How Important Is the Inflation Risk Premium?

By Pu Shen

Investors and market analysts generally believe that the yield on a nominal bond includes an inflation risk premium to compensate investors for bearing the inflation risk associated with the bond. Knowing how much of a risk premium investors require on nominal bonds can be valuable information for policymakers. For government Treasuries, the size of the risk premium represents the potential interest savings for governments when nominal securities are replaced with real, or inflation-indexed, securities. And, because the inflation risk premium reflects perceived inflation uncertainty, changes in the size of the risk premium can reveal to monetary policymakers how credible their policy actions are in the marketplace. Unfortunately, empirical evidence on the actual size of the inflation risk premium and its response to market events is scarce.

To address these empirical shortcomings, this article uses data from the United Kingdom, where about 20 percent of outstanding government debt is in the form of real bonds. The first section shows why investors require an inflation risk premium on a nominal bond and how the premium varies with the bond's maturity. The second section estimates the average sizes of the inflation risk premium for different maturities of nominal bonds in the UK market. The third section examines how the inflation risk premium on UK bonds changed in the fall of 1992, a time when the government suspended its membership in the European Exchange Rate Mechanism and the monetary authorities adopted explicit inflation targets.

The article finds that the inflation risk premium in nominal government bonds is sizable. It also finds that information regarding the inflation risk premium may give useful insight to monetary policymakers. In particular, changes in the estimated inflation risk premium in the UK in the second half of 1992 suggest that the announcement of an explicit inflation target did not gain instant credibility with financial market participants.

I. WHAT IS THE INFLATION RISK PREMIUM?

Economic theory tells us that, in general, the real value of a nominal bond declines when inflation increases unexpectedly. Because most investors do not like this uncertainty, they require compensation for bearing the inflation risk in the form of an additional yield on a nominal bond. This additional yield is called the inflation risk premium. Further, because inflation

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uncertainty generally increases with the maturity of a nominal bond, the size of the risk premium should increase with its maturity.[1]

Investors in nominal bonds bear inflation risk

The real value of a nominal bond declines when inflation increases because the nominal values of its interest payments and principal are fixed when the bond is issued. Thus, in terms of real purchasing power, payments to bondholders decrease when inflation rises and increase when inflation falls. In other words, the real yield on a nominal bond varies inversely with inflation: the real yield is equal to the nominal yield of the bond less the average inflation rate during the life of the bond.

An example shows how inflation uncertainty exposes investors in nominal bonds to inflation risk.[2] If the nominal yield on a 30-year U.S. Treasury bond ($y^{nominal}$) is 5.5 percent and the average inflation rate (π) for the 30 years is 2 percent, then the real yield (y^{real}) for an investor holding this bond to its maturity will be 3.5 percent:

$$y^{real} = y^{nominal} - \pi = 5.5 - 2 = 3.5.$$

If inflation over the 30 years averages 3 percent, then the real yield of this bond will be reduced to 2.5 percent (5.5 - 3). On the other hand, if actual inflation for the 30-year period turns out to be only 1 percent, the real yield of the bond will increase to 4.5 percent (5.5 - 1). This example shows that even though government bonds in industrialized countries are generally free from credit risk, they are still embedded with inflation risk.[3]

The compensation for bearing inflation risk is the inflation risk premium

Because investors are generally risk averse, an asset with uncertain future returns is worth less than an asset that generates the same expected returns with certainty.[4] If a borrower issues two bonds with the same expected future real payments, investors will not be willing to pay as much for the bond with uncertain future payments as for the bond with certain future payments. Consequently, to attract investors, the bond with uncertain payments must offer investors a better price. In other words, investors require a higher expected return to compensate for the risk of uncertain future real returns.[5]

To illustrate, assume a retiree has $500,000 in savings with an investment goal of preserving the purchasing power of the principal and consuming all investment income. If the retiree invests in a real government bond with a 4 percent real yield, she knows that she can spend all the interest income from the bond, which will be a constant $20,000 ($500,000 multiplied by 4 percent) per year in terms of real purchasing power. She also knows that her principal will remain at $500,000 in terms of purchasing power, regardless of the actual inflation level. By contrast, if she invests in a nominal government bond with a 6 percent nominal yield, then she will have to adjust her consumption according to actual inflation. If the actual inflation rate is 2 percent, the real yield on the bond will be 4 percent, which will allow the retiree to spend $20,000 per year in real terms. But if actual inflation for the year is 4 percent, she will only be able to spend $10,000 in real terms that year because the real yield on her nominal bond will be only 2 percent. Further, because our retiree typically knows the actual inflation rate only with a time lag, she may find herself having consumed too much or too little in hindsight.[6] Consequently, even if our retiree expects average inflation for the life of the bond to be 2 percent, which means the real yields on both bonds are *expected* to be the same, the nominal bond will be less attractive to her because of its uncertain real yield.

For this reason, our retiree will invest in the nominal bond only if it offers an expected yield higher than 6 percent. Using similar notations as before, let $y^{nominal}$ be the nominal yield on a nominal bond, y^{real} the real yield requested by investors, and π^{expect} the expected average future inflation for the life of the bond. Then typically,

$$y^{nominal} > y^{real} + \pi^{expect}.$$

If our retiree decides that a half percentage point in additional expected yield is enough compensation for the risk, and she is representative of general investors, then the market price for the nominal bond will be such that the nominal yield of the bond will equal 6.5 percent. That is, the inflation risk premium for this particular bond is 0.5 percent. Thus, there are three components in the nominal yield of a nominal bond:

$$y^{nominal} = y^{real} + \pi^{expect} + RP,$$

with *RP* being the inflation risk premium.

The inflation risk premium tends to increase with maturity

The inflation risk of a nominal bond, and hence its inflation risk premium, tends to increase with the maturity of the bond for two reasons. First, it is usually more difficult to forecast inflation in the distant future.[7] In the short term, the level of inflation is heavily influenced by past levels of inflation and the recent history of monetary policy. In the long term, average inflation is primarily determined by the stance of monetary policy, which is determined by both monetary policymakers and, ultimately, in a democratic society, the public support for controlling inflation. Public support is more difficult to forecast because it is influenced by many factors, some of which are not directly related to monetary policy, such as demographic changes, the distribution of net debtors and creditors, and the level of fiscal deficit and debt. Consequently, while recent history of inflation and monetary policy can help forecast inflation for the next few years, their usefulness diminishes as the forecasting horizon increases. Because forecasting future inflation is a key factor when investors determine the appropriate nominal yield of a bond, the longer the forecast horizon is, the more likely it is that forecasts will be wrong.

Second, inflation risk increases with the maturity of a bond because the same magnitude of forecast error results in a larger cost to investors in long-term bonds than in short-term bonds. For example, assume investors expect future inflation to average 2 percent. If an investor buys a $1,000 nominal bond with a maturity of one year and a nominal yield of 5 percent, she will get $1,050 at the end of the year, which, when adjusted for inflation, will be roughly $1,030 in real terms.[8] However, if actual inflation turns out to be 3 percent, the real purchasing power of the $1,050 will be only $1,020. Thus, the cost to the investor due to her mistake in forecasting future inflation is $10. In contrast, if she buys a 10-year nominal bond with a 5 percent annual yield, the same error of underpredicting inflation by one percentage point will cost her $10 every year for the next ten years.[9]

II. ESTIMATING THE INFLATION RISK PREMIUM USING UK DATA

Governments in many industrialized countries have accumulated huge amounts of debt due to years of deficit spending. For example, the U.S. government currently has more than $5 trillion of debt.[10] Almost all government debt is financed with nominal bonds. In the United Kingdom, however, the government has been issuing real bonds, or inflation-indexed gilts, since 1981. Today, about 20 percent of the outstanding UK government debt is in the form of real bonds. Australia, Canada, France, Sweden, and the United States have also begun to issue some form of real bonds (usually called indexed bonds), but such bonds form only a miniscule portion of their total outstanding government debts.[11]

The presence of real bonds makes it possible to estimate the inflation risk premium in nominal bonds. As shown earlier, the yield on a nominal government bond includes at least three components: the real yield required by investors, the average future inflation expected by investors, and the inflation risk premium required by investors. With both nominal and real government bonds being actively traded in the financial markets, the nominal and real yields can be directly observed from the bond markets.[12] The difference in the yields of nominal and real bonds, therefore, is simply the sum of expected inflation and the inflation risk premium. For example, if we observe that the market yield for a 10-year real government bond is 3.5 percent, then it is reasonable to assume the real yield component in a 10-year nominal government bond is also 3.5 percent. Thus, if we also observe that the market yield for the 10-year nominal government bond is 6 percent, we know the yield difference of 2.5 percent between the nominal and real bonds should be the sum of only two components: expected future inflation and the inflation risk premium.[13] Therefore, if we can separate the expected future inflation component, the remaining part of the yield difference will be the inflation risk premium in the nominal bond.

In theory, we could use data on the nominal and real U.S. Treasury securities and inflation expectations to estimate the inflation risk premium in nominal U.S. government bonds.[14] However, the results would be unreliable because the market for real bonds in the United States is quite new and it takes time for investors to understand new instruments. In particular, two factors may affect yields on U.S. real bonds differently from yields on nominal bonds. One factor is that the real bond market is still small and not very liquid. In comparison, the nominal U.S. Treasury bond market is one of the largest and most liquid markets in the world. Therefore, the yield on the real bond is likely to include a sizable compensating liquidity premium. The other factor is that the current participants in the real bond market may be quite different from the participants in the nominal bond market. Because real bonds are relatively new in the United States, it is likely that investors who venture into the new market are relatively more sophisticated or have different risk preferences than traditional bond investors. These differences are sometimes called the clientele effect, meaning that comparison across markets might be less informative because the two markets serve different clientele.[15]

Recent data from the UK nominal and real government bond markets, however, are less likely to suffer the same limitations because inflation-indexed gilts have existed there since 1981. Presumably, UK investors have gained enough experience and knowledge with real bonds so that the yield difference between the UK nominal and real government bonds should primarily reflect the fundamental factors of inflation expectations and the inflation risk premium. In other words, in the UK gilts market, it should be reasonable to assume that $y^{nominal} - y^{real} = \pi^{expect} + RP$. Therefore, this article will use recent data from the UK government bond markets to estimate the inflation risk premium embedded in nominal UK government bonds.[16]

Because yield differences of nominal and indexed government bonds are the sum of expected future inflation and the inflation risk premium, some assumptions must be made regarding inflation expectations in order to use the yield difference to estimate the inflation risk premium. This article uses two different types of assumptions about inflation expectations. First, the inflation expectation component is derived from surveys of inflation expectations. This approach assumes that inflation expectations according to survey data are the same as the inflation expectations embedded in the yield of nominal bonds. Second, the inflation expectation is derived by using the goal of the monetary authorities. That is, the expected inflation in the market yield of nominal bonds is assumed to be the same as the goal of the monetary authorities.

Table 1
RISK PREMIUM (1996-97)
Inflation expectations derived from survey data

Maturity (years)	Yield difference (1)	Average expected inflation (2)	Risk premium (3) = (1) – (2)
10	3.851	3.106	.74
15	3.995	3.104	.89
20	4.084	3.103	.98
25	4.146	3.103	1.04

Inflation risk premia using survey data on expected future inflation

One way to find out the inflation risk premium in nominal UK government bonds is to use survey data on expected future inflation to proxy the expected future inflation embedded in the nominal yields. This article uses the Consensus Forecasts of UK inflation expectations, published by Consensus Economics Inc., which are based on the average of survey results from roughly 30 financial institutions and forecast groups. The Consensus Forecasts include both forecasts of annual inflation rates for each of the next five years and a forecast of the average inflation rate for the period five to ten years ahead.

One problem with using the Consensus Forecasts is that they do not forecast beyond ten years in the future.[17] Hence, additional assumptions must be made about the path of inflation in the distant future. In this article, it is assumed that average expected inflation five to ten years ahead is the same as the average expected inflation for 10 to 15 years ahead, or 15 to 20 years ahead, and so on. That is, the forecast of the average inflation rate over the period five to ten years ahead is used as the expectation of the annual inflation rate for all periods beyond ten years.[18] Given these assumptions, the survey data can be used to calculate the expected inflation rate, π^{expect}, for any future period as the average of the annual expected inflation rates within the period.[19] Taking this as the proxy for the corresponding market expected inflation, π^{expect}, and subtracting it from $y^{nominal} - y^{real}$ gives the estimated inflation risk premium at the respective maturity.

Table 1 shows the estimated inflation risk premia on bonds with maturities of 10, 15, 20, and 25 years, using the Consensus Forecasts of inflation expectations. The data are market yields on nominal and indexed UK government bonds for 1996-97. This was a relatively calm period, both in terms of actual inflation and inflation expectations.[20] The average yield difference for 1996-97 was 3.851 percent for 10-year gilts, 3.995 percent for 15-year gilts, 4.084 percent for 20-year gilts, and 4.146 percent for 25-year gilts, as shown in column 1. In other words, the yield difference curve was upward sloping.

Column 2 of Table 1 shows the expected average inflation rates for the periods 10 years, 15 years, 20 years, and 25 years ahead. These inflation rates are calculated by averaging the annual expected inflation for each time period. The annual expected inflation for the first five years is reported in the Consensus Forecasts, and the annual inflation rates beyond five years are assumed to be the same as the forecast for average inflation for five to ten years ahead. Because inflation expectations are basically constant after five years, the main difference in the average expected inflation rates for the periods in

Table 2
RISK PREMIUM (1996-97)
Inflation expectations derived from the goal of monetary authorities

Maturity (years)	Yield difference (1)	Average expected inflation (2)	Risk premium (3) = (1) – (2)
10	3.851	2.525	1.33
15	3.995	2.517	1.48
20	4.084	2.512	1.57
25	4.146	2.510	1.64

Table 1 is the relative weights of the inflation rates in the first five years, which decrease as the period becomes longer.

Once average expected inflation for each maturity, π^{expect}, is determined, the inflation risk premium component in the yields of the nominal gilts can be calculated simply by subtracting π^{expect} from the yield difference. Consequently, the inflation risk premium is roughly 0.74 percent for 10-year gilts, 0.89 percent for 15-year gilts, 0.98 percent for 20-year gilts, and 1.04 percent for 25-year gilts, as shown in the column 3 of the table. Because the average expected inflation rates for long periods are fairly stable, the increases in the yield differences primarily reflect increases in the inflation risk premium.[21]

Inflation risk premia based on the goal of the monetary authorities

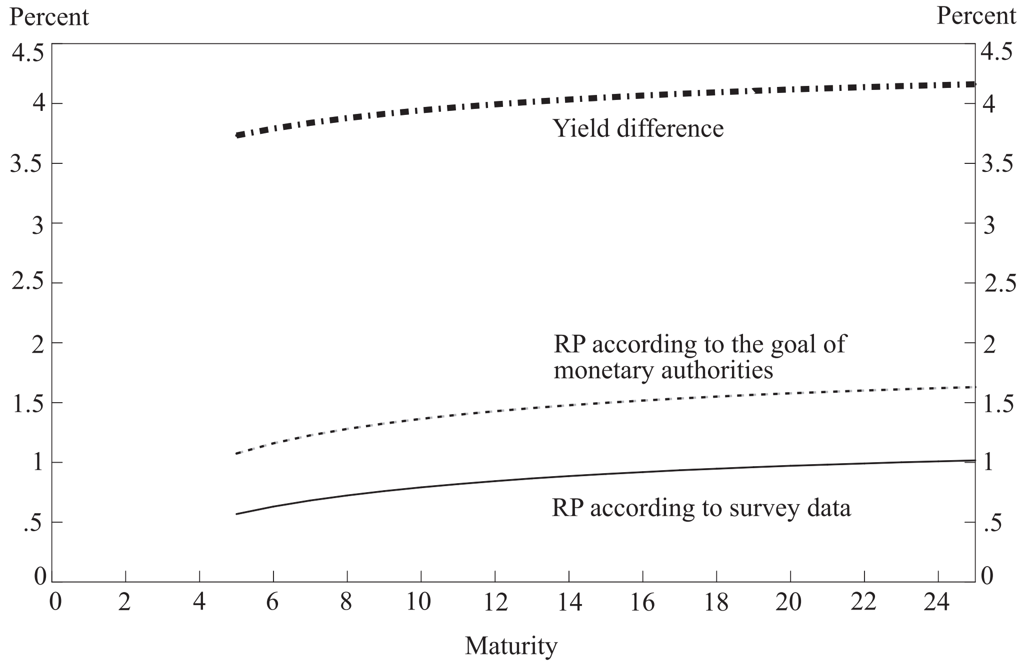
The expected future inflation based on survey data may not be the best proxy for the expected inflation embedded in the nominal yields. Survey forecasts reflect the opinion of a small group of experts, but the actual inflation expectations embedded in the nominal yields reflect the average opinion of millions of investors. An alternative way to specify the inflation expectations in the distant future is to use the goal of the monetary authorities as the inflation expectations of the market.

Under this approach, it is also necessary to specify when and how inflation will converge to its long-run target level. One possibility is to assume that the market expects annual inflation to converge linearly from its current level to the long-run goal of the monetary authorities in five years.[22] Just as before, the average expected inflation for a given maturity is then the average of the annual expected inflation.

Table 2 presents estimates of the inflation risk premia using these alternative assumptions. In particular, the long-term convergent level of inflation is assumed to be equal to the Bank of England's targeted inflation level of 2.5 percent.[23] Column 2 shows average expected inflation rates for maturities of 10, 15, 20, and 25 years. Average inflation rates are higher than 2.5 percent for all maturities because the actual inflation at the beginning of the period was higher than 2.5 percent.[24] Using this scenario of expected inflation, the inflation risk premium is higher: 1.33 percent for the 10-year gilts, 1.48 percent for 15-year gilts, 1.57 percent for 20-year gilts, and 1.64 percent for 25-year gilts.[25]

Chart 1 summarizes Tables 1 and 2. The top curve of the chart is the yield differences for maturities from 5 to 25 years. The bottom two curves show the inflation risk premia at these maturities. The curve derived from survey data lies below the curve derived from assuming credible monetary policy. Both are upward sloping,

Chart 1
YIELD DIFFERENCES AND INFLATION RISK PREMIUM (RP)



reflecting a positive relationship between the inflation risk premium and the maturity of the bond.

Implications for policymakers

In general, the UK data suggest that the inflation risk premium can be sizable. The inflation risk premium for 10-year nominal gilts is likely to be in the range of 0.7 to 1.4 percentage points; for 20-year gilts the range is likely to be between 1 to 1.6 percentage points. Such a sizable inflation risk premium has important implications to both fiscal and monetary policymakers.

For fiscal policymakers, the size of the inflation risk premium implies that a government can generally save interest expenses by increasing the proportion of its debt in real bonds. For example, if the UK government were to switch an additional billion pounds of outstanding debt from nominal 20-year gilts to indexed 20-year gilts, it would save around 10 to 16 million pounds of interest payment annually.[26]

For monetary policymakers, the size of the inflation risk premium is closely tied to the perceived uncertainty of future inflation in the marketplace. Because the stance of monetary policy determines the average inflation rate in the long term, the size of the inflation risk premium in long-term bonds is closely tied to the market's belief of how committed the country's monetary authorities are in controlling long-term inflation.[27] Thus, the size of the inflation risk premium in long-term nominal bonds is a measure of the credibility of the monetary authorities.

In the case of the United Kingdom, the implication from the estimates of inflation risk premia is that the credibility of its monetary authorities is still limited. The UK monetary authorities have been announcing explicit inflation targets since the fall of 1992. For the time period studied here, 1996-97, the targeted level was commonly regarded as 2.5 percent. Nevertheless, the Consensus Forecasts of long-term inflation were usually higher than 2.5 percent. Further, even if one is willing to disregard survey forecasts and assume that inflation expectations built into the market yields converge to the inflation target, this still suggests that the inflation risk premia on gilts with maturities of at least ten years are more than 1.33 percent. This is a sizable premium in the sense that it is about half of the target level of inflation. In other words, if market participants believe the UK monetary authorities will try to keep inflation at the target level, they probably also believe the probability is high that monetary policymakers will miss their target.[28]

III. HOW DID THE INFLATION RISK PREMIUM RESPOND TO THE INTRODUCTION OF INFLATION TARGETING?

Knowing the size of the inflation risk premium can help monetary authorities gauge how credible their commitment to controlling inflation appears to the public. In particular, changes in the size of the inflation risk premium largely reflect changes in the perceived uncertainty about future inflation by market participants, which in turn reflects the credibility of monetary policy. For example, an increase in the inflation risk premium may suggest there is increasing uncertainty about the monetary authorities' commitment to their policy goals. If the monetary policymakers can ascertain this information promptly, they may be able to reduce such uncertainty by better communicating with the public or by taking more forceful actions in policy operations, or both. Therefore, the timely knowledge of changes in the inflation risk premium may help the monetary authorities reduce market uncertainty about future inflation and thus make monetary policy more efficient and effective.

This section will use data from the second half of 1992 in UK government bond markets to show how the inflation risk premium changed in response to changes in the framework of monetary policy in the UK. The data suggest that the inflation risk perceived by financial market participants increased substantially in the transition period, and that the introduction of inflation targeting did not gain immediate credibility.

The framework for monetary policy in the UK changed significantly during the second half of 1992. At the beginning of the period, the UK was a member of the Exchange Rate Mechanism (ERM) for the European Monetary System and was expected to remain a member. Because investors generally believed that for the ERM to be successful, the long-run average inflation rates of its member countries had to be close to the long-run average inflation rate of Germany, the credibility of the UK monetary policy depended critically on its foreign exchange policy. In particular, if investors then believed the UK would remain in the ERM, they would also believe that the long-term inflation rate for the UK would converge to the long-term inflation rate in Germany.[29]

This framework changed dramatically when the UK government announced its decision to withdraw its ERM membership on September 16, 1992. Then, in the following month, for the first time in its history the UK monetary authorities announced an explicit inflation target. If the new framework of inflation targeting had been credible, the market would have expected, *with little uncertainty,* the long-run inflation rate to move toward the target level, which was regarded by most market participants as 2.5 percent.[30]

Chart 2
YIELD DIFFERENCE, EXPECTED INFLATION, AND RISK PREMIUM AT 10-YEAR MATURITY

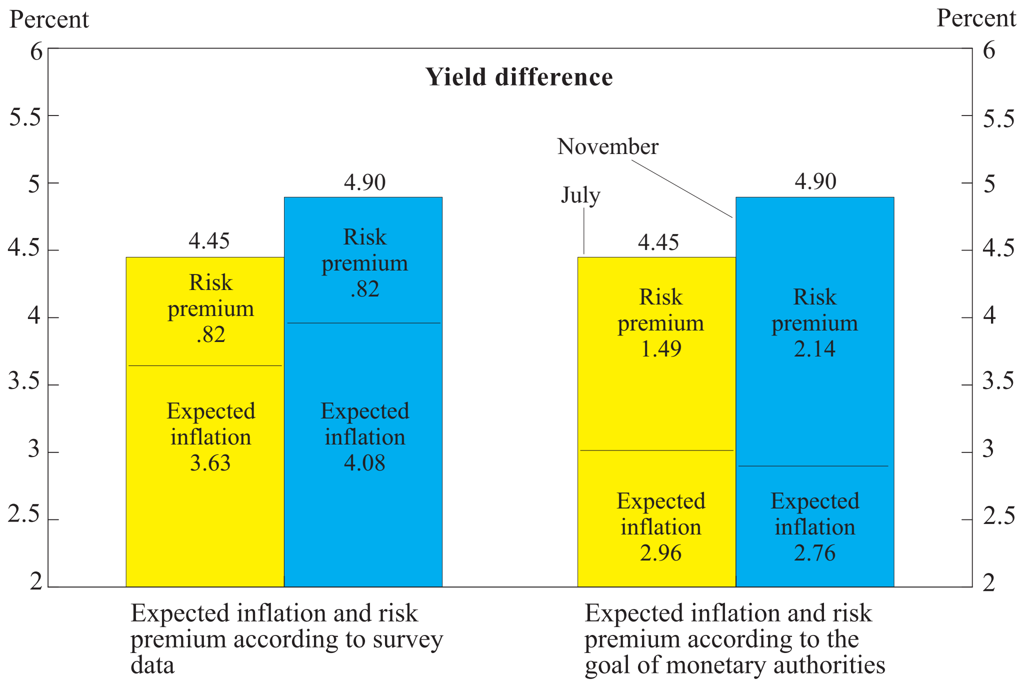
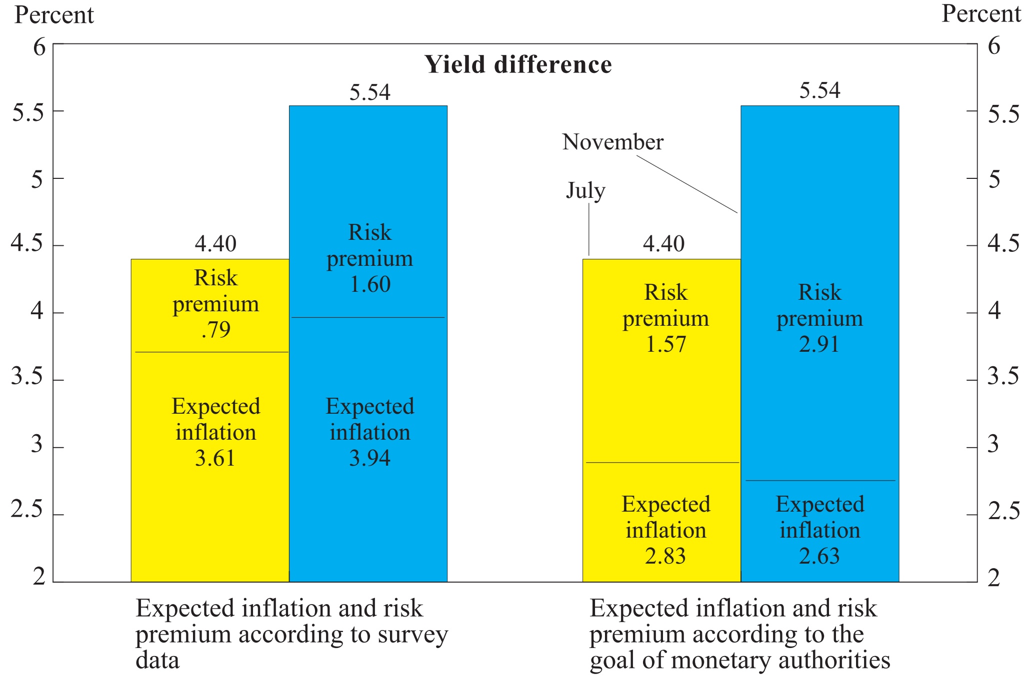


Chart 2 shows how expected inflation and the inflation risk premium changed for 10-year nominal gilts in the second half of 1992. As shown by the height of the bars, the yield difference between the nominal and real gilts increased substantially between July and November, rising by nearly a half percentage point. Because the yield difference is the sum of expected future inflation and the inflation risk premium, its increase suggests that at least one of its two components, or possibly both components, had increased. Decomposing the yield difference according to survey data suggests that the increase in the yield difference was attributable mostly to the increase in the expected future inflation rate.[31] On the other hand, decomposing the yield difference using the targeted level of 2.5 percent of the monetary authorities suggests that the increase in the yield difference was due entirely to the increase in the inflation risk premium.

Chart 3 shows the values of similar variables for the 20-year maturity. The yield difference at this maturity increased even more dramatically between the end of July and November, rising by more than a full percentage point. Further, both methods of decomposition of the yield difference for the 20-year maturity suggest sizable increases in the inflation risk premium. Taken together, Charts 2 and 3 suggest that the change in the framework of monetary policy was accompanied by an increase in inflation risk in the market, and that the introduction of inflation

Chart 3
YIELD DIFFERENCE, EXPECTED INFLATION, AND RISK PREMIUM AT 20-YEAR MATURITY



targeting did not immediately reduce inflation uncertainty.[32]

IV. SUMMARY AND CONCLUSIONS

This article provides estimates of the sizes of inflation risk premia using yield data in the UK government bond markets. It suggests that in general there are sizable inflation risk premia in nominal government bonds. For example, the inflation risk premium in 20-year UK nominal gilts has been in the range of 1.0 to 1.6 percentage points in recent years.

The article also shows that information regarding the inflation risk premium may provide useful insight to monetary policymakers. In particular, movements in inflation risk premia suggest that the perceived inflation uncertainty increased at the transition period when the framework of UK monetary policy was changed. Further, the introduction of inflation targeting did not immediately reduce inflation uncertainty in the marketplace, which is consistent with the general view that it takes time for inflation targeting to gain credibility with the public.

ENDNOTES

[1] To be exact, the inflation risk premium of a nominal bond tends to be more closely related to its duration than maturity. Ignoring this distinction will not be a problem in the empirical analysis, as the data are all in the form of zero-coupon equivalent bonds, for which maturity and duration are the same. For simplicity of exposition, the term maturity will be used throughout the article.

[2] The words "risk" and "uncertainty" in the article are largely interchangeable. There are no fundamental distinctions as defined by Frank Knight (1921) intended here.

[3] While all nominal bonds have inflation risk, this article will focus the discussion on government bonds in industrialized countries since they are considered to be free from default risk; thus the inflation risk is the major risk in these bonds. In contrast, corporate bonds and government bonds from emerging markets usually also have default risk; thus the risk premium in these bonds will have to cover both inflation risk and default risk.

[4] Even risk-neutral investors may not like uncertainty when it leads to "temporal risk." Temporal risk arises when investors have to take actions before the uncertainty is resolved. Even risk-neutral investors will not like temporal risk because the optimal action *ex ante* may not be optimal *ex post*. For example, suppose a consumer shopping for a holiday vacation likes two vacation packages equally—one to a Rocky Mountain ski resort, the other to Florida beaches. Say each will cost $2,000, but she will only need to pay $1,990 if she is willing to take the outcome of a coin toss between the two at the time of purchase. A risk-neutral consumer will take the deal with the coin toss because it is cheaper. Nevertheless, she is not likely to take the deal if she is told that she will not know the result of the coin toss until the night before the vacation starts. The reason is that she needs to pack for the vacation and not knowing which vacation she needs to pack for well in advance is costly.

[5] In a world with many financial assets, independent idiosyncratic risk can be diversified away. That is, investors can assemble a portfolio that can deliver the expected return with almost certainty. Therefore, in the real world, only risks that are correlated and thus cannot be diversified away will be compensated. Inflation risk is one of such risks.

[6] There is also the logistical inconvenience of having to reinvest some of the nominal interest income to keep the principal intact in terms of purchasing power.

[7] The time horizon here is generally in terms of years. In terms of months, it may be easier to forecast inflation for 12 months ahead than for the next month. The reason is that, on a monthly basis, some random events may have a huge effect on the aggregate price level, but such random effects are more likely to cancel each other out on an annual basis.

[8] For simplicity, assume the bond is bought at par.

[9] Even if the investor tries to sell the bond before its maturity once it is obvious that the forecast is wrong, she will still suffer the same loss because the market price of the bond will then be well below par to account for the much lower expected real yield over the remaining life of the bond.

[10] The outstanding federal debt was close to $5.6 trillion at the end of June 1998. The federal debt is the total accumulation of past budget deficits. Even though the consolidated budget deficit in the United States has turned to surplus for fiscal year 1998, the accumulated outstanding debt is still significant, equivalent to around 70 percent of the annual U.S. gross domestic product.

[11] For a more detailed discussion on U.S. indexed bonds, see Shen (1998).

[12] The discussion ignores the possibility that there may be a liquidity premium in the yields of real bonds. Because the nominal government bond market tends to be much more liquid than the real bond market, investors may require an additional premium in the yield of the real bond to compensate them for holding the less liquid asset. The issue of liquidity premium is also ignored in the estimation of the inflation risk premium but is discussed in endnote 26.

[13] Again, the market yields on both bonds should be their zero-coupon equivalent yields.

[14] Technically, U.S. Treasury securities with maturity from one year to ten years are called Treasury notes; only those with maturity above ten years are called Treasury bonds. For simplicity, they will all be called bonds in this article.

[15] These factors are likely to be temporary. The U.S. Treasury has committed to developing the indexed bond market. Thus, investors will understand the new securities and the new market better over time, which means the liquidity premium and the clientele effect are likely to decline. For a detailed discussion on the effects of liquidity, clientele, and taxes, see Shen (1995).

[16] The author is grateful to the Bank of England for providing the yield data. For details about the data, see Deacon and Derry (1994).

17 Many other surveys and forecasts, including those in the United States, also do not go beyond ten years.

18 This seems like a fairly reasonable assumption, especially for the time period used in this section (Tables 1 and 2). However, there are times when assuming constant future inflation appears somewhat questionable, and a different path of future inflation beyond ten years may be more appropriate. This article does not explore such alternatives.

19 For example, the average expected inflation for the period of 20 years will be equal to 1/20 x $(\pi_1^e + \pi_2^e + \pi_3^e + \pi_4^e + \pi_5^e + 15 \times \pi^e{}_{5-10})$. The subscripts 1 through 5 represent, respectively, expected annual inflation rates for years 1 through 5 ahead, and the subscript 5-10 represents the average expected annual inflation rate for the period 5 to 10 years ahead, as reported in the survey data.

20 The hidden assumption here is that the relationship between inflation expectations and the inflation risk premium is relatively stable during the period. Such an assumption may not hold if the time period is long because, over time, the size of the inflation risk premium is likely to change due to changes in expected future inflation, changes in the perception of the uncertainty about future inflation, or both. Consequently, it may not be meaningful simply to calculate the average of the inflation risk premium. This concern is the main reason that the article does not use all the data that are available. The author has repeated the estimation in Tables 1 and 2 with a longer time period, from January 1995 to April 1998, which is the last observation in the data set. The results are almost identical.

21 Notice that the increase of the inflation risk premium with maturity is consistent with the earlier theoretical discussion.

22 Assuming convergence in five years seems arbitrary. One way to think about the issue is that if the annual autoregressive coefficient of the inflation time series is 0.7, one percentage point of difference today will only be 0.17 percentage point of difference five years later, which is fairly small. Because the focus of the risk premium is for maturities of at least ten years, assuming slower convergence, such as convergence in ten years, gives very similar results. An alternative approach is to assume that the *average* inflation rate for the distant future will converge to the goal level of the monetary authorities, which implies that, in the long run, the monetary policymakers will overshoot and undershoot their goal with equal probabilities. This assumption tends to lead to a steeper sloped inflation risk premia for the UK data.

23 The exact meaning of the inflation target in United Kingdom has been changing over time. For a detailed discussion on the topic, see Bowen (1995) and Kahn and Parrish (1998).

24 For example, if the actual inflation rate at the beginning of the period was 3 percent, then the expected annual inflation would be 2.9 percent for one year ahead, 2.8 percent for two years ahead, 2.7 percent for three years ahead, 2.6 percent for four years ahead, and 2.5 percent for five years ahead and beyond. As a result, the average inflation rate for the entire period would be higher than 2.5 percent.

25 If we are also willing to assume that the inflation risk premium follows some particular functional form, we may be able to come to a tighter bound. For example, the slope of the inflation risk premium also provides useful information. It may be reasonable to assume that the slope of the inflation risk premium is positively related to the level of the inflation risk premium at a given maturity. Further, it may also be reasonable to assume that the inflation risk premium is likely to increase with the level of expected future inflation. In this article, neither of these possibilities will be explored.

26 In calculating the inflation risk premium, it is implicitly assumed that all other factors are negligible. In particular, the liquidity premium and tax distortions are ignored. As indexed gilts are traded less than nominal gilts, and thus are less liquid, there may be a liquidity premium in the yield of indexed gilts. Because such a liquidity premium is ignored, the estimated inflation risk premium may be understated. On the other hand, the tax code in the UK favors indexed gilts over nominal gilts. In particular, while the appreciation of the principals of indexed gilts is excluded from both income and capital gains taxes, all interest income in nominal gilts is subject to income taxes, including the part to cover expected inflation. Because such tax biases are not accounted for, the estimated inflation risk premium may be overstated. The overstatement, however, is likely to be limited because pension funds are major players in both nominal and real gilts markets, and pension funds are exempted from both income and capital gains taxes derived from gilts. Thus, the net effect of the liquidity premium and tax bias is likely to be small.

27 In the short term, inflation could be heavily influenced by factors not controlled by monetary policymakers, such as an oil crisis. In the long term, the average inflation rate is primarily determined by the stance of monetary policy.

28 The credibility of the monetary authorities can be characterized by the representative probability distribution that market participants attach to the average long-term inflation rate, which specifies the probability that the long-run average inflation will be in the target range. While a probability distribution can be described by its moments,

such as its mean, variance, skewness, etc., empirically, it is very difficult to separate shifts in the various moments. For example, the market yield data alone do not contain enough information to tell a shift in the mean from a shift in the variance of the probability distribution. Therefore, in the text, when survey data are not used, it is assumed that the monetary authorities' target is equal to the mean of the distribution. Under this approach, the probability that the monetary authorities will miss their target is mainly reflected in the variance of the distribution, which is captured by the risk premium.

[29] For a detailed discussion of the issue, see Bowen (1995), Kahn and Parrish (1998), and McCallum (1996). In the empirical calculations presented below, the future inflation rate for Germany is assumed to be constant for five years or beyond and equal to the Consensus Forecast for the five-to-ten-year average of 2.7 percent.

[30] In reality, the actual level of targeted inflation was somewhat complicated, as both intermediate and long-run targets were introduced. For details, see Bowen (1995).

[31] The level of expected future inflation, however, was much higher than the announced inflation target. Survey data could be somewhat misleading here as they were reported in October, which may have been collected before the announcement of the new framework of inflation targeting.

[32] It is not surprising that the inflation target at the end of November 1992 did not gain much confidence in the marketplace. In general, monetary authorities can only gain credibility by their consistent actions in controlling inflation. Announcements alone are not very useful. Further, setting up and announcing an explicit target level of inflation was a new experiment at the time and market participants had not had much experience with it. Table 2 used more recent data and confirmed the general view that the monetary authorities in the UK have gained considerable credibility with inflation targeting since 1992. As shown in the table, when the targeted level of inflation was used as the market expected inflation, the inflation risk premium was much smaller during the period of 1996-97.

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