Inflation-Indexed Bonds: The Dog That Didn't Bark

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The introduction by the U.S. Treasury of inflation-indexed notes was one of the most widely publicized innovations in the U.S. capital markets in recent years. Since their introduction in January 1997, $57 billion in 5-, 10-, and 30-year Treasury Inflation-Protected Securities (TIPS) has been issued, and the Treasury has recently announced that TIPS will also be offered as small-denomination savings bonds. Because both the coupon and the principal of TIPS vary with the consumer price index, the Treasury believes these notes will appeal to risk-averse investors seeking protection from inflation. Proponents of TIPS have argued that their issuance should reduce the cost of borrowing to the Treasury by eliminating the risk premium associated with uncertain inflation; they also point out that the difference between the yields on TIPS and conventional Treasuries of the same maturity would provide an immediate, easily available, and clear measure of investors' forecasts of inflation.

Despite their promise, the demand for TIPS has not yet been very great. In the United States, these notes account for less than 2 percent of the marketable federal government debt outstanding. In the 5-, 10-, and 30-year maturities in which they have been issued, TIPS accounted for only 13 percent of new issues during the period from January 1997 through June 1998.[1] The three mutual funds devoted to TIPS held a total of only $30 million as of July 1998. This modest demand for TIPS is similar to that in other industrialized countries experiencing low or moderate inflation. In the United Kingdom, which has offered tax-sheltered inflation-indexed bonds since 1982, these bonds equal 12 percent of the outstanding public debt.

This article analyzes inflation-indexed bonds in general and TIPS in particular to better understand their modest appeal to investors. The first section discusses the experience of other countries with inflation-indexed debt, and the second reviews the design of the Treasury's TIPS. The third section compares the returns and risks of TIPS to conventional bonds, using a model that also weighs the consequences of taxes and various risk premiums. The model indicates that TIPS should appeal primarily to risk-averse investors in high tax brackets, investors who are especially wary of rising inflation, and investors who are not especially concerned about fluctuations in the real rate of return. The fourth section simulates the potential risk and return characteristics of TIPS using data from the past 13 years and finds that TIPS often can be dominated by more attractive combinations of other securities. In particular, a suitable combination of stocks and conventional bonds offers savers a greater, albeit potentially riskier, real rate of return than TIPS. Despite their unique design, TIPS are not alone in offering investors inflation-protected returns, so their appeal is limited for investors accustomed to holding diversified portfolios of securities.

I. Indexed Bonds

Today, the most common form of debt in developed countries is the conventional bond, a contract that obligates borrowers to repay their creditors a certain amount of their country's currency over the life of the contract according to a specific schedule. Since the inception of lending, however, some debt contracts have taken the form of indexed bonds, whose payments vary according to the value of a commodity, currency, or security. Indexed bonds tend to have been most popular when the purchasing power of a country's currency has been most unstable or unpredictable. Borrowers and lenders also have agreed to index their contracts when they wished to hedge specific risks.

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In principle, indexed bonds would seem to dominate conventional bonds. Even in countries with a history of stable currencies and comparatively constant relative prices among goods and services, indexed debt may offer its parties a greater degree of security than conventional bonds. Indexed bonds better insure the purchasing power of creditors' loans. In return for this insurance, creditors require a lower rate of interest from borrowers.[2]

Despite a long-standing recognition of the advantages of indexed debt, conventional bonds overwhelmingly predominate in credit markets. In particular, the most liquid, most highly rated securities in many countries—those of the central government—are almost exclusively conventional bonds. The cost of issuing indexed bonds would seem especially low for these governments owing to their ability to raise funds by taxing the nominal value of output; yet, they generally issue conventional bonds denominated in a foreign currency rather than indexed bonds in their own currency when creditors lack sufficient faith in the stability of their currencies.[3]

Indexed bonds would seem to be particularly suitable for countries experiencing high rates of inflation, especially developing countries trying to foster the growth of their capital markets, but relatively few have done so. The consequences of indexing depend on the government's strategy for fiscal and monetary policies (Fischer 1983). Although a government can promote the demand for its debt and reduce its cost of funds by issuing indexed bonds, it does so by assuming the cost of reimbursing its creditors for their loss of purchasing power. Governments that are not committed to reducing inflation, that instead might even rely on inflationary monetary policies to finance their spending, could very well conclude that the cost of indexed bonds exceeds their benefit. Even governments committed to fiscal balance might regard in-

[1] During the period from January 1997 to June 1998, TIPS constituted 6.5 percent of 5-year, 23.3 percent of 10-year, and 28 percent of the 30-year bonds issued by the U.S. Treasury.

[2] Among others, Jevons (1875), Fisher (1930), Bach and Musgrave (1941), Tobin (1971), and Munnell and Grolnic (1986) have discussed the merits of indexed debt. The prevalence of fixed exchange rates (enforced by specie standards or Bretton Woods agreements) might have limited the appeal of indexation before the last half of the twentieth century. Even so, indexed debt currently receives so little attention from traders and investors that information about these securities is not readily available for most countries.

[3] In one respect, central governments assume more risk by issuing bonds denominated in a foreign currency than by issuing indexed debt. Debt denominated in a foreign currency is subject to some risk of default, while issuers of indexed debt can always pay their obligations as a result of their power to tax or issue money. Governments issuing bonds denominated in foreign currencies regard the credit risk premium in the interest rates on these bonds to be low compared to the currency risk premium embedded in the interest rates on debt denominated in their domestic currencies, including indexed bonds.

Table 1
18 Countries Issuing Government Debt Indexed to Prices of Goods and Services

Country	Outstanding Indexed Public Debt ($ millions)	Percent of Total Government Debt
Israel	79,037	80.2
Australia	27,860	29.5
Turkey	7,561	24.3
Brazil	45,291	19.6
Sweden	15,475	12.5
United Kingdom	55,288	12.0
Mexico	2,528	8.4
Hungary	394	3.0
New Zealand	361	2.3
Czech Republic	150	1.7
Canada	6,636	1.5
Ireland	260	1.1
United States	57,014	.8
France	3,994	.6
Greece	197	.2
India	166	.2
Norway	30	.1
Finland	.7	.0

Source: Bank for International Settlements; Bloomberg.

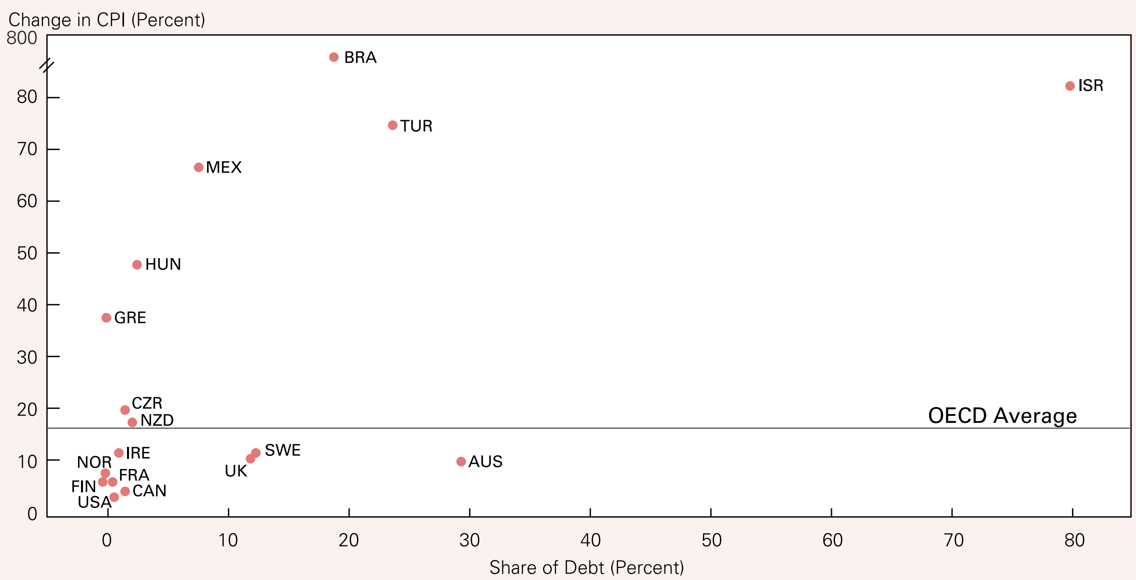
dexed bonds as too costly. The total risk premium for indexed bonds might not be very much less than that for conventional bonds if investors suspect the government's competence to reduce inflation, or if investors believe that the government's policies entail fiscal duress and higher real rates of interest.

In countries prone to high and, more significantly, highly variable rates of inflation, indexed bonds account for a substantial share of their government's debt. Table 1 lists some of the countries that have issued public debt that is indexed to the price of goods and services. While most introduced this debt only after they experienced relatively high rates of inflation (Campbell and Shiller 1996), the average rate of inflation during the past 18 years in about half of the countries shown in Table 1 has not exceeded the average rate of inflation for the economies constituting the OECD (Figure 1). Although the overall correspondence between a country's average rate of inflation and its reliance on indexed debt is not particularly strong, this reliance does appear to increase with the average rate of inflation for those countries with higher-than-average rates of inflation. When these countries are ranked according to the volatility of their inflation rates over the past 18 years, a more signifi-

Figure 1

Average Annual Change in CPI and the Share of Total Government Debt in Indexed Bonds

Selected Countries, 1978 to 1996

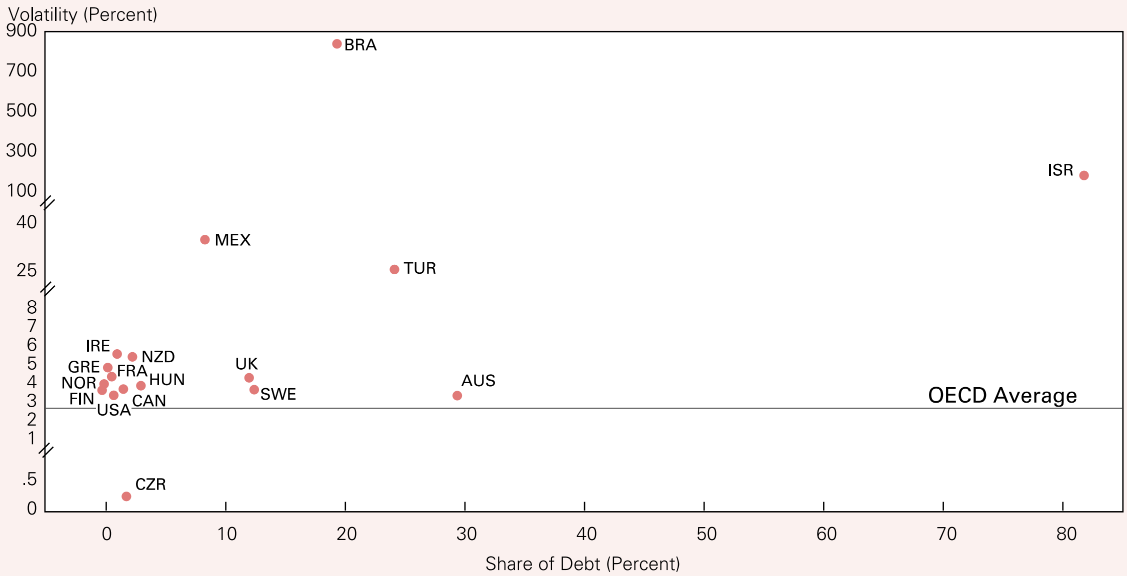


Note: CPI data for India were not available from the OECD.
Source: Bank for International Settlements; Organisation for Economic Co-operation and Development; Bloomberg.

Figure 2

Average Volatility of CPI and the Share of Total Government Debt in Indexed Bonds

Selected Countries, 1978 to 1996



Note: CPI data for India were not available from the OECD.
Source: Bank for International Settlements; Organisation for Economic Co-operation and Development; Bloomberg.

cant relationship emerges. In almost all of the countries that have issued indexed debt, the rate of inflation has been more volatile than average (Figure 2). Moreover, those with the most variable rates of inflation tend to have relied most on indexed debt. Of course, indexed bonds cannot account for a substantial portion of debt in countries that only recently have begun offering these securities, and in many countries these bonds do not account for a large share of newly issued debt because their rate of inflation has been low and stable during much of this decade.

Brazil

Brazil issued indexed bonds in order to facilitate economic reforms. By 1964, the country's inflation rate was nearly 100 percent and the government of Brazil financed its large budget deficit almost entirely by issuing money, as the high and variable rate of inflation discouraged savers from purchasing conventional bonds. Although the government planned to reduce inflation, it intended to do so gradually in order to avoid taking measures that might entail a sharp drop in income and saving. By financing its spending with indexed bonds instead of new money, the government could reduce inflation while it promoted saving, reduce the growth of the money stock, and adopt policies to reduce its deficit. Accordingly, Brazil introduced bonds whose face value changed at first quarterly, then monthly, at a rate that depended on the rate of change of an index of prices.

At first, Brazil's experience with indexed bonds was not entirely successful. During the first decade of the program, households and businesses were reluctant to issue indexed debt, so the government's indexed securities tended to displace private conventional securities, deterring private capital formation. Unlike the government, households, businesses, and financial institutions apparently did not wish to bear the risk of issuing indexed bonds. Although the government's risk might be hedged if its tax revenues tended to grow at the rate of inflation, a private issuer assumes substantial basis risk when relative prices are volatile. "Brazilians have been very happy to have assets with index-linking, but never liabilities, and the 'optimal' arrangement was to have a government agency backing indexed-linked liabilities with nominal assets" (Baer and Beckerman 1980, p. 693).

Furthermore, during the 1970s the government's ability to hedge the risk of indexed bonds diminished as the rising price of imports, especially oil, and a faltering economy caused the value of its indexed debt to increase more rapidly than its tax revenues. As a result, the government altered its formula for indexing the face value of its bonds on several occasions, eventually allowing only fractional indexation when inflation exceeded 15 percent and diminishing indexation for "supply shocks" (Simonsen 1983, pp. 126–28). By 1979 the rate of inflation exceeded the appreciation of the face value of indexed bonds by 30 percentage points. During the 1980s, as oil prices subsided and the economy recovered, subsequent revisions to the formula eventually achieved a closer correspondence between the bonds' rate of appreciation and the rate of inflation.[4]

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United Kingdom and Canada

After experimenting with other forms of indexed securities during the 1970s, the United Kingdom introduced marketable indexed bonds in 1982.[5] Since then, the Commonwealth countries of Australia, Canada, and New Zealand have offered their own versions of indexed bonds built upon the U.K.'s design. The indexed debt now offered by the U.S. Treasury most closely resembles that of Canada.

The United Kingdom introduced its marketable indexed bonds after a decade of high and rising inflation. Intending that such high rates of inflation not persist, the government wished to avoid paying high rates of interest on its outstanding long-term debt after inflation subsided. The cost of indexed debt, unlike that of conventional debt, would fall when inflation subsided. Indexation also could reduce the government's interest expenses even before inflation ebbed, partly by reducing its cost of funds, as described below, and partly by deferring its debt service payments by promising to increase its liability over time in step with the prices of goods and services.

Both the face values and the periodic interest payments of the U.K.'s indexed bonds increase at the same rate as the country's retail price index;[6] consequently, the interest rate on its conventional bonds should tend to exceed that of its indexed bonds by at least the rate of inflation. The rate of interest on indexed bonds, unlike that on conventional bonds, need not compensate investors for the erosion of the purchasing power of their investment due to inflation. Furthermore, the difference between the interest rates on indexed and conventional bonds ordinarily should exceed the rate of inflation, partly because the rate of interest on indexed bonds need not include an inflation risk premium and partly because the returns on them are not taxed as greatly as those on conventional bonds. The U.K. taxes the interest paid on all bonds as income; therefore, the gross inflation premium on conventional bonds must exceed the rate of inflation if their net return is to cover their loss of purchasing power for investors who pay taxes. On the other hand, the U.K. has not taxed the appreciation of bonds since 1985, so the rate of interest on indexed bonds need not compensate investors for any tax liability on their "inflation premium," which is represented by the increase in their face values.[7]

The difference between the rates of interest on conventional bonds and indexed bonds in the U.K. also should tend to vary with the rate of inflation. The U.K.'s retail price index measures the cost of shelter by including interest payments on home mortgages, which are predominantly financed by floating-rate notes. Therefore, when interest rates rise with inflation, those holding indexed bonds tend to receive a windfall capital gain: Not only will the face value

[4] In recent years, especially since 1995, bonds linked to U.S. dollars have accounted for an increasing share of Brazil's domestic debt, as the currency risk premium in the interest rate on debt denominated in reals has increased. See also footnote 3.

[5] The U.K. commenced tenders for indexed debt in 1981, but until the fourth quarter of 1982, eligible investors were restricted to pension funds, insurance companies, and registered friendly aid societies.

[6] The face value of these bonds from one month to the next appreciates at the same rate as the rate of change of the retail price index eight months prior.

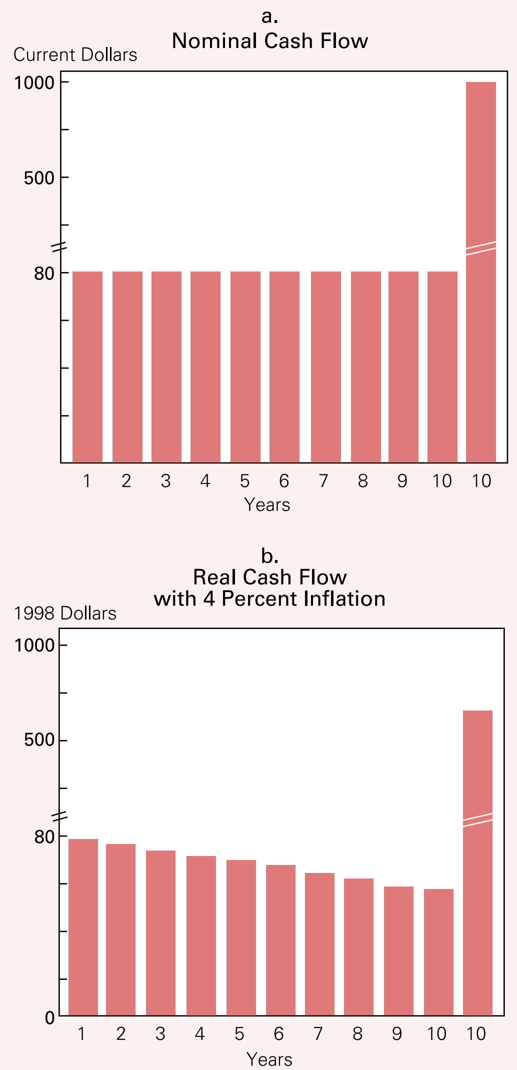
[7] Between March 1982 and July 1985, the U.K. taxed only the real capital gains on bonds held less than one year; before then the U.K. taxed nominal short-term capital gains.

of indexed bonds grow with prices, it also increases with the inflation premium that bondholders require of conventional debt. Should inflation fall, however, those holding indexed bonds receive a loss. By including both the change in prices and the inflation premium in conventional debt contracts, the U.K.'s formula for indexing its bonds entails a form of double-crediting. Accordingly, when investors expect the rate of inflation to rise, they might require a lower rate of interest on indexed bonds compared to that on comparable conventional bonds; with falling inflation, they might require a relatively high rate of interest on indexed bonds. Therefore, the rate of interest on the U.K.'s indexed bonds and the rate of inflation could tend to move in opposite directions.

Canadian indexed bonds generally resemble those of the U.K., but they differ in several important respects. The face value of Canadian bonds appreciates according to the rate of change in an index of consumer prices that includes a measure of implicit rents for owner-occupied homes, rather than the cost of mortgage financing.[8] For this reason, the rate of inflation and the rate of interest on Canada's indexed bonds should not tend to move in opposing directions, as they might in the U.K. However, any change in the face value of Canadian indexed bonds is taxed as current income. As a result of this tax liability, the net return on these bonds tends to fall when inflation rises, and rise when inflation falls. Accordingly, the rate of interest on these indexed bonds might rise when investors expect inflation to increase, and fall when investors expect the rate of inflation to decrease. Such a tendency for the rate of inflation and the rate of interest on Canada's indexed bonds to move in concert could diminish the appeal of these bonds as inflation hedges.

Figure 3

Cash Flows on a Conventional Bond with an 8 Percent Coupon



II. *The Design of the U.S. Treasury's Inflation-Protected Securities*

Savers who purchase financial assets or durable goods forgo current consumption in order to increase their capacity for consumption in the future. In exchange for deferring their spending, savers anticipate receiving a return which further increases their wealth. This yield, when measured in dollars, is the nominal return on savers' assets; when measured in purchasing power, it is their real return.

Conventional bonds and debt securities offer investors a clearly defined nominal yield, but their real yield is more uncertain. For example, by purchasing for $1,000 a newly issued 10-year U.S. Treasury note bearing a yield of 8 percent, investors receive annual interest payments of $80 over the life of the note and the return of their initial investment when the note matures (Figure 3a). The amounts of the payments of interest and principal are certain, but the purchasing power of these payments depends on the rate of

[8] The face value of Canada's bonds is indexed to prices two months prior rather than eight months prior as is done in the U.K. The U.S. also has adopted a two-month lag.

change of prices of goods and services. If, for example, investors expect prices to rise 4 percent annually during the next 10 years, the real value of the note's annual interest payment will fall 4 percent annually, and the real value of its payment of principal at maturity will be only $675.56 (Figure 3b). Accordingly, investors should regard part of the note's nominal yield as compensation for the steady erosion of the purchasing power of their investment.

Should investors revise their forecast of future inflation substantially, perhaps expecting prices to rise only 2 percent annually, then they would expect the purchasing power of the note's payments to erode less rapidly, and its 8 percent nominal rate of interest would offer a greater real rate of interest. Other things equal, forecasts of lower inflation would allow borrowers to sell their new debt at a lower nominal rate of interest, because investors would require less compensation for their loss of purchasing power.

The difference between the nominal and real rates of interest on conventional bonds depends substantially, but not exclusively, on investors' forecasts of inflation. Investors who expect to earn a specific real return from their investment in bonds ordinarily add several premia to this real rate of interest to determine the nominal rate of interest that they require of their investment. In addition to the inflation premium that compensates investors for their loss of purchasing power, investors also require various risk premia and a premium for any income tax liabilities that accrue on their interest income.

Taxes diminish a bond's yield. Accordingly, investors require their bonds' rate of interest after taxes to cover their required real rate of interest and inflation premium (see the Appendix for details).[9] If investors require a real rate of interest of ρ, their forecast of the rate of inflation is π, and their tax rate is τ, then the nominal rate of interest demanded by investors is $i = (\pi + \rho(1 + \pi))/(1 - \tau)$. Accordingly, an investor with a tax rate of 33 percent, who anticipates that inflation will average 2 percent, will require a nominal rate of interest of 4.5 percent in order to earn a 1 percent real rate of interest.

The nominal rate of interest also must compensate investors for any risks they bear. For U.S. Treasury bonds, the principal subject of this article, the risk of default is negligible. Yet, those who purchase the government's conventional debt bear the risk of committing their savings to a fixed nominal yield. Should either the rate of inflation or real rates of interest rise unexpectedly during the life of a bond, then this commitment would cost investors the opportunity to earn competitive returns on their wealth. This opportunity cost is reflected in the lower value of bonds whose nominal rates of interest are lower than those offered by newly issued debt securities. Of course, should the rate of inflation or real rates of interest fall more than investors currently anticipate, then the commitment would provide investors a yield that exceeds competitive returns, and this rent would be reflected in the greater value of bonds bearing relatively high rates of interest. Even if the odds of surprisingly low versus surprisingly high interest rates are equal, risk-averse investors require a premium for purchasing longer-term debt securities.[10] This risk premium, like the risk itself, rises with the duration of a bond's life span. It also varies with the uncertainty inherent in the forecast of any future rate of interest.

The difference between the nominal and real rates of interest on conventional bonds depends substantially, but not exclusively, on investors' forecasts of inflation.

The risk premium included in a Treasury bond's nominal rate of interest contains at least two components: a premium for investors' uncertainty about inflation (γ_π), and a premium for their uncertainty about real rates of interest in the future (γ_ρ).[11] These premia are likely to change with prevailing economic conditions, and they are not likely to be the same for bonds with different maturities. Taking these risks

[9] This description of the nominal rate of interest assumes savers earn a full inflation premium. Because interest rates often do not change by the amount of this premium when the rate of inflation changes, some have questioned whether interest rates include the entire premium. This comparison, however, assumes that real rates of interest remain constant. When interest rates seemingly fail to compensate savers for their expected loss of purchasing power, savers expect to earn a lower real return, which can be warranted by shifts in the supply and demand for funds. See also the fourth section of this article.

[10] To the degree that investors accumulate funds to pay for certain long-term commitments that are fixed in terms of dollars, they might require a lower risk premium on long-term bonds that closely hedge their obligations.

[11] This article confines its discussion to these risks although other premia, such as that for uncertainty about future income taxes or liquidity, can be present.

into consideration, the nominal rate of interest on conventional Treasury bonds must cover investors' tax liabilities as well as the real rate of interest, the inflation premium, and the risk premium demanded by investors: $i = (\pi + (\rho + \gamma_\pi + \gamma_\rho)(1 + \pi))/(1 - \tau)$. Continuing the previous example, if each risk premium is 30 basis points, then the bond's nominal rate of interest must be 5.4 percent for investors to earn a 1 percent real rate of interest.

Treasury Inflation-Protected Securities

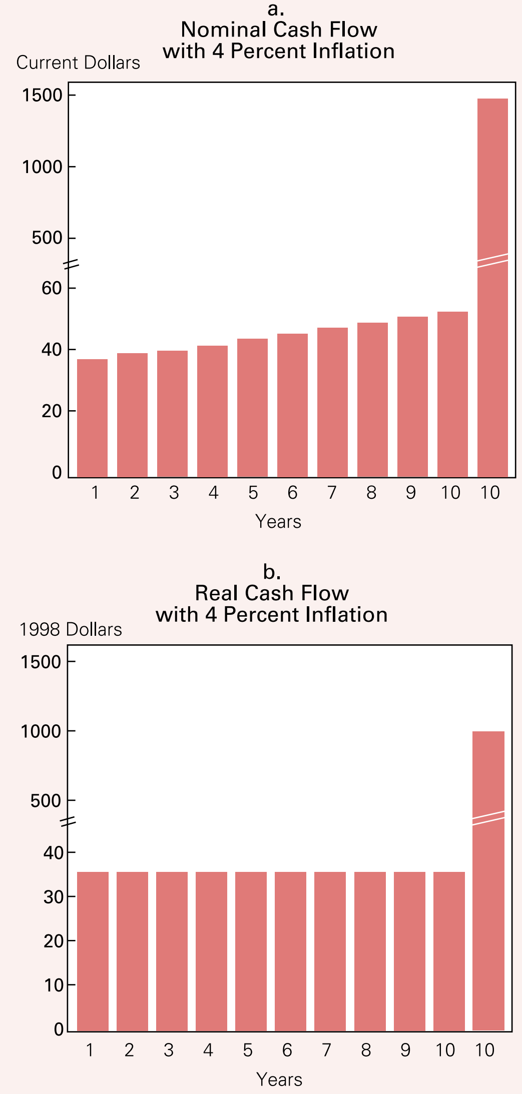
Since the beginning of 1997, the Treasury has issued inflation-protected securities (TIPS) as well as conventional bonds. The dollar value of both the interest payments and the principal of TIPS increases at essentially the same rate as the price index for consumption goods. Bonds whose nominal yields vary with the rate of inflation can relieve investors of the burden of forecasting inflation and bearing the risk of the inevitable errors in their forecasts. To the degree TIPS eliminate this burden, they reduce the cost of the government's financing, because investors do not require the return on these bonds to cover the risk premium for inflation.

Whereas the purchasing power of the interest payments and principal of a conventional bond diminishes as the prices of consumption goods rise, the purchasing power of the returns on a TIPS (before taxes) remains constant. As is the case for a conventional bond, investors who invest \$1,000 in a newly issued 10-year TIPS bearing a yield of 3.5 percent receive annual interest payments equal to 3.5 percent of the face value of the note during its life and are paid the face value of the TIPS at the note's maturity. Unlike a conventional bond, however, the face value of the TIPS does not remain constant at \$1,000; instead, it rises each year at a rate essentially matching that of the consumer price index. If the rate of inflation were 4 percent each year, then the face value of the note and the amount of its annual payments of interest would rise 4 percent annually (Figure 4a). When this TIPS matures, the U.S. Treasury would pay those who hold this note \$1,480.24 to discharge this debt. Inasmuch as the Treasury's nominal obligations rise at the same rate as the prices of goods and services, the real value of the TIPS' gross interest payments remains constant throughout its life, and the real value of its repayment of principal would be \$1,000 (Figure 4b).

The rate of interest on TIPS is not a real rate. Because investors must pay taxes on any appreciation of the face value of their TIPS, the rate of interest on

Figure 4

Cash Flows on an Inflation-Protected Bond with a 3.5 Percent Coupon



these notes must cover the tax liability that investors expect to incur on their TIPS' inflation gains.[12] Consequently, investors must forecast inflation over the life of a TIPS in order to determine the rate of interest they initially require to compensate for their expected loss of purchasing power due to taxes. For instance, investors with a tax rate of 33 percent who anticipate

[12] The case of investors that incur no current tax liability is discussed below.

2-percent inflation would require the interest rate on TIPS after taxes to contain a premium of 67 basis points to cover the tax liability on their expected gains. Should inflation subsequently exceed their expectations, this initial allowance would be inadequate, and investors would fail to earn their anticipated real rate of interest. If the inflation rate were to rise to 4 percent, then investors' required inflation premium would double, and the real rate of interest on outstanding TIPS would fall by 67 basis points. Investors, accordingly, should require the yields on TIPS to cover the risk that arises from the uncertain tax liability on future inflation gains as well as the tax liability on their expected inflation gains. Accordingly, for investors to earn their required real rate of interest (ρ), the rate of interest on TIPS must equal $r = (\rho + \gamma_\rho + \tau(\pi/(1 + \pi) + \gamma_\pi))/(1 - \tau)$.[13]

The divergence between the nominal rate of interest on TIPS and their real after-tax yield can be substantial. If, for example, inflation is 2 percent, investors' tax rate is 33 percent, and each risk premium is 30 basis points, then the TIPS' rate of interest must be 3.1 percent for investors to earn a 1 percent real rate of interest.

The Treasury could reduce investors' risk further by allowing the inflation gains on the face value of TIPS to accrue free of taxation.

Just as the rate of interest on a TIPS is not a real rate, the difference between the yields on conventional Treasury bonds and TIPS with similar durations is not a clear measure of investors' average forecasts of inflation. Instead, this difference reflects the risk premia embedded in the Treasury's bonds, the real rate of interest, and investors' rate of income taxation: $(i - r) = [(\rho + \gamma_\rho)\pi + (1 + \pi - \tau)(\gamma_\pi + \pi/(1 + \pi))]/(1 - \tau)$. Furthermore, because the rate of inflation and risk premia are prone to vary over time and with the maturity of bonds, the difference between the yields on conventional bonds and TIPS also will vary with the maturity of these bonds. Resuming the previous example, when the rate of inflation is only 2 percent, the rate of interest on a conventional bond is about 2.4 percentage points more than the rate of interest on the TIPS. This positive bias increases with forecasts of inflation if investors also believe that accelerating prices either warrant greater risk premia or entail greater real yields in the future due to a tighter monetary policy.

An Alternative Design for TIPS

If the current design of TIPS reduces investors' risk only partially, the Treasury could reduce their risk further by allowing the inflation gains on the face value of TIPS to accrue free of taxation, as is done in the United Kingdom. In this case, the rate of interest on TIPS would behave more like a real rate of interest—the purchasing power of an investment in these notes, after taxes, would not fall as the rate of inflation rises or rise as inflation falls. The rate of interest on TIPS, therefore, would not need to cover either investors' tax liabilities on their inflation gains or their risk premium for any unexpected variations in this tax liability due to their errors in forecasting inflation: $r = (\rho + \gamma_\rho)/(1 - \tau)$. As discussed in the next section, this alternative design for TIPS also is less expensive for the Treasury. Reducing the risk premia that investors require of their investment ultimately tends to reduce the Treasury's cost of funds.

Perhaps ironically, as the rate of interest on TIPS represents more accurately the real rate of interest that investors require of their investments, the difference between the yields on conventional bonds and TIPS overstates forecasts of inflation by greater margins. Returning to the examples above, where expected inflation is 2 percent, investors' tax rate is 33 percent, each risk premium is 30 basis points, and investors require a real return of 1 percent, the rate of interest on the TIPS falls from 3.1 to 1.9 percent when its inflation gains are not taxed. The rate of interest for this alternative version of the TIPS exceeds the real rate of interest by only 0.9 of a percentage point, 1.2 percentage points less than the rate on the current design of TIPS. But as the rate on TIPS approaches the real rate of interest, the difference between the rate on conventional bonds and TIPS increases, thereby increasing its tendency to overstate forecasts of inflation. As described above, this difference in yields exceeds

[13] According to many analysts, TIPS are also subject to a degree of risk arising from possible future revisions in the methodology used to construct the consumer price index. One such change, which will occur relatively soon, will reduce the rate of inflation as reported by the CPI. Also, until TIPS trade in sufficient volume, their rates of interest will include a liquidity premium.

forecasts of inflation because it must cover various risk and tax premia. Because the premium representing the tax liability on TIPS' inflation gains tends to reduce this difference in yields, the elimination of this tax increases the rate of interest on conventional bonds compared to that on TIPS.

III. The Appeal of TIPS

Because the yield on TIPS adjusts in concert with inflation, these bonds might provide investors a more secure means of funding their future goals, such as retirement commitments or college tuition.[14] Although the rate of interest on conventional bonds exceeds that on TIPS partly to compensate investors for assuming greater risk, those who regard conventional bonds as inadequate "hedges" for their future obligations might find the risk premium on conventional bonds wanting. From the viewpoint of these investors, those who price conventional bonds either are not sufficiently averse to risk or underestimate the errors inherent in forecasting inflation. Even so, wary investors might not necessarily favor TIPS over conventional bonds. As discussed below, investors who are not subject to substantial tax liabilities on their current income—retirement plans, for example—tend to receive a greater real rate of interest on conventional bonds than on TIPS, a margin that augments the otherwise insufficient risk premia offered by conventional bonds.

The more investors fear that real rates of interest might rise with inflation over the medium run, the more those who foresee the most inflation will prefer short-term securities to any bond.

TIPS, in principle, should appeal also to those investors who anticipate the greatest rates of inflation. If the interest rates on conventional bonds and TIPS are regarded as equally attractive by investors who accept the "consensus" forecast of inflation, then those who expect inflation to exceed the consensus forecast will regard the real yields on conventional bonds to be inadequate compared to those on TIPS. Yet even in these circumstances, wary investors might shun TIPS in favor of bills if they believed that TIPS' yields are not sufficient to cover their risk premia for changes in the real rate of interest. The more investors fear that real rates of interest might rise with inflation over the medium run, the more those who foresee the most inflation will prefer short-term securities to any bond.

The government's strategy for managing its debt also can depress the demand for TIPS. If the government limits the supply of TIPS so that it does not exceed the demand by investors who either anticipate the most inflation or require the greatest risk premium for inflation, then these investors will dominate the demand for TIPS, bidding down their yields relative to those on conventional bonds. In this case, the difference between the yields on conventional bonds and TIPS would be enlarged by the discrepancy between the view of the most pessimistic investors and the consensus view, further contributing to the bias in using this difference as a measure of expectations of inflation. More important, however, by limiting the supply of TIPS in order to obtain a lower rate of interest, the government could increase the apparent risk of investing in these bonds. To the degree the difference between the most pessimistic forecast of inflation and the consensus forecast is substantial and variable, then many investors will judge the expected return on TIPS low relative to the volatility of their yields, and all will regard TIPS as less liquid investments.

Investors' Tax Rates and the Demand for TIPS

TIPS offer the greatest value to investors who are subject to the highest tax rates. Some advisers have proposed that TIPS are most suitable for retirement or annuity plans, partly because the deferral of taxes offered by these plans seemingly obviates investors' concerns about paying income taxes on TIPS' inflation gains well before they realize the income from these gains. Nonetheless, the real yields on conventional bonds are likely to exceed those on TIPS for those investors who are subject to lower tax rates.

Suppose investors who are subject to the highest tax rates are indifferent between holding conventional Treasury bonds and TIPS—the prospective real rate of interest on each type of bond is the same from their

[14] TIPS are not necessarily suited for all goals. For example, to the degree that investors expect college tuition to increase more rapidly than the price index, they might prefer other means of funding future college expenses.

point of view.[15] Investors who pay less tax, of course, receive higher real yields on both bonds, with the greatest yields redounding to investors who pay no taxes. The real yields on conventional bonds rise more rapidly than those on TIPS as investors' tax rates fall. Because investors who purchase conventional bonds require their net yields to cover the full risk premium for inflation, and because those who pay the highest tax rates require the largest pretax risk premium, investors who pay lower tax rates tend to receive a generous net premium when purchasing conventional bonds. TIPS, on the other hand, offer investors who are subject to lower tax rates a smaller bonus, inasmuch as the risk premium for inflation in these bonds is smaller than that in conventional bonds. This divergence in real yields for investors who do not pay the highest tax rate is illustrated most clearly by comparing the returns on conventional bonds and TIPS for tax-exempt investors.

For the conventional bond, the real yield for tax-exempt investors is the rate at which their purchasing power grows as a result of this investment: $(1 + i)/(1 + \pi) - 1$. For the TIP, the tax-exempt investors' real yield is simply the bond's rate of interest, r. The difference between these yields equals the risk premium for inflation, γ_π. Therefore, tax-exempt investors should tend to find the yields on conventional bonds more appealing than those of TIPS, and investors who pay the most tax should bid more aggressively than other investors for newly issued TIPS. If, contrary to prevailing beliefs, the risk premium for inflation were sufficiently small so that the yields of TIPS appealed to tax-sheltered investors, then the government's potential benefits from supplanting conventional bonds with TIPS also would be relatively small.

The Relative Risk of TIPS

In one sense, TIPS expose investors to more risk than conventional bonds of the same maturity, because investors can extract the value of their investment sooner from conventional bonds than they can from TIPS. The duration of a bond is a measure of the timing of its cash flows and, therefore, indicates how sensitive the bond's price will be to changes in interest rates. For example, the duration of a conventional 10-year Treasury bond currently is only approximately 7½ years, because the present value of its annual interest payments is considerable, compared to the present value of its return of principal when it matures. The duration of a 10-year TIPS is longer, approximately 8½ years, because the bond's interest payments increase over time and are relatively small compared to the bond's redemption value at its maturity.

TIPS also expose investors to more risk arising from unexpected changes in real rates of interest than do conventional bonds. If interest rates rise, investors who purchased conventional securities will be able to reinvest all of their annual receipts in bonds bearing greater yields, while those who purchased TIPS will automatically reinvest a greater portion of their annual returns in their TIPS at the same rate of interest as originally offered on the TIPS. Should interest rates rise more than investors expect, this characteristic of TIPS becomes a liability. This reinvestment risk is greatest when real rates of interest rise unexpectedly. Consequently, the risk premia that investors require from a TIP, especially the risk premium for potential changes in the real rate of interest, likely exceed those for a conventional bond with the same maturity. This consideration introduces another bias to using the difference between the yields on conventional bonds and TIPS of the same maturity as an estimate of investors' forecast of inflation.

Table 2 shows how the value of a previously issued, conventional Treasury bond changes as investors alter their forecasts of inflation and real rates of interest in coming years. The value of this seasoned bond changes in much the same way both for investors who pay their full tax liabilities as they accrue and for investors who pay no taxes. Should the real rate of interest fall unexpectedly from 2 percent to zero, for example, the value of the bond to both types of investor would rise 24 percent (second column, second and first rows). Should the inflation rate rise unexpectedly from 2 percent to 4 percent, the value of the bond to both would fall about 19 percent (second row, second and third columns). Should the real rate fall 2 percentage points and the inflation rate simultaneously rise 2 percentage points, then the value of the bond changes only negligibly. As shown in the table, the price of the bond changes little when changes in the real rate are matched by an opposite change in the rate of inflation—the entries along rising diagonals are very nearly the same—because changes in the nominal interest rate, after taxes,

[15] These conditions make TIPS as attractive as possible for annuities and pension plans. If the yield on TIPS were any lower, conventional bonds would seem all the more appealing to tax-sheltered investors (see the Appendix). The following also assumes that TIPS offer yields that are sufficiently high to appeal to investors who accept the consensus forecast of inflation.

Table 2

Value of a Conventional Bond[a] to Taxable[b] and Tax-Exempt Investors

(percent of face value)

Real Rate of Interest	Rate of Inflation 0%	**2%**	4%	6%
Taxable Investors				
0%	157	124	100	82
2%	125	**100**	81	67
4%	101	81	66	55
6%	82	67	55	46
Tax-Exempt Investors				
0%	157	124	100	82
2%	125	**100**	81	67
4%	101	82	67	56
6%	82	68	56	48

[a]Originally issued assuming that inflation and the real rate of interest are 2 percent; the risk premia for inflation and the real rate are each 0.3 percentage points.

[b]The tax rate is 33 percent.

Table 3

Value of an Inflation-Protected Bond[a] to Taxable[b] and Tax-Exempt Investors

(percent of face value)

Real Rate of Interest	Rate of Inflation 0%	**2%**	4%	6%
Taxable Investors				
0%	138	130	122	113
2%	108	**100**	92	83
4%	86	78	70	61
6%	69	61	53	44
Tax-Exempt Investors				
0%	125	107	92	80
2%	78	**67**	59	52
4%	51	45	40	36
6%	35	31	28	25

[a]Originally issued assuming that inflation and the real rate of interest are 2 percent; the risk premia for inflation and the real rate are each 0.3 percentage points.

[b]The tax rate is 33 percent.

matter more than changes in its components: the inflation premium, the real rate, and the risk premia.

The value of a seasoned TIPS, more than a conventional bond, depends on the components of the nominal rate of interest. As shown in Table 3, the value of the TIPS varies most when the real rate of interest changes unexpectedly. Should the real rate fall to zero, for example, the value of the TIPS in the table rises 30 percent for taxable investors, about one-fourth more than the rate of appreciation of the conventional bond. Although the value of the TIPS changes proportionately more than the value of a conventional bond in response to variations in the real rate of interest, the value of the TIPS does not change as much in response to variations in the rate of inflation because the TIPS' yield varies with inflation. Should the rate of inflation rise to 4 percent, the value of the TIPS falls only 9 percent, about one-half the depreciation of the conventional bond.

Table 3 also shows that TIPS are not as valuable to tax-exempt investors as they are to taxable investors, because tax-exempt investors can earn a greater real rate of return on conventional bonds, as discussed above. The table also shows that the difference between taxable and tax-exempt investors' valuations shrinks as the nominal rate of interest falls. When the TIPS are first issued, they are worth about 33 percent less to tax-exempt investors than they are to taxable investors (column 2 and row 2 of both panels). Should both inflation and the real rate of interest subsequently fall 2 percentage points (column 1 and row 1), the value of the TIPS rises 87 percent for tax-exempt investors, and only 38 percent for taxable investors. Even so, as long as investors require more than a negligible premium for bearing the risk that inflation might rise, nominal yields cannot fall sufficiently to make seasoned TIPS as valuable to tax-exempt investors as they are to investors who are subject to the highest tax rates.

The Cost of TIPS to the Treasury

The real cost of the government's borrowing is the amount of future real resources that it pledges creditors for each unit of resources that it borrows this year. Because this commitment is not necessarily the same for conventional bonds and TIPS, the government might regard TIPS as more economical than conventional bonds. In any case, however, the current design of TIPS likely does not achieve the lowest prospective real cost of funds for the government. Any saving that TIPS currently offer over conventional bonds would be greater for an alternative design of TIPS that would allow inflation gains to accrue free of taxation.

Superficially, TIPS appear to be less expensive than conventional bonds because the rate of interest on 10-year TIPS, currently about 3.8 percent, is significantly lower than that on conventional bonds, about 5 percent. But, as discussed above, investors do not require a greater rate of interest on TIPS because their face value rises at the rate of inflation and because they transfer some of the risk associated with errors in forecasting inflation from investors to the government. From the investors' point of view, the prospective real rates of return on TIPS and conventional bonds are the same, because the value of these additional features compensate for the TIPS' lower rate of interest. Similarly, if the government values inflation protection and risk premia no differently than the investors who price these bonds, then TIPS are no less expensive to the government than conventional bonds. However, to the degree the government values these gains and premia less than its creditors, TIPS reduce its prospective cost of financing.

By issuing conventional bonds, the government incurs a net nominal cost of funds equal to the rate of interest it pays less the taxes it receives from investors who hold these bonds, $(1 - \tau^g)i$. Because conventional bonds also fix the government's commitment whether real rates of interest or inflation rise during their lifespan, these bonds also reduce the government's real cost of funds to the degree the government values transferring this risk, $\gamma_\rho{}^g + \gamma_\pi{}^g$, to its creditors. From the government's point of view, the real cost of funds on conventional bonds is $\rho_i{}^g = ((1 - \tau^g)i - \pi^g)/(1 + \pi^g) - (\gamma_\pi{}^g + \gamma_\rho{}^g)$. If the government's forecast of inflation, its valuation of risk premia, and its tax yield on these bonds match the forecasts, valuations, and tax rates of the investors who price these bonds, then the government's real cost of funds for issuing conventional bonds matches the investors' real rate of interest. If, however, conventional bonds are priced to attract investors who pay high tax rates, and if some of these bonds are purchased by investors who pay lower tax rates, then the government's real cost of funds exceeds the investors' real rate of interest. Also, if the government is not as averse to risk as investors and it values risk premia less than investors, then too its real cost of funds on conventional bonds exceeds the investors' real rate of interest.

By issuing TIPS, the government incurs a real cost of funds equal to these bonds' rate of interest less their tax yield and the government's valuation of their inflation and risk premia, $\rho_r{}^g = ((1 - \tau^g)r - \tau^g\pi^g/(1 + \pi^g) - (\tau^g\gamma_\pi{}^g + \gamma_\rho{}^g)$. As is the case for conventional bonds, if the government's tax yield or its valuation of these premia is less than the tax rates or premia for the investors who price these bonds, then the government's real cost of funds on TIPS exceeds the investors' real rate of interest.

Because investors pay substantially different rates of income taxes, conventional bonds could entail a greater real cost of funds than TIPS. As discussed above, conventional bonds should be more appealing than TIPS to those investors who are not subject to the highest tax rates, which implies that the government's tax yield on conventional bonds should be less than that on TIPS. Consequently, to the degree that investors in lower tax brackets shun TIPS in favor of conventional bonds, the government's real cost of funds is greater for conventional bonds than for TIPS.

The real cost of issuing conventional bonds also could exceed that of issuing TIPS if investors' valuation of the risk premium for inflation exceeds that of the government. Suppose, for example, the government were neutral regarding the risk of inflation's running either surprisingly high or low in the future, so that its valuation of the risk premium for inflation would be zero. In this case, from the government's point of view the real cost of funds on conventional bonds would include the excess risk premium required by investors, γ_π. The government's real cost of funds on TIPS includes only a fraction of this premium, $\tau^g\gamma_\pi$.

If the government's tax yield or risk premium for inflation is less than that of investors who price its bonds, the government might attain its lowest cost of funds by not taxing TIPS' inflation gains. Because net yield on these alternative TIPS would not vary with inflation, their rate of interest need not include any premium to compensate investors for bearing the risk that inflation might increase unexpectedly. From the government's point of view, these alternative TIPS achieve greater savings than other bonds by eliminating its need to pay a premium for inflation risk.

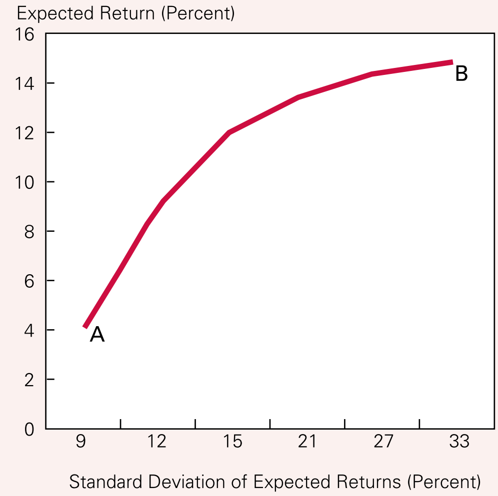
If the inflation gains of TIPS were not taxed, the value of these bonds also would tend to be less volatile (Table 4). For investors in the highest tax brackets the value of these alternative TIPS will not vary with unexpected changes in the rate of inflation, because their real yield also will not vary with inflation. Furthermore, the value of these bonds will change proportionately less should real rates of interest rise or fall, so the risk premium for unexpected changes in the real rate of interest can be slightly lower for this alternative design of TIPS than it is for the current design. Tax-exempt investors, however, would regard this alternative TIP as even less attractive than the current design. The generous pretax risk premium for inflation on conventional bonds would become even more appealing to these investors if TIPS' yields offered no such premium.

Table 4
Value of an Inflation-Protected Bond[a] with Tax-Free Indexing to Taxable[b] and Tax-Exempt Investors
(percent of face value)

Real Rate of Interest	Rate of Inflation 0%	2%	4%	6%
Taxable Investors				
0%	129	129	129	129
2%	100	**100**	100	100
4%	78	78	78	78
6%	62	62	62	62
Tax-Exempt Investors				
0%	115	97	83	72
2%	70	**60**	52	46
4%	45	39	34	31
6%	30	27	24	21

[a]Originally issued assuming that inflation and the real rate of interest are 2 percent; the risk premia for inflation and the real rate are each 0.3 percentage points.
[b]The tax rate is 33 percent.

Figure 5
The Efficient Frontier



IV. TIPS in an Efficient Portfolio

As discussed above, TIPS offer only partial protection against the effects of inflation and are likely to be more sensitive than comparable conventional bonds to fluctuations in the real rate of return. Moreover, conventional bonds are likely to offer higher real rates of returns to all investors except those in the higher income tax brackets. These characteristics alone may dampen enthusiasm for TIPS. But the demand for any asset is not just a function of that asset's risks and returns, but also of the risks and returns of alternative assets, as well as the correlations of returns among all available assets.

Modern portfolio theory emphasizes that the incremental risk of adding a security to a portfolio is determined principally by the correlation between that security's return and the returns of other securities already in the portfolio. Adding a security whose returns are highly correlated with the existing assets will increase risk more than adding a security whose returns have a low or negative correlation with the returns of the existing assets.

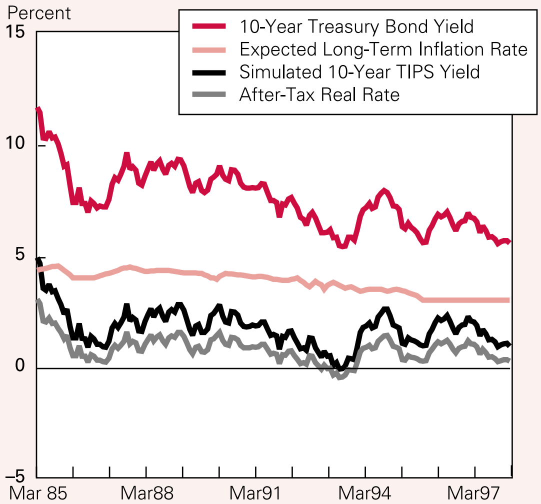
The efficient frontier is a concept that can be used to analyze the demand for securities with different risk/return characteristics. The frontier depicted in Figure 5 shows the maximal return for a given level of risk (or equivalently, the minimal risk for a given return) that investors can achieve through different combinations of securities in their portfolios. The curve AB shows the efficient frontier that can be attained by investing a fixed amount of money in different combinations of a low-risk/low-return security A and a high-risk/high-return security B.[16] Points above and to the left of the frontier are unattainable given the characteristics of A and B. Points below and to the right of the frontier represent combinations of other securities that offer lower returns or higher risks than portfolios on the frontier and, thus, are dominated by the efficient portfolios.

The position and shape of an efficient frontier depends on the expected returns, the standard deviations of expected returns, and the correlations among returns for the assets available to investors. These statistics customarily are derived from historical data, which obviously presents a difficulty for constructing an efficient frontier that includes TIPS, since the latter have been offered only since January 1997. However, it is possible to use the model presented in Section II to simulate a series of TIPS yields derived from historical yields for conventional Treasury

[16] The curve is convex because the correlation coefficient between the returns on A and B is assumed to be positive, but less than one.

Figure 6

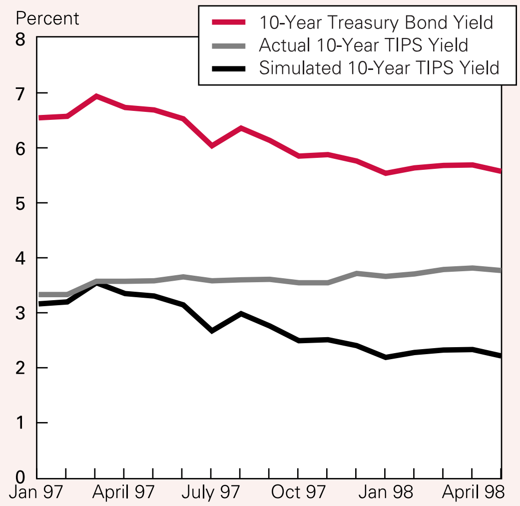
Yield on TIPS and Yield on 10-Year Treasury Bonds
(March 1985 to April 1998)



Source: See the Appendix.

Figure 7

Yield on TIPS and Yield on 10-Year Treasury Bonds
(January 1997 to May 1998)



Source: See the Appendix.

securities.[17] This derived series of yields and historical inflation rates then yields a simulated total return series for TIPS that can be compared with the total returns for other assets to derive an efficient frontier that includes TIPS.

Figure 6 compares the simulated yields for a 10-year TIP to actual yields on a conventional 10-year Treasury bond from March 1985 to April 1998. The figure also shows the estimated real rate of interest for these securities as well as contemporaneous long-term inflationary expectations. Although the expected long-term inflation rate was not very volatile over the period, trending gently downward, nominal rates of interest on conventional Treasuries varied considerably, implying that real rates of interest also were very volatile over this period. Because the model assumes that at the margin investors expect TIPS and conventional Treasuries to offer similar risk-adjusted real rates of return, the simulated nominal yields for TIPS closely correspond to the nominal yields for conventional Treasury bonds. This tight correspondence implies that, despite the relative stability in expectations of inflation, the yields of TIPS can vary considerably as a result of changes in expected real rates of interest, suggesting that TIPS would not have protected investors from much of the interest rate risk since 1985.[18]

TIPS and Conventional Treasury Yields Since 1997

Figure 7 compares the actual data for the yields on TIPS with the simulated yields since January 1997. The derived series corresponds closely to the actual data for the first three months, but then the two series begin to diverge. From April 1997 to May 1998, the derived series for TIPS fell from 3.35 percent to 2.22 percent, primarily because of a 116-basis-point decline in the conventional 10-year Treasury yield over the same period. In contrast, actual TIPS yields increased slightly over the same period, from 3.57 percent to 3.77 percent.

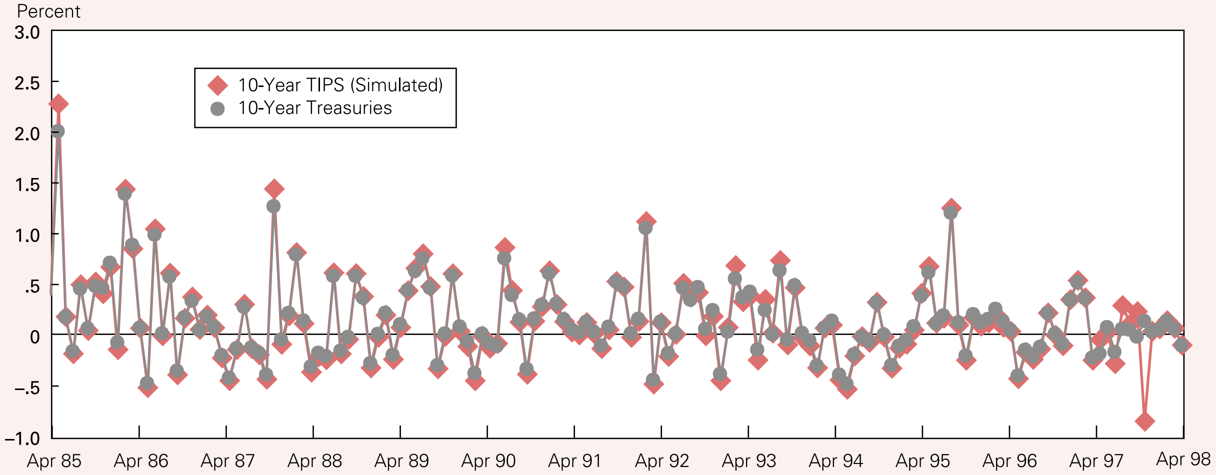
[17] Expected long-term inflation was taken from a survey series compiled by the Federal Reserve Bank of Philadelphia. Because no data exist on either inflation or real rate risk premia, each was assumed to be constant at 30 basis points. Hammond, Fairbanks, and Durham (1999) estimate the inflation risk premium to be 41 basis points. For a detailed description of the construction of the derived TIPS yield series, see the Appendix.

[18] The simulated yield series for TIPS was calculated assuming that the risk premia for real interest rate risk and inflation risk were constant. To the extent that they are not, they may offset some of the TIPS volatility due to changes in expected real rates.

Figure 8

Annualized Monthly Total Returns on TIPS and Treasuries

(April 1985 to April 1998)



Source: See the Appendix.

Atypical conditions in the market for U.S. government securities that have affected both demand and supply might explain this divergence. The financial crisis in Asia resulted in a flight to quality and a greater demand for U.S. Treasury securities by investors who value the liquidity of their assets. Even the yields on less liquid, seasoned Treasuries often rose significantly compared to the on-the-run debt during this period. Consequently, it is not surprising that prices for the comparatively thinly traded TIPS fell relative to benchmark Treasuries as savers required greater liquidity risk premia. Large flows of funds into and out of TIPS might shift their prices substantially, thereby threatening savers' holding-period yields. At the same time, the federal budget has shifted into surplus for the first time in 30 years, decreasing the supply of new U.S. Treasuries. Thus, the decline in conventional Treasury yields that occurred over the period might be the result of both increased demand and decreased supply.

The recent divergence between the yields for derived and actual TIPS also might reflect the limited appeal of TIPS. As argued above, TIPS should appeal most strongly to risk-averse investors in high-tax brackets who are especially wary of inflation. As the Treasury increased the supply of TIPS, the demand of these investors might have been satiated, so TIPS must now appeal to others by offering higher real yields.[19]

Total Returns and Efficient Portfolios

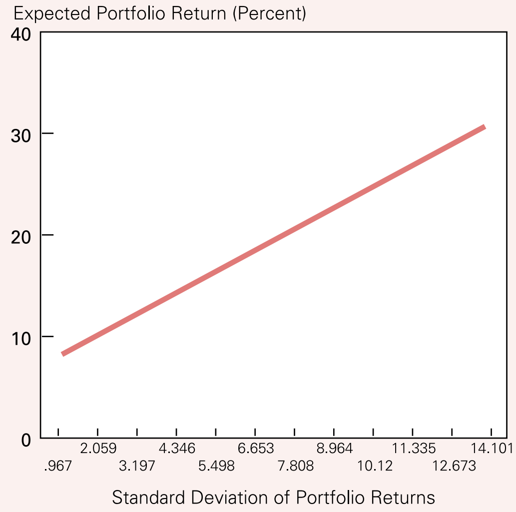
The derived yield series for TIPS shows the interest rate that equates the present value of their expected cash flows to their price, but the return that investors actually receive is their total return. For conventional bonds the total return consists of the sum of coupon payments and capital gains and losses associated with changes in the nominal pretax yield. For TIPS, the total return consists of the coupon payment, the increment to the principal due to the inflation adjustment, and the capital gains or losses associated with changes in their nominal pretax yield. A simulated total return series for TIPS can be generated from actual rates of inflation and the series of derived and actual yields.[20] Figure 8 shows both this

[19] This explanation is similar in tone to the "habitat" model of the term structure of interest rates. See Modigliani and Sutch (1966).

[20] Derived TIPS yields were used for the period from April 1985 to December 1996. Actual TIPS yields were used for the period

Figure 9

The Efficient Frontier for a Portfolio of Stocks, T-Bills, 10-Year Treasuries, and TIPS



Source: Ibbotson Associates, *Stocks, Bonds, Bills & Inflation, 1997 Yearbook*; authors' estimates.

simulated total return series for 10-year TIPS and the total returns for comparable conventional Treasury bonds from 1985 to 1997. The simulated total return for TIPS closely matches that for conventional Treasuries until April 1997. Overall, however, conventional Treasuries tend to outperform TIPS. Indeed, from April 1985 through April 1998, simulated TIPS yielded an average annual geometric rate of return of 12.80 percent, compared to 15.34 percent for conventional Treasury bonds. To a great extent this relatively poor performance by the simulated TIPS is due to the discrepancy between expected and actual inflation over the period. For example, in April 1985, the expected 10-year inflation rate was 4.38 percent; yet, actual inflation over the subsequent 10 years averaged 3.53 percent. Over holding periods when actual inflation is less than that expected on the issue date, conventional bonds will outperform TIPS because the inflation premium embedded in the yields on conventional bonds will be too generous, and it will exceed the rate of appreciation of TIPS.

While the simulated TIPS returned substantially less than conventional Treasuries, the volatility of the simulated yields for TIPS was comparable to that of conventional bonds. From April 1985 to March 1998, the annualized standard deviation of the simulated total return for TIPS was 10.51 percent, compared to 7.77 percent for conventional Treasuries. Thus conventional Treasury bonds dominated TIPS over the period, offering higher returns with lower risk.

Although TIPS appear unattractive compared to conventional bonds, TIPS might still be attractive as part of a diversified portfolio if they offset the risks embedded in other securities. Figure 9 shows the efficiency frontier for a portfolio of Treasury securities and stocks, using the simulated historical return series for 10-year TIPS and conventional Treasury securities and actual total return series for T-bills and stocks as compiled by Ibbotson Associates (1998).[21] Figure 10 shows the blends of assets for the portfolios on the frontier. For very low levels of risk, the optimal portfolio comprises essentially only Treasury bills, which provide good protection against unexpected changes in real and nominal interest rates as a result of their short maturities. As the level of risk rises, the optimal portfolio includes increasing shares of stocks and conventional bonds, until stocks displace all Treasuries at the highest levels of risk. TIPS are not included at any level of risk, indicating that TIPS hedge little of the risk that investors incur from holding conventional bonds and stocks.

To see which assets displaced TIPS from the efficient portfolios, alternative efficient frontiers were constructed for a series of three-asset portfolios by deleting in turn T-bills, 10-year conventional Treasuries, and stocks. Of the possible combinations, TIPS appeared in the optimal portfolio only when T-bills were excluded, and only for low levels of risk. This indicates that TIPS are a substitute for T-bills rather than for conventional 10-year Treasuries.

TIPS and Expectations of Inflation

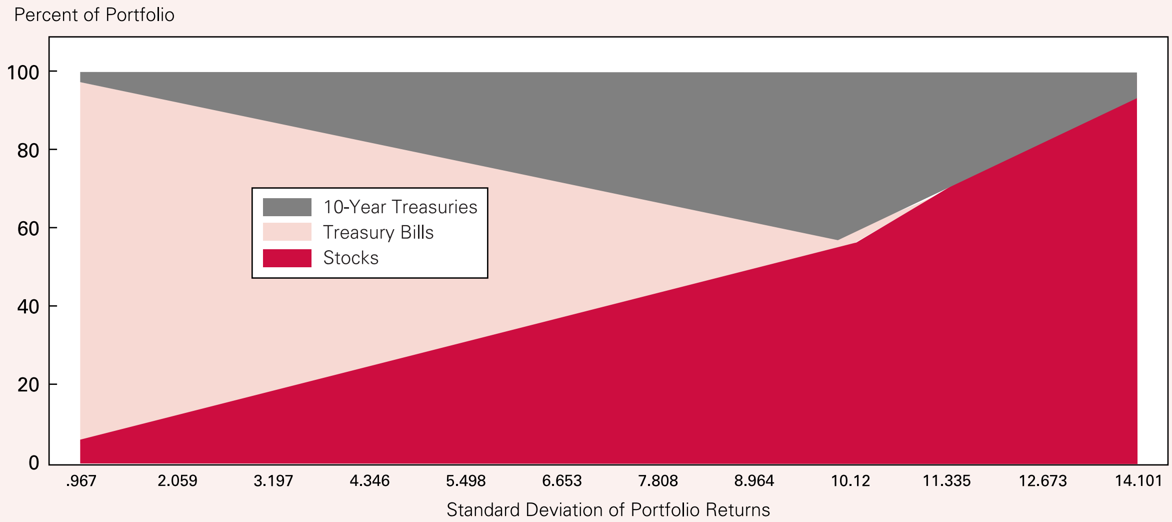
As mentioned before, the foregoing analysis suggests that investors might not find TIPS very attractive when actual inflation is less than that expected when Treasury securities are first issued. This analysis predicts only a modest demand for TIPS during periods of low and falling rates of inflation, like that which

January 1997 to May 1998. The derivation of this total return series is described in the Appendix.

[21] The efficient frontier shown in Figure 9 has very little convexity because it includes Treasury bills, which have very low risk.

Figure 10

Composition of Efficient Portfolios for Different Levels of Portfolio Risk, 1985 to 1997



Source: See Figure 9.

has prevailed since 1985, once investors no longer are so wary of high inflation and have come to suspect that their forecasts are more likely to err by overestimating, instead of underestimating, the rate of inflation. But economic environments have not always been so benign. From 1974 to 1981 a rising rate of inflation discouraged wary investors from buying conventional bonds and triggered fears that forecasts were prone to underestimating inflation. During periods such as this, might TIPS not occupy a more prominent share of the optimal portfolio?

During the early 1980s, conditions were much more unsettled than they have been since. From 1980 to 1981, expectations of inflation and the yields on debt were especially volatile compared to recent experience.[22] During 1980, the expected 10-year inflation rate for the CPI increased from 6.9 to 8.25 percent, only to decline to 7.05 percent by the end of 1981. Nominal rates on conventional 10-year Treasuries were also volatile, increasing from 11.1 percent at the beginning of 1980 to a peak of 15.4 percent in August 1981, and ending at 14.5 percent in December 1981.

By applying the efficient frontier to the period from 1980 to 1981, using the derived total returns for TIPS with the actual total returns for conventional 10-year Treasuries, stocks, and T-bills, a somewhat different picture of demand for TIPS emerges. Over this period, the average return for TIPS was substantially higher than that for comparable conventional Treasuries. At the same time, the average return on TIPS was substantially more volatile, as shown in Table 5. The composition of portfolios on the efficient frontier reflects this shift in relative returns and risks, as shown in Figure 11. While Treasury bills still comprise the largest share of low-risk portfolios, TIPS and stocks account for a greater share of higher-risk portfolios. Indeed, at very high levels of risk and return, TIPS constitute almost all of the efficient portfolio. Moreover, in a reversal from the more stable 1985–97 period, TIPS supplant conventional bonds in efficient portfolios over the entire range of risk. Thus in periods of unsettled inflationary expectations and rapidly changing real rates, the potentially high returns on TIPS tend to compensate investors more fully for bearing the considerable risks involved.

[22] This is the earliest period for which the Federal Reserve Bank of Philadelphia's series on long-term expected inflation rates exists. Analysis of earlier inflationary periods, such as that from 1973 to 1980, would require the econometric construction of a series for inflationary expectations.

Table 5
Returns and Risks on Stocks and Government Securities, 1980 and 1981

	TIPS	Stocks	Treasury Bills	10-Year Conventional Treasuries
Average Annualized Monthly Return	43.33	29.26	13.01	19.59
Standard Deviation of Average Annualized Monthly Returns	25.98	15.94	.81	15.51

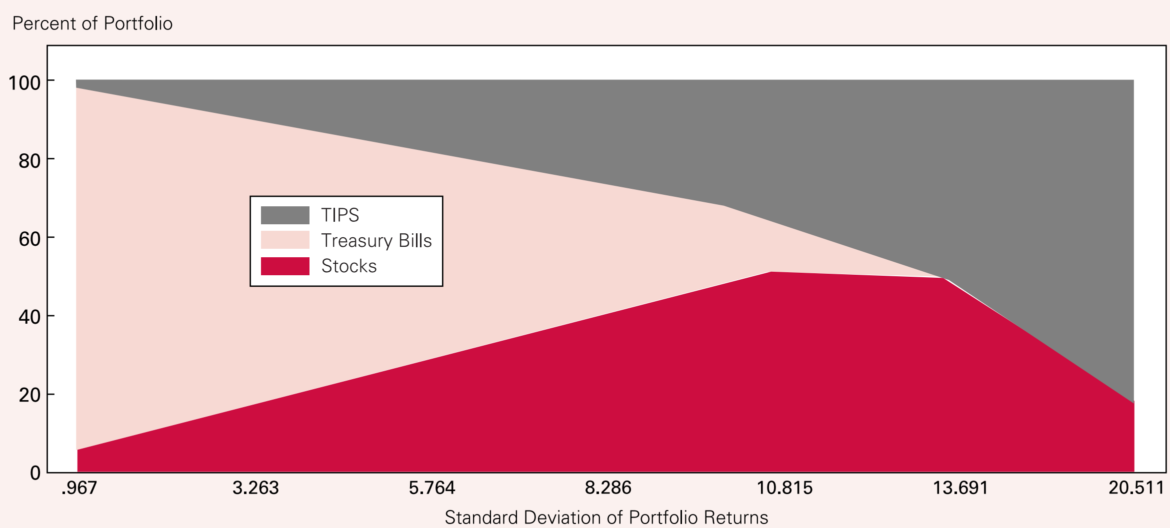
Source: Authors' estimates and Ibbotson Associates, *Stocks, Bonds, Bills and Inflation, 1997 Yearbook.*

V. Conclusion

By compensating investors for much of the unanticipated variation in the rate of inflation, TIPS offer a more stable real rate of return than is commonly available on comparable debt bearing a fixed nominal rate of return. Even so, investors have long been able to construct portfolios that offer inflation-protected returns by holding a suitable blend of stocks and bonds. The net revenue that businesses earn on their assets defines the real rate of return available in our economy. The claims on these net revenues are divided between investors holding the companies' debt and equity, respectively, in the form of interest payments and profits. Investors that hold "index funds," which blend this debt and equity in proportions that correspond to the supply of these securities, can earn a real rate of return corresponding to that on companies' real assets. The return on this synthetic inflation-protected investment will likely vary much more than that on TIPS over the course of cycles in economic growth, but over the long run this synthetic inflation-protected return should exceed that available on TIPS. Public debt that promises a (risk-adjusted) rate of return that exceeds the return anticipated on productive capital will divert saving from productive investment, thereby depressing the accumulation of capital and growth. Although TIPS are not unique in offering investors an inflation-protected return, they will appeal to savers who are especially averse to risk and who are especially wary of inflation. For others, a suitable combination of stocks and bonds will continue to offer the most attractive real rates of return.

Figure 11

Composition of Efficient Portfolios for Different Levels of Portfolio Risk, 1980 and 1981



Source: See Table 5.

Appendix

The Design of the Treasury's Inflation-Protected Securities (TIPS)

A TIPS is issued with a rate of interest that is constant for the life of the security. Its semiannual interest payments equal one-half its stated rate of interest multiplied by its face value. The face value of a TIPS on any date equals its face value at its time of issue multiplied by an index ratio, which is the reference CPI for that date divided by the reference CPI for the date that the bond was issued.

The reference CPI lags the conventionally reported CPI by nearly three months: The reference CPI for the first day of a month is the CPI as reported for the third preceding month (a number that is released during the second preceding month). The reference CPI for any other day in a month is the linear interpolation of the reference CPI for its first day and the reference CPI for the first day of the next month.

If the CPI is revised, the Treasury will continue to use the previously reported CPI in calculating the face value of TIPS and their payments of interest. If the CPI is rebased to a different year during the life of a bond, the Treasury will continue to use the CPI corresponding to the base year in effect when the bond was issued, as long as this older index is published. In the event of a material change in the definition of the CPI, the Treasury has the authority to use an appropriate substitute.

Semiannual interest payments on TIPS are taxed when they are received or accrued. Any increase in a TIPS' face value must be included as interest income in the year that it occurs. A decrease in a TIPS' face value reduces taxpayers' previous (or future) taxable interest income from TIPS. If a TIPS matures or is sold before taxpayers can fully apply the decrease in its face value against its interest payments, then the remaining loss is treated as a capital loss.

Equilibrium Interest Rates for Conventional Bonds and TIPS

Savers who are willing to forgo 1 unit of consumption this year in return for $(1 + \rho)$ units of consumption next year require a real rate of interest on their bonds and loans equal to ρ. Conventional bonds that bear the yield i offer these savers $\$(1 + i)$ for each dollar that they save this year. If the prices of goods and services are increasing at the rate π, then the price of 1 unit of consumption this year, P, increases to $P(1 + \pi)$ next year. Accordingly, savers who forgo 1 unit of consumption now by investing P in conventional bonds will receive $P(1 + i(1 - \tau))$ next year, after paying taxes at rate τ on their income. At that time, the total cost of $(1 + \rho)$ units of consumption will be $P(1 + \pi)(1 + \rho)$. For the conventional bond to offer savers the required real rate of return,

$$(1 + i(1 - \tau)) = (1 + \pi)(1 + \rho), \quad \text{or} \tag{A-1}$$

$$i(1 - \tau) = \rho(1 + \pi) + \pi. \tag{A-2}$$

Each dollar that savers invest in TIPS buys a bond whose face value increases to $\$(1 + \pi)$ next year. TIPS that bear the yield r, therefore, offer savers $P(1 + \pi)(1 + r)$ before taxes, next year, for an investment of P this year. Because both the appreciation of the bond and its payment of interest are taxable income, savers receive $P[(1 + \pi)(1 + r(1 - \tau)) - \tau\pi]$. For this investment to purchase $(1 + \rho)$ units of consumption next year,

$$(1 + \pi)(1 + r(1 - \tau)) - \tau\pi = (1 + \pi)(1 + \rho), \quad \text{or} \tag{A-3}$$

$$r(1 - \tau) = \rho + \tau\pi/(1 + \pi). \tag{A-4}$$

Savers ordinarily require compensation in addition to their real rate of return ρ for bearing the risks entailed by their investments in bonds. Accordingly, the rates of interest on conventional bonds and TIPS should cover the premia for savers' risks of forecasting inaccurately either inflation (γ_π) or the real returns on other investments (γ_ρ).

$$(1 + i(1 - \tau)) = (1 + \pi)(1 + \rho + \gamma_\pi + \gamma_\rho), \tag{A-5}$$

$$i(1 - \tau) = (\rho + \gamma_\pi + \gamma_\rho)(1 + \pi) + \pi, \quad \text{or} \tag{A-6}$$

$$i = ((\rho + \gamma_\pi + \gamma_\rho)(1 + \pi) + \pi)/(1 - \tau). \tag{A-7}$$

The rates of interest on TIPS should cover the same premium for uncertainty regarding the real rate of return, but the premium for uncertainty regarding inflation should be lower than that for conventional bonds. Savers who purchase TIPS only run the risk of an uncertain tax burden on their bonds' inflation gains.

$$(1 + \pi)(1 + r(1 - \tau)) - \tau\pi = (1 + \pi)(1 + \rho + \gamma_\rho + \tau\gamma_\pi), \tag{A-8}$$

$$r(1 - \tau) = \rho + \gamma_\rho + \tau(\pi/(1 + \pi) + \gamma_\pi), \quad \text{or} \tag{A-9}$$

$$r = (\rho + \gamma_\rho + \tau(\pi/(1 + \pi) + \gamma_\pi))/(1 - \tau). \tag{A-10}$$

The difference between the rates of interest on conventional bonds and TIPS is

$$i - r = [(\rho + \gamma_\rho)\pi + (1 + \pi - \tau)(\gamma_\pi + \pi/(1 + \pi))]/(1 - \tau). \tag{A-11}$$

If the inflation gains of TIPS were not taxed, then their rate of interest would be

$$r^a = (\rho + \gamma_\rho)/(1 - \tau), \tag{A-12}$$

and the difference between the rates of interest on conventional bonds and TIPS would be

$$i - r^a = [(\rho + \gamma_\rho)\pi + (1 + \pi)\gamma_\pi + \pi]/(1 - \tau). \tag{A-13}$$

These rates of interest on the various bonds make them equally attractive to investors who pay the tax rate τ on their current investment income. Investors who pay a lower tax rate earn higher real returns that are not necessarily the same for conventional bonds and TIPS. For tax-exempt investors, the real rates of interest implied by the nominal rates above are as follows:

$$\rho_i^{te} = (1 + i)/(1 + \pi) - 1$$

$$= (\rho + \gamma_\pi + \gamma_\rho)/(1 - \tau) + \tau\pi/((1 + \pi)(1 - \tau)). \tag{A-14}$$

$$\rho_r^{te} = (1 + r)(1 + \pi)/(1 + \pi) - 1 = r$$

$$= (\rho + \gamma_\rho)/(1 - \tau) + \tau(\pi/(1 + \pi) + \gamma_\pi))/(1 - \tau). \quad \text{(A-15)}$$

The difference between these real yields is simply the risk premium for inflation,

$$\rho_i^{te} - \rho_r^{te} = \gamma_\pi . \quad \text{(A-16)}$$

The real rate of interest on conventional bonds for tax-exempt investors exceeds that on TIPS as long as the risk premium for inflation exceeds zero.

Effect of Changes in Inflation and Real Rates on the Value of Bonds

The previous formulas for i and r show how the yields on conventional bonds and TIPS depend on savers' required real rates of return, forecasts of inflation, tax rates, and risk premia. The semi-annual coupon rates that are implied by these yields are

$$ci = (1 + i)^{1/2} - 1, \quad \text{and} \quad \text{(A-17)}$$

$$cr = (1 + r)^{1/2} - 1. \quad \text{(A-18)}$$

Once these bonds are issued, the values of these bonds in secondary trading depend on any subsequent changes in savers' required real rates of return or in their forecasts of inflation. The values of the bonds respond to changes in the risk premia in much the same way that they respond to changes in the corresponding expectations of inflation and the real rate of interest. The value of a seasoned conventional bond (with m coupon payments remaining) to savers who pay taxes on their current investment income is the value of its net coupon payments and its repayment of principal, discounted by the prevailing net nominal yield on newly issued conventional bonds, i, a function of ρ, π, and τ as specified above.

$$V_c^t = \sum_{k=1}^{m} \frac{(1-\tau)ci - \tau(1 - V_c^t)/m}{(1 + (1-\tau)i)^k} + \frac{1}{(1 + (1-\tau)i)^m} \quad \text{(A-19)}$$

$$= \frac{(1-\tau)ci - \tau(1 - V_c^t)/m}{(1-\tau)i}\left(1 - \frac{1}{(1 + (1-\tau)i)^m}\right)$$

$$+ \frac{1}{(1 + (1-\tau)i)^m} . \quad \text{(A-20)}$$

The second term in the first numerator reflects any tax liability on bonds purchased at a discount. The value of this bond to a tax-exempt investor is the same as the previous expression, except for the omission of the tax liabilities.

$$V_c^{te} = \sum_{k=1}^{m} \frac{ci}{(1+i)^k} + \frac{1}{(1+i)^m} \quad \text{(A-21)}$$

$$= \frac{ci}{i}\left(1 - \frac{1}{(1+i)^m}\right) + \frac{1}{(1+i)^m} . \quad \text{(A-22)}$$

Tables 2 and 3 show the values for V per $100 of the face values of conventional bonds and TIPS, assuming that inflation and the real rate of interest change shortly after 10-year bonds are issued with coupons dictated by inflation of 2 percent and a real rate of 2 percent.

The value of the TIPS to both types of investor is derived in a manner similar to that for the conventional bond (Table 3). The equilibrium values for the real rates of interest for investors—r and ρ_i^a (the maximal real rate of return available to tax-exempt investors, which is offered by conventional bonds)—are determined by the formulas above.

$$V_r^t = \sum_{k=1}^{m} \frac{(1-\tau)cr - \tau\pi - \tau(1 - V_r^t)/m}{(1 + (1-\tau)r - \tau\pi)^k} + \frac{1}{(1 + (1-\tau)r - \tau\pi)^m}$$

$$= \frac{(1-\tau)cr - \tau\pi - \tau(1 - V_r^t)/m}{(1-\tau)r - \tau\pi}\left(1 - \frac{1}{(1 + (1-\tau)r - \tau\pi)^m}\right)$$

$$+ \frac{1}{(1 + (1-\tau)r - \tau\pi)^m} . \quad \text{(A-23)}$$

$$V_r^{te} = \sum_{k=1}^{m} \frac{cr}{(1+\rho_i^{te})^k} + \frac{1}{(1+\rho_i^{te})^m}$$

$$= \frac{cr}{\rho_i^{te}}\left(1 - \frac{1}{(1+\rho_i^{te})^m}\right) + \frac{1}{(1+\rho_i^{te})^m} . \quad \text{(A-24)}$$

Finally, the value of a TIP featuring tax-free inflation gains to investors who pay taxes is the same as the expression above except that the term $\tau\pi$ is omitted wherever it appears (Table 4). Also, π is omitted from the expression determining r. Because the coupons on TIPS would fall if inflation gains were exempt from taxation while the value of ρ_i^{te} (tax-exempt investors' real return on conventional bonds) would not change, the value of this TIPS to tax-exempt investors would be less than the value of the TIPS shown in Table 3.

Derived Yields on TIPS

From equation A-7, the after-tax real rate on a conventional bond is equal to:

$$\rho = ((1-\tau)i - \pi)/(1+\pi) - \gamma_\pi - \gamma_\rho. \quad \text{(A-25)}$$

If investors demand the same after-tax real yield on TIPS as on nominal conventional bonds, then the nominal pre-tax yield on TIPS is given by equation A-10:

$$r = (\rho + \gamma_\rho + \tau(\pi/(1+\pi) + \gamma_\pi)/(1-\tau). \quad \text{(A-26)}$$

To calculate the nominal yield on TIPS, the anticipated after-tax real return is first calculated using equation A-7. The marginal tax (τ) is assumed to be 30 percent. The inflation and real rate risk premiums (γ_π and γ_ρ) are each assumed to equal 30 basis points, based on the work of Hammond, Fairbanks, and Durham (1999). The long-term (10-year) expected inflation rate (π) is taken from a series compiled by the Federal Reserve Bank of Philadelphia based on surveys of economists. Notice that since γ_π, γ_ρ, and τ are all assumed to be constant, and π is for the most part a slowly moving smooth series, then any fluctuations in the yield to maturity on conventional bonds (i) will result in change in the real rate (ρ) and in the nominal yield on TIPS (r).

Monthly Total Returns on Conventional Bonds

The one-period total return on a bond equals the change in its price over the period divided by the price of the bond at the beginning of the period, where the price is defined as the settlement price, including accrued interest. Assuming a 10-year conventional Treasury bond is issued at the beginning of each month at par, carrying a coupon equal to the current reported yield to maturity on the bond, then at the end of the month the settlement price of the bond is:

$$P = (1000/(1 + i/2)^{N-1+T/b}) + (\Sigma\, C/2/((1 + i/2)^{j-1+T/b}) + a,$$

where
i = the current yield to maturity
N = number of remaining coupon dates
T = number of days from settlement to next coupon date
b = number of days in the compounding period in which settlement occurs
C = the annual coupon
a = accrued interest.

Then the monthly total return is equal to:

$$TR_i = (P - 1{,}000)/1{,}000.$$

Monthly Total Returns on TIPS

Assuming a new TIPS is issued at the beginning of the month at par, carrying a coupon rate equal to the current yield from the simulated series of TIPS' yields, then at the end of the month the settlement price for the TIPS equals:

$$P^t = ((CPI_{t-3}/CPI_{t-4})1000/(1 + r_t/2)^{N-1+T/b}) + (\Sigma\, C_t/2/((1 + r_t/2)^{j-1+T/b}) + a,$$

where new variables are:
CPI_{t-i} = the consumer price index at period t−i
C_t = the current coupon on the TIPS
r_t = the end of month yield to maturity on the TIPS, derived from equation A-26 above.

Then the monthly total return is equal to:

$$TR_i = (P^t - 1{,}000)/1{,}000.$$

References

Bach, G. L. and R. A. Musgrave. 1941. "A Stable Purchasing Power Bond." *The American Economic Review*, 41, pp. 823-25.

Baer, Werner and Paul Beckerman. 1980. "The Trouble with Index-Linking: Reflections on the Recent Brazilian Experience." *World Development*, 8, pp. 677–703.

Campbell, John Y. and R. J. Shiller. 1996. "A Scorecard for Indexed Government Debt." In B.S. Bernanke, J. Rotemberg, eds., *NBER Macroeconomics Annual*. Cambridge, MA: The MIT Press.

Fischer, Stanley. 1983. "Indexing and Inflation." *Journal of Monetary Economics*, 12, pp. 519–42.

Fisher, I. 1930. *The Theory of Interest*. New York: Macmillan.

Hammond, P. Brett, Andrew C. Fairbanks and J. Benson Durham. 1999. "Understanding the Inflation Risk Premium." In John Brynjolfsson and Frank J. Fabozzi, *Handbook of Inflation Indexed Bonds*, pp. 157–82. New York: Frank J. Fabozzi Associates.

Ibbotson Associates. 1998. *Stocks, Bonds, Bills & Inflation: 1997 Yearbook*. Chicago: Ibbotson Associates.

Jevons, W. S. 1875. *Money and the Mechanism of Exchange*. New York: D. Appleton and Co.

Lowe, J. 1822. *The Present State of England in Regard to Agriculture, Trade, and Finance*.

Modigliani, Franco and Richard Sutch. 1966. "Innovations in Interest Rate Policy." *The American Economic Review*, 56 (May), pp. 178–97.

Munnell, Alicia H. and Joseph B. Grolnic. 1986. "Should the U.S. Government Issue Indexed Bonds?" *New England Economic Review*, September/October, pp. 3–21.

Simonsen, Mario Henrique. 1983. "Indexation: Current Theory and the Brazilian Experience." In Rudiger Dornbusch and Mario Henrique Simonsen, eds., *Inflation, Debt, and Indexation*, pp. 99–132. Cambridge, MA: The MIT Press.

Tobin, James. 1971. "An Essay on the Principles of Debt Management." *Essays in Economics: Vol. 1, Macroeconomics*. Chicago: Markham.