Investment Insights
THE INVESTMENT RESEARCH JOURNAL from BlackRock
September 2011 | Volume 14 Issue 4
9.11

Optimizing Fixed Income Index Funds

Tradeoffs in Portfolio Construction and Management

by Stephen Laipply and Christopher Woida

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The authors wish to thank Mark A. Taylor, Matthew Tucker, Scott Radell, and Marcia Roitberg for their many contributions to this article.

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Executive summary

The primary role of an index fund is to track the fund's designated benchmark. Holding every security in the benchmark can be challenging in liquid markets, such as exchange traded equities, but it is nearly impossible in the less liquid, over-the-counter bond markets.

As a result, many fixed income index fund managers seek to address this problem by holding an optimized subset of available, liquid securities that strives to balance market risk and portfolio management costs using risk models and optimization techniques. However, this conventional solution does not account for the short volatility risk inherent in sampled portfolios.

Optimized portfolios rely heavily on assumptions about asset volatilities, correlations, and transaction costs. Rising volatility often leads to a destabilization of correlations, an increase in idiosyncratic risk, and a widening in bid/offer spreads, which typically results in higher-than-expected realized tracking error. Realized tracking error is the aggregate of both realized performance tracking error (i.e., how the sampled portfolio performs relative to its stated benchmark) and realized transaction costs driven by portfolio rebalancing.

We first examine the relationship between sample size, projected tracking error, and transaction costs, which allows us to better understand the tradeoffs among these variables in minimizing realized tracking error. More broadly sampled portfolios should result in lower realized performance tracking error but may also result in higher realized transaction costs, ultimately driving realized tracking error higher.

To determine the optimal tradeoff between sample size and transaction costs, we test and quantify tradeoffs among portfolio solutions through historical market cycles. We examine two key fixed income sectors: investment-grade credit and US Treasuries. These sectors were chosen both for their relevance to fixed income investors and also because they highlight specific tradeoffs in portfolio construction and management.

The investment-grade credit example highlights the tradeoff between sample size and idiosyncratic risk, while the US Treasuries example highlights the tradeoff between sample size and transaction costs. In both instances, portfolio managers would have benefited from holding a broader sample set than would have been prescribed by a traditional mean/variance optimization, due to the downside tracking risk portended by periods of elevated market volatility and dislocation.

Using these results, fund managers are better equipped to assess and trade off sample size with projected tracking error and projected transaction costs, so as to minimize realized tracking error across a range of volatility regimes and market conditions.

Balancing risk and cost

The primary role of an index fund manager is to track the fund's designated benchmark. In practice, it is difficult to obtain near-zero tracking error, unless the manager holds every single security in the benchmark *and* perfectly synchronizes portfolio rebalancing activity with benchmark changes at minimal cost.

Holding every security in the benchmark can be challenging in liquid markets, such as exchange traded equities. In less liquid markets, such as the over-the-counter bond markets, it is virtually impossible. Because of the discontinuous liquidity and wide bid/offer spreads often present in the OTC fixed income markets, holding more securities may reduce tracking error in theory, but may also ultimately result in much higher transaction costs.

Many fixed income index fund managers seek to address this problem by holding an optimized subset of available, liquid securities. This strategy strives to balance market risk and portfolio management costs using risk models and optimization techniques to locate the intersection of projected tracking error and projected transaction costs. In short, the manager will attempt to drive projected tracking error down to the point where any further decreases would be outweighed by increases in projected transaction costs.

However, this conventional solution does not account for the "short volatility" risk inherent in sampled portfolios. Optimized portfolios rely heavily on assumptions about asset volatilities, correlations, and transaction costs. Rising volatility often leads to a destabilization of correlations, an increase in idiosyncratic risk, and a widening in bid/offer spreads. The combined effects (and their correlation with each other) often result in higher-than-expected realized tracking error in an environment of rising volatility.

In this paper, we test and quantify tradeoffs among portfolio solutions through historical market cycles to identify a portfolio construction and management approach that minimizes realized tracking error across a range of volatility regimes and market conditions.

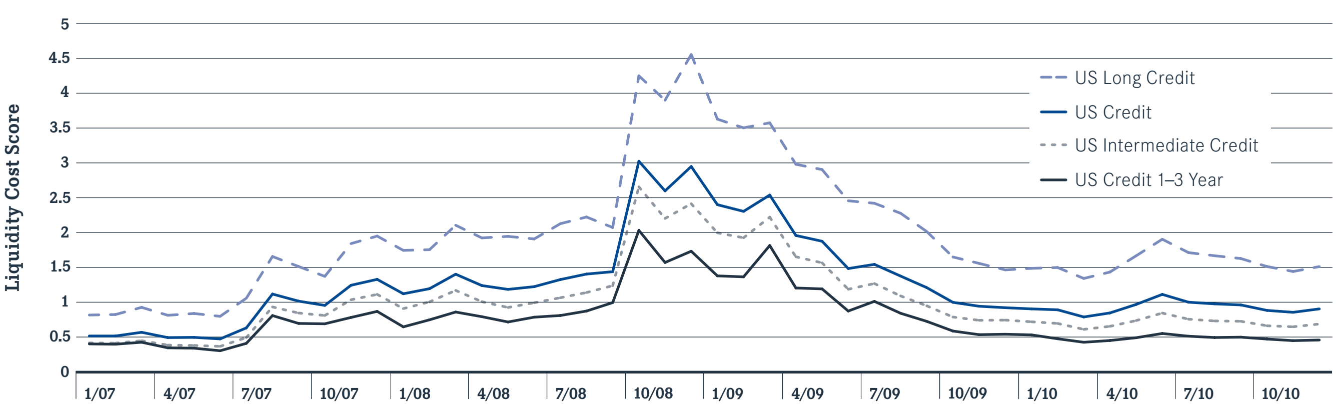
Portfolio construction and management

Fixed income index portfolio managers strive to minimize realized tracking error by targeting projected tracking error and transaction costs. Projected tracking error (PTE) is typically defined as the forecast standard deviation of the performance differential between a portfolio and its benchmark. This projected variation is based on a risk model and specific assumptions about market parameters such as correlations and volatility. Projected tracking error consists of common factor risk (i.e., risk that is common to all securities and therefore cannot be diversified away on an absolute basis) and idiosyncratic (or, security specific) risk. While common factor risk *relative to a benchmark* may be eliminated by holding a relatively small sample of securities, reducing idiosyncratic risk relative to a benchmark is far more difficult and costly because a significantly larger sample set of securities may be necessary. The larger the sample size, the greater the proportion of less liquid securities, which, in turn, increases transaction costs.

Traditional optimized portfolio construction strategies rely heavily on the stability of correlations among portfolio constituents (e.g., constructing a portfolio to minimize tracking error based on a historical covariance matrix). The challenge with this approach is that shifts in correlation often invalidate the original optimized solution. As a result, the portfolio manager is forced to choose between incurring higher transaction costs in order to rebalance to the new optimized solution or facing higher potential tracking error by choosing not to rebalance.[1] Overreliance on correlations—which the financial crisis proved is not an advisable practice—can be mitigated by employing rigorous stratified sampling techniques to construct index tracking portfolios. Stratified sampling seeks to identify and quantify index risk exposures that are not dependent on correlation assumptions and can be matched through judicious portfolio construction. A portfolio construction approach based on stratified sampling techniques will potentially be more stable and less vulnerable to sudden shifts in asset correlations during market dislocations.

Shifts in correlation often occur in an environment of rising volatility, which also may result in an increase in idiosyncratic risk due to an increase in sampling error. If a portfolio manager is holding a subset of securities relative to the benchmark in an optimized portfolio (and is therefore exposed to idiosyncratic risk because not all benchmark holdings are represented), higher volatility will likely result in higher sampling error. Conversely, at the limit, zero volatility should result in zero sampling error.

Exhibit 1: Transaction costs observed during the financial crisis

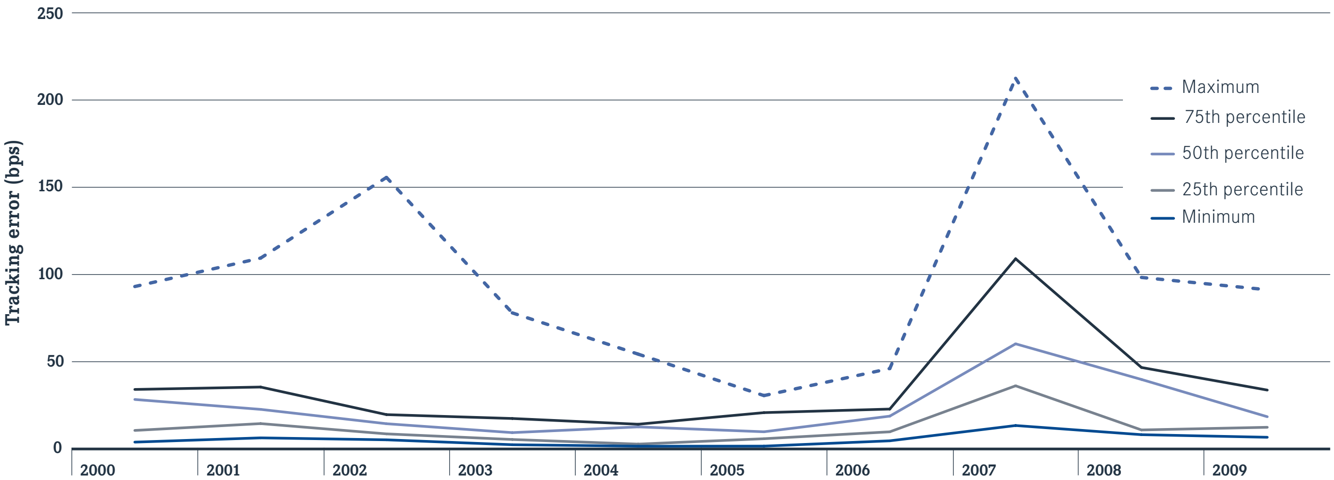


For illustrative purposes only.

Source: Barclays Capital Liquidity Cost Scores.

1. For a discussion on portfolio rebalancing under varying market conditions, see Lydia Chan and Sunder Ramkumar, "Efficient Portfolio Rebalancing in Normal and Stressed Markets," *Investment Insights* 13 no. 3 (September 2010) BlackRock Inc., New York.

Exhibit 2: Tracking error observed during the financial crisis



For illustrative purposes only.
Source: eVestment Alliance.

The impact of higher volatility on tracking error was pronounced in 2008 and 2009. As the financial crisis unfolded, index optimization strategies incurred large realized tracking error due to a destabilization in correlations, an increase in sampling error/idiosyncratic risk, and an increase in transaction costs. Exhibits 1 and 2 illustrate the volatility in transaction costs and tracking error during the crisis.

> Incurring higher transaction costs in a low-volatility base case is somewhat similar to purchasing an option or an insurance policy.

Sampling error may only be mitigated by increasing the optimized sample size. Transaction costs, unfortunately, are also a function of market volatility. As volatility increases, transaction costs (as measured by bid/offer spreads) tend to widen, as shown in Exhibit 1. The implication is that, in a regime shift from a period of low volatility to one of high volatility, it will become far more expensive to respond *ex post* by increasing the optimized sample size. In effect, this dynamic resembles a short-volatility position, because tracking error and transaction costs will both move directionally with market volatility.

Accordingly, it may be advantageous to hold a broader-than-prescribed optimized sample in a low-volatility environment (thereby incurring greater transaction costs during rebalancing) to protect against regime shifts to a higher volatility environment later on. Incurring higher transaction costs in a low-volatility base case is somewhat similar to purchasing an option or an insurance policy. If volatility remains low or falls, such a strategy may look expensive relative to a strategy of not holding any protection. However, if volatility rises and is accompanied by correlation shifts and increases in idiosyncratic risk and transaction costs, such a strategy would be vindicated.

To determine the effectiveness of this approach, we look at historical market cycles. Before doing so, we first develop a conceptual framework of the relationship between projected tracking error and transaction costs.

Projected tracking error versus transaction costs

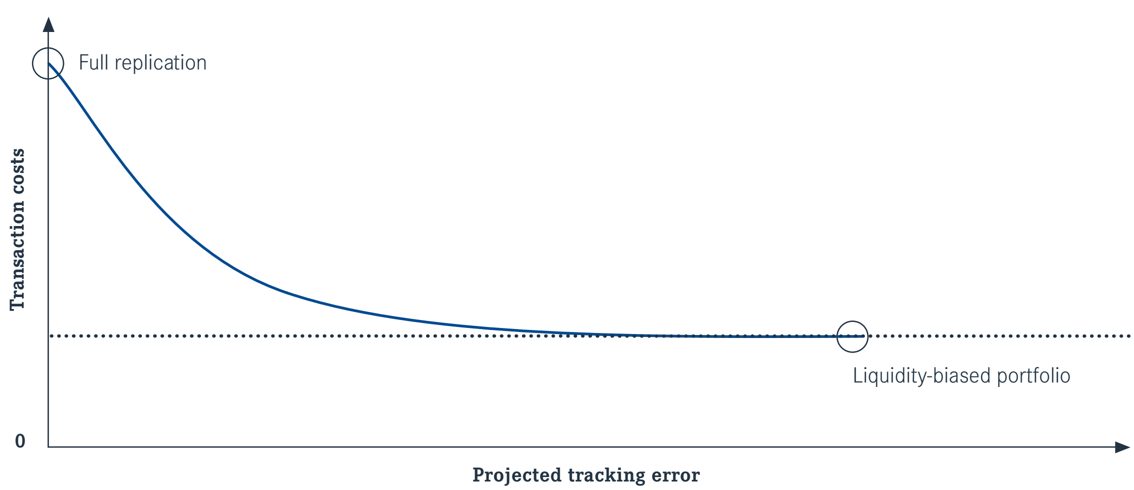
The conceptual relationship between sample size, transaction costs, and PTE, referred to here as the "portfolio operating curve," is depicted in Exhibit 3.

Transaction costs are plotted as a function of the PTE targeted by the fund manager. In this conceptual representation, it is assumed that marginal transaction costs are unaffected by position trading size and portfolio flows; that is, client flow crossing opportunities are not contemplated. Note that, while a full replication of the benchmark eliminates PTE, it also results in the highest level of transaction costs, due to a higher percentage of less liquid securities with wider bid/offer spreads. Accordingly, we should see significant marginal savings in transaction costs as the manager moves from full replication to an optimized solution using more liquid securities. This is represented by the portfolio operating curve in Exhibit 3, as we move from left to right along the PTE axis.

Similar to an efficient frontier, each point on the portfolio operating curve corresponds to a passive portfolio targeting a specific PTE relative to its benchmark that is available to the manager. Points above this curve correspond to portfolios that are feasible but less efficient (i.e., portfolios that may be constructed at a similar PTE but using less liquid securities with higher transaction costs); portfolios that lie below the curve are not feasible. A floor on transaction cost savings occurs at the point at which the fund liquidates only those securities that leave the benchmark and reinvests proceeds based solely on a lowest-transaction-cost criterion. We refer to this as the liquidity-biased portfolio. This scenario, which incurs significant PTE, represents the limit to which transaction costs can be reduced.

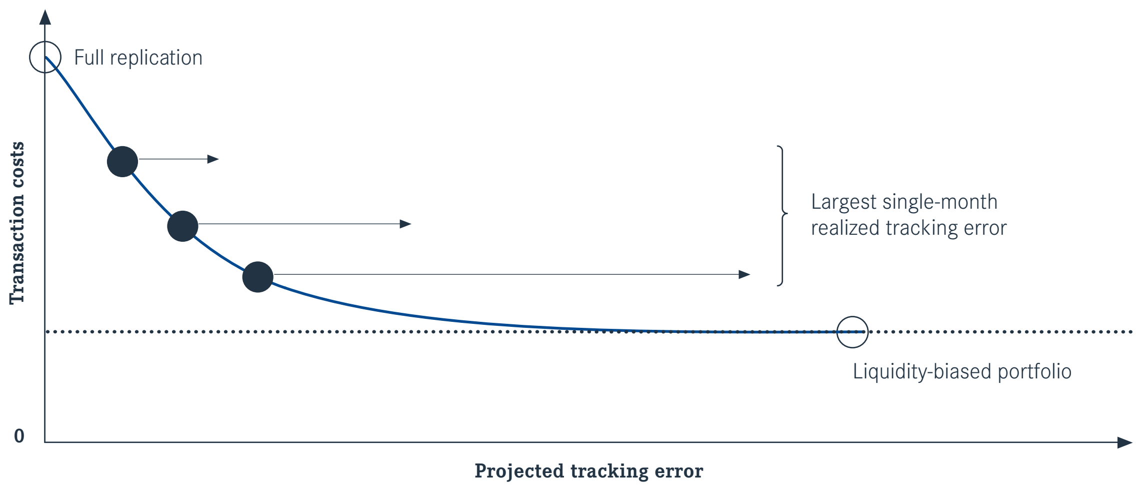
A key question is how portfolios along this curve perform in various market environments. To find out, we constructed and backtested different portfolio solutions along the portfolio operating curve relative to the appropriate market benchmarks and estimated the realized tracking error associated with each.[2] Portfolios were simulated and rebalanced monthly, with the objective of minimizing a combination of PTE *and* transaction costs over the backtest horizon. Exhibit 4 is a conceptual illustration of transaction costs, PTE, and realized tracking error, based on actual relationships that were observed in these backtests. Realized tracking error is a function of the fund performance relative to the index as well as transaction costs incurred through portfolio rebalancing. For a given point on the portfolio operating curve, the length of the arrow emanating from that point (i.e., the distance between the point and the end

Exhibit 3: Portfolio operating curve: Annualized transaction costs as a function of target PTE



2. Note that portfolios were constructed through risk model-based optimizations. Stratified sampling techniques were not employed to simplify the implementation of the simulations.

Exhibit 4: Portfolio operating curve versus largest single-month realized tracking error observations



of the arrow) represents the largest single-month realized tracking error observed over the historical backtested horizon. This chart illustrates the relationship between PTE and realized tracking error, and the potential pitfalls associated with optimized solutions that emphasize transaction-cost minimization at the expense of PTE. The higher the target PTE, the greater the potential for high realized tracking error during periods of elevated volatility due to shifts in correlations, increased idiosyncratic risk, and increased transaction costs resulting from managers' attempting to mitigate increased tracking error by expanding optimized portfolios.

Although portfolios with lower PTE appear to be more expensive *ex ante* due to higher projected transaction costs, they may ultimately prove to be less expensive and more efficient *ex post* due to changes in market conditions. Hence, it may be beneficial to insure against adverse market environments by holding a greater sample of securities (and thereby incur higher baseline transaction costs) than is typically prescribed by the conventional optimization approach. By doing so, the portfolio manager may ultimately spend *less* on future transaction costs while experiencing a smaller divergence between projected and realized tracking error in a higher-volatility environment. We illustrate this concept through two asset class examples: investment-grade credit and US Treasuries. These sectors were chosen both for their relevance to fixed income investors and because they highlight specific tradeoffs in portfolio construction.

Example one: 1–3 year investment-grade credit

Consider a fund benchmarked to the Barclays Capital US 1–3 Year Credit Index. This benchmark typically contains more than 600 securities and over 300 issuers. Portfolio solutions were simulated over a backtested horizon from 2007 to 2010. The inputs for the portfolio construction process were the risk factors of the index (e.g., key rate durations and spread durations). The common factor covariance matrix and idiosyncratic risk estimates were derived from time-weighted historical data. Because data on bid/offer spreads in credit sectors is either not available or not robust, transaction costs are modeled based on Barclays Capital Liquidity Cost Scores. Additional assumptions for the simulations include:

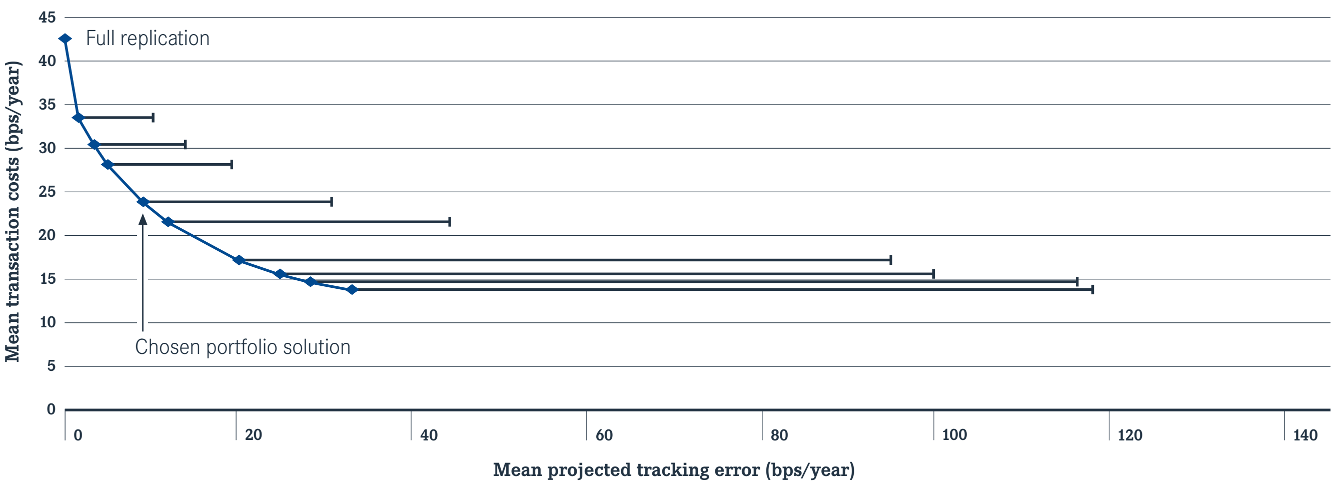
- Full investment,
- No minimum trade size,
- Monthly rebalancing,
- Trading limited to rebalancing activity (i.e., potential inflows are not incorporated),
- No out-of-benchmark holdings,
- Transaction costs (in basis points) are constant (i.e., no market impact due to trade size), and
- Portfolio manager does not actively take advantage of liquidity events.

The resulting portfolio operating curve for this benchmark is shown in Exhibit 5. First, note that the absolute level of transaction costs in this credit sector is relatively high for full replication (over 43 bps per year with 83% annualized turnover). Due to the level and dispersion of transaction costs for corporate securities (which represent 80% of the market value of this index), there is a substantial marginal savings in transaction costs for each increase in target PTE, which is evidenced by the steep drop in the portfolio operating curve with respect to increasing PTE.

Note that each increase in PTE corresponds to fewer securities. Along this curve, the fund is still holding most of the *issuers* in the benchmark but tends to overweight more-liquid *issues*. As an example, General Electric (the issuer) had 40 different issues in the Barclays Capital U.S. Credit Index, as of 3/31/11. Five of these issues came to market in the previous 12 months, with the remainder more than 12 months old. Exhibit 6 shows the relationship between bid/offer spreads and seasoning for GE issuance.

There is an explicit tradeoff to this strategy in the form of idiosyncratic risk. In periods of elevated market volatility,

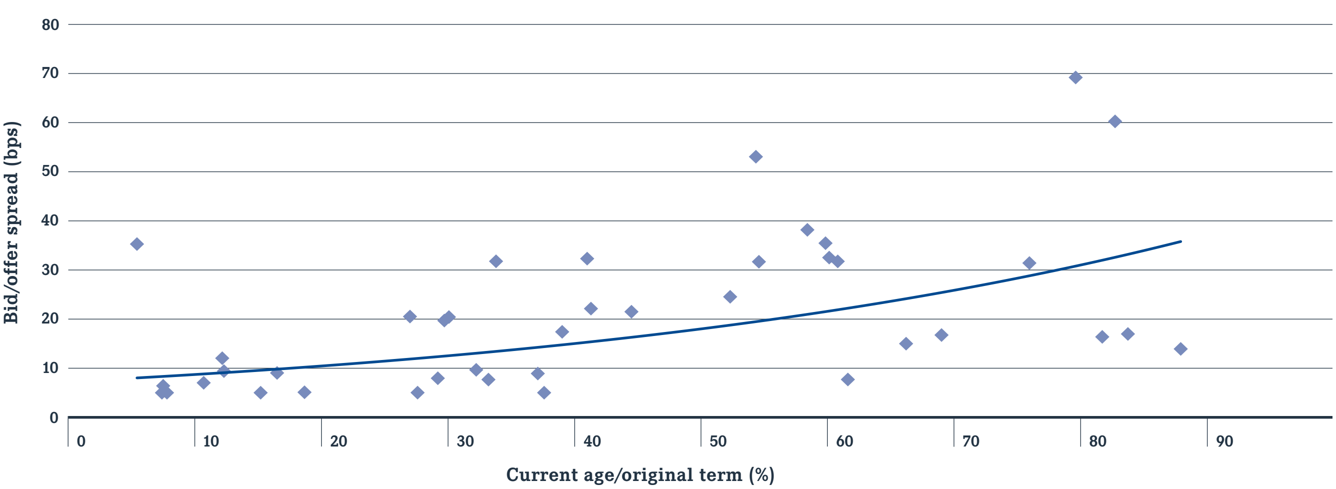
Exhibit 5: Barclays Capital US 1–3 Year Credit Bond Index portfolio operating curve versus largest single-month realized tracking error observations (2007–2010, backtested results)



Sources: BlackRock and Barclays Capital.

Note: Mean PTE is expressed in bps per year, while largest single-month realized tracking error is in absolute bps (not annualized).

Exhibit 6: Bid/offer spreads versus seasoning for General Electric



Sources: BlackRock and Barclays Capital.

the realized tracking error, driven by the idiosyncratic risk between liquid on-the-run and less liquid off-the-run issues (i.e., sampling error), can be quite high and can differ significantly from PTE, as evidenced by Exhibit 5. This exhibit depicts the realized tracking error for a given portfolio solution along the transaction cost versus PTE operating curve and illustrates the risk of liquidity-biased solutions in the presence of idiosyncratic risk and market volatility.

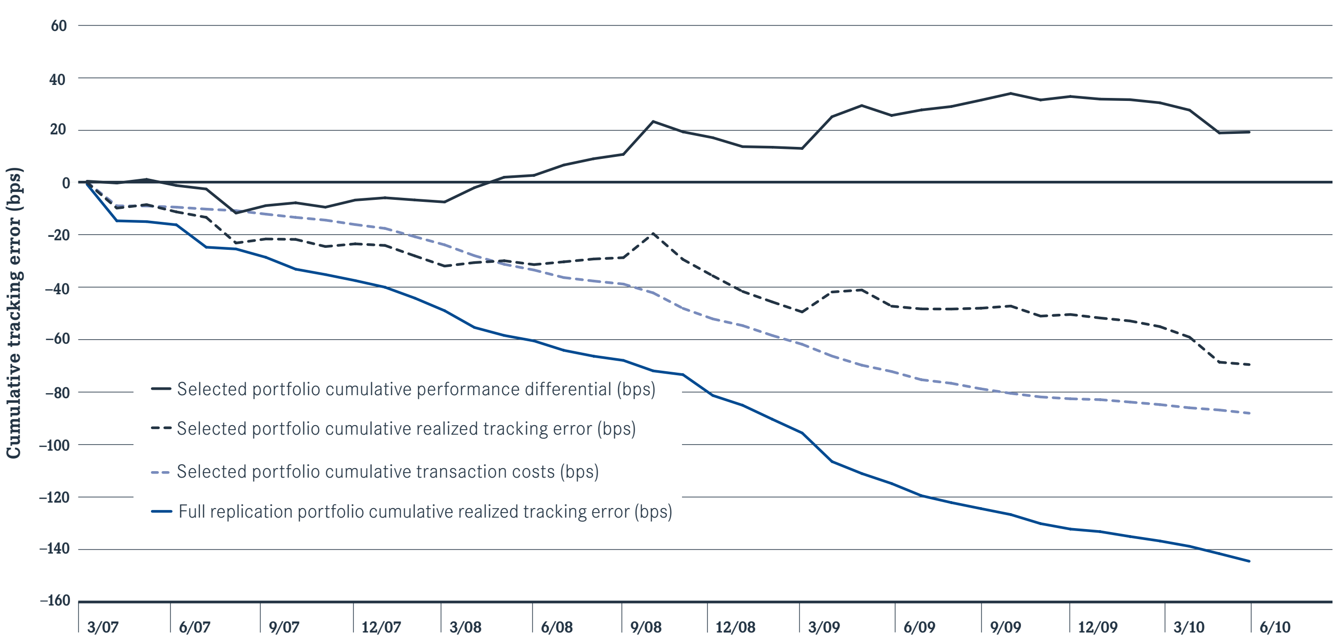
Accordingly, the portfolio manager would use the information in this exhibit to trade off PTE, transaction cost estimates, and historical realized tracking error in order to determine an optimal portfolio solution across different volatility regimes. Assume, for example, that the manager selected a solution with 9 bps per year average PTE and 24 bps per year of estimated transaction costs, corresponding to 71% annualized turnover (the “chosen portfolio solution” in Exhibit 5). While solutions with much lower transaction costs exist with favorable tradeoffs in PTE, the worst-case historical realized tracking errors for such solutions are far greater than PTE would suggest, and would easily overwhelm any perceived transaction cost savings.

Exhibit 7 illustrates the backtested results of the chosen solution. The horizontal axis represents time and the vertical axis represents cumulative realized tracking error.

Note how the solid line corresponding to the fully replicated portfolio steps down each month due to incurred transaction costs related to turnover in the benchmark (by definition, there is no performance differential with the fully replicated portfolio—the only source of tracking error for such a portfolio is transaction costs). The light blue dashed line corresponding to realized transaction costs in the sampled portfolio solution is above the full replication line. This is because the sampled portfolio solution trades off lower transaction costs for higher PTE, which decreases annualized turnover (from 83% to 71%).

In addition to transaction costs, each passing month results in a cumulative performance differential relative to the benchmark (the black solid line) for the chosen sampled solution. The black dashed line—cumulative realized tracking error—represents the sum of the cumulative realized transaction costs and cumulative realized performance differential between the portfolio and the benchmark. Note that the chosen portfolio solution was superior to a full replication because the portfolio manager was able to successfully trade off tracking error with transaction costs.

Exhibit 7: Barclays Capital US 1–3 Year Credit Bond Index: Selected portfolio solution versus full replication cumulative realized tracking error (backtested results)



Sources: BlackRock and Barclays Capital.

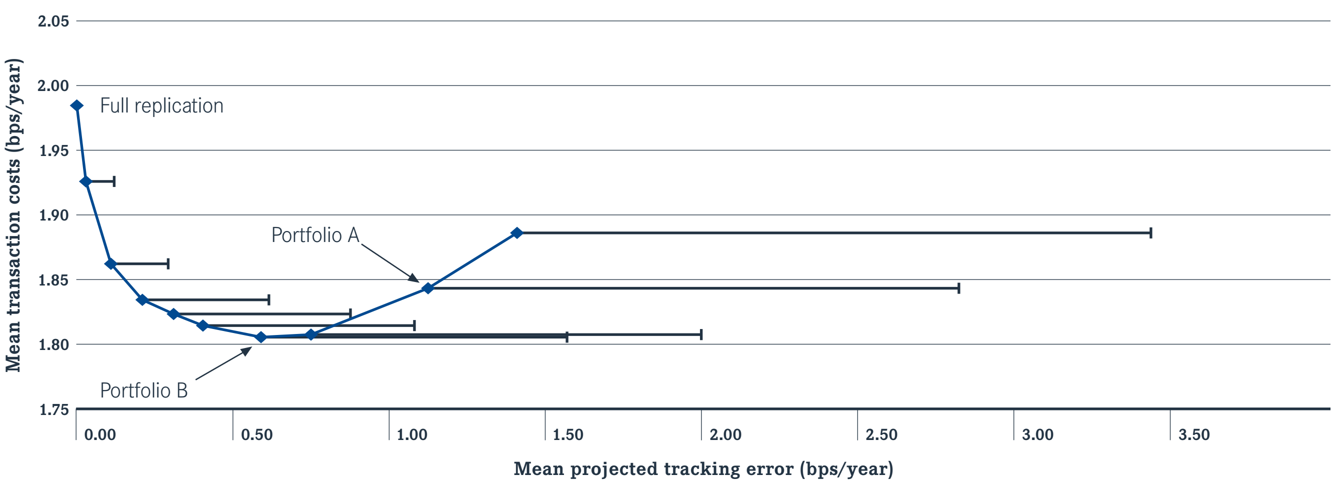
This example demonstrates the importance of incorporating the potential impact of different volatility regimes in less liquid asset classes. The level of idiosyncratic risk increases dramatically as we move from relatively homogenous sectors, such as US Treasuries, to more heterogeneous sectors, such as investment-grade and high-yield credit. Credit sectors in particular are prone to periods of dislocation, resulting in sudden shifts in correlations, sharply increasing transaction costs, and reduced liquidity in volatile market conditions. A liquidity-biased portfolio solution is likely to experience far more realized tracking error in an environment of elevated volatility; the portfolio manager, in an effort to lower idiosyncratic risk, may find it too costly to increase the sample size of securities after market conditions have deteriorated.

With this understanding of the tradeoff between PTE, estimated transaction costs, and historical realized tracking error, a set of portfolio management guidelines could be developed. Using the backtest results, corresponding portfolio risk attributes and performance statistics could be compiled and tolerances for aggregated risk could be generated using dimensions more intuitive to the portfolio manager (e.g., key rate durations, spread durations, and concentration measures). Because the tolerances for these risk dimensions would be based on observations compiled over the backtested horizon covering a variety of market cycles, they could serve as a useful guide in managing portfolio risk over a range of volatility regimes and market conditions. These guidelines could be used as heuristics by the portfolio manager for monitoring risk on a daily basis.

Example two: 7–10 year US Treasury Fund

Now consider a fund benchmarked to a US Treasury index, the Barclays Capital US Treasury 7–10 Year Bond Index. This benchmark typically contains approximately 20 securities (notes recently issued with 10 years to maturity and older securities originally issued at longer maturities). Portfolio solutions were simulated over a backtested horizon from 2005 to 2010. The inputs for the portfolio construction process were the common risk factors of the index, as defined by US Treasury spot rates. Idiosyncratic risk was defined as the volatility between on-the-run and off-the-run yields and the fitted US Treasury spot curve; security exposure was defined by key rate durations. The common factor covariance matrix and estimates of idiosyncratic risk were derived from time-weighted historical data. Transaction costs were determined by bid/offer spreads for both on- and off-the-run securities. To capture the impact from the financial crisis, transaction cost estimates were doubled from July 2007 to September 2009; in some instances, actual transaction costs for this period were even higher. All other assumptions are the same as those noted in the preceding example.

Exhibit 8: Barclays Capital US Treasury 7–10 Year Bond Index portfolio operating curve versus largest single-month realized tracking error observations (2005–2010, backtested results)



Sources: BlackRock and Barclays Capital.

Note: Mean PTE is expressed in bps per year, while largest single-month realized tracking error is in absolute bps (not annualized).

Results of the backtest are illustrated in Exhibit 8, which depicts the portfolio operating curve for this Treasury index. From a qualitative perspective, the results are mostly as expected. Full replication has the highest transaction costs: almost 2 bps per year with 48% annualized turnover. There is a steep initial savings in transaction costs, as the fund takes on risk by employing more sampled portfolios (moving from left to right). Similar to Exhibit 5, the largest single-month observations of realized tracking error for a given portfolio also increase with the degree of sampling.

Unlike the preceding investment-grade credit example, however, the curve eventually turns *upward*, indicating that, despite the fund's being managed at a higher level of PTE, it would actually have cost *more* to stay *within* this PTE range over the entire backtest horizon than it would have to run the fund at a lower overall PTE target.

This effect is due to the increase in market volatility during the financial crisis, which affected the management of this fund in two specific ways. First, spreads of on-the-run and off-the-run US Treasury yields relative to the fitted spot US Treasury curve dislocated and became much more volatile. This can be thought of as an increase in idiosyncratic risk. Second, bid/offer spreads across all US Treasury securities widened, driving transaction costs higher. To simply remain within the target PTE during this period of elevated volatility, the portfolio manager would have had to increase the sample size of the portfolio to offset the increase in idiosyncratic risk. The subsequent portfolio rebalance would have resulted in much higher transaction costs than originally anticipated. These transaction costs were higher due to both the nature of the securities themselves (i.e., less liquid, off-the-run securities) and higher volatility (resulting in wider bid/offer spreads for these securities) observed over the backtest period. The higher the initial PTE of the sample portfolio, the higher the ultimate realized transaction costs and realized tracking error observed over the backtest period.

The manager in this scenario was faced with a challenging tradeoff: By running more highly sampled portfolios, they could either incur high realized tracking error or attempt to reduce this realized tracking error by incurring higher-than-anticipated transaction costs through rebalancing to a broader portfolio. Either way, a better solution would have been to incur higher baseline transaction costs by holding a broader initial sample of securities and, therefore, ultimately incur lower realized tracking error and rebalancing costs (i.e., less rebalancing would be necessary with a broader initial portfolio).

As an example, operating the fund at a PTE target of 1.1 bps per year (Portfolio A in Exhibit 8) would indeed have resulted in lower transaction costs in 2005 and 2006. However, these early initial transaction cost savings would have ultimately been eclipsed by higher realized transaction costs in 2007 and 2008, as the portfolio manager would have had to expand the portfolio sample into less liquid securities in order to maintain the original PTE target. Accordingly, from a realized tracking error perspective, it would actually have been more efficient, on average, to operate the fund closer to the benchmark at a higher rate of turnover and a higher level of *ex ante* transaction costs than to take on more PTE in an attempt to decrease turnover and save on transaction costs.

> It would actually have been more efficient to operate the fund closer to the benchmark at a higher rate of turnover and a higher level of *ex ante* transaction costs than to take on more projected tracking error.

Alternatively, suppose the portfolio manager selected a portfolio solution with 0.60 bps per year mean PTE and an estimated 1.8 bps per year of transaction costs corresponding to 44% annualized turnover (Portfolio B in Exhibit 8). Similar to Exhibit 7, Exhibit 9 shows the backtested results of the realized tracking error for this solution versus full replication.

Although this particular solution did incur elevated realized tracking error during the onset of the financial crisis, it is likely that anything other than the fully replicated portfolio would have done so for the reasons discussed. Ultimately, however, the chosen solution successfully balanced transaction costs and PTE across both low- and high-volatility environments, and it provided lower total realized tracking error than a full replication solution over the backtest horizon. This example illustrates the pronounced impact that market volatility may have on bid/offer spreads and transaction costs (even in the relatively liquid market for US Treasuries), greatly hindering a portfolio manager's ability to meet tracking objectives.

Similar to the preceding example, this data could be used to develop a set of portfolio management guidelines. Using these guidelines, the portfolio manager could position and manage this particular Treasury fund across varying market conditions and volatility regimes, trading off PTE, transaction costs, and historical realized tracking error.

An alternative approach

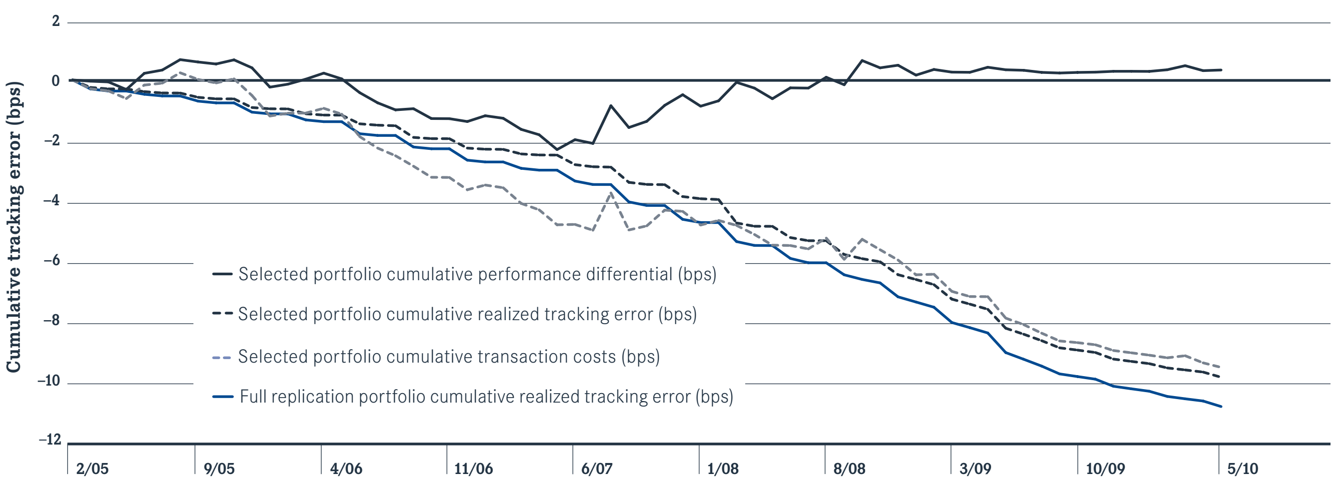
The empirical results of the backtest simulations suggest an approach to fixed income index portfolio management that would incorporate a variety of potential volatility regimes and their impact on common and idiosyncratic risks and transaction costs. Such an approach would have properties similar to that of an option-based or insurance-based strategy designed to manage the portfolio to the tightest realized expected tracking error across a range of market conditions.

Using this alternative approach, a portfolio manager would examine the tradeoffs among the following three dimensions and attempt to choose an optimal portfolio construction/management strategy:

- Projected tracking error (based on risk model forecasts),
- Historical realized tracking error for different portfolio solutions (based on empirical data), and
- Transaction costs (based on forecasts and empirical data).

The strategy would be monitored and adjusted accordingly relative to market conditions.

Exhibit 9: Barclays Capital US Treasury 7–10 Year Bond Index: Portfolio solution cumulative realized total tracking error versus full replication (backtested results)



Sources: BlackRock and Barclays Capital.

The approach to fixed income index portfolio management described herein moves beyond traditional optimized solutions that rely heavily on historical correlations and static assumptions about idiosyncratic risk and transaction costs. To obtain efficient index exposure, it is crucial to explicitly recognize and quantify the impact of market volatility on the stability of correlations as well as the level of idiosyncratic risk and transaction costs. While stratified sampling techniques seek to reduce dependency on correlation estimates, an option-based approach seeks to also intelligently trade off idiosyncratic risk and transaction costs through sample size during lower volatility periods so as to insulate the portfolio against higher volatility market environments later on.

With a more thorough understanding of the interplay between market volatility, transaction costs, and potential and realized tracking error, portfolio managers are better equipped to manage index portfolios and minimize realized tracking error across a variety of potential volatility regimes and market conditions.

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CTF-02883662-01-II-0911_PRD_v03MW_08/11

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