Are TIPS the "Real" Deal?: A Conditional Assessment of their Role in a Nominal Portfolio

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Abstract

This paper documents predictable time-variation in the *real return* beta of U.S. Treasury inflation protected securities (TIPS) and in the Sharpe ratios of both indexed and conventional bonds. The conditional mean and volatility of both bonds and their conditional correlation are first estimated from predetermined variables. These estimates are then used to compute conditional real return betas and Sharpe ratios. The time-variation in real return betas and the correlation between TIPS and nominal bonds coincides with major developments in the fixed income market. One implication of this predictability is that portfolio managers can assess more efficiently the risk of investing in TIPS versus conventional bonds. Conditional Sharpe ratios indicate that over the sample period, TIPS had superior volatility-adjusted returns relative to nominal bonds. This finding is striking in view of the absence of a major inflation scare during the sample period from February 1997 through August 2001, but is loosely consistent with the possibility that TIPS elevated rather than reduced Treasury borrowing costs. On the other hand, mean-variance spanning tests indicate that TIPS did not enhance the mean-variance efficiency of diversified portfolios.

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Since the first auction of U.S. Treasury Inflation Protected Securities (TIPS) in January 1997, TIPS have become a significant component of debt issuance, representing roughly 1/3 of 10- and 30-year Treasury gross auction amounts from 1997 through 2001. One motivation for offering TIPS was the Treasury's belief that lower borrowing costs would result from meeting an unsatisfied demand for debt securities that offer a fixed real interest rate and, hence, are immune from inflation increases. An additional benefit of TIPS is that policymakers and market participants would be able to use the yield differential between nominal bonds and TIPS to determine market participants' inflation expectations, subject to assumptions concerning risk premiums.[1]

As TIPS issuance has increased in recent years, fixed income investors have considered the strategic and tactical roles that these bonds should play in portfolios. A major concern is that TIPS will underperform their nominal counterparts, especially when performance is assessed relative to a nominal benchmark. When a portfolio manager allocates funds to TIPS, tracking error risk or the risk of underperforming a nominal benchmark index increases. This risk rises as the correlation between the nominal bond index and TIPS returns falls. Hence, a portfolio manager who is able to forecast the correlation between TIPS and nominal returns will be better able to manage tracking error risk.

[1] See Sack (2000) for a discussion of using TIPS and nominal bonds to uncover implied inflation rates and related issues. See Price (1997) for a detailed discussion of indexed bonds.

Previous studies, including Lucas and Quek (1998), Lamm (1998), Rudolp-Shabinsky and Trainer (1999), and Phoa (1999), have asserted that because TIPS offer a fixed real interest rate, the correlation between TIPS and nominal returns should vary systematically depending on the extent to which interest rate movements reflect changing real interest rates versus changing inflation expectations. These studies argue that when inflation expectations change, returns on nominal and inflation-indexed securities tend to drift apart, while real interest rate changes cause greater co-movements of returns. However, none of these studies estimate whether this correlation changes in a predictable manner across different market environments.

The present paper investigates the predictability of the correlation between TIPS and nominal bond returns using readily available market information, such as the slope of the nominal yield curve and the spread between nominal and TIPS yields. The paper employs a conditional framework, which affords several advantages. First, we estimate the conditional means and variances of TIPS and nominal bond returns. The estimated expected returns and volatilities are used to construct time-varying Sharpe ratios, which provide information about the volatility-adjusted expected returns offered by the two instruments across different environments and whether TIPS have been a good deal for investors. The Treasury's Borrowing Advisory Committee, a private-sector panel, recently claimed that TIPS have raised borrowing costs and has recommended that TIPS no longer be offered. This paper also sheds indirect light on whether TIPS have been a good deal for the Treasury.

The second and more important advantage to the conditional approach is that we can estimate a time-varying TIPS *return* beta with respect to returns on nominal bonds, which is important for assessing the risk of investing in TIPS rather than in nominal bonds. The time-varying TIPS return beta provides an ex-ante measure of the sensitivity of TIPS returns to nominal bond returns across different market environments and can be viewed as an ex-ante hedge ratio. The time-varying TIPS return beta is useful for managing the interest rate exposure and the duration of a portfolio when an investor swaps out of nominal bonds into TIPS and vice-versa. For example, an investor swapping out of nominal bonds into TIPS who wants to maintain a given exposure to nominal interest rate changes would require a forecast of how much TIPS (real) rates are likely to change for a given change in nominal rates in order to calculate the swap ratio.[2] Taken together, these conditional measures of risk and reward can provide the basis for superior investment performance.[3]

Other key issues for investors considering the role of TIPS in a portfolio are whether TIPS offer payoffs across various scenarios that cannot be replicated readily with other fixed income securities and whether adding TIPS to diversified portfolios enhances mean-variance efficiency. The fundamental issue is whether TIPS are a meaningful "new asset" in the sense of allowing investors who incorporate TIPS into diversified portfolios to achieve a statistically significant upward shift in the mean-variance frontier.[4] While a high correlation between TIPS and nominal bond returns reduces tracking error risk vis-à-vis nominal benchmarks, a low correlation may provide a strategic opportunity to construct portfolios that have superior mean-variance characteristics.[5]

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[2] This issue is discussed at length in Rudolp-Shabinsky and Trainer (1999).

[3] The conditional approach has at least two additional benefits (which are not considered in the present paper). First, the performance of portfolio managers can be more efficiently assessed with conditional measures of alphas, betas, and Sharpe ratios relative to their unconditional counterparts (see, e.g., Christopherson, Ferson, and Turner (1999)). Second, time-vary Sharpe ratios may be exploitable using relatively naïve market timing strategies to yield significantly higher risk-adjusted reward (e.g., Whitelaw (1997)).

[4] The belief that TIPS offered investors an asset not previously in their opportunity sets was one of the major motivating factors behind the introduction of TIPS.

[5] This point is analogous to the literature on foreign currency denominated bonds where it is argued that adding foreign currency denominated bonds to a domestic bond portfolio increases tracking error vis-à-vis a domestic benchmark but may result in more efficiently diversified portfolios. See Faillace and Thomas (1998) for a discussion.

Previous studies that have examined the role that TIPS play in increasing the mean-variance efficiency of portfolios, including Lamm (1998), Phoa (1999), and Brynjolfsson and Rennie (1999), have used both unconditional volatilities of TIPS and unconditional correlations between TIPS and other assets or have performed sensitivity analyses over an assumed range of values. If the means, volatilities, and correlation of TIPS and nominal bond returns are time varying, assessing portfolio efficiency in a conditional rather than in an unconditional framework is far more meaningful. The present paper extends the literature by using conditional mean-variance spanning tests to address whether the availability of TIPS shifts upward the mean-variance frontier of various portfolios in different market environments. [6]

The main findings of this paper are that TIPS and nominal returns and their correlations can be predicted using the slope of the yield curve and the yield spread between nominal Treasuries and TIPS over the sample period from February 1997 through August 2001. Similarly, the TIPS return beta varies significantly over the sample period. Conditional Sharpe ratios indicate that TIPS had superior volatility-adjusted returns relative to nominal bonds through their first four and a half years. This finding is striking in view of the absence of a major inflation scare during this period, but is loosely consistent with the lackluster demand for these securities and with the possibility that TIPS may have elevated rather than reduced Treasury borrowing costs. However, the conditional mean-variance spanning tests suggest that TIPS did not provide statistically significant diversification benefits to investors holding diversified portfolios comprised of nominal bonds, Treasury bills, and equities.

The paper proceeds as follows. Section 1 provides a brief discussion of the international experience with inflation-indexed bonds and explains how inflation-adjusted principal and coupon payments are calculated. Section 2 describes the bivariate GARCH methodology used to

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[6] These tests have been used extensively in the equity market literature. See deRoon and Nijman (2001) for a survey.

estimate the time-varying correlations between TIPS and nominal bonds, discusses and provides some justification for the selection of the instrumental variables, provides preliminary information about the data, and presents estimation results. Section 3 describes the methodology for assessing whether TIPS provide incremental reward-to-risk benefits in a portfolio context and presents the test results and section 4 summarizes and interprets the findings of the paper.

1. Background on Inflation-Indexed Bonds

1.A The International Experience with Inflation-Indexed Bonds

The motivation for issuing inflation-indexed debt varies across countries. Price (1997) maintains that governments that have issued inflation-indexed bonds generally can be divided into two groups that roughly separate developing from industrialized countries. Many of the developing countries that have issued inflation-indexed bonds did so in response to high or hyperinflation to avoid the collapse of their long-term capital markets. These countries include Argentina (with the first issue in 1973), Brazil (1964), Chile (1956), Colombia (1967), and Israel (1955). More recently they have been joined by other developing economies that have a history of high inflation and, hence, low government credibility with respect to maintaining low inflation. These include Mexico (1989) as part of a more general financial restructuring, Poland (1992) to reduce government dependence on bank-supplied funds for budgetary purposes, and Jamaica (2001) to extend the government’s debt maturity profile by tapping into otherwise unavailable long-term sources of funds.

The governments of industrialized countries that issued inflation-indexed bonds early on were motivated by the view that such bonds were a cost-effective means of raising funds, especially at maturities that otherwise would not attract investors. These governments include Finland (1945), Sweden (1952), Iceland (1964), UK (1981), Italy (1983), Ireland, and Norway. More recently, inflation-indexed bonds have been introduced in several industrialized countries that enjoy relatively low and stable inflation rates. Australia began issuing indexed bonds in 1985, discontinued the program in 1988, but resumed in 1993. Canada began issuing inflation-indexed bonds in 1991. New Zealand issued inflation-indexed bonds from 1977 to 1984, and then resumed issuance in 1995 owing to the government's view that it was paying an oversized inflation risk premium on its nominal debt. Similarly, Sweden first issued indexed debt in 1993. The survey by Price (1997) maintains that the rationales for these industrialized countries include cost savings, complementing monetary policy, and completion of financial markets.

Aside from the UK, little empirical research has been conducted to determine whether inflation-indexed bonds have reduced the average cost of government borrowing and have served to complete financial markets. One of the main reasons for this is that inflation-indexed bond issuance has been sporadic and a relatively minor component of total debt issuance in industrialized countries other than the UK, which has limited secondary market trading. Côté et al. (1996) and Price (1997) report that inflation-indexed bonds comprise roughly 11 percent of total debt in the UK, but only about 4 percent in Australia, 1 percent in Canada and Sweden, and about 0.5 percent in New Zealand.

The major question addressed by empirical studies on the UK experience is whether the issuance of inflation-indexed bonds has lowered borrowing costs, which hinges on the size of the inflation risk premium in nominal interest rates. Along these lines, Foresi et al. (1997) examine the differential in inflation risk premium curves for nominal and indexed bonds and find borrowing cost savings of roughly 300 basis points in the UK. Barr and Campbell (1997) find that the returns on UK nominal bonds averaged almost 500 basis points over those of indexed bonds from 1983 to 1994 after adjusting for the indexing lags on indexed gilts. However, the authors point out that their sample period was dominated by unexpected inflation declines. Reschreiter (2002) estimates latent variable models and finds evidence that suggests that the UK government has experienced considerable cost savings (up to half of the inflation risk premium) by issuing medium- to long-term indexed bonds in place of nominal bonds of similar maturity.

1.B. A Primer on Inflation-Indexed Bonds

Inflation-indexed bonds provide cash flow streams and risk exposures that are different from those of nominal bonds. While both U.S. Treasury nominal and inflation-indexed bonds pay semi-annual coupons, TIPS pay fixed semi-annual coupons on an underlying principal that is indexed to inflation. Thus, while the coupon and principal of inflation-index bonds are fixed in real terms, their nominal payoffs vary over time according to realized inflation rates. Hence, the value of indexed bonds changes with real interest rate fluctuations.

To compute the dollar coupon on an indexed bond, we first calculate the inflation-adjusted principal. The (real) coupon rate of the indexed bond multiplied by the inflation-adjusted principal results in the nominal (dollar) coupon value. At maturity the investor receives the maximum of the inflation-adjusted principal, equivalent in real terms to the original principal, and the nominal amount of the original principal if there has been deflation over the life of the indexed bond. The inflation-adjusted principal is equal to the original principal times the bond’s index ratio, which is the current level of the reference consumer price index (CPI) on a given date divided by the base reference CPI level on the issue date of the bond. The reference CPI for U.S. Treasury indexed bonds is the non-seasonally adjusted CPI–U index from three months earlier.

To compute the index ratio on a given day requires that we account for the fact that the CPI is released once per month as of the first day of the month. Hence, the reference CPI level between the first day of the month and any other day is linearly interpolated. For instance, if a bond were issued on December 11, the base CPI would be the CPI on September 1 adjusted for the additional 10 days after the first of the month. Assume that the CPI for September 1 is 105.5 and that for October 1 is 106. To obtain the adjusted base CPI for December 11, we compute the daily adjustment in the CPI for December: (106.0–105.5)/# of days in December. This results in an interpolated, base CPI on December 11 equal to 105.5 + (0.5/31)*10 = 105.661.

Accrued interest is equal to the inflation-adjusted principal times the fixed coupon rate summed over the days since the last coupon payment. For the above bond, to compute accrued interest, say, on May 8, we follow the above procedure. First we obtain the CPIs for February 1 and March 1. Assume these are, respectively, 107.2 and 107.4. The interpolated CPI on May 8 is: 107.2 + 7*[(107.4 – 107.2)/31] = 107.245. The index ratio on May 8 is, therefore, 107.245/105.661 = 1.01499. Hence, the adjusted principal is $1000*1.01499 = $1014.99. Accrued interest is then computed as: [real annual coupon rate/2]*$1014.99*$N$, where N is the number of days since the last coupon (or since the bond was issued in this case). In the present paper, weekly TIPS returns are calculated from the percentage changes in the inflation-adjusted prices plus accrued interest.

2. Time-Varying Correlation between TIPS and Nominal Bonds

2.1 Methodology

A bivariate conditional correlation GARCH(1,1) model (Bollerslev (1990), Longin and Solnik (1995)) is employed to estimate the conditional means and volatilities of TIPS and nominal bond returns and their conditional correlations. The model is estimated as shown below:

$$R_{i,t} = b_0 + b_1 R_{i,t-1} + b_2 R_{j,t-1} + b_3 YC_{t-1} + b_4 SPREAD_{t-1} + \varepsilon_{i,t} \tag{1}$$

$$h_{i,t} = c + \alpha\varepsilon_{i,t-1}^2 + \beta h_{i,t-1} \tag{2}$$

$$h_{ij,t} = (r_0 + r_1 YC_{t-1} + r_2 SPREAD_{t-1}) * [\sqrt{h}_{TIPS,t} \sqrt{h}_{NOM,t}] . \tag{3}$$

Equation (1) is the conditional mean model for both nominal and indexed bond returns, *i* and *j*, respectively. The conditional means are modeled as functions of a constant, the own first lag, the first lag of the other dependent variable, the first lag of the slope of the yield curve between the 10-year constant maturity Treasury rate and the 3-month Treasury bill coupon equivalent rate (YC), and the first lag of the spread between the nominal and TIPS yields (SPREAD).[7]

Equation (2) models the conditional variance of nominal and TIPS returns as GARCH(1,1) processes. We do not include exogenous variables in this equation since the typical GARCH parameterization provides a well-specified volatility process.

The conditional covariance ($h_{ij,t}$) between nominal and TIPS returns is modeled in equation (3). The time-invariant component of the correlation between TIPS and nominal returns is represented by r_0. If the correlation between the returns varies over time in accordance with changes in the predetermined instruments, the coefficients r_1 and r_2 will be significantly different from zero. The fitted value of the conditional correlation for each period t is constructed from the linear combination of the estimated parameters times the realization of the instruments at t-1.[8] The conditional real return beta for TIPS with respect to nominal returns is then computed with the estimated conditional standard deviations and correlation to gauge the time-varying sensitivity of TIPS returns to nominal bond returns.[9]

We use the quasi-maximum likelihood (QML) approach of Bollerslev and Wooldridge (1992) to estimate the GARCH models where the log likelihood function from the conditional normal specification is maximized, but the estimated standard errors of the parameter estimates are robust to non-normal error distributions. Given the non-normality that is often found in financial data, this allows us to make the usual statistical inferences even if the error terms are non-normal. An additional benefit is that the Wald tests that we perform are robust to the non-normality of the error terms. The reported models are selected on the basis of the coefficients, diagnostics, and a plot of the conditional variances and covariances. If two models performed similarly based on the above criteria, then the multivariate Schwartz Bayesian criterion is the final arbiter.

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[7] The model was also estimated with the spread between 3-month commercial paper and the 3-month Treasury bill rates (default premium) included in the conditional mean and correlation equation but this term did not enter either equation with a statistically significant coefficient and dropping it does not change the results.

[8] The term in parentheses in equation 3 (the estimated constant plus the parameter estimates times the predetermined instruments) is equal to the conditional correlation because equation (3) sets the conditional covariance equal to this term times the product of the conditional standard deviations of TIPS and nominal returns.

[9] The real return beta is: $\beta_{real} = (\sigma_T / \sigma_N)\rho_{T,N}$, where T represents TIPS, N nominal, σ the volatility of returns, and ρ the correlation between TIPS and nominal returns. Much of the literature refers to real *yield* beta, which is the first derivative of real yields with respect to a change in nominal yields (e.g., Lucas and Quek (1999), Rudolph-Shabinsky and Trainer (1999)). Although the real yield beta and the real returns beta are generally similar, we model the real return beta because portfolio managers who invest in TIPS are concerned about tracking error and hence the correlation of returns. Conditional TIPS return betas also are important inputs for stress tests such as Value at Risk assessments.

2.2 Instrument Selection

The first lag of the other dependent variable is included in the mean equations to allow for the possibility that a lead-lag relationship exists between nominal and TIPS returns. In particular, the greater liquidity of nominal bonds relative to TIPS might cause TIPS returns to adjust to nominal returns with a lag. The yield curve slope (YC) is included in the model because several studies of the U.S term structure (see Campbell and Shiller (1991) and Ilmanen (1996)) have found that a steeper yield curve is associated with subsequent higher returns on longer maturity nominal bonds. The interpretation is that the yield curve steepens primarily because of an increase in the risk premium, which leads to a fall in longer-term rates and higher returns. To the extent that a subsequent rally in nominal bonds owes to a reduction in the real rate component of the nominal rate, the impact of a steeper yield curve on subsequent TIPS returns should also be positive. By examining the signs of the coefficients on the yield curve slope in both the TIPS and nominal equations, we can determine whether changing real rates or changing inflation expectations drives nominal returns.

The yield spread between nominal Treasuries and TIPS (SPREAD) is also included in the mean equations. Increases in this variable correspond mathematically to a higher breakeven inflation rate and can be interpreted as the market's expectation of future inflation, adjusted for inflation and liquidity premiums. These two premiums should offset each other to some extent, as an inflation risk premium causes nominal yields, and hence the spread between nominal and TIPS yields, to be higher than it otherwise would be, while the greater liquidity of nominal Treasuries relative to TIPS causes nominal rates and the spread to be lower than it otherwise would be. As the breakeven inflation rate rises, subsequent returns on nominal Treasuries should rise because of the risk premium that is built into the breakeven inflation rate. The impact of changes in the level of the breakeven inflation rate on subsequent TIPS returns depends on the direction of subsequent changes in the real rate component of nominal interest rate changes. If the subsequent movement in nominal rates owes to a sympathetic change in real rates, the impact of the level of the breakeven inflation rate on nominal returns and TIPS returns would be the same sign.

The predetermined instruments in the conditional covariance model (equation (3)) capture the changing influence of real interest rates and inflation expectations on nominal interest rates and are the same yield curve slope (YC) and yield differentials (SPREAD) that are in the conditional mean equations.[10] The correlation between TIPS and nominal returns depends on the extent to which real interest rate changes versus revisions to inflation expectations drive nominal interest rates. When changing inflation expectations play a more prominent role, the correlation between nominal bond and TIPS returns will be lower. For example, an increase in inflation expectations will cause nominal bonds to weaken contemporaneously, whereas contemporaneous TIPS returns would be determined by the associated change in real interest rates and therefore would not necessarily decline. TIPS prices might even rally if the increase in inflation expectations causes an increased demand for inflation protection. On the other hand, when real interest rate changes dominate nominal interest rate fluctuations, nominal bond and TIPS returns will have a higher positive correlation.

The yield curve slope is included to reflect market expectations about the state of the business cycle and the stance of monetary policy. Fama (1990) shows that short and long rates typically move in the same direction, but because short rates tend to move more than long rates,

[10] The conditional covariance model was also estimated with the lagged nominal and TIPS returns but these variables did not enter significantly and excluding them does not change the results.

the slope of the yield curve typically steepens as rates fall and flatten when rates rise.[11] He also shows that the yield curve tends to be flat at business cycle peaks and steep at troughs. Mishkin (1990) demonstrates that changes in the slope of the short end of the yield curve predict future real interest rate changes rather than future inflation. Thus, a steep yield curve generally indicates that the Fed has been in easing mode and lowering real rates, whereas a flat yield curve generally indicates that the Fed has been tightening monetary policy and raising real rates.

Because changes in the slope of the yield curve typically reflect the direction of short rates and real rates, the effect of the slope of the yield curve on the correlation between TIPS and nominal bond returns depends ultimately on whether nominal rate changes reflect real rate changes to a greater extent when the yield curve is flat rather than steep.[12] This in turn depends on whether the Fed changes short rates more aggressively at the peak of the business cycle when the yield curve is flat and the Fed has been in a tightening mode, or at the trough of the business cycle when the yield curve is steep and the Fed has been in easing mode. If the Fed more aggressively changes real rates when it is in tightening mode, a flatter yield curve should be associated with a higher correlation between TIPS and nominal bond returns, and the coefficient on the yield curve slope should be negative. This view is supported by unreported regression results which show that a flatter yield curve is associated with a higher ratio of absolute 3-month bill rate changes to absolute 10-year Treasury rate changes over the sample period.

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[11] These stylized facts hold on average during our sample period as unreported regression results indicate that a 10 basis point increase (decrease) in 3-month rates is associated with a 5 basis point increase (decrease) in 10-year Treasury rates. An exception to the tendency of yield curve flattening (steepening) to be associated with higher (lower) rates is the deflation shock caused by the Asian crisis and the Russian debt default when the yield curve flattened in a falling rate environment.

[12] Lucas and Quek (1999) show graphically that during the first year of TIPS trading in 1997, TIPS and nominal bond returns were more highly correlated when short rate changes dominate the slope of the yield curve. This occurs when the yield curve steepens in a rallying market and flattens in a declining market. Our attempts to model the correlation of TIPS and nominal bond returns as a function of how much of the yield curve slope is driven by short vs. long rates was not fruitful.

The yield differential between nominal Treasuries and TIPS is included to allow for the possibility that the correlation between nominal bonds and TIPS returns is affected by changes in the breakeven inflation rate. When the spread between nominal bond and TIPS rates is high and risk-adjusted expected inflation rates are correspondingly high, the correlation between TIPS and nominal rates should be higher and the coefficient on the spread should be positive for two possible reasons. The first is that the Fed is likely to be on inflation alert and expectations about Fed policy and real rate changes should be more volatile and constitute a greater component of nominal interest rate changes. The second reason is that periodic flights to quality and liquidity arising from concerns about the overall stability of the financial markets are concentrated in the more liquid nominal Treasuries and tend to depress nominal Treasury rates relative to TIPS rates. Because market situations that give rise to flights to quality and liquidity are not complete surprises, they tend to occur when the spread between nominal and TIPS rates are relatively low.[13]

2.3 *Preliminary Data Analysis*

The paper uses weekly Wednesday data from February 05, 1997 through August 28, 2001, for a total of 239 observations. The inflation-indexed securities are represented by the 3-3/8 percent coupon TIPS maturing in February 2007. This issue was the first TIPS auctioned by the Treasury in January 1997. The nominal bond that is examined is the 6-1/2 percent coupon Treasury note maturing in October 2006 that was auctioned in November 1996.[14] This issue is chosen rather than the 10-year note that was issued in February 1997 because the latter was the

[13] As mentioned earlier, the model was also estimated with the default spread between 3-month commercial paper and Treasury bill rates included in the covariance equation to capture the effects of flights to quality and liquidity but the coefficient on this term was not statistically significant and dropping it did not affect the results.

on-the-run 10-year note during the first few months of the sample period and because the greater liquidity of on-the-run issues cause them to trade at lower yields than their more seasoned counterparts. By contrast, the 6-1/2 percent 10-year note auctioned in November 1996 is not on-the-run during the sample period and is thus more comparable to TIPS. The weekly returns on the 6-1/2 percent nominal note and the 3-3/8 percent TIPS are calculated from price changes plus accrued interest, bearing in mind the specific features of each security. The instrument, YC, which measures the slope of the yield curve, is calculated from the 10-year constant maturity Treasury rate and the coupon equivalent rate on the most recently auctioned 3-month Treasury bill.

Table 1 presents summary statistics for the TIPS and nominal returns, and the instrumental variables, which are used in the GARCH model. The table also reports summary statistics for the weekly returns on the Merrill Lynch Treasury bill and corporate bond indexes, and the weekly S&P 500 index dividend-adjusted returns, which are used in the mean-variance spanning tests in section 3. The TIPS and nominal bond (annualized compounded) returns average roughly 6.21% and 8.44%, respectively. The economically higher average return on the nominal note is associated with a higher unconditional standard deviation. We compare risk-adjusted returns after estimating the conditional models.

The nominal and inflation-indexed securities are generally free of autocorrelation, although the TIPS return has significant third-order autocorrelation. The instruments, YC and

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[14] To determine whether our results are sensitive to the choice of particular bonds, all tests and analyses also were conducted using the Merrill Lynch U.S. TIPS and Master government bond indexes. There were no significant qualitative differences between the two sets of results. All unreported results are available upon request.

SPREAD, are both highly autocorrelated. However, the level of autocorrelation declines fairly quickly, indicating that these series are not integrated.[15]

The contemporary unconditional correlation between TIPS and nominal returns is a statistically significant 0.358. Additionally, the correlations show that nominal returns lead TIPS returns by one week. The cross correlation between the instruments is about .43, suggesting that they independently contribute to the time-varying moments. Both TIPS and nominal squared returns have significant autocorrelation, indicating the presence of ARCH errors, which supports the use of the GARCH framework. On the basis of the Jarque-Bera test for normality, not all of the series are normally distributed. The above characteristics of the data are taken into consideration in both the GARCH and mean-variance spanning models.

2.4 Estimation Results

The estimation results of the bivariate GARCH model are shown in Panel A of Table 2. The conditional mean equations demonstrate that nominal bond returns are significantly affected by the lagged spread between nominal and TIPS yields, but not by lagged own returns or by lagged TIPS returns (at the 5 percent level) or by the slope of the nominal bond yield curve. An increase in the spread between nominal and TIPS rates or equivalently an increase in the breakeven inflation rate is associated with subsequent higher returns on nominal bonds at the one percent significance level. This finding suggests that investors earned a risk premium when risk-adjusted inflation expectations were high. This result may also be an artifact of the Asian crisis and the Russian government debt default in 1998 and the ensuing problems at Long Term Capital. These events triggered sharp rallies in nominal bonds owing to flights to the quality and

[15] While near unit root variables can cause spurious predictability (e.g., Ferson et al. (1999)), we do not think this is a problem here given that in Table 2 the instruments are not always significant and the coefficients are relatively

liquidity of nominal Treasury securities. After the flight to quality and liquidity drove the spread between nominal and TIPS rates lower, and as the impact of these events on US economic growth turned out to be less severe than expected, nominal rates rose sharply, further contributing to the positive relationship between nominal returns and the spread between nominal and TIPS rates.[16]

The findings also demonstrate that TIPS returns are significantly lower at the six percent level when the lagged spread between nominal bond and TIPS rates is higher, which is the opposite of the effects described above for nominal returns. The results also demonstrate that TIPS returns are significantly affected by the lagged slope of the yield curve at the one percent level, with TIPS returns tending to be lower when the yield curve is steeper. Thus, during the sample period the real rate component of nominal rates tends to increase, leading to lower TIPS returns, as the slope of the yield curve steepens. In addition, an increase in nominal returns is associated with higher TIPS returns over the next week, indicating that nominal returns lead TIPS returns.

The conditional volatility estimation results in Panel A of Table 2 reflect the usual relations found in higher-frequency financial data. The conditional volatility of nominal bond and TIPS returns rise when lagged squared return innovations increase, but their impact on current volatility is much less than that of the lagged variance. The parameter estimates indicate that the conditional volatility of nominal and TIPS return shocks decay fairly quickly with half-lives of about 7 and 8 weeks, respectively.

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small (e.g., Valkanov (2001)).

[16] In addition, the related problems at Long Term Capital reportedly caused many investors to take the opposite side of their trades, which were long mortgage-backed securities and swaps against short positions in Treasuries. The buying pressure in nominal Treasuries led to sharp declines in nominal Treasury rates relative to many other instruments including TIPS. As these trades unwound, nominal Treasury rates rose and nominal returns fell.

The results for the conditional correlation reported in Panel A indicate that the correlation between TIPS and nominal bonds is predictable. Both the lagged slope of the yield curve (YC) and the lagged yield differential between TIPS and nominal bonds (SPREAD) have significant effects on the correlation between TIPS and nominal bond returns. A steeper (flatter) yield curve is associated with a lower (higher) conditional correlation of returns at the 5 percent confidence interval. The implication of this finding is that the real rate component of nominal rate changes is greater when the yield curve is flat rather than steep. This evidence is consistent with the notion that the Fed may be perceived to be more active and ready to change real rates when it is in tightening mode and trying to slow down the economy than when it is in easing mode and trying to stimulate the economy.

An increase in the yield spread between nominal Treasuries and TIPS (SPREAD) is associated with a higher correlation between nominal and TIPS returns at the 1% level. The finding that a higher yield spread between nominal and TIPS rates is associated with a higher correlation between future nominal and TIPS returns may reflect the possibility that when the breakeven inflation rate is high and market participants and policy makers are more concerned about the near-term prospects for inflation, interest rate movements largely reflect real interest rate changes rather than changing inflation expectations. This finding is consistent with the idea that the Fed has had inflation-fighting credibility in recent years.[17] Also, the flights to the quality and liquidity of nominal Treasuries during the sample period owing to the Asian crisis and Russian debt default lowered the yield spread between nominal Treasuries and TIPS. Because these crises were not complete surprises, the associated sharp drop in nominal rates relative to TIPS rates occurred when the spread between nominal and TIPS rates was low, causing the correlation of nominal Treasury and TIPS returns to fall when the spread was low. As the concerns about the stability of the financial system and the potentially deflationary consequences diminished, nominal Treasury rates rose sharply relative to TIPS rates contributing to the lower correlation of returns when the spread was low.

Panel B of Table 2 reports the results of several null hypotheses tests and diagnostics of the standardized residuals, which indicate that the model is well specified. The robust Wald tests reject the null hypotheses that the mean, variance, and correlation are constant and, therefore, not predictable. The model error terms are not all normally distributed as the estimation failed to remove all the skewness and kurtosis from the cross product of the residuals and the kurtosis from the TIPS. However, the quasi-maximum likelihood estimation corrects the standard errors for non-normally distributed errors, allowing us to draw the usual statistical inferences. The Ljung-Box (LB) test indicates that the individual residual series are free of significant autocorrelation, even though their cross product is autocorrelated. Ljung-Box (LB) tests also indicate that there are marginally significant higher-order ARCH errors remaining in the squared residuals. However, the LaGrange multiplier tests, which are more appropriate in the presence of non-normality (e.g., Susmel and Engle (1994)), suggest that, at conventional levels of significance, we cannot reject the null hypothesis that there are no ARCH errors.

To provide a clearer picture of the time-varying properties of our estimates (from Table 2), Figure 1 plots the time paths of the conditional means, conditional standard deviations, and correlation of TIPS and nominal returns, while Table 3 shows summary sample statistics. Figure 1 displays significant time variation for all three estimates. As expected, over much of the sample period the nominal security had both higher conditionally expected return and volatility

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[17] Indeed, one of the traditional arguments for issuing inflation-indexed bonds is that they enhance the inflation fighting credibility of a central bank because they reduce the possible incentive to allow higher inflation in order to

than the inflation-indexed security. The sample averages of the conditional expected returns and the standard deviations of the returns of the nominal and inflation-indexed securities (in Table 3) are quite similar to the unconditional averages reported in Table 1.

Figure 1 (third panel) plots the time path of the conditional correlation. The correlation is computed as a linear combination of the estimated parameters times the realized values of the instruments in the previous period: $\hat{\rho}_t = \hat{r}_0 + \hat{r}_1 YC_{t-1} + \hat{r}_2 SPREAD_{t-1}$. The correlation varies significantly over the sample period and appears to be characterized by four regimes. The first is from the start of the sample in February 1997 through August 1998, when the correlation averages roughly 0.4. The second period runs from September 1998 through December 1999. During this period the correlation is very low and averages about 0.24. The low correlation owes to both the intensification of the flights to quality and liquidity because of the worsening of the Asian crisis, the Russian debt default, and the problems at Long Term Capital and the subsequent unwinding of these pressures. The flights to quality and liquidity caused nominal Treasuries to rally sharply and then to weaken substantially with little corresponding effect on TIPS. The third period runs from January 2000 through the middle of the first quarter of 2001 during which the correlation rises and averages around 0.6. The higher correlation during this period owes to the successive rounds of tightening by the Fed, followed by the subsequent easing. During this period, the real rate component of nominal interest rate changes was more prominent as Fed policy changes moved real interest rates. The fourth period begins around the middle of the first quarter of 2001 and is characterized by a low correlation, which falls to roughly zero at the end of the sample period. During this period, TIPS yields were relatively stable, while nominal bond yields fell. Given that 3-month Treasury bill rates were also fairly stable over this period, one

reduce the burden of repaying nominal debt.

interpretation is that despite continued weakness in the economy and the subdued inflation outlook, which caused nominal bond rates to fall, market participants saw an end to the Federal Reserve easing moves, and as a result real rates did not fall further.[18] Thus, the fourth period is characterized by a low conditional correlation between nominal bond and TIPS returns because most of the change in long-term rates reflects inflation expectations. The overall sample mean of the conditional correlation is equal to 0.37, which is close to the unconditional average of 0.36, and ranges over the sample period from a low of -0.02 to a high of 0.72.

Previous research on the investment characteristics of TIPS (e.g., Lamm (1998) and Lucas and Quek (1998)) uses unconditional performance measures, which ignore available information about the time-varying nature of reward and risk. However, the predictability of not only the means and volatilities of the nominal and inflation-indexed securities, but also the correlation of their returns, is important to portfolio managers who allocate funds in a non-passive manner.[19] In light of the above, we turn our attention to three specific measures that are important to the conditional performance evaluation of TIPS and nominal Treasuries. First, we compute the conditional TIPS real return beta and the conditional reward-to-risk ratios of the TIPS and nominal securities.

While the conditional correlation, examined above, provides information about the degree to which TIPS and nominal security returns are expected to move together, the beta standardizes this measure and gives the expected change in TIPS returns for a unit change in the expected returns of nominal securities. The predictability of the TIPS return beta is important for risk management, given that most fixed-income portfolio managers are evaluated relative to a

[18] From the beginning of May 2001 through the end of August, the nominal bond yield fell about 60 basis points, while TIPS rates rose eight basis points and 3-month Treasury bill rates fell 30 basis points.
[19] In addition, Christopherson et al. (1999), and others, point out that unconditional estimates of risk and return can be biased if portfolios are actively managed.

nominal benchmark. The ability to forecast the next period's TIPS return beta on the basis of currently available information allows portfolio managers to adjust their TIPS positions in anticipation of the returns on the nominal benchmark and to manage their overall interest rate exposure. Table 3 shows the conditional return beta of TIPS. The conditional return beta has a sample average of 0.16 and ranges from 0.0 to 0.36. The mean of the unconditional counterpart, from Table 1, is 0.17. Figure 2 shows the time path of the return beta, which loosely mirrors the variation in the conditional correlation between TIPS and nominal returns, suggesting that the beta is driven mostly by the same instruments that predict the correlation rather than by the standard deviations of the returns.

Table 3 also reports sample statistics of conditional Sharpe ratios, whose time paths are plotted in Figure 3. Despite the higher expected returns of nominal bonds relative to TIPS, the volatility-adjusted conditional returns are significantly higher at the one percent level for TIPS than for nominal bonds. This finding is consistent with the results in Table 1, which show that the unconditional Sharpe ratio is significantly higher for TIPS than for nominal bonds over the sample period. These findings are striking given the absence of a major inflation scare during the sample period and are loosely consistent with the view of the Treasury Borrowing Advisory Committee of the Public Securities Association that TIPS have been a bad deal for the Treasury.

The finding that TIPS have higher average conditional Sharpe ratios than nominal securities over the sample period suggests the possibility that even in periods of low inflationary expectations investors can benefit from TIPS. However, the issue remains of whether adding TIPS to a portfolio comprised of nominal securities pushes the investor's mean-variance frontier significantly upwards. If so, inflation-indexed securities represent a meaningful new class of securities because they increase investors' opportunity sets; if not, inflation-indexed securities are a redundant asset. In the next section, we address the question of whether augmenting various portfolios with TIPS provides investors with greater mean-variance efficiency.

3.1 Do TIPS Expand the Mean-Variance Frontier?

In this section, we address whether TIPS provide additional diversification benefits to investors who hold a balanced portfolio of nominal bonds, cash-equivalent securities, and equities. So far, there is no consensus on whether TIPS significantly shift investors' mean-variance frontiers upward. Phoa (1998) argues that the extent to which TIPS should replace nominal bonds in a portfolio that includes equities depends on the volatility of TIPS. He concludes that TIPS add little if any value to asset allocation because TIPS are more closely correlated with equities than are nominal bonds and TIPS have lower expected returns than nominal bonds. At the other extreme, Lamm (1998), on the basis of assumptions much friendlier to TIPS, provides portfolio simulations that show that TIPS dominate nominal bonds and drive them out of a diversified portfolio entirely. These assumptions are that TIPS have a higher Sharpe ratio than nominal bonds and have similar correlations to other asset classes.

Our approach differs from the above in two important respects. First, we formally test if a statistically significant upward shift in the mean-variance frontier of a diversified portfolio occurs when augmented by TIPS. These tests are executed within the non-parametric generalized method of moments (GMM, Hansen (1982)) framework, and as such are robust to the fairly short data series and any non-standard distribution of the data, relative to a parametric-type test. Second, because unconditional measures of mean-variance efficiency are likely to lead to biased results, we use a conditional test, where the conditioning instruments are the yield curve slope and yield spread previously identified as possessing significant predictive power for the means of TIPS and nominal securities returns and their correlation.

Intuitively, if we form an efficient frontier from a set of spanning assets (nominal bonds, bills, and equity) and then add a set of test assets (TIPS), the resulting frontier will lie above the original frontier only if the portfolio with the test assets (TIPS) included is more efficient in a mean-variance sense than the spanning assets. That is, the frontier will shift upwards if the investor's reward-risk ratio is improved by adding the test assets. The following mean-variance spanning test is designed to determine if the upward shift in the efficient frontier is statistically significant.

To test the hypothesis that a portfolio of nominal bonds, cash equivalents, and equities spans the augmented portfolio including TIPS, we use a modified Huberman and Kandel (1987) mean-variance spanning technique (see also Ferson, Foerster, and Keim (1993), De Santis (1994), and Bekaert and Urias (1996); and DeRoon and Nijman (2001) for a survey).

From a set of N assets (i.e., nominal bonds, cash equivalents, equities, and TIPS) in an $N\times 1$ vector $\mathbf{R}$, define $\mathbf{R}_1$ as a $K\times 1$ vector of returns on the spanning (or *factor-mimicking*) assets and trace out a mean-standard deviation frontier from these assets. Let $\mathbf{R}_2$ be the $(N\text{-}K)\times 1$ vector of returns on the remaining N-K test assets (TIPS). Consider the following linear model:

$$\mathbf{R}_{2,t} = \mathbf{a} + \mathbf{B}\mathbf{R}_{1,t} + \mathbf{e}_{2,t} \tag{4}$$

where $\mathbf{a}$ and $\mathbf{e}_{2,t}$ are N-K vectors, and $\mathbf{B}$ is an $(N\text{-}K)\times K$ matrix of coefficients. Imposing orthogonality between $\mathbf{e}_{2,t}$ and $\mathbf{R}_{1,t}$, and assuming $\mathrm{E}(\mathbf{e}_{2,t}) = \mathbf{0}$, Huberman and Kandel (1987) show that mean-variance spanning exists when the following linear restrictions hold:

$$\mathbf{a} = \mathbf{0} \text{ and } \mathbf{B}\,\boldsymbol{\iota}_K = \boldsymbol{\iota}_{N\text{-}K} \quad \text{or} \quad \sum_{j=1}^{K} b_{ij} = 1, \quad i = K+1,\ldots, N, \tag{5}$$

where $\boldsymbol{\iota}_K$ is the K-dimension unit vector. That is, for each test asset in $\mathbf{R}_2$, if the intercept is zero and the regression coefficients sum to one, then the (unconditional) mean-variance boundary of the larger set of N assets in $\mathbf{R}$ can be generated from the returns on the K assets in the *subset* $\mathbf{R}_1$. In this case (unconditional) mean-variance spanning of the test assets (TIPS) by the spanning assets is said to exist. That is, adding TIPS to the spanning assets does not significantly expand the mean-variance frontier derived from the spanning assets.

The mean-variance spanning concept is based on the principle of *mutual fund separation* (specifically, *K-fund separation*, which states that the entire minimum-variance frontier traced out by the portfolios from a *set* of assets can be replicated by the appropriate combination of K distinct portfolios on the frontier, formed from a *subset* of the assets). These K factor-mimicking portfolios are equivalent to the number of common factors underlying the return-generating process of the *set* of assets and should be sufficient to span the mean-variance frontier of the larger set of assets. In other words, from equation (4), if the K portfolios are factor-mimicking portfolios sufficient to span the entire set of assets $\mathbf{R}$, then they will explain the total variation of the returns on the test assets $\mathbf{R}_2$. Hence, the coefficients sum to one and the intercept is zero. In other words, the weighted returns on the factor-mimicking portfolios, each weighted according to its coefficient in $\mathbf{B}$, will be able to mimic the returns on the test assets. Therefore, the latter does not offer any significant diversification benefits.

Rejection of mean-variance spanning may result from a breach of normality and *iid* assumptions of the error terms. Since financial data series are usually characterized by non-normality, we estimate the model using the GMM framework (see, e.g., Ferson, Foerster, and Keim (1993)), which controls for autocorrelation and heteroscedasticity. Furthermore, the unconditional model above does not make use of investor's information in managing their portfolios. The unconditional spanning model assumes that investors engage in a buy-and-hold strategy. This results in a loss of information relative to the conditional model, which could lead to an under-rejection of the null hypothesis that the test assets do not expand the mean-variance frontier of the spanning assets. Hence, we also estimate a conditional mean-variance spanning model.

Considering $\mathbf{Z}_{t-1}$ as an L vector of information variables we obtain:

$$E\left[\left(\mathbf{R}_{2,t} - \mathbf{B}\mathbf{R}_{1,t}\right) \otimes \mathbf{R}_{1t} \otimes \mathbf{Z}_{t-1}\right] = \mathbf{0} \tag{6}$$

and $\sum_{j=1}^{K} b_{ij} = 1,\ i = K+1,...,N$, with $(N\text{-}K)\times(K\text{-}1)$ unknown parameters and $(N\text{-}K)\times K\times L$ orthogonality conditions. The J test of over-identifying restrictions, consistent with mean-variance spanning, is:

$$J_T = T[\mathbf{h}'_T(b_{ij})\mathbf{W}_T\mathbf{h}_T(b_{ij})] \sim \chi^2_\alpha \tag{7}$$

where T is the number of observations, $\mathbf{W}_T$ is a symmetric, positive definite matrix and is the inverse of a consistent estimate of the covariance matrix of the orthogonality conditions, $\mathbf{h}_T(b_{ij})$ is the sample moment of the orthogonality conditions, and α is the difference between the number of orthogonality conditions and the number of parameters.

We use iterated GMM to estimate **B** as it has better finite-sample properties and is invariant to the scaling of the data and to the initial weighting matrix. To control for the non-normal distribution usually found in financial markets data, the reported p-values are based on the Newey-West heteroscedasticity- and autocorrelation-consistent covariance matrix, with a large enough lag-truncation parameter based on the number of observations.

The tests are conducted over the sample period from February 1997 through August 2001, using weekly as well as monthly data. This is because investors who engage in an active trading strategy--the underlying assumption of the conditional model--perhaps are more likely to make portfolio allocation decisions on a monthly rather than on a weekly basis.[20] Further, to examine the robustness of the results to investors who explicitly do the mean-variance calculations in real terms, we also estimate the mean-variance spanning models on the returns of the various assets adjusted for the contemporaneous (interpolated) CPI-U changes.[21] The TIPS and nominal bond returns are based on the same instruments examined in the previous section. The more diversified portfolios include Treasury bill and corporate bond returns, proxied by the Merrill Lynch Treasury bill and corporate bond master index, and the dividend-adjusted returns on the S&P 500.

3.2. Empirical Results

Table 4 reports the results of the mean-variance spanning tests over the sample period from February 1997 through August 2001. We report results for both real and nominal data at the monthly interval. Results using weekly data generally are not qualitatively different and are available on request. Panel A reports the results from the unconditional model and Panel B displays the conditional results. With the unconditional model, we strongly reject the null hypothesis that the nominal bond spans TIPS. That is, when a buy-and-hold investor adds TIPS to the nominal Treasury bond, the reward-to-risk ratio significantly increases for each specification. If the investor holds a portfolio of nominal Treasury bonds and bills, there is no significant increase (at the 5 percent level) in the reward-to-risk ratio for any of the returns. Further, if the investor already has a more diversified portfolio that includes nominal Treasury

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[20] We also estimated the GARCH models in the previous section with monthly data but were unable to achieve convergence due to the small number of data points.

bonds and bills and corporate bonds, or nominal Treasury bonds, bills, corporate bonds and equity, the addition of TIPS to the portfolio also does not provide additional reward-to-risk benefits. In other words, the efficient frontier computed from any of these augmented portfolios is statistically similar to the frontier from the same portfolio plus the inflation-indexed security.

The conditional tests are more powerful in detecting rejections of mean-variance spanning and are more consistent with the real life practice of active portfolio management by an investor who forms portfolios using the information reflected by the instruments in the previous period. The conditional spanning test results in Panel B indicate that this investor experiences only a marginally significant increase in the reward-risk ratio from adding TIPS to the nominal Treasury bond when we use monthly real data (p-value = 0.082). However, there are no statistically significant increases in efficiency when TIPS are added to the same more diversified portfolios described above. Therefore, over this sample period the conditional spanning tests show that TIPS did not benefit broadly diversified fixed-income investors and do not appear to be a new asset class in the sense of offering investors return patterns that cannot be duplicated by combinations of other existing securities.

To further assess the possible role of TIPS in a fixed income portfolio we examine whether or not a portfolio containing only Treasury bills spans TIPS. Since the Fed's targeting of the federal funds rate affects both Treasury bill rates and the real rate component of longer-term rates, we wish to find out if Treasury bills replicate the performance of TIPS, which is driven by real rate changes. Campbell and Shiller (1996) state that one argument against indexed debt is that it is similar to Treasury bills in that bill rates adjust rapidly to changes in expected future inflation. In fact, financial empiricists frequently use the return on Treasury bills in lieu of

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[21] If TIPS returns were perfectly indexed to inflation, then deflating TIPS returns by the contemporaneous interpolated inflation rate would merely undo the inflation adjustment. However, because the adjustment to TIPS is

the return on the riskless real asset. However, Campbell and Shiller also point out that indexed debt is different from Treasury bills in that TIPS but not bills allow investors to lock in a real rate.

The results reported in Panel C of Table 4 demonstrate that while the unconditional nominal model rejects the null hypothesis that Treasury bills span TIPS, the unconditional real model and both of the conditional models do not reject the null hypothesis. Thus, the results on balance do not provide strong support for the view that adding TIPS to a bill portfolio enhances mean-variance efficiency. More interestingly, the results suggest that Treasury bills may be a reasonable substitute for inflation-indexed bonds, at least in periods without any major inflation shocks.

4. Summary and Conclusions

In this paper, we examine the relationship between Treasury Inflation Protected Securities (TIPS) and nominal bonds using weekly data from February 1997 to August 2001. We use a bivariate GARCH framework to model the conditional means and volatilities of TIPS and nominal Treasury returns as well as their conditional correlations. We document that commonly available information, such as the slope of the Treasury yield curve and the spread between nominal Treasury and TIPS rates, has predictive power for these moments. We also find that conditional Sharpe ratios vary significantly across different economic environments and that TIPS have significantly higher Sharpe ratios than nominal Treasuries over the sample period. This finding indicates that on a volatility-adjusted basis, TIPS have been a good deal for investors. A possible explanation for this finding is that because the Federal Reserve has

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based on the inflation rate from three months earlier, the indexing is imperfect.

achieved inflation fighting credibility in recent years and inflation has remained low, the demand for inflation protection has been tepid and investors have been able to extract higher compensation per unit of volatility from TIPS compared to nominal Treasuries. At the same time, it is less clear that the Treasury has significantly lowered its borrowing costs as a result of issuing inflation-indexed bonds. We then compute a time-varying return beta for TIPS, which is important for risk management, particularly for investors who allocate funds to TIPS but are evaluated against a nominal benchmark. The time-varying beta largely mirrors the time-varying correlation.

The finding that TIPS have higher Sharpe ratios than nominal Treasuries along with the finding that the conditional correlation between TIPS and nominal bond returns is frequently low raises the issue of whether inflation-indexed bonds constitute a meaningful new asset class in the sense of increasing the reward-to-risk ratio when added to reasonably well diversified portfolios. We examine this issue using conditional and unconditional mean-variance spanning tests and find that adding TIPS to a portfolio of Treasury bills, nominal bonds, and equities does not significantly enhance the opportunity set for investors. However, it is important to note that these tests were conducted over a period of relatively well-behaved inflation rates and does not preclude the possibility that TIPS would enhance portfolio efficiency during more inflationary periods.

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Table 1. Summary Statistics of Nominal and Inflation-Indexed Bonds (Weekly Data from February 1997-August 2001, Nobs =239)

TIPS and NOMS are the returns on the 3-3/8 percent TIPS issue maturing in February 2007 and the 6-1/2 percent nominal Treasury note maturing in October 2006, respectively. Bills and Corporate bond index are the returns on the Merrill Lynch Treasury bill and Master Corporate bond index, respectively, and S&P 500 is the dividend-adjusted returns on the S&P 500 index. YC is the slope of the yield curve between 10-year constant maturing Treasury rates and 3-month coupon equivalent Treasury bill rates. SPREAD is the yield differential between the above nominal and TIPS yields to maturity. Q(*x*) is the Ljung-Box Q statistic (*p*-value) from a test of the null hypothesis of zero autocorrelation up to lag *x*. J-B statistic (*p*-value) is the Jarque-Bera test for normality.

	Mean (%) (*t*-value)	Std Dev	Min	Max	Skewness (*p*-value)	Kurtosis (*p*-value)	J-B Stat (*p*-value)
Nominal bond (NOMS)	0.156***	0.678	-1.900	2.074	0.068	0.333	1.283
					(0.670)	(0.302)	(0.527)
TIPS	0.116***	0.327	-1.240	1.251	-0.330	1.814	36.94
					(0.039)	(0.000)	(0.000)
YC[a]	0.597***	0.638	-0.881	1.910	-0.229	-0.401	3.695
					(0.151)	(0.212)	(0.158)
SPREAD[a]	2.026***	0.559	0.814	3.313	0.216	0.036	1.867
					(0.176)	(0.910)	(0.393)
Bills	0.100***	0.025	-0.014	0.174	-0.210	1.698	30.33
					(0.190)	(0.000)	(0.000)
S&P 500	0.251	2.683	-8.556	7.950	-0.303	0.294	4.520
					(0.057)	(0.361)	(0.104)
Corporate bond index	0.144***	0.530	-1.484	1.490	-0.130	0.140	0.862
					(0.417)	(0.664)	(0.650)
Treasury Nominal Index	0.144***	0.527	-1.394	1.417	-0.116	0.036	0.548
					(0.467)	(0.912)	(0.760)
TIPS Index	0.122 ***	0.342	-0.942	1.090	0.144	0.527	3.579
					(0.366)	(0.102)	(0.167)

Autocorrelation of Various Series

	NOMS	TIPS	YC	SPREAD	Bills	S&P 500	Corporate bond index	Squared (NOMS)	Squared (TIPS)
r (1)	-0.008	-0.054	0.979	0.980	0.318	-0.096	-0.018	-0.085	0.088
r (2)	0.033	0.083	0.958	0.963	0.264	0.024	0.006	-0.020	0.158
r (3)	0.054	0.115	0.935	0.944	0.351	-0.022	0.037	0.108	0.158
r (12)	-0.047	0.130	0.640	0.783	0.169	-0.062	-0.031	0.022	0.166
Q(4)	1.205	5.568	871.5	883.8	82.00	3.136	1.948	7.241	39.90
	(0.877)	(0.234)	(0.000)	(0.000)	(0.000)	(0.535)	(0.745)	(0.124)	(0.000)
Q(12)	10.09	18.38	2037.1	2298.9	150.7	12.39	7.180	22.02	69.47
	(0.608)	(0.105)	(0.000)	(0.000)	(0.000)	(0.415)	(0.846)	(0.037)	(0.000)

Cross-correlation of Various Series

Lag[b]	-2	-1	0	1	2
NOMS and TIPS	0.033	0.129**	0.358***	-0.070	0.038
YC and SPREAD	0.442***	0.435***	0.433***	0.405***	0.376***

*, **, *** Significant at the 10%, 5%, and 1% level.

[a] These are annualized spreads.

[b] Lag (*x*) implies the following: correlation ($NOMS_t$, $TIPS_{t-x}$).

Table 2. Conditional Means, Variances, and Correlation of Nominal and TIPS Returns (Weekly Data from February 1997-August 2001, Nobs =239)

The model estimated for the conditional mean is equation (1) where the dependent variables are the weekly total returns on the 6-1/2 percent nominal bond (NOMS) maturing October 2006 and the 3-3/8 percent TIPS maturing February 2007. The independent variables in the conditional mean equations are a constant, the first lag of the dependent variable and the other dependent variable, the slope of the yield curve between the 10-year constant maturity Treasury rates and the coupon equivalent rate on the 3-month Treasury bill (YC) and the yield spread between the NOMS and TIPS (SPREAD). The conditional volatilities are modeled as shown in equation (2) as GARCH(1,1) processes. The model estimated for the conditional correlation between nominal and TIPS returns is equation (3). The instrumental variables are the first lags of YC and SPREAD. All *t*-values in Panel A are based on a quasi-maximum likelihood (QML) estimation robust to non-normality in the residuals. LB(*x*) ($LB^2(x)$) is the Ljung-Box chi-squared statistic for testing the null hypothesis of zero autocorrelation up to lag *x* in the (squared) standardized residuals. LM (24) is the LaGrange Multiplier test for ARCH errors in the residuals, with 24 degrees of freedom.

Panel A

Conditional Mean Equations

	Constant	Lagged own dependent Variable	Lagged other dependent variable	Lagged YC	Lagged SPREAD
NOMS	-0.0989 (-0.762)	0.0136 (0.193)	-0.236 (-1.698)	-0.0945 (-1.550)	0.1683 (2.762)
TIPS	0.2190 (5.870)	-0.1071 (-1.554)	0.0644 (2.050)	-0.0698 (-2.965)	-0.0335 (-1.880)

Conditional Variance Equations

	Constant	Lagged Square Error	Lagged Variance
NOMS	0.0403 (1.576)	0.0551 (1.498)	0.8550 (13.26)
TIPS	0.0086 (2.891)	0.1330 (2.861)	0.7847 (26.61)

Conditional Correlation

	Constant	YC	SPREAD
NOMS and **TIPS**	0.0250 (0.270)	-0.2749 (-2.373)	0.2488 (3.733)

Panel B

Wald Tests of Coefficient Restrictions*

	H_0: Constant Mean ($\chi^2 = 4$)	H_0: Constant Variance ($\chi^2 = 2$)	H_0: Zero Correlation ($\chi^2 = 3$)	H_0: Constant Correlation ($\chi^2 = 2$)
NOMS	11.39 (0.022)	244.47 (0.000)		
			43.28 (0.000)	14.00 (0.001)
TIPS	21.47 (0.000)	1483.3 (0.000)		

Standardized Residual Diagnostics

	Skewness (*p*-value)	Kurtosis (*p*-value)	JB Statistic (*p*-value)	LB (4) (*p*-value)	LB (12) (*p*-value)	LB^2 (4) (*p*-value)	LB^2 (12) (*p*-value)	LM (24)	Log-lik.
NOMS	0.300 (0.062)	-0.012 (0.971	3.537 (0.171)	0.976 (0.913)	8.782 (0.721)	3.949 (0.413)	18.86 (0.092)	23.35 (0.499)	
TIPS	0.134 (0.405)	1.691 (0.000)	28.69 (0.000)	6.082 (0.193)	12.42 (0.412)	6.668 (0.154)	18.54 (0.100)	23.29 (0.503)	
Standardized Cross-Product	-10.62 (0.000)	135.0 (0.000)	182937 (0.000)	48.70 (0.000)	52.68 (0.000)				165.258

* Hypotheses tests are based on the Wald test made robust to the distribution (e.g., non-normality) of model errors.

Table 3. Summary Statistics of Estimated Conditional Means, Standard Deviations, Correlation, Sharpe Ratios, and Beta (Weekly Data from February 1997-August 2001, Nobs =239)

The measures are estimated from the results of the GARCH(1,1) in equations (1) to (3). Hypotheses tests are based on the two-sided *t*-test. TIPS and NOMS are the returns on the 3-3/8 percent TIPS issue maturing in February 2007 and the 6-1/2 percent nominal Treasury note maturing in October 2006, respectively.

	Sample Mean	Std Deviation	Minimum	Maximum
TIPS conditional returns	0.1083[a] ***	0.0722	-0.0565	0.2949
NOMS conditional returns	0.1597[b] ***	0.1125	-0.1847	0.5029
TIPS conditional standard deviation	0.3099[a] ***		0.2202	0.6063
NOMS conditional standard deviation	0.6694[b] ***		0.5721	0.8897
Conditional correlation – TIPS&NOMS	0.3652 ***	0.1694	-0.0153	0.7237
TIPS conditional return beta	0.1640 ***	0.0779	-0.0088	0.3591
TIPS conditional Sharpe ratio	0.3756[a] ***	0.2650	-0.1679	1.1977
NOMS conditional Sharpe ratio	0.2418[b] ***	0.1669	-0.2813	0.7229

[a], [b] *a* is significantly different from *b* at less than the 1% level. *** Significantly different from zero at the 1% level.

Table 4. Assessment of the Diversification Benefits of TIPS in a Balanced Portfolio

Panel A: Unconditional Spanning

The most general unconditional model is: $E\left[\left(R_{4,t} - B\begin{bmatrix}R_{1,t}\\R_{2,t}\\R_{3,t}\end{bmatrix}\right)\otimes\begin{bmatrix}R_{1,t}\\R_{2,t}\\R_{3,t}\end{bmatrix}\right] = 0$ and $\sum_{j=1}^{K} b_{ij} = 1$, where $i = K+1,\ldots,N$, the test assets, and $j = 1,\ldots, K$, the spanning assets. In this test, $R_{1,t}$ to $R_{3,t}$ are the returns on the *spanning assets* and $R_{4,t}$ is the *test asset*, the TIPS. *The table presents a test of whether or not different benchmarks, respectively, span the TIPS.* The test statistic [*p*-value] is the number of observations times the minimized objective value of the GMM, which is approximately chi-square distributed with one degree of freedom based on (N-K)×K orthogonality conditions and (N-K)×(K-1) unknown parameters. Bills and Corporate bond index are the returns on the Merrill Lynch Treasury bill and Master Corporate bond index, respectively, and S&P 500 is the dividend-adjusted returns on the S&P 500 index.

Test Asset	**Spanning Assets** (d.f.)			
TIPS	**Treasury Nominal bond** (1)	**Treasury Nominal bond, Treasury bill index** (1)	**Treasury Nominal bond, Treasury bill index, and corporate bond index** (1)	**Treasury Nominal bond, Treasury bill index, and equity (S&P 500) index** (1)
χ^2 (*p*-value)				
Monthly Nominal Data	7.602 (0.006)	2.315 (0.128)	1.791 (0.181)	2.332 (0.127)
Monthly Real Data	4.471 (0.034)	2.988 (0.084)	2.650 (0.104)	2.882 (0.090)

Panel B: Conditional Spanning

The most general conditional model is: $E\left[\left(R_{4,t} - B\begin{bmatrix}R_{1,t}\\R_{2,t}\\R_{3,t}\end{bmatrix}\right)\otimes\begin{bmatrix}R_{1,t}\\R_{2,t}\\R_{3,t}\end{bmatrix}\otimes \mathbf{Z}_{t-1}\right] = 0$ and $\sum_{j=1}^{K} b_{ij} = 1$, where $i = K+1,\ldots,N$, the test assets, and $j = 1,\ldots, K$, the spanning assets. In this test, $R_{1,t}$ to $R_{3,t}$ are the returns on the *spanning assets* and $R_{4,t}$ is the *test asset*, the TIPS. **Z** is an L vector of instruments including a constant, the slope of the yield curve between the 10-year constant maturity Treasury rates and the coupon equivalent rate on the 3-month Treasury bill (YC), and the yield spread between the nominal and TIPS (SPREAD). *The table presents a test of whether or not different benchmarks, respectively, span the TIPS, when the investor uses conditioning information*. The test statistic [p-value] is the number of observations times the minimized objective value of the GMM, which is approximately chi-square distributed with degrees of freedom based on (N-K)×K×L orthogonality conditions and (N-K)×(K-1) unknown parameters.

Test Asset	**Spanning Assets** (d.f.)			
TIPS	**Treasury Nominal bond** (3)	**Treasury Nominal bond, Treasury bill index** (5)	**Treasury Nominal bond, Treasury bill index, and corporate bond index** (7)	**Treasury Nominal bond, Treasury bill index, and equity (S&P500) returns** (7)
χ^2 (*p*-value)				
Monthly Nominal Data	5.411 (0.144)	4.421 (0.490)	3.765 (0.806)*	1.251 (0.990)
Monthly Real Data	6.689 (0.082)	4.422 (0.490)	3.693 (0.814)*	1.249 (0.990)

Panel C: Analysis of Whether or Not Treasury Bills Span TIPS

Test Asset: **TIPS**	**Monthly Nominal Data**	**Monthly Real Data**	**Monthly Nominal Data**	**Monthly Real Data**
Model (d.f.)	Unconditional (1)	Unconditional (1)	Conditional (3)	Conditional (3)
	4.430 (0.035)	1.228 (0.268)	3.793 (0.285)	3.788 (0.285)

The χ^2 (*p*-value) tests the null hypothesis that the test asset (TIPS) are spanned by the spanning assets (e.g., Treasury nominal bond). A rejection of the null hypothesis means that TIPS provide portfolio diversification benefits to an investor holding the spanning asset(s). All data are from February 1997 to August 2001 (55 monthly observations). * This model failed to fully converge.

Figure 1: **Conditional Moments of TIPS and Nominal (NOMS) Securities**

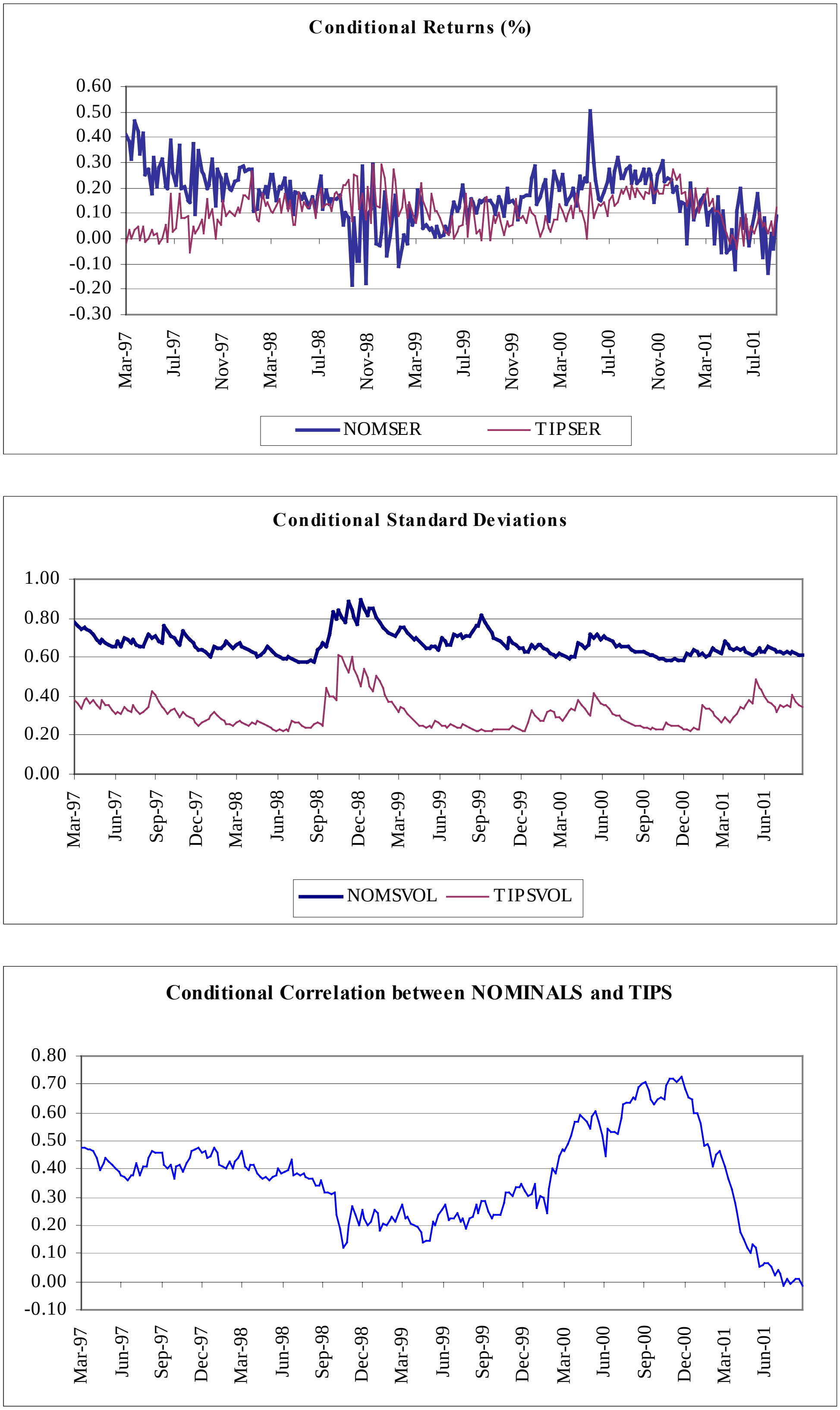

Figure 2: TIPS Conditional Return Beta Relative to Nominal Securities

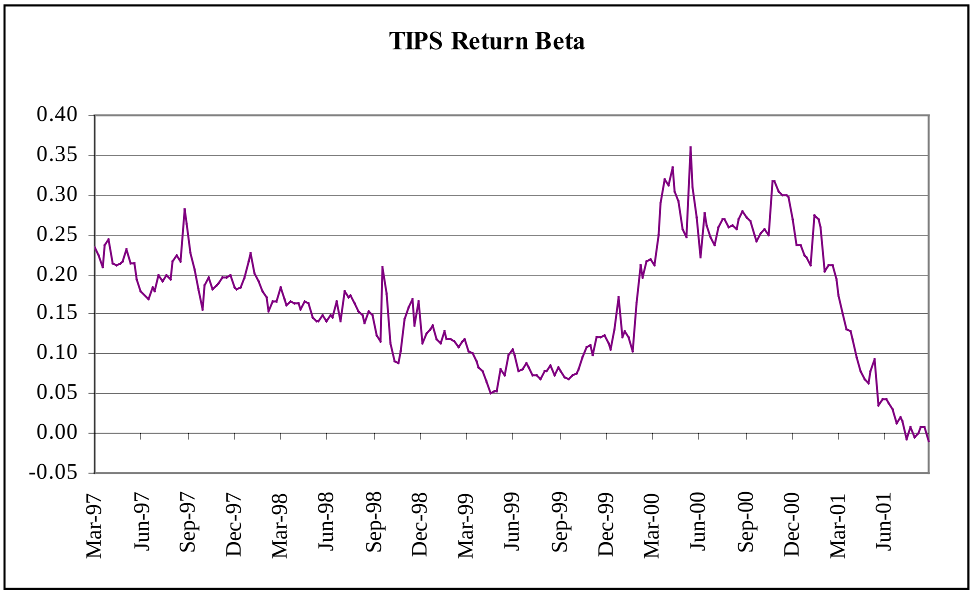

Figure 3: Conditional Sharpe Ratios of TIPS and Nominal (NOMS) Securities