CAMBRIDGE ASSOCIATES LLC

U.S. TREASURY INFLATION-PROTECTED SECURITIES: AN INTRODUCTION

Introduction

While inflation-indexed bonds have been around for some time, most observers date the modern market to the United Kingdom's initial issuance in 1981; even the United States resisted issuing inflation-protected bonds until 1997. Since then, the global inflation-indexed market has expanded at a break-neck pace, more than doubling in size in less than five years. From 1999 to December 31, 2004, the global market has increased from roughly US$250 billion (representing 34 outstanding issues from six countries) to US$700 billion (nearly 51 issues from nine countries). The share of such bonds issued as a percentage of total government debt, meanwhile, continues to rise, along with investor demand. Institutional and retail investors alike seem to have warmed to the concept of inflation-protected returns.

Performance of Inflation-Linked Bonds

Since the United States introduced Treasury Inflation-Protected Securities (TIPS) in October 1997, the compound annual return has been 8.4% (through December 31, 2004), while inflation was 2.3%, as measured by the CPI, for a real return of 6.0%. In order to understand how TIPS will perform under various market conditions, however, it is necessary to extrapolate some logical expectations from the short history that already exists, from the economic basis of their return, and from performance simulations. Additionally, inflation-protected U.K. bonds (U.K. linkers) have existed since the early 1980s, and provide useful insight into performance expectations. However, structural differences between the U.S. and U.K. markets, such as the effective requirement of U.K. pension funds to buy inflation-protected bonds to meet regulatory requirements, may reduce the accuracy of comparisons with U.S. TIPS.

Simulated data are also of dubious value. The approach to modeling real yields is to subtract inflation expectations, typically based on the trailing 12-month inflation rate or survey consensus inflation expectations, and the inflation-risk premium, from nominal bond yields, to arrive at real yields. This assumes that the spread between real and nominal yields inevitably expands and contracts as inflation rises or falls—which may hold true *generally*, but not necessarily *always*. Nevertheless, this methodology has proved useful in estimating real yields, and, in our analyses, we use a simulated real yield and performance series based on this approach, provided by Bridgewater, a U.S.-based bond manager. Bridgewater's simulated real yield series has been highly correlated with actual real yields in the United Kingdom since 1981.

Economic Basis of Returns

Six principal factors affect the performance of TIPS: (1) actual CPI-U, (2) the value of the embedded principal guarantee, (3) actual real yields, (4) expected real yields, (5) the real rate risk premium, and (6) liquidity premium/discount. As with nominal bonds, in a flat interest rate environment, the return on inflation-linked bonds is its yield to maturity. However, the yield on an inflation-linked bond is its real inflation-adjusted expected return, while the yield on a nominal bond is its nominal expected return. In nominal terms, if you buy an inflation-linked bond and hold it to maturity, the expected return is the yield to

maturity plus inflation over the life of the bond. Additionally, the return will vary as real yields vary because of the changing environment for reinvesting coupon payments (unless you invest in zero-coupon securities) and the changing value of the bonds should you sell prior to the bond's maturity. Holders of TIPS receive a floating coupon payment that is based upon the fixed coupon percentage multiplied by the inflation-indexed principal and receive the greater of the original principal amount of the bond or the inflation-adjusted principal upon the bond's maturity. See the Appendix for more detail on the inflation adjustment of TIPS.

Expected Returns

Due to the brief history of TIPS, Bridgewater's simulated performance series, with its drawbacks, does provide further insight into TIPS' performance relative to that of other asset classes. The simulated series provides returns of constant eight-year duration TIPS between 1958 and 1996, with actual data used after the introduction of TIPS in January 1997. For the full period ended December 31, 2004, the average annual compound return of the simulated TIPS series is 8.7%, compared to 11.1% for U.S. equities, 7.0% for U.S. government bonds, and 5.9% for cash. In real terms, TIPS' annual return averaged 4.1% over the period. Although we would expect TIPS to underperform equities over the long term, they may outperform over shorter time horizons—even over periods as long as 20 years. In the period 1958-99, simulated TIPS outperformed U.S. equities in about half of the rolling 20-year periods, bonds in about three-quarters of the periods, and cash in every period. The results are similar for rolling ten-year periods.

These results suggest that over long periods we should expect TIPS to underperform equities and outperform cash, although there may also be extended periods in which TIPS beat equities. However, the economic basis of returns for TIPS and conventional bonds suggests that nominal bonds should *outperform* TIPS over most periods because a market as efficient as the Treasury bond market should price inflation expectations accurately most of the time, and add a sufficient premium to compensate investors for the element of uncertainty that investors in TIPS do not incur. During short-term periods of unexpectedly high inflation, TIPS may outperform comparable nominal Treasuries, but during periods of disinflation nominal bonds should outperform inflation-protected bonds. The outperformance of TIPS during these periods may make up for the underperformance during disinflationary periods.

Standard Deviations

The volatility of the real returns of TIPS is a function of their duration and of the volatility of the change in real yields. Since TIPS yields are low relative to nominal bond yields, and the inflation adjustment to the principal results in larger cash flows as TIPS mature (assuming a rising price environment), the duration of TIPS is longer than that of nominal bonds of comparable maturity. However, the standard deviation of TIPS returns is generally lower than that of nominal bonds of comparable maturity because real yields tend to be much less volatile than nominal yields. Since TIPS were first issued in January 1997, the ratio of the standard deviation of the annual change in real yields to the change in nominal yields of Treasuries of comparable maturity (rolling monthly data) is approximately 60%. However, this relationship

has been unstable and the period is too short to draw any firm conclusions. For long-term planning purposes, we assume that the standard deviation of TIPS is about 85% that of a diversified portfolio of investment-grade nominal bonds based on a comparison of relative standard deviations over multiple time horizons.

Correlations

Nominal bond returns are influenced by changes in yields that are in turn influenced by three factors: changes in real yields, changes in inflation expectations, and changes in the inflation premium demanded by bond holders. In contrast, nominal returns on TIPS are influenced by actual inflation and changes in real yields. To the extent that most of the change in nominal yields is driven by the change in real yields, we would expect the correlation between nominal Treasuries and TIPS to be high when inflation expectations priced into nominal bonds approximate actual inflation. However, during periods when nominal yields change due to shifting inflation expectations and/or a shifting risk premium, correlations should be low. Additionally, when inflation is unexpectedly high, we would expect TIPS to perform well and conventional bonds to perform poorly, while the reverse would be true during periods of disinflation or deflation. Furthermore, if the simulated real yield series proves to model reality in the U.S. market, we will find that real yields tend to decline during periods of rising inflation, such that TIPS returns would benefit in this environment both from falling real yields and from rising inflation. Nominal bonds would also benefit from falling real yields, but this would probably be offset by a rise in both inflation expectations and the inflation premium, which would push nominal yields higher.

The correlations between TIPS and other asset classes vary significantly from one period to another. For example, for the period 1958-99, the correlations of quarterly real simulated TIPS returns with real conventional bond returns were 79%, with equities, 15%, and with cash, 7%. Since the inception of TIPS, the correlations have been 80% with bonds, -20% with equities, and -3% with cash. However, correlations based on annual or on rolling three-year return data are quite different—lower between TIPS and nominal bonds and equities. This is because changes in real yields dominate the performance of TIPS over short periods of time, while the inflation hedge is a more important contributor over longer periods.

As would be expected, correlations also vary depending on the inflationary environment. During the high-inflation period of 1973-81, correlations between simulated real TIPS quarterly returns and real returns of equities and conventional bonds were higher than that measured during low-inflation periods. However, the correlation of the nine annual returns—a statistically insignificant sample size—was negative over the same period, which is what one would expect in this type of environment. In short, we would expect the correlation between TIPS and nominal bonds to be about 75%, on average, over the long term, but with periods of divergence from this average during extreme economic conditions.

Many participants in the TIPS market assume TIPS have zero or negative correlations to equities. However, it may not be prudent to assume such attractive correlations on the basis of so little live data. Correlations with equities probably will be zero or negative on occasion; however, a more conservative assumption would be a slightly positive relationship, similar to that for cash and equities.

A Valuation Framework for TIPS

Similar to nominal bonds, TIPS are valued based on the relationship between yields, in this case, real yields, and the underlying supply and demand fundamentals for TIPS. Simulated real yields dating back to 1958 have ranged from 2.7% to 4.7%, while since their inception in 1997, actual TIPS yields have ranged from 1.5% to 4.3%.

Relative to nominal bonds, inflation-linked bonds offer a good value if the yield spread between inflation-linked bonds and nominal bonds of the same maturity is lower than inflation expectations. In other words, if the premium provided by nominal bonds over inflation-linked bonds does not adequately compensate for inflation expectations, inflation-linked bonds represent a better value. Our framework for valuing inflation-linked bonds relative to nominal bonds is based on implied break-even inflation rates and the asymmetric distribution of relative returns.

Break-even Inflation. Paul Fisher, an economist, argues that break-even inflation is based on the following equation, which states that a nominal bond yield has three components:

Nominal Interest Rate = Real Interest Rate + Inflation Expectations + Inflation Risk Premium

The break-even inflation rate is the level of inflation an investor could experience over the life of a bond and remain indifferent between holding a nominal bond and inflation-linked bond. Break-even inflation rates can be approximated in a simplified manner, by subtracting the nominal yield from the real yield of two bonds of equal maturity and credit quality.[1]

We then compare the break-even inflation rate to inflation expectations for the maturity of the bond. For example, if the break-even inflation rate were 2.0%, what is the likelihood that actual inflation would exceed this rate, making TIPS more attractive than nominal bonds. From an historical perspective, there have been few ten-year periods in which inflation has been less than 2.0%. Inflation has averaged less than 2.0% annually in only 26% of ten-year rolling periods since the period ended 1923, and in only 16% since the period ended 1941. However, even if inflation were below 2.0% over the next ten years, the underperformance would be limited to the difference between implied and realized inflation. For example, if actual inflation over the period is 1.5% and the break-even inflation rate is 2.0%, the yield loss relative to nominal bonds would be 0.5%.

[1] Due to the semi-annual nature of the coupon, reinvestment risk of coupons, variable inflation-linked coupon stream, and indexation lags, the exact calculation is more complex. However, simple subtraction offers a good comparative estimate.

Advantages and Disadvantages of TIPS

Inflation Hedging Characteristics

TIPS are logical inflation hedges because they are indexed to the CPI. However, their success in this role depends on whether an investor is attempting to hedge against a decline in asset value triggered by rising inflation, an increase in a specific liability tied to inflation, or the need to liquidate equities at depressed prices in order to sustain spending during periods of unexpected inflation.

Preserve Purchasing Power. Over the long term, a portfolio primarily invested in equities should provide a hedge against a decline in purchasing power as the return of equities should exceed the rate of inflation as they are a claim on real assets. TIPS would also serve this purpose, provided that the real yield on TIPS is greater than or equal to the rate of endowment spending. However, since the long-term expected return of equities is higher than that of TIPS, and since liabilities have grown faster than the rate of consumer inflation for most institutional investors, equities would fill this hedging role better, for all but the most risk averse. In addition, it should be noted that although reinvestment risk can be eliminated over the maturity of the TIPS for investors that buy and hold zero-coupon inflation-linked bonds, it is necessary to plan so that TIPS yields will be sufficiently high to support spending without depleting purchasing power when the time comes to roll over the principal.

Hedge a Liability Tied to Inflation. Similar to the way nominal bonds provide a hedge against nominal liabilities, inflation-linked bonds should provide a hedge against inflation-linked liabilities, such as cost-of-living adjustments to benefit payments in pension plans. However, duration-matching strategies of the sort routinely implemented with nominal bonds will not work in the same way because TIPS' inflation hedge is based on the adjustment of coupon payments and principal in response to inflation, rather than on the movement of interest rates. In fact, in the short term, TIPS returns are more sensitive to changes in real yields, which will not necessarily move in a favorable direction during inflationary periods. If an institution is buying and holding TIPS until maturity, changes in real yields only affect returns to the extent that coupons are reinvested in higher- or lower-yielding TIPS. Therefore, inflation-related liabilities would be best hedged by holding TIPS that mature on the date the liabilities are due—and a laddered portfolio would usually serve this purpose best. Alternatively, holding a portfolio of TIPS without regard to matching the specific liabilities could prove to be a successful strategy, but would involve a higher degree of risk that real yields would increase, depressing TIPS prices when assets are needed to fund the liabilities.

Hedge a Spending Stream. A simple example provides insight into how an allocation to TIPS can hedge spending. Assume that an endowment of $100 million is invested 70% in equities, 20% in nominal bonds, and 10% in TIPS. The endowment spends the greater of 5% of its beginning market value or last year's spending. Further, assume a worst-case, two-year scenario in which inflation runs at 6.5% in year one and 10.5% in year two, causing equity returns of -20% and -30%, respectively, and nominal bonds returns of approximately -10% and -4%. The $70 million invested in stocks would have fallen to $57 million and the $20 million invested in nominal bonds would have decreased to $18 million, while the $10 million invested in TIPS would have increased to just over $11 million at the end of the first year before spending and

rebalancing. The annual return on the TIPS in a flat interest rate environment would be equal to the real yield of 4% plus the inflation of 6.5%, or 10.5%. The income plus appreciation of TIPS totals only $1,076,000 in year one, falling far short of the $5 million required for spending. However, since the total value of the endowment has declined to $81 million after spending, a 10% allocation to TIPS would total approximately $8 million. After selling TIPS to rebalance, nearly $3 million is available for spending without selling any stocks or bonds at depressed prices. Add to this the proceeds from rebalancing nominal bonds, and one is only $350,000 short of the required $5 million. Moreover, during the second year of this extreme scenario, the sale of appreciated TIPS, combined with the sale of nominal bonds to rebalance, would be sufficient to support spending. Additionally, over $1.5 million would be rebalanced into equities in order to restore their allocation to 70% of the portfolio. Although TIPS hedge only approximately 60% of spending needs under these extreme conditions, the outcome is far better for the endowment than would have been the case if no inflation-hedging assets were available.

Diversification

Because of the relatively low correlation between inflation-linked bonds and other asset classes, efficient frontier analysis suggests that inclusion of TIPS in a portfolio—under most reasonable risk, return, and correlation assumptions—would increase portfolio efficiency for lower-risk/lower-return portfolios, allowing a higher expected return for a given level of risk, or a lower level of risk for a given expected return. However, since TIPS are relatively new and their performance characteristics unproven, it may not be prudent to invest in TIPS purely to increase portfolio efficiency. Nevertheless, the benefits of diversification should be considered in determining the advantages relative to the opportunity costs of investing in TIPS as an inflation hedge.

Asymmetric Return Distribution Relative to Nominal Bonds

While TIPS are expected to outperform nominal bonds during inflationary periods, and underperform during deflationary periods, assuming real yields remain flat, TIPS have larger potential outperformance during inflation than their potential underperformance during deflation.[2] The asymmetric relative returns are attributable to the Treasury's guarantee that an investor will receive, at minimum, par value of the bond back at maturity. Simply stated, the principal guarantee combined with the Fisher equation implies that the maximum underperformance one can expect from TIPS relative to nominal bonds is the break-even inflation rate plus any accrued inflation and the premium paid over par. While this is only completely true of zero-coupon TIPS, the difference is not substantial for coupons bearing TIPS.[3] The assumption that real yields remain constant is significant. Although TIPS provide an opportunity to observe the behavior of real yields, they have not been in existence for a sufficient length of time to observe their behavior during these adverse economic environments. For example, during the 1929-38 deflationary period in the United States, real yields initially increased, then decreased (real yields are estimated by subtracting inflation expectations, which are defined as trailing 12-month CPI, from nominal yields). Since we cannot

[2] This topic is explored extensively in our 2001 report: *U.S. TIPS: Fixed Income Substitute?*

[3] In a deflationary scenario, coupons are accrued on a deflating notional amount. Using the CPI-U time series from 1929-39, the extra loss due to the coupon effect would be approximately 67 basis points (bps) over the break-even inflation rate.

know how real yields will move in future periods of prolonged economic contractions and unexpected inflation, this analysis leaves real yields unchanged, while recognizing that the performance of TIPS would be significantly worse if real yields rose, and better if real yields fell.

Opportunity Costs

The major risk of investing in TIPS is the potential for opportunity costs, particularly when real yields are low. For most institutions adopting a policy allocation to TIPS as an inflation hedge, the challenge is to determine how best to fund that allocation. In theory, the logical answer is that if TIPS are used to protect the fund's equities, funding should come from that source. However, for some investors, the opportunity cost of investing in TIPS is too high to justify the hedging benefits, even after considering the diversification benefits. For institutions with relatively low return objectives, under most reasonable assumptions, TIPS would qualify as an efficient allocation, but for institutions with relatively high return objectives, TIPS' inflation-hedging benefits must be weighed against the expected opportunity cost.

The opportunity cost of investing in TIPS as part of the nominal bond portfolio is lower, as the expected return differential between TIPS and nominal bonds is lower and TIPS are expected to hold their value reasonably well during periods of prolonged economic contraction. However, investors that include TIPS in their bond portfolio need to make sure that they maintain an adequate hedge against prolonged economic contraction. The best way to insure that a portfolio is sufficiently hedged against prolonged economic contraction is to stress-test the portfolio to determine if its allocation to conventional bonds and TIPS is sufficient to prevent the sale of equities at depressed prices in order to support spending needs. If the conventional bond allocation is reduced to allow for investing in TIPS, the hedging characteristics of the conventional bonds that remain in the portfolio may be improved by increasing their duration and/or quality. TIPS may hold their value relatively well during a deflationary environment, but their value largely depends upon the behavior of real yields in this environment, which is an unknown factor.

Tax Treatment

In general, TIPS are not attractive in taxable accounts because the inflation accruals to principal are taxed in the period in which they are accrued, even though no income is distributed—as is also the case with zero-coupon bonds. Consequently, there is a threshold rate of inflation above which coupon payments will fail to cover the tax liability, leaving the investor out-of-pocket. This threshold inflation rate decreases as tax rates rise and as coupon payments decline. Investors paying the highest marginal Federal tax rates therefore incur a significant risk that their tax liability will exceed the cash flow from their TIPS coupons.

Implementation

Endowments and foundations generally seek both the inflation- and deflation-hedging features of TIPS. While these characteristics are not mutually exclusive, proper implementation is critical to ensure that the desired balance of these hedges is achieved.

Deflation Hedging

In theory, the best TIPS for hedging deflation would have no inflation accrual, trade at par, and have a long duration. The most effective way to obtain TIPS with these characteristics would be to buy them at the Treasury auction on issue. Annually, one should trade the old bond for the most recently issued one (this is called "rolling the bond forward") in order to reset the inflation accrual back to zero.[4] While rolling the bond forward historically was an inexpensive, or even cost free, means of preserving the deflation-hedging properties of TIPS, the increased efficiency of the market has made this a much less mechanical process. In the past, the lack of demand at auction time and a positively sloped real yield curve enabled investors to roll into the most recent bond while picking up a yield premium. However, investors must now be more vigilant in evaluating the yield differential between the old and new bonds to determine if any loss in yield is worth the increased deflation-hedging properties of the new bonds.

Inflation Hedging

In theory, a portfolio of TIPS with a low real duration would provide the best inflation hedge because the short duration limits the exposure of these bonds to a rise in real rates, should that occur at the same time as a burst of unexpected inflation.[5] Since one cannot predict with accuracy what will happen to real interest rates during inflation, sensitivity to real interest rates should be kept to a minimum. However, in an upward-sloping real yield-curve environment, yield must be sacrificed in order to obtain the shorter duration.

Active Implementation versus Investor-Directed

Given that the two objectives above imply contradictory portfolio construction, how should one implement a TIPS allocation? If TIPS are used as a substitute for nominal bonds, a long-duration portfolio may be desirable to maintain some deflation-hedging characteristics. If the allocation is a pure inflation hedge or cash substitute, shorter maturity TIPS are most appropriate. Below we explore the implementation alternatives.

Active Management. Active management or indexing of TIPS is an operationally simple way to implement a TIPS allocation. An indexed portfolio would have a duration of 9.8[6] years and significant inflation accruals, making it possess neither of the attributes needed if one desires either low-inflation accruals to maximize deflation protection or low duration to reduce sensitivity to real interest rates. Active managers, unless otherwise instructed in their guidelines, are likely to own a portfolio that is relatively close to the index in order to reduce index and peer tracking error, therefore making most active portfolios less than optimal for institutions with specific inflation- or deflation-hedging objectives.

[4] See our 2001 report, *U.S. TIPS: Fixed Income Substitute?*
[5] Our discussion of inflation hedging relates specifically to hedging endowment spending against inflation, such that TIPS could be sold to support spending during periods of unexpected inflation when the value of equities and nominal bonds decreases.
[6] Characteristics of the Barclays Inflation-Linked Bond Index as of October 7, 2002.

Another potential issue with active management is the use of the yield enhancement technique of borrowing against the value of the TIPS portfolio to purchase short-term corporate paper. During extreme deflation, we would expect corporate spreads and default rates to increase, reducing the value of the portfolio, and defeating the purpose of the hedge. Finally, an active management fee of 20 bps is a large hurdle to overcome in a maturing asset class with a relatively small number of outstanding issues.

For institutions that choose to employ an active manager, a clearly specified investment mandate is essential. If indexing is used, one should be cognizant of the index characteristics and how they relate to the desired role of the allocation.

Investor-Directed Investing. While not operationally as simple as active management, the investor-directed approach allows investors to control both inflation accruals and portfolio duration. However, as noted above, recent market developments make the "do-it-yourself" approach potentially less straightforward than it has been, requiring analysis of the trade-off between the yield differential and deflation-hedging properties of held bonds and new issues at each auction. While the "do-it-yourself" days of TIPS have not passed, investors should consider that this is becoming a more efficient market and that the deflation protection may not always be available for "free" as it has been in the past.

To date, most active TIPS managers have been able to add value relative to their passive TIPS benchmarks through the strategies described above. It remains to be seen whether this will persist as the market matures, and investors should always remember that many of these active strategies also reduce the inflation-hedging characteristics of TIPS portfolios. The expected excess return gained by active management must be worth the reduction in hedging characteristics for these active strategies to be adopted.

Exhibit 1

SIMPLIFIED SCENARIO USING TIPS TO HEDGE ENDOWMENT SPENDING

	Year One		Year Two	
	$ million	Percent (%)	$ million	Percent (%)
Initial Assumptions				
Total Beginning Market Value	$ 100.00		$ 80.93	
Asset Allocation				
Stocks	$ 70.00	70.0	$ 56.65	70.0
Bonds	$ 20.00	20.0	$ 16.19	20.0
Inflation-Linked Bonds	$ 10.00	10.0	$ 8.09	10.0
Spending	$ 5.00	5.0	$ 5.00	6.2
Current Yield				
Bonds		6.7		8.8
Inflation-Linked Bonds		4.1		4.1
Real Estate		6.1		7.2
Inflationary Period				
Expected Inflation		4.1		8.2
Actual Inflation		6.5		10.5
Total Returns				
Stocks		-18.9		-28.8
Bonds		-10.3		-4.4
Inflation-Linked Bonds		10.8		14.9
Additions/(Withdrawals)				
Stocks	($0.35)		$1.66	
Bonds	($1.77)		($3.56)	
Inflation-Linked Bonds	($2.88)		($3.10)	
Ending Market Value	**$ 80.93**		**$ 60.05**	
Stocks	$ 56.65	70.0	$ 42.04	70.0
Bonds	$ 16.19	20.0	$ 12.01	20.0
Inflation-Linked Bonds	$ 8.09	10.0	$ 6.01	10.0
Real Ending Market Value	**$ 75.99**		**$ 51.03**	

Exhibit 1 (continued)

SIMPLIFIED SCENARIO USING TIPS TO HEDGE ENDOWMENT SPENDING

The exhibit on the facing page provides a simple example of how an allocation to TIPS can hedge spending.

Assumptions

- An endowment of $100 million is invested 70% in equities, 20% in nominal bonds, and 10% in TIPS.
- The endowment spends the greater of 5% of its beginning market value or last year's spending.
- Inflation reaches 6.5% in year one and 10.5% in year two.
- Equities return approximately -20% in year one and -30% in year two, and nominal bonds return approximately -10% and -4%, respectively.
- The annual return on the TIPS in a flat interest rate environment would be equal to the real yield of 4% plus the inflation of 6.5% and 10.5%.

Results

- At the end of year one, the income plus appreciation of TIPS totals only $1,076,000 in year one, falling far short of the $5 million required for spending. However, since the total value of the endowment has declined to $81 million after spending, a 10% allocation to TIPS would total approximately $8 million. After selling TIPS to rebalance, nearly $3 million is available for spending without selling any stocks or bonds at depressed prices. Add to this the proceeds from rebalancing nominal bonds, and one is only $350,000 short of the required $5 million.
- During year two, the sale of appreciated TIPS, combined with the sale of nominal bonds to rebalance, would be sufficient to support spending. Additionally, over $1.5 million would be rebalanced into equities in order to restore their allocation to 70% of the portfolio.
- Although TIPS hedge only approximately 60% of spending needs under these extreme conditions, the outcome is far better for the endowment than would have been the case if no inflation-hedging assets were available.

Appendix

THE MECHANICS OF TIPS PRICING

TIPS in the United States are indexed to the nonseasonally adjusted U.S. City Average All Items Consumer Price Index for All Urban Consumers (CPI-U) with a lag of three months. The coupon percentage stays fixed and the principal is adjusted by the change in CPI-U. The lag in the CPI-U is necessary in order to allow for daily pricing of TIPS through linear interpolation (described below), given that the CPI is released on a monthly basis. Therefore, a TIPS issued on December 1, 2004, would be indexed to inflation occurring after September 1, 2004. The three-month lagging date is referred to as the reference date, and the CPI-U level on that date is the reference CPI. The Treasury announces reference CPI dates and reference CPI values to prevent confusion and to simplify the process of calculating TIPS prices.

Pricing information on the 2.0% ten-year TIPS issued on January 15, 2004, is provided in Exhibit A-1. On December 1, 2004, the principal value of the inflation-linked bond issued on January 15, 2004, was adjusted by increasing its principal value by the rate of inflation that occurred between October 15, 2003 and September 2004. The indexed principal value is calculated by multiplying the face value of the TIPS of $100 by the index ratio, which was 1.028 on December 1, 2004, resulting in a principal value of $102.77. The index ratio is equal to the ratio of the reference CPI at the date of valuation, 189.900 (CPI-U level in September 2004) to the reference CPI at issuance, 184.774 (interpolated CPI-U level on October 15, 2003).

As noted above, daily pricing of TIPS is achieved through linear interpolation of monthly CPI levels. In the example above, the reference CPI at issuance of the TIPS issued on January 15, 2004, represents a linear interpolation between the reference CPI on January 1, 2004 (CPI-U level in October 2003) and February 2004 (CPI-U in November 2003). This is calculated by taking the reference CPI on January 1, 2004 of 185.000 and adding approximately one-half (the fraction of full days elapsed during the month, or 14/31, on January 15) of the difference between the reference CPI-U level 184.500 on February 1, 2004 and 185.000 on January 1, 2004. This results in a reference CPI of 184.774 [185.0 + 14/31 * (184.5 - 185.0)].

The Treasury guarantees that maturing TIPS will be redeemed at least at face value. However, the Treasury does not guarantee a minimum coupon payment. Coupon payments are calculated as the fixed coupon rate multiplied by the indexed principal. If inflation is negative, the indexed principal value declines, and the coupon payments decline, including the final coupon payment that is distributed at the same time as the repayment of principal.

Exhibit A-1

PRICING OF THE 2% TEN-YEAR TIPS; ISSUED 01/15/2004, PAR $100

Date	Three-Month Lagging CPI-U Date	Ref CPI	Index Ratio	Principal Value	Semi-Annual Coupon Payment
01/01/2004	Oct-03	185.000	---	---	---
01/15/2004	---	184.774	1.000	$100.00	---
02/01/2004	Nov-03	184.500	0.999	$99.85	---
03/01/2004	Dec-03	184.300	0.997	$99.74	---
04/01/2004	Jan-04	185.200	1.002	$100.23	---
05/01/2004	Feb-04	186.200	1.008	$100.77	---
06/01/2004	Mar-04	187.400	1.014	$101.42	---
07/01/2004	Apr-04	188.000	1.017	$101.75	---
07/15/2004	---	188.497	1.020	$102.01	$1.02
08/01/2004	May-04	189.100	1.023	$102.34	---
09/01/2004	Jun-04	189.700	1.027	$102.67	---
10/01/2004	Jul-04	189.400	1.025	$102.50	---
11/01/2004	Aug-04	189.500	1.026	$102.56	---
12/01/2004	Sep-04	189.900	1.028	$102.77	---
01/01/2005	Oct-04	190.900	1.033	$103.32	---
01/15/2005	---	190.945	1.033	$103.34	$1.03
02/01/2005	Nov-04	191.000	1.034	$103.37	---
03/01/2005	Dec-04	190.300	1.030	$102.99	---
04/01/2005	Jan-05	190.700	1.032	$103.21	---
05/01/2005	Feb-05	191.800	1.038	$103.80	---
06/01/2005	Mar-05	193.300	1.046	$104.61	---

Notes: Ref CPI on the first day of the month = The non-seasonally adjusted CPI-U lagged three months.
Index Ratio = Reference CPI on date of pricing/Reference CPI at issuance.
Intra-Month Ref CPI = Ref CPI on first day of current month + (percent of full days elapsed in month) *
(Ref CPI on first day of following month - Ref CPI on first day of current month).
Principal Value = Index Ratio * 100.
Semi-Annual Coupon Payment = Principle Value * Real Yield/2.