Brian Sack and Robert Elsasser

Treasury Inflation-Indexed Debt: A Review of the U.S. Experience

- Treasury inflation-indexed securities (TIIS) have yet to live up to one of their primary goals: reducing the U.S. Treasury's expected financing costs.
- Since 1997, yields on TIIS have been surprisingly high relative to yields on comparable nominal Treasury securities, with the spread between yields falling, on average, well below survey measures of long-run inflation expectations.
- This study attributes this "valuation puzzle" to several factors: investor difficulty adjusting to a new asset class, divergent supply trends between TIIS and nominal Treasuries, and the lower liquidity of TIIS. In addition, investors may have had a benign outlook for inflation and inflation risks.
- More recently, the liquidity and breadth of investor participation in the TIIS market have increased notably, and the valuation of these securities appears to have improved.

1. Introduction

In January 1997, the U.S. Treasury began issuing Treasury inflation-indexed securities (TIIS)—debt securities with coupon and principal payments that adjust in line with a measure of consumer prices. Through 2003, the Treasury had issued $172 billion of these securities, with maturity dates ranging from 2002 to 2032. By the end of 2003, the amount of TIIS outstanding (including inflation accrual) totaled approximately $176 billion, or nearly 7 percent of all outstanding Treasury notes and bonds.

Inflation-indexed debt held the promise of providing benefits to both investors and the Treasury. Investors could benefit, it was argued, from access to a new type of asset that reduces the risks associated with inflation. By purchasing inflation-indexed securities, they could lock in a real rate of return—measured in terms of the amounts of goods and services that can be purchased—over the maturity of the security, thereby protecting themselves against the possibility that an unexpected rise in inflation would erode the real return on a nominal debt security.[1] Moreover, the Treasury's willingness to issue TIIS could provide a benchmark that would spur private issuance of inflation-indexed securities.

The Treasury would also benefit, some argued, because the issuance of inflation-indexed debt would likely reduce its

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financing costs. The rationale was that investors typically demand a higher return on nominal debt securities to compensate for the risks associated with future inflation. By issuing inflation-indexed debt, the Treasury would eliminate that risk for investors and therefore avoid having to pay this "inflation risk premium," which would also lower its financing costs.[2]

In addition, some argued that issuing indexed debt would offer ancillary benefits by providing policymakers and market participants with a useful reading of real interest rates. In that case, comparing the yields on TIIS with those on nominal securities would provide a measure of the amount of compensation that investors demand to offset future inflation and the associated risks—a potentially useful gauge for monetary policymakers.

This article describes the U.S. experience with inflation-indexed debt, including the evolution of activity in the TIIS market since its inception and the valuation of those securities relative to nominal Treasury issues. We show that despite the potential appeal of TIIS, their yields have been surprisingly high relative to those on comparable nominal Treasury securities. Indeed, the spread between ten-year yields on nominal securities and TIIS has, on average, fallen about 50 basis points below the long-run inflation expectations reported in the Survey of Professional Forecasters, conducted by the Federal Reserve Bank of Philadelphia. We analyze several explanations for this "valuation puzzle" as well as offer evidence that bears on those explanations.

> *Despite the potential appeal of TIIS [Treasury inflation-indexed securities], their yields have been surprisingly high relative to those on comparable nominal Treasury securities.*

One possibility is that the low relative valuation of TIIS has reflected investor difficulty adjusting to a new asset class. Over much of the period examined, participation in the TIIS market has been quite limited, although the investor base appears to have broadened considerably in recent years.

A second possibility is that divergent trends in supply affected the relative values of TIIS and nominal Treasury securities over this period. The market had to digest fairly rapid growth in the supply of TIIS at a time when investor participation was subdued, which may have put upward pressure on the yields of those securities. The robust expansion in outstanding TIIS contrasted with substantial declines in the supply of nominal Treasury notes and bonds from 1997 to early 2002.

A third possibility is that the low relative valuation of TIIS has reflected the lower liquidity of those securities. TIIS liquidity was particularly poor during the first several years of the securities' existence. Liquidity has improved in recent years as participation in the market has expanded, but TIIS will likely never achieve the same liquidity as nominal Treasury debt, largely because of the different roles that the two types of securities play in financial markets. As we discuss, TIIS are held primarily by "end users," or investors that tend to buy and hold the instruments. By contrast, nominal Treasury securities, especially recently issued ones, are to a large extent used as hedging and trading instruments, with primary dealers playing a very active role in the market.[3]

Factors such as the difficulty of launching a new asset class, supply trends, and the lower liquidity of indexed debt clearly have weighed on the valuation of TIIS over parts of our study period. However, even after adjusting for the influence of these factors, we argue that the observed valuation of TIIS relative to nominal Treasury securities suggests that investors simply had a very benign outlook for inflation over this period and did not demand much, if any, of an inflation risk premium for holding nominal securities.

Because of the low valuation of TIIS relative to nominal securities, inflation-indexed debt has not yet lived up to its purpose of reducing financing costs for the Treasury.[4] Our results suggest that based on inflation through mid-2003, the TIIS program has cost the Treasury nearly $3 billion more than the issuance of comparable nominal securities. Moreover, we find that future consumer price index (CPI) inflation would have to come in at about 1.7 percent for the Treasury to break even on the outstanding TIIS securities. According to the Survey of Professional Forecasters, long-run inflation is expected to be about 2.5 percent. If that forecast proves accurate, the Treasury would pay roughly 80 basis points of additional financing costs on the outstanding TIIS relative to comparable nominal securities.

Nevertheless, the TIIS market seems to be evolving. Anecdotal evidence suggests that investor participation in the market has widened considerably in recent years and that the liquidity of TIIS has increased noticeably. Moreover, these developments appear to have coincided with some improvement in the relative valuation of TIIS, although the evidence is still quite tentative to date.

2. The Mechanics of TIIS

Treasury inflation-indexed securities differ from nominal debt securities in the sense that payments on the TIIS adjust over time based on the rate of CPI inflation. More specifically, the principal amount of the TIIS increases daily by an amount determined by the increase in the CPI measure between the third and second preceding months—the minimum indexation lag possible given the timing of the CPI data release. Coupon payments on TIIS are determined as a fixed percentage of the indexed principal amount and therefore also increase in line with the CPI. Because of indexation, the principal and coupon payments on the TIIS are fixed in real terms—that is, on an inflation-adjusted basis. As a result, the quoted yield on a TIIS is approximately the real rate of return that an investor would earn by holding the security to maturity.[5]

The spread between the yield on a TIIS and that on a comparable nominal security—often called the rate of inflation compensation—is influenced by investors' views about future inflation. (See the appendix for a more formal discussion of the pricing of TIIS relative to nominal securities.) If investors were risk-neutral, the rate of inflation compensation would (approximately) equal the annualized cumulative rate of inflation that investors expect over the maturity of the security, up to an adjustment for convexity. The reason is that investors would demand the same expected return on the two securities, equal to the quoted yield for the nominal security or to the sum of the quoted yield on the TIIS and the expected inflation accrual.

As one might expect, this leaves open the issue of determining the appropriate nominal security to compare with the TIIS. The most common practice is to use a nominal coupon security with a similar maturity. However, the two securities have different payment flows: the nominal payments on the TIIS are much more back-loaded than those on a standard nominal coupon security; in real terms, the coupon payments on the nominal security decline over time, unlike the constant real coupon payments on a TIIS.[6] We explicitly take this issue into account later when calculating the relative cost of TIIS.

One complication with interpreting inflation compensation involves the adjustment for convexity. For a given level of the yield on a nominal security, uncertainty about future inflation increases the expected return on that security. This is a mechanical relationship that arises from the convexity of real returns in inflation—specifically, because higher inflation erodes the real return on the security at a slower rate than lower inflation boosts it (see the appendix). This point was originally made by Fischer (1975); a more recent description of the relationship between inflation compensation and future inflation can be found in McCulloch and Kochin (1998).

Although convexity tends to pull down inflation compensation relative to expected inflation, there may be an inflation risk premium that works in the opposite direction.

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Indeed, investors are most likely not risk-neutral and hence will not expect to earn the same return on a TIIS and a nominal Treasury security. Because future inflation erodes the real payments on a nominal security but not those on a TIIS, one might expect risk-averse investors to demand a higher expected return on nominal securities when future inflation is uncertain. Such a risk premium would push up inflation compensation relative to expected inflation, thereby increasing the financing cost to the Treasury on nominal debt securities. Indeed, eliminating this additional cost was one of the primary arguments for issuing TIIS.

Unfortunately, the inflation risk premium is difficult to measure, and there is considerable uncertainty about its magnitude and even its sign. One estimate comes from Campbell and Shiller (1996), who use the historical behavior of inflation and real interest rates in a capital asset pricing model to estimate the inflation risk premium for the five-year nominal bond.[7] They estimate the inflation risk premium to be between 50 and 100 basis points.

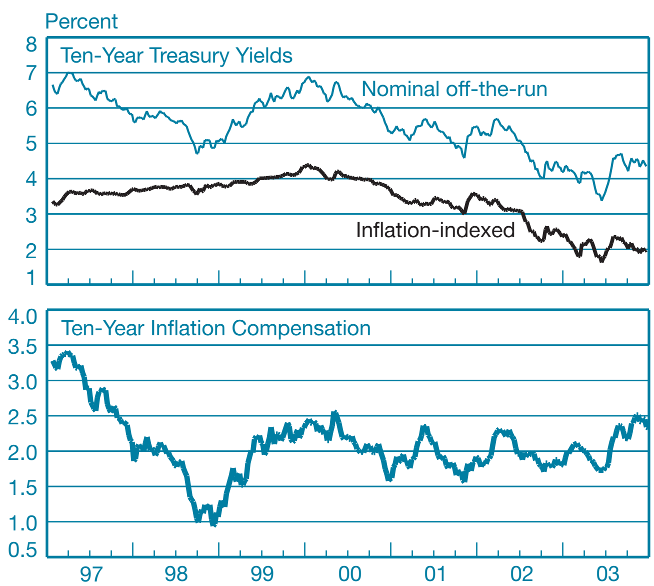
A final consideration in valuing TIIS is that the securities offer deflation protection, in the sense that the cumulative adjustment to the principal amount of the inflation-indexed security at maturity cannot be negative. In terms of real returns, this feature gives investors a put option on cumulative inflation with a strike of zero. We ignore the value of this option in assessing the spread between nominal and inflation-indexed debt. Over most of our sample, the option was likely viewed as being sufficiently out-of-the-money so as to have little value.

3. TIIS Market Developments

The TIIS program got off to an impressive start. The program's inaugural auction of a ten-year note in January 1997 was very well received by investors, creating a brief period of enthusiasm for the new asset class. The amount of bids at the first auction was impressive, with a bid-to-cover ratio (the amount of bids divided by the amount issued) equal to 5.3, compared with only 2.4 and 1.9 for the preceding and subsequent nominal ten-year-note auctions, respectively. Moreover, the stop-out rate (the yield at which the security was issued based on investor bidding) for the inaugural auction was 3.449 percent, which was more than 3 percentage points below the yields on comparable nominal Treasury securities.[8]

The spread between nominal and TIIS yields that prevailed over the first several months would in fact be the widest level observed during the TIIS program to date. Chart 1 shows the history of the yields on nominal and inflation-indexed ten-year Treasury securities, where an off-the-run nominal yield is used to limit the difference in the liquidity of the nominal and indexed securities.[9] (Off-the-run securities are previously issued securities, which are much less liquid than the most recently issued, or on-the-run, securities. The liquidity of off-the-run securities and TIIS is discussed in more detail below.)

Chart 1
Treasury Yields and Inflation Compensation



Source: Smoothed yield curves are estimated by the Board of Governors of the Federal Reserve System based on proprietary market quotes collected by the Federal Reserve Bank of New York.

Note: Inflation compensation is measured relative to off-the-run nominal Treasury securities.

The chart's bottom panel shows a measure of ten-year inflation compensation based on the difference between the nominal and indexed yields. We see that the inflation compensation measure averaged about 3 1/4 percent over the first several months of 1997, which was greater than the prevailing level of inflation expectations from various surveys. In response to the favorable valuation of indexed debt, the initial Treasury offering was followed by a flurry of other borrowers issuing

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inflation-indexed securities of their own. Between February and July 1997, fifteen different U.S. non-Treasury issuers offered a total of $2.3 billion of inflation-indexed securities.

The enthusiasm for inflation-indexed debt was not long-lived, though. Inflation compensation fell steadily over 1997 (Chart 1), reaching a level of about 2 percent during the first half of 1998. This decline may partly reflect the fact that the strongest demand for TIIS—by those investors willing to give up the largest amount of yield to hold inflation-indexed rather than nominal securities—was quickly saturated. In addition, the fall in inflation compensation may be partly attributed to a broad decline in inflation expectations. In 1997, various currency crises abroad and concerns about a global economic slowdown, particularly in Asia, dominated market attention. As commodity prices plummeted and the dollar surged, inflation indicators consistently fell below expectations. Chart 2 shows the actual headline CPI figure and the unexpected component of the monthly CPI release calculated from a Bloomberg survey of market participants. Throughout this period, inflation declined to very low levels and consistently surprised market participants to the downside. In this environment, investors apparently had little interest in purchasing the inflation protection offered by TIIS.

In the fall of 1998, financial market volatility abroad spread to U.S. financial markets, causing investors to place great value on the liquidity of their portfolios. The increased preference for liquidity at that time pushed down nominal yields relative to TIIS yields, given that nominal securities are more liquid (Chart 1). On-the-run nominal Treasury securities were viewed as the ultimate liquid instruments, but even off-the-run

Treasuries benefited, which contributed to the sharp decline in their yields. In contrast, yields on TIIS dipped only modestly, as trading activity in these securities was reportedly viewed as too limited to provide the flexibility needed in such unpredictable market conditions. As a result, inflation compensation fell to a remarkably low level, reaching a trough at around 1 percent in October 1998.

Over the first half of 1999, some of the factors that may have been limiting the appeal of TIIS began to unwind. CPI inflation turned higher and began to show some upward momentum (Chart 2), in part due to considerable increases in energy prices. In addition, investors' preference for liquidity, while still elevated, fell back from its extreme levels. In response, inflation compensation rose sharply over the first half of 1999.

Since 1999:2, movements in nominal and TIIS yields appear to have become more correlated, and inflation compensation has remained in a narrower range—typically between 1 1/2 and 2 1/2 percent—in contrast to the wide swings seen during the first two years of the TIIS program. Inflation compensation edged higher over most of 1999 as the economy grew at a rapid pace and reached a new peak at slightly more than 2 1/2 percent in May 2000, when concerns about inflation seemed to crest. TIIS yields also rose over this period as the tightening of monetary policy led to expectations of a higher path for real interest rates.

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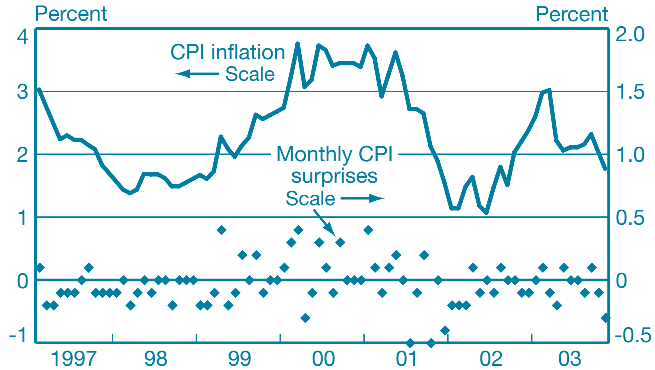
As the growth of the economy moderated over the latter part of 2000, real interest rates and inflation compensation drifted lower. Once it became apparent late in 2000 that the economy was slowing more rapidly, real interest rates and inflation compensation fell considerably, although inflation compensation retraced part of that decline after the Federal Reserve began to ease monetary policy in early 2001. Inflation compensation remained at fairly low levels on average through mid-2003, as the recession and the resulting slack in resource utilization damped inflation pressures. Real yields also fell dramatically, as the Federal Reserve cut the federal funds rate to 1 percent. More recently, inflation compensation again turned higher as investors became more optimistic about the economic outlook.

Additional information about real interest rates can be obtained by looking at the term structure of TIIS yields. Chart 3 presents several snapshots of the TIIS yield curve over the past four years. It shows that the curve shifted down somewhat from mid-2000 to early 2001, as investors came to expect slower economic growth and some easing of monetary policy. Realized policy easing through early 2002 was much more aggressive than expected, causing the TIIS curve to fall further and to steepen dramatically. Indeed, the yield on the TIIS maturing in 2002 declined all the way to, and even below, zero.[10] TIIS yields generally continued to move lower in 2003, as the economic recovery turned out to be more anemic than expected, although by the end of the sample they had risen off their lows reached earlier in the year.

Chart 2

CPI Inflation and Expectation Errors

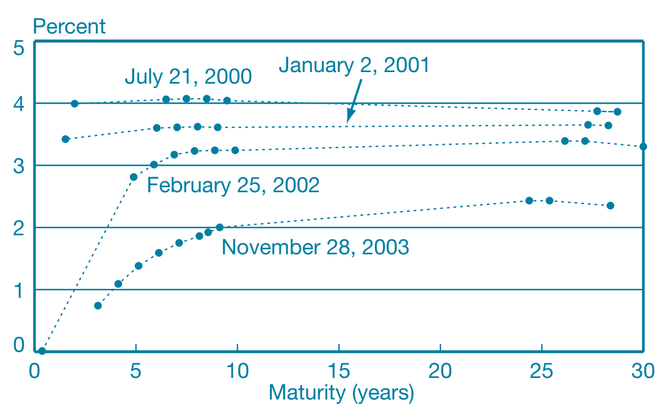


Sources: U.S. Department of Labor, Bureau of Labor Statistics (CPI); Bloomberg (CPI expectations).

Notes: Consumer price index (CPI) inflation is the twelve-month change in the nonseasonally adjusted overall index. Data are through November 2003.

Chart 3

Yield Curves of Treasury Inflation-Indexed Securities



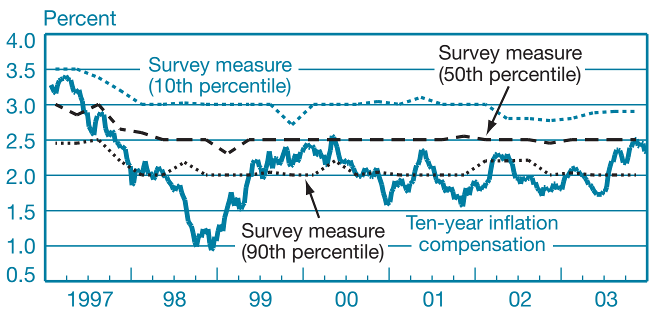
Source: Bloomberg.

4. The Low Relative Valuation of TIIS

Although recent trends in TIIS and nominal Treasury yields seem reasonable given the changes in macroeconomic conditions that have taken place, the *level* of TIIS yields relative to nominal yields has been somewhat puzzling. In particular, the yields on TIIS have been quite high relative to nominal Treasury yields, so that the level of inflation compensation has consistently fallen below many survey measures of expected inflation. Chart 4 again shows the ten-year inflation compensation measure plotted with a measure of ten-year inflation expectations from the Survey of Professional Forecasters, conducted by the Federal Reserve Bank of Philadelphia. On average, market-based inflation compensation has been about 50 basis points below the median survey response. This average difference is only slightly smaller (45 basis points) if we focus only on the period since early 1999, when inflation compensation seemed to stabilize somewhat. Even more striking, the level of inflation compensation has often fallen around or below the responses of 90 percent of the survey participants.[11]

One consideration is whether the difference between inflation compensation and the survey measure can be explained by the convexity adjustment described earlier. This adjustment is likely not large enough to account for the difference. Under a reasonable estimate of uncertainty about future inflation (discussed in Section 5), the convexity effect decreases ten-year inflation compensation by 11 basis points or less—a small portion of the average 50-basis-point gap between inflation compensation and the survey.

Chart 4
Inflation Compensation and a Survey Measure of Inflation Expectations



Source: Federal Reserve Bank of Philadelphia, Survey of Professional Forecasters.

Note: The survey measure is expected ten-year consumer price index inflation.

The findings from Chart 4 suggest either that some special factors weighed on TIIS prices, or that investors had very low perceptions of future inflation and the associated risks. We now consider some of these possible interpretations.

4.1 Difficulty Adjusting to a New Asset Class

The low valuations of TIIS may, in part, reflect the difficulties associated with launching a new type of asset. The securities are somewhat complex and likely require a nontrivial investment in a potential buyer's infrastructure (such as accounting and trading systems), thereby hindering the expansion of the investor base. Furthermore, investors have had only a relatively short track record of evaluating the behavior of these securities, including the likely volatility of TIIS prices and their correlations with other asset prices. Given these considerations, one might expect it to take some time to build a sizable investor base for the TIIS market.

Data on the distribution of end users of TIIS are not available, but anecdotal reports suggest that the investor base for these securities has been much more concentrated than the base for nominal Treasuries. As expected, the primary participants in the market are large institutional investors such as pension funds and insurance companies—investors with significant amounts of long-term real liabilities that can be counterbalanced by holding long-term real assets.

Notably, the primary dealers, which are the major participants in the market for nominal Treasury securities, have generally been much less active in the TIIS market than they are in the nominal Treasury market. For the dealer activity present in the TIIS market, trading volume is concentrated among a small number of dealers. The share of total TIIS transaction volume among the top quintile of primary dealers averaged 80 percent in 2002, compared with 47 percent for nominal Treasury securities.

Importantly, however, investor interest in the TIIS market appears to have expanded significantly in the past couple of years. Large numbers of investors reportedly have entered the market, particularly after the Treasury reaffirmed its commitment to the TIIS program in February 2002 and indicated that it would seek ways to develop the market further.[12] Indeed, dealers report that their customer base has been expanding robustly, particularly among medium-sized institutional investors. Moreover, anecdotal reports suggest that several dealers began to increase their market-making activity in the TIIS market in late 2002 and 2003.

In addition, small investors appear to be increasing their holdings of TIIS. At least seven different companies currently offer mutual funds that hold inflation-indexed securities. The most recent data available from these funds indicate that the funds have a total of approximately $16 billion in assets. These holdings still represent only a modest portion of outstanding TIIS, but the funds are growing rapidly. In fact, the total amount of assets in the funds appears to have expanded five-fold since 2001.

Overall, the "newness" of TIIS was probably an important factor weighing on the valuations of the securities over the earlier parts of our study period. The fact that the breadth of investor participation in the market has continued to increase even recently suggests that it has taken some market participants quite a long time to incorporate TIIS into their investment strategies. At this point, however, any lingering effect of this adjustment process on the valuation of TIIS has probably diminished substantially. TIIS have now traded in the market for more than seven years, giving potential investors enough experience to understand and adjust to the asset class.

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4.2 Lower Liquidity of TIIS

Another factor that may have weighed on the value of TIIS is their lower liquidity relative to that of nominal Treasury debt.[13] As we observed, primary dealers are generally much less active in the TIIS market than they are in the nominal Treasury market. The inactivity of the primary dealers largely reflects the fact that TIIS do not play the same role as hedging and trading vehicles that nominal Treasuries do, in part because of the absence of private inflation-indexed debt that needs to be hedged. As a result, dealer positions in TIIS pale in comparison to those in nominal securities. Over 2002, for example, primary dealers in total had an average of $102 billion in long positions in nominal Treasury coupon securities and $164 billion in short positions. By comparison, those same dealers had on average only $7 billion in long positions in TIIS and $4 billion in short positions.

Instead, activity in the TIIS market is dominated by end users that might find the securities appealing as an investment vehicle (a buy-and-hold asset). This characteristic can be seen from Chart 5, which shows weekly trading volume in TIIS reported by primary dealers as a percentage of total outstanding TIIS (the turnover rate). Most of the trading in the TIIS market takes place between dealers and customers. Further evidence of the greater appeal of TIIS to institutional investors than to primary dealers is available from the awards at Treasury auctions. Over 2001 and 2002, an average of 77.5 percent of the awards of nominal ten-year Treasury notes went to primary dealers and only 8.2 percent went directly to institutional investors such as mutual funds, pension funds, and insurance companies. By contrast, 54.7 percent of the awards at ten-year TIIS auctions went to primary dealers while 30.5 percent went to institutional investors.[14]

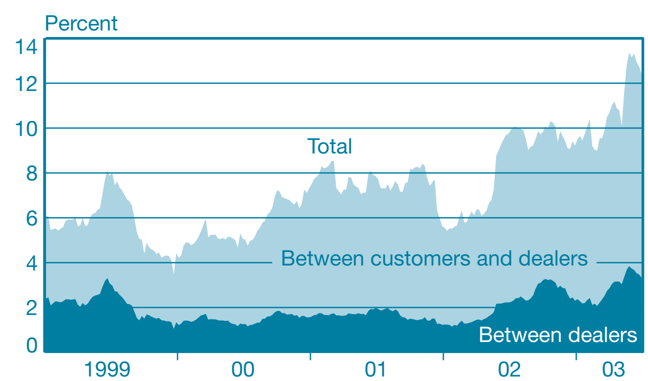
Given these differences in the composition of market participants and in the nature of trading activity, the liquidity of TIIS will likely never rival that of on-the-run nominal Treasury securities. Nevertheless, anecdotal reports suggest that TIIS liquidity has improved much in recent years and is currently not far below that of off-the-run nominal Treasuries.

These anecdotal reports are corroborated by the trading volumes depicted in Chart 5. As is evident, trading activity increased significantly over this period, with the weekly turnover rate reaching an average of about 11 percent over the first three quarters of 2003, compared with an average of less than 6 percent in 1999. In dollar terms, trading volume

Chart 5

Trading Turnover of Treasury Inflation-Indexed Securities

Weekly Trading Volume Relative to Outstanding Debt



Sources: Federal Reserve Bank of New York (trading volume); U.S. Treasury Department (outstanding amounts).

Notes: The series shown are thirteen-week moving averages. Data are through August 2003.

increased even faster, given that the supply of TIIS was expanding robustly over this period. This improvement has largely coincided with the greater participation of investors and dealers in the TIIS market.

The 11 percent turnover rate for TIIS is not far below the rate for some other types of fixed-income assets. Indeed, the average weekly turnover rate for agency debt securities over the same period was roughly 17 percent; for mortgage-backed securities, it was about 21 percent. Trading volume in nominal Treasury securities was instead much higher over that period, with an average weekly turnover rate of 82 percent across all outstanding coupon securities. It is important to note, though, that most of this trading took place in on-the-run issues, which turned over more than fourteen times per week on average and accounted for 74 percent of the total volume in Treasury coupon securities. Excluding on-the-run issues, we note that the turnover rate for all off-the-run Treasury coupon securities was approximately 22 percent—much closer to, although still above, the turnover rate for TIIS.

TIIS also appear to be somewhat less liquid than off-the-run nominal Treasury securities when liquidity is measured by transaction costs. Table 1 summarizes indicative bid-ask spreads observed for TIIS and for nominal Treasury securities. Bid-ask spreads on on-the-run nominal Treasuries are shown to be the narrowest, reflecting the remarkable liquidity of those issues. The spreads on TIIS are closer to those on off-the-run nominal securities, although the TIIS spreads are still wider. Moreover, the market for nominal Treasuries appears to be deeper than the TIIS market, in the sense that a larger volume of securities can be traded at posted bid and ask prices.[15]

Table 1
Typical Bid-Ask Spreads for Treasury Securities
1/32nds of Price

Type	Maturities of Five Years or Less	Maturities of Five to Ten Years	Maturities beyond Ten Years
On-the-run nominal	1/4 to 1/2	1/2	NA
Off-the-run nominal	1/2 to 1	1/2 to 1	2
Inflation-indexed	1 to 2	2	4 to 16

Source: Federal Reserve Bank of New York (informal survey of dealers conducted in mid-2003).

Notes: Bid-ask spreads are measured in 1/32s of a point, where a point roughly equals 1 percent of the security's par value. Spreads are for trades of approximately $25 million for Treasury inflation-indexed securities and up to $100 million for nominal Treasuries.

Overall, TIIS appear to be somewhat less liquid than off-the-run nominal securities—a factor that could boost TIIS yields and reduce measured inflation compensation. However, at least in recent years, the difference in liquidity has been sufficiently limited that, judging from observed liquidity premia in other markets, the difference would have had a fairly modest effect on the relative valuations of nominal and indexed securities.[16]

4.3 Relative Supply

From March 1997 through March 2002, the Treasury on net paid down $688 billion of nominal Treasury coupon securities, or 26 percent of the outstanding stock. In contrast, the supply of TIIS increased from zero at the beginning of 1997 to more than $145 billion (including inflation accrual) by March 2002. The divergent trends for supply may have affected the relative pricing of these securities. Indeed, the transition to a smaller nominal Treasury market at times seemed to result in a heightened premium for nominal Treasuries relative to other fixed-income securities.

While supply considerations at times may have weighed on the valuation of TIIS relative to nominal Treasury securities, any such effects have likely weakened substantially in recent years.

However, the paydown of Treasury debt has reversed in recent years, and the Treasury has been forced to implement sizable increases in its issuance of nominal securities. Indeed, it issued $96 billion in nominal ten-year Treasury notes over 2003—an amount well above the $47 billion of gross issuance in 1997. By comparison, gross issuance of ten-year TIIS increased less dramatically over that period, from $15 billion to $26 billion (and gross issuance of all TIIS has actually fallen over this period). Thus, while supply considerations at times may have weighed on the valuation of TIIS relative to nominal Treasury securities, any such effects have likely weakened substantially in recent years.

4.4 What Is the Total Effect of These Factors?

In general, the three factors we described—the difficulty adjusting to a new asset class, the lower liquidity of TIIS relative to nominal Treasury securities, and changes in the relative supply—may have weighed on the relative values of TIIS over the earlier parts of the period examined. However, those effects have probably weakened substantially in recent years. It therefore may be informative to focus on changes over time in the valuation of TIIS relative to nominal Treasury securities.

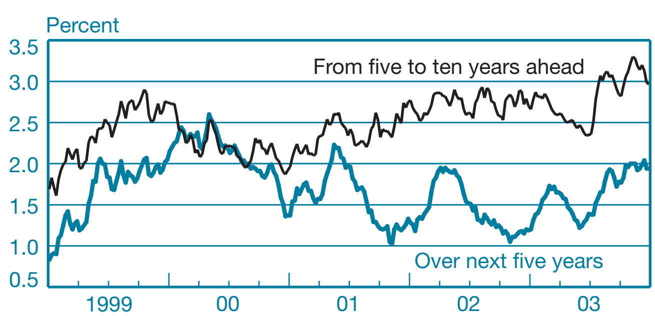
One difficulty in conducting such an exercise, however, arises because the economy weakened in the latter part of the study period, resulting in a decline in near-term inflationary pressures that presumably pulled down inflation compensation. This cyclical influence would likely have the largest effect on inflation expectations over the next several years and would fade at longer horizons. In contrast, the three factors considered above would likely be felt at all maturities, given that they influence the demand for all TIIS. Thus, one way to remove some of the cyclical effect and focus on the influence of these factors is to look at a *forward rate* of inflation compensation.

More specifically, the ten-year inflation compensation measure depicted in our charts can be decomposed into the rate of inflation compensation over the next five years and the forward rate of inflation compensation from five to ten years ahead.[17] (The average of these two rates will approximately equal the ten-year measure.) These measures are shown in Chart 6 for the period since 1999, which is as far back as the measures are computed.[18] As expected, the five-year measure fell to fairly low levels over the past few years, which in turn held down ten-year inflation compensation. However, the forward rate of inflation compensation from five to ten years ahead generally trended up over the period, despite the weakening economy.

The rising pattern of the forward inflation compensation rate provides some tentative evidence of an improvement in the relative valuation of TIIS over time that might be associated with some unwinding of the three factors discussed above. However, this evidence must be viewed with some caution. As one might expect, the forward rate is a very crude measure of the influence of these factors, as it is also influenced by changes to long-run inflation expectations and the inflation risk premium.

Overall, the total magnitude of the influence of these factors is difficult to quantify. The upward trend in forward inflation compensation appears to be on the order of 50 basis points or more, suggesting that these factors were having a fairly sizable effect earlier in the period.[19] It also seems likely that the effects of these factors had largely disappeared by the end of the sample. Indeed, our discussion suggests that the influence of the newness of TIIS and supply trends should have largely unwound and that the premium associated with remaining liquidity differences between TIIS and off-the-run nominal Treasuries should be relatively small.

Chart 6
Inflation Compensation Measures



Source: Smoothed yield curves are estimated by the Board of Governors of the Federal Reserve System based on proprietary market quotes collected by the Federal Reserve Bank of New York.

Note: Inflation compensation is measured relative to off-the-run nominal Treasury securities.

4.5 A Benign View of Inflation and Associated Risks

Even assuming that the three factors we identified depressed inflation compensation by 50 basis points on average over the period since 1999, their effects would just offset the average gap between the ten-year inflation compensation measure and survey expectations (see Chart 4). As we discussed, based on Campbell and Shiller's analysis (1996), one might expect the inflation risk premium to be between 50 and 100 basis points.[20] For these factors to be consistent with that hypothesis, they would have required a much larger effect—between 100 and 150 basis points—which we view as implausibly large. Thus, we are left to conclude that the low level of inflation compensation observed over this period to a large extent reflects investors' very benign outlook for inflation and the associated risks of holding nominal securities.[21]

5. The Cost of TIIS to the Treasury

The seemingly low valuation of TIIS relative to nominal debt securities has important implications for the relative cost of those securities to the Treasury. We now provide estimates of the cost of issuing the outstanding TIIS relative to the cost incurred by the Treasury had it instead issued nominal securities.

While the previous analysis compared TIIS yields with yields on off-the-run nominal securities, the relevant comparison from the perspective of financing costs is between TIIS and on-the-run nominal issues. The Treasury benefits from a liquidity premium that tends to lower the yields on its on-the-run nominal issues. This liquidity premium thus provides a cost advantage to nominal debt relative to TIIS.

The difficulty in obtaining cost estimates occurs in specifying the counterfactual, or the issuance strategy that the Treasury would have followed in the absence of TIIS. Because the payment flows on nominal and inflation-indexed securities differ considerably, there is no obvious choice of a nominal security for comparison to the TIIS. One might be tempted to compare TIIS with nominal debt securities having the same maturity, but the nominal coupon security has declining real coupon payments that give it a shorter duration than the TIIS. To minimize the effect of differences in payments, we instead compare the cost of each outstanding TIIS with the cost of a portfolio of hypothetical on-the-run zero-coupon nominal securities that replicate the back-loaded payments on the TIIS.[22] To be sure, the Treasury would not follow such a strategy in the absence of TIIS, but would instead likely increase its issuance of a variety of on-the-run securities. Nevertheless, this approach effectively captures the cost of replacing issuance of TIIS with issuance of nominal on-the-run securities, while minimizing any effects arising from differences in their payment streams.[23]

The seemingly low valuation of TIIS relative to nominal debt securities has important implications for the relative cost of those securities to the Treasury.

The first step in our analysis is to calculate break-even inflation rates for each TIIS auction, or the rate of inflation at which the cost to the Treasury of issuing a TIIS will exactly equal the cost of raising the same amount of funds by issuing the comparable nominal security (the portfolio of zero-coupon securities).[24] If inflation exceeds the break-even rate, the TIIS will be more costly than the nominal security, and vice versa. (The break-even inflation rate is the same concept as the inflation compensation rate discussed earlier, but here it is measured relative to on-the-run nominal securities rather than off-the-run securities.)

The break-even inflation rates for all auctions (including reopenings) of TIIS to date are shown in Table 2, column 5. The highest break-even inflation rates are for the first two auctions of inflation-indexed securities (both of which are the ten-year note maturing in 2007). As we observed, this result could reflect the fact that investors with the strongest demand for inflation protection were among the first to purchase TIIS. The lowest break-even inflation rates are for those securities issued around the financial market turbulence in the fall of 1998, perhaps because of the heightened preference for liquidity at that time. For auctions since April 1999, break-even inflation rates have remained in a narrower range, between 1.48 and 2.36 percent.

The cost of each TIIS issue to date depends on the difference between actual inflation and the break-even inflation rate. Column 6 of Table 2 shows the inflation rate realized over the period since each auction, adjusted for the indexation lag and expressed on an annualized basis. Deviations of actual inflation from the break-even inflation rate generate a stream of differences in payments on the nominal and inflation-indexed securities over the maturity of those issues. In our computations, we express the relative cost of the TIIS as the present value of all past and future differences in the payments on the two securities.[25]

Column 7 presents this cost measure for each outstanding TIIS as of June 30, 2003, based on realized inflation through that date. As we see, the largest cost savings to the Treasury occurred at the first two TIIS auctions, which together saved the Treasury more than $1 billion. By contrast, the TIIS issued at all auctions since October 1997 have been more expensive than comparable nominal securities.[26] The relative cost is especially high for those securities issued in October 1998 and January 1999. Summing across all securities, we estimate that the excess cost of all outstanding TIIS based on inflation to date is just under $3 billion.[27]

While these calculations account only for realized inflation to date, it may also be useful to estimate the total cost of the program under an assumption about inflation going forward. We find that future inflation would have to come in at about 1.7 percent for the Treasury to make up its realized costs to date and to break even on outstanding TIIS (in present-value terms). Of course, most economic forecasts project that CPI inflation will come in well above this level. For example, the Survey of Professional Forecasters discussed earlier expects inflation to be around 2.5 percent in the long run. In that case, it appears that the Treasury will pay nearly 80 basis points of additional yield on TIIS than it would have paid on comparable nominal debt.

Under the assumption that inflation will edge up to 2.5 percent by 2005 and remain at that level thereafter, we can compute the total cost of the TIIS program, or the present value of the differences in all past and future payments on the securities.[28] The results in Table 2, column 8, indicate that the Treasury will incur a higher relative cost on all but the first three TIIS auctions. The total cost of the inflation-indexed securities outstanding is estimated to be about $12 billion under the assumed path of inflation.

We obtain similar results if we instead consider an alternative exercise in which the Treasury follows a dynamic strategy for issuing coupon-bearing nominal securities. The basic insight of this approach is that the accrual of inflation compensation on indexed debt is similar to the issuance of additional debt, in the sense that it increases the principal and all future coupon payments. In fact, the Treasury can employ a strategy in which it issues the nominal coupon security with the same maturity date as the TIIS every six months so as to replicate all of the payments of the indexed security up to its maturity date. The relative cost of nominal and indexed debt is then captured entirely by the single difference in the payments on the maturity date. Under this approach, the estimated cost of outstanding TIIS (not shown) is very close to the cost found in Table 2.[29]

Table 2
Estimated Costs of Treasury Inflation-Indexed Securities (TIIS)

Auction	Auction Date (1)	Maturity Date (2)	Coupon Rate (Percent) (3)	Par Amount Issued (Billions of Dollars) (4)	Break-Even Inflation (Percent) (5)	Actual Inflation (Percent) (6)	Cost to Date (Millions of Dollars) (7)	Total Cost (Millions of Dollars) (8)
1	1/29/1997	1/15/2007	3 3/8	7.0	3.20	2.33	-586	-838
2	4/8/1997	1/15/2007	3 3/8	8.0	3.26	2.33	-697	-1,005
3	7/9/1997	7/15/2002	3 5/8	8.0	2.40	2.34[a]	-38	-38
4	10/8/1997	7/15/2002	3 5/8	8.0	2.34	2.39[a]	23	23
5	1/8/1998	1/15/2008	3 5/8	8.0	1.75	2.40	381	668
6	4/8/1998	4/15/2028	3 5/8	8.0	2.17	2.49	185	740
7	7/8/1998	4/15/2028	3 5/8	8.0	1.93	2.50	307	1,281
8	10/7/1998	1/15/2008	3 5/8	8.0	0.69	2.55	894	1,632
9	1/6/1999	1/15/2009	3 7/8	8.0	0.83	2.59	810	1,632
10	4/7/1999	4/15/2029	3 7/8	7.0	1.59	2.69	427	1,820
11	7/7/1999	1/15/2009	3 7/8	7.0	1.87	2.58	271	526
12	10/6/1999	4/15/2029	3 7/8	7.0	1.94	2.64	253	1,119
13	1/12/2000	1/15/2010	4 1/4	6.0	2.36	2.60	73	107
14	7/12/2000	1/15/2010	4 1/4	5.0	2.03	2.43	82	236
15	10/11/2000	4/15/2029	3 7/8	5.0	1.83	2.35	92	833
16	1/10/2001	1/15/2011	3 1/2	6.0	1.58	2.25	121	544
17	7/11/2001	1/15/2011	3 1/2	5.0	1.80	1.87	6	269
18	10/10/2001	4/15/2032	3 3/8	5.0	1.98	2.07	7	568
19	1/9/2002	1/15/2012	3 3/8	6.0	1.67	2.41	75	493
20	7/10/2002	7/15/2012	3	9.0	1.79	2.33	52	591
21	10/9/2002	7/15/2012	3	7.0	1.48	2.71	66	681
22	1/8/2003	7/15/2012	3	6.0	1.69	3.08	41	456
Total							2,846	12,337

Sources: U.S. Treasury Department (columns 1-4); authors' calculations (columns 5-8).

Notes: Columns 7 and 8 are the amount by which the cost of TIIS exceeds the cost of comparable nominal securities, where the cost is measured by the present value of the differences in the payments on the TIIS and the nominal securities. All cost figures are measured as of June 30, 2003. Column 7 shows the cost based on inflation through that date, accounting for the indexation lag. Column 8 presents the total cost if future inflation follows the path assumed by Congressional Budget Office (2003). Par amounts issued exclude securities issued to the Federal Reserve.

[a]Actual inflation for the July 15, 2002, security is measured only through its maturity date.

Although the above calculations suggest that TIIS appear to have been an expensive form of borrowing for the Treasury in expected terms, the actual (ex-post) cost of TIIS will depend on the realized level of CPI inflation over the life of those issues. Given the difficulties involved in making long-run economic forecasts, realized inflation can deviate substantially from expected inflation. If inflation was to come in above expectations, the ex-post cost of TIIS would be higher than these estimates. Conversely, if inflation was to come in far enough below the expectations assumed above, the outstanding TIIS could result in a lower financing cost than the cost of nominal debt. We estimate that each 0.01 percentage point of additional inflation adds about $150 million to the total cost of the TIIS program.

It is difficult to calibrate the uncertainty involved in predicting long-run inflation. A reasonable estimate, based on simulations of the Federal Reserve's FRB/US model and the past prediction errors reported by the Congressional Budget Office, is that the standard deviation of annualized ten-year inflation is somewhere between 0.5 and 1.5 percentage points.[30] If the average level of inflation in the long run is around 2.5 percent, as assumed above, then this range of uncertainty suggests that the probability of breaking even on outstanding TIIS is approximately between one-sixth and one-third. Of course, the probability of breaking even would increase if the average level of inflation is below 2.5 percent.

6. Conclusion

Over the first seven years of its existence, Treasury inflation-indexed debt has not appeared to be a less expensive form of financing for the Treasury. To some extent, the high relative cost of these securities to date may reflect the difficulties associated with launching a new type of asset, the lower liquidity of indexed debt relative to nominal Treasury securities, and the considerable growth in the supply of indexed debt. Furthermore, we argue that TIIS investors over the period appear to have had a very benign outlook for inflation and the associated risks of holding nominal securities.

In recent years, however, some of the factors that may have weighed on the relative value of TIIS have likely weakened. By now, investors have had ample time to adjust to the new security, and investor participation in the TIIS market has expanded considerably; liquidity appears to have improved noticeably with the increased market participation; and supply trends have become less favorable for nominal Treasury securities. Perhaps for these reasons, there is some tentative evidence that the relative valuation of TIIS has improved in recent years, although additional time and data will be needed for that conclusion to become more decisive.

Although the TIIS program thus far has appeared to be expensive, the Treasury has indicated its intention to sustain its issuance of indexed debt and to encourage the development of the market. In general, the Treasury pursues a more complicated debt management strategy than simply minimizing its current financing costs.[31] For example, the Treasury currently issues securities with maturities out to ten years, even though it pays a larger term premium at the margin on the longer maturities than it does on short-term debt. Instead, the Treasury likely takes into account the relationship between its borrowing needs and the costs of issuing different types of debt over time. Indeed, tax revenues might tend to increase with inflation, in which case the Treasury may be better able to absorb inflation risk than investors. Given these considerations, the optimal debt structure for the Treasury could contain some indexed debt.[32]

In addition, the Treasury likely recognizes that the TIIS market is still evolving and that the ultimate borrowing costs associated with these securities relative to nominal Treasury securities remain very uncertain. The behavior of the TIIS market going forward will therefore be of considerable interest.

Appendix: The Pricing of TIIS

As we describe in Section 2, the payments on Treasury inflation-indexed securities (TIIS) increase in line with the consumer price index (CPI). Specifically, the value of the principal on a given day is scaled up by an index ratio determined by dividing the reference CPI for that day by the reference CPI at the time of issuance. The reference CPI on the first of the month is the nonseasonally adjusted CPI index published by the Bureau of Labor Statistics for the third preceding calendar month, and its value within the month is determined by linear interpolation. This is the minimum indexation lag possible given the timing of the CPI data release.

Because of this indexation, the nominal payments on the indexed security are back-loaded relative to those on a nominal security, assuming that the rate of inflation is positive. An indexed security issued at time *t* with a coupon rate of *c*, a maturity of *N* years, and a par value of $100 has coupon payments after *n* years of $c \cdot 100 \cdot P_{t+n} / P_t$, where P_{t+n} is the reference CPI at time *t*+*n*, and a principal payment after *N* years of $100 \cdot P_{t+N} / P_t$. (For notational simplicity, we assume that coupons are paid annually and ignore semiannual compounding.) This back-loaded pattern allows the real coupon payments, $c \cdot 100$, to be constant.

If future inflation were known, the price of the inflation-indexed security at time *t*, B_t, would be determined by the sum of future nominal payments multiplied by the value of those payments, as follows:

$$\text{(A1)} \qquad B_t = \sum_{n=1}^{N} c \cdot 100 \cdot (P_{t+n} / P_t) \cdot \delta_t(n) + 100 \cdot (P_{t+N} / P_t) \cdot \delta_t(N),$$

where $\delta_t(n)$ is the discount function, which equals the value at time *t* that investors place on a nominal payment *n* periods into the future.[33] The discount function is determined by the term structure of nominal interest rates $\delta_t(n) = 1/(1+i_t^n)^n$, where i_t^n is the *n*-period zero-coupon nominal interest rate at time *t*. Rewriting the index ratio P_{t+n} / P_t as $(1+\pi_t^n)^n$, where π_t^n is the average annualized rate of inflation over the next *n* periods, and writing out the discount function, equation A1 becomes

$$\text{(A2)} \qquad B_t = \sum_{n=1}^{N} \frac{c \cdot 100 \cdot (1+\pi_t^n)^n}{(1+i_t^n)^n} + \frac{100 \cdot (1+\pi_t^N)^N}{(1+i_t^N)^N}.$$

To derive a simpler equation for TIIS, we define the *n*-period zero-coupon real interest rate r_t^n by the following:[34]

$$\text{(A3)} \qquad (1+r_t^n) = \frac{(1+i_t^n)}{(1+\pi_t^n)}.$$

Using this definition, equation A2 becomes

$$\text{(A4)} \qquad B_t = \sum_{n=1}^{N} \frac{c \cdot 100}{(1+r_t^n)^n} + \frac{100}{(1+r_t^N)^N},$$

which states that the TIIS is valued like a regular bond with a fixed coupon of *c*, only discounted using real interest rates rather than nominal rates. Note that the real payments on the TIIS security are independent of inflation, so that equation A3 holds regardless of whether future inflation is known. In practice, the quoted yield on a TIIS is the real yield to maturity on the security, which is the constant real interest rate r^{ytm} ($r^n = r^{ytm}$ for all *n*) for which equation A4 holds.

The spread between the yield on a TIIS and the yield on a comparable nominal security will reflect investors' views about future inflation. If future inflation is known, the *N*-period returns on two investments—one making a real payment in *N* periods and one making a nominal payment—must be equal, which implies that

$$\text{(A5)} \qquad (1+r)^N = \left[\frac{(1+i)}{(1+\pi)}\right]^N.$$

(We drop the subscripts and superscripts for notational simplicity.) This equation will be approximately satisfied if $i - r = \pi$. Thus, in this case, the yield spread between comparable nominal and indexed zero-coupon securities should (approximately) equal the future rate of inflation.

Equation A5 would hold for zero-coupon yields, and hence for the valuation of all the individual payments on the TIIS. The relationship is more complicated for the yields to maturity on coupon-bearing bonds. For those securities, the choice of the appropriate nominal security to compare with the TIIS is not obvious. The most common practice is to use a nominal coupon security with the same maturity as the TIIS. However, those two securities have different payment flows: the nominal payments on the TIIS are much more back-loaded than those on a standard nominal coupon security; in real terms, the coupon payments on the nominal security decline over time, unlike the constant real coupon payments on a TIIS.

Sack (2000) instead derives a measure of inflation compensation based on a portfolio of nominal zero-coupon securities (read off an estimated yield curve) constructed to match the back-loaded payments of the TIIS. Under the additional assumption that inflation is expected to be relatively stable around some level π, the following relationship still holds:

$$(1 + r^{ytm}) = \frac{(1 + i^{ytm})}{(1 + \pi)}, \qquad \text{(A6)}$$

where i^{ytm} is the nominal yield that investors would demand on a security with the same back-loaded payment stream as the TIIS. Nevertheless, as demonstrated in the Sack paper, the resulting measure differs only modestly from a simple yield spread based on a nominal coupon security. Sack argues that a more important factor is choosing a nominal security with a level of liquidity comparable to that of the TIIS—as we do here by using off-the-run rather than on-the-run nominal securities.

One complication with interpreting inflation compensation measures involves uncertainty about future inflation. If investors are risk-neutral, then they will demand the same expected real return on nominal and inflation-indexed zero-coupon securities. In that case, equation A5 becomes:

$$(1 + r)^N = E_t\left[\frac{(1 + i)^N}{(1 + \pi)^N}\right], \qquad \text{(A7)}$$

which can be rewritten approximately as follows:

$$i - r = \frac{1}{E_t\left[\frac{1}{(1 + \pi)^N}\right]^{1/N}} - 1\,. \qquad \text{(A8)}$$

According to equation A8, inflation uncertainty tends to pull inflation compensation down relative to the expected rate of inflation. To see that, note that Jensen's inequality implies that

$$E_t\left[\frac{1}{(1 + \pi)^N}\right] > \left[\frac{1}{(1 + E_t\pi)^N}\right]. \qquad \text{(A9)}$$

As a result, the yield spread will be less than the expected rate of inflation,

$$i - r < E_t\pi, \qquad \text{(A10)}$$

by an amount that increases with the uncertainty surrounding future inflation. For a coupon-bearing security, the total effect is a bit more complicated—equation A8 shows the effect of uncertainty on the value of any single payment, and those effects have to be aggregated across all payments on the security.

While convexity tends to pull down inflation compensation relative to expected inflation, there may be an inflation risk premium that works in the opposite direction. If investors are not risk-neutral, they will generally not demand the same expected return on the two securities. Because future inflation erodes the real payments on a nominal security but not on a TIIS, one might expect investors to demand a higher expected return on nominal securities when future inflation is uncertain. Such a risk premium would push the yield spread $i - r$ up relative to expected inflation, thereby increasing the financing cost to the Treasury on nominal debt securities. Indeed, as we observe in this article, this was one of the primary arguments for issuing Treasury inflation-indexed securities.

Endnotes

1. Investors cannot precisely lock in a real return because of taxes and the indexation lag on TIIS.

2. Another argument for issuing inflation-indexed debt is that it might help commit the government to maintaining low inflation. However, this incentive mechanism is generally seen as less important at this time for the United States.

3. For a broad overview of the Treasury securities market, see Dupont and Sack (1999).

4. In part for this reason, in May 2001, the Treasury Advisory Committee of the Bond Market Association recommended that the Treasury discontinue issuance of inflation-indexed securities (see "Report to the Secretary of the Treasury from the Treasury Advisory Committee of the Bond Market Association," May 1, 2001, available at <http://www.treas.gov/offices/domestic-finance/debt-management/adv-com/reports/index.html>).

5. The yield to maturity on a TIIS is calculated from the standard bond pricing formula, only assuming that there will be no additional inflation accrual from the quote date forward.

6. Sack (2000) instead derives a measure of inflation compensation based on a portfolio of nominal zero-coupon securities (read off an estimated yield curve) constructed to match the back-loaded payments of the TIIS. Nevertheless, as demonstrated in that paper, the resulting measure differs only modestly from a simple yield spread based on a nominal coupon security.

7. Similarly, Kopcke and Kimball (1999) evaluate the role of TIIS in efficient investor portfolios.

8. The behavior of TIIS over the first several months following the first auction is described in more detail in Wilcox (1998).

9. The indexed yield shown is the yield on the most recently issued ten-year TIIS, with a small adjustment made to keep its maturity fixed at ten years (see endnote 18). The nominal yield shown is the ten-year par yield read from a smoothed nominal yield curve estimated using the Svensson method to fit outstanding off-the-run notes and bonds.

10. Note that there is no zero bound on the yield on TIIS, as there is on the yields on nominal securities, because the inflation compensation can result in a positive nominal return even when the real yield is negative. The yield on the 2002 TIIS fell well below zero after the date shown.

11. An alternative measure, the Michigan Survey Research Center's Survey of Households, asks about the expected level of inflation over the next five to ten years. On average, the median response has been about 32 basis points *above* the Philadelphia Fed survey, thus increasing the discrepancy with inflation compensation.

12. See the Treasury's February 2002 Quarterly Refunding Statement (available at <http://www.treas.gov/offices/domestic-finance/debt-management/remarks/index.html>) and the comments by Brian Roseboro, the Treasury's Assistant Secretary for Financial Markets.

13. The effect of liquidity on the relative valuation of TIIS is discussed in Shen and Corning (2001).

14. Some of the bidding by primary dealers is intended to cover short positions that they have established by selling the security in the when-issued market. Thus, a portion of their auction awards is essentially passed on to other investors.

15. In 2003:1, TIIS were also added to TradeWeb, an electronic trading platform widely used by large institutional investors. This addition likely lowered transaction costs for those investors.

16. For example, Lonstaff (2002) calculates that liquidity premia on Refcorp zero-coupon securities relative to Treasury zero-coupon securities are roughly 10 to 15 basis points. The difference in liquidity between those securities is presumably greater than the difference in liquidity between TIIS and off-the-run nominal securities.

17. We compute a five-year real rate and a forward real rate five to ten years ahead by smoothing a yield curve through outstanding TIIS. The TIIS yield curve is estimated using the Nelson-Siegel method, and securities with maturities of around five and ten years are given additional weight to force the curve to fit well at those horizons. We then compare these measures with their counterparts from the smoothed nominal Treasury yield curve to obtain the two inflation compensation measures.

18. It is difficult to estimate a TIIS yield curve before 1999, given the limited number of securities outstanding. In fact, the measures presented are probably better estimated over the period since 2001, when the maturities of outstanding securities have been closer to the five-year maturity range.

19. The forward rate seems to have increased from a typical level of around 2 1/2 percent from 1999 to 2001 to about 3 percent in recent months. The forward rate was even lower than 2 1/2 percent in early

Note 19 continued
1999—when investors may have still placed a very high premium on liquidity—and in 2000 and early 2001, when nominal Treasuries may have commanded a scarcity premium.

20. The authors' estimate was for a five-year nominal Treasury security. It is not clear how to extend this estimate to a ten-year security, although many market participants believe that the long end of the yield curve is the most sensitive to inflation expectations.

21. It is difficult to parse the rate of inflation compensation into its two components—expected inflation and the inflation risk premium. If one takes the survey measure as expected inflation, then the inflation risk premium would have been near zero. If one believes that expected inflation was lower than the survey measure, then the inflation risk premium would have been positive but small.

22. We do not consider the fact that the yields on nominal securities might have been higher if the Treasury had issued them in place of TIIS. However, it is unlikely that this consideration would fully offset the magnitude of the cost difference, which is estimated below to be around 80 basis points.

23. The values of the hypothetical zero-coupon securities are derived from the constant-maturity yield curve estimated by the Treasury, which is based primarily on the yields of on-the-run securities. We thank the Treasury for providing the zero-coupon data for the relevant dates. One concern is that this yield curve may be poorly estimated because of the limited number of data points.

24. This is strictly true only if inflation is constant over the maturity of the security. Allowing for a time-varying path of inflation would require additional assumptions.

25. This method discounts future payment differences and compounds past payment differences using our estimated off-the-run yield curve.

26. Interestingly, the Treasury roughly broke even on the only TIIS to have matured—the July 2002 note. As can be seen, it saved $38 million from its first auction of the issue but paid an extra $23 million on the reopening, leaving a net saving of $15 million.

27. One consideration that we ignore is that the Treasury recovers some of the additional interest it pays in the form of taxation on interest income.

28. More specifically, we assume that inflation follows the path assumed in Congressional Budget Office (2003), extrapolating the 2.5 percent level beyond the projection horizon in that report.

29. See the July 2002 working paper version of this article (available at <http://www.federalreserve.gov/pubs/feds/2002/200232/200232pap.pdf>) for more details on this approach and a comparison of the results to the static issuance strategy described here.

30. See the July 2002 working paper version of this article (available at <http://www.federalreserve.gov/pubs/feds/2002/200232/200232pap.pdf>) for estimates underlying this range. The FRB/US model is described in Reifschneider, Tetlow, and Williams (1999).

31. In a speech delivered on March 14, 2002, Under Secretary of the Treasury Peter Fisher stated that the objective of debt managers is to "meet the financing needs of the federal government at the lowest cost over time." This objective could allow for issuance of securities that are currently more costly if doing so would lower future borrowing costs.

32. The academic literature on optimal debt structure focuses on the objective of smoothing tax rates, which in some cases argues for issuing debt with stable real payments. See Barro (1997) and Bohn (1990) for a discussion.

33. We scale the security to produce an index ratio of 1 at time *t*. Otherwise, all payments would be scaled up by P_t / P_i, where P_i is the reference CPI at the time of issuance. We also assume that the first coupon payment is exactly one period away. Otherwise, equation A1 would represent the "dirty" price of the security, which we would have to adjust for accrued interest and inflation compensation to arrive at the quoted ("clean") price.

34. Note that this equation implicitly defines a real discount function $\delta^r(n) = \delta(n) \cdot (1 + \pi^n)$.

References

Barro, Robert J. 1997. "Optimal Management of Indexed and Nominal Debt." NBER Working Paper no. 6197, September.

Bohn, Henning. 1990. "Tax Smoothing with Financial Instruments." American Economic Review 80, no. 5 (December): 1217-30.

Campbell, John Y., and Robert J. Shiller. 1996. "A Scorecard for Indexed Government Debt." In Ben S. Bernanke and Julio Rotemberg, eds., NBER Macroeconomics Annual 1996, 155-97. Cambridge: MIT Press.

Congressional Budget Office. 2003. "The Budget and Economic Outlook: Fiscal Years 2004-2013." January 30.

Dupont, Dominique, and Brian Sack. 1999. "The Treasury Securities Market: Overview and Recent Developments." Federal Reserve Bulletin 85, no. 12 (December): 785-806.

Fischer, Stanley. 1975. "The Demand for Index Bonds." Journal of Political Economy 83, no. 3 (June): 509-34.

Kopcke, Richard W., and Ralph C. Kimball. 1999. "Inflation-Indexed Bonds: The Dog That Didn't Bark." Federal Reserve Bank of Boston New England Economic Review, January-February: 3-24.

Lonstaff, Francis A. 2002. "The Flight-to-Liquidity Premium in U.S. Treasury Bond Prices." NBER Working Paper no. 9312, November.

McCulloch, J. Huston, and Levis A. Kochin. 1998. "The Inflation Premium Implicit in the U.S. Real and Nominal Term Structures of Interest Rates." Ohio State University Department of Economics Working Paper no. 98-12, August.

Reifschneider, David, Robert Tetlow, and John Williams. 1999. "Aggregate Disturbances, Monetary Policy, and the Economy: The FRB/US Perspective." Federal Reserve Bulletin 85, no. 1 (January): 1-19.

Sack, Brian. 2000. "Deriving Inflation Expectations from Nominal and Inflation-Indexed Treasury Yields." Journal of Fixed Income 10, no. 2 (September): 1-12.

Shen, Pu, and Jonathan Corning. 2001. "Can TIPS Help Identify Long-Term Inflation Expectations?" Federal Reserve Bank of Kansas City Economic Review, fourth quarter: 61-87.

Wilcox, David W. 1998. "Policy Watch: The Introduction of Indexed Government Debt in the United States." Journal of Economic Perspectives 12, no. 1 (winter): 219-27.