An Empirical Analysis of the Liquidity and Tax Disadvantage of TIPS and Their Effect on Treasury Borrowing Costs

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Abstract

Treasury Inflation Protected Securities (TIPS) are unique in that they are inflation-indexed, default risk-free bonds. However, TIPS are not free from all risk— they are still subject to liquidity risk (due to a thin secondary market) and tax disadvantage risk (due a specific tax liability in their cash flows).
In this thesis, I demonstrate through various empirical models that liquidity and tax disadvantage premia are priced into TIPS yields in order to compensate for these risks. I determine that since mid-2004 the TIPS liquidity premium is relatively stable and averages 27 bp. My results also weakly support a time-variant TIPS tax disadvantage premium that averages 56 bp over the same time period. Furthermore, I find that these two premia are principally driven by the uncertain volatility of expected future inflation. Consequently, as a result of these premia, it is on average 3 bp more expensive for the Treasury to issue a TIPS rather than a conventional nominal bond, which has cost the Treasury over $221 million. So why does the Treasury continue to issue TIPS if they do not in fact lower borrowing costs, as was the intention of the program? It is possible that TIPS offer several nonmarketable public benefits that offset their additional cost, thus making the program worthwhile for the Treasury and market participants alike.

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I. Introduction

In January 1997, the United States Treasury began issuing Treasury Inflation Protected Securities (TIPS). Unlike conventional Treasury bonds, which are nominal in nature, TIPS are real bonds, as both their coupon and principal payments are linked to the Consumer Price Index (CPI). As of December 2011, the Treasury had over $738 billion in TIPS outstanding, constituting 7.43% of the total marketable Treasury debt outstanding.[2] Thus, TIPS constitute a small, yet nonetheless very significant, portion of the total United States Treasury debt market.

Though conventional Treasury bonds are generally considered "risk-free" since they are not subject to default risk, they are still in fact somewhat risky. Most notably, scholars have confirmed that nominal Treasury bond yields contain an inflation risk premium, since unexpected future inflation can wipe out the purchasing power of future nominal payments. (Grishchenko and Huang, 2008; Söderlind, 2011) This inflation risk premium constitutes an increase in Treasury borrowing costs that can be avoided by issuing a security with real cash flows. Thus, the rationale of the TIPS program was simple—that by developing the a real, inflation-indexed, default risk-free security, the Treasury could lower borrowing costs as well as secure several benefits for both investors and policymakers.

Issuing TIPS would reduce Treasury borrowing costs in two ways. First, since TIPS are real bonds, they would not require the inflation risk premium. This, in theory, would lower the offering yield of TIPS, thus making them cheaper for the Treasury to issue. Second, the TIPS program could actually lower the inflation risk premium that must be paid on nominal bonds. This is because inflation risk-averse investors, who would require a higher inflation risk premium, would exit the nominal bond market in order to buy TIPS. This would leave only inflation risk-tolerant investors, who require a lower inflation risk premium, in the nominal Treasury bond market. (Roll, 1996) Another potential benefit of the TIPS program is that TIPS would provide risk-averse investors with an asset that would reduce inflation risk. This would allow such risk-averse investors to secure a real rate of return over the lifetime of the security, and hence protect themselves against unexpected future inflation. (Sack and Elsasser, 2004) Thus, this property could potentially improve the efficiency of risk sharing in the economy. Furthermore, the TIPS program would provide an auxiliary benefit to actors in the national political economy, since it would reveal a rough measure of expected inflation to both market

2 Monthly Statement of the Public Debt, December 2011. 2011. U.S. Department of the Treasury, Bureau of the Public Debt. http://www.treasurydirect.gov/govt/reports/pd/mspd/2011/opds122011.pdf (accessed February 8, 2012)

participants and policymakers.

Despite these various benefits that result from issuing inflation-indexed bonds, TIPS in particular are very intriguing since they have specific properties that prompt two important costs to arise. First, even though a large amount of TIPS have been issued to date, this amount still pales in comparison to the size of the nominal Treasury bond market. The result is that TIPS have a rather small market for secondary trading. (Christensen and Gillan, 2011b) Additionally, TIPS tend to be bought by risk-adverse "buy-and-hold" investors, which causes trading on the secondary market to be quite thin. (Shen, 2009) These secondary market characteristics cause serious liquidity concerns to arise with TIPS. As a result, I argue that TIPS yields must include a liquidity premium that compensates investors for this liquidity risk. Second, and perhaps most interestingly, TIPS have a specific tax liability that is not present in nominal bonds. As a result, I argue that a tax disadvantage premium must also be included in TIPS yields, which compensates investors for this tax liability. I believe that these liquidity and tax issues significantly influence TIPS yields, perhaps bringing the net benefits of the TIPS program into question. Therefore, the opportunity to add a new empirical study that is focused on these two liquidity and tax topics to the current TIPS literature is quite appropriate.[3]

Though TIPS have a relatively short history, they have been studied rather extensively. Numerous economists have studied TIPS liquidity in various theoretical and empirical frameworks, and have confirmed the existence of a TIPS liquidity premium. However, the majority of this literature was written before 2009, and is thus unable to comment on the dynamics of TIPS liquidity in the recent financial crisis. This topic is particularly interesting given that between the fourth quarter of 2008 and the first quarter of 2009, TIPS yields surged upward[4] while the yields on nominal Treasury bonds plunged downward.[5] I believe that this phenomenon is due in large part to a fundamental increase in the TIPS liquidity premium, as inventors likely demanded a higher premium in order to hold illiquid TIPS during a time of financial crisis.

Unlike the liquidity characteristics of TIPS, very few scholars have examined the taxation of TIPS either theoretically or empirically. Though a few economists have concluded that the TIPS tax disadvantage premium is indeed priced into TIPS yields, I have found only two papers that have empirically

3 This paper is yield-centric and written from the viewpoint of the government. Therefore, all "premia" refer to increases in yield, and represent an increase in borrowing costs to the government. These are equivalent to price discounts from the perspective of investors, which is consistent with the nomenclature of related works.

4 10-Year Treasury Inflation-Indexed Security, Constant Maturity. 2011. Federal Reserve Bank of St. Louis, Federal Reserve Economic Data.

5 10-Year Treasury Constant Maturity Rate. 2011. Federal Reserve Bank of St. Louis, Federal Reserve Economic Data. http://research.stlouisfed.org/fred2/series/DGS10 (accessed March 24, 2011)

studied the taxation of TIPS. I believe that these two papers comprise a lack of empirical evidence regarding TIPS taxation, which I consider to be a significant shortcoming in the TIPS literature.

Therefore, the motivation for this paper is three-fold. First, I would like to thoroughly examine TIPS liquidity; I plan to determine precisely what influences the TIPS liquidity premium, as well as understand exactly why and how it increased so rapidly during the recent financial crisis. Second, I would like to eliminate the shortcoming in the TIPS taxation literature by empirically supporting the existence of the TIPS tax disadvantage premium. Since after-tax returns are what really matter to investors, the existence of the TIPS tax disadvantage premium could have a significant impact on investor behavior. Third, given these two premia, I believe it would be very interesting to see if the TIPS program has in fact lowered Treasury borrowing costs in an accounting framework, as was intended. I plan to accomplish all of this by completing a rigorous and specialized empirical analysis of the TIPS program since mid-2004.

Analogous to its motivation, this paper follows a three-step process. First, I show that the TIPS liquidity and tax disadvantage premia are in fact priced into TIPS yields through a specialized empirical model. Second, using a variation of this model, I calculate the magnitude of these two premia. Third, I use these calculated values to analyze whether the TIPS program has in fact lowered Treasury borrowing costs since mid-2004.

The rest of this paper is organized as follows. Section 2 provides a broad overview of TIPS. Section 3 reviews the relevant literature. Sections 4, 5 and 6 outline my methodology, describe my data, and present my hypotheses, respectively. Section 7 presents my results and discusses their significance, and Section 8 provides concluding remarks.

II. TIPS Overview

2.1 Conventional Bond Summary

A bond is a contract between two parties where the lender loans money (the principal) to the borrower at a specific interest rate (the coupon rate), for a specific period of time (the maturity). Once the bond matures, the borrower must repay the principal to the lender. A bond can be one of two types: a zero-coupon bond, where the principal plus accrued interest is all paid at the maturity date (via capital appreciation), or a coupon bond, where interest (coupon) payments are made at predetermined fixed intervals and only the principal is repaid at maturity.

Conventional Treasury bonds are coupon bonds, and they pay interest at semiannual intervals. The price of a bond is equal to the present value of its future cash flows, so the price of a conventional Treasury bond is:

$$P = \left(\sum_{t=1}^{2T} \frac{\frac{C}{2}}{(1+\frac{r}{2})^t} \right) + \frac{F}{(1+\frac{r}{2})^{2T}} \quad (1)$$

where P = the price of the bond, C = the fixed annual coupon payment, F = the face value of the bond, r = the yield to maturity, and T = the maturity of the bond.

When the coupon rate is equal to the yield to maturity, the price of the bond is equal to its face value (it is a par bond). When the coupon rate is less than the yield to maturity, the price of the bond is less than its face value (it is a discount bond). When the coupon rate is greater than the yield to maturity, the price of the bond is greater than its face value (it is a premium bond).

The yield of a nominal bond is made up of three parts: the real yield, the rate of expected inflation, and an inflation risk premium. The inflation risk premium compensates investors for the risk that future inflation will be greater than expected inflation, and thus decrease the purchasing power of their future cash flows. (Grishchenko and Huang, 2008; Söderlind, 2011)

2.2 Properties of TIPS

The defining characteristic that differentiates TIPS from conventional Treasury debt is that both the coupon and principal payments of TIPS are inflation-indexed. Thus, TIPS constitute real debt, as the purchasing power (not the dollar amount) of coupon and principal payments remains constant. Conventional Treasury debt, on the other hand, is nominal debt, since the dollar amount (not the purchasing power) of coupon and principal payments remains constant.

The inflation-indexation of TIPS occurs through linking the coupon and principal payments to the Consumer Price Index (CPI). TIPS are based on the Canadian Real Return Bond, (Roll, 1996) and are specifically structured in the following way:

When a TIPS is issued, it is linked to the concurrent level of the CPI. TIPS are issued with fixed, real coupon rates, and make coupon payments semiannually. Accordingly, TIPS are indexed to the CPI semiannually, meaning that every six months the face value of the TIPS is adjusted for inflation (or deflation). This indexation occurs by creating an “index ratio” of CPI values between the date of indexation and the date of issuance. That is, every six months, an index ratio is created by dividing the current CPI level by the CPI level at issuance. This index ratio is then multiplied by the initial face value of the TIPS, resulting in the new inflation-adjusted face value. This semiannual adjustment accounts for both inflation (if the CPI level increases) as well as deflation (if the CPI level decreases). The coupon *rate* of TIPS is fixed, but the coupon *payment* varies with the face value, which adjusts semiannually in the manner described above. So, coupon payments effectively move with inflation and deflation as well.

Upon maturity, the initial face value of the TIPS is repaid, as well as the accrued inflation adjustment, so long as it is positive. Specifically, at the maturity date, the TIPS will pay the inflation-adjusted face value if the index ratio at maturity is greater than one, or just the initial face value if the index ratio at maturity is less than or equal to one. Therefore, TIPS offer deflation protection since the *final* repayment of principal cannot be less than the initial principal (semiannual coupon payments *can* be adjusted downward due to periodic deflation, however). Therefore, this deflation protection of TIPS is akin to a put option on inflation with a strike price of zero. (Sack and Elsasser, 2004)

These basic mechanisms of TIPS are best clarified by example. The following example is simplified for ease of comprehension. Say that the Treasury issues a TIPS at par in January of 2010, with face value of $1000 and a 1% coupon rate. The CPI in January of 2010 was 216.687. Six months later in June 2010, the TIPS will be indexed for inflation for the first time. The CPI in June 2010 was 217.965. So, the index ratio in June 2010 is 217.965 / 216.687 = 1.0059. This means that the inflation-adjusted face value for June 2010 is (1.0059)($1000) = $1005.90. So, the June 2010 coupon payment will be (1%)($1005.90) = $10.06. In December 2010, the TIPS will be indexed for inflation for the second time. The CPI in December 2010 was 219.179. So, the index ratio in December 2010 is 219.179 / 216.687 = 1.0115. As a result, the December 2010 inflation-adjusted face value rises again, and is now (1.0115)($1000) = $1011.50. So, the December 2010 coupon payment will be (1%)($1011.50) = $10.12. This process will continue until maturity. Note that if the CPI decreases, the inflation-adjusted face value will decrease, and the coupon payments will also be adjusted downward because of this deflation. At maturity, the repayment of principal will consist of the inflation-adjusted face value (index ratio at maturity x $1000) if the index ratio is greater than one, or the initial face value ($1000) if the index ratio is less than or equal to one.

Using the present value approach, the price of a TIPS is found according to the following formula:

$$P = \left(\sum_{t=1}^{2T} \frac{\frac{E\left[C_t^A \middle| \pi_t^e\right]}{2}}{(1+\frac{r}{2})^t} \right) + \frac{E\left[F_{2T}^A \middle| \pi_t^e\right]}{(1+\frac{r}{2})^{2T}} \quad (2)$$

where P = the price of the bond, C_t^A = the annual, inflation-adjusted coupon payment at time t, $F_t^A = F_{t-1}^A(1+\pi_t)$ = the inflation-adjusted face value of the bond at time t, r = the yield to maturity, T = the maturity of the bond, π_t^e = expected inflation at time t, and π_t = realized inflation at time t. This looks very much like the pricing equation of a conventional nominal bond, except that the coupon and principal payments are now expectations conditional on inflation beliefs. This is because, as explained above, these payments will adjust regularly for changes in future inflation. Since future payments are unknown, TIPS are priced based on the expectations of these payments, which are in turn based on beliefs about future inflation.

Though TIPS are a good security for protecting future real wealth, they have several drawbacks that prevent them from *fully* protecting against inflation. First, there is a 2.5-month indexation lag between TIPS and the CPI. This is simply due to the fact that 2.5 months represents the minimum indexation lag possible given the timing of CPI data releases. (Sack and Elsasser, 2004) So, in the earlier simplified example, the coupon first coupon payment made in June 2010 would in reality be based on the index ratio from mid-March. Consequently, investors in TIPS are left unprotected from inflation in this rolling 2.5-month period. As a result, a slight inflation risk premium might actually exist in TIPS yields, in order to protect investors from this rolling 2.5-month unprotected window. However, this effect is likely to be minimal given the long-term investment horizon of TIPS. Hence, for the rest of this paper I assume TIPS to be perfectly indexed (I assume no lag period) for simplicity.

Second, and perhaps most significantly, TIPS are subject to different tax rules than conventional Treasury bonds. Assuming that you hold both securities until maturity, you must pay income tax on the coupon payments you receive from conventional Treasury bonds. On TIPS, you must pay this income tax on coupon payments, plus you must also pay income tax on the semiannual inflation adjustments to the initial principal, even though you do not actually receive this inflation accrual until maturity. Roll (1996) argues that this taxation rule exists to generate liquidity in the TIPS market. This so-called "phantom tax" on the inflation adjustment of TIPS is what leads them to be described as "tax disadvantaged." (Hein and Mercer, 2006) I will focus very heavily on this taxation issue in this paper. Particularly, I will verify if TIPS are actually "tax-disadvantaged" by determining if a tax disadvantage premium is in fact priced into TIPS yields.

Abstracting from Hein and Mercer (2006), the after-tax price of a TIPS using the present value approach is found according to the following formula:

$$P = \left(\sum_{t=1}^{2T} \frac{\frac{E\left[C_t^A(1-\tau)-\left(F_t^A - F_{t-1}^A\right)(\tau) \middle| \pi_t^e\right]}{2}}{\left(1+\frac{r}{2}\right)^t} \right) + \frac{E\left[F_{2T}^A \middle| \pi_t^e\right]}{\left(1+\frac{r}{2}\right)^{2T}} \tag{3}$$

where P = the price of the bond, C_t^A = the annual, inflation-adjusted coupon payment at time t, $F_t^A = F_{t-1}^A\left(1+\pi_t\right)$ = the inflation-adjusted face value of the bond at time t, r = the after-tax yield to maturity, T = the maturity of the bond, π_t^e = expected inflation at time t, π_t = realized inflation at time t, and τ = the income tax rate.

It is also worth noting here that there is a significant difference in the nominal payment flow of TIPS and conventional Treasury bonds. Sack and Elsasser (2004) point out that TIPS have a considerably higher duration than standard nominal bonds. This is because TIPS pay a lower coupon rate than conventional Treasury bonds (since TIPS pay a real rate whereas conventional Treasuries pay a nominal rate) and also because the vast majority of the inflation adjustment on TIPS comes at maturity. However, Wilcox (1998) notes that this higher duration does not necessarily translate into higher price volatility for TIPS, since they do not respond to nominal economic shocks.

Finally, TIPS also provide informational content to independent policymakers and market participants. The yield spread between TIPS and nominal bonds, called "breakeven inflation," is widely regarded as a basic measure of expected inflation. However, I argue in this paper that this variable is very crude, since I believe that there are many different premia embedded in this value. Accordingly, I believe that breakeven inflation is not a reliable measure unless you explicitly account for these premia.

2.3 The TIPS Market

Since 1997, TIPS have been offered in 5, 10, 20, and 30 year denominations. Currently, only the 5, 10, and 30 year maturities are offered. TIPS are issued in an auction format that is equivalent to that of nominal Treasury bonds. Reopenings of slightly different maturities have been very frequent throughout the history of the TIPS program. A reopening, which the Treasury also utilizes with nominal security auctions, is the additional issuance of a previous bond, with the same coupon rate, payment schedule, inflation adjustments, and maturity date, but usually at a different yield. (Roll, 1996) The reopening is an effective method of reducing Treasury borrowing costs because it eliminates the adverse effects of abnormally large bids, and can stop prices from "drifting out of line." (Roll, 1996)

Furthermore, Roll (1996) argues that given a continuous term structure of real interest rates, if the real yield at one maturity were to drop, then the Treasury could effectively lower borrowing costs by reopening a previous inflation-indexed bond of that maturity and secure the new, lower real yield. Conversely, if the real yield at one maturity were to increase, the Treasury could again effectively lower relative borrowing costs by repurchasing bonds at that maturity, while financing this operation by reopening previous bonds at other maturities.

Though auctions for TIPS and nominal Treasury bonds are identical, the secondary markets for the two securities are markedly different from one another. Primarily, the secondary market for TIPS is characterized by significantly reduced liquidity as compared to the secondary market for nominal Treasury bonds. Shen (2009) argues that this reduced secondary market liquidity for TIPS is the result of three factors: the inability of investors to evaluate future cash flows, the fact that TIPS are poor candidates for hedging purposes, and the difference in preferences between investors in TIPS and nominal Treasury bonds.

First, Shen (2009) states that because TIPS have coupon and principal payments that vary with inflation, investors struggle to price these future payments. That is, investors struggle to form expectations of future coupon and principal payments given beliefs about future inflation. Because of this inability to accurately predict future cash flows, fewer investors are willing to trade TIPS, resulting in reduced secondary market liquidity. Second, Shen (2009) argues that because TIPS have a reduced risk exposure profile, they are not an effective hedging tool. As a significant percentage of daily fixed-income trading volume is the result of hedging needs, TIPS will not be traded as actively as nominal Treasury bonds, thus again resulting in reduced secondary market liquidity. Third, Shen (2009) states that because TIPS are free from inflation risk, they are particularly appealing to investors with long-term horizons, especially "those whose future obligations are tied to inflation, such as pension funds and insurance companies." (Shen 2009) These are the types of investors though, that usually hold securities until maturity, and do not trade them actively. Therefore, these investor preferences also result in reduced secondary market liquidity for TIPS.

Having a liquid secondary market is important for TIPS because in its absence, a significant liquidity premium will arise that can raise TIPS yields. Since most of the reduction in borrowing costs from TIPS comes from not having to pay an inflation risk premium, a substantial liquidity premium can potentially wipe out the gains from this inflation risk premium savings. If in fact, the liquidity premium is greater than the inflation risk premium, than it actually costs the Treasury more to issue a TIPS rather than a nominal bond. In this paper, I study the liquidity premium of TIPS in great depth; I determine what exactly causes this liquidity premium, and also measure its magnitude. I then compare it (along with the tax disadvantage premium) to the inflation risk premium in order to determine if the Treasury has in fact reduced borrowing costs through the TIPS program.

III. Literature Review

3.1 TIPS Liquidity

Many economists have studied TIPS liquidity, and consequently have empirically confirmed the existence of the TIPS liquidity premium. Pflueger and Viceira (2011a) decompose the returns of TIPS and nominal bonds into liquidity, market segmentation, real interest rate, and inflation risk. Their study period ranges from 1999-2009, and thus does not include the majority of recent financial crisis. They regress a vector of three liquidity proxies (the 10 year off-on-the-run nominal Treasury spread, the GNMA spread, and the relative TIPS transaction volume in the secondary market) on breakeven inflation in order to determine the size of the TIPS liquidity premium. Ultimately, they find a systematic, time-variant TIPS liquidity premium with an average range of 40-120 bps (not including spikes to over 200 bps in 2008 during the beginning stages of the financial crisis) that explains up to 67% of the time-series variance of breakeven inflation.

Since TIPS have no inflation risk premium, breakeven inflation and expected inflation must be equal to each other in the absence of additional premia. Shen (2006) studies the difference between these two variables, and defines it as the TIPS liquidity premium. He then regresses this difference on a vector of liquidity proxies (the ratio of 5-10 year TIPS outstanding to 2-10 year nominal Treasuries outstanding, the log of primary dealers' TIPS transaction volume, and the 10 year off-on-the-run nominal Treasury spread) in order to determine the size of the TIPS liquidity premium. Ultimately, he finds a time-variant TIPS liquidity premium that has gradually declined since 2004, due to the deepening of the TIPS market.

Some scholars have determined the size the TIPS liquidity premium using pricing models. D'Amico, Kim, and Wei (2009) estimate a multifactor, no-arbitrage, term structure model using both TIPS and nominal Treasury bond yields. With this model, they find that the real rate, expected inflation, and the inflation risk premium are not enough to fully characterize breakeven inflation. They then derive an additional affine pricing model that accounts for reduced TIPS liquidity in order to calculate the TIPS liquidity premium. Ultimately, they find that the TIPS liquidity premium has averaged 1% since 1999, and was decreasing from 2005-2009.

Alternatively, other economists have used a model-independent approach to determine the size of the TIPS liquidity premium. Christensen and Gillan (2011b) derive the maximum range for the TIPS liquidity premium by studying how breakeven inflation corresponds to inflation swap rates. Since these two measures should be equal in the absence of other premia, they define any inequality to be the result of the TIPS liquidity premium. Using a few simplifying assumptions, they find that from 2005-2010 the maximum TIPS liquidity premium ranged from 30-44 bps, depending on maturity. Furthermore, they find that this range correlates well with the findings Pflueger and Viceira (2011a) and D'Amico, Kim, and Wei (2009), suggesting common causes of time-variation in TIPS liquidity. However these three papers differ significantly in the magnitude of the TIPS liquidity premium, thus leaving its effect on TIPS yields as well as Treasury borrowing costs unresolved.

Others have sought to determine which variables are the proper proxies for the TIPS liquidity premium. Kajuth and Watzka (2011) presume the existence of a TIPS liquidity premium based on past literature, and analyze which comparable measures of liquidity best characterize the pricing of TIPS. They define the TIPS liquidity premium as expected inflation minus breakeven inflation plus the inflation risk premium. After determining the inflation risk premium through a GARCH model, they calculate the TIPS liquidity premium and regress that value on the 10-year off-on-the-run nominal Treasury spread, the amount of TIPS outstanding, and TIPS transaction volume. Ultimately, they find that the 10-year off-on-the-run nominal Treasury spread is a good proxy for the TIPS liquidity risk premium.

Söderlind (2011) follows a very similar process as Kajuth and Watzka (2011), finding values from the Survey of Professional Forecasters (SPF) to be a good measure of inflation uncertainty rather than a GARCH model. He too finds the 10-year off-on-the-run nominal Treasury spread to be a good proxy for the TIPS liquidity premium, but additionally finds the VIX to be a significant TIPS liquidity proxy as well.

3.2 TIPS Taxation

A few scholars have studied the taxation of TIPS through a theoretical framework, and hypothesize that TIPS should in fact be tax disadvantaged. Reinhart and Keeling (2004) outline the taxation mechanics of TIPS, explaining that both the interest payments received as well as the inflation adjustments to the principal are taxable at the federal income tax rate each year. Since an investor in TIPS does not receive the inflation adjustments to the principal until maturity, yet must pay income tax on them each year, these inflation adjustments to the principal are sometimes called "phantom income," and likewise their taxation is referred to as the "phantom tax." They then point out that due to this phantom taxation method of TIPS, they can potentially have negative cash flows "in [very] high inflation environments," (Reinhart and Keeling, 2004) as the taxation of the phantom income from the inflation adjustment may be greater than the after-tax coupon payment. They conclude that TIPS should be held in tax-deferred accounts to overcome this tax disadvantage.

Wilcox (1998) illustrates that the taxation of TIPS adversely affects their ability to provide inflation protection. This is because the taxation of the inflation adjustments to the principal as ordinary income in each year makes their ultimate inflation protection imperfect. He goes on to show that the "real value of the tax liability rises with the rate of inflation, [and thus that] the real after-tax return to a taxable investor falls with the rate of inflation." (Wilcox, 1998) He does note though, that even though the specific taxation of TIPS makes their inflation protection imperfect, the after-tax inflation protection that it does offer is nonetheless very significant.

Even fewer economists have studied the taxation of TIPS empirically, and have concluded that their yields do include a tax disadvantage premium (which offsets their tax disadvantaged cash flows by providing a higher overall after-tax return). Hein and Mercer (2006) calculate the after-tax returns of TIPS and nominal Treasury bonds of the same maturity. They find that TIPS do not underperform nominal Treasury bonds after accounting for taxes. Ultimately, they conclude that market participants price the tax treatment of TIPS into TIPS yields, resulting in the existence of the tax disadvantage premium. Moreover, they also show that because of this tax disadvantage premium, the possibility of a TIPS investor receiving a negative cash flow due to the phantom tax of inflation accruals is very small.

Roll (2004) studies the characteristics of TIPS returns. Holding price constant, he derives the effect that changes in expected inflation have on pre-tax real yields of TIPS, and finds that TIPS yields must adjust directly to changes in expected inflation in order to maintain the same level of taxable demand. Hence, he shows that through this positive relationship between changes in expected inflation and changes in pre-tax real yields, a tax disadvantage premium is in fact priced into TIPS yields, which compensates investors for future phantom taxes. Finally, Roll determines that the effective marginal tax rate of TIPS is lower than the income tax rate, and argues that this is due to substantial institutional holdings of TIPS in tax-deferred accounts.

As previously mentioned, I have been able to find only these two papers that empirically test the tax disadvantage of TIPS. Accordingly, I make one of the prime objectives of this paper to add to this literature by empirically determining if the TIPS tax disadvantage premium is in fact priced into TIPS yields.

3.3 The TIPS Program and Treasury Borrowing Costs

There is great debate amongst economists whether the TIPS program has actually reduced Treasury borrowing costs, as was intended. Several scholars argue that the TIPS program has indeed reduced Treasury borrowing costs. Christensen and Gillan (2011b) initially study the liquidity premium of TIPS (since they note that TIPS fail to match the trading liquidity of nominal Treasury bonds), and subsequently examine how the size of this liquidity premium affects Treasury borrowing costs. Following from Christensen and Gillan (2011a), they use inflation swap rates and breakeven inflation to determine the sizes of the liquidity and inflation risk premia. Ultimately, they find that in a no-arbitrage framework with perfect markets, the inflation risk premium (which the Treasury does not have to pay on TIPS, assuming perfect indexation) has been large enough to offset the TIPS liquidity premium. As a result, they determine that since 2004, TIPS have lowered Treasury borrowing costs.

Sack and Meyer (2006) follow a different approach and examine the first TIPS issued (and reopened) in 1997. They calculate the ex-post borrowing cost of this matured series, and analyze if it was in fact lower than the ex-post borrowing cost of a comparable nominal Treasury bond. They determine that this first TIPS was issued during a period of high breakeven inflation, and that realized CPI values turned out to be less than breakeven inflation over the maturity of the TIPS. Given the higher relative duration of TIPS as compared to nominal Treasury bonds, this spread between breakeven inflation at issuance and realized CPI at maturity represents significant yield savings. Ultimately, they find that the Treasury saved over $1.1 billion on the first TIPS issued in 1997.

Conversely, various other scholars argue that the TIPS program has actually raised Treasury borrowing costs. Fleckenstein, Longstaff, and Lustig (2010) examine what they call the “TIPS-Treasury bond puzzle”—that an inflation-swapped TIPS issue does not accurately replicate the cash flows of a nominal Treasury bond. After regressing the difference between these two cash flows on several state variables and security characteristics (such as liquidity), they determine that this mispricing represents a significant arbitrage opportunity and that it is caused by supply factors. Ultimately, they find that TIPS cost the Treasury significantly more to issue than conventional nominal bonds.

Sack and Elsasser (2004) follow the same methodology as Sack and Meyer (2006). They show that as a result of declining breakeven inflation rates over time, realized CPI values are likely to exceed breakeven inflation going forward. This will result in significant relative costs to the Treasury from issuing TIPS over nominal debt, which they estimate at about $12 billion by 2005.

Roush (2007) analyzes the costs and benefits to the Treasury of the TIPS program in its entirety. Ultimately, she finds that there were very large costs at the beginning of the TIPS program, due mainly to market illiquidity, but that as the program progressed, it "yielded substantial net savings [to the Treasury], as investors were willing to [accept a lower yield in order] to insure against inflation risk." (Roush, 2007) But ultimately, she finds that the market illiquidity costs at the beginning of the program outweigh its latter benefits, resulting in the TIPS program raising Treasury borrowing costs overall.

It is worth nothing here that these are *accounting* costs and benefits. As Campbell and Shiller (1996) point out, payments on government debt constitute a direct transfer of wealth between taxpayers and bondholders, so there is no net change in the welfare of society as a whole (though distributional concerns may arise).

Accordingly, some other economists focus on the *economic*, rather than accounting, costs and benefits of the TIPS program, and conclude that the overall impact of the TIPS program is inconclusive. Campbell, Shiller, and Viceira (2009) study changes in short-term real interest rates, systematic bond risks, and liquidity risk, and find that though TIPS raise borrowing costs ex-post, they should lower borrowing costs ex-ante because they provide risk-averse investors economically significant and "desirable insurance against future variation in real interest rates." (Campbell, Shiller, and Viceira, 2009)

Dudley, Roush, and Ezer (2009) echo this sentiment; they also find that TIPS have resulted in high ex-post realized returns, and thus higher relative borrowing costs. However, they argue that TIPS provide significant ex-ante economic benefits to both investors and policymakers, such as market measures of expected inflation and the real interest rate. Thus, they argue that TIPS have meaningful long-run economic benefits for the government as a whole (including the independent Federal Reserve).

Due to the great debate on this subject, I make another one of the prime objectives of this paper to perform my own calculations of whether the TIPS program has indeed lowered Treasury borrowing costs in an accounting framework, as was intended.

IV. Methodology

Given the ongoing debate about both the magnitude of the TIPS liquidity premium as well as the existence of the TIPS tax disadvantage premium, I believe that a carefully constructed empirical analysis of TIPS yields will provide meaningful results that will significantly contribute to the literature regarding these two issues. Furthermore, this study will permit the analysis of whether the TIPS program has actually benefitted the Treasury by lowering borrowing costs.

As aforementioned, this is a three-part project: the first part of this study consists of confirming the existence of both the TIPS liquidity and tax disadvantage premia, and the second part consists of calculating their magnitudes through various empirical models. The third part of this thesis consists of using these values to measure the inflation risk premium of nominal bonds, in order to analyze the overall effect of the TIPS program on Treasury borrowing costs.

4.1 The TIPS Liquidity Premium

In order to study the liquidity of TIPS, I use a no-arbitrage framework. I construct one dependent variable that measures the pricing differential between an actual TIPS and a synthetic TIPS, and another that measures the pricing differential between a TIPS and a nominal Treasury bond while controlling for inflation expectations. This way, using nominal Treasury bonds as a benchmark, any deviations in the pricing of these two variables from the no-arbitrage criterion can be attributed to TIPS illiquidity. I call the two dependent variables that I construct SwapSpread and YieldSpread.

SwapSpread is equal to the price differential (quoted as a yield) between an actual TIPS and a synthetic TIPS. A synthetic TIPS is constructed by buying a nominal Treasury bond together with an inflation swap of the same maturity. Thus,

$$SwapSpread_i = TIPS_i - \left(TBond_i - SwapYield_i\right) \tag{4}$$

where $TIPS_i$ = the offering yield of a TIPS, $TBond_i$ = the offering yield of an analogous nominal Treasury bond, and $SwapYield_i$ = the price (quoted as a yield) of an inflation swap with the same maturity as both the TIPS and the corresponding nominal Treasury bond. A synthetic TIPS has a payment structure that is near identical to that of an actual TIPS. There is only one difference: since inflation swaps are by convention zero-coupon swaps, the coupon payments of this synthetic TIPS will not vary with realized inflation as they do on an actual TIPS. Since TIPS have a very high Macaulay duration, meaning that the final payment of the inflation-adjusted face value has much more influence on the price of a TIPS than the relatively small coupon payments, I assume that this one difference effectively has zero effect on the pricing of a TIPS. Hence, the payment structure of these synthetic TIPS should be effectively identical to the payment structure of an actual TIPS. Likewise, there is no difference in default risk, inflation risk, or compounding period between the two securities. So, assuming no-arbitrage, SwapSpread should always be equal to zero. Therefore, a positive value of SwapSpread represents a deviation from the no-arbitrage criterion that can be attributed to TIPS illiquidity. I regress several TIPS liquidity proxies on SwapSpread using matrix OLS in order to empirically confirm the existence of the TIPS liquidity premium, determine exactly what is causing this premium, as well as its average magnitude.

YieldSpread is equal to the price differential (quoted as a yield) between a TIPS and an analogous nominal Treasury bond. Thus,

$$YieldSpread_i = TIPS_i - TBond_i \tag{5}$$

where $TIPS_i$ = the offering yield of a TIPS and $TBond_i$ = the offering yield of a corresponding nominal Treasury bond of the same maturity. Hence, YieldSpread is also equal to (-1)(breakeven inflation). I include the price (quoted as a yield) of an inflation swap of the corresponding maturity (SwapYield) as one of the independent variables in regressions where YieldSpread is the dependent variable, in order to control for inflation expectations. This is because in theory, the price of an inflation swap should be equal to breakeven inflation, or equivalently (-1)(YieldSpread). Thus, since TIPS and nominal Treasury bonds have the same default risk and compounding period, and since the inclusion of SwapYield as an independent variable in these regressions effectively controls for inflation risk, the regression coefficients of the TIPS liquidity proxies should be equal to zero. Therefore, after controlling for appropriate inflation expectations, positive coefficients of the TIPS liquidity proxies again reveal sources of TIPS illiquidity. I regress the same TIPS liquidity proxies on YieldSpread using matrix OLS in order to once again empirically confirm the existence of the TIPS liquidity premium, determine exactly what is causing this premium, as well as its average magnitude.

4.4.1 TIPS Liquidity Risk Proxies

In order to empirically assess the TIPS liquidity premium, I first need to select the proper proxies for TIPS liquidity. After consulting with both the relevant literature as well as current fixed income asset managers, I have selected three proxies for TIPS liquidity: the 10-year off-on-the-run nominal Treasury spread, the GNMA spread, and the VIX.

The 10-year off-on-the-run nominal Treasury spread is equal to the yield difference between 10-year off-the-run and on-the-run nominal Treasury bonds. Off-the-run bonds are previously issued bonds, whereas on-the-run bonds are the most recently issued bonds. For example, a 20-year bond issued

10 years ago and a newly issued 10-year bond both have the same payment structures (all else equal), and if they have the same coupon rate, then they should theoretically trade at the same yield in the secondary market. But in fact, on-the-run bonds are more liquid than off-the-run bonds, and as a result, off-the-run bonds tend to include a liquidity premium. This makes off-the-run bonds trade at a higher yields in the secondary market. As a result, the off-on-the-run spread is generally positive. Thus, since off-the-run bonds have a thinner secondary market than on-the-run bonds, I believe that they are a good proxy for the secondary market trading characteristics (and thus liquidity) of TIPS. I choose the 10-year spread since it accounts for the general long-term nature of TIPS, without discounting the recent prominence of the medium-term five-year TIPS. I call this variable OffOnSpread in my regressions.

The Government National Mortgage Association (GNMA) spread, more colloquially known as the Ginnie Mae spread, is equal to the yield difference between a generic 30-year, 6% coupon mortgage-backed security (MBS) and a 30-year nominal Treasury bond. This spread is option-adjusted and is also adjusted for prepayment risk using the Bloomberg Prepayment Model, as mortgages can be repaid in full prior to their maturity. Since GNMA is fully owned and operated by the federal government's Department of Housing and Urban Development, their MBS are backed by "the full faith and credit guaranty of the United States Government."[6] So, because GNMA MBS have no default risk, their higher yields must be due to liquidity—either GNMA MBS must have a thinner market than nominal Treasury bonds, or they must have a smaller investor base than nominal Treasury bonds. In both cases, this yield premium on GNMA bonds is due to their illiquidity relative to nominal Treasury bonds. Thus, since GNMA MBS are default risk-free as well as less liquid than nominal Treasury bonds, I believe that the GNMA spread is a good proxy for TIPS liquidity. I call this variable GNMASpread in my regressions.

The Chicago Board Options Exchange Market Volatility Index (VIX) measures the "implied volatility of S&P 500 stock index option prices."[7] Thus, it is a popular measure of both "investor sentiment and [short-term] market volatility."[8] I would like to note that the VIX is quoted in percentage points, not dollars. Thus, a VIX value of 0.50 refers to a 50% short-term implied volatility of the S&P 500. Since both investor sentiment as well as market volatility can greatly affect asset prices, I thus believe that they can both also affect asset

6 About Ginnie Mae. 2011. Ginnie Mae. http://www.ginniemae.gov/about/about.asp?section=about (accessed February 22, 2011)

7 Introduction to VIX Options and Futures. 2011. Chicago Board Options Exchange. http://www.cboe.com/micro/VIX/vixintro.aspx (accessed February 22, 2011)

8 Introduction to VIX Options and Futures. 2011. Chicago Board Options Exchange. http://www.cboe.com/micro/VIX/vixintro.aspx (accessed February 22, 2011)

liquidity. Thus, I consider the VIX to be an important liquidity proxy of TIPS. I call this variable VIXLevel in my regressions.

4.1.2 Correcting for Autocorrelation

As I am examining TIPS offering yields since mid-2004, there will be a fair amount of autocorrelation in my independent variables. This is because the values of these independent variables (and hence of the results of the regressions) generally do not change very much in short periods of time. For example, in stable economic times, one would expect variables such as the on-the-run nominal Treasury yields or the value of the VIX to vary by only small amounts in one- to six-month increments. So, in addition to these three TIPS liquidity risk proxies, I have created generic time series variables for both SwapSpread and YieldSpread. I call these two generic time series variables SwapSpreadTS and YieldSpreadTS.

Rather than using TIPS and nominal Treasury bond offering yields to calculate SwapSpreadTS and YieldSpreadTS, I instead use the 10-Year Treasury Inflation-Indexed Security, Constant Maturity (10TIISCM) and 10-Year Treasury Constant Maturity Rate (10TCMR) indices from the Federal Reserve.

Using these indices, I then construct SwapSpreadTS and YieldSpreadTS in the same manner that I construct SwapSpread and YieldSpread. Namely,

$$SwapSpreadTS_i = 10TIISCM_i - \left(10TCMR_i - SwapYield_i\right) \quad (6)$$

$$YieldSpreadTS_i = 10TIISCM_i - 10TCMR_i \quad (7)$$

where $10TIISCM_i$ = the value of the 10-Year Treasury Inflation-Indexed Security, Constant Maturity index on the date of issuance of TIPS i, $10TCMR_i$ = the value of the 10-Year Treasury Constant Maturity Rate index on the date of issuance of TIPS i, and $SwapYield_i$ = the price (quoted as a yield) of an inflation swap with the same maturity as TIPS i.

I then lag these generic time series variables by one month. The one-month lagged variables are called SwapSpreadTSLag and YieldSpreadTSLag. I include the matching lagged, generic time series variable as an independent variable in each of my regressions. This corrects for autocorrelation in my results for several reasons. First, these variables are generic, constant maturity time series, and as such, their values will not change with independent events that may have occurred on any given TIPS offering date. Second, the estimated coefficient of the lagged, time series variable will be equal to the level of autocorrelation present in the dependent variable. Hence, the coefficients of the other independent variables will be free from any autocorrelation bias.

This allows for the isolation of the true effects of the TIPS liquidity proxies, so that their correct significance can be analyzed. Therefore, these lagged, generic time series variables are very important as they prevent autocorrelation bias from influencing my results and producing false estimations of statistical significance (or insignificance).

4.1.3 Models For Confirming the Existence of the TIPS Liquidity Premium

As previously mentioned, I constructed two dependent variables in order to examine TIPS liquidity: SwapSpread and YieldSpread. Likewise, I run one regression for each dependent variable in order to confirm the existence and examine the causes of the TIPS liquidity premium. I use robust matrix OLS to run my regressions.

The SwapSpread regression includes the three TIPS liquidity proxies (OffOnSpread, GNMASpread, and VIXLevel) as independent variables. It also includes SwapSpreadTSLag as an independent variable in order to control for autocorrelation bias. Using robust matrix OLS, this regression follows the reduced form:

$$y = X\beta + \varepsilon \tag{8}$$

where y is an n x 1 vector containing observations of SwapSpread, X is an n x 5 matrix containing a column of ones (so that the regression has a constant term) and observations of OffOnSpread, GNMASpread, VIXLevel, and SwapSpreadTSLag, ß is a 5 x 1 vector of coefficients, ε is an n x 1 vector of robust error terms, and n is equal to the number of observations.

In expanded form, this regression looks like:

$$\begin{bmatrix} SwapSpread_1 \\ SwapSpread_2 \\ \vdots \\ SwapSpread_n \end{bmatrix} = \begin{bmatrix} 1 & OffOnSpread_1 & GNMASpread_1 & VIXLevel_1 & SwapSpreadTSLag_1 \\ 1 & OffOnSpread_2 & GNMASpread_2 & VIXLevel_2 & SwapSpreadTSLag_2 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 1 & OffOnSpread_n & GNMASpread_n & VIXLevel_n & SwapSpreadTSLag_n \end{bmatrix} \begin{bmatrix} \alpha \\ \beta_1 \\ \vdots \\ \beta_4 \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \vdots \\ \varepsilon_n \end{bmatrix}$$

The YieldSpread regression also includes the three TIPS liquidity proxies (OffOnSpread, GNMASpread, and VIXLevel) as independent variables, as well as YieldSpreadTSLag in order to control for autocorrelation bias. Additionally, it includes SwapYield as an independent variable in order to control for inflation expectations. Using robust matrix OLS, this regression follows the reduced form:

$$y = Z\beta + \varepsilon \tag{9}$$

where y is an n x 1 vector containing observations of YieldSpread, Z is an n x 6 matrix containing a column of ones (so that the regression has a constant term) and observations of OffOnSpread, GNMASpread, VIXLevel, SwapYield, and YieldSpreadTSLag, ß is a 6 x 1 vector of coefficients, ε is an n x 1 vector of robust error terms, and n is equal to the number of observations.

Using these two regressions, I will be able to confirm the existence of the TIPS liquidity premium (in agreement with the relevant literature on the topic), and extensively analyze what causes this premium and why it is significant.

4.1.4 Models for Calculating the Size of the TIPS Liquidity Premium

The above regressions do not permit the calculation of the size of the TIPS liquidity premium, however. This is because of the presence of the constant term—by definition it captures the aspects of the relationship between the independent and dependent variables that are not related to TIPS liquidity. Accordingly, the constant term should not be included in calculations of the TIPS liquidity premium. Therefore, I must run two separate no-constant regressions, one for each dependent variable, for the purposes of calculating this premium. These results will allow me accurately estimate the magnitude of the TIPS liquidity premium. I again use robust matrix OLS for these no-constant regressions.

Using robust matrix OLS, the no-constant SwapSpread regression follows the reduced form:

$$y = \tilde{X}\beta + \varepsilon \tag{10}$$

where y is an n x 1 vector containing observations of SwapSpread, $\tilde{X}$ is an n x 4 matrix containing observations of OffOnSpread, GNMASpread, VIXLevel, and SwapSpreadTSLag, ß is a 4 x 1 vector of coefficients, ε is an n x 1 vector of robust error terms, and n is equal to the number of observations.

Similarly, again using robust matrix OLS, the no-constant YieldSpread regression follows the reduced form:

$$y = \tilde{Z}\beta + \varepsilon \tag{11}$$

where y is an n x 1 vector containing observations of YieldSpread, $\tilde{Z}$ is an n x 5 matrix containing observations of OffOnSpread, GNMASpread, VIXLevel, SwapYield, and YieldSpreadTSLag, ß is a 5 x 1 vector of coefficients, ε is an n x 1 vector of robust error terms, and n is equal to the number of observations.

Using these two regressions, I will be able to effectively estimate the size of the TIPS liquidity premium.

4.2 The TIPS Tax Disadvantage Premium

I follow the same general model that I use to study TIPS liquidity in order to examine the tax disadvantage of TIPS. Thus, I use the same independent variables, and again run two regressions on two separate dependent variables. The only significant difference in this model is that the two dependent variables that I construct are after-tax variables. This way, I can examine the difference between the before-tax regressions that I use to analyze TIPS liquidity and these after-tax regressions in order to infer the significance of the TIPS tax disadvantage premium. I call the two after-tax dependent variables that I construct ATSwapSpread and ATYieldSpread.

ATSwapSpread is equal to the after-tax price differential (quoted as a yield) between an actual TIPS and a synthetic TIPS. Here, I construct a synthetic TIPS in an identical manner as before. Thus,

$$ATSwapSpread_i = ATTIPS_i - \left(ATTBond_i - SwapYield_i\right) \qquad (12)$$

where $ATTIPS_i$ = the after-tax yield of a TIPS, $ATTBond_i$ = the after-tax yield of an analogous nominal Treasury bond, and $SwapYield_i$ = the price (quoted as a yield) of an inflation swap with the same maturity as both the TIPS and the corresponding nominal Treasury bond. There is again no difference in default risk, inflation risk, or compounding period between the two securities. However, these payment structures are *not* identical, as was assumed previously, due to the tax disadvantage of TIPS—the yearly taxation of positive inflation accruals that are not received until maturity. Therefore, ATSwapSpread should be positive, since an actual TIPS should have a higher after-tax yield than a synthetic TIPS in order to compensate investors for this tax disadvantage. I regress the same dependent variables on ATSwapSpread using robust matrix OLS in order to empirically confirm the existence of the TIPS tax disadvantage premium as well as calculate its magnitude.

ATYieldSpread is equal to the after-tax price differential (quoted as a yield) between a TIPS and an analogous nominal Treasury bond. Thus,

$$ATYieldSpread_i = ATTIPS_i - ATTBond_i \qquad (13)$$

where $ATTIPS_i$ = the offering yield of a TIPS and $ATTBond_i$ = the offering yield of a corresponding nominal Treasury bond of the same maturity. I again include SwapYield as an independent variable in regressions where YieldSpread is the dependent variable in order to properly control for inflation expectations. There is again no difference in default risk and compounding period, and since the inclusion of the SwapYield as an independent variable in these regressions effectively controls for inflation risk, the only difference between these two securities is again payment structure due to the tax disadvantage of TIPS. Thus, ATYieldSpread should also be positive, since TIPS should have a higher after-tax yield in order to compensate investors for this tax disadvantage. Therefore, after controlling for appropriate inflation expectations, non-zero coefficients of the independent variables reveal the sources and significance of the TIPS tax disadvantage premium. I once again regress the same dependent variables on ATYieldSpread using robust matrix OLS in order to empirically confirm the existence of the TIPS tax disadvantage premium as well as calculate its magnitude.

4.2.1 Calculating the After-Tax Yields of TIPS and Nominal Treasury Bonds

The after-tax yields of TIPS were calculated according to the after-tax TIPS pricing formula, mentioned earlier in this paper as Equation 3:

$$P = \left(\sum_{t=1}^{2T} \frac{\frac{E\left[C_t^A(1-\tau)-\left(F_t^A - F_{t-1}^A\right)(\tau) \middle| \pi_t^e\right]}{2}}{\left(1+\frac{r}{2}\right)^t} \right) + \frac{E\left[F_{2T}^A \middle| \pi_t^e\right]}{\left(1+\frac{r}{2}\right)^{2T}} \tag{13}$$

where P = the price of the bond, C_t^A = the annual, inflation-adjusted coupon payment at time t, $F_t^A = F_{t-1}^A\left(1+\pi_t\right)$ = the inflation-adjusted face value of the bond at time t, r = the after-tax yield to maturity, T = the maturity of the bond, π_t^e = expected inflation at time t, π_t = realized inflation at time t, and τ = the income tax rate.

This calculation is in fact quite difficult because the expected values of future payments are heavily dependent on the correct measure of present beliefs. Particularly, this method is very sensitive to expected inflation, since all future payments of the TIPS are expectations conditional on this belief at issuance. Thus, using the correct measure of expected inflation is crucial for accurate calculations of after-tax TIPS yields. In order to be both accurate and consistent with my methodology, I decided to extract inflation expectations from information embedded in both TIPS and nominal Treasury bonds at the time of issuance. Specifically, I created a synthetic bond consisting of the price and cash flows of a TIPS and the yield of a nominal Treasury bond. I was then able to extract the value of expected inflation that equates the price and yield of this synthetic bond. Mathematically, this generic, synthetic bond follows the form:

$$P_{TIPS} = \left(\sum_{t=1}^{T} \frac{C\left(1+\pi^{e}\right)^{t}}{\left(1+r_{Nom}\right)^{t}} \right) + \frac{F\left(1+\pi^{e}\right)^{T}}{\left(1+r_{Nom}\right)^{T}} \tag{14}$$

where P_{TIPS} = the offering price of a TIPS, C = the annual coupon payment of the TIPS, F = the face value of the TIPS at issuance, r_{Nom} = the yield to maturity of an analogous nominal Treasury bond, π^{e} = the annualized average level of expected inflation at issuance, and T = the maturity of both the TIPS and nominal Treasury bond.

Since π^{e} is the only unknown here, this method allowed me to determine a level of expected inflation that was consistent with the beliefs of market participants as well as the time horizon of the bond.

The after-tax yields of nominal Treasury bonds were calculated according the after-tax nominal bond pricing formula, derived from the pre-tax nominal bond pricing formula mentioned earlier in this paper as Equation 1:

$$P = \left(\sum_{t=1}^{2T} \frac{\frac{C(1-\tau)}{2}}{\left(1+\frac{r}{2}\right)^{t}} \right) + \frac{F}{\left(1+\frac{r}{2}\right)^{2T}} \tag{15}$$

where P = the offering price of the nominal Treasury bond, C = the fixed annual coupon payment, F = the face value of the bond, r = the yield to maturity, T = the maturity of the bond, and τ = the income tax rate.

Therefore, using these pricing models I was able to calculate the after-tax yield of TIPS (ATTIPS) and the after-tax yield of nominal Treasury bonds (ATTBond). I then used these two after-tax yield measures as inputs for calculating my two after-tax dependent variables, ATSwapSpread and ATYieldSpread, as previously described

4.2.2 Models for Conforming the Existence of the TIPS Tax Disadvantage Premium

Consistent with my previous method for examining TIPS liquidity, I run one after-tax regression for each dependent variable, ATSwapSpread and ATYieldSpread, and then compare them to my previous pre-tax regressions in order to analyze the existence of the TIPS tax disadvantage premium. I use robust matrix OLS to run my regressions.

The ATSwapSpread regression includes the same three TIPS liquidity proxies (OffOnSpread, GNMASpread, and VIXLevel) as independent variables as well as SwapSpreadTSLag in order to control for autocorrelation bias. Using robust matrix OLS, this regression follows the reduced form:

$$y = \breve{X}\beta + \varepsilon \tag{16}$$

where y is an n x 1 vector containing observations of ATSwapSpread, $\breve{X}$ is an n x 5 matrix containing a column of ones (so that the regression has a constant term) and observations of OffOnSpread, GNMASpread, VIXLevel, and SwapSpreadTSLag, ß is a 5 x 1 vector of coefficients, ε is an n x 1 vector of robust error terms, and n is equal to the number of observations.

The ATYieldSpread regression also includes the same three TIPS liquidity proxies (OffOnSpread, GNMASpread, and VIXLevel) as independent variables as well as YieldSpreadTSLag in order to control for autocorrelation bias. Again, it also includes SwapYield as an independent variable in order to control for inflation expectations. Using robust matrix OLS, this regression follows the reduced form:

$$y = \breve{Z}\beta + \varepsilon \tag{17}$$

where y is an n x 1 vector containing observations of ATYieldSpread, $\breve{Z}$ is an n x 6 matrix containing a column of ones (so that the regression has a constant term) and observations of OffOnSpread, GNMASpread, VIXLevel, SwapYield, and YieldSpreadTSLag, ß is a 6 x 1 vector of coefficients, ε is an n x 1 vector of robust error terms, and n is equal to the number of observations.

Using these two regressions, I can analyze the difference between the before-tax and after-tax regressions of each dependent variable, and thus can infer the significance of the TIPS tax disadvantage premium. I would like to note that the results for the TIPS tax disadvantage premium are very tricky, as they are extremely sensitive to the inputs of Equation 14. Thus, while the results may be revealing, they should be understood as rough estimations only.

4.2.3 Models for Calculating the Size of the TIPS Tax Disadvantage Premium

Once again, the above two regressions do not permit the calculation of the size of the TIPS tax disadvantage premium because of the presence of the constant term. So, I again run two separate no-constant, after-tax regressions, one for each dependent variable, in order to quantify this premium. I again use robust matrix OLS for these no-constant, after-tax regressions.

Using robust matrix OLS, the no-constant ATSwapSpread regression follows the reduced form:

$$y = \hat{X}\beta + \varepsilon \tag{18}$$

where y is an n x 1 vector containing observations of ATSwapSpread, $\hat{X}$ is an n x 4 matrix containing observations of OffOnSpread, GNMASpread, VIX-Level, and SwapSpreadTSLag, ß is a 4 x 1 vector of coefficients, ε is an n x 1 vector of robust error terms, and n is equal to the number of observations.

Similarly, again using robust matrix OLS, the no-constant ATYieldSpread regressions follows the reduced form:

$$y = \hat{Z}\beta + \varepsilon \tag{19}$$

where y is an n x 1 vector containing observations of ATYieldSpread, $\hat{Z}$ is an n x 5 matrix containing observations of OffOnSpread, GNMASpread, VIX-Level, SwapYield, and YieldSpreadTSLag, ß is a 5 x 1 vector of coefficients, ε is an n x 1 vector of robust error terms, and n is equal to the number of observations.

Using these two regressions, I will be able to effectively estimate the size of the TIPS tax disadvantage premium.

4.3 Measuring the Inflation Risk Premium

After calculating the magnitude of the TIPS liquidity and tax disadvantage premia, the inflation risk premium priced into nominal Treasury bond yields can also be calculated. I estimate the inflation risk premium so that I can accurately compare the cost of issuance of a TIPS to that of a nominal Treasury bond.

I have argued in this paper that TIPS and nominal Treasury bond yields are each made up of three components:

$$\begin{aligned} r_{TIPS} &= r_{real} + Liqprem + Taxprem \\ r_{Nom} &= r_{real} + \pi^{e} + Infprem \end{aligned} \tag{20}$$

where r_{TIPS} = the yield to maturity of a TIPS, r_{Nom} = the yield to maturity of a nominal Treasury bond, and rreal = the real yield. Accordingly, the inflation risk premium can be calculated in the following way:

$$\begin{aligned} r_{TIPS} - r_{Nom} = YieldSpread = Liqprem + Taxprem - \pi^{e} - Infprem \\ \Rightarrow Infprem_i = Liqprem_i + Taxprem_i - \pi_i^{e} - YieldSpread_i \end{aligned} \tag{21}$$

where Infprem$_i$ = the inflation risk premium of nominal Treasury bond i, Liqprem$_i$ = the liquidity premium of TIPS i, and Taxprem$_i$ = the tax disadvantage premium of TIPS i, π_i^e = the value of expected inflation extracted from TIPS i and nominal Treasury bond i, and YieldSpread$_i$ = the offering yield of TIPS i minus the offering yield of nominal Treasury bond i. Though this calculation of the inflation risk premium may not be the most robust due to its reliance on the estimated values of the TIPS liquidity and tax disadvantage premia, it should nonetheless provide a good approximation of this value.

It will also be interesting to see how the dynamics of the inflation risk premium of nominal Treasury bonds compare to those of the liquidity and tax disadvantage premia of TIPS.

4.4 The Costs/Benefits of TIPS to the Treasury

After calculating the inflation risk premium of nominal bonds, I can then proceed to analyzing whether the TIPS program has in fact lowered Treasury borrowing costs in an accounting framework, as was intended.

As previously mentioned, the pricing of TIPS and nominal Treasury bond payments are each based on several factors—TIPS cash flows are priced according to the real yield, the liquidity premium, the tax disadvantage premium, and inflation expected to be received, while nominal Treasury bond cash flows are priced according to the real yield, the rate of expected inflation, and the inflation risk premium. These pricing dynamics are illustrated in the following equations:

$$\begin{aligned} E\left[CF_{TIPS}\middle|\pi^e\right] &= r_{TIPS} + \pi^e = r_{real} + Liqprem + Taxprem + \pi^e \\ E\left[CF_{Nom}\middle|\pi^e\right] &= r_{Nom} = r_{real} + \pi^e + Infprem \end{aligned} \tag{22}$$

where CF$_{TIPS}$ = the cash flow of a TIPS and CF$_{Nom}$ = the cash flow of a nominal Treasury bond. Since the real yield and payments of expected inflation are common factors in the cash flows of both TIPS and nominal Treasury bonds, I analyze the relative borrowing cost of TIPS by comparing the sum of the liquidity and tax disadvantage premia to the inflation risk premium. That is, in order to determine if the TIPS program has in fact lowered Treasury borrowing costs since mid-2004, I calculate if:

$$\left(Liqprem_i + Taxprem_i\right)\overbrace{<=>}^{?}\left(Infprem_i\right) \tag{23}$$

where $Liqprem_i$ = the liquidity premium of TIPS i, $Taxprem_i$ = the tax disadvantage premium of TIPS i, and $Infprem_i$ = the inflation risk premium of nominal Treasury bond i. I then calculate the average of all observations for both sides of Equation 23 and compare them to one another. If the average left-hand side of Equation 23 is greater, then the TIPS program has cost the Treasury money. If the average right-hand side of Equation 23 is greater, then the TIPS program has saved the Treasury money. If the average left-hand and right-hand sides of Equation 23 are equal to one another, then the TIPS program has had no effect on Treasury borrowing costs.

V. Data

Since this paper is heavily founded on government borrowing costs and other related financial data, all of the data that I use as inputs in my calculations are consistently published on a daily basis by various reliable and credible sources, and are easily accessible.

The yields at which TIPS were issued by the Treasury were collected from the Unites States Department of the Treasury. I use these yields to construct SwapSpread, YieldSpread, ATSwapSpread, and ATYieldSpread.

The price (as a percent of par) and coupon rate at which TIPS were issued by the Treasury were again collected from the United States Department of the Treasury. I use these data to construct ATSwapSpread and ATYieldSpread, and to accurately determine inflation expectations.

The yields of nominal Treasury bonds were also collected from the Unites States Department of the Treasury. Since nominal Treasury bonds have historically not been issued on the same day as TIPS, I take these yields from the daily Treasury Yield Curve on the date of each TIPS issuance. This way, my data for both TIPS and nominal Treasury borrowing costs is accurate to the day. I use these yields to construct SwapSpread, YieldSpread, ATSwapSpread and ATYieldSpread, and again to accurately determine inflation expectations.

The price (as a percent of par) and coupon rate at which nominal Treasury bonds were issued by the Treasury were collected from the United States Department of the Treasury as well. I use these data to construct ATSwapSpread and ATYieldSpread.

The price (quoted as a yield) of a zero-coupon inflation swap was collected on a daily basis from Bloomberg, ticker USSWITxx Curncy, where xx represents the number of years (i.e., 05, 20, etc.). I collected this data for 1, 4, 5, 9, 10, 20, and 30-year maturities. I use this data to construct SwapSpread, SwapSpreadTSLag and ATSwapSpread, and I also include it as an independent variable in regressions where YieldSpread or ATYieldSpread is the dependent variable in order to properly control for inflation expectations.

The yields of 10-year off-the-run nominal Treasury bonds were collected on a daily basis from the Board of Governors of the Federal Reserve System, Table H.15. These yields are normalized to be constant maturity. I use them to construct OffOnSpread.

The yields of 10-year on-the-run nominal Treasury bonds were also collected on a daily basis from the Board of Governors of the Federal Reserve System, Table H.15. These yields are also normalized to be constant maturity. I again use them to construct OffOnSpread.

The GNMA spread, which is one of my TIPS liquidity proxies, was collected on a daily basis from Bloomberg, ticker GNSF060 Index. This spread is both option-adjusted as well as prepayment adjusted using the Bloomberg Prepayment Model. This is in order to account for the risk that a mortgage underlying a GNMA MBS may be repaid in full prior to maturity, causing the actual investment horizon of the MBS to be shorter than intended.

The value of the VIX, which is also one of my TIPS liquidity proxies, was collected on a daily basis from Bloomberg, ticker VIX Index.

The yields of the 10-Year Treasury Inflation-Indexed Security, Constant Maturity index were collected on a daily basis from the Board of Governors of the Federal Reserve System, Table H.15. These yields are normalized to be constant maturity. I use them to construct SwapSpreadTSLag and YieldSpreadTSLag.

The yields of the 10-Year Treasury Constant Maturity Rate index were again collected on a daily basis from the Board of Governors of the Federal Reserve System, Table H.15. These yields are normalized to be constant maturity as well. I again use them to construct SwapSpreadTSLag and YieldSpreadTSLag.

The study period of this paper is from July 2004 to December 2011. This is simply due to the availability of the required data from both Bloomberg and the Board of Governors of the Federal Reserve System.

5.1 Assumptions

In order to accomplish the goals of this paper, I make a few specific simplifying assumptions that permit me to ensure the time-consistency of my data, as well as capture a wider range of effects that the liquidity and tax disadvantage premia can have on TIPS.

First, when calculating the after-tax returns of both TIPS and nominal Treasury bonds, I assume that the income tax rate for all investors is equal to 35% for the entire study period. This assumption is fair since TIPS are generally held by large institutional investors, to whom this highest income tax rate applies. (Roll, 2004) This assumption ensures that my after-tax return data is consistent both across securities as well as over time.

Second and most importantly, I assume that the liquidity and tax disadvantage premia are already priced into TIPS yields at issuance. The purpose of this paper is to support their existence and determine their impact on yields at issuance. This assumption is also reasonable, since the large institutional investors who typically buy TIPS are very sophisticated, and certainty understand that TIPS are less liquid securities and that they also carry a tax disadvantage in their cash flows. Nevertheless, they buy them anyway, representing a willingness to take on these risks so long as they are properly compensated by the Treasury via the liquidity and tax disadvantage premia.

VI. Hypothesis

Following this methodology, I expect to find the following results. First, I expect to support the existence of the TIPS liquidity premium, and I expect it to be between 40-100 bps, consistent with the relevant literature. Second, I expect to support the existence of the TIPS tax disadvantage premium, however I am unsure what potential range to expect given the lack of relevant literature on this specific topic. Consequently, this means that I expect to find that TIPS are *not* in fact tax disadvantaged, since investors are properly compensated for their additional tax liability via the premium. Third, I expect to find that the government loses money overall from the TIPS program, since I expect the sum of TIPS liquidity and tax disadvantage premia to be greater than the inflation risk premium of nominal Treasury bonds since mid-2004.

VII. Results and Discussion

7.1 Confirming the Existence of the TIPS Liquidity and Tax Disadvantage Premia

7.1.1 The TIPS Liquidity Premium

The results supporting the existence of the TIPS liquidity premium are summarized in the following tables:

Table 1: SwapSpread on TIPS Liquidity Proxies

	1	2	3	4	5	6	7
Varaibles				*Coefficients*			
OffOnSpread	6.225609	-	-	-	1.882534	-	2.202288
	(4.33)				(0.87)		(1.23)
GNMASpread	-	.0030442	-	-	.0013118	-	.0007631
		(3.17)			(1.90)		(1.12)
VIXLevel	-	-	.0153135	-	.0108526	0.0089362	.0056774
			(3.85)		(2.36)	(2.33)	(1.40)
SwapSpreadTSLag	-	-	-	.7747398	-	0.5253689	.4907275
				(4.98)		(3.30)	(2.94)
R^2	0.22	0.27	0.42	0.46	0.48	0.56	0.59

robust t-statistics are in parentheses underneath coefficients

Table 2: YieldSpread on TIPS Liquidity Proxies

	1	2	3	4	5	6	7	8
Varaibles					*Coefficients*			
OffOnSpread	10.71323	-	-	-	-	1.808169	-	2.416733
	(2.87)					(0.85)		(1.37)
GNMASpread	-	.0040088	-	-	-	.0012378	-	.0011171
		(1.52)				(1.55)		(1.33)
VIXLevel	-	-	.0416378	-	-	.0117216	.0129528	.0059202
			(4.77)			(1.88)	(2.74)	(1.22)
SwapYield	-	-	-	-1.222257	-	-.9754156	-.7704242	-.856634
				(-9.44)		(-8.39)	(-5.63)	(-5.84)
YieldSpreadTSLag	-	-	-	-	.9225836	-	.2865174	.2921897
					(4.90)		(2.41)	(2.57)
R^2	0.14	0.09	0.66	0.81	0.61	0.89	0.91	0.92

robust t-statistics are in parentheses underneath coefficients

These tables are very revealing about the nature of the TIPS liquidity premium. Particularly, they show the effect of each TIPS liquidity proxy and control variable when it is the lone independent variable on both SwapSpread and YieldSpread, as well as its effect when it is part of a multivariate regression.

These tables confirm both the selection as well as inclusion of the control variables. First, it can be seen in both Column 4 of Table 1 and Column 5 of Table 2 that the generic time series lag variables are highly significant, as both have t-statistics near 5, and that they have coefficients that are close to 1. This means that there is a very high level of autocorrelation in both SwapSpread and YieldSpread that is clearly significant, and as a result that this autocorrelation bias must be taken into account. Thus, these generic time series lag variables must be included in all meaningful regressions since they very effectively control for autocorrelation bias. As shown in the two rightmost columns of both Tables 1 and 2, these generic time series lag variables remain significant when they are included as independent variables with the TIPS liquidity proxies. These results are useful since they prove that the lag variables are correctly controlling for autocorrelation bias. Second, it can be seen in Column 4 of Table 2 that the coefficient on SwapYield is -1.22 when it is the lone independent variable, and that it is highly significant with a t-statistic of -9.44. Referring back to Equation 5, it is apparent that YieldSpread is equal to (-1)(breakeven inflation), as was previously mentioned. Since SwapYield should in theory be equal to breakeven inflation, or equivalently (-1)(YieldSpread), then the coefficient on SwapYield should in theory be equal to -1. Hence, we see that the actual coefficient of -1.22 is in fact quite close to the theoretically correct value of -1. As additional independent variables are included in the YieldSpread regression, the coefficient on SwapYield decreases, yet it remains rather close to its theoretically correct value of -1. Moreover, in these multivariate regressions SwapYield remains highly significant. These two effects are both very important and useful since they confirm that SwapYield acts as an effective control variable for expected inflation and the bias that it can potentially introduce. Therefore, these results demonstrate that the generic time series lag variables as well as SwapYield are proper control variables, and that including them in multivariate regressions permits the accurate estimation of the effects of the TIPS liquidity proxies.

Furthermore, these tables are also quite revealing about the three TIPS liquidity proxies. What is most interesting about them in this regard though, is that they establish VIXLevel to be the lone robust estimator of TIPS liquidity. First, we see that VIXLevel is highly significant when it is the lone independent variable on both SwapSpread and YieldSpread, as it has t-statistics well above 1.96. As variables are added to the regressions, such as the generic time series lag variables and the other TIPS liquidity proxies, VIXLevel remains a robust estimator of TIPS liquidity. This is not true for the other two TIPS liquidity proxies, OffOnSpread and GNMASpread; though they each are significant estimators of TIPS liquidity when they are the lone independent variable, they lose this significance when additional variables are added to the regressions. The main reason that VIXLevel is the lone robust TIPS liquidity proxy is that it is multicollinear with both OffOnSpread and GNMASpread, as shown in the following table:

Table 3: Correlation Matrix of Independent Variables

	OffOnSpread	*GNMASpread*	*VIXLevel*	*SwapYield*
OffOnSpread	1	-	-	-
GNMASpread	0.4075746	1	-	-
VIXLevel	0.5205825	0.5134992	1	-
SwapYield	-0.212697	-0.102191	-0.695216	1

As Table 3 illustrates, VIXLevel has a correlation over 0.5 with both OffOnSpread as well as GNMASpread. Therefore, VIXLevel effectively captures the influences of these other TIPS liquidity proxies. This effect is observed in both Table 1 and Table 2. In Column 6 of Table 1, it can be seen that VIXLevel remains a robust estimator, even when controlling for the effects of autocorrelation. But when you add OffOnSpread and GNMASpread to the regression, as shown in Column 7 of Table 1, then the effects of all three TIPS liquidity proxies become insignificant. This pattern is repeated in Table 2; in Column 7 of Table 2, VIXLevel is again a robust estimator after controlling for the effects of both autocorrelation as well as expected inflation. However, when OffOnSpread and GNMASpread are added to the regression, as shown in Column 8 of Table 2, then the effects of all three TIPS liquidity proxies again become insignificant. This is principally due to the multicollinearity that exists amongst the three TIPS liquidity proxies, since when they are all included in the same multivariate regression, they confound one another, and thus introduce error into the estimation of the coefficients. So, since VIXLevel is the most robust estimator of the three TIPS liquidity proxies, and because it captures the effects of the other TIPS liquidity proxies due to their high level of correlation, I will focus my analysis on the multivariate regressions that include VIXLevel as the lone TIPS liquidity proxy along with the control variables (the generic time series lag variables and SwapYield).

Since VIXLevel is the most significant TIPS liquidity proxy, it is crucial to understand why this is so. In other words, what does VIXLevel actually mean in terms of TIPS liquidity, and what drives changes in its value? Since the VIX measures short-term volatility, there are many potential factors that can connect it to TIPS liquidity. For example, inflation expectations, Federal Reserve activity, the business cycle, and changes in investor risk-aversion are all factors that can affect overall short-term volatility measured by the VIX as well as even the thickest of bond markets. So what factor exactly, is driving VIXLevel to be a significant liquidity proxy of TIPS? The following tables, which show a variety of before- and after-tax effects of the TIPS liquidity proxies on both SwapSpread and YieldSpread, are quite revealing regarding the relationship between VIXLevel and TIPS liquidity.

Table 4: SwapSpread on TIPS Liquidity Proxies, Before- and After-Tax

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Varaibles	Before-Tax Coefficients							After-Tax Coefficients						
OffOnSpread	6.225609	-	-	-	1.882534	-	2.202288	-1.617409	-	-	-	4.338062	-	4.119158
	(4.33)				(0.87)		(1.23)	(-0.55)				(1.64)		(1.61)
GNMASpread	-	.0030442	-	-	.0013118	-	.0007631	-	.0011543	-	-	.0050027	-	.0052495
		(3.17)			(1.90)		(1.12)		(0.71)			(4.04)		(3.77)
VIXLevel	-	-	.0153135	-	.0108526	0.0089362	.0056774	-	-	-.0218848	-	-.0362427	-.0210185	-.0329444
			(3.85)		(2.36)	(2.33)	(1.40)			(-3.62)		(-6.61)	(-2.52)	(-5.04)
SwapSpreadTSLag	-	-	-	.7747398	-	0.5253689	.4907275	-	-	-	-0.62492	-	-.0383804	-.2853894
				(4.98)		(3.30)	(2.94)				(-2.24)		(-0.11)	(-0.93)
R^2	0.22	0.27	0.42	0.46	0.48	0.56	0.59	0.01	0.01	0.29	0.10	0.51	0.28	0.52

robust t-statistics are in parentheses underneath coefficients

Table 5: YieldSpread on TIPS Liquidity Proxies, Before- and After-Tax

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Varaibles	Before-Tax Coefficients								After-Tax Coefficients							
OffOnSpread	10.71323	-	-	-	-	1.808169	-	2.416733	2.870415	-	-	-	-	1.61587	-	1.569842
	(2.87)					(0.85)		(1.37)	(1.83)					(1.00)		(0.95)
GNMASpread	-	.0040088	-	-	-	.0012378	-	.0011171	-	.002119	-	-	-	.0022951	-	.0022983
		(1.52)				(1.55)		(1.33)		(3.39)				(2.96)		(2.87)
VIXLevel	-	-	.0416378	-	-	.0117216	.0129528	.0059202	-	-	.0044399	-	-	-.0044308	.0057729	-.0039979
			(4.77)			(1.88)	(2.74)	(1.22)			(1.52)			(-1.18)	(1.40)	(-0.97)
SwapYield	-	-	-	-1.222257	-	-.9754156	-.7704242	-.856634	-	-	-	-0.059825	-	-.1000388	.0287077	-.1092227
				(-9.44)		(-8.39)	(-5.63)	(-5.84)				(-0.67)		(-1.18)	(0.27)	(-1.25)
YieldSpreadTSLag	-	-	-	-	.9225836	-	.2865174	.2921897	-	-	-	-	.0576539	-	-.0168412	-.0212968
					(4.90)		(2.41)	(2.57)					(1.10)		(-0.20)	(-0.31)
R^2	0.14	0.09	0.66	0.81	0.61	0.89	0.91	0.92	0.06	0.17	0.05	0.01	0.01	0.20	0.05	0.20

robust t-statistics are in parentheses underneath coefficients

Table 4 and Table 5 show the before- and after-tax effects of the TIPS liquidity proxies on both SwapSpread and YieldSpread. For these tables, I calculated expected inflation as described in my methodology, and then used this measure of expected inflation to calculate expected after-tax yields (ATSwapSpread and ATYieldSpread). These two tables suggest that the main factor driving the relationship between VIXLevel and TIPS liquidity is expected inflation, particularly the uncertainty of expected inflation. The key to this premise is that the after-tax coefficients are measured after expected inflation has become realized inflation, and is thus no longer uncertain.

It can be seen in Column 7 of Table 5 that the before-tax coefficients on both VIXLevel and SwapYield are statistically significant, as was seen and discussed earlier in Table 2. However, once expected inflation becomes realized inflation, the after-tax coefficients on VIXLevel and SwapYield in Column 15 of Table 5 are no longer statistically significant. Based on the theory that expected inflation is driving the relationship between VIXLevel and TIPS liquidity, these results make sense; once expected inflation becomes realized inflation, SwapYield should lose its significance, since it is a control for expected inflation, which is no longer a concern. Likewise, because expected inflation has become realized inflation and is thus certain, it should have no affect on volatility (VIXLevel) since uncertainty is the fundamental aspect of volatility. Hence, these results suggest that VIXLevel is mostly an inflation proxy, driven particularly by the uncertainty of expected inflation.

This notion relates directly to TIPS liquidity since the uncertainty of expected inflation is a crucial influencer of TIPS yields, and can change the relative attractiveness of TIPS versus other assets. Thus, is makes sense that the level of uncertainty regarding expected inflation can affect TIPS liquidity. One would expect that given a relatively more risk-averse investor (which is the type of investor who buys TIPS), TIPS should be less liquid in times of high expected inflation uncertainty, as the investor will look to hold, not trade, TIPS in order to secure the real rate and guarantee indexation to uncertain future inflation. Likewise, TIPS should be more liquid in times of low expected inflation uncertainty, as investors will be more willing to trade TIPS, since the protection against inflation risk that TIPS provide becomes relatively less attractive. This makes sense in the framework of Equation 21, used to calculate the magnitude of the inflation risk premium of nominal Treasury bonds.

$$Infprem_i = Liqprem_i + Taxprem_i - \pi_i^e - YieldSpread_i \qquad (21)$$

In times of high expected inflation uncertainty, the inflation risk premium of nominal Treasury bonds increases in order to compensate investors for the risk surrounding this uncertainty. According to this equation, there is a direct relationship between the inflation risk premium of nominal Treasury bonds and the TIPS liquidity premium. Hence, an increase in the inflation risk premium is met (at least in part) by an increase in the TIPS liquidity premium, meaning that TIPS become less liquid. Likewise, in times of low expected inflation uncertainty, the inflation risk premium of nominal Treasury bonds decreases, which is met (at least in part) by a decrease in the TIPS liquidity premium, meaning that TIPS become more liquid.

It is notable though, that in Column 13 of Table 4, VIXLevel remains a statistically significant after-tax coefficient. This suggests that though expected inflation uncertainty may explain a large portion of the relationship between VIXLevel and TIPS liquidity, that VIXLevel still captures other liquidity aspects of TIPS.

In order to further investigate the relationship between VIXLevel and TIPS liquidity, I calculated two additional variables from realized values of past inflation. Since past inflation is a good estimator of future inflation, (Stock and Watson, 2007) including these variables in select regressions should further test the theory that VIXLevel is essentially another proxy for expected inflation. The two additional variables that I calculated were InfAvg, which equals the average annualized percent change in the CPI over the trailing 12 months, and InfVol, which equals the standard deviation of annualized percent changes in the CPI over the trailing 12 months. I calculated the values of these two variables for all dates of TIPS issuance, and then included them in select YieldSpread regressions. I include them only in YieldSpread regressions so that I can selectively exclude SwapYield. I cannot do this in SwapSpread regressions, as SwapYield is embedded in the dependent variable. Selectively excluding SwapYield is important since InfAvg and InfVol together also form a proxy for expected inflation. So, a regression that includes the combination of InfAvg and InfVol as well as SwapYield would experience severe multicollinearity problems. The results for these regressions are presented in the following table.

Table 6: YieldSpread on Inflation Measures and TIPS Liquidity Proxies, Before- and After-Tax

	1	2	3	4	5	6	7	8	9	10	11	12
Varaibles	*Before-Tax Coefficients*						*After-Tax Coefficients*					
InfAvg	-	-	-	-.0140039 (-0.32)	-0.088948 (-2.38)	-.0816377 (-1.16)	-	-	-	.0440464 (1.69)	0.0424164 (2.00)	.0430101 (1.92)
InfVol	-	-	-	.0007843 (0.05)	0.0244686 (1.21)	.0825427 (2.29)	-	-	-	.0306491 (2.82)	0.0305683 (2.84)	.035285 (3.36)
SwapYield	-.7704242 (-5.63)	-.8859944 (-8.04)	-1.222257 (-9.44)	-	-	-	.0287077 (0.27)	.0419877 (0.44)	-.0598249 (-0.67)	-	-	-
VIXLevel	.0129528 (2.74)	.0183146 (3.38)	-	.0277238 (2.73)	0.0395978 (4.61)	-	.0057729 (1.40)	.0055452 (1.61)	-	.0030188 (0.76)	0.003216 (1.15)	-
YeildSpreadTSLag	.2865174 (2.41)	-	-	.4627805 (1.72)	-	-	-.0168412 (-0.20)	-	-	.0110536 (0.13)	-	-
R^2	0.91	0.88	0.81	0.76	0.72	0.17	0.40	0.05	0.01	0.15	0.14	0.12

robust t-statistics are in parentheses underneath coefficients

The results from Table 6 further indicate that VIXLevel is a robust estimator of TIPS liquidity. It can be seen in Columns 2 and 5 of Table 6 that when controlling for expected inflation both through SwapYield as well as the combination of InfAvg and InfVol, VIXLevel remains a statistically significant before-tax variable. This confirms that VIXLevel is not just another inflation proxy, but rather that it does indeed robustly capture the specific aspects of TIPS liquidity.

Furthermore, Table 6 supports the theory that the uncertainty of expected inflation is the main factor driving the relationship between VIXLevel and TIPS liquidity; once expected inflation becomes realized inflation, VIXLevel loses its after-tax statistical significance, as seen in Column 11. But Table 6 permits the analysis of VIXLevel to go one step further; it can be seen in a comparison of Columns 11 and 12 that when VIXLevel is dropped, the after-tax statistical significance of InfAvg changes slightly, while that of InfVol increases greatly. Thus, the joint after-tax statistical significance of these two variables increases considerably when VIXLevel is dropped, suggesting that they are correlated (as this increase in statistical significance is due to the elimination of multicollinearity). Since the statistical significance of InfVol reacts more strongly to the exclusion of VIXLevel, this table implies that VIXLevel is more strongly related to the uncertainty of volatility regarding expected future inflation, rather than the uncertainty of the expected future average inflation rate. This, of course, makes sense, given that the VIX measures current market volatility.

Therefore, the results from Tables 4, 5, and 6 suggest as a whole that a stable TIPS liquidity premium does in fact exist, and that it is well predicted by VIXLevel. Furthermore, they show that TIPS liquidity is principally driven by the uncertainty of expected future inflation, not by the microstructure of the TIPS market. Specifically, it is the uncertain volatility of expected future inflation that drives the TIPS liquidity premium. Though the uncertainty of expected future inflation may be the main factor driving the TIPS liquidity premium, these results also suggest that other factors captured by VIXLevel can also influence TIPS liquidity, since VIXLevel is still a robust estimator of TIPS liquidity even after controlling for expected inflation.

7.1.2 The TIPS Tax Disadvantage Premium

Table 5 is also quite revealing regarding the TIPS tax disadvantage premium, as it provides evidence supporting the existence of this premium as a part of TIPS yields. As previously mentioned, it can be seen in Table 5 that VIXLevel becomes a statistically insignificant after-tax coefficient. This was very important regarding the TIPS liquidity premium, but it is also very important in terms of the TIPS tax disadvantage premium, particularly because this phenomenon is also due to the mechanics of the tax correction at work in this table. Specifically, when the after-tax dependent variable is used, expected inflation becomes realized inflation. As a result, investors must pay the "TIPS phantom tax" on this realized inflation. So, if a TIPS tax disadvantage premium existed in the before-tax dependent variable (which is a previously mentioned assumption that I make in this paper), then it should be offset by the "phantom tax" that has now been paid, causing the risk premia proxy to lose its statistical significance.

This process describes exactly what is occurring in Table 5. In this table, VIXLevel is a statistically significant before-tax coefficient, but loses this statistical significance after taxes have been paid. Thus, this suggests that a TIPS tax disadvantage premium was in fact included in the before-tax dependent variable and that its effect was captured by the statistically significant before-tax risk premia proxy. Likewise, the loss of statistical significance of the risk premia proxy in the after-tax regressions supports the notion that this TIPS tax disadvantage premium has been offset by payments of the TIPS phantom tax that accompany realized inflation. Therefore, these results establish that TIPS are not tax disadvantaged, since their offering yields do in fact contain the TIPS tax disadvantage premium that compensates investors for the additional tax liability that they incur by holding TIPS.

I would like to note however, that these results for the TIPS tax disadvantage are not very robust and that interpreting them is quite difficult. It can be seen in Column 13 of Table 4 and Column 15 of Table 5 that the generic time series lag variables take on a negative coefficient after accounting for taxes. Additionally, in Column 15 of Table 5 SwapYield takes on a positive coefficient after accounting for taxes. These specific outcomes are not theoretically correct, as the subtraction of taxes from future cash flows should not reverse the direction of autocorrelation or the effect that inflation expectations have on TIPS yields.

These incorrect after-tax outcomes could potentially be the result of biased future information in ATSwapSpread and ATYieldSpread. Though I extracted the inflation expectations that I used to calculate these two dependent variables at the date of issuance of each TIPS, and was thus very careful not to use future information in these after-tax yields, it is still possible that future information could be influencing these results for two main reasons.

First, extracting inflation expectations from a combination of TIPS and nominal Treasury bond metrics can result in bias because the expectations of the investor base for each asset may be very different; investors of nominal Treasury bonds and investors of TIPS vary significantly in terms of risk-aversion, trading activity, hedging activity, and investment horizon. Hence, inflation expectations extracted from a synthesis of both groups could potentially have a long-term bias, due principally to the long-term investment horizon of TIPS investors. If inflation expectations were in fact skewed toward the long-term horizon, this would be one way that future information could create bias in these calculations.

Second, a significant portion of the after-tax dependent variables were greater than the before-tax dependent variables, which initially does not make much sense since taxes are subtracted from the before-tax values. However, since TIPS are indexed to future inflation, there are very reasonable explanations of why this phenomenon could occur; this phenomenon could be the manifestation of the potential long-term inflation expectations bias discussed in the previous paragraph, or it could be due to a consistent underestimation of expected inflation by market participants. In either case, this phenomenon could also be a source of bias.

Therefore, though these results may not be very robust due to potential bias, they are still very useful for understanding the nature of the TIPS liquidity premium (as was previously discussed) as well as for providing a rudimentary measure of the TIPS tax disadvantage premium that is priced into TIPS offering yields.

7.2 Calculating the Size of the TIPS Liquidity Premium, the TIPS Tax Disadvantage Premium, and the Inflation Risk Premium

The results for estimating the magnitude of the TIPS liquidity and tax disadvantage premia, which was done using separate no-constant regressions, are summarized in the tables on the following page.

Table 7: SwapSpread on TIPS Liquidity Proxies, Before- and After-Tax, No Constant

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Varaibles	*Before-Tax Coefficients*							*After-Tax Coefficients*						
OffOnSpread	14.61922	-	-	-	2.00573	-	2.26311	61.70769	-	-	-	6.977458	-	7.769487
	(9.15)				(0.92)		(1.29)	(7.75)				(0.69)		(0.84)
GNMASpread	-	.0066306	-	-	.0014013	-	.0007203	-	.0284474	-	-	.0069217	-	.0026799
		(11.09)			(2.08)		(1.05)		(8.70)			(1.83)		(0.76)
VIXLevel	-	-	.0207433	-	.0156084	.0098586	.0066245	-	-	.0881025	-	.0656484	.035296	.0239
			(11.85)		(5.00)	(2.91)	(1.81)			(8.03)		(5.07)	(1.71)	(1.09)
SwapSpreadTSLag	-	-	-	.9985279	-	.5707835	.5390793	-	-	-	4.265562	-	2.73414	2.616545
				(13.26)		(3.81)	(3.37)				(7.55)		(2.31)	(2.09)
R^2	0.63	0.66	0.84	0.86	0.86	0.89	0.90	0.50	0.54	0.68	0.71	0.69	0.73	0.74

robust t-statistics are in parentheses underneath coefficients

Table 8: YieldSpread on TIPS Liquidity Proxies, Before- and After-Tax, No Constant

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Varaibles	*Before-Tax Coefficients*								*After-Tax Coefficients*							
OffOnSpread	-45.43863	-	-	-	-	1.749928	-	1.93126	1.650053	-	-	-	-	1.420708	-	1.394147
	(-5.89)					(0.81)		(1.05)	(1.37)					(0.87)		(0.83)
GNMASpread	-	-.0207043	-	-	-	.0011793	-	.0007549	-	.0011126	-	-	-	.0020992	-	.0021672
		(-5.95)				(1.69)		(1.04)		(2.44)				(2.92)		(2.74)
VIXLevel	-	-	-.0659391	-	-	.0125029	.0152525	.0120995	-	-	.0014203	-	-	-.0018124	.0035427	-.0017616
			(-5.77)			(3.12)	(4.04)	(3.36)			(0.98)			(-0.72)	(1.34)	(-0.67)
SwapYield	-	-	-	-.8233381	-	-.9554991	-.7205026	-.7385638	-	-	-	.0030433	-	-.0332994	-.019705	-.0664926
				(-72.73)		(-38.00)	(-6.39)	(-6.41)				(0.27)		(-1.78)	(-0.26)	(-1.12)
YieldSpreadTSLag	-	-	-	-	.9617933	-	.2624122	.2465805	-	-	-	-	-.0019188	-	.0065355	-.037803
					(59.67)		(2.27)	(2.09)					(0.14)		(0.09)	(-0.60)
R^2	0.40	0.42	0.56	0.98	0.97	0.99	0.99	0.99	0.04	0.10	0.02	0.00	0.00	0.19	0.05	0.19

robust t-statistics are in parentheses underneath coefficients

Given the results from Table 7 and Table 8, the equations for calculating the magnitude of the TIPS liquidity and tax disadvantage premia are as follows:

$$Liqprem_i = \left(\beta_i^{BT}\right)\left(VIXLevel_i\right) \tag{24}$$

$$Taxprem_i = \left(\beta_i^{AT} - \beta_i^{BT}\right)\left(VIXLevel_i\right) \tag{25}$$

where β_i^{BT} = the before-tax coefficient on VIXLevel and β_i^{AT} = the after-tax coefficient on VIXLevel for both SwapSpread and YieldSpread regressions. The reasoning for Equation 24 is straightforward—it quantifies the effect that liquidity (represented by VIXLevel) has on the pricing of TIPS yields. The reasoning for Equation 25 is as follows: an increase in the coefficient of VIXLevel from before- to after-tax represents additional risk compensation from realized inflation. I argue that this additional risk compensation from the receipt of inflation payments is due to the tax disadvantage premium.

Given the values for the TIPS liquidity and tax disadvantage premia from the above equations, the inflation risk premium of nominal Treasury bonds can be calculated according to Equation 21, as previously mentioned:

$$Infprem_i = Liqprem_i + Taxprem_i - \pi_i^e - YieldSpread_i \tag{21}$$

The values of the TIPS liquidity premium, the TIPS tax disadvantage premium, and the inflation risk premium of nominal Treasury bond are presented in Table 9 on the following page for all dates of TIPS issuance in my study period.

Table 9: The TIPS Liquidity Premium, the TIPS Tax Disadvantage Premium, and the Inflation Risk Premium

Date	TIPS Liqprem	TIPS Taxprem	TBond Infprem
07/30/04	0.192351%	0.389701%	0.633111%
10/15/04	0.188835%	0.382578%	0.558317%
10/29/04	0.204279%	0.413866%	0.642341%
01/18/05	0.156568%	0.317204%	0.515694%
01/31/05	0.160962%	0.326107%	0.455129%
04/15/05	0.222735%	0.451259%	0.699734%
04/29/05	0.192225%	0.389447%	0.361836%
07/15/05	0.129699%	0.262768%	0.435374%
07/29/05	0.145268%	0.294311%	0.300366%
10/17/05	0.184190%	0.373167%	0.524365%
10/28/05	0.178917%	0.362483%	-0.243850%
01/17/06	0.149537%	0.302959%	0.504364%
01/31/06	0.162594%	0.329414%	0.571806%
04/17/06	0.157949%	0.320002%	0.530210%
04/28/06	0.145519%	0.294819%	0.480906%
07/17/06	0.234035%	0.474153%	0.767468%
07/31/06	0.187705%	0.380289%	0.501082%
10/16/06	0.139241%	0.282101%	0.381053%
10/31/06	0.139367%	0.282355%	-0.133858%
01/16/07	0.134847%	0.273198%	0.464003%
01/31/07	0.130829%	0.265058%	0.462453%
04/16/07	0.150415%	0.304740%	0.439437%
04/30/07	0.178540%	0.361720%	0.532924%
07/16/07	0.195741%	0.396569%	0.652293%
07/31/07	0.295307%	0.598288%	0.756864%
10/15/07	0.241694%	0.489670%	0.742030%
10/31/07	0.232654%	0.471355%	0.231853%
01/15/08	0.293047%	0.593709%	1.398489%
01/31/08	0.328955%	0.666460%	0.544312%
04/15/08	0.286015%	0.579464%	0.804823%
04/30/08	0.261030%	0.528844%	0.776016%
07/15/08	0.358335%	0.725983%	1.119599%
07/31/08	0.288024%	0.583534%	0.988837%
10/15/08	0.869472%	1.761540%	2.444521%
10/31/08	0.751952%	1.523446%	1.270908%
01/15/09	0.640333%	1.297307%	1.937896%
01/30/09	0.562991%	1.140613%	1.796433%
04/15/09	0.454134%	0.920071%	1.562971%
04/30/09	0.458278%	0.928465%	1.344870%
07/15/09	0.325063%	0.658574%	1.016045%
07/31/09	0.325440%	0.659337%	1.056726%
10/15/09	0.272707%	0.552500%	0.756262%
10/30/09	0.385330%	0.780674%	0.821412%
01/15/10	0.224870%	0.455584%	1.033058%
02/26/10	0.244833%	0.496029%	0.794999%
04/15/10	0.199508%	0.404200%	0.610086%
04/30/10	0.276850%	0.560895%	0.845228%
07/15/10	0.315647%	0.639496%	0.977077%
08/31/10	0.327072%	0.662644%	0.986156%
09/15/10	0.277478%	0.562167%	0.865043%
10/29/10	0.266178%	0.539273%	0.762639%
11/15/10	0.253622%	0.513835%	0.789700%
01/31/11	0.245210%	0.496792%	0.765622%
02/28/11	0.206288%	0.417936%	0.670119%
03/31/11	0.222735%	0.451259%	0.630398%
04/29/11	0.185194%	0.375202%	0.511972%
05/31/11	0.193983%	0.393008%	0.388586%
07/29/11	0.317028%	0.642294%	0.950896%
08/31/11	0.397006%	0.804331%	0.803517%
09/30/11	0.539386%	1.092791%	1.620119%
11/30/11	0.349044%	0.707160%	1.008255%
12/30/11	0.293800%	0.595235%	0.147290%
Average	0.274659%	0.556455%	0.799098%

First, Table 9 shows that the TIPS liquidity premium is relatively stable. Between July 2004 and July 2008, the TIPS liquidity premium consistently hovered around 20 bp. It then spiked to over 80 bp in October of 2008, which coincides with the beginning of the recent financial crisis. The October 2008 TIPS were the first to be issued since the bankruptcy of Lehman Brothers (who was a significant player in the TIPS market according to Campbell, Shiller, and Viceira (2009)), and were issued in a financial environment where credit was tightening rapidly, and as a result, liquidity was drying up quickly. It is thus no surprise to see a rather large and sudden increase in the TIPS liquidity premium in this period, as investors certainly demanded additional yield in order to compensate for this vastly reduced market liquidity. Starting in April of 2009, the TIPS liquidity premium came back down to a reasonable level, and it quickly re-stabilized—from April 2009 to December 2011, it consistently hovered around 31 bp. Hence, the TIPS liquidity premium has in fact increased over the past few years as a result of reduced market liquidity and poor macroeconomic performance, yet it has nonetheless become stable once again. The overall sample range of the TIPS liquidity premium is 13-87 bp, and the overall sample average is 27 bp.

Second, Table 9 illustrates that the TIPS tax disadvantage premium is less stable. Between July 2004 and July 2008 it fluctuated regularly within a 40 bp range. Like the TIPS liquidity premium, the TIPS tax disadvantage premium increases greatly and suddenly in October of 2008, at the beginning of the recent financial crisis, and then afterwards returns to fluctuating in a slightly higher 40 bp range. The main question about the TIPS tax disadvantage though, is why does it fluctuate at all given that the income tax rate remains unchanged over this study period? The answer is that the TIPS tax disadvantage premium varies with the volatility of expected inflation. The reasoning is as follows; TIPS have an investor base largely made up of highly sophisticated institutional investors. These sophisticated institutional investors are aware of the additional tax liability present in TIPS cash flows, and also form their own expectations about the level of expected future inflation. Thus, they are able to price the tax disadvantage of TIPS (which is derived from their value of expected inflation) into their real bid yields. However, the volatility of future inflation remains unknown at the time of issuance, and can potentially cause future inflation to be higher than expected. This would increase the tax liability of TIPS, as their tax disadvantage increases with inflation. (Wilcox, 1998) This is the reason that investors require the TIPS tax disadvantage premium—to compensate them for the risk that the tax disadvantage of TIPS will be greater than expected. As a result, it is unsurprising that there is a positive correlation of 0.27 between the TIPS tax disadvantage premium and InfVol. The overall sample range of the TIPS tax disadvantage premium is 26-176 bp, and the overall sample average is 56 bp.

Third, Table 9 demonstrates that the inflation risk premium of nominal Treasury bonds is also not stable. Between July 2004 and July 2008 it too generally fluctuates within a 40 bp range, however it also sometimes jumps between 70-117 bp in either direction. I believe that this fluctuation occurs for the same reasons as the TIPS tax disadvantage premium; namely, that it is due to the volatility of expected inflation. But, the variation of the inflation risk premium is much more pronounced since this volatility has a much greater effect on the entire cash flow of a nominal Treasury bond than it does on the tax disadvantage of a TIPS. Since the level of expected future inflation is already a component of nominal Treasury bond yields, it is clear that the purpose of the inflation risk premium is to compensate investors for the risk that future inflation will be greater than its expected value. In other words, the inflation risk premium compensates investors for potential unexpected volatility in future inflation. It is thus once again unsurprising that there is a positive correlation of 0.28 between the inflation risk premium and InfVol, which is nearly identical to that of the TIPS tax disadvantage premium and InfVol. A very high positive correlation of 0.85 also exists between the TIPS tax disadvantage premium and the inflation risk premium of nominal Treasury bonds, further supporting that they are both driven by the common factor of expected future inflation volatility. Therefore, both premia compensate investors of each asset for the same risk: the risk that real cash flows become eroded by the unexpected volatility of future inflation. The only difference between the two premia is that they compensate for a different amount of the cash flow of each asset; the TIPS tax disadvantage premium offsets only the additional tax liability of TIPS that increases with inflation, whereas the inflation risk premium of nominal Treasury bonds compensates for the entire cash flow whose real value decreases with inflation. The overall sample range of the inflation risk premium is 15-244 bp, and the overall sample average is 80 bp.[9]

7.3 The Costs/Benefits of TIPS to the Treasury

The values from Table 9 are reorganized and redisplayed in Table 10 on the following page. Table 10 portrays a clear comparison of borrowing costs between the TIPS program and the nominal Treasury bond program.

9 I exclude the two negative values for the inflation risk premium. A negative value for the inflation risk premium can be caused by several factors in this paper. First, it can be the result of a very high level of expected inflation (which would greatly reduce the volatility of expected inflation since a wider range of potential outcomes is expected), or second, it can be due to a very low value of the TIPS liquidity premium (which was an input in the calculation).

Table 10: The Cost of Issuing TIPS as Compared to Nominal Bonds

Date	TIPS Liqprem + TIPS Taxprem	Nominal Infprem
07/30/04	0.582052%	0.633111%
10/15/04	0.571414%	0.558317%
10/29/04	0.618145%	0.642341%
01/18/05	0.473772%	0.515694%
01/31/05	0.487070%	0.455129%
04/15/05	0.673995%	0.699734%
04/29/05	0.581672%	0.361836%
07/15/05	0.392467%	0.435374%
07/29/05	0.439578%	0.300366%
10/17/05	0.557357%	0.524365%
10/28/05	0.541400%	-0.243850%
01/17/06	0.452496%	0.504364%
01/31/06	0.492009%	0.571806%
04/17/06	0.477951%	0.530210%
04/28/06	0.440338%	0.480906%
07/17/06	0.708189%	0.767468%
07/31/06	0.567995%	0.501082%
10/16/06	0.421342%	0.381053%
10/31/06	0.421722%	-0.133858%
01/16/07	0.408044%	0.464003%
01/31/07	0.395887%	0.462453%
04/16/07	0.455156%	0.439437%
04/30/07	0.540260%	0.532924%
07/16/07	0.592310%	0.652293%
07/31/07	0.893594%	0.756864%
10/15/07	0.731364%	0.742030%
10/31/07	0.704009%	0.231853%
01/15/08	0.886755%	1.398489%
01/31/08	0.995415%	0.544312%
04/15/08	0.865479%	0.804823%
04/30/08	0.789873%	0.776016%
07/15/08	1.084319%	1.119599%
07/31/08	0.871558%	0.988837%
10/15/08	2.631012%	2.444521%
10/31/08	2.275398%	1.270908%
01/15/09	1.937640%	1.937896%
01/30/09	1.703604%	1.796433%
04/15/09	1.374205%	1.562971%
04/30/09	1.386743%	1.344870%
07/15/09	0.983637%	1.016045%
07/31/09	0.984777%	1.056726%
10/15/09	0.825207%	0.756262%
10/30/09	1.166004%	0.821412%
01/15/10	0.680454%	1.033058%
02/26/10	0.740863%	0.794999%
04/15/10	0.603708%	0.610086%
04/30/10	0.837745%	0.845228%
07/15/10	0.955143%	0.977077%
08/31/10	0.989716%	0.986156%
09/15/10	0.839644%	0.865043%
10/29/10	0.805451%	0.762639%
11/15/10	0.767458%	0.789700%
01/31/11	0.742002%	0.765622%
02/28/11	0.624224%	0.670119%
03/31/11	0.673995%	0.630398%
04/29/11	0.560396%	0.511972%
05/31/11	0.586991%	0.388586%
07/29/11	0.959322%	0.950896%
08/31/11	1.201337%	0.803517%
09/30/11	1.632177%	1.620119%
11/30/11	1.056204%	1.008255%
12/30/11	0.889035%	0.147290%
Average	0.831114%	0.799098%

Table 10 illustrates that though the borrowing costs of the TIPS and nominal Treasury bond programs are very similar, that on average the TIPS program is more expensive, thus costing the Treasury in an accounting framework. Overall, from mid-2004 through the end of 2011, issuing a TIPS instead of a nominal bond cost the Treasury an additional 3 bp on average. This 3 bp amounts to a total cost of over $221 million, based on the amount of TIPS outstanding as of December 2011.

The question then, is why does the Treasury continue to issue TIPS, given that it loses money by doing so? I believe the answer is that there are several nonmarketable economic benefits that result from the TIPS program, and that these benefits make it worthwhile.

First, each TIPS auction has been met with great demand, showing that investors are clearly willing to buy TIPS, even though they have a significantly thinner secondary market than nominal Treasury bonds. This suggests that TIPS provide some sort of additional benefit to investors. As Lamm Jr. (1998) and Kothari and Shanken (2004) show, TIPS significantly extend the efficient frontier of investors using portfolio theory, and thus provide these investors with a greater return without any increase in risk exposure. Hence, TIPS could provide a public benefit by completing the market for government securities, and thus increasing the wealth of investors.

Second, the investor base for TIPS is significantly different than that of nominal Treasury bonds, as TIPS appeal to investors with long-term horizons. This is mainly because the inflation adjustment of TIPS is not received until maturity. Furthermore, TIPS are particularly appealing to investors "whose obligations are tied to inflation, such as pension funds and insurance companies." (Shen, 2009) Since these types of investors usually hold securities until maturity, in order to match the durations of their assets and liabilities, the thinner secondary market of TIPS is of minimal concern to them. Thus, TIPS are a well-tailored security for these specific investors, who previously had to make do with nominal Treasury bonds. So, TIPS could also provide a public benefit by increasing the efficiency of risk sharing in the economy, by providing a separate security and market for a distinct type of investor.

Third, Dudley, Roush, and Ezer (2009) state that the TIPS program incentivizes responsible fiscal and monetary policy. Unlike nominal Treasury debt, the payments on TIPS cannot be inflated away if the total federal debt burden becomes too large. Thus, they argue that the TIPS program can motivate government authorities "to conduct policy with an eye toward the consequences of inflation." (Dudley, Roush, and Ezer, 2009) Furthermore, they argue that the TIPS program "reduces the overall volatility of the Treasury's financing needs, [thus] smoothing their borrowing costs." (Dudley, Roush, and Ezer,

2009) Therefore, TIPS could provide additional public benefits by inducing future fiscal and monetary responsibility as well as reducing the volatility of government borrowing needs.

Though it is beyond the scope of this paper to put a monetary value on these nonmarketable economic outcomes, they could very well provide significant public benefits that make the additional accounting borrowing costs of the TIPS program worthwhile.

VIII. Conclusion

In this paper, I have supported the existence of the TIPS liquidity and tax disadvantage premia and estimated their values through various empirical models. I have also demonstrated that in an accounting framework, the TIPS program is in fact more expensive to the Treasury than the nominal bond program. In doing so, I believe that I have provided a rigorous, accurate, and informative evaluation of the TIPS program since mid-2004.

My results first show that the TIPS liquidity premium ranges from 13-87 bp, with an average of 27 bp, and that it varies with the volatility of expected future inflation. This is less than my hypothesized range of 40-100 bp. These results are reasonable however, as they are in line with the findings of Christensen and Gillan (2011b), who estimated the average TIPS liquidity premium to be between 30-44 bp. Furthermore, Shen (2006) notes that the TIPS secondary market deepened significantly in 2004, coinciding with a large increase in the frequency of TIPS issuance by the Treasury. Thus, since my study period begins in 2004, right when the TIPS market was deepening, it again makes sense that my estimates for the TIPS liquidity premium are a bit low.

My results also show that the TIPS tax disadvantage premium ranges from 26-176 bp, with an average of 56 bp. I consider it a great success that I was able to estimate this premium, albeit with weak evidence; though a few authors have previously verified the existence of the TIPS tax disadvantage premium, I am unaware that anyone has actually attempted to estimate its magnitude. Though I had no hypothesized range for the TIPS tax disadvantage premium due to this lack of relevant literature, these results are reasonable based on the notion that the TIPS tax disadvantage premium also varies with the volatility of expected future inflation.

Lastly, my results illustrate that in an accounting framework, it is indeed slightly more expensive for the Treasury to issue a TIPS rather than a nominal bond, thus confirming my hypothesis. It is notable however, that the TIPS program potentially brings about several nonmarketable economic benefits that can make the program worthwhile given its additional cost. Since the literature on the costs and benefits of the TIPS program is split rather evenly, my results cannot conclusively be placed on either side of the “for TIPS-against TIPS” divide.

Though I believe that my results are reliable and significantly contribute to the TIPS literature, there is still room for improvement in my analysis. First, I would have liked to have performed my analysis of the TIPS program in its entirely since 1997, rather than since mid-2004. However, data for several key variables (most notably SwapYield and the 10-Year Treasury Inflation-Indexed Security, Constant Maturity index) was only readily available since mid-2004. It would have been very interesting to examine the dynamics of the TIPS liquidity premium in the early years of the program, before the secondary market for TIPS deepened. Second, I could have obtained more reliable values for expected inflation by estimating them through a generalized autoregressive conditional heteroskedasticity (GARCH) model, rather than extracting them from a combination of TIPS and nominal Treasury bond metrics. This is an extremely complex econometric method however, and would have been beyond the scope of this thesis, as it could constitute an entire paper on its own. Third, I could have devised a separate econometric method to determine the size of the inflation risk premium, rather than relying on the TIPS liquidity and tax disadvantage premia in order to calculate it. This likely would have corrected for the two negative values of the inflation risk premium that resulted from my method. This too however, would also have been extremely challenging, complex, and beyond the scope of this thesis, as it could constitute an entire paper on its own as well.

Regarding future research, I think that it would be very worthwhile to examine the nonmarketable public benefits of the TIPS program. Particularly, if a monetary value could be assigned to these public benefits, then the costs and benefits of the TIPS program in its totality could be more accurately measured. Furthermore, this exercise would allow for the estimation of the additional return generated by investors’ portfolios as a result of TIPS completing the government securities market. It would also allow the estimation of the increase in risk-sharing efficiency that is primarily due to the TIPS program. Finally, this project would permit the estimation of how much these public benefits have influenced, if any, the equilibrium long-term national interest rate.

APPENDIX
The TIPS Liquidity Premium with Realized Inflation

In order to further investigate the relationship between VIXLevel and TIPS liquidity, I replicated Table 4 and Table 5 using realized inflation from the CPI rather than expected inflation. Table A1 and Table A2 show the before- and after-tax effects of the TIPS liquidity proxies on both SwapSpread and YieldSpread, using this realized inflation for after-tax yield calculations.[10] I would like to note however, that these two tables are meant strictly to investigate the relationship between VIXLevel and expected inflation as it pertains to TIPS liquidity. They are not intended to analyze the existence or size of the TIPS liquidity premium. This is because these tables invoke future information (realized CPI values) that is unknown at the time of issuance (whereas Table 4 and Table 5 use expected inflation at issuance, which is known, to reflect this uncertainty). Hence, the after-tax coefficients in these tables are unreliable predictors of TIPS premia, but can still shed light on their causes and dynamics.

10 For payments after December 2011, I assumed the CPI to grow at an annual rate of 2.5%, which is in line with expectations from the Philadelphia Fed's Survey of Professional Forecasters.

Table A1: SwapSpread on TIPS Liquidity Proxies, Before- and After-Tax, Using Realized Inflation

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Varaibles	*Before-Tax Coefficients*							After-Tax Coefficients						
OffOnSpread	6.225609	-	-	-	1.882534	-	2.202288	4.038197	-	-	-	3.572108	-	3.936738
	(4.33)				(0.87)		(1.23)	(2.34)				(1.43)		(1.67)
GNMASpread	-	.0030442	-	-	.0013118	-	.0007631	-	.0021326	-	-	.0021332	-	.0010543
		(3.17)			(1.90)		(1.12)		(1.75)			(1.41)		(0.78)
VIXLevel	-	-	.0153135	-	.0108526	.0089362	.0056774	-	-	.0026386	-	-.005093	-.0065029	-.0118556
			(3.85)		(2.36)	(2.33)	(1.40)			(0.58)		(-0.82)	(-1.00)	(-1.89)
SwapSpreadTSLag	-	-	-	.7747398	-	.5253689	.4907275	-	-	-	.6032415	-	.7847098	.7375544
				(4.98)		(3.30)	(2.94)				(3.98)		(3.21)	(3.22)
R^2	0.22	0.27	0.42	0.46	0.48	0.56	0.59	0.05	0.06	0.00	0.14	0.09	0.16	0.21

robust t-statistics are in parentheses underneath coefficients

Table A2: YieldSpread on TIPS Liquidity Proxies, Before- and After-Tax, Using Realized Inflation

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Varaibles	*Before-Tax Coefficients*								*After-Tax Coefficients*							
OffOnSpread	10.71323	-	-	-	-	1.808169	-	2.416733	8.525828	-	-	-	-	1.670632	-	2.739377
	(2.87)					(0.85)		(1.37)	(3.20)					(0.74)		(1.77)
GNMASpread	-	.0040088	-	-	-	.0012378	-	.0011171	-	.0030972	-	-	-	.000242	-	-.0001468
		(1.52)				(1.55)		(1.33)		(1.60)				(0.21)		(-0.14)
VIXLevel	-	-	.0416378	-	-	.0117216	.0129528	.0059202	-	-	.0289629	-	-	.0171272	.0100662	.0067609
			(4.77)			(1.88)	(2.74)	(1.22)			(5.54)			(2.28)	(2.12)	(1.20)
SwapYield	-	-	-	-1.222257	-	-.9754156	-.7704242	-.856634	-	-	-	-.7053072	-	-.3713835	-.1441415	-.1687631
				(-9.44)		(-8.39)	(-5.63)	(-5.84)				(-4.52)		(-1.97)	(-0.76)	(-0.86)
YieldSpreadTSLag	-	-	-	-	.9225836	-	.2865174	.2921897	-	-	-	-	.7625466	-	.5233446	.5371547
					(4.90)		(2.41)	(2.57)					(6.61)		(3.96)	(4.20)
R^2	0.14	0.09	0.66	0.81	0.61	0.89	0.91	0.92	0.13	0.09	0.48	0.41	0.61	0.53	0.67	0.68

robust t-statistics are in parentheses underneath coefficients

Table A1 and Table A2 generally support the theory that expected inflation uncertainty is the main factor driving the relationship between VIXLevel and TIPS liquidity, but that other factors are present. It can be seen in Column 13 of Table A1 that VIXLevel loses its statistical significance once expected inflation becomes realized CPI inflation, once again suggesting that it is a good proxy for expected inflation. Likewise, in Column 15 of Table A2 SwapYield loses its statistical significance, which supports this notion, as it is a well-defined proxy of expected inflation. However, in Column 15 of Table A2 it can also be seen that VIXLevel remains a statistically significant after-tax estimator even after controlling for expected inflation at issuance. Thus, these results also imply that there are some other factors that can affect TIPS liquidity, even if expected inflation uncertainty is the main cause.

Table A3 replicates Table 6 using realized CPI values rather than expected inflation. It introduces both InfAvg and InfVol into the YieldSpread regressions in order to confirm that expected inflation uncertainty is in fact the main cause of the TIPS liquidity premium.

Table A3: YieldSpread on Inflation Measures and TIPS Liquidity Proxies, Before- and After-Tax, Using Realized Inflation

	1	2	3	4	5	6	7	8	9	10	11	12
Varaibles	*Before-Tax Coefficients*						*After-Tax Coefficients*					
InfAvg	-	-	-	-.0140039 (-0.32)	-0.088948 (-2.38)	-.0816377 (-1.16)	-	-	-	-.0447432 (-0.97)	-0.112089 (-3.37)	-.1071851 (-2.05)
InfVol	-	-	-	.0007843 (0.05)	0.0244686 (1.21)	.0825427 (2.29)	-	-	-	.0079058 (0.47)	0.0274011 (1.17)	.0663593 (2.42)
SwapYield	-.7704242 (-5.63)	-.8859944 (-8.04)	-1.222257 (-9.44)	-	-	-	-.1441415 (-0.76)	-.3353452 (-1.83)	-.7049038 (-4.52)	-	-	-
VIXLevel	.0129528 (2.74)	.0183146 (3.38)	-	.0277238 (2.73)	0.0395978 (4.61)	-	.0100662 (2.12)	.020128 (3.38)	-	.0160766 (2.65)	0.0265637 (6.54)	-
YeildSpreadTSLag	.2865174 (2.41)	-	-	.4627805 (1.72)	-	-	.5233446 (3.96)	-	-	.4188272 (2.06)	-	-
R^2	0.91	0.88	0.81	0.76	0.72	0.17	0.67	0.52	0.41	0.67	0.62	0.25

robust t-statistics are in parentheses underneath coefficients

Table A3 does indeed support the theory that the uncertainty of expected inflation is the driving force behind the TIPS liquidity premium. In Column 2 and Column 5 of Table A3, it can be seen that VIXLevel is statistically significant, confirming that it is a robust liquidity proxy for TIPS. It can then be seen in Column 11 and Column 12 of Table A3 that once expected inflation has become realized CPI inflation, VIXLevel and InfVol are multicollinear—in Column 11 VIXLevel is very statistically significant and InfVol is not, but when VIXLevel is eliminated from the regression in Column 12, InfVol clearly becomes statistically significant. This supports the theory (which is consistently presented in this paper) that it is specifically the uncertain volatility of expected future inflation that is the main factor influencing TIPS premia.

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