1.89*	−2.11**	0.38	3.07**	0.124
	1.21	1.57		−0.17		−1.58	−1.52	0.14	4.82**	0.151
	1.28	1.55			−1.00	−1.64	−1.72*	0.23	5.77**	0.161
	0.81		0.20	−0.42		−1.81*	−1.97*	0.28	3.31**	0.121
	0.75		0.41		−0.78	−1.80*	−2.16**	0.27	8.28**	0.121

Table 5

Results from the Regression of Monthly Changes in the Absolute Value of TIPS–Treasury Mispricing on Monthly Changes in the Absolute Value of Alternative Arbitrages. This table reports the coefficients and Newey-West t-Statistics from the regression of the monthly changes in the absolute value of TIPS–Treasury mispricing on the lagging, contemporaneous, and leading changes in the indicated explanatory variables. The superscript ** denotes significance at the five-percent level; the superscript * denotes significance at the ten-percent level. The sample period is June 2004 to November 2009.

$$\Delta \text{ Mispricing} = \alpha + \sum_{i=t-2}^{t+2} \beta_i \text{ Arb}_i + \epsilon.$$

Explanatory Variable	Coefficient						t-Statistic						
	α	Arb $_{t-2}$	Arb $_{t-1}$	Arb $_t$	Arb $_{t+1}$	Arb $_{t+2}$	α	Arb $_{t-2}$	Arb $_{t-1}$	Arb $_t$	Arb $_{t+1}$	Arb $_{t+2}$	$\bar{R}^2$
CDS Arbitrage	0.7018	−0.0621	−0.0952	0.3270	0.0004	-0.0371	0.44	−1.34	−1.25	3.64**	0.00	−0.55	0.386
CDX Arbitrage	0.8579	−0.4227	0.4362	0.2662	−0.0439	0.2325	0.59	−2.74**	1.98*	1.90*	−0.18	1.11	0.289

Table 6

Results from the Regression of Monthly Changes in TIPS–Treasury Mispricing on Monthly Hedge Fund Index Returns. This tables reports the coefficients and Newey-West t-statistics from the regression of monthly changes in TIPS–Treasury mispricing on the lagging, contemporaneous, and leading monthly returns on the indicated hedge fund indexes. The superscript ** denotes significance at the five-percent level; the superscript * denotes significance at the ten-percent level. The sample period is June 2004 to November 2009.

$$\Delta \text{ Mispricing} \ = \ \alpha \ + \sum_{i=t-2}^{t+2} \beta_i \text{ Return}_i \ + \ \epsilon.$$

Hedge Fund Index	Coefficient						t-Statistic						
	α	Ret_{t-2}	Ret_{t-1}	Ret_t	Ret_{t+1}	Ret_{t+2}	α	Ret_{t-2}	Ret_{t-1}	Ret_t	Ret_{t+1}	Ret_{t+2}	$\bar{R}^2$
Fixed Income Arb Return	0.0102	1.9364	−0.5506	−2.2664	−0.6103	0.0279	0.66	1.93*	−0.50	−3.62**	−0.52	0.04	0.141
Convertible Arb Return	0.0149	1.1255	0.1022	−3.0779	0.3795	-0.1268	0.96	1.90*	0.11	−2.80**	0.61	−0.15	0.182
Merger Arb Return	0.0465	2.6145	−5.8550	−0.5706	−3.8181	0.4253	3.47**	1.30	−1.79*	−0.26	−1.51	−0.24	0.141