Total Return Fixed-Income Portfolio Management

A risk-based dynamic strategy.

Ulf Herold, Raimond Maurer, and Nader Purschaker

Bond portfolio management has not become easier in recent years. Government bond yields have fallen consistently over the last decade, and investors have been looking for yield pickup in the credit markets. Investing in corporate bonds, of course, involves additional sources of risk as the spectacular downgrades and defaults of several prominent names like Enron and Worldcom have shown.

Active portfolio managers are faced with the problem that trends in bond yields have become shorter. The volatility of yield changes has increased at the same time. This effect has been amplified in the U.S. by the rising market share of MBS. Hence, interest rate forecasting has become more difficult.[1]

Currently, corporate bond spreads are relatively tight in the investment-grade sector, and government yields started to rise sharply in mid-2004. The Federal Reserve Board has been expected to raise interest rates, and the danger of further yield increases is worrying investors. So, many investors move away from benchmark-oriented portfolio management and require positive absolute returns. Institutional investors like insurance companies or pension funds particularly want to avoid disclosing depreciation on their capital investments in their annual reports.

A major question is how to control portfolio duration to produce positive returns. This is the most important issue in government-only as well as broad mandates because interest rate risk is still the major source of risk in investment-grade corporates.[2]

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We investigate a fixed-income portfolio strategy that has been designed to generate positive returns. The basic idea is to permanently control the shortfall risk of the portfolio. The portfolio duration is adjusted (potentially) each day so that the shortfall probability—the probability of realizing a negative return (or, more generally, a return that falls below a prespecified threshold) at the end of the investment horizon—does not exceed a target value.

Such a strategy can be tailored to the specific objectives of an investor. The investor can specify the investment horizon, the minimum return below which the portfolio return should not fall, and the target shortfall probability.

The strategy is completely risk-based, requiring no forecasts about future interest rate movements. This distinguishes it from other total return strategies that rely heavily on return forecasts or on portfolio manager claims that they can choose the fixed-income assets and yield curve segments that will perform best in the future.

The success of these products depends on managers' forecast accuracy. If managers expect yields to rise and buy low-duration fixed-income securities, they give up yield carry in a steep yield curve environment, and do not participate if yields fall and prices rise. As a total return investor is often highly risk-averse, we think a risk-based strategy is more suitable.[3]

We first show why a total return strategy should be risk-based and dynamic. It is important to start with the investor's risk budget and then infer the portfolio structure from this risk budget. We illustrate the shortfall risk approach, and compare the results of the dynamic trading strategy and static portfolios in a backtest. The empirical study shows that the total return strategy achieves its objective of producing positive returns in each year, which is confirmed by a simulation study. At the same time, its average returns are somewhat higher than returns of the static portfolios. We compare our strategy to another dynamic asset allocation strategy, CPPI, and note how corporate bonds can be integrated in the shortfall risk approach.

MOTIVATION FOR A RISK-BASED DYNAMIC STRATEGY

The first advantage of a risk-based total return strategy is that it does not require yield curve forecasts. The second advantage is that it relies directly on the investor's risk budget. In general, an asset allocation can be expressed either in terms of portfolio weights or risk budgets. In other words, asset weights and risk contributions are two sides of the same coin.[4]

In investment practice, however, most investors think in terms of portfolio weights only. For example, a 20%/80% equities/bonds portfolio might be considered a suitable strategy for a modestly risk-averse investor. Investing in such a portfolio (on a fixed-mix basis, i.e., with periodic rebalancing) might indeed deliver the desired risk-return profile over the long run, but time-varying expected returns, volatilities, and correlations mean that its risk profile in general will be very different in the short to medium term. The short-run value at risk will substantially fluctuate along with the long-run value at risk (see Gupta and Kartinen [2000]). This is the reason we start with the investor's risk budget and then infer the portfolio structure from this risk budget.

Exhibit 1 explains the difference in holding portfolio weights constant (first graph) and holding portfolio risk constant (second graph). The portfolio of an investor allocating 100% of wealth to the government bond market portfolio has constant weights: 100% bonds (proxied by a market index like JPMorgan Germany) and 0% cash. The duration will change a little but has stayed around five years (modified duration) historically.

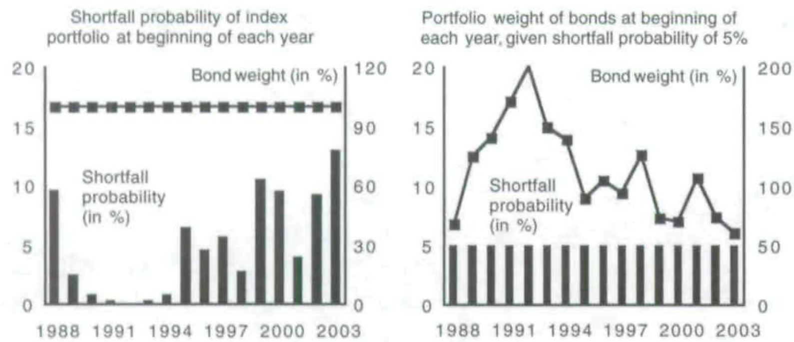
The risk profile fluctuates greatly, though. Shortfall probability was close to 0% at the beginning of the 1990s but over 12% at the beginning of 2003. An investor with a fixed-mix strategy ignores the fact that expected returns (bond yields), volatilities, and correlations change over time. All these parameters enter into the calculation of shortfall probability.

If investors require a constant shortfall probability of, say, 5% with respect to a minimum return of 0%—because this corresponds to their risk aversion—they need to change the exposure to bonds at the beginning of each year (see the second graph). At the beginning of the 1990s, they could increase the allocation to bonds beyond 100%, which they could implement by extending the portfolio duration beyond the index duration. In 2003, the bond weight needed to be reduced to 61%, cutting duration back to only 3.5 years. Therefore, with a constant risk aversion, the exposure to the risky asset class (bonds) will change over time.

Exhibit 1 also makes it clear that the shortfall probability at the beginning of a year does not provide much information about the realized return at the end of the year. For instance, in 1994, shortfall probability was close to 0%, yet bond investors suffered from significant losses in that year. This is why a total return strategy must also be designed as a dynamic trading strategy. Shortfall probability might be low at the beginning of the year, but if

EXHIBIT 1

Holding Portfolio Weights Constant versus Holding Shortfall Risk Constant



bond yields rise, it will increase. Hence, it is important to control shortfall risk each day during the year and to adjust the bond exposure in a dynamic way.

Appendix A provides more evidence that a buy-and-hold government bond investment (either through passive management or through active management with low tracking error) is too risky for an investor with a low risk budget (0% minimum return with high confidence level), at least at current yields. An investor who cares only about terminal wealth can conclude from Exhibit A-1 that shortfall probability declines to zero when the investment horizon is long enough, but the mean excess loss, i.e., the average loss if a shortfall occurs, rises with the investment horizon. Hence, even a long-term investor should be interested in dynamic strategies.

This, of course, is even more true for an investor who wants to maximize wealth in the long run but at the same time imposes restrictions on short-term returns. There is less than a 1% probability of generating negative returns at the end of a five-year horizon for a buy-and-hold investment in government bonds, but the probability rises to more than 50% if shortfall refers to the end of each of the five years (see Exhibit A-2 in Appendix A, where a negative return in at least one year implies a shortfall).

BASIC IDEA: CONTROLLING SHORTFALL RISK

The investor expresses the risk budget in terms of shortfall risk. Suppose a positive return is required over the next 12 months at a 95% confidence level. Then, the minimum return is 0%, the investment horizon is one year, and the probability of producing a return below 0% must not exceed 5%.

To operationalize shortfall risk, we use the lower partial moment of order zero and assume normality:

$$LPM_0(R) = \Phi\left(\frac{\tau - \mu}{\sigma}\right) \tag{1}$$

where R is the portfolio return, $\Phi(.)$ denotes the cumulative standard normal distribution, τ is the minimum return, and μ is the mean and σ the volatility of the return distribution. LPM_0 is equivalent to value at risk (VaR). For VaR, the shortfall probability is fixed, and Equation (1) is solved for τ.

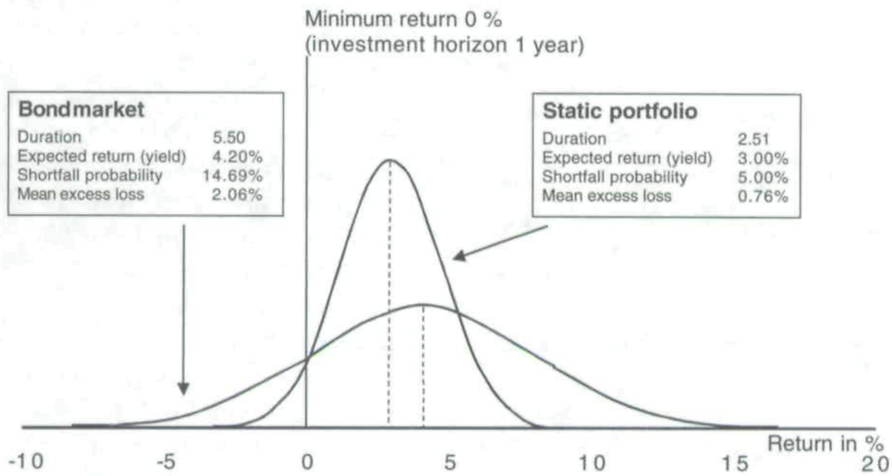
Assume that the bond market currently yields about 4.2% and exhibits a volatility of 4%. (We consider only government bonds here and corporate bonds later.) Then investing 100% into bonds implies a shortfall probability of around 15%. The area left of the 0% line under the wide distribution in Exhibit 2 is 14.69%. If a shortfall occurs, the expected shortfall or mean excess loss will be 2.06%. So this portfolio will be too risky for an investor who can stand only 5% shortfall risk.[5]

To reduce shortfall probability, we must shift from the risky asset (bonds) into the risk-free asset (cash). The distribution narrows and moves to the left; i.e., the mean is reduced—see the more peaked distribution, labeled static portfolio, in Exhibit 2. With 45% invested in bonds and 55% in cash, the shortfall probability amounts to exactly 5%. The conditional expected loss declines to 0.76%. The mean is reduced to 3.0% (assuming a cash yield of 2.0%), and the duration falls to 2.5 years.

Now, this process of aligning the portfolio structure with the risk budget does not take place on the first day of the investment horizon only—it is repeated every day. More specifically, each day the shortfall risk of the portfolio is measured depending on the current cushion (portfolio market value minus floor), the remaining investment horizon, the yield, and the volatility of the portfolio. Volatility is estimated using daily data. An exponential weighting scheme is applied to exploit the time-variability of the volatility. If the shortfall probability differs significantly from the target value, the portfolio duration is adjusted. If the shortfall risk is too high, duration is reduced; if it is too low, duration is increased.[6]

It is hard to determine ex ante the impact on the expected portfolio return. Protecting the portfolio from a shortfall should imply an insurance cost and hence reduce upside potential. On the other side, the strategy

EXHIBIT 2
Illustration of Shortfall Probability



should profit from the fact that market periods with high volatility often coincide with negative realized returns.

In a balanced portfolio, Gupta and Kartinen [2000] show that a dynamic risk-based strategy can significantly outperform a portfolio where stock and bond weights are held constant. When volatilities rise, the dynamic strategy shifts from equities to bonds to bring the short-run value at risk of the portfolio back to the long-run target level. In turbulent markets, stock markets fall in general. With the negative correlation between volatility and (subsequent) realized returns and with volatility clustering (if volatility increases, it normally remains at a high level for some time), the dynamic strategy performs better than a static strategy where the stock weight is fixed (and where the short-run value at risk fluctuates substantially).[7]

EMPIRICAL RESULTS

To backtest the strategy, we use JPMorgan daily data for Germany from December 31, 1987, to December 31, 2003. The dynamic strategy is allowed to invest in bonds (the JPMorgan government bond index for Germany) and cash (one-month yield). The bond weight is bounded between 0% and 110%, so we allow for a little leverage. In practice, this leverage could be realized either through futures or by overweighting long-term bonds. Transaction costs are assumed to be 5 basis points.[8]

In Exhibit 3, we set the minimum return to 0% and the target shortfall probability to 5%. The first column shows the return of the dynamic strategy (in %), and the second column displays the return of a duration-equivalent buy-and-hold strategy (in %). For example, on the first day of 2003, the index duration is 5.52 years (modified duration), and the strategy is invested 61% in bonds and 39% in cash to produce a duration of 3.36 years. It is assumed that the static portfolio in column (2) is held constant over the entire year, while the total return strategy in column (1) shifts dynamically between cash and bonds. The last column shows the turnover of the dynamic strategy (in %).[9]

In Exhibit 4, we keep the minimum return at 0% but let the shortfall risk vary from year to year so that the dynamic strategy is invested 100% in bonds on the first day of the year. With the current low yield levels, the shortfall probability has to be set to almost 13% in 2003, while it was close to 0% at the beginning of the 1990s. In the case of Exhibit 4, we compare the strategy performance in column (1) to the bond index in column (2). While the strategy's duration differs from the index duration at the beginning of each year in Exhibit 3, both durations are equal by construction in Exhibit 4.

It turns out that the total return strategy generates positive returns in each year (except a loss of 1 basis point in 1994 in Exhibit 3). In the bear market years 1994 and 1999, it avoids losses while the duration-equivalent static portfolios produce negative returns. In bull market years like 1995 or 2002, the dynamic strategy can also outperform its static counterparts because duration is extended beyond the index duration in these years. In the other years, the total return strategy often falls a little behind the static portfolios.

On average, the total return strategy outperforms the static portfolios by 40 bp (in the case of a constant shortfall probability in Exhibit 3) to 50 bp (in the case of a varying shortfall probability in Exhibit 4). So, besides achieving its primary goal of avoiding losses, the dynamic strategy also increases average return in the backtest as a positive side effect.[10]

Comparing Exhibit 4 to Exhibit 3, it would seem to be advantageous to increase portfolio duration at the start of the year (hence accepting a higher shortfall probability) in years like 2003 when there is no clear trend in yields and when the yield curve is fairly steep. When the

EXHIBIT 3
Backtest Results for Constant Shortfall Probability of 5%

Year	Total return strategy	Static portfolio	Difference	Index starting duration	Strategy starting duration	LPM	Turnover
1988	4.01	4.90	-0.89	5.60	3.81	5.00%	271.34
1989	0.15	0.38	-0.23	4.75	5.23	5.00%	418.64
1990	1.39	0.37	1.02	4.75	5.23	5.00%	244.79
1991	12.18	12.18	0.00	4.37	4.81	5.00%	3.01
1992	13.71	13.71	0.00	4.17	4.59	5.00%	3.01
1993	15.83	15.81	0.02	4.23	4.65	5.00%	3.27
1994	-0.01	-3.41	3.41	4.61	5.07	5.00%	213.38
1995	17.85	15.53	2.33	4.61	4.14	5.00%	24.21
1996	6.63	7.56	-0.93	4.37	4.57	5.00%	219.94
1997	6.04	6.11	-0.07	4.34	4.08	5.00%	92.39
1998	12.21	12.19	0.02	4.48	4.93	5.00%	3.51
1999	0.04	-0.81	0.85	4.96	3.62	5.00%	352.57
2000	6.69	6.35	0.34	4.81	3.39	5.00%	161.49
2001	5.08	5.20	-0.12	5.16	5.53	5.00%	40.73
2002	9.63	7.76	1.87	5.17	3.84	5.00%	113.00
2003	2.36	3.31	-0.95	5.52	3.36	5.00%	474.32
average	7.11	6.70	0.42	4.74	4.43	5.00%	164.98

EXHIBIT 4
Backtest Results for Varying Shortfall Probability*

Year	Total return strategy	Index	Difference	Index starting duration	Strategy starting duration	LPM	Turnover
1988	4.90	5.23	-0.34	5.60	5.60	9.54%	157.59
1989	0.79	0.97	-0.17	4.75	4.75	2.41%	170.11
1990	3.01	1.09	1.92	4.75	4.75	0.78%	63.40
1991	12.11	11.89	0.22	4.37	4.37	0.24%	31.14
1992	13.62	13.33	0.28	4.17	4.17	0.00%	13.32
1993	15.76	15.06	0.69	4.23	4.23	0.25%	19.23
1994	0.91	-2.62	3.53	4.61	4.61	0.76%	85.03
1995	18.01	16.80	1.21	4.61	4.61	6.38%	14.18
1996	6.68	7.38	-0.70	4.37	4.37	4.48%	216.44
1997	6.12	6.28	-0.16	4.34	4.34	5.64%	69.06
1998	12.09	11.40	0.69	4.48	4.48	2.73%	13.32
1999	0.00	-2.17	2.17	4.96	4.96	10.42%	450.28
2000	6.89	7.25	-0.37	4.81	4.81	9.46%	210.15
2001	4.93	5.14	-0.21	5.16	5.16	3.90%	88.51
2002	9.47	9.31	0.16	5.17	5.17	9.20%	208.66
2003	3.46	3.87	-0.41	5.52	5.52	12.94%	169.85
average	7.42	6.89	0.53	4.74	4.74	4.95%	123.77

**Strategy duration equals index duration at beginning of each year.*

duration is too low, one gives up too much carry.

For the sake of completeness, we should comment on the parameters we have chosen for the backtest. Volatility is estimated using a rolling window of 250 days of daily data and an exponential weighting scheme with a half-life of 125 days. To reduce turnover, a trade is induced when the current shortfall probability falls out of a bandwidth laid around the target shortfall probability. Its width has been chosen on the basis of empirical tests so that turnover and number of trading days are substantially reduced without producing a severe negative effect on the protection mechanism.[11]

If a trade is triggered, the average change in duration is about 0.10 years. The trading band and the parameters of the volatility estimation procedure have quite a limited impact on the performance of the strategy.

A more important issue to consider is leverage. The leverage is set to 1.1 in Exhibits 3 and 4; i.e., the bond weight is restricted to 110%. A higher leverage factor would increase the outperformance. For instance, if we allow for a duration of 1.5 times the index duration in Exhibit 4, the average return of the total return strategy would rise from 7.42% to 7.70%.

Higher leverage factors turn out to be good in bull years like 1995 or 2002 (and in bear markets, they do not hurt), but they have adverse effects on the strategy's performance in markets when yields drift sideways (like 2003). In these environments, the strategy loses because it cannot capture the yield movements as the trends are too short. The total return in 2003 falls from 3.46% to 1.18% if the leverage factor is set at 1.5.[12]

As a backtest represents only a limited number of years, we perform a Monte Carlo simulation to produce a variety of possible future bond market scenarios. We assume bond returns to be normally distributed with mean 4.2% and volatility 4%. To account for trends in bond yields, we assume a serial correlation of 0.05, which is close to the empirical autocorrelation coefficient in our data set. We set the minimum return to 0% and the shortfall probability to 14.69% so that the strategy portfolio is invested 100% in bonds at the beginning of each year. The bond weight is again bounded to 0% to 110%.[13]

Exhibit 5 displays the frequency distributions for the total return strategy and the hypothetical index portfolio for a simulation of 1,000 years with 250 days each. While the distribution of the index returns is symmetrical, the total return strategy produces a highly asymmetrical distribution. The tail left of the minimum return of 0% is cut off, which illustrates the protection against falling bond prices. The table below the plots shows that the 15% quantile is exactly 0%, so with a probability of 85% the strategy produces positive returns (as a shortfall probability of 15% implies). In the worst year, the hypothetical index loses more than 7%, while the losses of the strategy are limited to under 25 bp.

We have set up the simulation as a limiting case. We assume a constant volatility of 4% and do not model a (negative) correlation between volatility and realized returns. As argued above, volatility seems to be time-varying in real data, and there appears to be a relationship between volatility and returns that the strategy can exploit. Therefore, accounting for these effects should further improve the performance of the total return strategy in simulations. If the objective is to assess the mean return of the strategy in a simulation and compare it to a buy-and-hold portfolio, these effects should be included in the calculations.[14]

COMPARISON TO CPPI

It is instructive to compare the performance of the total return strategy and a constant proportion portfolio insurance (CPPI) strategy. CPPI is also a dynamic trading strategy that aims at protection of portfolio value above a prespecified threshold (see Black and Jones [1987]). In CPPI, the exposure to the risky asset is always set equal to the cushion times a multiplier. The cushion, C, is defined as the difference between the portfolio market value and the threshold (floor). CPPI is based on observable variables only, while the shortfall risk-based strategy needs several input variables to be estimated and makes distributional assumptions.[15]

At first glance, the requirement of observable variables only seems to be an advantage of CPPI. Yet the fact that a strategy needs to estimate some input parameters, in particular volatility, can also be an advantage. Volatility can be estimated quite precisely, and this way some empirical regularities like volatility clustering can be economically exploited.

To make both CPPI and risk-based total return comparable, we choose the multiplier M so that the bond exposure of the CPPI strategy, E, is equal to the bond exposure of the total return strategy:

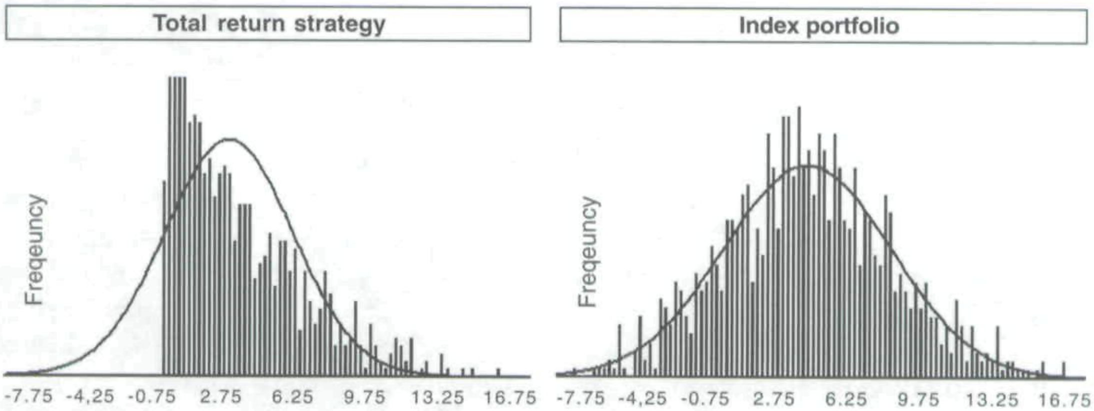
$$M = \frac{E}{C} \tag{2}$$

The multiplier is determined at the beginning of the year and then held constant over the year.

In Appendix B, we provide a proof that the shortfall risk-based approach can be interpreted as a generalized version of the CPPI model whose multiplier is dynamic and changes over time. The implied multiplier of the shortfall risk-based model depends on several parameters: the volatility estimate, the expected return estimates, the remaining time horizon, the fund price, and the cushion.

Equation (2) illustrates that CPPI works only for a pos-

EXHIBIT 5
Monte Carlo Simulation



Returns in the worst years

	1	2	3	4	5	...	10	...	50	150
Strategy (%)	-0.24	-0.20	-0.19	-0.18	-0.16		-0.10		-0.01	0.00
Index (%)	-7.64	-6.64	-6.32	-6.21	-5.87		-5.33		-2.80	-0.17

itive cushion ($C > 0$). With a cushion of zero, CPPI must start with a cash-only portfolio. This is an advantage of the total return strategy. Even with a cushion of zero (minimum return of 0%), the strategy can start with up to 100% bonds and earn the yield carry that a steep yield curve offers.

This is why we have set the minimum return to –1% in Exhibit 6. The target shortfall probability varies from year to year. The bond exposure is 100% in each strategy at the beginning of the year.

The last two columns of Exhibit 6 show the return of the CPPI strategy and its turnover (in %). CPPI avoids losses (compared to the minimum return) in the bear years of 1994 and 1999. The mean return is about 40 bp below that of the total return strategy in column (1).

CPPI also produces a higher turnover. Part of the difference in turnover occurs because CPPI adjusts portfolio weights daily, while the total return strategy leads to transactions only if the shortfall probability diverges significantly from the target level. If we force the total return strategy to rebalance daily, the average annual turnover increases from 80% to about 200%, but still remains substantially lower than the CPPI turnover.

Investors should recognize that both CPPI and the risk-based strategy produce portfolios that lag the performance of the market portfolio (or a constant-mix portfolio in general) in some circumstances. Portfolio insurance strategies show a convex payoff diagram (see Perold and Sharpe [1988]). They outperform the market in bull or bear environments but fall behind in volatile markets without a clear trend.

In the backtest, the strategies performed quite well in those volatile years, but it is easy to imagine a path of bond yields where they will underperform heavily (e.g., rising yields in the first 10 or 11 months of the year and then a short strong decline in yields). To enhance the performance of the risk-based strategy, the trading band can be adjusted (to prevent unnecessary trades) or the leverage factor can be reduced.

Another possibility is to use a moving threshold to lock in part of the gain when the portfolio value rises by raising the floor. In bull years, however, this procedure penalizes performance.

INCLUSION OF CORPORATE BONDS

The risk-based total return strategy is not limited to duration management only. In fact, the only requirement is to control portfolio risk. *How* this risk is produced—whether by duration, or credit, or whatever—is up to the manager. (This is also a further advantage over a CPPI strategy that shifts between the same two assets.) It is thus possible to include corporate bonds in the portfolio as long as the resulting risk is accounted for. We use a simple risk model to show the impact on shortfall risk if investment-grade corporate bonds are included in the portfolio.

To calculate the shortfall probability in Equation (1), we set the mean, μ, equal to the portfolio yield, adjusted for an expected loss due to downgrades and defaults. To estimate portfolio volatility, σ, we adopt a multifactor approach. Investing in corporate bonds involves interest rate risk, risk from spread changes, and specific risk. The specific risk depends mainly on the number of bonds held in the portfolio.

To model the specific risk, we follow Dynkin, Hyman, and Konstantinovsky [2002], who show how the specific risk of a corporate portfolio changes with the number of bonds and who calibrate their model to U.S. data. They show that a portfolio composed of 50 BBB bonds (chosen from a universe of more than 500 BBB bonds) produces a volatility of around 70 basis points annually. This volatility is due to specific risk only (i.e., systematic risk factors like duration or sector exposures are controlled for).

In Exhibit 7, we assume that investments in corporate bonds are made in 1% sizes. A portfolio invested 20% in corporates includes 20 single issuers; a portfolio with an allocation of 60% to credit includes 60 individual names. We then apply the Dynkin, Hyman, and Konstantinovsky model to get an estimate of the specific risk attributable to the corporate bond investment.

Next, we model the systematic risk using a two-factor model. The first factor represents (parallel) yield curve changes, and the second one changes in corporate spreads. The correlation between these two factors is slightly negative, implying a diversification effect.[16]

Exhibit 7 shows the shortfall probability for different duration and credit positions. If duration is set to two years, for example, the probability that a government-only portfolio will produce a negative total return in the next year is 2.23%. When the allocation to credit is increased, the shortfall probability first declines slightly, and then increases monotonically. For usual levels of shortfall probability (5%-10%), an allocation of about 30%-40% to corporate bonds seems appropriate, provided that the credit part is sufficiently diversified. This way the manager can profit from a yield pickup without substantially increasing shortfall risk.

The small numbers in italics below the shortfall probabilities in Exhibit 7 show how the overall risk is decomposed into interest rate risk, spread risk, and spe-

Exhibit 6

Backtest Results and Comparison to CPPI*

Year	Total return strategy	Index	Difference	Strategy starting duration	LPM	Turnover	CPPI performance	CPPI turnover
1988	5.13	5.23	-0.10	5.60	6.42%	57.58	4.74	203.98
1989	1.49	0.97	0.53	4.75	1.11%	14.65	0.03	1120.58
1990	2.79	1.09	1.71	4.75	0.31%	52.44	4.72	695.80
1991	12.11	11.89	0.22	4.37	0.09%	29.09	11.98	112.72
1992	13.61	13.33	0.28	4.17	0.00%	13.18	13.68	12.99
1993	15.76	15.06	0.69	4.23	0.07%	19.92	15.79	13.24
1994	0.37	-2.62	2.99	4.61	0.20%	81.28	-0.74	1884.83
1995	18.01	16.80	1.21	4.61	4.21%	14.14	17.77	123.03
1996	7.05	7.38	-0.32	4.37	2.23%	132.36	5.57	960.84
1997	6.15	6.28	-0.13	4.34	2.94%	57.11	4.64	597.38
1998	11.40	11.40	0.00	4.48	1.08%	0.00	12.17	13.48
1999	-0.97	-2.17	1.19	4.96	5.72%	469.59	-0.87	1224.71
2000	7.21	7.25	-0.05	4.81	5.90%	79.43	4.93	972.71
2001	5.15	5.14	0.01	5.16	1.70%	10.08	5.11	45.35
2002	9.69	9.31	0.38	5.17	5.46%	112.13	8.80	640.86
2003	3.67	3.87	-0.20	5.52	7.98%	102.00	3.43	191.36
average	7.41	6.89	0.53	4.74	2.84%	77.81	6.98	550.87

**Minimum return of –1% and varying shortfall probability.*

Exhibit 7

Shortfall Probabilities and Risk Decompositions for Portfolios with Corporate Bonds

Duration position	Credit allocation 0%			15%			30%			45%			60%		
2.0	2.23			1.91			2.56			4.04			6.11		
	100	0	0	92	-1	9	71	4	25	49	11	40	33	17	50
3.0	7.06			6.39			6.64			7.63			9.15		
	100	0	0	97	-1	4	86	0	13	71	4	24	56	9	35
4.0	11.45			10.89			10.95			11.59			12.66		
	100	0	0	99	-1	2	93	-1	8	83	1	16	72	4	24
5.0	14.87			14.56			14.68			15.19			16.04		
	100	0	0	100	-1	1	96	-1	5	90	0	11	81	2	17
6.0	18.44			18.26			18.37			18.76			19.41		
	100	0	0	100	-1	1	98	-1	4	93	-1	8	87	0	13

Minimum return of 0%.

Using such a risk model, it is possible to include corporate bonds in the total return strategy. Of course, this risk model makes some simplifying assumptions: only two systematic risk factors, normality of the systematic risk factors, and, for diversified corporate portfolios, normality of specific returns. Hence, the results give only some indication of how great the allocation to credit can or should be. If the credit part of the portfolio is not highly diversified, the normality assumption for specific returns does not hold, and a better credit risk model is needed. One good feature of the multi-factor model in Exhibit 7, however, is that the risk decomposition is relatively easy to perform.

For transaction cost reasons, it is reasonable to consider allocations to corporates as a medium-term buy-and-hold investment and to use bond futures to align the portfolio risk. Hence, a shortfall risk-based strategy allows the manager to spend the available risk budget in a flexible way (taking duration, yield curve, credit, and currency positions).[18]

The strategy is not purely mechanistic, but allows the manager to take advantage of skill in making investment decisions. At the same time, the total risk of the portfolio is controlled and adjusted on a daily basis to produce a positive total return (or a total return above a prespecified minimum-return threshold). To extend the strategy to other asset classes like equities, commodities, currencies, or high-yield bonds, the only requirement is the availability of a risk model to compute shortfall risk.

cific risk. With a duration of two years and an allocation of 60% to credit, for example, the shortfall probability is 6.11%. Roughly one-third of this risk is due to interest rate risk; 17% is due to changes of corporate spreads; and the remaining 50% can be attributed to issue selection.[17]

Except for portfolios with low durations, the dominant risk in an investment-grade portfolio is interest rate risk. Depending on their market views, managers can choose among a variety of portfolios that produce the desired target shortfall probability (they can also change the amount invested in a single corporate bond to control idiosyncratic risk).

SUMMARY

The investment strategy that we investigate is based on a shortfall risk approach and is designed to produce positive total returns in each year (or, more generally, returns above a required threshold within a prespecified investment horizon). Dynamic strategies like this and like constant proportion portfolio insurance control portfolio risk more efficiently than standard static strategies. Therefore, it is worthwhile for fixed-income investors to think about switching from buy-and-hold strategies (passive bond investment or active mandates with low tracking error) to a dynamic investment strategy, particularly when bond yields start to rise and the Fed is expected to increase interest rates.

APPENDIX A

Risk Analysis of a Long-Term Buy-and-Hold Investment

To analyze the risk-return profile of a buy-and-hold bond investment in more detail, we continue to assume that bonds have a periodic mean return of 4.2% and a volatility of 4%. Now, we assume bond returns to be lognormally (and independently over time) distributed in Exhibit A-1. (This is why the shortfall probabilities differ slightly from Exhibit 2, which is based on the normal distribution. The lognormal distribution is more suitable for long-term investments.)

Exhibit A-1 displays risk and return measures for investment horizons from one to ten years. The minimum return in the shortfall risk measures is set to 0% per year in the upper half of the exhibit and –2% in the lower half.

Given these parameters, the probability of realizing a negative return in the next year amounts to 14.62% in column (5). The shortfall probability falls rapidly when the investment horizon is extended. The 5% value at risk (VaR) is –2.25% for one year; i.e., with a probability of 5%, a loss of more than –2.25% will be realized. With longer horizons, the VaR turns positive. With a horizon of ten years, for example, the bond investment will yield more than 22.69% with a confidence level of 95%. The mean (cumulative) return over ten years is 50.90%.

Shortfall probability and VaR have the drawback that they provide no information as to what will happen if a worst case occurs, so we include worst case risk measures in Exhibit A-1. The mean excess loss (MEL) is defined as ratio of expected shortfall (LPM_1) and shortfall probability (LPM_0). It is the expected return in case of a shortfall.

Over one year, for example, LPM_0 is 14.62%. If a shortfall occurs, i.e., if one of the 14.62% worst cases materializes, the loss can be expected to be 1.94% as in column (7). While LPM_0 and (negative) VaR fall over time, MEL increases.

The conditional value at risk (CVaR) in columns (10) and (11) is similar to MEL except that the shortfall probability is fixed. The 5% CVaR over one year is –3.79%, for example; that is, if one of the 5% worst cases occurs, the loss will be at least –2.25% (VaR), and the expected loss will be –3.79% (CVaR).

So far, the risk measures have referred to what happens

EXHIBIT A-1

Risk and Return Characteristics of Buy-and-Hold Bond Portfolio

investment horizon (in years)	(1) required minimum return p.a.	(2) cumulative	(3) mean	(4) median	(5) end-of-period return and risk measures LPM0	(6) LPM1	(7) MEL	(8) 5% VaR	(9) 1% VaR	(10) 5% CVaR	(11) 1% CVaR	(12) within-periods risk measures LPM0	(13) 5% VaR	(14) 1% VaR
1	0%	0.0%	4.20%	4.12%	14.62%	0.28%	1.94%	-2.25%	-4.77%	-3.79%	-5.99%	NA	-4.43%	-6.33%
2	0%	0.0%	8.58%	8.42%	6.82%	0.16%	2.34%	-0.84%	-4.44%	-3.05%	-6.17%	NA	-4.99%	-7.35%
3	0%	0.0%	13.14%	12.89%	3.41%	0.09%	2.56%	1.20%	-3.29%	-1.55%	-5.42%	NA	-5.18%	-7.74%
4	0%	0.0%	17.89%	17.54%	1.76%	0.05%	2.71%	3.60%	-1.68%	0.37%	-4.17%	NA	-5.26%	-7.90%
5	0%	0.0%	22.84%	22.39%	0.93%	0.03%	2.81%	6.28%	0.24%	2.59%	-2.60%	NA	-5.29%	-7.98%
6	0%	0.0%	28.00%	27.43%	0.50%	0.01%	2.89%	9.18%	2.41%	5.04%	-0.76%	NA	-5.30%	-8.02%
7	0%	0.0%	33.37%	32.69%	0.27%	0.01%	2.95%	12.28%	4.78%	7.69%	1.28%	NA	-5.31%	-8.03%
8	0%	0.0%	38.98%	38.16%	0.14%	0.00%	3.00%	15.57%	7.33%	10.54%	3.52%	NA	-5.31%	-8.04%
9	0%	0.0%	44.81%	43.86%	0.08%	0.00%	3.04%	19.04%	10.06%	13.55%	5.92%	NA	-5.31%	-8.04%
10	0%	0.0%	50.90%	49.79%	0.04%	0.00%	3.08%	22.69%	12.95%	16.74%	8.48%	NA	-5.31%	-8.05%
1	-2%	-2.0%	4.20%	4.12%	5.71%	0.09%	1.58%	-2.25%	-4.77%	-3.79%	-5.99%	28.83%	-4.43%	-6.33%
2	-2%	-4.0%	8.58%	8.42%	1.28%	0.02%	1.78%	-0.84%	-4.44%	-3.05%	-6.17%	9.68%	-4.99%	-7.35%
3	-2%	-5.9%	13.14%	12.89%	0.31%	0.01%	1.86%	1.20%	-3.29%	-1.55%	-5.42%	3.25%	-5.18%	-7.74%
4	-2%	-7.8%	17.89%	17.54%	0.08%	0.00%	1.89%	3.60%	-1.68%	0.37%	-4.17%	1.09%	-5.26%	-7.90%
5	-2%	-9.6%	22.84%	22.39%	0.02%	0.00%	1.89%	6.28%	0.24%	2.59%	-2.60%	0.37%	-5.29%	-7.98%
6	-2%	-11.4%	28.00%	27.43%	0.01%	0.00%	1.89%	9.18%	2.41%	5.04%	-0.76%	0.12%	-5.30%	-8.02%
7	-2%	-13.2%	33.37%	32.69%	0.00%	0.00%	1.87%	12.28%	4.78%	7.69%	1.28%	0.04%	-5.31%	-8.03%
8	-2%	-14.9%	38.98%	38.16%	0.00%	0.00%	1.85%	15.57%	7.33%	10.54%	3.52%	0.01%	-5.31%	-8.04%
9	-2%	-16.6%	44.81%	43.86%	0.00%	0.00%	1.82%	19.04%	10.06%	13.55%	5.92%	0.00%	-5.31%	-8.04%
10	-2%	-18.3%	50.90%	49.79%	0.00%	0.00%	1.80%	22.69%	12.95%	16.74%	8.48%	0.00%	-5.31%	-8.05%

at the end of the investment horizon. Columns (12)-(14) give some indication of what can happen in between. The derivation of these continuous risk measures is outlined in Kritzman and Rich [2002]. While conventional VaR is –2.25% at the 95% confidence level, the continuous VaR is –4.43% over one year. Hence, the portfolio will suffer a loss of more than 2.25% at the end of one year, but there is a 5% probability that the portfolio value will drop by more than 4.43% during that year.

The (negative) continuous interim VaR rises with a longer investment horizon, which illustrates the risk of a long-term investment. The conventional VaR by contrast falls with a longer horizon. The probability of falling short of –2% at the end of the next year is 5.71%, but the probability of falling below –2% during the next year is much greater (28.83%).

In the real world, many investors have a long-term horizon but also require returns to stay above some threshold at the end of each individual year. For these investors, our total return strategy is an interesting option because a passive bond portfolio turns out to be too risky, as Exhibit A-2 shows.

Panel A of Exhibit A-2 illustrates a 14.69% probability that the average (arithmetic) annual return will fall below the minimum return of 0% over one year. (Exhibit A-2 assumes returns to be normally distributed with mean 4.2% and volatility 4%.) At the end of a five-year investment period, the shortfall probability is only 0.94%, but there is a probability of 54.80% that the annual return will not be positive in each of the five years.

Panel B displays the minimum returns that can be required by the investor so that the shortfall probability is 5%. If the minimum return is +1.26%, there is a 5% probability that the average annual return is lower than this number at the end of five years. The minimum return falls to –5.07% if the shortfall probability refers to each of the five years. There is a 95% probability that the portfolio return will be better than –5.07% in each year, so a passive bond investment is suitable for an investor with a high risk budget (VaR) of around –5% per year (provided the investor has a five-year horizon and cares about the annual returns).

To put this differently, a bond investment with a volatility of 4% needs to offer an expected return of 6.58% to reduce the shortfall probability with respect to a minimum return of 0% over one year to 5% (see Panel C). If the investment horizon is extended to five years and if shortfall refers to the end of the five-year period, the expected annual return on bonds needs to be only 2.94%. If the annual return is required to be positive at the end of each of the five years at a confidence level of 95%, the expected annual return of bonds increases to 9.27%—much higher than current yields.

The reason for the higher expected returns in the last column of Panel C is that losses in one year cannot be offset by gains in other years. Therefore, we can conclude that an investment in a passive bond portfolio is too risky for an investor who requires positive annual returns.

EXHIBIT A-2

Risk Measures for Bond Portfolio with Respect to Intermediate Years

a) investment horizon (in years)	shortfall probability* with respect to a minimum return of 0%: at the end of horizon	at the end of each year
1	14.69%	14.69%
2	6.88%	27.22%
5	0.94%	54.80%
10	0.04%	79.57%

b) investment horizon (in years)	minimum return that can be required so that the shortfall probability is 5%: at the end of horizon	at the end of each year
1	-2.38%	-2.38%
2	-0.45%	-3.62%
5	1.26%	-5.07%
10	2.12%	-6.07%

c) investment horizon (in years)	expected return of a bond investment that is needed so that the shortfall probability* is 5%: at the end of horizon	at the end of each year
1	6.58%	6.58%
2	4.65%	7.82%
5	2.94%	9.27%
10	2.08%	10.27%

* *Shortfall probability refers to the probability that the average annual return falls below the minimum return of 0% either at the end of the investment horizon (first column) or at the end of at least one year in the investment horizon (second column).*

APPENDIX B

Comparison of Shortfall Risk-Based Model and CPPI

We show that the shortfall risk-based (or VaR-based) model can be seen as a generalized version of CPPI with a dynamic and time-varying multiplier by extracting an implied multiplier in the VaR model.

The VaR of the portfolio is given by

$$\mathrm{VaR} = \mu_P - \Phi^{-1}(\alpha)\sigma_P \tag{B-1}$$

where $\Phi^{-1}(\alpha)$ is the α-quartile of the standard normal distribution (e.g., for $\alpha = 95\%$, $\Phi^{-1}(0.95) = 1.645$), and μ_p and σ_p denote the expected portfolio return and volatility scaled to the investment horizon.

The bond weight is chosen so that the VaR equals the minimum return τ. Without the drift term, the VaR is simply:

$$\mathrm{VaR} = -z_\alpha h_{FI}\sqrt{t}\sigma_{FI} \tag{B-2}$$

where $z_\alpha = \Phi^{-1}(\alpha)$; h_{FI} denotes the bond weight; t is the remaining horizon (in years); and σ_{FI} is the annual bond index volatility.

Solving for h_{FI} so that VaR = τ yields:

$$h_{FI} = \frac{\tau}{-z_\alpha \sqrt{t}\sigma_{FI}} \tag{B-3}$$

Note that there is no positive bond weight when $\tau \geq 0\%$. So, with $\tau \geq 0\%$, the VaR model without drift as well as CPPI ($C \leq 0$) is not applicable.

The implied multiplier of the VaR model is obtained by

$$M^{impl} = \frac{E}{C} = \frac{h_{FI}P}{C} = \frac{C/P \quad P}{z_a \sqrt{t}\sigma_{FI} \; C} = \frac{1}{z_a \sqrt{t}\sigma_{FI}} \tag{B-4}$$

where exposure E and cushion C are expressed in nominal terms, P is the market value (price) of the fund, and $\tau = -C/P$. τ is expressed in percentage terms.

Hence, the multiplier of the VaR model is time-varying. It depends on the remaining investment horizon, t, and the conditional volatility of the bond market. If volatility increases, the multiplier falls, and hence the bond weight is reduced.

Equation (B-4) can be interpreted economically. The inverse of the CPPI multiplier is the maximum loss or worst case return that is allowed to occur over the next period. If the loss is greater, a shortfall occurs. The portfolio market value falls below the floor and (with a cash yield of 0%) cannot recover any more because the bond exposure is set to 0. The same holds for the VaR model if the (negative) realized return exceeds the worst-case return, $1/M^{impl} = z_\alpha\sqrt{t}\sigma_{FI}$.

Our calculations include the drift term in the VaR calculation. This is justified because at least the cash yield is known on any date, and because the investment horizon is rather long (initially 12 months). Then the cash yield and the expected bond return (bond yield) enter in Equations (B-2) to (B-4). Now, the fund price and the cushion do not cancel out any more in (B-4). The implied multiplier depends on the volatility estimate, the cash yield, the expected bond return, the remaining time horizon, the fund price, and the cushion.

The volatility and expected return estimators have a small impact only. (This holds at least for the estimators that we have tested. If a conditional forecasting model produces forecasts that fluctuate highly over time, this picture might change.)

For example, if one does not rely on the bond yield as being a good estimate for expected bond returns and replaces it with the cash yield (assuming bonds earn no risk premium), the bond exposure will be reduced in general, but the dynamic behavior of the trading strategy (the change in the bond weight) will be virtually unaffected. Or, using an exponentially weighted volatility estimator instead of a constant value for volatility has positive effects on the strategy's performance, but the impact is again quite limited.

The main forces driving the dynamic change of the bond exposure are the remaining time horizon (which is not relevant for CPPI) and the cushion of the portfolio (market value minus floor). Further analysis shows that the implied multiplier falls when the portfolio market value rises, and vice versa (under CPPI, the multiplier is constant and does not depend on the cushion). This has the effect that there are fewer transactions and fluctuations in the bond weight in the shortfall risk model than in CPPI.

ENDNOTES

[1]Mortgage-backed securities have the undesirable property of negative convexity, i.e., duration falls as yields decline. To compensate for this effect, market participants buy Treasuries or go long Treasury futures to bring their portfolio duration back to a higher level when yields fall (convexity hedging). These long positions cause bond yields to fall further, thereby increasing volatility.

[2]Regressing the price returns of an investment-grade corporate index on the price returns of a government bond index yields a coefficient of determination of about 70%. With AA bonds only, the R^2 rises to about 90%.

[3]Many investors have switched to passive management because they have been dissatisfied with the forecasting skill and performance of active managers. It would be a contradiction if the investors returned to the same managers and relied on them to manage total return portfolios based purely on return forecasts.

[4]For the duality of portfolio weights and risk budgets, see Herold [2003] and Scherer [2002].

[5]As we want to design a strategy that does not require yield curve forecasts, we have chosen to use the yield as an estimate of the expected bond portfolio return. If the yield curve is parallel and does not move over the horizon (e.g., over the next year), the realized return of a bond will be equal to its internal rate of return. In other words, the investor earns a coupon return plus price appreciation or depreciation (pull-to-par) equal to the bond yield. If in investment practice, a portfolio manager has some skill in yield curve forecasting, we could replace the yield with that expected return estimate.

[6]Conceptually, both a shortfall risk optimization as well as a classical mean-variance optimization will yield the same efficient portfolios under the normality assumption. The shortfall risk constraint determines which portfolio of the MV efficient set the investor chooses. As we assume that the investor thinks in terms of shortfall risk—and in fact, most institutional investors impose shortfall risk targets—it is straightforward to directly control for shortfall risk instead of maximizing a mean-variance utility function.

[7]The empirical finding that a risk-based dynamic strategy outperforms a static strategy is not confined to the U.S. market. Herold [2001] obtains similar results for the German market.

[8]As in practice most transactions will be implemented using futures, we assume a rather low value for transaction costs.

[9]Please note that the second-to-last column in Exhibit 3 shows the target shortfall probability (LPM) of 5%. In some years like 1989-1994, the actual shortfall probability is lower than this

target level because the bond weight is restricted to 110% (a 5% shortfall probability would imply a higher bond weight in these years; see Exhibit 1).

[10]The setup we use for the backtest is rather simple: shifting between cash and the bond market portfolio. In practice, a manager would not increase cash to reduce duration but instead switch from long-term to short-term bonds, staying fully invested. This way the manager can earn the roll-down performance component (which is quite high in the case of a steep yield curve). In this regard, our backtest probably underestimates the average return from the dynamic strategy.

[11]In addition, we do not hold the trading band constant over the course of the year but widen it toward the end. With constant trading bands, trading frequency often sharply increases toward year-end, while with widening bands, the trades are distributed more evenly over the year.

[12]The same observation holds for the first half of 2004, which was also a volatile year without a trend. The total return of the strategy with 1.1 leverage is 1.83% compared to 1.76% for the JPMorgan index. With a leverage factor of 1.5, the total return falls to 0.77%.

[13]The assumption of a normal distribution does not seem to be too critical. Applying principal components analysis to historical yield curve changes, we extract the first three factors, which account for about 95% of the total variability of yield curve movements. The null hypothesis of normality cannot be rejected for the first factor (which captures parallel movements of the yield curve). It can be rejected for the second and third factor. The first factor is the most important one; it can explain almost 90% of yield curve movements.

[14]We have not accounted for these effects because our focus is on the left tail of the distribution only. Of course, to take these effects into consideration, one has to model them from the data. This introduces additional model uncertainty.

[15]In Equation (1), returns are assumed to be normally distributed to calculate shortfall probability. This assumption could be relaxed, and shortfall probability could be computed non-parametrically, based on the empirical frequency distribution of bond returns. Then the estimation error problem gets more severe as there are only a few observations in the calculation of shortfall probability. So there is a trade-off between model risk and estimation risk. Furthermore, the shortfall probability is calculated not only at the beginning of the year but also each day (with a shortening investment horizon). On the second-to-last day of the year, the probability that a shortfall occurs on the last day must not exceed the target value (of, e.g., 5%). If shortfall probability is misestimated due to the normality assumption, and if a shortfall occurs, it should be fairly limited because the horizon is only one day.

[16]Using monthly Merrill data for EMU indexes over 1997-2002, we estimate the correlation between yield curve changes and spread changes is −0.24. The volatility of yield changes is about 20 bp per month and the volatility of spread changes about 12 bp (for industrials). The current spread is assumed to be 70 bp. Downgrades/defaults of corporate bonds are assumed to be correlated, with a coefficient of 0.2.

[17]The risk decomposition is derived from marginal risk contributions; for the mathematics, see Herold [2003].

[18]How much risk is allocated to each of these decisions depends on the information ratio of the manager and is the output of a risk budgeting exercise; see Herold [2003] and Scherer [2002].

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