Morgan Stanley

MORGAN STANLEY RESEARCH
NORTH AMERICA

Morgan Stanley & Co. LLC

Martin Leibowitz
Martin.Leibowitz@morganstanley.com
+1 212 761 7597

Anthony Bova
Anthony.Bova@morganstanley.com
+1 212 761 3781

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Portfolio Strategy

Duration Targeting: A New Look at Bond Portfolios

The term Duration Targeting (DT) refers to bond portfolios that maintain a more or less stable duration over time. An earlier series of studies examined this DT process and found return behavior that differed significantly from traditional beliefs. This report summarizes and integrates these findings.

Even when not explicitly designated as DT, the vast majority of bond portfolios actually follow a DT process. Some form of DT can usually be seen in active and passive institutional bond funds, bond mutual funds, and in the fixed income component of multi-asset funds. Laddered bond portfolios, even with illiquid holdings, implicitly function in a DT mode. Despite this widespread presence in the marketplace, the risk/return nature of DT is generally under-appreciated.

The key insight is that price changes from a move in yields tend to be offset by going-forward accruals at the new yield level. In the earlier studies, we developed an analytic expression to approximate DT returns. This model led to the rather surprising conclusion that the annualized return should converge back toward the starting yield over time, regardless of how dramatically yields rose or fell in the intervening years.

The behavior suggested by these theoretical DT models was tested using 1977 – 2011 yields for constant maturity Treasury bonds. Over 6- to 10-year holding periods, both concentrated and laddered portfolio returns converged to within 90 bps of the initial yield. In another test against Barclay bond indexes, the returns exhibited similar convergence with R^2's of 77% to 80%.

These findings have a number of investment implications relating to bond volatility, the expected returns associated with scenario analysis, and the volatility of the bond components within a multi-asset framework.

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Duration Targeting

A New Look at Bond Portfolios

We thank Dr Stanley Kogelman, who is a consultant (not a member of Morgan Stanley's Research Department), for his important contributions to the development of the mathematics and the research in this report. Unless otherwise indicated, his views are his own and may differ from the views of the Morgan Stanley Research Department and from the views of others within Morgan Stanley.

Summary
Almost all bond portfolio managers control their interest rate risk through a Duration Targeting (DT) process. As bonds age and interest rates shift, managers typically maintain a specific duration target through periodic portfolio re-balancing. In this paper, we consolidate the results of earlier research papers [1-8] and explore the return characteristics of active and passively managed DT portfolios across a wide range of interest rate environments.

Despite the wide use of either explicit or implicit DT, the full implications of this strategy generally have been under-appreciated. In earlier papers, we showed that the annualized returns of DT portfolios exhibit a surprisingly robust convergence pattern. As the length of the holding period approaches the portfolio's "effective maturity," portfolio volatility decreases as the starting yield exerts a "gravitational pull" on returns. This convergence holds even if yields exhibit a pronounced rising or falling trend.

The intuition behind convergence is related to the balance between price changes and accruals. For DT portfolios, the cumulative capital gains/losses depend on the difference between the final yield and the initial yield. In contrast, the accrual component of returns is highly path dependent.

For example, along a rising trendline (TL) path to the terminal yield, accruals build in lockstep with the higher yields. At the "effective maturity," which depends only on the duration, accrual gains precisely offset price losses, and the annualized return equals the initial yield.

When the yield path does not follow a TL, the corresponding accrual and annualized return will deviate from the TL return. However, the average annualized return across all non-TL paths to a given terminal yield will almost always equal the TL return. This averaging property provides important insights that can be applied to scenario-based forecasting.

The theoretical model was tested by following the return paths of constant maturity Treasury portfolios, the Barclays Government/Credit Index, and hypothetical 10-year laddered portfolios. Our key finding is that, since 1977, the annualized returns of these portfolios over 6- to 10-year holding periods has generally been within 90 basis points of the initial yield. The Barclays Index starting yield was found to match the 6-year return with an R^2 of 77% to 80%.

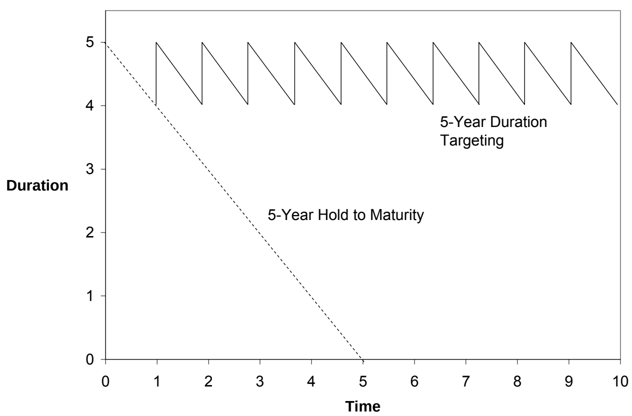
These findings suggest that the initial yield is likely to provide the best estimate of annualized returns over an appropriate horizon, even in the face of an anticipated rising or falling rate trend. Moreover, the convergence of DT portfolios has important implications for asset allocation policy, since the multi-year volatility of such portfolios will be considerably lower than what is derived from commonly-used traditional models.

Buy and Hold vs. Duration Targeting
Most bond portfolio management can be characterized as either Buy-and-Hold (B&H) or Duration-Targeted (DT). B&H is the ultimate passive approach. For example, if a 5-year zero-coupon bond is held to maturity, the duration simply "ages down" year-by-year until maturity and the annualized return will equal the initial yield.

In contrast to B&H, the constant duration of DT is maintained over the entire investment horizon by periodic rebalancing. At the end of one year, the 5-year bond ages to a 4-year bond, which is sold and replaced by a new 5-year bond. Exhibit 1 contrasts the time-evolution of the duration for B&H versus DT for a 5-year zero coupon bond.

Exhibit 1

Duration Targeting vs. Hold-to-Maturity



Source: Morgan Stanley Research

There are some important parallels between single bond B&H returns and DT portfolio returns. For example, the aging duration of B&H results in decreasing volatility of the mark-to-market return as the holding period approaches the bond maturity. At its stated maturity, the B&H bond's return will coincide with the initial yield.

With DT portfolios, the duration does not age down, but rather is sustained at the targeted level. For this reason, DT portfolios are not generally thought to share the B&H property of convergence to the starting yield. But as we show in the following sections, the annualized return volatility for DT formats also decreases with longer holding periods.

DT Portfolio Rebalancing

The DT process can be achieved in a variety of ways. The simplest case is illustrated in Exhibit 2 with a single bond having with an initial duration of 5 years. Over the course of a year, the portfolio ages down to a 4-year duration. The bond is sold and the proceeds are then used to purchase a new 5-year duration bond. This simplest of all DT processes relies on having liquid bonds with minimal transaction costs.

However, a DT process can be at work in a more complex bond portfolio with illiquid holdings. For example, Exhibit 3 depicts an equal-weighted bond "ladder" with maturities ranging from one to five years. The average maturity/duration of this portfolio is three years.

After one year, each bond (and the portfolio) ages by one year. The 1-year bond matures and the 5-year bond position is vacant.

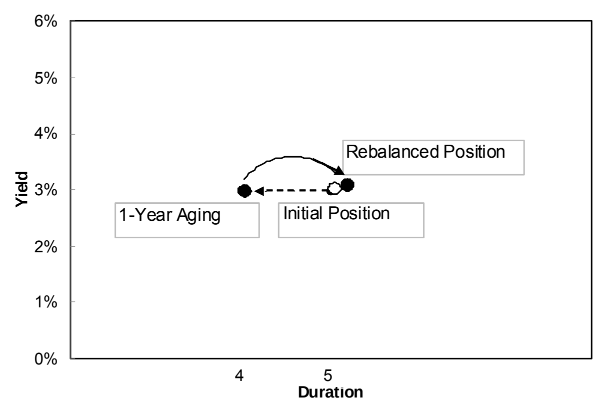
The portfolio can be "rebalanced" without selling any bonds by simply using the proceeds of the maturing bond to buy a new 5-year bond. The bond durations will then again range from one to five years, and the initial 3-year average duration will have been restored.

This simple example can be generalized to more complex coupon bond portfolios with unequal bond weights. Even for such portfolios, rebalancing can often be accomplished by using the proceeds of maturing bonds and interim coupon flows. When few forced bond sales are required, many bonds can be held to maturity, and such DT portfolios may have a substantial B&H component.

In the case of bond indices, bonds typically must have a maturity greater than one year. Bonds that age to the one-year point must be sold and the proceeds used to purchase newly available bonds typically having longer maturities. Without any explicit commitment to a DT framework, this sale/purchase process in bond indices tends to lead to relatively stable durations.

Exhibits 2

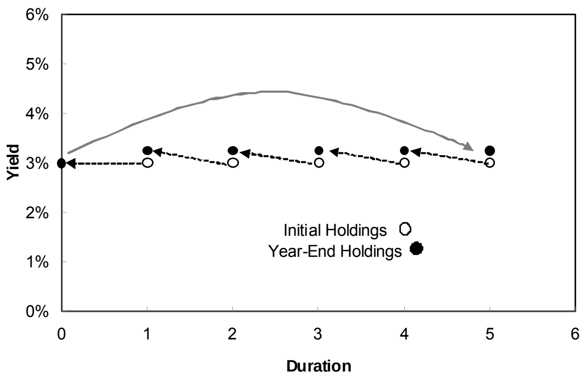
Total Sale-and-Repurchase Rebalancing



Source: Morgan Stanley Research

Exhibits 3

Rebalancing of Illiquid Ladders



Source: Morgan Stanley Research

Trendline Paths and DT Returns

To illustrate the DT process, we use the most basic model of a zero-coupon bond with a 5-year duration. At the end of each one-year holding period, the aged bond is sold and the proceeds invested in a new 5-year bond.

All returns from zero-coupon bonds take the form of price movements. However, in this analysis, we differentiate between two forms of return: 1) price effects derived from changes in yield, and 2) "accruals" that result from the passage of time without any change in yields.

To illustrate how yield changes impact returns, we begin with a simple 9-year yield trendline (TL) path that proceeds from an initial yield of 3% to a final 7%. Exhibit 4 is based on yields rising at a constant of 50 bp per year and also displays the corresponding annual returns and annualized cumulative returns.

Exhibit 4

Trendline Returns

Year	Yield Accrual	Price Loss	Annual Return	Cum Return	Annualized Cum Return
1	3.0%	-2.0%	1.0%	1.0%	1.00%
2	3.5%	-2.0%	1.5%	2.5%	1.25%
3	4.0%	-2.0%	2.0%	4.5%	1.50%
4	4.5%	-2.0%	2.5%	7.0%	1.75%
5	5.0%	-2.0%	3.0%	10.0%	2.00%
6	5.5%	-2.0%	3.5%	13.5%	2.25%
7	6.0%	-2.0%	4.0%	17.5%	2.50%
8	6.5%	-2.0%	4.5%	22.0%	2.75%
9	7.0%	-2.0%	5.0%	27.0%	3.00%
Total	45.0%	-18.0%	27.0%	27.0%	

Source: Morgan Stanley Research

The first year accrual corresponds to the 3% initial yield. Over the year, the bond ages and the initial 5-year bond duration is reduced to 4. Since the year-end TL yield is 0.5% higher than the initial yield, the rebalancing bond sale results in a price loss that is approximately -4 x 0.5% = -2%. The total return is therefore 1% (3% accrual - 2% price loss).

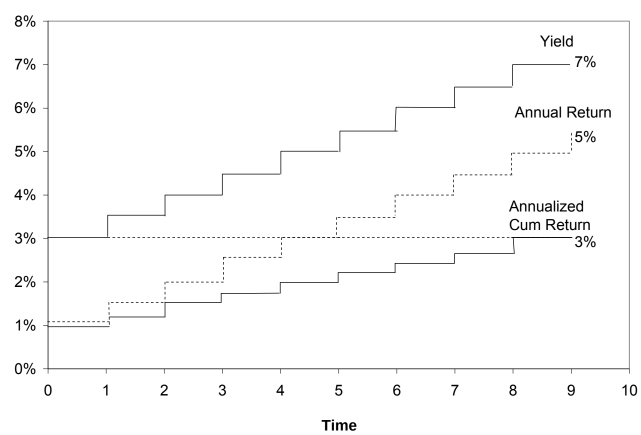
The sale proceeds are then re-invested in a new 5-year bond with the new 3.5% yield. This 3.5% yield then becomes the basis for the second-year accrual. Since the TL yield increases by another 0.5%, the second-year price loss is again -2%. This -2% loss combines with the second-year accrual of 3.5%, leading to an annual return of 1.5%. With each subsequent year, the accrual rate increases by another 50 bps, while the price loss remains the same at -2%, so that the total return increases by 0.5% each year.

After four years of 0.5% yield increases, yields and accruals rise by 2%, from 3% to 5%. In the fifth year, the excess accrual (i.e., the difference between the accrual and the initial yield) of 2% precisely offsets the -2% price loss, so the annual return is the same as the initial yield. In later years, with ever higher accruals, annual returns continue to grow so that, after 9 years, the accruals completely offset the cumulative price losses. This 9-year horizon at which the annualized return comes back to the starting yield can be viewed as an "effective maturity" for this DT example.

Exhibit 4's TL process is depicted graphically in Exhibit 5.

Exhibit 5

TL Yields, Annual Returns, and Annualized Cumulative Returns



Source: Morgan Stanley Research

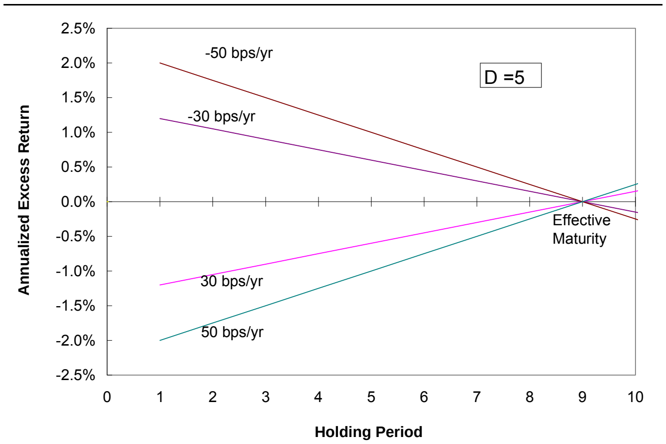
DT Effective Maturity
In the following, it is helpful to focus on the "excess return" measure that is the annualized cumulative return above the starting yield.

The Appendix develops an analytic expression for the excess return over any TL path. This formula shows that the effective maturity for a TL-based DT path is equal to twice the target duration minus one. Thus, the effective maturity depends only on the duration and is independent of the size and direction of yield changes. For the example of the 5-year duration bond, the effective maturity is 9 years (2*5-1).

Exhibit 6 illustrates how annualized excess returns approach zero as the holding period approaches the 9-year effective maturity for a 5-year duration target. Each line represents a different yield path. When yields decline at -50 bp per year (the uppermost line), price gains in the early years dominate accruals, resulting in relatively high returns. Over time, ever lower yields lead to declining accruals that eventually completely offset all price gains.

At the other extreme of +50 bp annual yield increases, initial price losses lead to negative excess returns in the early years. But those early losses are gradually mitigated by accrual gains, and the excess return again becomes zeroed out at the same 9-year horizon. More generally, Exhibit 6 illustrates that a given duration target has the same effective maturity for any drift rate, as long as yields progress in a TL fashion.

Exhibit 6
Excess Returns for Various Trendline Drift Rates

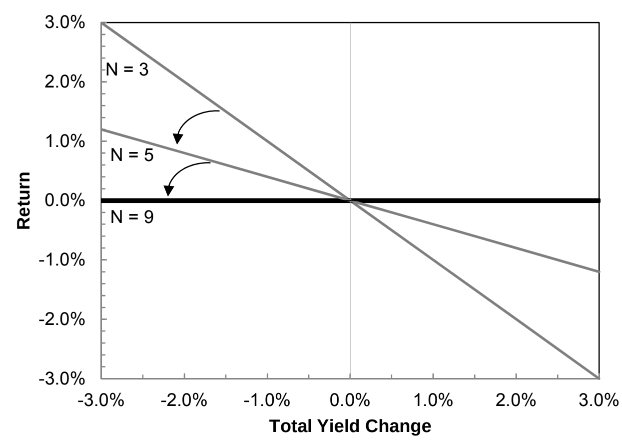


Source: Morgan Stanley Research

DT Return Sensitivity at a Fixed Horizon
Exhibit 7 focuses on the relationship between the annualized excess DT returns and the total yield change over 3-, 5- and 9-year holding periods. The slope of the 3-year return line reflects the sensitivity of excess returns to the total yield change. As the holding period increases, the total yield change sensitivity decreases and the return line rotates counter-clockwise.

For a 9-year holding period, the return line becomes horizontal and the excess return is zero, regardless of the magnitude of the yield change. Thus, this zero excess return implies that the annualized return will come back to the starting yield along a TL path to ANY terminal yield.

Exhibit 7
Returns vs. Total Yield Change for Various Time Horizons

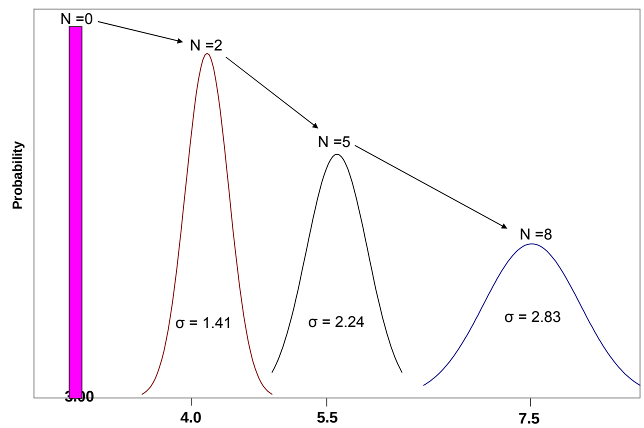


Source: Morgan Stanley Research

Terminal Yield and Return Distributions
Until this point, we have focused on TL paths that lead to a specific terminal yield. We now turn our attention to probability distributions of terminal yields as generated by a random walk.

In the following example, we assume that yield changes are subject to an annual volatility of 1% around a 50 bp upward drift from the 3% starting yield. Exhibit 8 shows the progression of yield distributions over time. At the outset, the investment horizon N = 0, and there is no volatility around the 3% initial yield. As the horizon increases, the mean of the yield distribution moves up at the drift rate of +50 bp per year, while the "volatility" — the standard deviation of the yield change distribution — increases by a factor of √N x the 1% yield volatility.

Exhibit 8
The Progression of Yield Distributions Over Time



Source: Morgan Stanley Research

Thus, at the 5-year horizon, the yield distribution has a mean of 5.5% (=3.0% +5x 0.5%) and a volatility of 2.24% (=√5x1). There is a unique TL leading from the initial 3% to each terminal yield in the distribution. The annualized return for each TL path can be determined by applying the return formula in the Appendix. Thus, the total annualized return to the 5.50% yield is 2.0% (as in Exhibit 4), while the TL path to a 2.50% yield would produce a return of 3.2%. The probability associated with terminal yields in the 5.0-6.0% range is 18%. Similarly, terminal yields falling around 2.5% ± 0.5% have a 7% probability. Exhibit 9 depicts the returns and associated probabilities for a range of terminal yields at the 5-year horizon.

Exhibit 9
Probability Distribution of 5th Year TL Returns

5-Year Yield	Probability	Annualized Return
2.5%	7%	3.2%
3.5%	12%	2.8%
4.5%	16%	2.4%
5.5%	18%	2.0%
6.5%	16%	1.6%
7.5%	12%	1.2%
8.5%	7%	0.8%
Average Yield = 5.5%		Average Return = 2.0%
Yield Volatility = 2.24%		Return Volatility = 0.9%

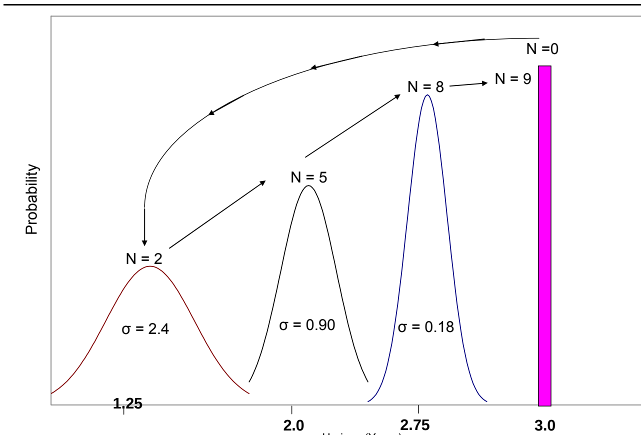
Source: Morgan Stanley Research

Thus, by associating the probability for the terminal yields with the corresponding returns, the probability distribution of yields can be translated into a distribution of returns. However, from Exhibits 6 and 7, the TL returns for any terminal yield are seen to be compressed with longer horizons, eventually converging back to the starting yield. Thus, even while the yield distributions have an underlying volatility that widens over time, this return compression drives the return distribution to follow the strikingly different sequence shown in Exhibit 10.

For horizons such as N =2, the rising drift in yields leads to price losses that result in the lower 1.25% mean return. The relatively wide volatility of returns reflects the high sensitivity to yield moves shown in Exhibit 7. However, as the investment horizon lengthens, the returns are compressed for all terminal yields, resulting in a mean return that converges back to 3% with an ever decreasing volatility of return.

In other words, as shown in Exhibit 10, the progression of return distributions is almost the opposite of the progression of the terminal yield distributions from the random walk.

Exhibit 10
The Progression of Annualized Returns Over Time

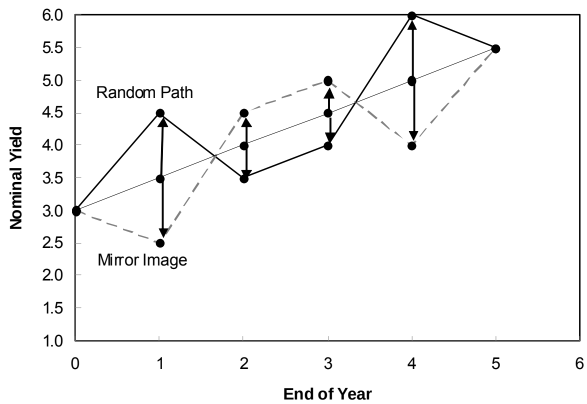


Source: Morgan Stanley Research

Mirror Image Paths

To this point, we have focused on a TL model in which yields move in equal increments from the initial yield to the terminal yield. We now turn to non-TL paths such as the random path displayed in Exhibit 11, along which the yields lie intermittently above and below the TL.

Exhibit 11
Mirror Image Paths Relative to a Trendline



Source: Morgan Stanley Research

The second path in Exhibit 11 is a "mirror image" of the random path relative to the TL. Along the mirror pair, corresponding points have equal vertical deviations from the TL, but the opposite sign. Consequently, at the end of each year, the accrual deviations for the mirror paths cancel each other.

As shown in Exhibit 12, if the two non-TL paths have equal probability of occurring, the expected accrual of the mirror pair will equal the TL accrual. The total capital gain/loss for the random path (and mirror path) is also the same as for the TL since price effects depend only on the initial and terminal yields. It therefore follows that the average return across any such mirror pairs will just equal the TL return.

Exhibit 12
TL and Mirror Pair Returns

	Accruals			
	TL Path	Random Path	Mirror Image	Mirror Path Average
Year 1	3.0%	3.0%	3.0%	3.0%
Year 2	3.5%	4.5%	2.5%	3.5%
Year 3	4.0%	3.5%	4.5%	4.0%
Year 4	4.5%	4.0%	5.0%	4.5%
Year 5	5.0%	6.0%	4.0%	5.0%
Annualized Accrual	4.0%	4.2%	3.8%	4.0%
Annualized Price Effect	-2.0%	-2.0%	-2.0%	-2.0%
Excess Return	2.0%	2.2%	1.8%	2.0%

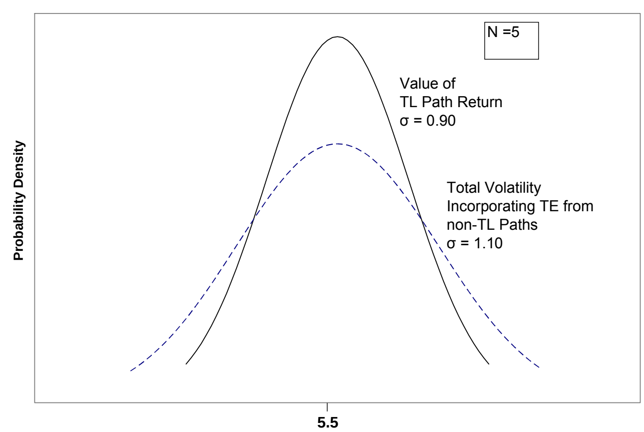
Source: Morgan Stanley Research

The averaging illustration in Exhibit 12 can be extended to the full range of terminal yields. For each terminal yield, there is a unique TL with a specific TL return. If both non-TL paths have comparable probabilities, then the mirror paths will have the same expected return as the TL return. By extension, each TL return to a given terminal yield can be taken as a reasonable estimate of the average return across all of the many non-TL paths leading to that same terminal yield. Moreover, it would then also follow that the average of all TL returns across all terminal yields would reflect the average return across all paths derived from the random walk.

Tracking Errors around the TL Return

From Exhibit 12, one can also see that even though the mirror pairs may have returns that average to the TL return, each individual non-TL path will generally have a return that differs from the TL. This "scatter" from the non-TL paths then becomes a source of tracking error (TE) relative to the TL returns, and has the effect of widening the distribution of returns around the mean return (Exhibit 13).

Exhibit 13
Total Volatility Incorporating TE from non-TL Paths



Source: Morgan Stanley Research

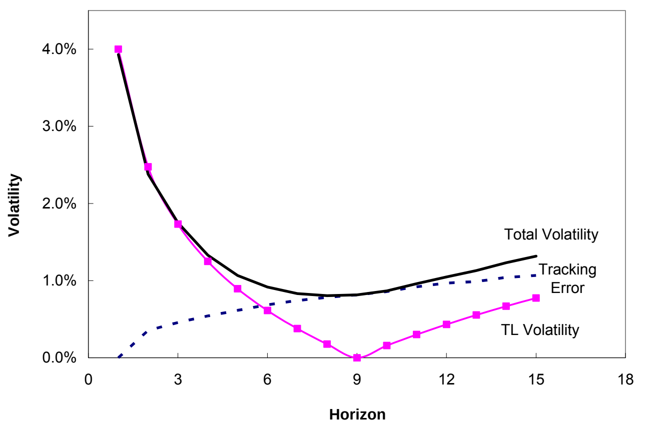
For a typical random walk process, we were able to develop good approximation formulas for the TE and the "total volatility" of the all-pathway return distribution (see Appendix).

Exhibit 14 shows the three volatility measurements as a function of the horizon period. The TL volatility (the light dotted line) decreases with time and reaches zero at the 9-year effective maturity. The TE volatility from non-TL paths (the dashed line) increases with time as the $\sqrt{N}$. The total all-path volatility (the solid line) is derived from the sum of squares of the first two volatilities. This total volatility curve declines sharply at the outset and then becomes relatively flat at around 1% for horizons in the range of 6-9 years.

This flattening is important because it implies that the uncertainty around the TL mean return will be 1% whether the horizon is 6 or 9 years. In a sense, the 6-year horizon could be interpreted as a much shorter "statistical effective maturity" that provides roughly the same all-path total volatility as the 9-year effective maturity.

This flattening of the total volatility curve enables the 6th year horizon to be a reasonable point for expecting returns to fall within ±1% of the starting yield.

Exhibit 14
Total Return Volatility



Source: Morgan Stanley Research

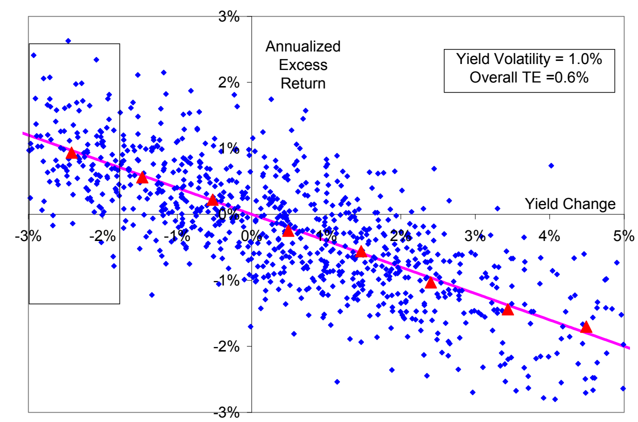
Simulation Tests

As one way of testing these theoretical models, a Monte Carlo simulation was performed based on a 5-year random walk with a mean yield change of 0% and standard deviation of 1%. In Exhibit 15, each scatter point represents a 5-year simulation path for a DT strategy with a 5-year duration.

The vertical axis represents the excess return for each path — the annualized return above or below the initial yield — while the horizontal axis corresponds to the total yield move experienced by the end of the 5th year. The solid line represents the TL return for each ending yield move (as in Exhibit 7). This TL line has a slope of -0.4 based on the TL formula derived in the Appendix.

The diamonds show the average of the simulated path returns within each yield change interval. It can be seen that these averages fall very close to the TL return. Moreover, the TE and total volatility from the simulation are extraordinarily close to the model estimates of 0.6% and 1.1%, respectively.

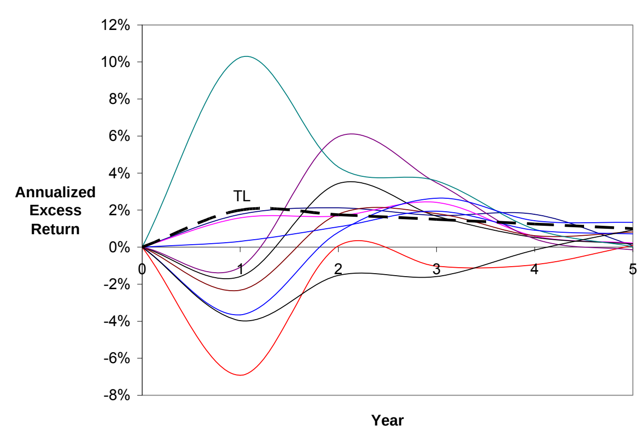
Exhibit 15
Simulation Returns for D=5, N =5



Source: Morgan Stanley Research

Each point in Exhibit 15 represents a specific pathway. To see how these pathways evolve over time, Exhibit 15 focuses on those simulated paths leading to yield declines between 2-3% over the 5-year horizon. Exhibit 16 displays a sampling of the associated return paths, depicted schematically as smooth curves over time. The returns vary considerably in the early years, but then all converge rapidly towards the 1% TL return in years 4 to 5.

Exhibit 16
Simulated Return Paths Given 2-3% Yield Declines



Source: Morgan Stanley Research

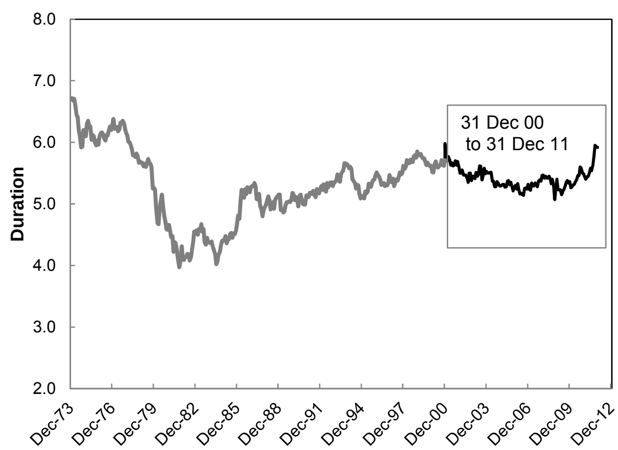
Historical Barclays Govt/Credit Index Data

In this section, we show that the theoretical DT model and the simulated results are consistent with actual market returns as represented by a Barclays bond index.

Exhibit 17 shows that over 1973-2011, the Barclays Government/Credit Index duration has remained relatively stable, ranging between 4 and 6 years and averaging 5.3. Since 2000, the average duration is 5.4, about the same as the long-term average. Since duration stability is the key characteristic of DT portfolios, we can view this index as an implicit DT portfolio.

Exhibit 17

Barclays Government/Credit Index Duration (31 Dec 73 to 31 Dec 11)

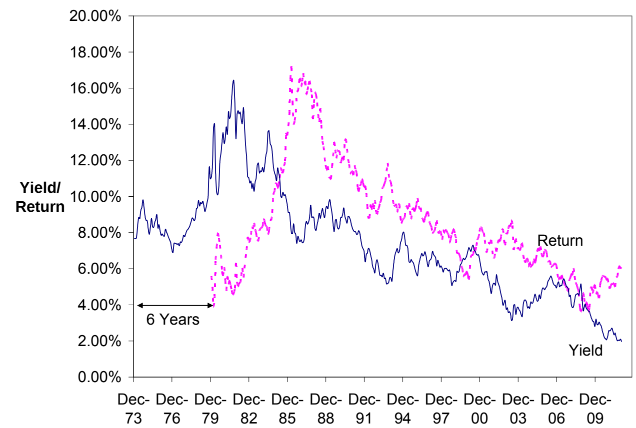


Source: Morgan Stanley Research, DataStream

The dotted line in Exhibit 18 plots the annualized compound returns for 6-year holding periods that start each month beginning in 1973 and ending in 2006. These returns are aligned with the final date of the 6-year investment horizon. For example, the first return point in Exhibit 18 represents the annualized return for the holding period extending from Dec 31, 1973 to Dec 31,1979.

Exhibit 18

Government/Credit Index Yields and Returns Over 6-Year Holding Periods

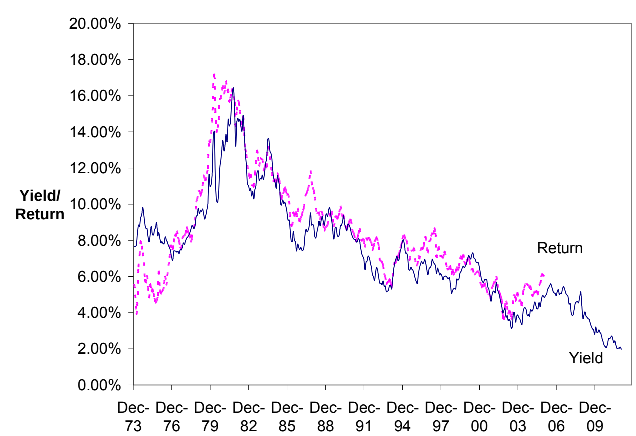


Source: Morgan Stanley Research, DataStream

As evident in Exhibit 18, the 6-year holding period returns have followed the same general declining pattern as the yields. However, this relationship is far more specific than just the obvious general trend. To better illuminate this relationship, Exhibit 19 shifts the dotted line so that the returns move into the same position as the yields at the beginning of the 6-year period. Thus, the first return point in Exhibit 19 still represents the 6-year holding period from 1973-1979, but it is now lined up with the yield at the beginning of the period. This superimposition shows that, far beyond simply sharing a general downward trend, these 6-year returns correlate very tightly with the starting yield.

Exhibit 19

Government/Credit Index Yields and Shifted Returns Over 6-Year Holding Periods

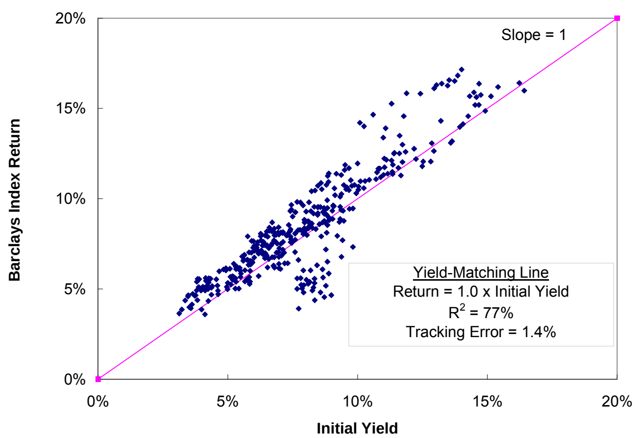


Source: Morgan Stanley Research, DataStream

Index Returns vs. Starting Yield
To more directly test the efficacy of the starting yield as a return estimate for this index, Exhibit 20 plots the 6-year return against the starting yield. The 45° line in Exhibit 19 represents a "forced" yield-matching relationship.

One can compute an alternative "R^2" that measures the percentage of the variance in returns that is explained by the yield-matching line. This "R^2" turns out to have a value of 77% with a TE of 1.40%.

Exhibit 20
Government/Credit Returns Over 6-Year Holding Periods (1972-2006) vs. Yield Matching Line



Source: Morgan Stanley Research, DataStream

The same tests were applied to the individual components of this index, and similar R^2 results were obtained.

Conclusions
High-grade bonds fundamentally differ from equities in that their initial yield accrues return over time. With Duration Targeting, repeated duration extension keeps end-of-year duration constant while the rebalancing process incorporates the new levels of accruals that result from rising or falling rates. These accruals offset the duration-based price effects. As the investment horizon lengthens, the role of accruals grows, leading to multi-year bond returns that converge in both mean and volatility around the starting yield.

The theoretical model developed to represent this convergence effect has generally stood up well in a series of tests involving simulation-based yield paths derived from Monte Carlo random walks and historical constant maturity Treasury data. More stringent tests based on various Barclays indices also proved to be supportive.

These findings have a number of investment implications:

1) The DT process is far more widespread than generally recognized.

2) In scenario analysis, the TL formula can provide a reasonable estimate for the return to a given terminal yield.

3) Over an appropriate horizon depending only on the duration target, the annualized mean return will converge to the starting yield subject to a modest standard deviation (for a 5-year duration, the convergence to roughly ±1% takes place over 6 years).

4) On the one hand, for DT investors who are content with the current yield levels, this convergence suggests that they need not be overly worried about the impact of higher rates on their multi-year returns.

5) On the other hand, DT investors committed to a fixed duration target should not count on the prospect of higher — or lower — yields to augment their multi-year return above the current level of yields.

6) A DT bond portfolio has a much lower multi-year volatility than generally believed.

7) Finally, in an asset allocation framework, the overall fund level volatility contributed by the bond component will generally be far less than that derived from a standard mean/variance model.

References

1) Langetieg, Terence C., Martin L. Leibowitz and Stanley Kogelman. "Duration Targeting and the Management of Multiperiod Returns." *Financial Analysts Journal*, September/October 1990

2) Leibowitz, Martin L. and Anthony Bova. "Duration-Targeting Over Multiple Yield Pathways ", *Morgan Stanley Research*, May 9, 2012

3) Leibowitz, Martin L. and Anthony Bova. "Convergence to Yield ", *Morgan Stanley Research*, May 24, 2012

4) Leibowitz, Martin L. and Anthony Bova. "Trendline Returns and Historical Tracking Errors ", *Morgan Stanley Research*, June 26, 2012

5) Leibowitz, Martin L. and Anthony Bova. “Historical Returns Convergence to Beginning Yield ”, *Morgan Stanley Research*, July 9, 2012

6) Leibowitz, Martin L. and Anthony Bova. “Barclays Index and Convergence to Yield”, *Morgan Stanley Research*, July 16, 2012

7) Leibowitz, Martin L. and Anthony Bova. “Duration Targeting and Index Convergence ”, *Morgan Stanley Research*, October 11, 2012

8) Leibowitz, Martin L. and Anthony Bova. “Bond Ladders as Duration Targeted Portfolios ”, *Morgan Stanley Research*, November 19, 2012

Appendix

Path Return and Volatility

In this Appendix, we derive formulas for total return volatility, trendline volatility and trendline tracking error. Under the assumption of a random walk model of interest rates, an initial investment is made in a D-year zero-coupon bond with nominal yield Y_0 . Although we do not do so, we note that the model can easily be adjusted to accommodate rate drift.

We assume a duration-targeting (DT) strategy in which the same duration is maintained throughout the holding period by re-pricing the bond at the end of each year and "rolling" the proceeds into a new D-year bond.

For zero-coupon bonds, the time to maturity D is the same as the Macaulay duration. After one year, the aged bond duration is D – 1. The return over any year is approximately the sum of the accrual (the yield at the beginning of the year) and –(D – 1) multiplied by the simulated yield change. In a later section of this Appendix, we show that this approximation is quite accurate for modest yield changes and moderate investment horizons.

Returns are calculated over N-year yield paths. Each path, j, originates at the same initial yield, Y_0. The yield at time i along path *j* is $Y_{j,i}$. The change in yield from time $i-1$ *to time i is* $\Delta Y_{j,i}$. The terminal yield for path *j*, $Y_{j,N}$, is Y_0 plus the sum of all the yield changes along path j.

$$Y_{j,0} = Y_0 \tag{1}$$

$$Y_{j,1} = Y_0 + \Delta Y_{j,1} \tag{2}$$

$$Y_{j,2} = Y_0 + \Delta Y_{j,1} + \Delta Y_{j,2} \tag{3}$$

$$\cdots \quad \cdots \quad \ldots$$

$$Y_{j,N} = Y_0 + \Delta Y_{j,1} + \Delta Y_{j,2} + \cdots + \Delta Y_{j,N}$$

$$Y_{j,N} = Y_0 + \sum_{i=1}^{N} \Delta Y_{j,i} \tag{4}$$

The return $R_{j,i}$ over period *i* for path *j* is the accrual $A_{j,i}$ and minus the year-end duration D – 1 multiplied by the yield change $\Delta Y_{j,i}$. The accrual $A_{j,i}$ is the yield at the beginning of the period $Y_{j,i-1}$.

$$A_{j,i} = Y_{j,i-1}$$

$$R_{j,i} = A_{j,i} - (D-1)\Delta Y_{j,i}$$

The average N-year return associated with path j, symbolized by $\overline{R_j}$, is equal to the average accrual $\overline{A_j}$ minus by D – 1 multiplied by the average annual yield change $\overline{\Delta Y_j}$.

$$\overline{R_j} = \overline{A_j} - (D-1)\overline{\Delta Y_j} \tag{5}$$

$$\overline{A_j} = \frac{1}{N}\sum_{i=1}^{N} A_{j,i}$$

$$\overline{A_j} = \frac{1}{N}\sum_{i=1}^{N} Y_{j,i-1} \tag{6}$$

$$\overline{\Delta Y_j} = \frac{1}{N}\sum_{i=1}^{N} \Delta Y_{j,i} \tag{7}$$

The summation on the right side of the equation (6) is “calculated” by substituting the expressions from equations (1) – (4).

$$\overline{A_j} = \frac{1}{N}\left\{NY_0 + (N-1)\Delta Y_{j,1} + (N-2)\Delta Y_{j,2} + \cdots + \Delta Y_{j,N-1}\right\}$$

$$\overline{A_j} = Y_0 + \frac{1}{N}\left\{(N-1)\Delta Y_{j,1} + (N-2)\Delta Y_{j,2} + \cdots + \Delta Y_{j,N-1}\right\} \tag{8}$$

The average path return is found by substituting (8) in (5).

$$\overline{R_j} = Y_0 + \frac{1}{N}\left\{(N-1)\Delta Y_{j,1} + (N-2)\Delta Y_{j,2} + \cdots + \Delta Y_{j,N-1}\right\} - (D-1)\overline{\Delta Y_j} \tag{9}$$

Trendline Returns

When the path from Y_0 to any final yield $Y_{j,N}$ is a trendline (TL), yields change in N equal increments of the average yield $\overline{\Delta Y_j}$. In equation (8), when we replace $\Delta Y_{j,i}$ by $\overline{\Delta Y_j}$ for all *i*, equation (8) takes a much simpler form.

$$\overline{A_{TL,j}} = Y_0 + \frac{1}{N}\left\{(N-1)\overline{\Delta Y_j} + (N-2)\overline{\Delta Y_j} + \cdots + \overline{\Delta Y_j}\right\}$$

$$= Y_0 + \frac{1}{N}\left\{(N-1) + (N-2) + \cdots + 1\right\}\overline{\Delta Y_j}$$

$$= Y_0 + \frac{1}{N}\frac{(N-1)N}{2}\overline{\Delta Y_j}$$

$$\overline{A_{TL,j}} = Y_0 + \frac{(N-1)}{2}\overline{\Delta Y_j}$$

$$\overline{R_{TL,j}} = \overline{A_{TL,j}} - (D-1)\overline{\Delta Y_j}$$

$$\overline{R_{TL,j}} = Y_0 + \frac{(N-1)}{2}\overline{\Delta Y_j} - (D-1)\overline{\Delta Y_j}$$

The above expression can be written more compactly so that the average return can be expressed in terms of the total yield change $N\overline{\Delta Y_j}$.

$$\overline{R_{TL,j}} = Y_0 - \left\{(D-1) - \frac{(N-1)}{2}\right\}\overline{\Delta Y_j}$$

$$= Y_0 - \left\{\frac{D-1}{N} - \frac{N-1}{2N}\right\}N\overline{\Delta Y_j} \tag{10}$$

The quantity in the brackets above can be interpreted as a "trendline duration" that incorporates both accrual and price effects. D_{TL} is a measure of the sensitivity of TL returns to the total yield change $N\overline{\Delta Y_j}$. The average annual return can, in turn, be expressed more compactly in terms of the initial yield, total yield change and trendline duration.

$$D_{TL} = \frac{D-1}{N} - \frac{N-1}{2N} \tag{11}$$

$$\overline{R_{TL,j}} = Y_0 - D_{TL} N \overline{\Delta Y_j} \tag{12}$$

For reference, we note that D_{TL} can be written more compactly.

$$D_{TL} = \frac{D}{N} - \frac{(N+1)}{2N} \tag{13}$$

From the above equation, it is clear that $D_{TL} = 0$ when N = 2D – 1. We refer to 2D – 1 as the "effective maturity" of the DT process. Over that holding period, the average TL return will equal the initial yield, regardless of the interim yield changes, and the volatility of TL returns will be zero.

Referring back (11), we observe that the trendline duration incorporates a duration factor and an accrual factor that reflect the separate duration and accrual impacts of the total yield change.

$$\frac{D-1}{N} = \text{Duration Factor} \tag{14}$$

$$\frac{N-1}{2N} = \text{Accrual Factor} \tag{15}$$

Duration Effect = Duration Factor × Total Yield Change
Accrual Effect = Accrual Factor × Total Yield Change

Note that as N increases, the duration factor decreases and ultimately approaches zero as N → ∝. In contrast, the accrual factor approaches ½ as N → ∝. It therefore follows that the trendline duration also approaches ½ as N → ∝.

Trendline Volatility

The yield changes $\Delta Y_{j,i}$, *i* = 1, 2, … N, are assumed to be independent and their distributions have mean zero and standard deviation $\sigma_{\Delta Y}$. Consequently, the mean of the average yield changes $\overline{\Delta Y_j}$ across all paths also will be zero. From equation (12), it follows that μ_{TL} , the mean of annualized N-period TL returns across all paths equals Y_0. The standard deviation of annualized TL returns σ_{TL} turns out to be proportional to the underlying yield change volatility $\sigma_{\Delta Y}$ multiplied by $\sqrt{N}$. The constant of proportionality is $|D_{TL}|$.

$$\mu_{TL} = Y_0$$

To calculate σ_{TL} , we first compute the variance, i.e., the expected value of the square of $\overline{R_{TL,j}} - Y_0$.

$$(\sigma_{TL})^2 = E\left[\left(D_{TL} N \overline{\Delta Y_j}\right)^2\right]$$

$$(\sigma_{TL})^2 = (D_{TL})^2 \bullet E\left[\left(N\overline{\Delta Y}_j\right)^2\right]$$

$$= (D_{TL})^2 \bullet E\left[\left(\sum_{i=1}^{N}\Delta Y_{j,i}\right)^2\right]$$

$$(\sigma_{TL})^2 = (D_{TL})^2 \bullet E\left[\sum_{i=1}^{N}(\Delta Y_{j,i})^2 + CrossTerms\right]$$

The cross terms above are terms similar to $\Delta Y_{j,1} \bullet \Delta Y_{j,2}$. Since yield changes are assumed independent, the expected value of such terms is zero.

$$(\sigma_{TL})^2 = (D_{TL})^2 \bullet \left\{N(\sigma_{\Delta Y})^2 + E[CrossTerms]\right\}$$

$$= (D_{TL})^2 \bullet N(\sigma_{\Delta Y})^2$$

$$\sigma_{TL} = |D_{TL}| \bullet \sqrt{N}\sigma_{\Delta Y} \quad (16)$$

Total Volatility

We now return to Equation (9), and focus on the total volatility of returns $\overline{R}_j$ across all paths derived from a random walk model of yield changes over an N-year horizon. As with TLs, the mean $\mu_{TOT} = Y_0$ since the distributions of yield changes $\Delta Y_{j,i}$ are assumed independent with zero mean. There is no loss of generality in this zero mean assumption because the analysis easily can be extended to include rate drift. The calculation of the total volatility σ_{TOT} is similar to the calculation of TL volatility, but a bit more algebraically complicated.

$$\mu_{TOT} = Y_0$$

$$(\sigma_{TOT})^2 = E\left[\left(\frac{1}{N}\left\{(N-1)\Delta Y_{j,1} + (N-2)\Delta Y_{j,2} + \cdots + \Delta Y_{j,N-1}\right\} - (D-1)\frac{1}{N}\sum_{i=1}^{N}\Delta Y_{j,i}\right)^2\right]$$

$$= E\left[\frac{1}{N^2}\left\{\sum_{i=1}^{N-1}(N-i)^2(\Delta Y_{j,i})^2\right\} - \frac{2(D-1)}{N}\frac{1}{N}\sum_{i=1}^{N}(N-i)(\Delta Y_{j,i})^2 + \left((D-1)\overline{\Delta Y}_j\right)^2 + CrossTerms\right]$$

$$(\sigma_{TOT})^2 = \frac{1}{N^2}\left\{\sum_{i=1}^{N-1}(N-i)^2 E[(\Delta Y_{j,i})^2] - 2(D-1)\sum_{i=1}^{N-1}(N-i)E[(\Delta Y_{j,i})^2] + (D-1)^2 E\left[\left(\overline{\Delta Y}_j\right)^2\right] + E[CrossTerms]\right\}$$

The assumed independence of yield changes implies that the expected value of cross terms is zero. Also, we earlier noted that $E[(\Delta Y_{j,i})^2] = (\sigma_{\Delta Y})^2$ for all *i* and $E\left[\left(\overline{\Delta Y}_j\right)^2\right] = N(\sigma_{\Delta Y})^2$. The above equation can therefore be simplified as follows:

$$(\sigma_{TOT})^2 = \frac{(\sigma_{\Delta Y})^2}{N^2}\left\{\sum_{i=1}^{N-1}(N-i)^2 - 2(D-1)\sum_{i=1}^{N-1}(N-i) + (D-1)^2 N\right\}$$

$$(\sigma_{TOT})^2 = \frac{(\sigma_{\Delta Y})^2}{N^2}\left\{\frac{(N-1)(N)(2N-1)}{6} - 2(D-1)\bullet\frac{(N-1)N}{2} + (D-1)^2 N\right\}$$

$$= \frac{(\sigma_{\Delta Y})^2}{N}\left\{\frac{(N-1)(2N-1)}{6} + (D-1)^2 - 2(D-1)\bullet\frac{(N-1)}{2} + \left(\frac{(N-1)}{2}\right)^2 - \left(\frac{(N-1)}{2}\right)^2\right\}$$

$$= \frac{(\sigma_{\Delta Y})^2}{N}\left\{\frac{(N-1)(2N-1)}{6} + \left((D-1) - \frac{(N-1)}{2}\right)^2 - \left(\frac{(N-1)}{2}\right)^2\right\}$$

$$(\sigma_{TOT})^2 = (\sigma_{\Delta Y})^2\left\{\frac{(N-1)}{2N}\left(\frac{2N-1}{3} - \frac{N-1}{2}\right) + N\left(\frac{D-1}{N} - \frac{N-1}{2N}\right)^2\right\}$$

The last term in the brackets incorporates the trendline duration D_{TL}. After some further simplification of the first term, the equation becomes:

$$(\sigma_{TOT})^2 = (\sigma_{\Delta Y})^2\left\{\frac{(N^2-1)}{12N} + N(D_{TL})^2\right\}$$

$$(\sigma_{TOT})^2 = (\sigma_{\Delta Y})^2 N (D_{TL})^2 + (\sigma_{\Delta Y})^2 N \frac{(N^2-1)}{12N^2} \tag{17}$$

$$\sigma_{TOT} = \sigma_{\Delta Y}\sqrt{N}\sqrt{(D_{TL})^2 + \frac{(N^2-1)}{12N^2}} \tag{18}$$

The first term on the right side of equation (17) is the TL variance derived in the previous section. The second variance term reflects the additional volatility associated with deviations of individual paths from their associated TL. These additional deviations can be interpreted as tracking error, which is discussed in detail in the next section.

Tracking Error

We can view $\overline{R_j}$, the annualized return across any path *j*, as comprised of the TL return, $\overline{R_{TL,j}}$, plus an uncorrelated residual return $\overline{r_j}$. The residual return is simply the difference between the annualized path return and the annualized TL return. The volatility of residual (or excess) returns across all random paths is the tracking error *TE*.

Specifically, we define *TE* as the square root of the average of the squared residuals. Since the means of both $\overline{R_j}$ and $\overline{R_{TL,j}}$ equal Y_0, the mean residual must be zero. In this case, the *TE* is the same as the standard deviation of the residuals. Since the residuals are assumed to be uncorrelated, the total path volatility can be decomposed into the sum of squares of the TL volatility and residual volatility. This relationship can, in turn, be used to derive a formula for *TE*.

$$\overline{R_j} = \overline{R_{TL,j}} + \overline{r_j}$$

$$(\sigma_{TOT})^2 = (\sigma_{TL})^2 + (TE)^2$$

$$(TE)^2 = (\sigma_{TOT})^2 - (\sigma_{TL})^2$$

From Equation (17), it follows that

$$(TE)^2 = (\sigma_{\Delta Y})^2 N \frac{(N^2-1)}{12N^2}$$

$$TE = \frac{1}{\sqrt{12}} \sqrt{N} \sigma_{\Delta Y} \sqrt{1-\frac{1}{N^2}} \tag{18}$$

$$= 0.29\sqrt{N}\sigma_{\Delta Y}\sqrt{1-\frac{1}{N^2}}$$

$$TE \approx 0.29\sqrt{N}\sigma_{\Delta Y}\left(1-\frac{1}{2N^2}\right)$$

$$TE \approx 0.29\sqrt{N}\sigma_{\Delta Y} \text{ for N > 3} \tag{19}$$

The simple approximation above implies that *TE* is proportional to the rate change volatility and increases with $\sqrt{N}$.

A simple approximation for zero-coupon bond returns

In order to develop simple formulas for duration-targeted bond returns, we utilize a simple linear model of annual bond returns. Specifically, we show that for zero coupon bonds, modest yield changes and moderate investment horizons, the one-year return is approximately the initial yield reduced by D – 1 times the actual yield change.

At the outset, the price P_0 (per dollar of maturity value) for a zero coupon bond with duration D and yield Y_0 is found by taking the present value of 1.

$$P_0 = (1+Y_0)^{-D}$$

At the end of one year, the time to maturity decreases by one. If the yield increases by ΔY , the year-end price is:

$$P_1 = (1+\{Y_0+\Delta Y\})^{-(D-1)}$$

The return for the first year is one less than the ratio of the final price to the initial price.

$$R_1 = P_1 / P_0 - 1$$

$$= \frac{(1+Y_0+\Delta Y)^{-(D-1)}}{(1+Y_0)^{-D}} - 1$$

$$= (1+Y_0+\Delta Y)\left(\frac{1+Y_0+\Delta Y}{1+Y_0}\right)^{-D} - 1$$

$$R_1 = (1+Y_0+\Delta Y)\left(1+\frac{\Delta Y}{1+Y_0}\right)^{-D} - 1$$

The quantity in brackets can be replaced by the first two terms in a Taylor series expansion.

$$R_1 = (1+Y_0+\Delta Y)\left(1-D\frac{\Delta Y}{1+Y_0}+\frac{D(D+1)}{2}\left[\frac{\Delta Y}{1+Y_0}\right]^2+\cdots\right)-1$$

$$= Y_0+\Delta Y-D\Delta Y-D\frac{(\Delta Y)^2}{1+Y_0}+\frac{D(D+1)}{2}\frac{(\Delta Y)^2}{1+Y_0}+\text{Higher Order Terms in }\Delta Y$$

$$R_1 = Y_0-(D-1)\Delta Y+\frac{D(D-1)}{2}\frac{(\Delta Y)^2}{1+Y_0}+\cdots \tag{20}$$

The second term on the right represents the percentage price change that is directly attributable to a “duration” effect when the bond ages by one year and the yield changes by ΔI. The third term on the right represents a “convexity” effect. That term is always positive and therefore provides an offset to the pure duration effect.

The convexity is relatively small within a reasonable range of durations and yield changes. For example, if D = 5, ΔY = 0.5% and Y_0 = 3%, the convexity correction will amount to only 1% of the duration effect. If we neglect the convexity term, the relationship between return and yield change becomes linear.

$$R_1 \approx Y_0-(D-1)\Delta Y \tag{21}$$

Continuous Re-Balancing

In the first section of this Appendix, we showed that the accrual factor approaches ½ as N increases. Alternatively, we can view N as the re-balancing frequency. As N approaches infinity, re-balancing is continuous. We can also directly derive the accrual factor for continuous re-balancing.

A = Yield change per unit time

C(t) = Cumulative yield change to time t

= *at*

Y(t) = Y_0+at

A(t) = Cumulative accrual to time *t*

$$= \int_0^t (Y_0+au)\,du$$

A(t) = $Y_0t + \frac{1}{2}at^2$

Cumulative Return(t) = $A(t) - D[Y(t)-Y_0]$

= $Y_0t + \frac{1}{2}at^2 - Dat$

R(t) = *Annualized return to time t*

= *Cumulative Return(t)/t*

$$R(t) = Y_0 + \tfrac{1}{2}at - (D/t)at$$

$$\text{Net Excess Return}(t) = R(t) - Y_0$$

$$= \tfrac{1}{2}at - (D/t)at$$

The first term above, *½at,* is the excess average accrual resulting from a total yield change (*at*).

The Accrual Factor is the excess average accrual divided by the total yield change. So, for continuous re-balancing

$$\text{Accrual Factor} = (\tfrac{1}{2}at)/(at)$$

$$= \tfrac{1}{2}$$

The second term in the Excess Return equation is the average price return resulting from the move *at*. The factor D/t is the associated duration factor. As t increases, D/t approaches zero.

We can combine the duration and accrual factors into a path duration. The excess return that results from a yield change is the negative of the path duration *x* total yield change.

$$\text{Duration Factor} = D/t$$

$$\text{Path Duration} = D/t - \tfrac{1}{2}$$

$$\text{Net Excess Return}(t) = -\text{Path Duration} \times at.$$

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Total	**2,966**		**1114**		

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The Americas	Europe	Japan	Asia/Pacific
1585 Broadway	20 Bank Street, Canary Wharf	4-20-3 Ebisu, Shibuya-ku	1 Austin Road West
New York, NY 10036-8293	London E14 4AD	Tokyo 150-6008	Kowloon
United States	**United Kingdom**	**Japan**	**Hong Kong**
Tel: +1 (1) 212 761 4000	Tel: +44 (0) 20 7 425 8000	Tel: +81 (0) 3 5424 5000	Tel: +852 2848 5200