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Bond Investing in a Rising Rate Environment

Fixed income market returns during periods of rising interest rates are affected by both the magnitude of yield increases and their timing. They are also influenced by the initial level and shape of the yield curve and the composition of the investable universe. Both of these change over time. Therefore, a historical analysis of bond index returns during specific cycles of rising rates, such as the hikes of 1994 or those from 2002 to 2006, does not necessarily provide an accurate picture of prospective returns in future rising rate regimes. An analytical framework, which takes current yields and index durations properly into account, can help to more accurately identify the tradeoffs and prospective returns fixed income investors may face going forward. We use such a framework to analyze the potential performance of the most widely used fixed income index across a wide range of potential future yield curve scenarios. As part of the analysis we provide several rules of thumb for anticipating the impact of rising rates on fixed income returns. We also quantify the tradeoff between a reduction of duration risk and the associated opportunity cost in the form of lower carry.[1] Our analysis highlights the fact that expectations for increasing yields in the future may not warrant a strategic shift into short duration fixed income portfolios or cash. In a steep yield curve environment, investors need to carefully assess how much yields will have to rise (and how fast) from their current levels to make it worthwhile to reduce duration risk in fixed income portfolios.

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We use the Barclays U.S. Aggregate Bond Index (BAGG) to illustrate the impact of future yield curve changes on fixed income returns.[2] Table 1 summarizes the duration, convexity, yield-to-maturity (YTM), and carry of the BAGG (as of 30 November 2013).

TABLE 1: INDEX CHARACTERISTICS

	Statistics			
	Duration	Convexity	YTM	Carry
Barclays U.S. Aggregate Bond Index	5.2	0.1	2.3%	2.7%

As of 30 November 2013. Source: PIMCO

The methodology we use to estimate the total returns of the index in a particular rising rates environment has two steps.

First, we construct a portfolio of par-coupon bonds and zero-coupon bonds along the yield curve which replicates the par key rate durations (KRDs) of the index. This KRD-replicating portfolio has the same price sensitivities to changes in the key rates as the index. PIMCO estimates KRDs based on 13 key points along the par swap curve. We replicate each of the KRDs with one par-coupon bond (or zero-coupon bond for maturities shorter than one year) on the yield curve with the corresponding key rate maturity. For example, to replicate the index's 5-year KRD of 0.65, we allocate 14% of the replicating portfolio to the 5-year par-coupon bond with estimated duration of 4.8 years. Going through all the key rate maturities one by one, we end up with the KRD-replicating portfolio in Table 2, where the KRDs and weights are grouped into key rate buckets. To complete the construction, we normalize the sum of the weights of the replicating portfolio to 100% by adding a long or short position in overnight LIBOR.

Since regular duration measures the sensitivity of bonds to parallel shifts in the entire yield curve, it is useful to look at sensitivities to shifts in certain segments of the yield curve (e.g., to changes in the 10-year yield). These partial durations are known as **key rate durations**.

TABLE 2: KRD-REPLICATING PORTFOLIO FOR THE BARCLAYS U.S. AGGREGATE BOND INDEX

Key rate buckets	1M-1Y	2Y-3Y	5Y	7Y	10Y-15Y	20Y+
KRDs (years)	0.16	0.74	0.65	0.82	1.61	1.20
Weights in the replicating portfolio	26%	29%	14%	13%	18%	7%

As of 30 November 2013. Source: PIMCO
Hypothetical example for illustration purposes only.
See appendix for a mathematical description of the construction of the KRD-replicating portfolio.

Second, we approximate the total return of the BAGG as the total return of the KRD-replicating portfolio, plus the index's credit spread[3] and minus the expected default loss. The total return of the replicating portfolio is the sum of its income return (coupon/principal payments and reinvestment income) and price return obtained by re-pricing the bonds in the replicating portfolio at the end of each rebalancing period. To simulate index returns over longer periods that span several or many years, the portfolio is rebalanced periodically to the original weights in the individual key rate maturities. This rebalancing assumption ensures the duration of the portfolio will be relatively stable but still evolve with the yield curve over time. It is therefore in direct contrast to a buy-and-hold strategy and is similar to, but slightly different from a duration-targeting strategy.

1. Scenarios with parallel shifts of the yield curve

We start our analysis with scenarios that entail parallel shifts of the yield curve. Movements in the yield curve are rarely completely parallel in nature (i.e., all yields shift up by the same amount). However, parallel shifts of the yield curve tend to drive most of the returns to fixed income portfolios. These scenarios also turn out to be useful in terms of building intuition and allowing us to derive convenient rules of thumb. Table 3 describes five hypothetical scenarios with parallel shifts in the U.S. yield curve. Scenario A is the baseline scenario with a static yield curve. Scenarios B and C entail instantaneous shocks to the yield curve, while scenarios D and E describe gradual shifts of the yield curve over the first 4 years.

TABLE 3: PARALLEL SHIFTS IN THE U.S. YIELD CURVE

Description of yield curve scenarios		Yield curve shift (bps)				
		Year 1	Year 2	Year 3	Year 4	Year 5+
A	No shift to the yield curve	0	0	0	0	0
B	+100 bps instantaneously	100	0	0	0	0
C	+200 bps instantaneously	200	0	0	0	0
D	+100 bps gradually over the first 4 years	25	25	25	25	0
E	+200 bps gradually over the first 4 years	50	50	50	50	0

Hypothetical example for illustration purposes only.
In scenario A, the yield curve stays constant. In scenarios B and C, the yield curve shifts up by 100 bps and 200 bps at the beginning of the first year and stays constant thereafter. In scenarios D and E, the yield curve shifts are evenly distributed and applied at the beginning of each quarter over the first 4 years, and there are no further shifts thereafter. More details about the scenario curves are provided in the appendix.

Table 4 shows the estimated scenario returns of the index for each year and the average returns of the index over different investment horizons up to 10 years.

In scenario A, the yield curve stays constant and the investors get carry year after year. Consider now the immediate, parallel shock to the yield curve of 100 bps in scenario B. The BAGG has 5.2 years of duration, so this shift in the yield curve translates into approximately a 5.2% immediate negative capital loss for the portfolio. The return in the first year is therefore approximately $-5.2\% + (2.7\% + 1\%) = -1.5\%$. The carry return increases by almost 100 bps to 3.7% per year after the rate shock. As the investment horizon extends, the carry return in each subsequent year remains 100 bps higher relative to the baseline scenario where the yield curve stays constant. The average return differential between the two scenarios therefore shrinks over time. About 5 years (which is the duration of the portfolio) after the initial rate shock, the total cumulative increase in carry returns ($\approx 5\times100$ bps) has exactly offset the initial capital loss due to the shift of the yield curve ($\approx -5\times100$ bps). As a result, the cumulative return in scenario B

TABLE 4: SCENARIO RETURNS FOR THE BARCLAYS U.S. AGGREGATE BOND INDEX

Estimated yearly returns

Description of yield curve scenarios		1	2	3	4	5	6	7	8	9	10
A	No shift to the yield curve	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%
B	+100 bps instantaneously	-1.5%	3.7%	3.7%	3.7%	3.7%	3.7%	3.7%	3.7%	3.7%	3.7%
C	+200 bps instantaneously	-5.3%	4.7%	4.7%	4.7%	4.7%	4.7%	4.7%	4.7%	4.7%	4.7%
D	+100 bps gradually over the first four years	1.5%	1.8%	2.1%	2.3%	3.7%	3.7%	3.7%	3.7%	3.7%	3.7%
E	+200 bps gradually over the first four years	0.4%	0.9%	1.5%	2.0%	4.7%	4.7%	4.7%	4.7%	4.7%	4.7%

Estimated annualized cumulative returns

Description of yield curve scenarios		1	2	3	4	5	6	7	8	9	10
A	No shift to the yield curve	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%
B	+100 bps instantaneously	-1.5%	1.1%	2.0%	2.4%	2.7%	2.8%	3.0%	3.1%	3.1%	3.2%
C	+200 bps instantaneously	-5.3%	-0.4%	1.3%	2.1%	2.6%	3.0%	3.2%	3.4%	3.6%	3.7%
D	+100 bps gradually over the first four years	1.5%	1.7%	1.8%	1.9%	2.3%	2.5%	2.7%	2.8%	2.9%	3.0%
E	+200 bps gradually over the first four years	0.4%	0.7%	0.9%	1.2%	1.9%	2.4%	2.7%	3.0%	3.2%	3.3%

As of 30 November 2013. Scenario analysis assumes quarterly rebalancing.
Hypothetical example for illustration purposes only.

is close to that in scenario A by the end of the 5th year. If the investment horizon is longer than 5 years, the scenario B return will exceed the scenario A return.

The same argument applies to scenario C, which only differs from scenario B in the magnitude of the rate shock. The annualized cumulative returns under both scenarios B and C converge to that under scenario A, which is the initial carry, when the investment horizon is close to the duration of the portfolio.

We can summarize this result in the following rule of thumb.

Simple Rule of Thumb: *For an instantaneous and parallel shock to the yield curve of ΔY ($\Delta Y > 0$), the return of a bond portfolio with duration Dur over an investment horizon H will be:*

i) ***lower than*** *the no-shock return, if $H < Dur$, since the increase in carry* ***only partially*** *offsets the negative price effect.*

ii) ***equal to*** *the no-shock return, if $H = Dur$, since the increase in carry* ***exactly*** *offsets the negative price effect.*

iii) ***higher than*** *the no-shock return, if $H > Dur$, since the increase in carry* ***more than*** *offsets the negative price effect.*

The portfolio scenario return will differ from the no-shock return by approximately $\Delta Y(H - Dur)$ cumulatively or $\Delta Y(1 - \frac{Dur}{H})$ on an annualized basis.

Next, we consider scenarios D and E where the parallel curve shifts are realized over an extended period of time.

In scenario D, a 100 bps parallel shift of the yield curve is evenly distributed for each quarter in the first 4 years. Each quarter, the yield curve shifts up by a small amount (6.25 bps) which results in a small negative price effect each quarter. The cumulative price effect of the gradual curve shift remains close to -500 bps. The cumulative carry return will however be smaller than that in scenario B for any given horizon. Instead of the immediate 100 bps increase in carry in scenario B, carry increases by only 25 bps every year over 4 years. Consequently, it will now take an investment horizon that is longer than the duration of the portfolio for the cumulative carry effect to completely offset the negative price effect.

It is possible to extend the simple rule of thumb to scenarios where the yield curve shift takes place over a period of time.

Extended Rule of Thumb: *For a gradual and parallel shift of the yield curve of ΔY ($\Delta Y > 0$) which is realized over the next T years, the return of a bond portfolio with duration Dur over an investment horizon H ($H \geq T$) will be:*

i) ***lower than*** *the no-shock return, if $H < Dur + \frac{T}{2}$, since the cumulative carry effect* ***only partially*** *offsets the negative price effect.*

ii) ***equal to*** *the no-shock return, if $H = Dur + \frac{T}{2}$, since the cumulative carry effect* ***exactly*** *offsets the negative price effect.*

iii) ***higher than*** *the no-shock return, if $H > Dur + \frac{T}{2}$, since the cumulative carry effect* ***more than*** *offsets the negative price effect.*

The portfolio scenario return will differ from the no-shock return by approximately $\Delta Y(H - Dur - \frac{T}{2})$ cumulatively or $\Delta Y(1 - \frac{Dur}{H} - \frac{T}{2H})$ on an annual basis.

Notice that the Simple Rule of Thumb is nothing but a special case of the Extended Rule of Thumb when $T = 0$. The additional term $-\frac{T}{2}$ reflects the fact that, in the case of a gradual shift, the carry effect will not be fully realized until all the incremental shifts are completed.

Another interesting special case of the Extended Rule of Thumb is when $T = H$. This means the curve shifts occur gradually over the entire investment horizon. In this case, the portfolio scenario return will differ from the no-shock return by approximately $\Delta Y(\frac{H}{2} - Dur)$ cumulatively. Therefore, the scenario return will converge to the no-shock return if the investment horizon is close to $2 \times Dur$, regardless of the magnitude of the curve shifts.[4]

In scenarios D and E, we have $Dur = 5$ and $T = 4$, so the horizon it takes for the scenario return to converge to the no-shock return is approximately $5+\frac{4}{2} = 7$ years, which is consistent with Table 4.

Both rules of thumb above assume that the curve shift starts right away. A natural extension would be to consider a scenario where the curve shift starts later in the investment horizon.

General Rule of Thumb: *For a gradual and parallel shift of the yield curve of ΔY ($\Delta Y > 0$) which starts after T_1 years and is realized over T_2 years, the return of a bond portfolio with duration Dur over an investment horizon H ($H \geq T_1 + T_2$) will be:*

i) ***lower than*** *the no-shock return, if $H < Dur + T_1 + \frac{T_2}{2}$, since the cumulative carry effect* ***only partially*** *offsets the negative price effect.*

ii) ***equal to*** *the no-shock return, if $H = Dur + T_1 + \frac{T_2}{2}$, since the cumulative carry effect* ***exactly*** *offsets the negative price effect.*

iii) ***higher than*** *the no-shock return, if $H > Dur + T_1 + \frac{T_2}{2}$, since the cumulative carry effect* ***more than*** *offsets the negative price effect.*

The portfolio scenario return will differ from the no-shock return by approximately $\Delta Y(H - Dur - T_1 - \frac{T_2}{2})$ cumulatively or $\Delta Y(1 - \frac{Dur}{H} - \frac{T_1}{H} - \frac{T_2}{2H})$ on an annual basis.

This is the most general rule of thumb among the three. It indicates that an early and quick parallel rate hike will result in higher *long-term* returns for bond portfolios than a delayed and/or slow one of the same magnitude. The intuition is that the total negative price effects due to the rate hikes are similar, whereas the cumulative carry effect is higher when the curve shift happens quickly and early in the horizon.

In the extreme case where all the curve shock takes place at the end of the investment horizon ($T_1 = H$ and $T_2 = 0$), the annualized scenario return will differ from the no-shock return (initial carry) by approximately $-\frac{Dur \times \Delta Y}{H}$. This would be the worst-case scenario in terms of timing of a positive curve shift since there would be no carry effect to offset the negative price effect within the investment horizon.

Please note that all the rules of thumb discussed in this section ignore the effect of convexity and the possible small changes in the duration of the portfolio over time due to curve shifts. They are also based on the assumption of frequent rebalancing (such as quarterly) and constant spread. They work better for portfolios of plain vanilla bonds with moderate duration and spread under moderate parallel curve shifts.

Although our discussion focuses on rising interest rates due to the current low yield environment, the rules of thumb above also apply to negative parallel curve shifts in general, except when the negative curve shifts are truncated due to the non-negativity constraints for rates.

2. Non-parallel shifts of the yield curve

The previous section considered parallel shifts of the yield curve. In practice, the slope of the yield curve varies over the business cycle. It is often the steepest at the end of a recession reflecting counter-cyclical monetary policy and becomes flatter during economic expansions as policy rates normalize. The slope of the yield curve is an important determinant of the roll-down component of returns to fixed income portfolios. It is therefore appropriate to extend the analysis above to take into account the likely changes in the shape of the yield curve, which typically accompany rising rates and monetary policy cycles.

To evaluate the impact of changing slopes on the scenario returns, we alter our scenarios with this curve effect. Based on a review of the business cycle dynamics in the yield curve from 1989 to 2013, we select betas of 2 and 0.7 for changes in the 2-year and 30-year yields relative to changes in the 10-year yield. They imply that a 100 bps increase in the 10-year yield is associated with a 200 bps increase in the 2-year yield and a 70 bps increase in the 30-year yield, and hence a so-called bear-flattening of the yield curve. The revised scenarios are summarized in Table 5.

TABLE 5: NON-PARALLEL SHIFT SCENARIOS FOR THE U.S. YIELD CURVE WITH $\beta_{2,10}$ = 2 AND $\beta_{30,10}$ = 0.7

Description of yield curve scenarios		Changes in [2-year, 10-year, 30-year] yields (bps)				
		Year 1	Year 2	Year 3	Year 4	Year 5+
A	No shift to the yield curve	[0, 0, 0]	[0, 0, 0]	[0, 0, 0]	[0, 0, 0]	[0, 0, 0]
B'	+100 bps for 10-year yield instantaneously	[200, 100, 70]	[0, 0, 0]	[0, 0, 0]	[0, 0, 0]	[0, 0, 0]
C'	+200 bps for 10-year yield instantaneously	[400, 200, 140]	[0, 0, 0]	[0, 0, 0]	[0, 0, 0]	[0, 0, 0]
D'	+100 bps for 10-year yield gradually over the first four years	[50, 25, 18]	[50, 25, 18]	[50, 25, 18]	[50, 25, 18]	[0, 0, 0]
E'	+200 bps for 10-year yield gradually over the first four years	[100, 50, 35]	[100, 50, 35]	[100, 50, 35]	[100, 50, 35]	[0, 0, 0]

Hypothetical example for illustration purposes only.
In scenario A, the yield curve stays constant. In scenarios B´ and C´, the 10-year yield shifts up by 100 bps and 200 bps at the beginning of the first year and stays constant thereafter, with 2-year and 30-year yields shifting based on the assumed betas. In scenarios D´ and E´, the yield curve shifts are evenly distributed and applied at the beginning of each quarter in the first 4 years. More details about the scenario curves are provided in the appendix.

Compared to a parallel shift, a bear flattening of the yield curve will reduce the roll-down component of the carry returns across the curve after the shock. Therefore, for each individual par-coupon bond in the replicating portfolio, it takes longer for the scenario return to recover to its initial carry. However, at the portfolio level, a bear flattening of the yield curve implies that yield increases are bigger for short rates than for long rates. Since short maturity bonds in the replication portfolio also have shorter durations, they benefit from yield increases more quickly than long bonds. This redistribution of yield curve shocks to the front end of the yield curve will therefore tend to increase portfolio returns relative to the parallel shock scenario. The roll-down effect and the redistribution effect compete with each other. The net effect, which is determined by many factors such as duration and key rate durations of the portfolio, magnitude, shape, and timing of the curve shifts, and the current yield curve, will explain any deviation from the return patterns predicted by the rules of thumb for parallel shocks.

Table 6 shows the scenario returns for the BAGG under these nonparallel-shift yield curve scenarios based on hypothetical yield betas. The resulting scenario returns for the BAGG exhibit similar patterns as those in the previous section, indicating that the roll-down effect and redistribution effect, or the net effect, is small relative to the main effect of the rate hikes on total returns of the portfolio.

3. Duration management in a rising rate environment

In anticipation of rising rates, many investors may reduce the duration of their fixed income portfolios. In an environment with a steep yield curve, this decision is associated with an opportunity cost in terms of reduced portfolio carry return. An illustration of this tradeoff between duration and carry along the U.S. swap curve is provided in Figure 1. To quantify the potential opportunity cost to reduce the portfolio's sensitivity to rising rates, we look at the effects on both the yield and roll-down components of carry. Roll-down can be a significant component of carry. For example, it contributes more than 50% of the carry for a 5-year par bond as shown in Figure 1.

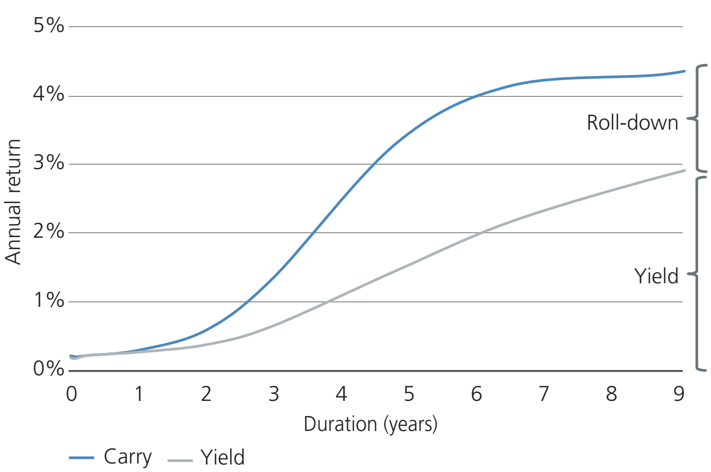
TABLE 6: SCENARIO RETURNS FOR THE BAGG UNDER NON-PARALLEL CURVE SHIFT SCENARIOS WITH $\beta_{2,10}$ = 2 AND $\beta_{30,10}$ = 0.7

Estimated yearly returns											
Description of yield curve scenarios		1	2	3	4	5	6	7	8	9	10
A	No shift to the yield curve	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%
B'	+100 bps for 10-year yield instantaneously	-2.4%	3.9%	3.9%	3.9%	3.9%	3.9%	3.9%	3.9%	3.9%	3.9%
C'	+200 bps for 10-year yield instantaneously	-6.8%	5.2%	5.2%	5.2%	5.2%	5.2%	5.2%	5.2%	5.2%	5.2%
D'	+100 bps for 10-year yield gradually over the first four years	1.1%	1.7%	2.0%	2.3%	3.9%	3.9%	3.9%	3.9%	3.9%	3.9%
E'	+200 bps for 10-year yield gradually over the first four years	-0.3%	0.7%	1.3%	2.0%	5.2%	5.2%	5.2%	5.2%	5.2%	5.2%

Estimated annualized cumulative returns											
Description of yield curve scenarios		1	2	3	4	5	6	7	8	9	10
A	No shift to the yield curve	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%
B'	+100 bps for 10-year yield instantaneously	-2.4%	0.7%	1.8%	2.3%	2.6%	2.9%	3.0%	3.1%	3.2%	3.3%
C'	+200 bps for 10-year yield instantaneously	-6.8%	-1.0%	1.0%	2.0%	2.6%	3.1%	3.4%	3.6%	3.8%	3.9%
D'	+100 bps for 10-year yield gradually over the first four years	1.1%	1.4%	1.6%	1.8%	2.2%	2.5%	2.7%	2.9%	3.0%	3.1%
E'	+200 bps for 10-year yield gradually over the first four years	-0.3%	0.2%	0.6%	0.9%	1.8%	2.3%	2.7%	3.0%	3.3%	3.5%

As of 30 November 2013. Scenario analysis assumes quarterly rebalancing.
Hypothetical example for illustration purposes only.

FIGURE 1: TRADEOFF BETWEEN DURATION AND CARRY



Source: PIMCO. As of 30 November 2013.
Hypothetical example for illustration purposes only.
Carry and components of carry are estimated for hypothetical par bonds on the U.S. swap curve with PIMCO key rate maturities up to 10 years. Numbers for other maturities are interpolated. Analysis assumes quarterly rebalancing.

Bond versus cash: an example

Perhaps the most obvious way to reduce duration in an investor's portfolio is to move an existing fixed income allocation into cash. Figure 2 compares the estimated scenario returns for the BAGG and cash, 3-month USD LIBOR, under the same five parallel scenarios we discussed in the first section.

In scenario B, the initial carry of the BAGG is around 2.5% higher than that of cash. After a *parallel shift* of +100 bps across the yield curve, the carry returns of both portfolios will increase by about 100 bps. Therefore, the carry *difference* between the two portfolios remains the same over time. The negative price impacts of the rate shock, on the other hand, will be about 5% bigger for the BAGG than for cash due to the difference in their duration exposures ($100\ bps \times \Delta Dur$). An investor in the BAGG who believes that scenario B will be realized and who is able to switch back from cash to the BAGG one year later will most likely decide to switch, since the benefit of switching (5%) outweighs the cost (2.5%). If the investor has to stay committed to the cash portfolio over a 2-year horizon, the expected payoff of the switching strategy is zero since the benefit exactly offsets the cost.

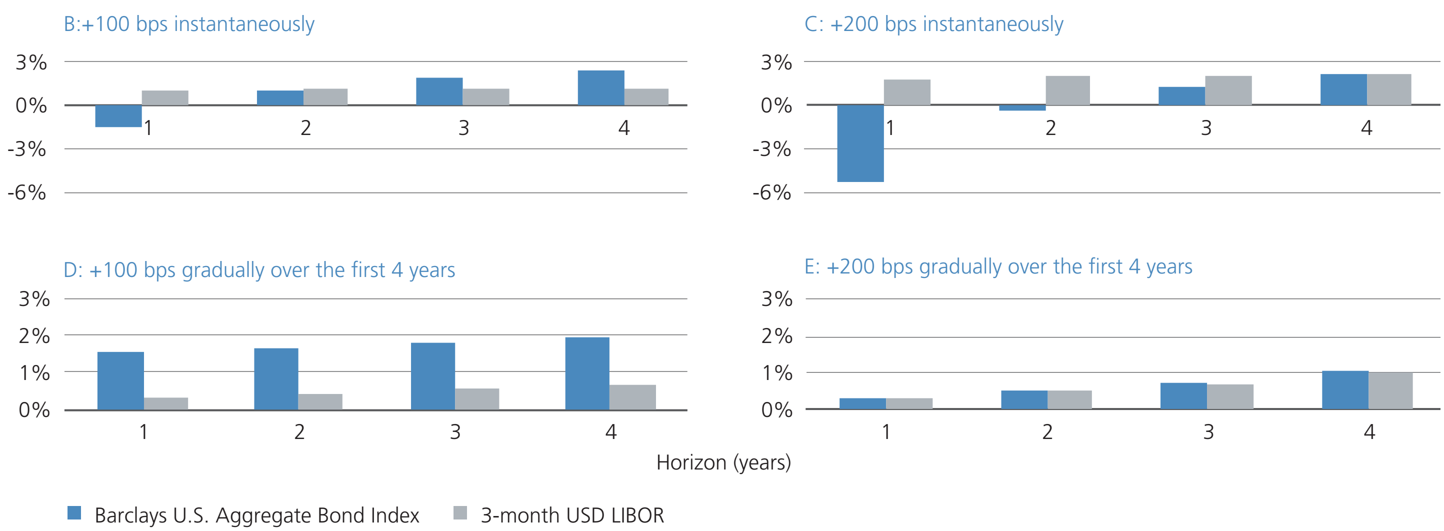
We can define the break-even rate shock for a pair of bond portfolios as the *parallel shock to the yield curve per year* that will make an investor break even between the two portfolios *over a given investment horizon*. As a rule of thumb, this value is approximately the initial carry difference (which is persistent over time despite shifts of the yield curve) divided by the duration difference between the two portfolios. In other words, the break-even rate shock equates the benefit ($\Delta Y \times \Delta Dur$) and cost ($H \times \Delta Carry$) of switching between the two portfolios:

$$\left(\frac{\Delta Y}{H}\right)_{BE} = \frac{\Delta Carry}{\Delta Dur}$$

In the case where we consider switching between the BAGG and cash, the break-even rate shock is equal to $\frac{\Delta Carry}{\Delta Dur} \approx \frac{2.5\%}{5} = 50\ bps$ per year. This is consistent with the 2-year horizon it takes to break even in scenario B. If the investor has to stay in cash for more than 2 years after switching, the average shock per year will be lower than 50 bps and hence the investor is better off not switching to cash at the very beginning.

As another example, let's look at scenario E. The +200 bps parallel shift of the yield curve is distributed evenly over the next 4 years. This means that for any investment horizon up to 4 years, the average shock is 50 bps per year. Each year, the carry component of the BAGG's return will be 2.5% higher than that of cash, which is 10% cumulatively over 4 years. The price impact of the curve shifts on the BAGG is 2.5% bigger in absolute value than that on cash for each of the first 4 years, which is also 10% over 4 years. An investor will therefore break even between the BAGG and cash for any investment horizon up to 4 years. If the investor has to stay in cash for

FIGURE 2: COMPARISON OF ANNUALIZED CUMULATIVE RETURNS UNDER PARALLEL SHOCK SCENARIOS



As of 30 November 2013.
Source: PIMCO.
Hypothetical example for illustration purposes only.
Scenario analysis assumes quarterly rebalancing.

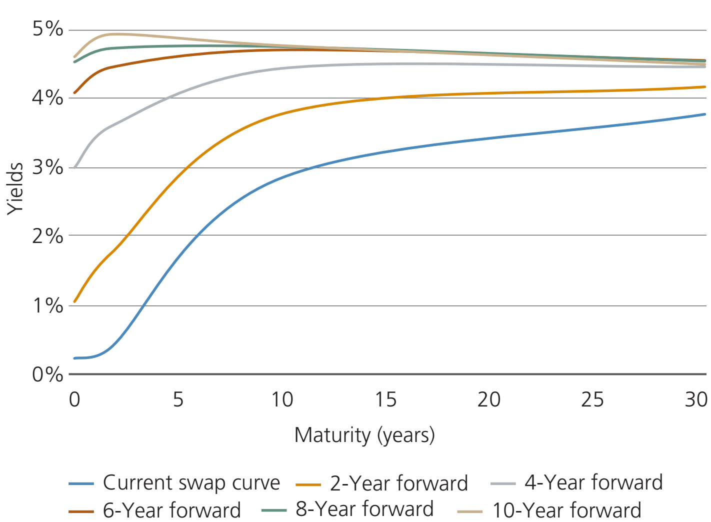
more than 4 years, the cost of switching in reduced carry returns will outweigh the benefit in reduced capital losses.

If the rate hike happens quickly, such as in scenarios B and C, a bond investor with good market-timing skills can potentially benefit from switching from the BAGG to cash right before the shock and switching back right after. However, if the curve shift is very slow such as in scenario D (25 bps per year), switching from the BAGG to cash would always reduce scenario returns even if the investor can forecast the timing perfectly.

Will duration risk pay?

Today's forward curves provide a convenient way of assessing the attractiveness of duration risk for investors. This is due to the fact that bond returns will be equal across maturities if the spot curve moves exactly to the forward curves over time. Figure 3 illustrates how the U.S. swap curve would evolve in the next 10 years if it follows the path implied by today's forward curves.

FIGURE 3: SELECTED IMPLIED FORWARD CURVES BASED ON THE CURRENT U.S. SWAP CURVE



As of 30 November 2013.
Source: PIMCO
Hypothetical example for illustration purposes only.
Forward curves shown are par curves with semi-annual compounding.

Table 7 shows the estimated yearly scenario returns for the BAGG, cash, and selected hypothetical par bonds along the swap curve under this scenario and the scenario with no shifts. Bonds across maturities, including cash, earn the same holding-period returns if implied forwards are realized. The BAGG has slightly higher returns due to its small spread over the swap curve. These one-year returns net of spread are equal to the corresponding one-year forward rates implied by the current spot curve. Furthermore, the annualized return will be approximately equal to today's yield at each investment horizon.

If the yield curve increases by more than what is implied by the forward rates, exposures to duration risk will tend to have a negative contribution to returns of a bond portfolio. If the yield curve turns out to rise slower or less than the path implied by forwards over a certain investment horizon, duration exposure tends to contribute positively to the bond portfolio return. The decision between cash and duration risk can and should therefore always be framed in terms of a given yield curve scenario *relative to* the current implied forwards.

4. Summary

Given the unusual monetary policy stance that has characterized the last few years and the historically low real and nominal yields that have accompanied this monetary policy regime, bond investors have naturally been concerned about rising rates. This concern has been fueled over the last year as the 10-year yield increased by more than 100 bps.

There are a number of conclusions that can be drawn across a wide set of scenarios for the evolution of the yield curve over the next 10 years by analyzing prospective returns for the Barclays U.S. Aggregate Bond Index, the most widely used fixed income benchmark. First, consider parallel shifts in the yield curve. While sudden increases in yields may result in an immediate capital loss for fixed income investors, the long-term total return impact for a strategic allocation to bonds is positive. The net effect turns positive once the investment horizon exceeds the duration of the portfolio.

TABLE 7: SCENARIO RETURNS UNDER TWO SCENARIOS: NO CURVE SHIFT AND FORWARD CURVES REALIZED

Estimated yearly returns	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Barclays U.S. Aggregate Bond Index										
No shift to the yield curve	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%
Implied forward curves are realized	0.6%	0.8%	1.5%	2.6%	3.6%	4.3%	4.7%	4.9%	5.1%	5.1%
Cash (3M LIBOR)										
No shift to the yield curve	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
Implied forward curves are realized	0.3%	0.5%	1.2%	2.3%	3.2%	4.0%	4.3%	4.6%	4.8%	4.7%
Hypothetical 2-year par bond										
No shift to the yield curve	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%
Implied forward curves are realized	0.3%	0.5%	1.2%	2.3%	3.2%	4.0%	4.3%	4.6%	4.8%	4.7%
Hypothetical 5-year par bond										
No shift to the yield curve	3.4%	3.4%	3.4%	3.4%	3.4%	3.4%	3.4%	3.4%	3.4%	3.4%
Implied forward curves are realized	0.3%	0.5%	1.2%	2.3%	3.2%	4.0%	4.3%	4.6%	4.8%	4.7%
Hypothetical 10-year par bond										
No shift to the yield curve	4.4%	4.4%	4.4%	4.4%	4.4%	4.4%	4.4%	4.4%	4.4%	4.4%
Implied forward curves are realized	0.3%	0.5%	1.2%	2.3%	3.2%	4.0%	4.3%	4.6%	4.8%	4.7%

As of 30 November 2013. Source: PIMCO
Hypothetical example for illustration purposes only.
Hypothetical par bonds are constructed and rebalanced based on the time-varying U.S. swap curve under different hypothetical yield curve scenarios. Scenario analysis assumes quarterly rebalancing.

Also, with parallel shifts of the yield curve, an instantaneous rate hike tends to result in higher cumulative returns than a gradual increase in yields.

Analyzing non-parallel shifts in the yield curve, where the yield curve flattens as rates increase, which is a realistic assumption over the medium term, offers additional insights. Our analysis shows that this bear flattening in the yield curve gives rise to two opposite effects. The first effect is that the roll-down component of carry is reduced due to the curve flattening during rate increases. The second effect is a complicated redistribution effect which is due to the fact that shorter maturity key rate exposures (shorter than the duration of the portfolio) will be positively affected by the larger increase in their yields, whereas long maturity key rate exposures (longer than the duration of the portfolio) will tend to benefit from smaller initial price shocks. These two effects compete. So contrary to what is commonly believed, a flattening of the yield curve may or may not result in a worse outcome for the fixed income portfolio relative to a parallel increase in yields. It depends on the exact nature of the key rate durations and the assumed non-parallel shift in the curve.

A typical response to concerns about rising interest rates is to consider reducing the duration risk in the fixed income portfolio. One way to do this is to replace long bonds with cash or short-term bonds. A steep yield curve implies an opportunity cost which includes both a meaningful yield differential and a significant "roll-down" differential. We define the "break-even" rate shock for a pair of bond portfolios as the *parallel shock to the yield curve per year* that will make an investor break even between the two bond portfolios *over a given investment horizon.* As of 30 November 2013, the break-even rate shock for the BAGG versus cash is about 50 basis points per year due to steepness of the yield curve.

The dynamics for the yield curve that make investors better or worse off in cash versus intermediate or longer duration fixed income portfolios can also be directly observed from the current implied forward curves. If the yield curve shifts up faster than the forward curve, investors tend to be better off in cash. If the yield curve shifts up at a slower pace or even stays at current low levels for the time being, investors tend to be worse off by moving into cash.

As with any model based on simplifying assumptions, there are important caveats to the analysis in this paper. First, the methodology is designed for portfolios consisting mostly of fixed rate bonds without embedded options. Portfolios of derivatives, bank loans or mortgage-backed securities, are not good candidates for this model. Second, to isolate the impact of yield curve shifts on bond returns, spreads are assumed to be constant over time. Historically, spreads tend to narrow when interest rates rise due to economic recovery. This can potentially offset some effect of the curve shifts. Third, our analysis focuses on implications of rising rates for strategic fixed income investors. Active management of fixed income portfolios such as market timing can potentially generate alpha on top of the passive bond market returns but that is beyond the scope of this paper.

Appendix: Construction of the initial KRD-replicating portfolio

Let $KRD\ (i)$ be the ith par key rate duration of a bond portfolio ($i = 1, 2 \ldots 13$). Let $KRD_j(i)$ be the ith par key rate duration of the jth bond (which is a par-coupon bond if its maturity is longer or equal to one year and a zero-coupon bond otherwise) whose maturity is equal to the jth key rate maturity ($i, j = 1, 2 \ldots 13$). Let $w(i)$ be the weight of the ith bond in the KRD-replicating portfolio.

By construction, $KRD_j(i) = 0$ if $i \neq j$. In other words, each bond in the replicating portfolio only has one non-zero key rate duration exposure, which corresponds to the key rate maturity equal to its own maturity. This greatly simplifies the construction of the KRD-replicating portfolio since we now only need

$$w(i) \times KRD_i(i) = KRD(i) \Rightarrow w(i) = \frac{KRD(i)}{KRD_i(i)}\ (i = 1, 2 \ldots 13)$$

Lastly, we normalize the sum of portfolio weights to 100% by adding overnight LIBOR into the replicating portfolio with its weight equal to 100% $-\sum_{i=1}^{13} w(i)$. This completes the construction of the initial KRD-replicating portfolio.

For subsequent rebalancing, our model assumes the same target weights rather than constant target key rate durations. This allows the duration of the portfolio to evolve in a way consistent with the evolving yield curve under each scenario.

Appendix: Scenario yield curves at the beginning of each year

TABLE 8: PARALLEL SHIFT SCENARIOS FOR THE U.S. SWAP CURVE

Scenario B: +100 bps instantaneously										
Maturity	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
2	0.4%	1.4%	1.4%	1.4%	1.4%	1.4%	1.4%	1.4%	1.4%	1.4%
5	1.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%
10	2.8%	3.8%	3.8%	3.8%	3.8%	3.8%	3.8%	3.8%	3.8%	3.8%
30	3.7%	4.7%	4.7%	4.7%	4.7%	4.7%	4.7%	4.7%	4.7%	4.7%

Scenario C: +200 bps instantaneously										
Maturity	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
2	0.4%	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%
5	1.5%	3.5%	3.5%	3.5%	3.5%	3.5%	3.5%	3.5%	3.5%	3.5%
10	2.8%	4.8%	4.8%	4.8%	4.8%	4.8%	4.8%	4.8%	4.8%	4.8%
30	3.7%	5.7%	5.7%	5.7%	5.7%	5.7%	5.7%	5.7%	5.7%	5.7%

Scenario D: +100 bps gradually over the first 4 years										
Maturity	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
2	0.4%	0.6%	0.9%	1.1%	1.4%	1.4%	1.4%	1.4%	1.4%	1.4%
5	1.5%	1.7%	2.0%	2.2%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%
10	2.8%	3.1%	3.3%	3.6%	3.8%	3.8%	3.8%	3.8%	3.8%	3.8%
30	3.7%	4.0%	4.2%	4.5%	4.7%	4.7%	4.7%	4.7%	4.7%	4.7%

Scenario E: +200 bps gradually over the first 4 years										
Maturity	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
2	0.4%	0.9%	1.4%	1.9%	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%
5	1.5%	2.0%	2.5%	3.0%	3.5%	3.5%	3.5%	3.5%	3.5%	3.5%
10	2.8%	3.3%	3.8%	4.3%	4.8%	4.8%	4.8%	4.8%	4.8%	4.8%
30	3.7%	4.2%	4.7%	5.2%	5.7%	5.7%	5.7%	5.7%	5.7%	5.7%

As of 30 November 2013. Source: PIMCO.

TABLE 9: NON-PARALLEL SHIFT SCENARIOS FOR THE U.S. SWAP CURVE WITH $\beta_{2,10}$ = 2 AND $\beta_{30,10}$ = 0.7

Scenario B′: +100 bps for 10-year yield instantaneously

Maturity	1	2	3	4	5	6	7	8	9	10
2	0.4%	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%
5	1.5%	3.1%	3.1%	3.1%	3.1%	3.1%	3.1%	3.1%	3.1%	3.1%
10	2.8%	3.8%	3.8%	3.8%	3.8%	3.8%	3.8%	3.8%	3.8%	3.8%
30	3.7%	4.4%	4.4%	4.4%	4.4%	4.4%	4.4%	4.4%	4.4%	4.4%

Scenario C′: +200 bps for 10-year yield instantaneously

Maturity	1	2	3	4	5	6	7	8	9	10
2	0.4%	4.4%	4.4%	4.4%	4.4%	4.4%	4.4%	4.4%	4.4%	4.4%
5	1.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%
10	2.8%	4.8%	4.8%	4.8%	4.8%	4.8%	4.8%	4.8%	4.8%	4.8%
30	3.7%	5.1%	5.1%	5.1%	5.1%	5.1%	5.1%	5.1%	5.1%	5.1%

Scenario D′: +100 bps for 10-year yield gradually over the first 4 years

Maturity	1	2	3	4	5	6	7	8	9	10
2	0.4%	0.9%	1.4%	1.9%	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%
5	1.5%	2.1%	2.4%	2.8%	3.1%	3.1%	3.1%	3.1%	3.1%	3.1%
10	2.8%	3.1%	3.3%	3.6%	3.8%	3.8%	3.8%	3.8%	3.8%	3.8%
30	3.7%	3.9%	4.1%	4.3%	4.4%	4.4%	4.4%	4.4%	4.4%	4.4%

Scenario E′: +200 bps for 10-year yield gradually over the first 4 years

Maturity	1	2	3	4	5	6	7	8	9	10
2	0.4%	1.4%	2.4%	3.4%	4.4%	4.4%	4.4%	4.4%	4.4%	4.4%
5	1.5%	2.4%	3.1%	3.8%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%
10	2.8%	3.3%	3.8%	4.3%	4.8%	4.8%	4.8%	4.8%	4.8%	4.8%
30	3.7%	4.1%	4.4%	4.8%	5.1%	5.1%	5.1%	5.1%	5.1%	5.1%

As of 30 November 2013. Source: PIMCO.
Hypothetical example for illustration purposes only.

[1]In this paper, we define "carry" as the expected total return of a bond portfolio under a static yield curve and spread, after adjustment for expected default loss. The expected total return of the portfolio under any other scenario yield curve and a static spread can then be decomposed into "carry," which would be the expected return without any curve shift, and the expected return due to the curve shifts.

[2]Our framework is designed to model forward-looking long-horizon scenario returns for plain vanilla bond portfolios. Although the BAGG may not be a perfect candidate due to its securitized component, the model still provides decent approximations given the dominance of other components in the index.

[3]Alternatively, we could adjust the swap curve by spread and construct a replicating portfolio with par-coupon bonds on the adjusted curve. Here we simplified the total return estimation by treating credit spread as an additive term so that total return of a portfolio before default loss adjustment is the sum of its "swap equivalent return" and its spread above the swap curve. This simplification is based on the assumption of constant and moderate spreads.

[4]In their simplified model with a flat yield curve, annual rebalancing, and a duration targeting strategy, Leibowitz et al. (2014) find that the annualized return for a zero-coupon bond across all trendline paths is equal to the starting yield if the investment horizon is one year less than twice the duration target. Since we assume much higher frequency of rebalancing , the effects of length of rebalancing periods on bond returns and convergence investment horizons are very small and therefore ignored.

References

Leibowitz, Martin L., Anthony Bova, and Stanley Kogelman. 2014. "Long-Term Bond Returns under Duration Targeting." *Financial Analysts Journal*, January/February 2014, Vol. 70, No. 1: 31–51.

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