Expected Inflation and Real Interest Rates Based on Index-linked Bond Prices: The U.K. Experience

by Gabriel de Kock

Recently some analysts have suggested that the Treasury finance part of the federal deficit by floating indexed bonds.[1] One of the claims made for this strategy is that it would yield significant monetary policy benefits. In particular, the prices of indexed bonds could offer timely and accurate market measures of expected inflation and ex ante real interest rates. As such they could provide the Federal Reserve System with valuable information about market perceptions of, and reaction to, its policies. The argument has also been made that a real-time market measure of expected inflation might provide the Federal Reserve System with a valuable indicator of the future course of inflation and offer the public a ready means of monitoring the Fed, thereby encouraging public interest in better policies.

A market measure of expected inflation may be useful in the formulation of policy even if is not a good gauge of the actual future inflation performance of the economy. It may be a poor indicator of future inflation because private sector inflation expectations are, in fact, not realized. Even in this case, however, the associated real interest rate should nevertheless be a good measure of ex ante real interest rates faced by the private sector. That is, at the macroeconomic level, indexed bond prices should contain useful information about real economic activity.

The potential value of a real-time market measure of expected inflation to policy makers can only be assessed indirectly because no "true" alternative measure of private sector inflation expectations exists. This article evaluates the usefulness of a market measure of expected inflation by applying two closely related tests: first, whether the market measure of expected inflation is a good indicator of inflation developments; and second, how well the market measure captures private sector inflation expectations even if the expectations do not reflect actual inflation performance.

The second of these tests is based on two propositions. The first proposition is the familiar Fisher hypothesis that nominal interest rates should equal expected inflation plus the ex ante real interest rate; the second, a prediction shared by all standard dynamic macroeconomic models, is that true real interest rates should provide information about future economic activity.[2] If the market-expected real interest rate, measured as the difference between a long-term nominal rate and the market measure of expected inflation, has no significant effect on future real economic activity, it seems likely that it is also a poor measure of the true real interest rate. Under these circumstances, the market measure of expected inflation would then seem likely to be a poor measure of "true" private sector inflation expectations. If a real-time measure of inflation expectations neither anticipates future inflation developments nor conveys useful information about real economic activity, it is probably of only limited use to policy makers.

Drawing on this framework, this article examines the U.K. experience with indexed gilts (IGs) to assess whether indexed bond prices convey information useful in formulating and monitoring monetary policy.

[1]See, for example, Robert Hetzel, "A Better Way to Fight Inflation," *The Wall Street Journal*, April 25, 1991

[2]In theory, higher real interest rates do not necessarily lead to lower real economic activity (GNP), in fact, the two variables may be positively associated with each other In the context of standard macroeconometric models, however, real interest rates and economic activity are, ceteris paribus, negatively related to each other

More specifically, the article evaluates whether the expected inflation rate derived from the prices of indexed and nominal bonds predicts future inflation and whether the corresponding expected real interest rate provides information about real economic activity not obtainable from more traditional information variables and measures of policy stance. Although several countries have experimented with indexation since World War II, the experience of the United Kingdom, where marketable index-linked gilts have been issued since March 1981, is likely to be the most relevant to the United States.

While the market for index-linked gilts does provide a real time measure—accurate or not—of expected inflation and ex ante real interest rates, this information does not appear to be of much practical value in formulating and evaluating monetary policy. This general interpretation of the data derives from two specific conclusions: First, the expected inflation rate embodied in nominal bond yields is no better than simple measures of inflation expectations based on past inflation alone. It is a biased predictor of the future level of inflation, although it does provide minimal information about acceleration and deceleration of inflation. Second, indexed gilt prices do not seem to provide information about future movements in real economic activity, suggesting that the real interest rate on indexed gilts is unlikely to be a good measure of ex ante real interest rates faced by the private sector in the markets for goods and services. The expected inflation rate embodied in U.K. bond yields, therefore, appears to be a poor measure of true inflation expectations, given our empirical results. By contrast, lagged inflation and nominal interest rates often used to derive real interest rates that may measure monetary policy *do* have predictive content for U.K. real GNP growth.

The first section of the article summarizes the development of the U.K. indexed gilt market. More specifically, it focuses on the particular circumstances surrounding the introduction of IGs in the United Kingdom and the main features of the IG market at present. There follows a brief discussion of the potential monetary policy role of indexed bonds and a review of the decomposition of nominal yields into expected real interest rate and expected inflation components. The article then examines the information about future inflation provided by indexed bonds and the ability of indexed gilt prices to predict developments in real economic activity.

The evolution of the U.K. market for index-linked gilts

The Conservative government introduced IGs in 1981 as part of its anti-inflation program. Three reasons were given for the move: (1) the introduction of IGs would improve the Bank of England's control over monetary aggregates, (2) indexation would result in substantial savings to the Treasury if, as anticipated, inflation declined significantly as a result of the government's policies, and (3) indexing government debt would signal the government's determination to reduce inflation. These reasons reflected policy concerns specific to the United Kingdom in the early eighties, although the third is sometimes viewed as relevant to current U.S. policy, if only on a theoretical level.[3]

Issuing IGs was expected to bring about closer control over the monetary aggregates by ameliorating constraints on monetary policy imposed by the distinctive structure of the U.K. gilts market. Because market makers, considered essential to the smooth functioning of the market, were weakly capitalized, the authorities felt obliged to minimize fluctuations in gilt prices that would threaten the market makers' survival. Thus, the Bank of England was constrained to stabilize nominal interest rates, a policy that entailed loss of control over monetary aggregates.[4] Most notably, in the late seventies and early eighties, market expectations of rising inflation forced the Bank of England to follow a destabilizing expansionary policy to prevent gilts prices from falling too steeply. Index-linked gilts, which could be sold in times of market expectations of rising inflation, enabled the authorities to reestablish control over monetary aggregates. In this way, inflation expectations could be kept in check, thereby mitigating fluctuations in conventional gilts prices.

The second argument for issuing indexed bonds, that the real cost to the government of issuing index-linked debt would be lower than that of borrowing on conventional terms, is valid if the government expects an inflation rate lower than the market expectation of inflation embedded in nominal yields (assuming that the tax system is neutral with respect to inflation). These conditions were clearly fulfilled in the United Kingdom in early 1981: long-term bond rates were close to 14 percent and retail prices were still rising rapidly, but the government expected its firm anti-inflation policies to pay off in the near future. However, under the indexation scheme envisaged, the tax system would not be neutral with respect to inflation, because the inflation component of nominal rates would be fully taxable while only

[3]See Charles A E Goodhart, *Money, Information and Uncertainty* (Cambridge: M I T Press, 1989), for a discussion of the policy debate surrounding the introduction of indexed gilts

[4]The Bank of England could not use open market operations at the short end of the market because the stock of Treasury bills outstanding was very small by U S standards At the end of March 1980, for example, Treasury bills accounted for only 2.9 percent of market holdings of government debt.

part of the inflation compensation on index-linked gilts would be taxed. Thus, although government interest outlays would be lower with indexed gilts, conventional gilts could be expected to produce much more tax revenue. Initial calculations suggested that inflation would have to decline very rapidly before the reduction in outlays brought about by indexation IGs would exceed the loss in revenue entailed.

The government's third reason for introducing indexed bonds—to enhance the credibility of its anti-inflation program—derives from the fact that index-linking reduces the benefits of unanticipated inflation. Investors will be justly skeptical of announced anti-inflationary policies if the government at the same time issues nominally denominated debt, because the government may always be tempted to resort to unanticipated inflation to reduce the real value of its debt. By contrast, unanticipated inflation does not promise any capital gains to the government if its debt is indexed. Consequently, by issuing indexed debt, the government could enhance its credibility.[5]

The advantages of IGs were partly offset by a number of possible disadvantages. First, there was concern that issuing an attractive long-term asset could have a negative impact on equity prices and corporate financing opportunities. Second, it was feared that foreign demand for IGs might put upward pressure on the pound, which was already overvalued as a result of tight monetary policies and the discovery of North Sea oil. Third, since capital gains were not yet indexed for tax purposes, issuing indexed debt would entail the taxation of purely inflationary capital gains on IGs—a step that could in turn stimulate political pressure for the indexation of taxes. Finally, the United Kingdom faced strong political pressure from other OECD governments concerned that any form of indexation would fuel OPEC pressure to index-link oil prices.

Indexed gilts were issued consistently throughout the 1980s at coupon rates mostly between 3 and 4 percent (compared with 2 percent for the first two issues). As early as end-March 1985, IGs made up 6.5 percent of total market holdings of U.K. public debt; by March 1990, the total amount of IGs outstanding was about £17.5 billion, or 10.9 percent of market holdings of British government debt and 19.3 percent of the value of gilts outstanding (Table 1).[6] The stock of IGs outstanding is made up of thirteen issues with maturities varying from two to thirty-three years. Long-dated issues make up the bulk of the value of IGs outstanding; only 7.3 percent of the amount outstanding are of maturities shorter than five years, and 16.5 percent of maturities shorter than ten years (Table 2).

Anecdotal evidence suggests that holdings of IGs remain concentrated and that the number of customers remains small.[7] The most important holders of IGs are pension funds, followed by insurance companies, while individual investors are largely confined to the short end of the market. These features match those of the gilt market as a whole. The IG market is thin in comparison with the market for conventional gilts. Although turnover varies, it only amounted to 2.9 percent of total gilt turnover in 1990 and 3.1 percent for the first four months of 1991 (Table 2). The demand for new issues of IGs has been disappointing when the ex post real yields on conventional gilts exceed those on IGs, as they did during the rapid decline of inflation in 1982-83 and 1985-86. (The issuance of IGs also resulted in substantial savings to the Treasury during this period for the same reason.)

The potential role of indexed bonds in monetary policy

Proponents of issuing indexed bonds in the United States have emphasized monetary policy benefits that depend critically on the informational role of indexed bond prices. This consideration figures importantly in the academic literature on indexed bonds although it did not arise in the U.K. policy debate.[8] Advocates argue

[5]Note, however, that indexation could also have an adverse impact on expectations (and thereby make it more difficult to reduce inflation) if it was interpreted as an effort by the monetary authorities to decrease the political cost of inflation before giving up the battle against inflation altogether. But such an adverse impact would be more likely if indexation covered a wide range of contracts—something the Conservative government had taken great pains to avoid. Issuing index-linked gilts probably also enhanced the government's credibility over time because it effected immediate cosmetic improvement in the Public Sector Borrowing Requirement. Indexation was implemented in a way that pushed compensation for inflationary depreciation of principal into the future, whereas the government would have had to pay higher nominal interest rates immediately had it issued conventional bonds.

[6]By the end of 1990 this percentage had risen to 20.5 percent because under the scheme of indexation used in the United Kingdom, the value of the IGs outstanding rises in line with inflation. Nonmarketable national savings certificates or "granny bonds," which have been issued since 1975, have had a limited impact, making up less than 2 percent of market holdings of British government debt as of end-March 1990.

[7]The Bank of England does not compile separate statistics on holdings of IGs and conventional gilts by type of institution. At the end of March 1990, pension funds and insurance companies held 57.5 percent of U.K. government debt outstanding, while individuals and private trusts held about 38 percent ("The Net Debt of the Public Sector: End-March 1990," *Bank of England Quarterly Bulletin*, November 1990, pp. 519-26).

[8]A theoretical literature on the relative efficiency of open market operations in indexed and nominal bonds dates back to James Tobin, "An Essay on the Principles of Public Debt Management," reprinted in *Macroeconomics*, vol. 1 of *Essays in Economics* (Markham Publishing Co., 1971). Tobin argued that open market operations in indexed bonds will affect real activity more strongly and with greater certainty than will open market operations in

Table 1

Composition of U.K. National Debt

	March 1985		March 1990	
	Billions of Pounds	Percentage	Billions of Pounds	Percentage
Market holdings	146 7	100 0	160 0	100 0
Sterling marketable debt	114 4	78 0	117 0	73.2
Government stock				
Index-linked	9 5	6 5	17 5	10 9
Other	103 7	71 5	90 5	56 6
Treasury bills	1 2	0 8	9 0	5 7
Sterling nonmarketable debt	29 3	20 0	36 5	22 8
National savings†				
Index-linked	3 6	2 4	3 0	1 9
Other	18 8	12 8	26 1	16 3
Other	6 9	6 8	7 4	4 6
Foreign currency debt	2 9	2 0	6 5	4 0
Official holdings	11 6		32 5	

Source Bank of England

†National savings include a variety of non-negotiable savings instruments issued by the government

that indexed bond prices would provide policy makers and the public with information on inflation expectations and ex ante real interest rates on a real-time basis In this view, the Federal Reserve System would gain valuable information about market perceptions of, and reaction to, its policies Furthermore, this information could provide policy makers with a good predictor of inflation and a measure of the impact of monetary policy on both inflation and real economic activity Hetzel has argued that the ready availability to policy makers and the public of an indicator of the inflationary consequences of monetary policies would have three benefits First, it would increase public understanding of, and support for, anti-inflationary policies Second, it would serve as a barometer of Fed credibility and consequently increase incentives for the Fed to commit itself to anti-inflationary policies. Finally, by exposing the true consequences of policies that trade off inflation for short-term output gains, it would strengthen the Fed's effort to focus attention on its long-term price stability objectives.

Table 2

Features of U.K. Market for Index-linked Gilts

Maturity Composition of IGs Outstanding	Millions of Pounds†	Percentage
Less than one year	865	4 2
One to five years	638	3 1
Five to ten years	1,920	9 2
Over ten years	17,365	83 5
Total	20,788	100 0

Contribution of IGs to Monthly Gilt Turnover	Total Turnover (Billions of Pounds)	IG Turnover (Billions of Pounds)	IG Turnover (Percentage of Total)
1990 average	75,445 5	2,196 6	2 9
January-April 1991 average	85,702 9	2,630 6	3 1

Source Bank of England

†Includes indexation of principal up to the beginning of 1991

However, the benefits cited by Hetzel are only likely to materialize if the market measure of expected inflation is a reliable indicator of the effects of monetary policies and macroeconomic disturbances on inflation.[9]

Footnote 8 (continued)
nominal bonds because indexed bonds are likely to be a closer substitute for equity than nominal bonds Tobin has been criticized by Stanley Fischer, "The Demand for Indexed Bonds," *Journal of Political Economy*, vol 83, no 3 (June 1975), pp 509-34, and by Paul Beckerman, "Index-linked Government Bonds and the Efficiency of Monetary Policy," *Journal of Macroeconomics*, vol 2, no 4 (Fall 1980), pp 307-31 Fischer suggested that open market operations in nominal bonds that are complements for equity in private portfolios may have a more pronounced impact on Tobin's q, and thus on real activity, than open market operations in indexed bonds that serve as substitutes for equity Beckerman has pointed out that Tobin's conclusion requires a set of potentially inconsistent assumptions

[9]Earlier advocates of indexation—for example, Alicia H Munnell and Joseph B Grolnic ("Should the U S Government Issue Index Bonds," *New England Economic Review*, September-October 1986, pp 3-22)—have emphasized the provision of index-linked government liabilities that could be used to back indexed pension contracts

To be sure, a market-based decomposition of nominal interest rates into their expected inflation and expected real interest rate components may be useful to policy makers, even if the market measure of expected inflation is not a good predictor of inflation. This would be especially true if the market measure of expected inflation were a good gauge of private sector inflation expectations. If so, it would provide a reliable measure of ex ante real interest rates and thus convey information on private decisions and future economic developments. More generally, indexed bond prices could offer policy makers and private agents up-to-date information about the sources of macroeconomic disturbances. In fact, Boschen, using a simple model, has shown that a market for indexed bonds could reduce the magnitude of business cycle fluctuations by allowing private agents to distinguish real and nominal disturbances more accurately.[10]

The empirical analysis in this section evaluates whether the U.K. market for index-linked gilts actually conveys the policy-relevant information about future inflation and real economic activity that advocates of indexed bonds have attributed to it. Data on IG and conventional gilt prices are used to construct a monthly series of expected inflation rates and expected real interest rates spanning the period from March 1982 to March 1991. As detailed below, these data indicate that the derived measure of expected inflation, termed the IG measure, is a poor predictor of inflation and that the IG market does not provide information about future real economic activity.

Inflation expectations and expected real interest rates derived from IG prices

The data on expected real interest rates and expected inflation are constructed by using an indexed bond's price to decompose the yield on a nominal bond into expected real interest rate and expected inflation components. The calculation assumes that the expected real yields of indexed and conventional bonds of the same maturity must be equal and consequently that the IG measure of the inflation rate expected by investors to prevail *over the remaining lifetime of the bonds* can be estimated as the difference between the redemption yields on the nominal and indexed bonds. In practice, the calculation and interpretation of the expected inflation rate and expected real rate are somewhat more involved, because IGs are not fully indexed, investors may be risk averse, and the indexed and conventional bonds may differ in liquidity and tax treatment. More detailed information on the nature of indexed gilts and the calculation and interpretation of expected inflation and real interest rates is given in the box.

Data on the IG measure of expected inflation and the corresponding long-term real interest rate are derived by decomposing the nominal yield on a conventional bond maturing in 1996. This calculation yields the longest data series because the first IGs issued mature in 1996. The top panel of Chart 1 illustrates the decomposition of this long-term yield into its expected real yield and expected inflation components. Note that there is a break in the series in 1986.[11] For reference, the lower panel of Chart 1 shows the nominal yield on the 1996 bond along with the yield on ten-year gilts. The yield on the 1996 bond moves closely with the yield on ten-year gilts, confirming that the 1996 bond (as well as the decomposition of its yield) is representative of the long-term government bond market in the United Kingdom.

Chart 1 suggests that changes in expected inflation account for the bulk of nominal interest rate movements. This result is the counterpart of the striking stability of the real interest rate measure, which varies between 2.36 percent and 4.37 percent per annum. The underlying stability of the real yield on IGs is confirmed by the Bank of England's calculations: although based on the assumption of a fixed 5 percent inflation rate over the remaining lifetime of the IG, the Bank's estimate of the real yield varies over a similar range.[12]

Chart 1 also illustrates the response of the IG measure of expected inflation and the corresponding real

[10]See John F Boschen, "The Information Content of Indexed Bonds," *Journal of Money, Credit, and Banking*, vol 18, no 1 (February 1986), pp. 76-87

[11]The data for the period from October 1986 to March 1991 pertain to a 10 percent coupon bond maturing in November 1996 and those for the period from March 1982 to September 1986 to a 14 percent coupon bond maturing in July 1996 The decomposition of the nominal yield is based on price data for a 2 percent indexed gilt maturing in September 1996 In both cases the maturity match is probably close enough not to affect the results The decomposition is somewhat sensitive to the particular matched-maturity conventional bond used, presumably because the different bonds are not equally liquid The yields on the 14 percent bond and the 10 percent bond differ by 29 basis points, on average, in the months for which overlapping observations are available. Our results nevertheless indicate that only the *levels* of calculated expected real yields and inflation rates are affected, not their movements over time. For example, the correlation coefficient of the two expected inflation rates calculated for the overlapping observations is 0 99 For the purposes of Chart 1 and the empirical analysis discussed below, the earlier observations were adjusted by the mean difference calculated from the overlapping observations Specifically, the real rate increased about 6 basis points and the expected inflation rate declined by about 35 basis points

[12]The Bank of England's real interest rate measure is somewhat higher, on average, than the measure reported here (3.64 percent compared with 3 54 percent) and somewhat less volatile, its standard deviation is about 40 5 basis points, compared with 42 6 basis points for the measure used here The correlation coefficient of the two measures is 0 93 In "Sources of Fluctuation," Gaske documents that in the early part of the sample the co-movements between the Bank of England's series and macroeconomic variables are quite different from those of an ex ante real rate measure like the one used in this article.

Box: Extracting Ex Ante Real Yields and Expected Inflation from Indexed Gilts Prices

Features of U.S. index-linked gilts

The form of index-linking adopted in the United Kingdom may be called principal value indexation. The value of the principal of an IG is linked to the retail price index (RPI), and coupon payments, payable every six months, are calculated as a fixed percentage of this inflation-adjusted principal. Holders of IGs are not fully protected against inflation, and hence the real return on an IG is uncertain, because the principal—and consequently interest payments—are indexed to the RPI with an eight-month lag. That is, the value of the bond for the purpose of calculating the coupon payment for a given six-month interest period exceeds its initial face value by the increase in the RPI over the period starting eight months before the issue date and ending eight months before the date on which the coupon payment is made. For example, the principal in period t of a £100 bond issued on date I and paying a 2 percent coupon is £100 $\times (RPI_{t-8}/RPI_{I-8})$, and the coupon payment on date t will be £1 $\times (RPI_{t-8}/RPI_{I-8})$, where time is measured in months. Note also that, because of the lag in indexation, an IG is a pure nominal bond during the last eight months of its lifetime. The eight-month lag is needed to ensure that the rate of interest accrual in money terms for any six-month period is known before the start of that period so that purchasers can compensate sellers for interest accrued since the last coupon payment preceding the transaction. The period for which interest is due accounts for six of the eight months, the normal lag in availability of the RPI data for the seventh month; and the need to avoid problems that could arise if the publication lag exceeded one month, for the eighth month.†

Eligibility to take up the initial offerings of IGs in 1981 and early 1982 was restricted to domestic tax-exempt institutions (pension funds, life insurance companies taking pension business, and charitable societies) in order to forestall potential tax problems and to avoid repercussions for the exchange rate. These restrictions on the ownership of IGs became redundant and were removed when the government introduced indexation of capital gains for tax purposes in March 1982. Since that time, IGs have enjoyed a significant tax advantage relative to conventional gilts. While holders of conventional gilts are taxed at the income tax rate on nominal interest earnings—a rate that consists in part of compensation for depreciation of principal—holders of IGs pay no taxes at all on inflationary increases in the nominal value of the IGs. Consequently, an anticipated increase in inflation will tend to depress conventional gilts prices relative to IG prices by more than necessary to equate pretax nominal yields on conventionals and IGs.

Calculation method

The imperfect indexation of IGs makes it impossible to calculate an expected real redemption yield on the IG without making an assumption about inflation over the bond's remaining lifetime. Nevertheless, as long as investors are risk neutral, the prices of an IG and a nominal gilt of matched maturity can still be used to decompose the nominal yield on the conventional gilt into an expected real rate and an expected inflation rate. The procedure used to calculate the expected real yield and the expected inflation rate derives from work by Arak and Kreicher, Woodward, and Gaske.‡ It can be explained by a simple example that captures the salient features of the U.K. gilt market. Consider a maturity-matched pair of nominal and indexed bonds with face values F^n and F^i (at issue) maturing in period T. Let P_t^n and P_t^i denote the (nominal) prices of the nominal and indexed bonds, respectively, at the beginning of period t, with time measured in months. Coupon payments are made every six months. The first payment after period t occurs in period t+j (j≤6), and the last payment coincides with redemption in period T. The coupon payment on the nominal bond is denoted by C^n. If the IG was issued in period I, its redemption value will be $F_T^i = F^i \times (RPI_{T-8}/RPI_{I-8})$, and the nominal coupon paid in period t+j will be $C_{t+j}^i = C^i \times (RPI_{t+j-8}/RPI_{I-8})$, where C^i is the face coupon ($C^i = F^i \times c$ = face value × coupon rate) on the index-linked bond. Finally, let i_t denote the period-t annual yield to maturity on the nominal bond, π_t^e the annual inflation rate expected to prevail from period t to period T, and r_t the annual expected real interest rate from period t to period T. Then i_t is the solution to

†For a discussion of institutional features of the indexed gilt market, see Patrick Phillips, *Inside the New Gilt-edged Market*, 2d ed. (Cambridge, England: Woodhead-Faulkner, 1987).

‡See Marcelle Arak and Lawrence Kreicher, "The Real Rate of Interest: Inferences from the New U.K. Indexed Gilts," *International Economic Review*, vol. 26, no. 2 (June), pp. 399-407, G. Thomas Woodward, "Comment: 'The Real Rate of Interest: Inferences from the New U.K. Indexed Gilts,'" *International Economic Review*, vol. 29, no. 3 (August), pp. 565-68, and Mary Ellen Gaske, "Sources of Fluctuations in Expected Long-term Real Rates: Evidence Extracted from U.K. Indexed Bond Rates," Unpublished Ph.D. Dissertation, University of Maryland.

Box: Extracting Ex Ante Real Yields and Expected Inflation from Indexed Gilts Prices *(continued)*

$$\text{(A 1)}\quad P_t^n = C^n \sum_{k=0}^{K} (1+i_t/12)^{-(6k+j)} + (1+i_t/12)^{-(T-t)}F^n,$$

where $K \equiv [T-(t+j)]/6$. The decomposition of i_t into π_t^e and r_t must satisfy

$$\text{(A 2)}\quad P_t^i = \sum_{k=0}^{K} [(1+r_t/12)(1+\pi_t^e/12)]^{-(j+6k)}C_{t+j+6k}^i] + [(1+r_t/12)(1+\pi_t^e/12)]^{-(T-t)}F_T^i$$

and

$$\text{(A 3)}\quad (1+r_t/12)(1+\pi_t^e/12) = (1+i_t/12)$$

Since the expected nominal coupon on the indexed bond in period $t+j+6k$ is

$$C_{t+j+6k}^i = (1+\pi_t^e/12)^{6k}C_{t+j}^i = (1+\pi_t^e/12)^{6k} \times (RPI_{t+j-8}/RPI_{t-8}) \times C^i$$

and the expected nominal redemption value of the indexed bond is

$$F_T^i = (1+\pi_t^e/12)^{T-t-8} \times (RPI_t/RPI_{t-8}) \times F^i,$$

equation A 2 can be simplified to

$$\text{(A 4)}\quad P_t^i = (RPI_{t+j-8}/RPI_{t-8})[(1+\pi_t^e/12)(1+r_t/12)]^{-j}C^i + (RPI_t/RPI_{t-8})(1+\pi_t^e/12)^{-8}\left\{\sum_{k=0}^{K}(1+r_t)^{-(6k+j)}C^i + (1+r_t)^{-(T-t)}F^i\right\}$$

The gilt prices provided by the Bank of England are clean prices that is, they do not include accrued interest For these calculations, accrued interest was added to the clean prices in proportion to the number of months that had elapsed since the previous interest payment

Limitations of the IG measures of the expected inflation and real interest rates

The decomposition of the nominal long-term bond rate into its expected inflation and real interest rate components will be strictly correct if two requirements are met. (1) investors are risk neutral, and (2) nominal and indexed-linked bonds are identical in all respects other than indexation (specifically risk, maturity, liquidity, and tax treatment) If investors are not risk neutral, interpreting the IG measure of expected inflation and the corresponding expected real yield is complicated by the existence of risk premia Suppose, for expository purposes, that the indexed bond is fully indexed so that the ex ante real interest rate on the IG can be determined from its price alone In this case, the expected real yield on the nominal bond will differ from that on the indexed bond by an inflation risk premium. Consequently, the estimate of expected inflation will be contaminated by an inflation risk premium that may vary systematically with expected inflation. It is difficult to predict the sign of this correlation on a priori grounds or to separate the contaminated measure of expected inflation into its two components because standard models of asset pricing under uncertainty fit real-world data very poorly. A further problem arises because holders of IGs are not fully compensated for inflation, the expected real return on the IG will also contain an inflation risk premium if investors are not risk neutral This premium is likely to be negligible unless the IG is close to maturity, because the investor's exposure to inflation depends on the change in the RPI during the last eight months of the IG's lifetime For a long-dated IG, this change is likely to have only a small impact on the average ex post real return over its lifetime Thus, it would be safe to assume that the measure of expected inflation is much more likely to be contaminated by a risk premium than is the expected real interest rate

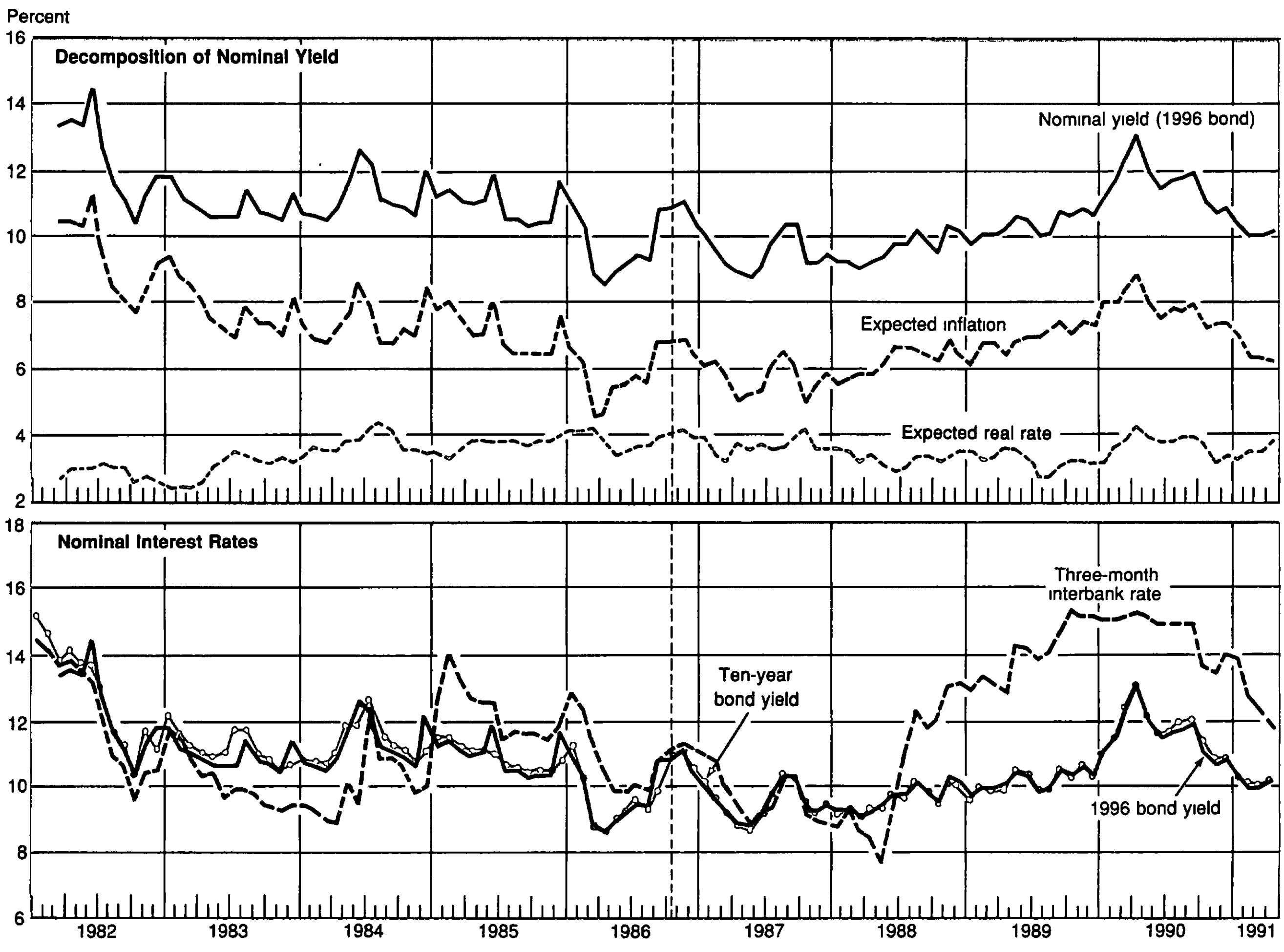
If the two bonds used for the calculations differ in their liquidity—say the indexed bond is less liquid—the measure of expected inflation will be further contaminated by a liquidity premium As noted in the text, IG turnover is small relative to the turnover of conventional gilts, and thus IGs are presumably less liquid overall than conventional gilts Nevertheless, because this general statement may not necessarily apply to a particular maturity-matched pair of index-linked and conventional gilts, it is difficult to determine whether a specific IG pays a liquidity premium. Finally, although index-linked gilts enjoy tax advantages compared with conventional gilts, the procedure for decomposing nominal yields ignores tax effects for two reasons First, the difference in tax treatment may not be of much practical import because of the dominant role that tax-free institutions play in the gilt market Second, Gaske found that taking tax effects into account did not change results qualitatively.

interest rate to changes in monetary policy. British monetary policy was tightened very sharply in the middle of 1988 and remained restrictive until September 1990. This tightening is reflected in the three-month interbank rate, which rose by more than 700 basis points from May 1988 to the end of 1989 and remained in the neighborhood of 15 percent until September 1990 (Chart 1, lower panel). The term structure, inverted since mid-1988, also shows the effects of monetary tightness. The sharp slowing of the U.K. economy in 1990 tends to confirm that high nominal rates did in fact reflect monetary tightness rather than a mere run-up of interest rates in anticipation of accelerating inflation; it also suggests that real rates probably rose from 1988 to 1990. However, the decomposition of the long-term bond yield indicates that this monetary tightening did not raise expected real long-term interest rates by much or, more implausibly, did not lower expected inflation at all.[13] In fact, the decomposition largely attributes the

[13]The real rate did rise somewhat from mid-1988 to mid-1989 and again from February 1990 to September 1990. However, the average real rate during the twenty-nine months of policy tightening was actually 30 basis points lower than the average real rate over the preceding twenty-nine months.

Chart 1

Expected Inflation and Real Interest Rates Derived from Index-linked Bond Prices



Sources: Bank of England data and author's calculations.

Note: Dashed vertical line denotes break in the data due to a change in the nominal bond used in the calculation.

steady rise in long-term government bond yields from early 1988 to mid-1990 to an increase in expected inflation. It is difficult not only to reconcile this pattern of real and nominal interest rate movements with the conventional view that monetary policy affects real economic activity through long-term real interest rates, but also to believe that private sector long-term inflation expectations were not adjusted downwards in the face of a very resolute tightening of policy.[14] These stylized facts suggest that, at least for the 1988-90 period, the IG measure was a poor measure of expected inflation and that the corresponding real interest rate did not accurately reflect ex ante real interest rates faced by the private sector.

The IG measure of expected inflation as a predictor of inflation

Chart 2 shows the IG measure of expected inflation along with actual inflation measured by the twelve-month percentage changes in the retail price index (RPI). Note that the expected inflation rate on a particular date is the average annual rate from that date to late 1996, while the actual inflation rate is the percentage change in the RPI over the past twelve months. Chart 2 generally contradicts assertions that the IG measure of expected inflation simply mimics the behavior of actual inflation.[15] The IG measure of expected inflation has remained above the actual rate for most of the sample period and is also rather less volatile than actual inflation. It has, however, been fairly close to the actual rate from late 1989 onwards.

Although the IG measure of expected inflation applies to an interval that is longer than the short- to medium-term horizon of primary concern to policy makers, it may nevertheless provide a good forecast of inflation over a horizon of immediate policy interest To assess this possibility, the IG measure of expected future inflation was compared with three simple measures based on past inflation. the average rates of RPI inflation over the past twelve, twenty-four, and thirty-six months.[16] Each measure of expected inflation was evaluated as a

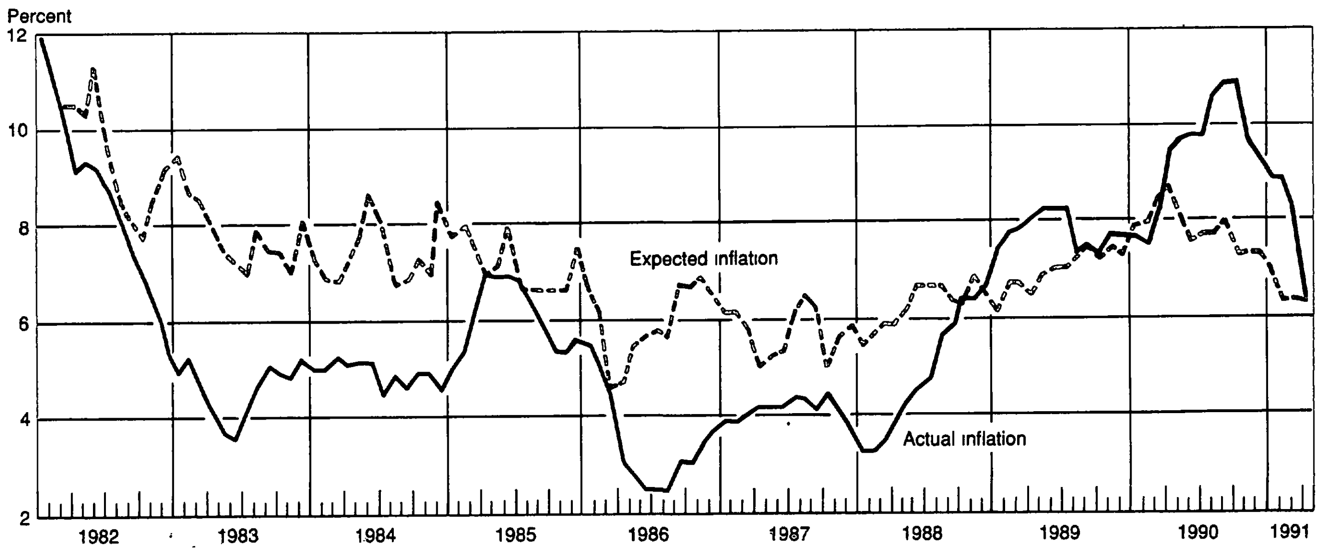
[14]Expectations of rising inflation could coincide with a monetary policy tightening if the tightening occurred at the same time as an exogenous increase in demand

[15]See, for example, Anthony Harris, "Lessons from the Indexed Decade," *Financial Times*, April 29, 1991

[16]A measure based on a shorter period of past inflation was not used because the RPI is not available on a seasonally adjusted basis

Chart 2

Actual versus Expected Inflation



Sources. Bank of England data and author's calculations.

Notes: Actual inflation is measured by the percentage change in the retail price index over the preceding twelve months Expected inflation is the measure derived from prices of index-linked gilts forecast of inflation over three horizons. twelve, twenty-four, and thirty-six months The results of this exercise, reported in Table 3, rely on two yardsticks of forecast accuracy: the root mean squared forecast error, which measures average predictive accuracy over the forecast period, and the regression coefficient of actual inflation on the measure of expected inflation, which measures bias—that is, the tendency to over- or underpredict persistently. The average rate of inflation over the past twelve months is the most accurate predictor, on average, of the level of inflation over all three horizons considered (it has the smallest root mean squared forecast error). Although by no means unbiased, it has the smallest bias; the regression coefficient of actual inflation on this measure is closer to unity at the one- and two-year horizons than are those on the other measures. The performance of the IG measure of expected inflation is significantly better (over all three horizons) than that of the average inflation rate over the past thirty-six months and similar to that of the average inflation rate over the past twenty-four months Note, however, that the IG measure is only moderately inferior to the best of the autoregressive measures (the twelve-month measure). For example, the root mean squared forecast errors indicate that about two-thirds of actual inflation rates over a one-year horizon will lie no further than 2.42 percentage points from the rate predicted on the basis of the past twelve months' inflation, and no further than 2.79 percentage points from the rate predicted by the IG measure.

It should come as no surprise that the IG measure fares no better than recent inflation in forecasting future inflation As Chart 2 shows, the IG measure is a biased predictor of inflation, exceeding the actual inflation rate over most of the sample period [17] A plausible interpretation of the upward bias in the IG measure of inflation expectations in the early part of the sample is that the U K monetary authorities were not credible in the early eighties. After a long period of fairly high inflation, several years of low inflation might have been necessary to convince market participants that the monetary authorities would maintain noninflationary policies. Alternatively, the bias may simply reveal that the IG measure is flawed.

One might ask whether the IG measure, if purged of bias, would predict inflation over a policy-relevant horizon more accurately than would naive measures based on past inflation Using the monthly change in the IG measure, rather than its level, to forecast future inflation

[17]The poor forecasting performance of the IG measure relative to autoregressive measures is also to be expected from a purely statistical viewpoint The RPI inflation rate is nonstationary, that is, changes in the inflation rate tend to be permanent and consequently the inflation rate does not tend to return to its long-run average after a change Under these conditions, inflation over the recent past will generally be the best simple predictor of future inflation Note, however, that using past inflation as a predictor of (the level of) inflation over longer horizons results in large expectations errors That is, the variance of the forecast error, conditional on information available at the time the forecast is formed, is proportional to the length of the forecast horizon Similarly, if the IG measure were an accurate predictor of future inflation, it would tend to move very closely with current inflation Thus, from a purely statistical viewpoint, it might be considered surprising that the IG measure does not respond one-to-one to changes in actual inflation

Table 3

Comparison of Indexed Gilt Measure and Naive Autoregressive Measures of Expected Inflation

Root Mean Squared Forecast Errors (Percentage per Year)

	Forecast Horizon		
Measure of Expected Inflation	One Year	Two Years	Three Years
IG measure	2.79	2.73	2.78
Inflation over past twelve months	2.42	2.41	2.52
Inflation over past twenty-four months	2.81	2.77	2.77
Inflation over past thirty-six months	3.58	3.57	3.57

Regression Coefficient of Actual on Expected Inflation

	Forecast Horizon		
Measure of Expected Inflation	One Year	Two Years	Three Years
IG measure	−0.07	−0.37	−0.44
Inflation over past twelve months	0.26	0.00	−0.32
Inflation over past twenty-four months	−0.02	−0.24	−0.28
Inflation over past thirty-six months	−0.18	−0.20	−0.16

Note Sample periods are as follows March 1982 to July 1990 for one-year forecasts, March 1982 to July 1989 for two-year forecasts, and March 1982 to July 1988 for three-year forecasts.

will eliminate bias that remains constant over time But if the bias is in fact due to credibility problems, it has probably decreased over time, and consequently some bias is likely to remain in the data. Nevertheless, unless one knows the process whereby market participants change their views on the credibility of the monetary authorities, any method of eliminating bias will be imperfect. The results in Table 4 suggest that when purged of bias in this manner, the IG measure does marginally better than simple autoregressive measures in predicting future acceleration and deceleration of inflation. The table compares the performance of the monthly change in the IG measure in forecasting the change in the RPI inflation rate over the following twelve months with that of four naive autoregressive measures the changes in the RPI inflation rate over the preceding one-, three-, six-, and twelve-month periods [18] The monthly change in the IG measure is not only the most accurate predictor, on average, of the RPI inflation rate (it has the smallest root mean squared forecast error), but it is also appreciably closer than the naive measures to offering an unbiased forecast of changes in the RPI inflation rate (the regression coefficient of actual on predicted changes is the closest to unity).[19] It should be emphasized, however, that the difference in the forecasting performance of the IG measure and the change in the RPI inflation rate over the preceding month is so small as to be of no practical significance. Over longer data samples or different time periods, the ranking of the two measures could easily be reversed.

The preceding comparisons of the IG measure and naive autoregressive measures of expected inflation were designed to show whether the IG measure is a better predictor of inflation than are simple alternatives. The predictive value of the IG measure of expected inflation can also be assessed by determining whether it provides information that improves the forecasting ability of an autoregressive model based on past inflation The test results reported in Table 5 provide evidence that the additional information contributed by the IG measure, while statistically significant, is too marginal to be of practical use The test evaluates whether the IG measure of expected inflation can predict changes in the RPI inflation rate, measured as the monthly percentage change in the RPI, once thirteen lagged changes in the inflation rate (and seasonal dummies) have been taken into account in forming the predictions. The first four lagged values of monthly changes in the IG measure of expected inflation are jointly statistically significant at the 2 5 percent level, and eight lagged values are jointly significant at the 10 percent level. However, the addition of eight lagged changes in the IG measure only raises the adjusted $\bar{R}^2$ of the forecasting equation from 0 8 to 0 82, too small an improvement to be of practical import. These results are not sensitive to the number of lagged changes in the inflation rate in the regression, although the number included (thirteen) is somewhat arbitrary In addition, the limited predictive value of the IG measure

[18]The twelve-month forecast horizon was chosen somewhat arbitrarily for illustrative purposes Although clearly of interest to policy makers, this horizon is not necessarily the most relevant

[19]Comparing the ability of alternative measures of inflation expectations to predict changes in inflation is also advisable on purely statistical grounds Because the inflation rate is nonstationary, the change in the inflation rate contains all the new information pertaining to the future course of inflation

Table 4
Forecast Performance for Changes in Retail Price Index Inflation: Comparison of Indexed Gilt and Naive Measures

Measure	Criterion of Forecast Accuracy: Root Mean Squared Error (Percentage per Year)	Regression Coefficient of Actual on Predicted Inflation
One-month change in IG Measure	2 34	0 69
One-month change in RPI inflation	2 37	0 32
Three-month change in RPI inflation	2 57	0 03
Six-month change in RPI inflation	2 95	−0 01
Twelve-month change in RPI inflation	3 53	0 03

Notes Changes in RPI inflation are measured as twelve-month changes in the twelve-month percentage change in the RPI Sample period is April 1982 to July 1990.

Table 5
Contribution of Indexed Gilt Measure in Predicting Monthly Changes in Inflation

Lags of IG Measure of Expected Inflation	$\bar{R}^2$	Marginal Significance† (F-Test)
None	0 80	—
One to four	0 82	0 024
One to eight	0 82	0 094
One to thirteen	0 81	0 146

Notes In the baseline regression, the monthly change in the RPI is regressed on thirteen own lags and a set of seasonal dummies Sample period is May 1983 to April 1991

†Measures the highest significance level at which one can reject the null hypothesis that the number of lagged changes in the IG measure of expected inflation does not contribute to forecasting the change in RPI inflation over the next month The confidence level in the null hypothesis is given by 1-marginal significance

may simply reflect the degree of predictability of the RPI that derives from purely mechanical aspects of its calculation. For example, changes in the banks' base interest rates have a foreseeable effect on mortgage interest rates because variable rate mortgages are the rule in the United Kingdom; consequently, these changes affect the RPI predictably through the effect of mortgage payments on the cost of housing.

Expected inflation and expected real interest rates as predictors of real economic activity

The IG market may convey information useful in the formulation of monetary policy even though the IG measure of expected inflation is no more successful in forecasting inflation than are simple measures based on past inflation. The IG measure may be an imperfect predictor of future inflation simply because it faithfully reflects the private sector's unrealized expectations of inflation. In this case, the IG market may provide policy makers with a reliable measure of ex ante real interest rates. If private sector spending is interest-sensitive, the market may also yield information about private sector spending plans and near-term economic developments. In sum, the IG measure of expected real long-term interest rates may be a potentially valuable indicator of macroeconomic developments.

One way to test the accuracy of the IG measure in gauging private sector inflation expectations is to determine whether the IG measure of ex ante real long-term interest rates provides information about future real economic activity. Compared with more direct tests such as correlating the IG measure with survey measures of inflation expectations, this test has a disadvantage: it can only provide information about the accuracy of the IG measure as a yardstick of private sector inflation expectations to the extent that private sector decisions are interest-sensitive. This shortcoming is also an important advantage, however, because the test measures the accuracy of the IG measure in terms of a goal variable of direct interest to policy makers. Furthermore, the test captures any potential leading indicator role of indexed bond prices and as such is of interest to policy makers.

To determine whether the indexed gilt market provides information about future real economic activity, real GNP growth is regressed on lagged GNP growth and various nominal interest rates and inflation rate measures, including those obtained from index-linked gilts. The results from these regressions are probably best appreciated in the context of the stylized facts established by similar regressions on U.S. data. In particular, although U.S. real GNP growth is typically very difficult to predict, Estrella and Hardouvelis and Stock and Watson have found that short-term nominal interest rates and measures of the slope of the term structure convey information about future movements in

Table 6

Predictive Value of Nominal Interest Rates for Real GNP Growth in the United States and the United Kingdom

	United States		
	Four Lags of		
Statistic	Real GNP Growth	Ten-Year Government Bond Yield	Six-Month Commercial Paper Rate
F	0.99	3.61***	6.48***
LR	4.27	15.04***	26.00***
$\bar{R}^2$	0.27		
	United Kingdom		
	Four Lags of		
Statistic	Real GNP Growth	Ten-Year Government Bond Yield	Three-Month Interbank Rate
F	3.45**	1.20	2.44*
LR	14.38***	5.35	10.65**
$\bar{R}^2$	0.12		

Notes. Sample period for the United States is 1954-II to 1991-I, for the United Kingdom, 1965-I to 1991-II. F and LR are the F statistic and likelihood ratio statistic for testing the null hypothesis that a particular variable has no explanatory power for future real GNP growth in a regression including the listed variables as regressors. One asterisk denotes significance at the 10 percent level, two, significance at the 5 percent level, and three, significance at the 1 percent level.

Interest rates are measured as quarterly averages of month-end observations. GNP growth is measured as quarterly percentage changes seasonally adjusted at an annual rate.

real output.[20] Table 6 provides benchmark regression results illustrating the predictive value of nominal short- and long-term interest rates for U.S. real GNP growth. It also shows that nominal interest rates are less informative in the United Kingdom than in the United States.

Results for the United Kingdom spanning the period since the inception of the index-linked market are presented in Table 7. The table illustrates how adding different variables in an equation to forecast real GNP growth affects the adjusted R^2 of the equation. Note that the components of the real interest rate are added separately, in part because the hypothesis that the nominal rate and the inflation rate have coefficients equal but opposite in sign is generally rejected by the data. The regression results support three specific conclusions: First, U.K. real GNP growth, like its U.S. counterpart, is hard to predict, but in contrast to the U.S. experience, long- and short-term nominal interest rates (and by implication measures of the slope of the term structure) do not forecast future movements in real GNP (columns 1 and 2). Second, the decomposition of long-term nominal rates based on indexed gilt prices provides no significant information about future real GNP growth in the United Kingdom. (The adjusted R^2 of the forecasting equation actually falls when the IG measure of expected inflation is added to the forecasting equation.) Finally, backward-looking measures of short- and long-term real interest rates, often used as indicators of the stance of monetary policy, do yield significant information about future real economic activity. Four lags of the three-month interbank rate together with four lags of the RPI inflation rate (the percentage change in the RPI over the preceding twelve months) raise the adjusted R^2 of a regression of real GNP growth on four lagged values of real GNP growth from 0.16 to 0.55 (column 4).

[20]See Arturo Estrella and Gikas Hardouvelis, "Possible Roles of the Yield Curve in Monetary Policy," *Intermediate Targets and Indicators for Monetary Policy*, Federal Reserve Bank of New York, New York, 1990, and James H Stock and Mark W Watson, "The Business Cycle Properties of Selected U.S Economic Time Series, 1959-1988," National Bureau of Economic Research, Working Paper no. 3376

Table 7

Predictive Value for Future Real GNP Growth: Comparison of Indexed Gilt and Other Variables

Four lags of	Regression Number			
	(1)	(2)	(3)	(4)
Real GNP growth	X	X	X	X
Long-term government bond yield		X	X	X
Three-month interbank rate		X	X	X
IG measure of expected inflation			X	
Twelve-month change in RPI				X
$\bar{R}^2$	0.16	0.17	0.14	0.55
Standard error	2.69	2.67	2.72	1.97

Note: Sample period is 1983-II to 1990-IV.

The results reported here show that the prices of index-linked gilts do not convey policy-relevant information about future trends in economic activity. If we accept that private sector decisions are sensitive to real interest rate movements, the results imply that the IG measure of ex ante real long-term interest rates does not accurately reveal real interest rates faced by the private sector. The limitations of the IG measure of expected inflation as a gauge of private sector inflation expectations could be due to any of three causes. First, limited participation in the U.K. indexed gilt market may have made the IG real interest rate relevant to only a very small part of the private sector. Second, the expected rate of inflation and the corresponding real interest rate in the bond market may not be relevant to the majority of participants in the goods and factor markets. Finally, the poor performance of the IG measure of expected inflation may derive from tax distortions or the fact that market participants are risk averse.

Two caveats to these conclusions deserve mention, however. First, the predictive power of IG prices will depend on the monetary policy rule followed by the authorities. If the Bank of England were stabilizing real interest rates, one would not expect the IG measure of the real interest rate to have predicted real GNP changes. Second, the conclusions are tentative, because the U.K experience with indexed bonds is comparatively short. The addition of only a few years' data may very well lead to conclusions more favorable to the position held by proponents of indexed bonds.

Conclusion

This article has used data from the U.K. market for index-linked gilts to assess the alleged policy benefits of indexed bonds. It has been suggested that a real-time market measure of expected inflation (and the corresponding ex ante real interest rate) derived from indexed bond prices could provide the Federal Reserve System with valuable information about market perceptions of, and reaction to, its policies, and convey information about future inflation and real economic developments. The evidence presented in this article, however, suggests that the prices of index-linked gilts may not convey much information about future inflation and real economic activity. For this reason, authorities may question whether a real-time market measure of expected inflation can shed light on private sector reactions to monetary policy.

The ability of the IG measure of expected inflation to anticipate future inflation developments appears to be, at best, mixed. It is a biased predictor of future inflation, fares no better than simple inflation expectations measures based on past inflation, and does not add appreciably to the predictive power of a more sophisticated backward-looking model of inflation expectations.

U.K. indexed bond prices also do not seem to convey policy-relevant information about future real economic activity. This finding is consistent with the IG measure's being an imperfect gauge of private sector inflation expectations and with the failure of the corresponding real interest rate to reflect accurately ex ante real interest rates faced by the private sector. The behavior of the IG measures of expected inflation and the real long-term interest rate during the period of restrictive monetary policy from mid-1988 to late 1990 further supports this judgment. In sum, these results suggest that the U.K. IG measure of inflation expectations seems to offer only limited, if any, information for the conduct of monetary policy.