Salomon Brothers

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Does Duration Extension Enhance Long-Term Expected Returns?

Understanding the Yield Curve: Part 3

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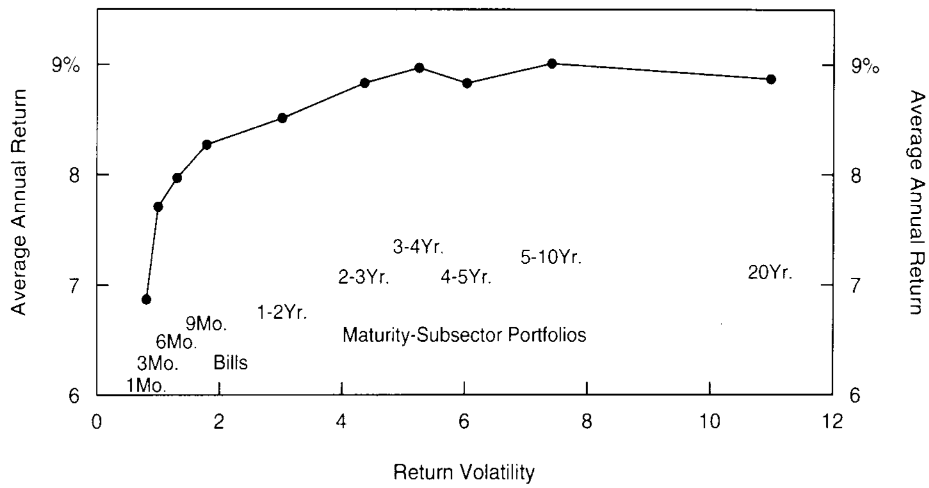
INTRODUCTION

Consider the situation of an investor — such as a central bank, a commercial bank, an insurance company, or a pension fund sponsor — that has **to choose the neutral benchmark duration for its U.S. dollar portfolio. This choice depends on the long-run reward-risk trade-off offered in the U.S. bond market** (as well as on the investor's investment horizon and risk tolerance) and not on any tactical interest rate views. Three directors of the investing institution meet to discuss their combined knowledge about the long-run bond risk premium. One director argues that the typical upward slope of the yield curve is evidence of a positive risk premium. Another director points out that the curve shape might reflect expectations of rising rates instead of a risk premium. It is better to look directly at historical return data, he argues, and presents the others some data that show how average returns over the past decade increased strongly with duration. The third director recalls that over a very long period (1926-94) long-term bonds earned only somewhat higher average returns than one-month bills and lower average returns than intermediate-term bonds. These findings are hard to reconcile until the directors realize that the recent sample reflects findings from a disinflationary period that was exceptionally favorable for long-term bonds. In contrast, the poor returns of long-term bonds in the longer sample partly reflect the yield rise over the decades. What should the directors conclude?

The goal of this paper is to help investors assess whether duration extension is rewarded in the long run. We present extensive empirical evidence mainly from the U.S. Treasury bond market over the past 25 years. All findings about historical returns depend on the interest rate trend in the sample period, but we alleviate concerns about sample-specific results by studying a period without a strong trend. Further, by examining the historical returns over many subperiods, across markets and from several perspectives, we can give as conclusive answers about long-run *expected* returns as possible.

The main conclusion is that **duration extension does increase expected returns at the front end of the curve —** the one-year bill earns about a 150 basis point higher annual return than the one-month bill. The slope of the average return curve flattens gradually, and **for durations longer than two years, no conclusive evidence exists of rising expected returns** (see Figure 1, which we explain in detail further in the report). Subperiod analysis shows that the average return differentials at short durations are quite stable, suggesting that the shortest Treasury bills are quite inefficient investments. In contrast, the relative performance of intermediate-term and long-term bonds varies with the interest rate trend (bull and bear markets).

Figure 1. Return-Risk Trade-Off in the U.S. Treasury Market, 1970-94



This report is the third part in a series titled *Understanding the Yield Curve*, and it focuses on the long-run expected return differentials across bonds with different maturities. **We refer to a long-term bond's expected holding-period return in excess of the short-term riskless rate as the bond risk premium.** (We discuss this terminology at some length in the Appendix.) The bond risk premium is an important determinant of the yield curve shape, but it is not the only determinant. Parts 2 (*Market's Rate Expectations and Forward Rates*) and 5 (*Convexity Bias and the Yield Curve*) in the series describe how the market's rate expectations and convexity bias influence the curve shape. Moreover, the risk premium may not be constant; thus, the long-run average of realized excess bond returns may not be the best forecast of the near-term bond risk premium. Part 4 in the series (*Forecasting U.S. Bond Returns*) discusses the evidence about the time-varying risk premium and its investment implications.

WHAT DO THEORIES TELL US ABOUT THE BOND RISK PREMIUM?

Various theories make very different predictions about the bond risk premium. These theories suggest many possible determinants of the bond risk premium; they tell us something about its likely sign, shape across maturities and constancy over time; but they tell us very little about its likely magnitude.

Our brief survey discusses six alternative theories. We begin with three classic term structure hypotheses. (i) The pure expectations hypothesis implies that no bond risk premium exists. That is, the influence of risk-neutral arbitrageurs drives all government bonds' expected returns to equal the short-term riskless rate. (ii) According to the liquidity (or risk) premium hypothesis, long-term bonds earn a positive risk premium as a compensation for their return volatility. Underlying this hypothesis is the idea that most investors dislike short-term fluctuations in returns.[1]

[1] In other words, they are risk averse and have a short investment horizon. An alternative and more subtle argument states that most investors have a vague investment horizon. If the horizon is so uncertain that it does not guide an investor's decision making and if he is more averse to price risk than to reinvestment risk, he is likely to bias the portfolio toward a short duration. Public accountability makes many investors more averse to price risk than to reinvestment risk. Erring toward a too-short duration exposes an investor "only" to reinvestment risk, which is akin to an opportunity cost. Erring toward a too-long duration exposes an investor to price risk, which is visible and, if realized, is more likely to cause a public outcry.

(iii) The preferred habitat hypothesis states that expected returns may increase or decrease with duration. Many pension funds and life insurance companies view the long-term bond as less risky than the short-term asset because it better matches the average duration of their liabilities. These investors, which we refer to as long-horizon investors, would accept a lower yield for the long-term bond than for the short-term asset. Even if horizons and subjective risk preferences vary across investors, each asset has only *one* market price. For this reason, the risk premium offered by the market will depend on "the market's investment horizon" and, therefore, on the relative importance of short-horizon and long-horizon investors. Casual empiricism suggests that the long-horizon investors still represent a minority: thus, the risk premium should increase with duration.[2] However, the risk premium offered by the market may be lower than that required by the short-horizon investors.

Modern asset pricing theories relate risk premium to amount of risk and price of risk rather than to investment horizons and the relative importance of different investor groups. (iv) In many one-factor term structure models, a bond's risk premium is proportional to its return volatility. In partial equilibrium models, bonds are viewed in isolation and volatility is the relevant risk measure. These models ignore the correlations between bond returns and other assets or other economic variables. (v) In the Capital Asset Pricing Model, any asset's risk depends on its sensitivity to the aggregate wealth. This is often measured by an asset's stock market sensitivity (that is, its beta or the asset's relative volatility multiplied with its correlation with the stock market). An asset's risk premium is the product of its beta and the market risk premium, which in turn depends on the market volatility and the market's risk aversion level. Given that long-term bond returns tend to be positively correlated with the stock market return, their betas (and the bond risk premia) are positive. In fact, bonds' estimated return volatilities and betas are approximately proportional to their durations. Thus, **many theories imply that the bond risk premium should increase linearly with duration.**[3]

The most complex theories allow risks and rewards to be time-varying instead of constant, and they allow multiple factors that reflect fundamental economic risks. (vi) The intuition behind all general equilibrium models is that assets that perform poorly in "bad times"[4] should earn a positive risk premium. In contrast, assets which perform well in "bad times" are accepted for very low yields. To the extent that long-term bonds are a good hedge against recessions, they might even earn a negative risk premium. This may have been the case during the Great Depression of the 1930s, but it certainly has not been the case in the post-World War II period. Bonds performed extremely poorly during the inflationary recessions of 1973-75 and 1980-82. Thus, the spirit of the general equilibrium models suggests that long-term bonds should earn a positive risk premium.

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[2] In a sense, the long-horizon investors are fortunate to be in the minority among market participants; they earn a positive risk premium even though they might accept a lower yield for long-term bonds. Andre Perold and William Sharpe show that an investment strategy's long-run profitability is inversely related to its popularity in the marketplace: see "Dynamic Strategies for Asset Allocation," *Financial Analysts Journal*, January-February 1989.

[3] However, these models specify a linear relation between expected returns and return volatility (or beta). A linear relation between expected returns and duration only follows if yields are equally volatile across the curve (because a bond's return volatility is approximately equal to its duration times the volatility of the yield changes). Empirically, however, the short-term rates tend to be more volatile than the long-term rates, making the return volatility increase by less than one-for-one with duration. Because return volatilities are somewhat concave as a function of duration, also expected returns (and bond risk premia) should be somewhat concave as a function of duration.

[4] In these models, bad times are associated with a high marginal utility of a dollar. Intuitively, a dollar is more valuable when you are hungry and poor. For the economy as a whole, periods of high marginal utility ("bad times") may coincide with recessions.

Many bond market participants feel that the expected return differentials across bonds mostly reflect bonds' characteristics that are not related to the risk characteristics on which the modern theories focus. For example, less liquid bonds earn higher expected returns, as evidenced by the positive yield spreads between duration-matched short-term Treasury coupon bonds and Treasury bills, between off-the-run and on-the-run bonds, and between the illiquid 20-year sector and the liquid 10- and 30-year sectors.[5] Unpopular assets, such as recent poor performers, may earn higher returns because holding them exposes portfolio managers to a "career risk." Temporary supply and demand imbalances also can cause expected return differentials across the curve sectors. In general, most asset-pricing theories ignore such technical factors, institutional constraints and any supply effects. In this report, **the term "risk premium" encompasses all expected return differentials across bonds,** whether risk-related or other factors cause them.

To summarize this survey, many theories suggest that the long-term bonds are riskier than short-term bonds and that investors can earn a *positive* risk premium for bearing this risk. Some models specify that expected returns are *linear* in duration or in return volatility. According to the various models, several factors can influence the slope of the expected return curve. For example, the slope may increase with bond market volatility, stock-bond correlation, the market's risk aversion level, the relative wealth of short-horizon investors (versus long-horizon investors), and the relative supply of government bonds across the curve. In the rest of this report, we examine empirically whether (and by how much) expected returns increase with duration and whether this relation, if it exists, is linear. It is more difficult to explain which factors cause the documented expected return differentials.

EMPIRICAL EVIDENCE ABOUT THE BOND RISK PREMIUM IN THE TREASURY MARKET

Estimating the Risk Premium from Historical Yield or Return Data

The (expected) bond risk premium is not directly observable. However, one can use historical yield or return data to estimate the average risk premium. We will use both approaches, but first we discuss their underlying assumptions and the pitfalls in their use. We also discuss these topics and the terminology in the Appendix.

Average yield curve shapes may help us estimate the average bond risk premium. The term spreads (that is, yield differentials between long-term bonds and short-term bonds) contain information about required bond risk premia, but they also reflect the market's expectations of future rate changes. It is notoriously difficult to disentangle these components. Conceptually, they can be isolated in the extreme versions of the pure expectations hypothesis and the liquidity premium hypothesis. According to the pure expectations hypothesis, an upward-sloping yield curve only reflects expectations of future rate changes; there are no risk premia.[6] The

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[5] However, more liquid bonds have two advantages over less liquid bonds that may offset their lower yield and expected cheapening (as they lose their liquidity premium). First, liquid bonds are more often "special" in the repo market; thus, they offer a financing advantage. Second, their smaller bid-ask spread can be viewed as an option to trade at small transaction costs.

[6] The expected rise in a long-term bond's yield will cause a capital loss that exactly offsets the bond's initial yield advantage over the short-term bond. The capital loss equals the product of the bond's expected yield rise and its duration — if we ignore the convexity bias (which we discuss in other parts of this series).

liquidity premium hypothesis makes the opposite claim: An upward-sloping yield curve reflects only required risk premia and no rate expectations. In reality, the shape of the yield curve probably reflects both rate expectations and risk premia.

The average term spread may be a good measure of the long-run average bond risk premium if the expected yield changes average to zero in the sample period. This requirement is often violated in short sample periods. For example, if the market has persistently expected rising rates during the sample, the average yield curve shape exaggerates the risk premium.

It is more direct to study return data. Historical average return differences are often used to estimate the expected risk premium. Even this approach contains implicit assumptions. By definition, any realized return can be split into an expected part and an unexpected part. Similarly, realized excess return can be split into the bond risk premium and the unexpected excess return. For a given day's or month's realized return of a risky asset, the unexpected part dominates. Yet, when many observations are averaged over time, the positive and negative unexpected parts begin to offset each other. Thus, a long-run average reflects the expected part more than the unexpected part. However, the historical average of realized excess returns is a good measure of the long-run expected risk premium only if the unexpected parts exactly wash out.[7] This is more likely to happen if the sample period is long and does not contain an excessively bearish or bullish bias (yield trend).

In other words, this approach is valid if the market's yield forecasts are correct, on average, during the sample period, so that the average unexpected yield changes are zero. The disinflation of recent years has surprised the bond markets positively, causing a realized risk premium that exaggerates the expected premium. (Many firms' databases begin in the early 1980s, near the peak yield levels, which may have given bond market participants a too optimistic view about expected bond returns.) Much longer sample periods suffer from the opposite problem, because of the persistent inflation surprises since the 1950s, which have caused capital losses to bondholders. It is not reasonable to assume that the market correctly anticipated the increase in long-term rates from the 3% levels in the 1950s.

This discussion illustrates how empirical evidence about historical average returns can vary dramatically across samples even when long sample periods are used. Period specificity is a problem that sophisticated econometric techniques cannot overcome. In this report, we focus on a neutral sample period, chosen so that the beginning and ending yield levels are not far apart. (Of course, it is possible that the expected and unexpected rate changes are large but offsetting, even when the realized rate changes average to zero.)

[7] Even if the historical average risk premium is the optimal predictor of the long-run future risk premium, it is not the optimal predictor of the *near-term* risk premium unless the risk premium is *constant* over time. However, many recent studies show that the bond risk premium varies over time. At the end of this report, we present simple evidence that illustrates the time-variation in the risk premium.

Data Description

We analyze average yields and returns of strategies that concentrate portfolio holdings in a certain maturity sector of the U.S. Treasury market. We also offer some additional evidence from other U.S. bond market sectors and from international government bond markets.

The main analysis covers the past quarter century (1970-94). We chose this period for three reasons:

- **Length.** 300 monthly observations reduce the problem of period-specific findings.

- **Relevance.** Lengthening the sample period makes sense only if the world has not changed so much that old data are irrelevant. This quarter century has been a period of fiat money (that is, money backed only by the government's promise), floating exchange rates, volatile inflation, and large budget deficits. However, some may argue that bond markets have changed so dramatically with globalization, deregulation, securitization, and technological change, that the 1970s data are not relevant. If we eliminated the 1970s data, we would be left with a biased sample that covers only the disinflationary 1980s and 1990s.

- **Neutrality.** Net yield changes (declines in the short-term rates and increases in the long-term rates) were small between January 1, 1970, and December 31, 1994. Thus, a sample-specific yield trend does not excessively influence the historical average returns during this period.[8]

Because this report studies the behavior of bond markets over a longer period, we need to analyze portfolios whose characteristics do not change too much over time, such as constant-maturity or maturity-subsector portfolios. Therefore, we use yield and return series whose underlying assets are rebalanced monthly. The ten yield series include one-month, three-month, six-month, nine-month, and 12-month Treasury bill series constructed by the Center of Research for Security Prices (CRSP) at the University of Chicago[9], Salomon Brothers's "on-the-run" two-year, three-year, five-year, and ten-year Treasury bond series, and Ibbotson Associates's 20-year Treasury bond index. The ten return series include four Treasury bill portfolios (one-month, three-month, six-month, and nine-month) and five maturity-subsector Treasury bond portfolios (one to two years, two to three years, three to four years, four to five years, and five to ten years) from CRSP, and the 20-year Treasury bond index from Ibbotson Associates. The 20-year bond is the longest that we study because 30-year bonds were not issued regularly before 1977.

Evidence From the Treasury Yield Curve Shapes

Figure 2 displays the path of the short-term rate and the long-term rate during the sample period. The time series have a distinct inverse "V" shape. In the first half, both rates increased dramatically; in the second half, they declined equally dramatically. In the first half, the yield curve frequently was inverted; through most of the second half, the curve was steeply upward sloping.

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[8] The earliest reasonable starting year would be 1952 in order to exclude a period of regulated long-term rates from the sample. The 1952-94 sample period would be somewhat less relevant and, because of the rising rates, much less neutral than the 1970-94 period.

[9] The CRSP series have been updated with Salomon Brothers data for 1994.

Figure 2. Yield Levels, 1970-94

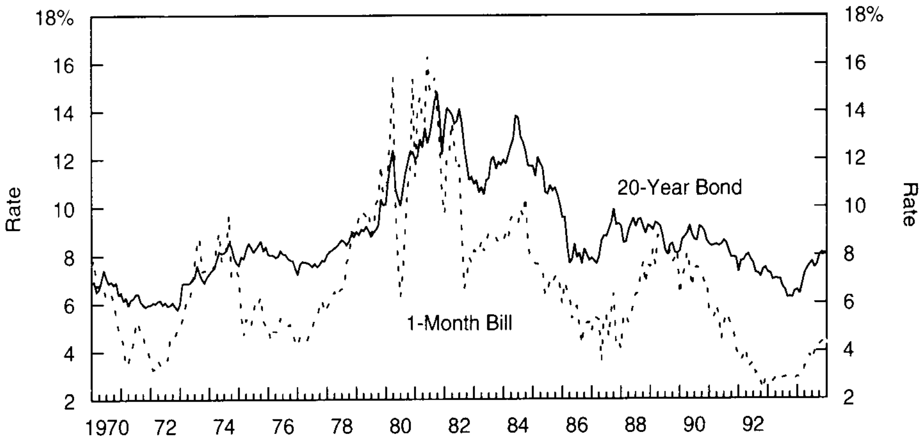


Figure 3 reports average yields (semiannually compounded) and yield spreads over the shortest rate, as well as the annualized standard deviations of monthly yield changes. The main conclusions are as follows:

- Average yields are increasing across the curve. An upward-sloping curve shape probably reflects a positive bond risk premium, but perhaps also rising rate expectations. Such expectations may have been rational even if they were not realized, given the inflation fears in a world of fiat money and large budget deficits.
- The curve is concave in maturity (as well as in duration), that is, yields increase at a decreasing rate as a function of maturity. Potential explanations for this shape include the demand for long-term bonds from the long-horizon investors and the convexity advantage of long-term bonds.
- The term structure of yield volatilities is inverted, likely reflecting mean reversion in short rates.[10] This observation implies that return volatility does not increase quite one-for-one with duration. For this reason, we present the risk-reward trade-off in Figure 1 by plotting average bond returns on return volatilities, not on durations.

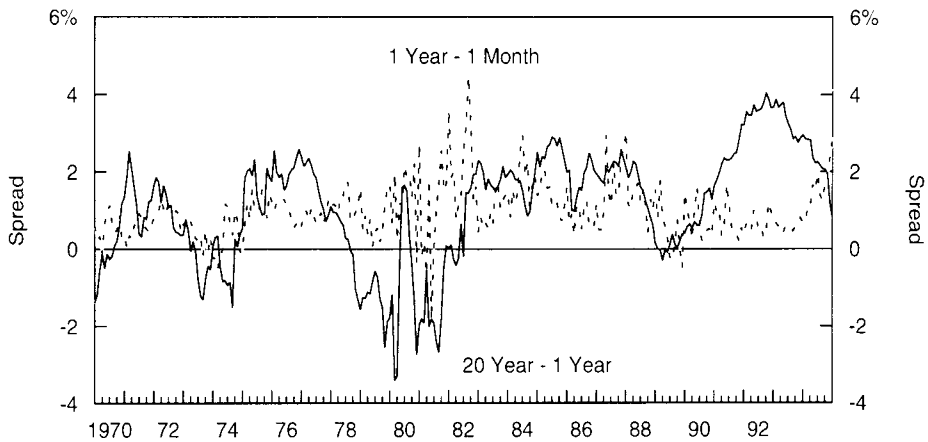
Figure 3. Treasury Instrument Yields, 1970-94

	Bills					On-the-Runs				Ibbotson
	1 Mo.	3 Mo.	6 Mo.	9 Mo.	12 Mo.	2 Year	3 Year	5 Year	10 Year	20 Year
Average Yield	6.75%	7.21%	7.56%	7.66%	7.73%	8.04%	8.18%	8.44%	8.63%	8.85%
Volatility of Yield Changes	3.04	2.40	2.42	2.41	2.37	2.07	1.87	1.71	1.41	1.31
Term Spread Over One-Month Rate	0.00	0.46	0.81	0.92	0.98	1.30	1.44	1.70	1.89	2.11

[10] It is widely known that interest rate volatility was exceptionally high between 1979 and 1982, when the Federal Reserve did not target the short-term rate behavior. Over the past decade, volatilities have been lower and the term structure of volatility has been flatter than in Figure 3. For the 1985-94 period, the volatilities of all maturity rates between three months and 20 years are 1.1%-1.3% (110-130 basis points), peaking at intermediate maturities.

Figure 4 displays the term spreads at the short end and at the long end of the curve. The shorter spread has been much more consistently positive. This may be an indication of the persistence of a positive bond risk premium at short maturities. We will next examine return data to study this issue in more detail.

Figure 4. Yield Spreads, 1970-94



Evidence From Government Bond Returns

As explained before, historical bond returns offer more direct evidence about the bond risk premium than historical bond yields do. Figure 5 shows the annual arithmetic and geometric means (averages) and other statistics for the ten return series described above. Most of the analysis in this report focuses on geometric mean returns rather than on the arithmetic means. The geometric mean reflects the multiperiod compound return that various strategies would have accumulated over the sample. The arithmetic mean exaggerates the historical performance, but it may be a better measure of expected return.[11]

The arithmetic mean return curve increases almost monotonically, while the geometric mean return curve is quite flat after two years. There appears to be a positive bond risk premium, but mainly at the front end of the curve: roughly 150 basis points between one-month and one-year durations and an additional 50 basis points between one- and two-year durations. Beyond two years, it is unclear whether duration extension increases expected returns at all.[12] The pattern of Sharpe ratios confirms that the reward to volatility decreases with maturity.[13]

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[11] The arithmetic mean (AM) and geometric mean (GM) are computed using the following equations:

$$AM = (h_1+h_2 + ... + h_N)/N$$

$$GM = [(1 + h_1) * (1 + h_2) * ... * (1 + h_N)]^{1/N} - 1.$$

where h are one-period holding-period returns and N is the sample size. The geometric mean is less than or equal to the arithmetic mean, and the difference increases with the return volatility. The geometric mean is the correct number to use in historical analysis. It is harder to say which number is relevant when describing the future prospects of a given strategy. The arithmetic mean is the mathematically correct measure of expected return, while the geometric mean better represents a typical outcome (median). For further discussion, see "What Practitioners Need to Know about Future Value," Kritzman, *Financial Analysts Journal*, May-June 1994.

[12] In the earlier academic analysis of the average bond risk premium, long-term bonds perform even more poorly. Fama (1984) finds that over the 1953-82 period, average returns peak at the 12- to 18-month maturity. Fama's sample period was, however, clearly inflationary and thus "bearish"; as explained above, the 1970-94 period is more neutral.

[13] Incidentally, the t-statistics of the excess returns are five times larger than the Sharpe ratios (given a sample of 300 months); thus, most bonds have statistically significant positive excess returns.

Figure 5. Treasury Maturity Subsector Annual Returns and Other Statistics, 1970-94

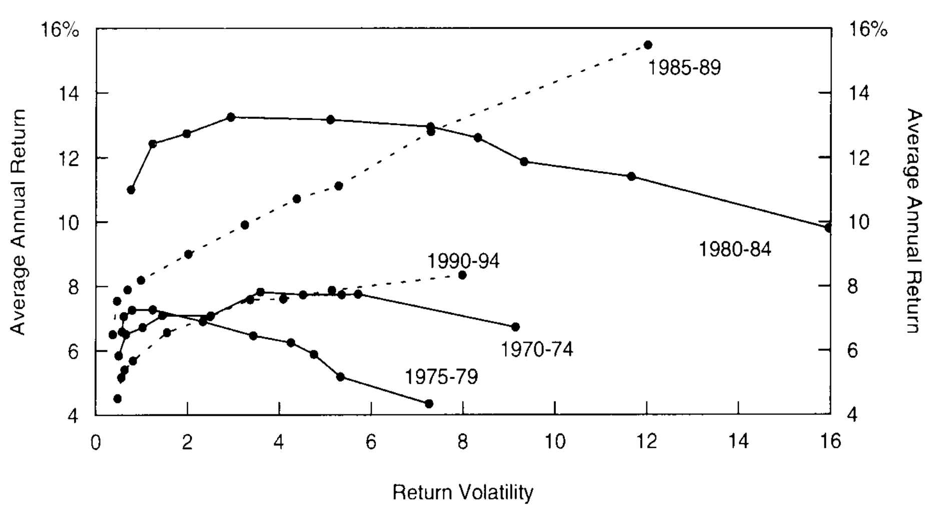
	1 Mo.	3 Mo.	6 Mo.	9 Mo.	1-2 Yr.	2-3 Yr.	3-4 Yr.	4-5 Yr.	5-10 Yr.	20 Yr.
Arithmetic Mean	6.87%	7.71%	7.98%	8.28%	8.56%	8.91%	9.10%	9.01%	9.28%	9.51%
Geometric Mean	6.87	7.71	7.97	8.27	8.52	8.81	8.95	8.82	8.98	8.87
Geom. Premium	0.00	0.84	1.11	1.40	1.65	1.94	2.09	1.95	2.12	2.00
Volatility	0.81	1.00	1.31	1.79	3.02	4.36	5.26	6.03	7.43	10.98
Avg. Duration	0.08	0.24	0.48	0.71	1.3	2.1	2.9	3.7	5.1	9.8
Sharpe Ratio	NA	1.92	1.10	0.87	0.55	0.45	0.40	0.34	0.31	0.22

NA Not applicable. Note: The Geom. premium is the annualized geometric mean return of a bond portfolio in excess of the one-month rate. Volatility is the annualized standard deviation of a bond portfolio's monthly returns. The Sharpe ratio is the annualized mean-to-volatility ratio of a bond portfolio's excess return.

Figure 1 shows the ex-post risk-reward trade-off in the bond market (based on data from Figure 5) by plotting the geometric mean returns on their return volatilities. Recall that many theories predict that expected returns increase linearly with return volatility or with duration. The pattern in Figure 1 contradicts these predictions; average returns are concave in return volatility. The explanation that many market participants would offer is related to the old preferred habitat hypothesis. **The expected returns of the long-term bonds are "pulled down" by the demand from long-horizon investors,** such as pension funds, which perceive the long-term bond as the least risky asset because it best matches the average duration of their liabilities. However, these long-horizon investors are a minority in the marketplace; thus, they do not pull the expected return of the long-term bonds quite as low as that of the short-term bonds.

Even if the sample period is well chosen, the findings are still period-specific unless the expected bond risk premium is very stable. We try to alleviate the problem of period specificity by conducting extensive subperiod analysis to search for patterns that hold across periods. Figure 6 shows separate reward-risk curves (similar to Figure 1) for five five-year subperiods. The bond markets were bearish or neutral in the first three subperiods and bullish (trend declines in long yields) in the last two

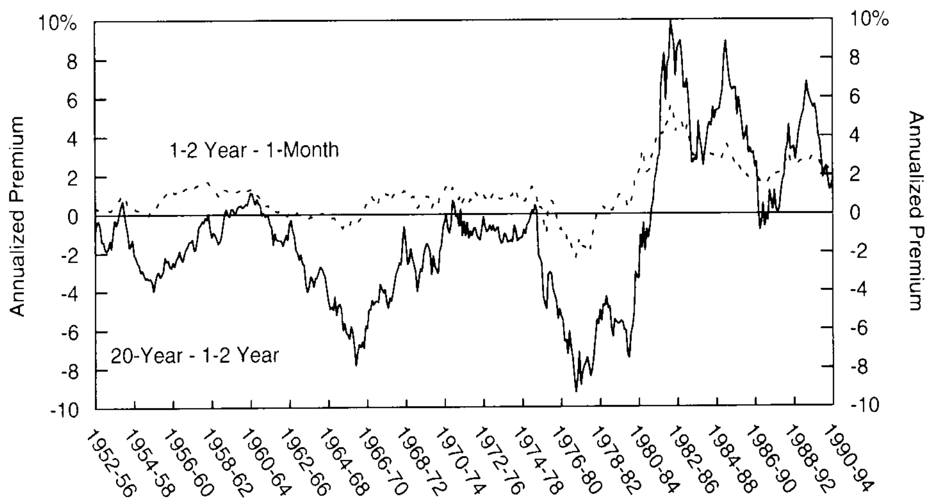
Figure 6. Return-Risk Trade-Off in the U.S. Treasury Market in Five Subperiods Between 1970 and 1994



subperiods. One striking pattern in Figure 6 is that **average returns increase monotonically from the one-month bill to the nine-month bill in all five subperiods**. This pattern provides further evidence regarding a persistent positive risk premium at the front end of the yield curve.[14]

We further study the stability of the bond risk premium over time by plotting in Figure 7 a moving average of the past 60 months' excess bond returns at the front end of the curve (one- to two-year bonds minus one-month bill) and at the long end of the curve (20-year bond minus one- to two-year bonds). We include in this figure the rolling premium already from the 1950s and 1960s to illustrate how bearish the bond market environment was before our main sample period. Again, **the premium at the front end is almost always positive.** In contrast, the premium at the long end is very often negative. In fact, the performance of the 20-year bond is surprisingly consistently bad until the mid-1980s. Only very recent samples support the claim that long-term bonds offer higher returns than intermediate-term bonds. These findings reflect the powerful impact that the slow and systematic changes in inflation rates have had on long-term bond returns.

Figure 7. Rolling 60-Month Return Premium, 1957-94



We turn to one more way to study the bond risk premium. We estimate the probability of earning a positive bond risk premium in a short period. We also evaluate the marginal benefit from duration extension by estimating the probability of earning a higher holding-period return than the previous-maturity asset. The intuition behind this analysis is the following. If bond returns are symmetrically distributed and no risk premium exists, the outcome of a duration extension is like a coin toss. There is a 50% probability of gain and a 50% probability of loss. If a positive risk premium exists, long-term bonds will outperform short-term bonds more frequently than half of the time.[15]

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[14] It is also worth noting that return volatility peaked in the early 1980s even though bond durations were at their lowest (because of high yield levels). Thus, the increased yield volatility more than offset the risk-reducing impact of higher yields on bond durations.

[15] An alternative explanation is that returns are not symmetrically distributed. Even if long-term bonds outperform short-term bonds 60% of the time, it is conceivable that the negative returns of long-term bonds are rare but severe, leading to the same average returns as for the short-term bond.

The first panel of Figure 8 shows that the yield curve has been upward sloping in the bill market about 95% of the sample and somewhat less frequently at longer maturities. The second and third panels show how frequently each asset outperforms the previous-maturity asset and the one-month bill at monthly and annual horizons. Our comments focus on the third panel, because many investors are concerned about the performance of different strategies at an annual horizon. Again we see that there is a consistent positive risk premium in the bill market. For example, a strategy of rolling over three-month bills outperforms a strategy of rolling over one-month bills 99% of the time, and a strategy of rolling over six-month bills outperforms a strategy of rolling over three-month bills 67% of the time. **At the longer end, the reward for a marginal duration increase approaches a coin toss.** However, the four- to five-year maturity sector is the only area in which a marginal duration increase makes underperformance more likely.

Figure 8. Frequency of Upward-Sloping Yield Curve or Return Curve, 1970-94

Frequency of an Asset's *Monthly Yield* Exceeding the Monthly Yield of	1 Mo.	3 Mo.	6 Mo.	9 Mo.	12 Mo.	2 Yr.	3 Yr.	5 Yr.	10 Yr.	20 Yr.
Previous Maturity	NA	0.94	0.96	0.78	0.74	0.81	0.79	0.75	0.72	0.78
One-Month Bill	NA	0.94	0.98	0.97	0.95	0.90	0.88	0.88	0.84	0.85

Frequency of an Asset's *Monthly Return* Exceeding the Monthly Return of	1 Mo.	3 Mo.	6 Mo.	9 Mo.	1-2 Yr.	2-3 Yr.	3-4 Yr.	4-5 Yr.	5-10 Yr.	20 Yr.
Previous Maturity	NA	0.81	0.58	0.57	0.54	0.52	0.53	0.47	0.48	0.48
One-Month Bill	NA	0.81	0.68	0.66	0.58	0.56	0.55	0.56	0.56	0.51

Frequency of an Asset's *Annual Return* Exceeding the Annual Return of	1 Mo.	3 Mo.	6 Mo.	9 Mo.	1-2 Yr.	2-3 Yr.	3-4 Yr.	4-5 Yr.	5-10 Yr.	20 Yr.
Previous Maturity	NA	0.99	0.67	0.67	0.56	0.55	0.53	0.44	0.53	0.51
One-Month Bill	NA	0.99	0.88	0.82	0.69	0.64	0.61	0.59	0.57	0.56

NA Not applicable.

EVIDENCE FROM OTHER MARKETS

In this section, we examine whether the yield and return patterns documented above are specific to the U.S. Treasury markets. We extend our historical analysis to the U.S. non-government debt markets and to the government debt markets outside the United States. All yields in this section are expressed in the semiannual compounding frequency, and all returns are geometric averages. Figure 9 shows the average yields for various money market instruments. The last column shows that all private-sector yield curves are much flatter than the Treasury bill curve. In fact, the average return curves would be even steeper for Treasuries because they tend to roll down the steeper bill curve and earn larger rolldown returns in addition to their yields.

Figure 9. Average Yield Curve Steepness in Public- and Private-Issuer Money Markets, 1970-94

	1 Mo.	3 Mo.	6 Mo.	Spread (6 Mo.-1 Mo.)
Treasury Bill	6.75%	7.21%	7.56%	0.81%
Certificate of Deposit	7.68	7.81	7.97	0.29
Commercial Paper	7.87	8.01	8.14	0.27
Eurodeposit	8.23	8.39	8.57	0.34

From another perspective, Figure 9 shows that the credit spreads are wider at a one-month maturity than at a six-month maturity. Fama (1986) already has noted such inversion of the term structure of money market credit spreads. This shape can be contrasted with the typical upward-sloping credit spread curve in the corporate bond market beyond one year [see Litterman and Iben (1991) and Iwanowski and Chandra (1995)]. Only one spread is available at shorter and longer maturities than one year: Treasuries versus Eurodeposits. Figure 10 confirms that, between 1985 and 1994, the term structure of this spread typically had a "V" shape. One investment implication is that it often makes sense to take a large share of the desired credit exposure at short maturities.

The wide spread between one-month bill and other assets is difficult to explain as a rational credit spread. More likely, it **reflects some investors' return-insensitive demand for the ultimate safe asset.** The narrowing of the Eurodeposit-Treasury bill spread in recent years may indicate that such demand for safety "at any cost" is shrinking. (The spread at one-month maturity averaged more than 160 basis points both in the 1970s and in the 1980s, but only 73 basis points in the 1990s.)

Figure 10. Average Yields in Treasury and Eurodeposit Curves, 1985-94

	1 Mo.	3 Mo.	6 Mo.	9 Mo.	12 Mo.	2 Yr.	3 Yr.	5 Yr.
Treasury	5.43%	5.94%	6.17%	6.31%	6.40%	6.96%	7.20%	7.62%
Eurodeposit	6.49	6.58	6.68	6.81	6.95	7.46	7.84	8.30
Credit Spread	1.06	0.64	0.51	0.50	0.54	0.51	0.64	0.68

Figures 11 and 12 offer further evidence of the risk premium from other bond markets. We compare yields and returns in the one- to three-year maturity subsector and the seven- to ten-year maturity subsector of each market. Data availability restricts the analysis to the past decade. Figure 11 shows that the reward for duration extension in the corporate bond market is somewhat lower than in the Treasury market. However, this conclusion is subject to several reservations: (1) the duration difference between the short and long maturity subsector is smaller in the corporate bond market than in the Treasury market; (2) the yields in Figure 11 ignore the impact of the bonds' option features (negative convexity); and (3) both the yield spreads and the return premia may be biased because different sectors have different industry structures.[16]

Figure 11. Average Yield Spread and Return Premium in Various U.S. Bond Market Sectors, 1985-94

	Yield			Return		
	1-3 Yr.	7-10 Yr.	Spread	1-3 Yr.	7-10 Yr.	Premium
Treasury	6.93%	8.04%	1.11%	8.00%	10.52%	2.52%
Agency	7.20	8.53	1.33	8.19	10.47	2.28
AAA/AA	7.79	8.75	0.96	8.64	10.41	1.77
A	8.09	9.04	0.95	8.81	10.48	1.67
BBB	8.62	9.77	1.15	9.03	10.85	1.81

Source: Salomon Brothers's Broad Investment Grade Index.

Figure 12 shows local currency yields and returns in eight countries' government bond markets. **Yield spreads and return premia are positive almost everywhere, but lower than in the United States.** In most countries, the average return premium is higher than the average yield spread; the capital gains caused by long-term bonds' yield decline between 1985 and 1994 augment the premium. Clearly, the past decade offered a favorable environment for bondholders, except in Germany and the

[16] In general, more creditworthy borrowers are able to issue longer-term debt. In the U.S. corporate bond market, the (relatively safe) public utilities are important issuers of long-term debt, while the (more risky) financial companies typically issue short-term debt. These issuance patterns flatten the term structure of aggregate corporate credit spreads.

Netherlands.[17] Unfortunately, few government bond markets outside the United States are liquid at very short durations; thus, we cannot study whether the return curves in countries other than the United States have the concave shape of the average return curve in Figure 1.[18]

Figure 12. Average Yield Spread and Return Premium in International Government Bond Markets, 1985-94

	Yield			Return		
	1-3 Yr.	7-10 Yr.	Spread	1-3 Yr.	7-10 Yr.	Premium
United States	6.93%	8.04%	1.11%	8.00%	10.52%	2.52%
Canada	9.01	9.42	0.41	9.59	10.94	1.36
Japan	4.83	5.38	0.55	5.48	7.12	1.63
Australia	11.28	11.65	0.37	12.16	13.82	1.65
Britain	9.58	9.82	0.24	10.08	11.53	1.45
France	8.43	8.67	0.24	9.30	10.97	1.67
Netherlands	6.95	7.15	0.21	7.03	6.98	-0.05
Germany	6.47	7.03	0.56	6.65	6.70	0.06

Source: Salomon Brothers's World Government Bond Index.

CONCLUSIONS AND EXTENSIONS

What Is the Best Estimate of the Long-Run Bond Risk Premium Today?

Any statements about the expected risk premium are partly subjective because expectations are not directly observable. Thus, caution is warranted when interpreting the empirical findings. However, we can draw some general conclusions. **The U.S. Treasury market does reward duration risk, but expected returns do not increase linearly with duration** (or even with return volatility). The reward for duration extension is high at the front end of the Treasury curve (almost 200 basis points from the one-month to the two-year duration), but after two years, the expected return curve appears quite flat.

We argue that the numbers in Figure 5 are our best estimates of the long-run bond risk premium in the U.S. Treasury market. If we can take these numbers at face value, yield curve analysts can subtract each maturity's risk premium from today's yield curve and, after adjusting for the rolldown effect and the convexity bias, infer the market's expectations of future rates. However, this approach is not valid if the risk premium varies over time.

While expected returns do not always increase with duration, short-run return volatility always does. This finding has important implications for fixed-income investors. **If an investor has a short investment horizon** and he is averse to the short-run fluctuations in bond returns, **he has little incentive to extend the long-run benchmark duration beyond two years.** Of course, long-duration bonds are good investments for investors who have long-duration liabilities or an otherwise long investment horizon. In addition, long-duration bonds may be excellent tactical investments if an investor can identify in advance periods of declining interest rates or if the yield curve is abnormally steep beyond the two-year maturity.

[17] Analysis of average returns is notoriously sensitive to the chosen sample period. The period specificity is illustrated well by the fact that an extensive historical study by Bisignano (1987) identified Germany as the country with the highest reward for maturity extension. Bisignano used bond market data between the 1960s and mid-1980s. Rising rates caused by the German reunification have now pushed the former star performer to near the bottom of the ladder.

[18] One-month Eurodeposit rates are available for all eight countries, however. The average annual returns from rolling over these deposits are 6.68%, 8.92%, 5.19%, 12.34%, 10.98%, 9.44%, 6.99%, and 6.66%, respectively. Thus, the average premium of the one- to three-year government bond sector over the one-month Eurodeposits was negative in four of the eight countries. The average return curves in other countries than the United States appear to have different shapes than Figure 1, but we stress that ten years is quite short period for this type of analysis and that the comparison is contaminated by the use of default-risky data. Further analysis is clearly needed.

Another major finding is that **the shortest Treasury bills appear to be systematically overpriced.** In particular, the one-month bill has offered quite consistently a 100 basis point lower return than the more liquid three-month bill or other high-quality one-month papers in the money market.[19] Substituting longer bills or other money market instruments for the one-month bills in a portfolio may well provide the best reward-to-risk ratio in all capital markets.

Will the Bond Risk Premium Be Different in the Future?

We conclude with some observations about the stability of these risk premium estimates. Realistically, the long-run bond risk premium will change over time. It probably has changed quite a bit during the past 40 years. Figure 13 shows that many plausible measures of long-term bonds' riskiness[20] were low until the mid-1960s and then rose systematically for 15 years. However, this fact is only known with the benefit of hindsight. Surely, the bond investors of the 1950s and 1960s were not demanding as high a risk premium as today's bond investors are. Part of the U.S. bond market's poor performance in the 1960s and 1970s probably reflects the reassessment of the market's riskiness, which increased the required risk premium and thus (initially) led to higher yields and lower bond prices. Now that this major reassessment is over, bondholders can "enjoy" the higher expected returns. In fact, opposite forces may have helped the bond markets in the past decade. Inflation rates have declined and bond volatility has subsided. In addition to the reduced risk, structural changes may be lowering the long-run bond risk premium that the market offers, such as:

- The increasing importance of long-horizon investors who perceive the long-term assets as safe;
- Strengthening anti-inflationary tendencies such as central bank independence and the discipline imposed by financial markets;
- Risk-reduction caused by greater international diversification; and
- Improving liquidity.

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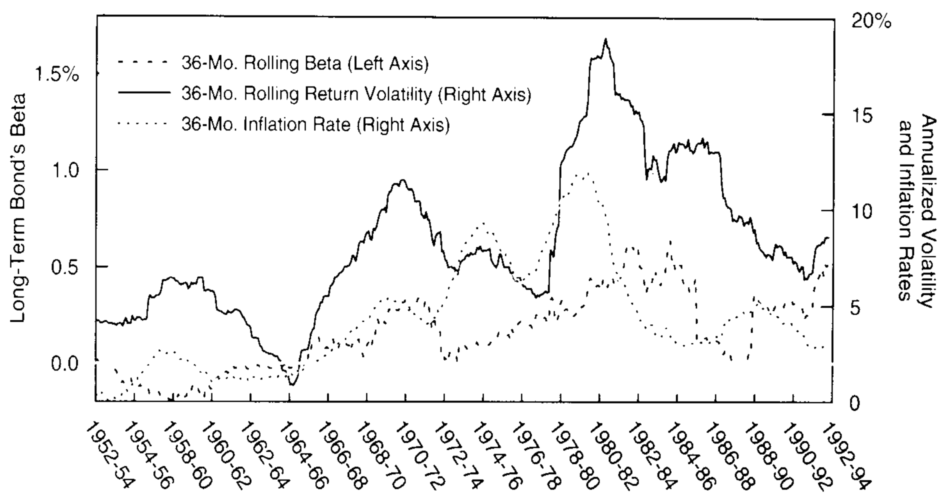
[19] The wide credit spreads at the front end imply that it is not easy to exploit the positive risk premium. A simple strategy of purchasing leveraged two-year notes will lose a large part of its profits when the borrowing is done at a private-issuer rate and not at a Treasury bill rate. Because most arbitrageurs must borrow at the private-issuer rate, they cannot eliminate the overpricing of short-term Treasury bills; only the holders of the expensive bills or the government can do it (by selling or by issuing more bills).

[20] The figure shows the 20-year bond's annualized return volatility and its sensitivity (beta) to U.S. stock market returns as well as the recent 36 months' annualized inflation rate. Many market participants think that bond risk (and not just losses from bond holdings) increases with the inflation level because inflation uncertainty appears to increase with the inflation level.

Figure 13. Reevaluating Long-Term Bond Riskiness, 1955-94



The historical average risk premium is the optimal forecast of the future risk premium only if the required risk premium is constant over time. However, the above discussion shows that we expect the long-run risk premium to vary slowly when there are *structural* changes. In addition, the bond risk premium appears to fluctuate in a (short-run) *cyclical* fashion. As an introduction to the time-variation in expected returns, we offer a simple analysis in Figure 14.

Figure 14. Average Return of the 20-Year Treasury Bond in Months that Begin with an Inverted, Mildly Upward-Sloping or Steep Yield Curve, 1970-94

Spread (20 Yr.-1 Mo.)	No. of Months	Annualized Return
<0bp	45	-2.57%
0-300bp	148	9.41
>300bp	107	12.46

bp Basis points.

The central question is whether we can identify, *ex ante*, periods when the near-term bond risk premium is particularly high or low. The most natural predictor is the steepness of the yield curve. Figure 14 shows that the curve shape has been able to distinguish good and bad times to invest in long-term bonds. **Steep curves tend to be followed by abnormally high returns, and inverted curves tend to be followed by negative returns.** These patterns have obvious investment implications, suggesting that strategies that adjust duration dynamically can produce superior long-run returns. We discuss the time-variation in the bond risk premium extensively in other papers (see "Literature Guide").

APPENDIX: BOND RISK PREMIUM TERMINOLOGY

We discuss bond yields, returns, and risk premia from many different perspectives in our series of reports on the theme *Understanding the Yield Curve*. In this Appendix, we describe and motivate some key concepts and the terminology used throughout the series. We begin with a definition: ***The bond risk premium* is the expected holding-period return of a long-term bond in excess of the riskless return of the one-period bond.**

Why the *name* "bond risk premium"? Based on many academic theories, expected return differentials across bonds compensate for risk differentials across bonds. Nevertheless, we use the term "bond risk premium" broadly to include any expected return differential over the riskless rate, whether it is caused by risk or by factors unrelated to risk. The term "bond risk premium" has many synonyms: interest rate risk premium; term premium; liquidity premium; and the more neutral "expected excess bond return."

Why *return*? Most investors are primarily interested in an investment's expected return, *as opposed to its yield*. For this reason, our analysis focuses on expected return differentials across bonds. Yield spreads do reflect these expected return differentials, but they also are influenced by other factors, such as the market's expectations about future rates. Furthermore, yields of different bonds are directly comparable only under restrictive conditions.

Why *excess* return? It is useful to decompose any bond's holding-period return to the *riskless return*[21] over the holding period (reward for time), which is known in advance and common to all bonds, and to the *excess return* over the riskless rate (reward for risk or for bond's other characteristics), which is uncertain and may be specific to each bond. (Sometimes the excess bond returns are low even though bond returns are quite high, for example, when inflation and short-term rates are very high.)

Why *expected* excess return? Realized returns have an *expected* part and an *unexpected* part. Active investors must try to earn high realized excess returns by capturing high expected excess returns, even though a large part of the realized excess returns is unexpected.[22]

Which *holding-period* return? In our theoretical analysis, we use *annual* holding periods because it simplifies the notation (because yields are expressed as percent per annum). In our empirical analysis, we focus on *monthly* holding periods, and we examine the excess returns of long-term bonds over the nominally riskless one-month rate.

How is the bond risk premium *estimated*? The answer to this question depends on the stability of the risk premium. If the risk premium is *constant* over time, a historical average return differential between the long-term bond and the riskless short-term bond is the best estimate of the future bond risk premium.[23] (Over a long sample period, the unexpected parts of the monthly returns should wash out, leaving only the expected

[21] We measure the riskless return by the return of the Treasury bill that matures at the end of the horizon (holding period). This return is nominally riskless because the bill's holding-period return is known from its price today and its known maturity value (100). Treasury issues are perceived to be default-free but they have some purchasing power (or inflation) risk.

[22] We sometimes add the redundant word "expected" before bond risk premium to emphasize the distinction between the expected bond risk premium and the realized bond risk premium (or equivalently, between the expected excess return and the realized excess return). We may also use the term "required return" instead of expected return, because the latter term may have a misleading optimistic connotation: in reality, expected bond returns are more likely to be high in bad times when investors *require* a high risk premium for holding risky assets.

[23] A further question is whether we should use an arithmetic or a geometric average of the monthly returns, or perhaps an arithmetic average of the continuously compounded returns.

return differential.) However, if the bond risk premium *varies over time*, we should use the information in the current yield curve and in other variables that describe current economic conditions to find out whether the near-term bond risk premium is abnormally high or low.[24] In Figure 14 of this report, we use the term spread as a crude measure of the information in the yield curve. A better measure would include the impact of the so-called rolldown return. The rolling yield differential between a long-term bond and the riskless rate is a proxy for the bond risk premium under the scenario of no change in the yield curve, but even this measure ignores the impact of convexity on expected returns. Finally, we can combine the information in the yield curve and in other predictor variables to develop an optimal forecast for the near-term bond risk premium. The other reports in this series discuss these topics in detail.

[24] A historical average of excess bond returns may still be an excellent forecast for the long-run expected excess bond return (relevant for strategic investment decisions) but not the optimal forecast for the near-term excess bond return. The near-term and the long-run forecasts are equal only if the bond risk premium is constant over time.

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