Asset Allocation with Conventional and Indexed Bonds

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Abstract

A series of hypothetical indexed bond returns is created using historical yields on conventional Treasury bonds and an inflation-forecasting model. We find that the real (inflation-adjusted) returns on indexed bonds are less volatile than the returns on otherwise similar conventional bonds. Moreover, the correlation with stock returns is much lower for the indexed bonds. An examination of asset allocation between stocks, indexed bonds, conventional Treasuries, and a riskless asset suggests that substantial weight should be given to indexed bonds in an efficient portfolio. These conclusions are supported by analysis of the short history of actual returns on TIPS (Treasury inflation-protected securities).

1. Introduction

In January 1997 the U.S. Treasury began issuing 10-year inflation-protected bonds with principal and interest payments linked to the consumer price index of all urban consumers. We refer to these as indexed or inflation-linked bonds. In this paper we examine whether and how the availability of indexed bonds might affect investors' asset allocation decisions. We also study the extent to which the availability of indexed bonds enables investors to construct superior mean-variance efficient portfolios.[1] The latter question is important. The increase in an investor's welfare from a change in asset allocationdepends on the degree of improvement in the risk-return trade-off, i.e., the ability to achieve higher rates of return for a given level of risk.

Indexed bonds have long been a topic of interest to the investment community and government policymakers (see Campbell and Shiller, 1996). For example, advocates of indexed bonds have argued the benefits of such bonds to retirees and other investors who are vulnerable to inflation risk. Other benefits, like lowering financing costs to the Treasury, have also been suggested. Somewhat surprisingly, there has been limited work on the impact of the availability of indexed bonds on investors' asset allocation decision. Should investors hold a different mix of stocks and bonds in the presence of indexed bonds than otherwise? How does this change the risk-return trade-off facing investors? We offer guidance on this important question.

To examine the effect of indexed bonds on asset allocation, we first compare the properties of a portfolio of stocks and indexed bonds with a portfolio of stocks and non-indexed or conventional bonds. Mean, variance, and covariance measures for stock and bond returns are examined. Going through this exercise provides insight into the basic economic characteristics of the different bond classes. Later, we consider the joint optimization problem over stocks and both bonds. Since investors should, in principle, be concerned with the real purchasing power of

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[1] A mean-variance efficient portfolio offers the maximum expected rate of return for a given level of risk, as measured by the standard deviation of portfolio return.

their nominal wealth, we emphasize results based on real returns, but present results using nominal returns as well.

While historical time series of stock and conventional bond prices are available, the same is not true for indexed bonds in the U.S. The U.S. Treasury only began issuing inflation-protected bonds in 1997. Therefore, we construct a time series of hypothetical zero-coupon indexed bond prices as if the bonds were available since the 1950s.[2] The indexed bond prices are calculated each month by discounting the payoff to a hypothetical zero-coupon bond by an estimated real rate of interest (see sections 2 and 3 for details). Returns are then computed from the hypothetical indexed bond prices. Optimal asset allocations are estimated using historical stock and conventional bonds returns, together with the hypothetical indexed bond returns.

The results show that there can be considerable diversification benefits for investors using indexed bonds, rather than conventional bonds. Using data from 1953 to 2000, we find that the real returns estimated for hypothetical indexed bonds are virtually uncorrelated with stock returns, whereas the non-indexed bonds exhibit positive correlation near 0.4. This is not surprising since numerous studies (e.g., Fama and Schwert, 1977, and Fama, 1981) show that stock prices, as well as conventional bond prices, react negatively to news of increased inflation. In addition, we find that indexed bond returns, particularly the real returns, are less variable than non-indexed bond returns.

Naturally the risk-reduction benefits of indexed bonds must be weighed against the possibility of a reduction in expected return. Interest rates on conventional bonds can be viewed as compensation for expected inflation plus an expected real rate of return. This expected real rate, in turn, equals the real riskless rate on an indexed bond of the same maturity plus a premium

[2] We implicitly assume that the covariance matrix of stock and conventional bond returns would not have been materially affected by the existence of indexed bonds. In principle, some endogenous adjustment might be expected, but consideration of such issues is beyond the scope of this research.

for inflation risk. If the inflation risk premium is positive, as might be expected, then indexed bonds will have lower expected returns than conventional bonds. However, as Campbell and Shiller note, in theory the "premium" could even be negative.

The pricing of indexed bonds traded in the market the past few years suggests that this may indeed be the case. For example, the yield on conventional ten-year Treasury bonds at the end of 1999 was 6.44%, while the real yield on ten-year indexed bonds was 4.37%. Therefore, the sum of expected inflation and the inflation risk premium was only a little more than 2% per year. Since expected inflation was apparently at least 2.5% at this time (see Monetary Trends, 2000, p. 8), the implied inflation risk premium is negative. As a recent example, conventional /indexed ten-year yields were 5.03%/3.53% at the end of 2001, a difference of 1.5%. The November 2001 University of Michigan survey indicates that consumers expect very low inflation for 2002, but 2.8% average inflation over the next five years. Again, the implied risk premium is negative. Our base computation of indexed bond returns assumes the inflation risk premium is zero, but we also consider alternative scenarios.

In addition to the analysis of *hypothetical* indexed bond returns, we use the data since 1997 to see whether the initial U.S. experience has been anything like our model-based predictions. The qualitative risk and correlation properties are quite similar, though the volatility of actual indexed bond returns has been much lower than that observed in our historical simulation.

The current study is preliminary and could be expanded along several lines. We consider a one-year investment horizon and restrict ourselves to mean-variance analysis. In future work, the analysis might be extended to a multi-year horizon. Exploring expectations based on survey data might be informative as well. We examine the effect of the availability of hypothetical five-year zero-coupon or *actual* ten-year coupon-paying indexed bonds on asset allocation. Sensitivity to variations in coupon and maturity should also be explored. Finally, we work with the unconditional covariance matrix of returns here. It is likely that the covariance matrix changes over time, however, and it may be possible to model some of these changes in terms of observable variables that can be incorporated into the asset allocation decision.

Section 2 describes the research design at an intuitive, non-technical level. We present the inflation forecasting models, calculations of the real interest rates and prices of hypothetical indexed bonds, and descriptive statistics for inflation forecasting models and bond returns in section 3. An analysis of diversification across stocks and indexed or conventional bonds is given in section 4. The main results on asset allocation with indexed and/or conventional bonds, using nominal and real return data, appear in section 5. We summarize and conclude in section 6.

2. Research design

Our research design for assessing the potential effect of the availability of indexed bonds on investors' asset allocation decisions is straightforward. We estimate the time series of annual returns on hypothetical indexed bonds from June 1953 to December 2000. Using these hypothetical bond returns, the time series of returns on the value-weighted portfolio of stocks, and a series of riskless rates, we compute the stock-bond allocation for the mean-variance optimal portfolio. We report the Sharpe ratio and M^2 value for the optimal portfolio and for portfolios with various stock-bond weights.

The Sharpe ratio is the ratio of mean excess return to standard deviation and is a commonly used portfolio reward-to-risk measure. The M^2 value is the mean excess return on a portfolio, levered up or down at the riskless rate, so as to have the same standard deviation as the stock market index; M^2 equals the Sharpe ratio of the portfolio times the standard deviation of the stock index return. M^2 provides the same ranking of portfolios as the Sharpe ratio, but is perhaps easier to interpret in that portfolios are compared on the basis of a return metric with risk held constant. Examining statistics for a range of portfolios provides some indication of the sensitivity of these performance measures to deviations from the estimated optimal weights. We also compare the optimal portfolio's stock-bond allocation with that of an optimal portfolio using conventional bonds and stocks.

Once a time series of returns on our hypothetical bonds is estimated, optimal portfolio construction employs standard mean-variance optimization techniques. The construction of a return series on hypothetical indexed bonds, however, is largely uncharted territory. We begin by assuming that the indexed bonds are five-year zero-coupon bonds. Since its cash flows are fixed in real terms, the annual real return on an indexed bond equals the change in the discounted present value of the real principal, as a result of any changes in real riskless rates from the beginning to the end of the year, divided by the initial value.

To calculate this annual real return, we estimate a five-year indexed bond's real price at the beginning and end of the first year. Nominal return on the same bond is obtained by subtracting one from (1+ Real return)*(1 + Realized inflation). Price at the beginning of the first year, i.e., at the time of issuing the bond, is the present value of the principal calculated using the five-year real interest rate. The same bond's price at the end of the year is computed using the four-year real interest rate. However, since real interest rates are not observed, they must be estimated.

The difference between the nominal interest rate and the real interest rate is due to the market's expected inflation and an inflation risk premium. Neither expected inflation nor the inflation risk premium is observable. In estimating the real interest rate to be used in calculating the initial price of a five-year indexed bond, we subtract forecasted inflation for five years from the nominal yield on a conventional five-year bond. The price of the five-year bond at the end of the first year is calculated similarly, using the real interest rate on a four-year bond.[3] Thus, the

[3] More precisely, we work with log real prices and log (one plus) real returns following Barr and Campbell, 1997. We ignore the 3-month indexation lag. Prices are then backed out from the log prices and used to compute the actual return series. Further details are provided in section 3.2.

inflation risk premium is ignored at this stage. The effect of a positive risk premium is considered later in our asset allocation analysis.

3. Estimation

In this section, we describe the estimation procedures that generate our time series of annual returns on hypothetical zero-coupon five-year indexed bonds. The empirical analysis begins with the estimation of expected inflation out to five years. We then back out real spot rates of interest. Finally, we estimate the time series of annual returns on hypothetical five-year zero-coupon indexed bonds. We present descriptive statistics at each stage of the estimation. After estimating expected inflation, we separately report the entire analysis using nominal and real (i.e., deflated by realized inflation for the year) returns.

All analysis is based on monthly time series of overlapping annual observations. Reported standard errors correct for biases due to serial dependence that arises from the use of overlapping data. The Newey and West, 1987, standard errors correct for heteroskedasticity as well as autocorrelation. All returns and inflation rates used in estimating expected inflation and calculating prices of hypothetical indexed bonds are continuously compounded in this section unless otherwise noted. Working with logs simplifies the analysis in that the usual discounted cash flow procedure becomes additive rather than multiplicative. However, the mean-variance portfolio analysis in section 4 uses buy-and-hold returns, not continuously compounded returns.

3.1 Estimating expected inflation

Since we analyze zero-coupon bonds with five-year maturity, we need forecasts of inflation up to five years out, denoted years t+1 to t+5. Unlike other studies, we forecast changes in adjacent-year inflation rates beyond the first year, rather than the levels. Insofar as expected inflation is well approximated by a random walk in univariate time series analysis (e.g., Nelson and Schwert, 1977, Fama and Gibbons, 1984), forecasted changes should be identically zero. In this case, working with inflation *levels* would require forecasts over an indefinitely long horizon.

If there is some degree of mean-reversion in expected inflation, forecasted changes won't equal zero near-term, but will be approximately zero looking sufficiently far out. Our regression analysis suggests that there is no ability to forecast *changes* in inflation beyond the third year. Therefore, expected inflation for the fourth and fifth years is assumed to equal forecasted inflation for the third year. The forecasted changes from the first to the second and from the second to the third years are added to the forecasted level of the first year's inflation to give forecasts of two- and three-year-ahead inflation rates.

Inflation-forecasting model. We now describe the inflation-forecasting models for one-year-ahead inflation level and two- and three-year-ahead changes in inflation. Our regression approach implicitly assumes that investors had rational expectations that can be inferred from the *ex post* relation between realized inflation and the forecasting variables.

We forecast one-year-ahead inflation by regressing realized inflation for year t+1, Inf_{t+1}, on the nominal spot interest rate, Int_{t+1}, the spread between the nominal yield on a five-year zero-coupon bond and the spot interest rate, $Yld_{t,t+5} - Int_{t+1}$, lagged one-year inflation, Inf_t, and the sum of realized real returns on one-month bills over the past 12 months, $Realbill_t$.

Inclusion of the spot rate follows the early work of Fama, 1975, and is based on the simple observation that interest rates should impound expectations of future inflation. Insofar as expected real rates vary over time, however, the relation between spot rates and expected inflation is not perfect. Thus, forecasting power may be enhanced by the inclusion of other variables. The addition of lagged inflation is motivated by the work of Nelson and Schwert, 1977, who find that information in past inflation rates has incremental explanatory power beyond the spot rate for forecasting near-term inflation. The yield spread is not standard in this context, and is included as a general proxy for business conditions (Fama and French, 1989), which may be correlated with expected real rates. Similarly, the sum of real bill returns serves as a direct, albeit noisy, measure of expected real rates, as in the work of Fama and Gibbons, 1984.[4]

Formally, we have

$$\mathrm{Inf}_{t+1} = b_0 + b_1\,\mathrm{Int}_{t+1} + b_2\,(\mathrm{Yld}_{t,t+5} - \mathrm{Int}_{t+1}) + b_3\,\mathrm{Inf}_t + b_4\,\mathrm{Realbill}_t + e_{t+1.} \qquad (1)$$

The forecasting model for the change in inflation, from year t+1 to t+2, is

$$\mathrm{Inf}_{t+2} - \mathrm{Inf}_{t+1} = b_0 + b_1\,(\mathrm{Fint}_{t+2} - \mathrm{Int}_{t+1}) + b_2\,\mathrm{Inf}_t + b_3\,\mathrm{Realbill}_t + e_{t+2}, \qquad (2)$$

where Fint_{t+2} is the time t forward interest rate for year t+2. This equation is motivated by the expectations hypothesis, in which the forward rate equals the expected spot rate for year t+2 which, as mentioned above, should incorporate information about expected inflation for that year. We then use the forward - spot spread to capture differences in expected inflation for years t+2 and t+1. Forecasted inflation for year t+2, $E_t(\mathrm{Inf}_{t+2})$, equals $E_t(\mathrm{Inf}_{t+1})$ plus the forecasted change in inflation from equation (2). The forecasting model for the change in inflation from year t+2 to t+3 is similar to equation (2), except that the difference between the forward rates for years t+3 and t+2 is used:

$$\mathrm{Inf}_{t+3} - \mathrm{Inf}_{t+2} = b_0 + b_1\,(\mathrm{Fint}_{t+3} - \mathrm{FInt}_{t+2}) + b_2\,\mathrm{Inf}_t + b_3\,\mathrm{Realbill}_t + e_{t+3} \qquad (3)$$

To estimate models (1) to (3), we use the following data. Annual inflation is calculated from the Consumer Price Index, CPI, as reported on the Wharton WRDS database. Continuously compounded annual inflation rates are obtained by taking the natural logarithm of the ratio of the CPI numbers one year apart. We use the Fama and Bliss, 1987, continuously compounded zero-coupon bond yields from WRDS. The one-year yield serves as the one-year spot interest rate. We construct the forward rate for year t+k+1, Fint_{t+k+1}, by subtracting the total

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[4]We also experimented with inflation forecasts from integrated moving average models of order one for monthly inflation, but find little difference between these results and those based on lagged inflation for one year. This is consistent with the fact that the moving average parameter is around –0.8, so that the forecast is highly correlated with an average of past monthly inflation rates. A similar model for expected real returns on one-month bills has also been examined.

yield on the k-period zero-coupon bond from t to t+k from the total yield on the k+1-period bond from t to t+k+1. Spreads are then computed from the yields and forward rates.

The results of estimating models (1) through (3) appear in table 1. As expected, the spot rate is significantly positively related to one-year-ahead inflation. The real bill return variable is significantly negatively related to next year's inflation; holding the spot rate constant, a higher expected real rate implies lower expected inflation. Overall, the model explains over 70% of the variation in next-year's inflation rate and exhibits a statistically significant fit (i.e., a significant F-statistic).

[Table 1]

The forward spreads are significantly positively related to the changes in inflation two and three years ahead. That is, forward spreads contain reliable information about future inflation. The coefficient on lagged inflation is significantly negative for model (2), reflecting a degree of mean-reversion in inflation, with high inflation last year forecasting a negative change in inflation. This indication of mean-reversion implies a rejection of the random walk model for expected inflation. Like the one-year-ahead model, the two- and three-year-ahead inflation-forecasting models also exhibit a statistically significant fit.

3.2 Real interest rates

Background. The (continuously compounded) nominal interest rate in a period is the sum of the expected real interest rate and expected inflation for the period. The expected real interest rate is, in turn, the sum of the real risk-free rate and the inflation risk premium. In estimating real interest rates, we assume that the inflation risk premium is zero. Later, in our asset allocation analysis, we assume that the inflation risk premium for a given maturity bond is constant over time, although it may vary with bond maturity. In this case, the expected real return on an indexed zero-coupon bond equals the expected real return on a nominal bond of the same maturity minus a constant risk premium. Thus, if the risk premium in the nominal term structure is positive, ignoring it overstates the expected and realized returns on the indexed bond, but has no impact on the computation of second moments. Campbell and Shiller (1996) make a similar point.

While the assumption of a constant inflation risk premium is somewhat restrictive, our approach does not require that term premia in the real term structure are constant over time. In this regard, we extend the analysis in Campbell and Shiller (1996). They derive hypothetical indexed bond returns by assuming that the expected real returns on bonds of all maturities equal the expected real return on a three-month bill. This requires that real term premia, as well as the inflation risk premium, are constant over time. In contrast, we back out the real term premia from a broader set of bond prices at each point in time, thereby permitting the real term premia to change over time.

Following Barr and Campbell (1997), the log real price of a zero-coupon indexed bond at t equals the expected log real payoff minus the time t expected (continuously compounded) real return on the indexed bond from t to t+k. The time t expected real return from t to t+k on a *nominal* zero-coupon bond maturing in k years equals k times the (continuously compounded) k-period spot rate minus the sum of expected inflation rates for years t+1 to t+k. Thus, to compute the expected real return from t to t+k, it suffices to estimate the time t expected inflation rates and subtract the sum from k times the nominal rate. Without loss of generality, we assume that the bond's face value is one, so that the log real payoff equals zero. In this case, the log real price is the negative of the expected real return from t to t+k.. We use this relation to compute hypothetical indexed bond prices.

Estimation. For our five-year indexed zero-coupon bond with unit payoff, the log real price of the bond at time t is –1 times the difference between the total 5-year nominal yield and the sum of the inflation forecasts for five years, t+1 to t+5. This procedure is repeated every month to obtain a time series of log real prices for a bond with five years to maturity. We similarly construct a price series for a bond with a 4-year maturity. These two price series are used to calculate a time series of annual buy-and-hold real returns on hypothetical five-year zero-coupon indexed bonds from June 1953 to December 2000. We obtain an overlapping time series of annual returns because prices and annual returns are calculated every month. Nominal returns for the same bonds are calculated by subtracting 1 from (1 + real return)*(1 + realized inflation), where realized inflation is the one-year inflation rate (not continuously compounded) calculated using the CPI index.

Nominal returns on non-indexed bonds are calculated directly using nominal prices for 4- and 5-year bonds from the WRDS database. We calculate real returns by subtracting 1 from (1 + nominal return)/(1 + realized inflation).

Finally, we estimate the one-year real riskless rate, which is used to calculate excess real returns on stocks and bonds for the purpose of mean-variance portfolio optimization. This return is not continuously compounded. If the inflation risk premium is zero, the one-year real riskless rate equals the expected real return on a conventional one-year bond. The expected real return is obtained by subtracting one from the product of one plus the nominal one-year spot rate and the expected value of 1/(1 + inflation). To evaluate this (conditional) expected value, we assume the log of one plus inflation is normally distributed with mean equal to expected continuously compounded inflation, μ, the fitted value from the inflation forecasting model (1), and variance, σ^2, equal to the model's residual variance. The log of 1/(1 + inflation) is then normally distributed with mean $-\mu$ and variance σ^2. It follows that the required expected value of 1/(1 + inflation) is $\exp[-\mu + \sigma^2/2]$.

3.3 Descriptive statistics

Interest rates and inflation. Table 2 contains descriptive statistics for interest rates, and inflation over a one-year period. None of these series is continuously compunded. The spot rate averages over 6%, while estimated (expected) inflation is just over 4% per annum, resulting in an average real interest rate of about 2%. All of these series exhibit considerable variation over time. The maximum estimated real riskless rate, 9.0%, occurs in 1982 when the spot rate was over 14%. The minimum is –2.3% in 1974. Previous research also reports negative real interest rates and large variation in estimated real returns. For example, Bodie (1988, p. 7) concludes, "In the 1970s the real rate on bills was substantially negative, averaging –1% per year for the 10 years from January 1970 to December 1979. In the 1980s, it has averaged 4% per year." Estimates of *ex ante* real rates based on the Livingston survey of professional economists are also negative in the mid-70s.

Stock and bond returns. The statistics for stocks in Table 2 exhibit the familiar properties of high average return (13.7% nominal, 9.4% real) accompanied by high volatility. Table 3 reports descriptive statistics for nominal and real annual returns on non-indexed and hypothetical indexed five-year zero-coupon bonds. We discuss the longer series in Panel A first. Figure 1 portrays the time series of annual bond returns. There are 571 overlapping annual return observations from June 1953 to December 1998. The mean nominal and real returns on the hypothetical indexed bonds are slightly lower than those for the corresponding non-indexed bonds.

[Table 2]

[Figure 1]

Table 3 reveals two attractive properties of the indexed bond returns. First, they are less variable than their conventional bond counterparts. For example, the standard deviation of the indexed bond's real returns is 5.88% compared to 7.55% for the non-indexed bonds. Second, the correlation between indexed and non-indexed bond returns is only 0.52 using nominal returns and 0.58 using real returns. The relatively low correlation between the two series reflects the differential impact of unanticipated inflation on the indexed and non-indexed bond returns.

Non-indexed bond prices are, naturally, negatively impacted by unanticipated inflation. Indexed bond prices are only affected insofar as the unanticipated inflation is correlated with changes in real riskless rates, however, since the indexed cash flows are hedged against inflation. The correlation between our estimates of unexpected inflation and annual changes in the one-year real riskless rate is actually negative, –0.54. The correlation is –0.45 using changes in expected inflation. Fama and Gibbons, 1982, likewise find a negative relation. Thus, real rates tend to fall and indexed bond prices rise with unexpected inflation.

This is good news from a portfolio diversification standpoint for an investor considering a mix of stocks and bonds, given that previous research shows that stocks react negatively to unanticipated inflation (e.g., Fama and Schwert, 1977, and Fama, 1981). Thus, non-indexed bonds and stocks are expected to correlate positively because of their similar sensitivity to inflation, whereas indexed bond returns and stock returns might comove less strongly, as indexed bond returns are, if anything, positively affected by inflation.[5] We present empirical evidence on the correlation between stock returns and indexed and non-indexed bond returns in the next section.

We also note, in Table 3, that the standard deviation of real returns is lower than the standard deviation of nominal returns for indexed bonds, but higher for conventional bonds. To understand this, recall that real returns are roughly equal to nominal returns minus the inflation rate. The variance of this difference equals the sum of the variances of each component minus twice the covariance between them. Since increases in inflation lower non-indexed bond prices, this covariance term is negative and subtracting it increases the overall variability of real returns on conventional bonds. Now consider the nominal returns on indexed bonds, i.e., the sum of real returns and inflation. The real prices of indexed bonds increase when real interest rates fall. Insofar as movements in real rates and expected inflation are negatively related, as noted earlier, the covariance between the real returns on indexed bonds and inflation is positive. This effect

[5] A detailed examination of the separate roles inflation and real rates play in stock and bond returns will be conducted in future work.

tends to increase the volatility of nominal returns on indexed bonds relative to their real variability.

[Table 3]

Recent history. Panel B of Table 3 contains descriptive statistics for annualized monthly returns on ten-year coupon-paying Treasury bonds over the period from February 1997 to December 2000. The statistics for both indexed and non-indexed bonds are based on actual returns, i.e., no model is involved. As in Panel A, indexed-bond volatility is lower than non-indexed bond volatility, with real volatility lower than nominal volatility for the indexed bonds. The actual levels of (annualized) indexed bond volatility are less than 3%, much lower than that suggested by the model.[6] In contrast, actual conventional bond volatility is only a bit lower than that observed over the 1953-2000 period. In general, the bond return correlations are quite similar to those implied by the model. Plots of the nominal returns for both bond series are given in Figure 2a.

Figure 2b displays plots of the nominal yield on non-indexed bonds, the real yield on indexed bonds, and the difference, commonly referred to as break-even inflation (BEI). Roughly speaking, since the cash flows for indexed-bonds are adjusted for inflation, these bonds will out-perform conventional bonds if realized inflation exceeds BEI *over the life of the bond* and will underperform otherwise. The mean conventional bond yield was 5.83% and the mean real yield on indexed bonds was 3.84%, so BEI averaged about 2%. Actual inflation over this period was about 30 bps higher. On average, real yields increased by about a basis point per month over the 1997-2000 period, while yields on conventional Treasuries declined by about 3 bps per month. Accordingly, the average return on conventional bonds was much higher than that of indexed bonds. In fact, the average real return was nearly twice that for the longer 1953-2000 period.

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[6] The higher durations of the ten-year bonds would, if anything, increase volatility.

While these numbers are of interest, one cannot infer much about *expected* returns from such a short period.

Also noteworthy is the fact that changes in indexed-bond yields are negatively related to inflation (-0.38) based on the actual data, similar to the results for estimates of the one-year real rate and unanticipated inflation based on our pricing model.

4. Diversification Analysis

We begin this section by examining the correlation between stock returns and indexed and non-indexed real and nominal returns. We then analyze the risk of portfolios of stocks and bonds with weights on each ranging from zero to 100%. This gives an intuitive feel for the benefits of diversification from using indexed bonds instead of conventional bonds with stocks.

Stock-bond correlations. The first panel of Table 4 reports Pearson product-moment correlations between annual returns on the CRSP value-weighted stock index and returns on 5-year zero-coupon indexed and non-indexed bonds over the 1953-2000 period. The correlations are estimated using both real and nominal returns. Nominal indexed bond returns' correlation with stock returns is –0.05, compared to 0.24 using the non-indexed bond returns. Corresponding numbers using real returns are 0.11 and 0.39. The lower correlation for indexed bonds is consistent with the discussion of inflation in Section 3.3; non-indexed bonds and stock returns are negatively impacted by unanticipated inflation while indexed bond returns are positively affected through the negative relation between inflation and real interest rates.

The correlations for actual indexed bond and stock returns in the second panel of Table 4 are likewise close to zero. In this period, however, the correlations for conventional bonds are not much bigger.

[Table 4]

The minimal correlation between indexed bond returns and stock returns is perhaps surprising. Higher correlation might have been expected because of the common effects of shocks to real interest rates on bonds and stocks. While indexed bonds would be negatively affected by shocks to real returns, there does not appear to be a strong relation for stock returns, perhaps due to a positive relation between real rates and expected economic growth (Fama and Gibbons, 1982). This positive relation is plausible given our earlier observation that real rates and expected inflation are negatively correlated, as high inflation has also been negatively correlated with future real activity since the early 1950's (Fama, 1981). It may also be that a positive effect of real rates on the stock/indexed bond relation is offset by the opposite impact of inflation.

Risk reduction. The lack of correlation between indexed bond returns and stock returns has desirable diversification implications. The third row of each panel in Table 5 provides an indication of these benefits for portfolios of five-year zero-coupon bonds and the CRSP value-weighted stock index. The standard deviation of excess portfolio returns is presented, with excess returns computed by subtracting the one-year riskless rate, either nominal or real. These standard deviations can be viewed as *conditional* risk measures, given the riskless rate at each point in time.

For given weights, we consider the percentage reduction in risk achieved by investing in indexed bonds, rather than conventional bonds. With the real returns and an equal-weight portfolio of stocks and bonds, the standard deviation is about 13% lower with indexed bonds in panel B compared to using non-indexed bonds in panel A. It is about 30% lower when the portfolio weight on bonds is 80-90%. The reductions for nominal returns in Table 6 are smaller, as might be expected given the discussion of real and nominal bond risk in section 3.3.[7] With

[7] Recall that our estimation of the risk characteristics of indexed bonds proceeds under the assumption of a constant inflation risk premium. It seems likely that this assumption will bias upward our estimate of the correlation between

actual indexed bond (nominal) returns in Table 7, the risk reductions are again substantial since the indexed bond volatility is so low.

[Table 5]

5. Asset Allocation

Numerous studies of portfolio optimization demonstrate that the portfolio weights obtained can be quite sensitive to relatively small changes in the expected return inputs, particularly when many assets are included. Moreover, it is well known that historical estimates of variances and covariances are much more reliable than sample means in terms of future prediction. A recent survey of financial economists (Welch, 2001) suggests a risk premium for stocks much lower than the historical mean excess return, which was about 7.5% per year (nominal) for our 1953-2000 sample. The mean excess return for five-year conventional bonds was less than 1% over this period. Given these considerations, in our analysis of stock/bond asset allocation, we will specify the mean return inputs, rather than simply using ex post sample means. Our base case uses an expected *excess* return (nominal or real) of 6% for stocks and 1% for five-year bonds (indexed or non-indexed). We explore sensitivity to alternative inputs, including the possibility of a positive inflation risk premium (IRP) in the pricing of conventional bonds.[8]

A potential criticism of our analysis is that the changes in financial markets just alluded to imply that the process governing inflation and interest rates has also changed over time.

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real stock returns and indexed bond returns. Therefore, the actual diversification benefits of investing in indexed bonds may exceed those measured above. To see this, assume that inflation uncertainty increases with the level of inflation, and that the risk premium increases as well (Buraschi and Jiltsov, 1999). Also, suppose that stock prices tend to fall with increases in inflation (Fama and Schwert, 1977 and Fama, 1981). Under these assumptions, holding the real term structure constant, a rise in inflation should have no effect on the price of the indexed bond, as its real payoff is fixed. However, given the procedure outlined above, the increase in the inflation risk premium in nominal rates will carry over to the *imputed* real rate when expected inflation is subtracted. Thus, our hypothetical indexed bond price will be lowered (too far) through a discount rate effect, moving in the same direction as stock prices.

[8] Grinold (1996) suggests that reasonable expected excess returns are 5-7% for stocks and 0.75-1.75% for bonds.

While this is probably true, it is important to appreciate that our forecasts of inflation, the key input to our simulated indexed bond prices, rely heavily on *current* market interest rates and recent inflation experience. The prevailing rates in the market at a given point in time reflect the perceptions of investors at that time, including recognized changes in the relation between inflation and economic growth or monetary policy. In this sense, such changes can be implicitly captured in our model. Nonetheless, variation in the coefficients over time cannot be ruled out and could be considered in future work.

Indexed versus conventional bonds. Table 5 provides asset allocation results based on real returns analysis with the excess return inputs just discussed, i.e., 6% for stocks, and 1% for bonds. Panel A considers stocks and conventional (non-indexed) bonds. Given our inputs, the optimal asset allocation entails an investment of about 20% of one's portfolio in conventional bonds and the rest in stock. Naturally, investment in bonds lowers both the expected return and risk of the overall portfolio. Surprisingly, though, the opportunity for diversification across stocks and bonds barely improves the Sharpe ratio (or M^2 value) over what would be achieved with full investment in stocks. This means that the stock index is close to the "tangency portfolio" in this case.

[Table 5]

In contrast, when indexed bonds are considered in panel B, the optimal allocation to bonds is about 70% of the portfolio. This assumes that the IRP is zero. With IRP = 50 basis points, the allocation to indexed bonds is still 50% of the portfolio, reflecting the diversification benefits of indexed bonds considered earlier. Without the risk premium, the optimal M^2 value is 6.9%, an increase of about 15% over the 6% value for stocks alone. Given the high investment in bonds, an investor wishing to bear the amount of risk implicit in a traditional 60/40 stock/bond portfolio (8.8%) would need to "lever up" the tangency portfolio.[9] With IRP = 50 bps, the expected excess return on the indexed bond is cut in half and the M^2 measure falls to 6.2%. Recall, however, that the existence of a positive IRP in the relative pricing of conventional and indexed bonds is unclear.

Table 6 provides an identical analysis in terms of nominal returns. The optimal allocation to conventional bonds increases to the traditional 40% level, while the allocations to indexed bonds remain around 50-60%. The relative advantage of indexed bonds in terms of M^2 declines only a bit.

[Table 6]

Results for the recent period are given in Table 7. The very low risk of indexed bonds suggested by this short history of actual data implies an optimal allocation of fully 80% in these bonds. The M^2 measure improves dramatically as well, rising to 7.7%. In this case, considerable leverage would be required to raise portfolio risk to a more "normal" level, however. Alternatively, one can ignore the issue of real riskless borrowing and ask how much more one could invest in stocks, in combination with indexed bonds, so as to achieve the same risk level as a traditional 60/40 portfolio of stocks and conventional bonds. From Panel A of Table 7, the required risk is 10.1% and the corresponding weight on stock is 63.3%, not that much higher. The expected excess return on this portfolio would be 4.16%, as compared to the 4% premium for the 60/40 mix. Thus, the indexed-bond advantage is less compelling when the bond component of the overall portfolio is more modest.

[Table 7]

Indexed and conventional bonds. We now consider simultaneous mean-variance optimization across stocks, indexed bonds, and non-indexed bonds together with a riskless asset.

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[9] What this amounts to in practice is less clear for the real returns analysis than the nominal returns analysis and depends on the ability to approximate borrowing opportunities that are riskless in real terms.

We rule out short-selling of the risky assets. The inputs to these optimizations are the excess return means and standard deviations used above plus the correlations between excess returns.

First, the 1953-2000 period using hypothetical indexed-bond returns. For real returns, we have the surprising result that the optimal portfolios do not put *any* weight on the conventional bonds. This is true even when the IRP is positive. Thus, the efficient (tangency) portfolios are identical to those obtained in Panels B and C of Table 5. This is nearly true, as well, for nominal returns when IRP = 0, as the optimal weight on conventional bonds is less than 3%. When IRP = 50 bps, the weight rises to 18%, with 34% in indexed bonds, and 48% in stock. M^2 improves slightly in this case, to 6.3% from 6.2% in Panel C of Table 6.

Finally, we examine the actual indexed bond returns for 1997-2000 and draw similar conclusions. With IRP = 0, there is no weight on non-indexed bonds and the optimal solution is that in Panel B of Table 7. The weight rises to 13% with IRP = 50 bps, and the optimal M^2 increases from 6.3% to 6.4%.

Naturally, changing the risk premium for stock influences the optimal weight on the stock index, but our conclusions about the dominance of indexed bonds over conventionals are robust. Only when the spread between indexed and non-indexed expected returns increases to roughly 100 bps do equal weights for the two bond classes emerge as optimal.

6. Summary, conclusions, and recommendations

We have created a series of prices and computed the corresponding returns for a hypothetical five-year zero-coupon bond, as if it had existed back to 1953. To create the series, we develop models for expected inflation and use these models to back out real rates of interest from the historical series of nominal interest rates. Several important properties of the time series of indexed bond returns are observed.

First, the real (inflation-adjusted) returns on indexed bonds are less volatile than the returns on otherwise similar conventional bonds. Moreover, unlike conventional bonds, the real returns on indexed bonds are less volatile than the nominal indexed bond returns. Second, as a result of the inflation protection, the correlation between aggregate real stock returns and indexed bond returns is close to zero, whereas the correlation between real conventional bond returns and stocks is 0.40. Thus, indexed bonds provide better opportunities for diversification in a portfolio of stocks and bonds. Because of the lower volatility and correlation, the standard deviation of an equal-weighted portfolio of stocks and bonds is about 12% lower using indexed bonds, as compared to conventional bonds. The risk-reduction more than doubles for conservative portfolios more heavily invested in bonds.

Of course, the asset allocation decision depends on expected returns as well as risk. If conventional bond yields contain a positive premium for inflation risk, then the expected returns on indexed bonds will be lower than those for non-indexed bonds. On the other hand, the indexed bond market is less liquid than the market for conventional bonds. Other things equal, this will tend to increase the yields on indexed bonds and make them more attractive to longer-term investors. Whatever the reason, there does not appear to be a positive premium in the yields of conventional bonds in recent years.

We examine asset allocation between stocks, indexed bonds, conventional Treasuries, and a riskless asset. Over a wide range of scenarios, the results suggest that substantial weight should be given to indexed bonds in an efficient portfolio. We don't recommend that an investor's actual asset allocation be based solely on observations of this sort, but the results certainly have affected our beliefs about the potential benefits of indexed bonds.

Only if a large positive inflation risk premium is postulated does a significant role for conventional bonds emerge. The risk-reduction benefits of indexed bonds reflect fundamental economic relations and are likely to persist in the future, though the magnitude of these benefits will likely vary with the inflationary environment. Our analysis of the recent series of returns on *actual* indexed bonds in the U.S. supports this conclusion and, if anything, suggests even greater benefits in terms of low volatility. It is more difficult to speculate about the future yield spread for indexed vs. non-indexed bonds. However, if one thinks that the inflation risk premium is, in some sense, “too low” in the current marketplace, the anticipation of a future correction should enhance the attractiveness of indexed bonds in today’s asset allocation decision.

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Table 1
Inflation forecasting regressions: June 1953 to December 2000

Variable	Coefficient	Std error[1]	t-stat[1]
Forecast of one-year-ahead inflation			
$\mathbf{Inf_{t+1} = b_0 + b_1\, Int_{t+1} + b_2\, (Yld_{t,t+5} - Int_{t+1}) + b_3\, Inf_t + b_4\, Realbill_t + e_{t+1}}$			
Intercept	0.98	0.44	2.22
Int_{t+1}	0.53	0.18	3.00
$Yld_{t,t+5} - Int_{t+1}$	-0.21	0.22	-0.94
Inf_t	0.18	0.17	1.10
$Realbill_t$	-0.63	0.20	-3.18
Adjusted R^2	71.0%		
Forecast of change in two-year-ahead inflation over one-year-ahead inflation			
$\mathbf{Inf_{t+2} - Inf_{t+1} = b_0 + b_1\, (Fint_{t+2} - Int_{t+1}) + b_2\, Inf_t + b_3\, Realbill_t + e_{t+2}}$			
Intercept	0.88	0.37	2.36
$Fint_{t+2} - Int_{t+1}$	0.80	0.25	3.17
Inf_t	-0.25	0.06	-3.91
Realbill	-0.13	0.12	-1.09
Adjusted R^2	25.3%		
Forecast of change in three-year-ahead inflation over two-year-ahead inflation			
$\mathbf{Inf_{t+3} - Inf_{t+2} = b0 + b1\, (Fint_{t+3} - Fint_{t+2}) + b2\, Inf_t + b3\, Realbill_t + e_{t+3}}$			
Intercept	0.10	0.38	0.26
$Fint_{t+3} - Fint_{t+2}$	0.83	0.37	2.25
Inf_t	-0.07	0.08	-0.93
Realbill	0.04	0.10	0.36
Adjusted R^2	9.5%		

Inf_{t+1} = realized inflation for year t+1 (in %)
Int_{t+1} = spot nominal interest rate for year t+1
$Yld_{t,t+5} - Int_{t+1}$ = the spread between the nominal yield on a five-year zero-coupon bond and the spot interest rate
Inf_t = lagged inflation
Realbill = sum of past 12 months real returns on one-month bills
$Fint_{t+k}$ = time t forward interest rate for year t+k.

[1]Newey-West adjustment with 11 lags.

Table 2

Descriptive Statistics for Basic Annual Series Computed at Monthly Intervals. June 1953 to December 2000. Figures are reported in %.

Statistic	One-Year Inflation	One-Year Expected Inflation[1]	One-Year Spot Rate	One-Year Riskless Real Rate[2]	VW Mkt[3] Nominal Return	VW Mkt Real Return
Mean	4.04	4.08	6.19	2.06	13.74	9.42
Median	3.27	3.32	5.77	1.57	14.57	9.94
Maximum	14.76	15.34	17.13	8.97	66.9	62.7
Minimum	-0.74	0.18	0.63	-2.28	-41.1	-47.7
Standard deviation	3.06	2.57	3.03	2.08	16.11	16.66
Skewness	1.33	1.41	0.96	1.12	-0.10	-0.09
Kurtosis	4.55	4.90	4.18	4.18	3.04	3.17

[1] Estimated from regression model in Table 1.
[2] Estimated from pricing model under the assumption that the inflation risk premium is zero.
[3] VW = Value-weigh stock market index.

Table 3

Descriptive statistics for annual overlapping hypothetical indexed bond returns and for actual monthly indexed bond returns

Panel A: Five-year zero-coupon non-indexed and hypothetical indexed bond annual returns from June 1953 to December 2000 (T=571)

Statistic	Hypothetical indexed bonds		Non-Indexed bonds	
	Nominal return, %	Real return, %	Nominal return, %	Real return, %
Mean	6.69	2.56	6.78	2.73
Median	5.76	2.02	5.07	2.04
Maximum	27.8	23.0	35.6	29.6
Minimum	-10.1	-17.7	-7.9	-17.1
Standard deviation	6.58	5.88	7.15	7.55
Skewness	0.33	0.29	1.28	0.84
Kurtosis	3.04	4.45	5.34	4.70
Correlation Matrix				
	Indexed Nominal Bond Returns	Indexed Real Bond Returns	Non-Indexed Nominal Bond returns	Non-Indexed Real Bond Returns
Indexed Nominal	1	0.89	0.52	0.34
Indexed Real		1	0.59	0.58
Non-Indexed Nominal			1	0.93

Panel B: Panel B: Ten-year maturity indexed and non-indexed coupon bond annualized monthly returns from February 1997 to December 2000 (T = 47)

Statistic	Indexed bonds[1]		Non-Indexed bonds	
	Nominal return, %	Real return, %	Nominal return, %	Real return, %
Mean	1.75	-0.55	7.29	4.99
Median	2.44	0.32	3.99	2.16
Maximum	37.3	27.2	63.3	61.7
Minimum	-21.4	-24.4	-52.8	-54.2
Standard deviation	2.99	2.64	6.27	6.24
Skewness	0.47	0.20	0.09	0.13
Kurtosis	5.15	4.70	3.51	3.51
Correlation Matrix				
	Indexed Nominal Bond Returns	Indexed Real Bond Returns	Non-Indexed Nominal returns	Non-Indexed Real Returns
Indexed Nominal	1	0.98	0.52	0.45
Indexed Real		1	0.56	0.52
Non-Indexed Nominal			1	0.99

[1]Based on real price quotes, with 32 bps added to approximate one-month accrued interest.

Table 4

Correlations between real and nominal stock returns and bond returns

Panel A: Five-year zero-coupon non-indexed and hypothetical indexed bond annual returns from June 1953 to December 2000

Indexed bonds		Non-indexed bonds	
Nominal	Real	Nominal	Real
-0.05	0.11	0.24	0.39

Estimates based on monthly series of one-year historical returns (non-indexed bond/value-weight market) or simulated returns (indexed bond) from June 1953 to December 2000.

Panel B: Ten-year maturity indexed and non-indexed coupon bond monthly returns from February 1997 to December 2000

Indexed bonds		Non-indexed bonds	
Nominal	Real	Nominal	Real
0.07	0.08	0.14	0.14

Estimates based on monthly historical returns on non-indexed bonds and value-weight market or returns on indexed bonds from February 1997 to December 2000.

Table 5

Standard deviation, Sharpe ratio, and M^2 of stock-bond asset allocation portfolios using real returns: Data from June 1953 to December 2000

Panel A: Non-Indexed Bond							
% Bond	0	20	40	50	60	80	100
% Excess Return	6.0	5.0	4.0	3.5	3.0	2.0	1.0
% Std Deviation	16.5	13.7	11.1	9.9	8.8	7.1	6.5
Sharpe Ratio	0.36	0.37	0.36	0.36	0.34	0.28	0.15
% M^2	6.0	6.0	6.0	5.8	5.6	4.7	2.5
Panel B: Indexed Bonds with No Inflation Risk Premium							
% Bond	0	20	40	50	60	80	100
% Excess Return	6.0	5.0	4.0	3.5	3.0	2.0	1.0
% Std Deviation	16.5	13.2	10.1	8.6	7.2	5.0	4.7
Sharpe Ratio	0.36	0.38	0.40	0.41	0.42	0.40	0.21
% M^2	6.0	6.2	6.5	6.7	6.9	6.6	3.5
Panel C: Indexed Bonds with Inflation Risk Premium of 50bp							
% Bond	0	20	40	50	60	80	100
% Excess Return	6.0	4.9	3.8	3.3	2.7	1.6	0.5
% Std Deviation	16.5	13.2	10.1	8.6	7.2	5.0	4.7
Sharpe Ratio	0.36	0.37	0.38	0.38	0.37	0.32	0.11
% M^2	6.0	6.1	6.2	6.2	6.2	5.2	1.8

Variances and covariances are based on monthly series of one-year historical excess returns (non-indexed bond/stock) or simulated excess returns (indexed bond) from June 1953 to December 2000. Real riskless rate is simulated.

Table 6

Standard deviation, Sharpe ratio, and M^2 of stock-bond asset allocation portfolios using nominal returns: Data from 1953 to 2000

Panel A: Non-Indexed Bond							
% Bond	0	20	40	50	60	80	100
% Excess Return	6.0	5.0	4.0	3.5	3.0	2.0	1.0
% Std Deviation	16.4	13.5	10.7	9.4	8.2	6.4	5.9
Sharpe Ratio	0.37	0.37	0.38	0.37	0.37	0.31	0.17
% M^2	6.0	6.1	6.1	6.1	6.0	5.1	2.8
Panel B: Indexed Bonds with No Inflation Risk Premium							
% Bond	0	20	40	50	60	80	100
% Excess Return	6.0	5.0	4.0	3.5	3.0	2.0	1.0
% Std Deviation	16.4	13.1	10.0	8.5	7.3	5.5	5.8
Sharpe Ratio	0.37	0.38	0.40	0.41	0.41	0.36	0.17
% M^2	6.0	6.3	6.6	6.7	6.8	5.9	2.8
Panel C: Indexed Bonds with Inflation Risk Premium of 50bp							
% Bond	0	20	40	50	60	80	100
% Excess Return	6.0	4.9	3.8	3.3	2.7	1.6	0.5
% Std Deviation	16.4	13.1	10.0	8.5	7.3	5.5	5.8
Sharpe Ratio	0.37	0.37	0.38	0.38	0.37	0.29	0.09
% M^2	6.0	6.1	6.2	6.2	6.1	4.7	1.4

Variances and covariances are based on monthly series of one-year historical excess returns (non-indexed bond/stock) or simulated excess returns (indexed bond) from June 1953 to December 2000. Riskless rate equals historical one-year riskless return.

Table 7

Standard deviation, Sharpe ratio, and M^2 of stock-bond asset allocation portfolios using annualized nominal returns: February 1997 to December 2000

Panel A: Non-Indexed Bond							
% Bond	0	20	40	50	60	80	100
% Excess Return	6.0	5.0	4.0	3.5	3.0	2.0	1.0
% Std Deviation	15.8	12.9	10.1	8.9	7.8	6.3	6.3
Sharpe Ratio	0.38	0.39	0.40	0.39	0.39	0.32	0.16
% M^2	6.0	6.1	6.2	6.2	6.1	5.0	2.5
Panel B: Indexed Bonds with No Inflation Risk Premium							
% Bond	0	20	40	50	60	80	100
% Excess Return	6.0	5.0	4.0	3.5	3.0	2.0	1.0
% Std Deviation	15.8	12.7	9.6	8.1	6.7	4.1	3.0
Sharpe Ratio	0.38	0.39	0.41	0.43	0.45	0.49	0.33
% M^2	6.0	6.2	6.6	6.8	7.1	7.7	5.3
Panel C: Indexed Bonds with Inflation Risk Premium of 50bp							
% Bond	0	20	40	50	60	80	100
% Excess Return	6.0	4.9	3.8	3.3	3.3	1.6	0.5
% Std Deviation	15.8	12.7	9.6	8.1	8.1	4.1	3.0
Sharpe Ratio	0.38	0.39	0.39	0.40	0.40	0.39	0.17
% M^2	6.0	6.1	6.2	6.3	6.3	6.2	2.6

Variances and covariances based on annualized values of monthly excess returns on indexed and non-indexed bonds and CRSP value-weight stock market portfolio from February 1997 to December 2000. Riskless rate equals historical one-year riskless return.

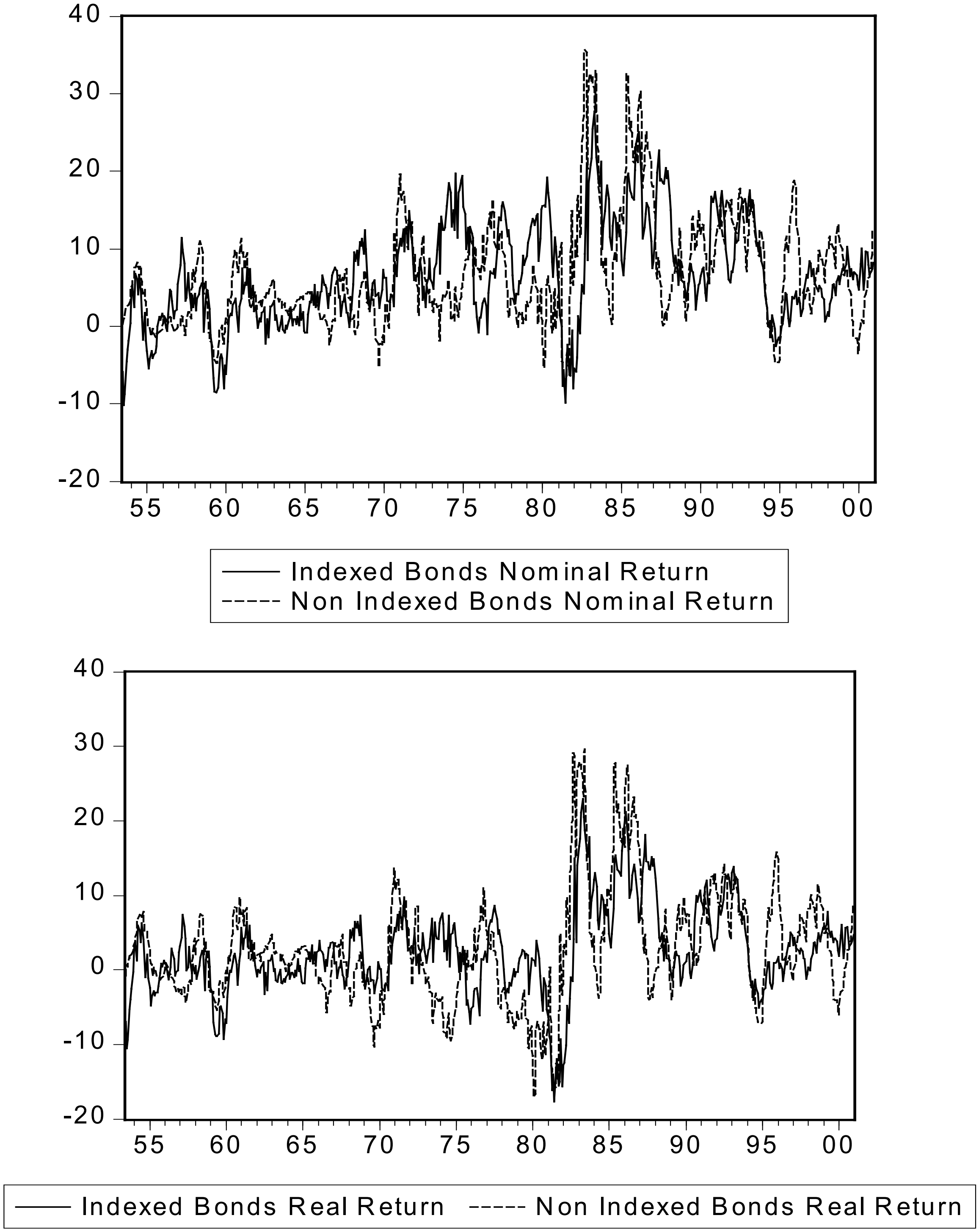

Figure 1: Overlapping annual return series for hypothetical indexed and actual non-indexed five-year zero-coupon bonds.

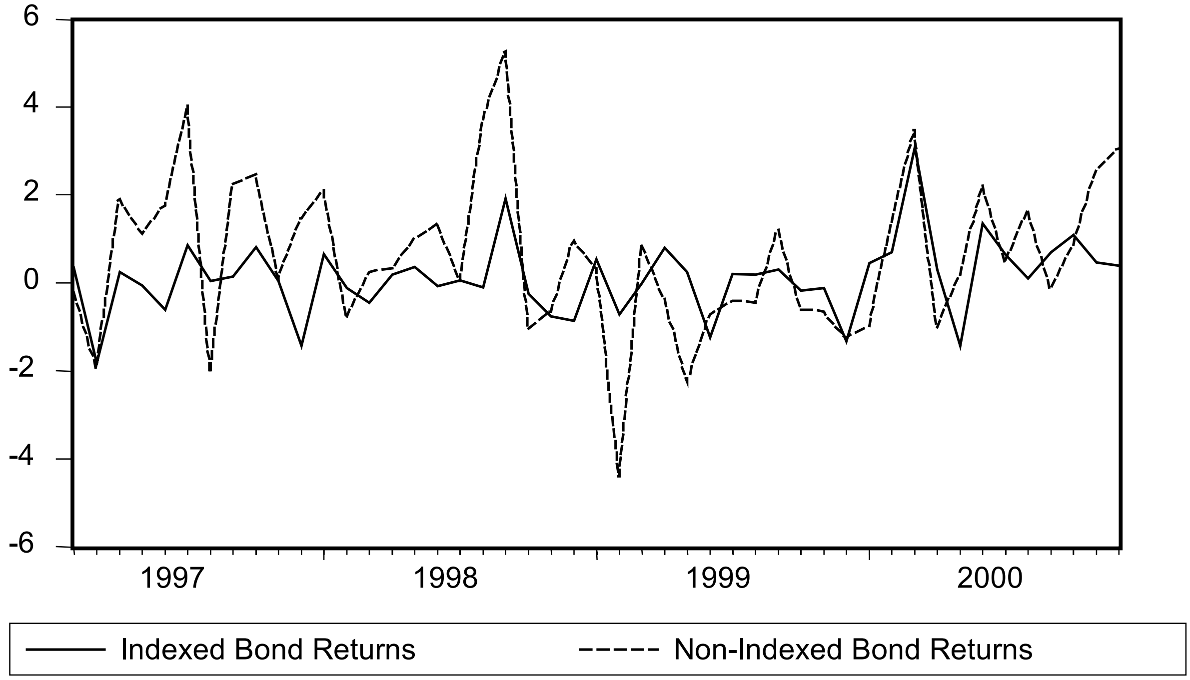

Figure 2a: Monthly realized nominal returns for 10-year indexed and non-indexed coupon-paying Treasury Bonds.

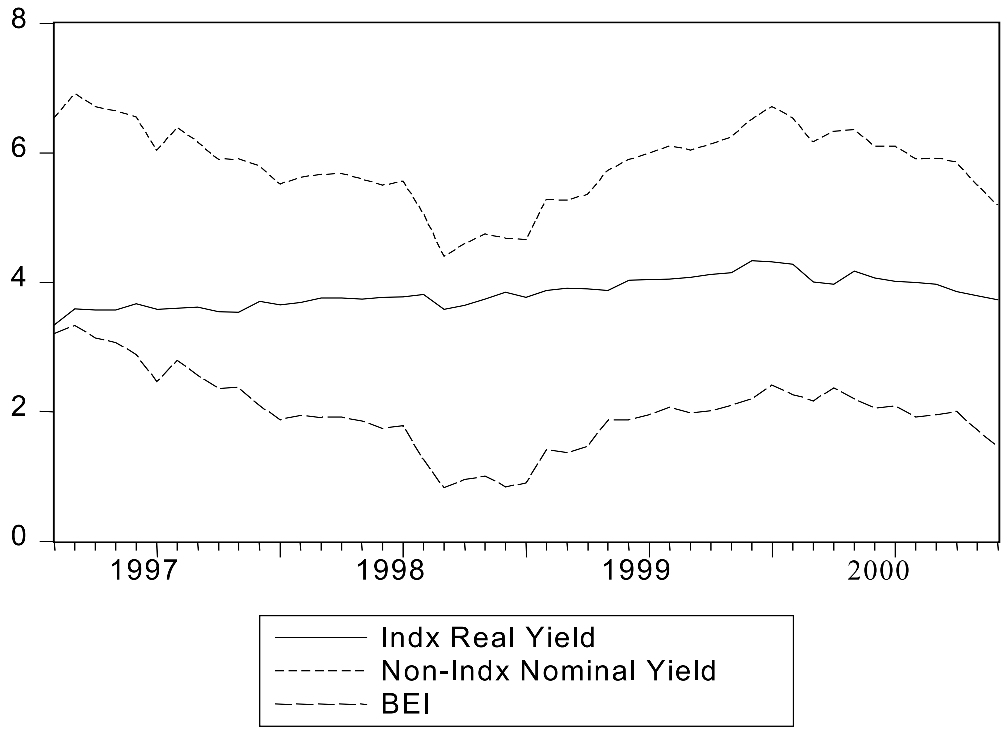

Figure 2b: Monthly Treasury yields and break-even inflation (BEI)