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FICC Research
Quantitative Portfolio Strategy
14 August 2019

Integrating Value and Momentum Strategies into Credit Portfolios

- Systematic investing has become increasingly popular with credit investors. However, integrating quantitative signals into an actual portfolio can be challenging due to high transaction costs, large variations of liquidity across individual bonds, and the requirement to follow a benchmark index.
- In the absence of a long industry track record of managing according to systematic strategies, we design realistic simulations that illustrate the performance and characteristics of quantitatively managed corporate bond portfolios.
- We focus on two well-known thematic strategies – relative value and momentum – and base our analysis on scorecards published under Barclays Research: Excess Spread to Peers (ESP) for relative value and Equity Momentum in Credit (EMC) for equity momentum.
- Together with Barclays liquidity analytics (Liquidity Cost Scores and Trade Efficiency Scores), the ESP and EMC scorecards help build realistic strategy portfolios of liquid bonds. We consider two case studies: the first utilises a turnover buffer to avoid buying or selling bonds with intermediate signal levels; and the second uses a turnover budget to explicitly control rebalancing volumes. Exposure constraints relative to the index are applied to reduce tracking error volatility.
- We find that realistic strategies based on ESP and EMC scores have outperformed the Bloomberg Barclays US Corporate Bond Index after transaction costs with information ratios above 1 since 2007. The results of our study support the case for systematic style investing in credit.

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Introduction

Systematic investment strategies have become popular with investors. Indeed, quantitative models and strategies are often used by institutional investors in liquid markets: value, momentum, reversion and sentiment signals[1] have been adopted by traders and portfolio managers in equity, rates and FX markets.

Interest in systematic strategies has recently broadened to the credit market. Informative signals based on valuation, momentum and sentiment have been advocated in the industry as well as in academic literature[2]. In our reports on *Relative Value Investing in Credit* and on *Equity Momentum in Credit (EMC)* we introduced systematic strategies based on value and stock-bond momentum. We then launched quantitative scorecards called Excess Spread over Peers (ESP) and Equity Momentum in Credit (EMC).[3] These scorecards provide security-level value and momentum signals in US and European corporate bond markets. Monthly bulletins document scorecard performances.[4]

Implementing quantitative strategies in credit portfolio entails some unique challenges. In addition to quantitative signals that must be produced periodically for a broad universe, portfolio construction must be carefully designed to control turnover, prudently estimate transaction costs and ensure the portfolio structure conforms with the allocation of a market index.

This contrasts with the much simpler approach commonly followed in equity markets. Stock-selection strategies often involve *percentile* portfolios, where individual names are sorted on an informative signal with the top percentile forming a strategy portfolio.

For example, individual stocks in an equity index can be sorted on valuation into decile portfolios with the strategy portfolio represented by the top decile. The performance of this top value portfolio, after estimated transaction costs, can be compared to that of a benchmark index in order to assess the usefulness of the signal.

In contrast to the equity market, however, similarly sorted bond *percentile* portfolios are unlikely to be practical for credit portfolio managers because they ignore turnover, transaction costs, bond liquidity and the structure of an underlying benchmark index.

Transaction costs of corporate bonds can be high, so that excessive turnover can create a significant drag on portfolio performance. Implementing a realistic strategy portfolio of corporate bonds requires turnover controls as well as a reliable way to measure transaction costs. In addition to high transaction costs, liquidity of corporate bonds varies over time and across individual securities. A corporate bond included in a broad market index may often be unavailable to buy in the secondary market. A practical implementation of a strategy portfolio should therefore correctly identify and avoid highly illiquid securities. This can be especially challenging in a back-test as historical liquidity characteristics of individual corporate bonds are required to make a portfolio simulation realistic.

We address these challenges by building and back-testing realistic strategy portfolios net of transaction costs between 2007 and 2019 using Barclays quantitative scorecards and analytics. In the absence of a long industry track record of managing actual credit portfolios according to systematic styles, our portfolio simulation can help inform investors about the performance and properties of systematic investing in corporate bond markets.

[1] See, for example, Asness, C., T. Moskowitz, and L. Pedersen *Value and Momentum Everywhere*; Jegadeesh, N., *Evidence of Predictable Behavior of Security Returns*; Stambaugh, R., J. Yu, and Y. Yuan, *The Short of It: Investor Sentiment and Anomalies*.

[2] See, for example, Haesen, D., P. Houweling, and J. van Zundert, *Momentum Spillover from Stocks to Corporate Bonds;* Correia, M., S. Richardson, and A. Tuna, *Value Investing in Credit Markets*, and Ben Dor A., J. Guan, and X. Zheng, *Is Information Extracted from Earnings Call Transcripts Using Natural Language Processing (NLP) Predictive of Future Bond Returns?*

[3] See *Quantitative Credit Scorecards for Relative Value (ESP) and Cross-Asset Momentum (EMC)*.

[4] See, for example, *Excess Spread over Peers (ESP) Scorecard - July 2019* and *Equity Momentum in Credit (EMC) Scorecard - July 2019*.

In our analysis we apply Excess Spread to Peers (ESP) and Equity Momentum in Credit (EMC) quantitative models to US corporate IG bonds and we explain how relative value and equity momentum signals can be integrated into an actual investment portfolio, while limiting turnover and respecting benchmark-related constraints.

Using liquidity cost scores (LCS) as a conservative measure of bond-level trading costs, we confirm that strategy portfolios based on ESP and EMC signals delivered sizable returns over the Bloomberg Barclays US Corporate index *net of rebalancing costs*.

In the next section, we explain the quantitative relative value (Excess Spread to Peers, ESP) and equity momentum (Equity Momentum in Credit, EMC) strategies in credit, and provides the case for combining them in a strategy portfolio. We then review Barclays Liquidity Cost Scores (LCS) and explain how they can be used to measure historical transaction costs and monitor security-level liquidity. Next we explain how strategy portfolios based on a combination of ESP and EMC signals can reduce rebalancing costs by implementing a turnover buffer that precludes trading securities with intermediate signal levels. Finally, we focus on implementing benchmarked portfolios with an explicit turnover budget and exposure constraints.

Relative Value and Equity Momentum Strategies in Credit

Quantitative strategies based on relative value and equity momentum have gained prominence among corporate bond investors. In *Relative Value Investing in Credit* and *Equity Momentum in Credit (EMC)*, we document characteristics and the performance of these strategies before transaction costs. We have also introduced quantitative scorecards that rank corporate bonds on relative value[5] and stock-bond momentum: Excess Spread to Peers (ESP) and Equity Momentum in Credit (EMC). Security-level (ESP) or issuer-level (EMC) scores are updated monthly and cover corporate bonds included in major indices.[6]

In this publication, we consider Barclays relative value model called Excess Spread over Peers (ESP). The methodology and strategy characteristics are explained in *The ESP Scorecard: A Framework to Identify Relative Value in Credit* and *Relative Value Investing in Credit*. The scorecard assigns scores from 1 to 10 to bonds according to their relative valuation with a high score indicating attractiveness.

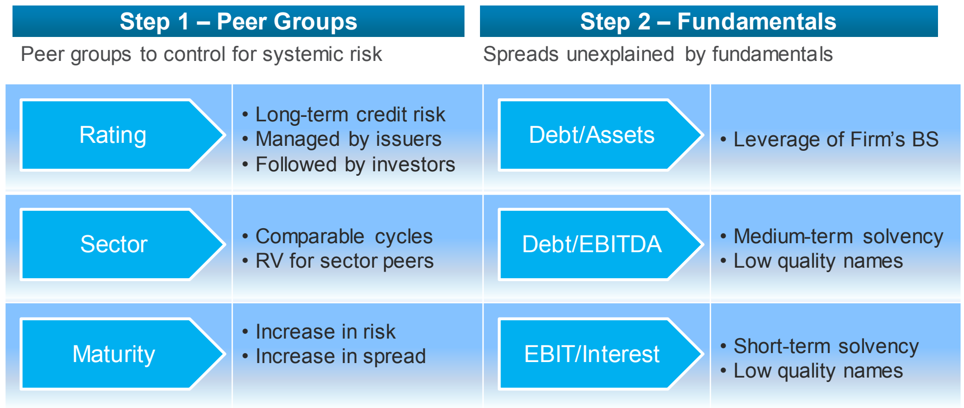
The model is implemented in two steps as outlined in Figure 1. First, peer groups are identified within the corporate bond universe. In this process, individual bonds are grouped based on rating, sector, and maturity to capture systematic credit risk. The ESP scorecard calculates the excess spread of each bond over its peer group average. Bonds with *high* or *low* excess spreads over peers are deemed *undervalued* or *overvalued*, respectively.

[5] We have produced two relative value models in credit, called Excess Spread over Peers (ESP) and Spread Per unit of Debt to Earnings Ratio (SPiDER). ESP looks at relative spread within peer groups of issuers while controlling for issuer fundamentals and bond characteristics. ESP signals (scores) are updated monthly although the effective horizon of the strategy can be 1-6 months. SpiDER looks at issuer spread per unit of debt to earnings ratio as the valuation measure. The SPiDER investment horizon is 6-12 months, see *Value Investing in Credit using SPiDER (Spread Per unit of Debt to Earnings Ratio)*. In our analysis, we focus on ESP as a measure of relative value.

[6] ESP and EMC scores are produced at the beginning of each month and are available on Barclays Live. Both ESP and EMC scorecards cover US IG, US HY and Euro IG markets. EMC was recently extended to cover the Sterling corporate bond market. Monthly bulletins document the performance of the scorecards before transaction costs, please see *Excess Spread over Peers (ESP) Scorecard - July 2019* and *Equity Momentum in Credit (EMC) Scorecard - July 2019*.

FIGURE 1

Excess Spread to Peers (ESP) Scorecard Implementation



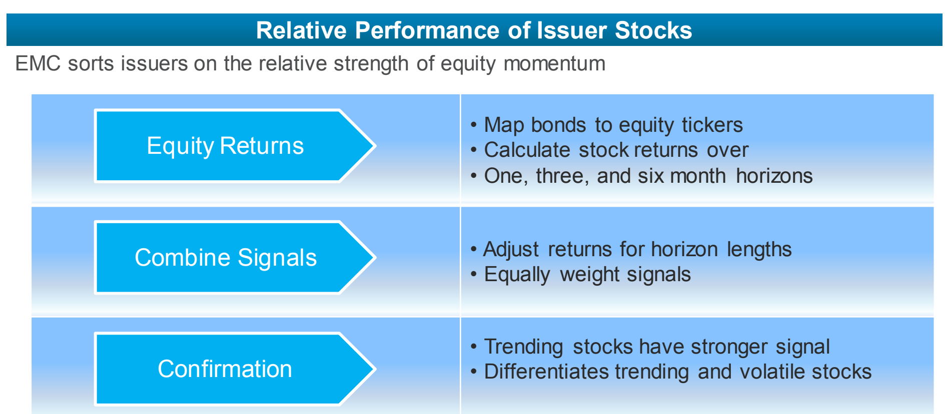
Source: Barclays Research

In the second step, the ESP scorecard corrects excess spreads for differences in issuer fundamentals and bond characteristics using a regression analysis. Three fundamental ratios are used to capture variation in excess spreads: financial leverage, net debt to EBITDA, and interest coverage.[7] The *unexplained* part of excess spread over peers is translated into the ESP score by ranking all bonds in an index.[8] Securities with higher *unexplained* spreads over peers are assigned high ESP scores and are deemed undervalued. Issues with high *negative* unexplained spread over peers receive low ESP scores and are deemed overvalued.

The cross-asset momentum strategy is called Equity Momentum in Credit (EMC). It is designed to differentiate issuers by their stock price momentum, as shown in Figure 2, and is based on a positive empirical relationship between past equity returns and subsequent excess returns of corporate bonds. The methodology and strategy characteristics are documented in *Equity Momentum in Credit (EMC)*. EMC assigns scores from 1 to 10 to issuers, with a high score indicating strong equity momentum.

FIGURE 2

Equity Momentum in Credit (EMC) Scorecard Implementation



Source: Barclays Research

[7] These ratios apply to non-financial issuers. For financials, only the ratio of long-term debt over long-term assets is used in the second step.

[8] The methodology is separately applied to constituents of the US Corporate IG, US HY, and Euro Corporate Senior IG Indices.

The equity momentum of an issuer is measured as the equally-weighted combination of stock price returns calculated over 1, 3 and 6 month horizons and adjusted for the lengths of the signal formation periods. This helps differentiate between trending stocks and stocks with short-term price volatility.

Bond- and issuer-level signals produced by ESP and EMC scorecards are informative of subsequent performance as illustrated in Panels A and B of Figure 3. Corporate bonds are sorted by ESP and EMC scores into market-capitalization weighted portfolios, and records subsequent excess returns[9]. This exercise is repeated for each month from 2007 to 2019. The results for portfolios sorted on ESP and EMC are shown in Panels A and B respectively.

Panel A shows that average excess returns of portfolios sorted on relative value (ESP score) increase as the score becomes larger. Portfolios of bonds with the lowest ESP scores (ESP = 1, 2) have a negative realised average return of -0.74%/yr. In contrast, portfolios of bonds with the highest ESP scores (ESP = 9,10) have a positive average return of 3.39%/yr. Over the same period, the Bloomberg Barclays US Corporate IG index delivered an average excess return of 1.08%/yr.

Similarly, Panel B shows that average excess returns of bond portfolios sorted by equity momentum (EMC) score increase as the score becomes higher. Portfolios of bonds with the lowest EMC scores (EMC = 1, 2) have an average return of -4.25%/yr. In contrast, portfolios of bonds with the highest EMC scores (EMC = 9,10) have an average return of +4.55%/yr.

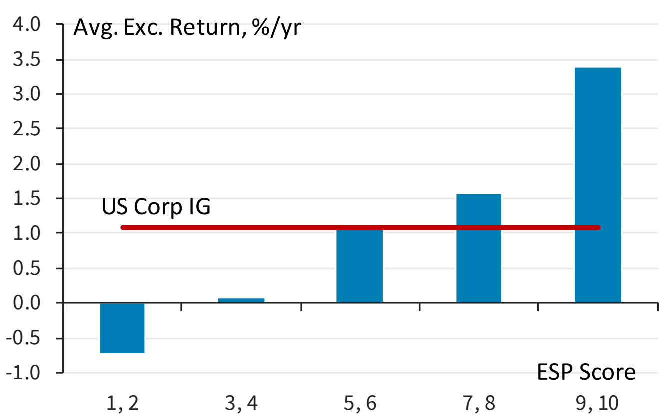
These results clearly indicate that both ESP and EMC scores can add value in bond selection: investors overweighting (underweighting) securities with high (low) scores could have outperformed the benchmark index. In addition, both scorecards can be utilized as quantitative filters to identify issues with attractive value and equity momentum characteristics in order to narrow the focus of subsequent fundamental analysis.

FIGURE 3

Average Excess Returns of Corporate Bond Portfolios Sorted on ESP and EMC Scores, March 2007 – July 2019

PANEL A

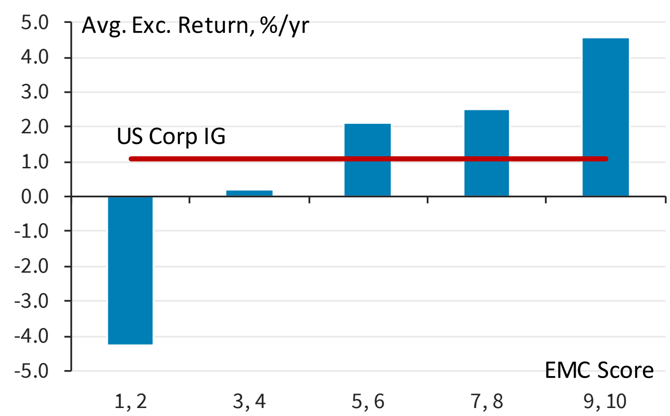
Portfolio Excess Returns by ESP Score



Source: Bloomberg, Barclays Research

PANEL B

Portfolio Excess Returns by EMC Score



Source: Bloomberg, Barclays Research

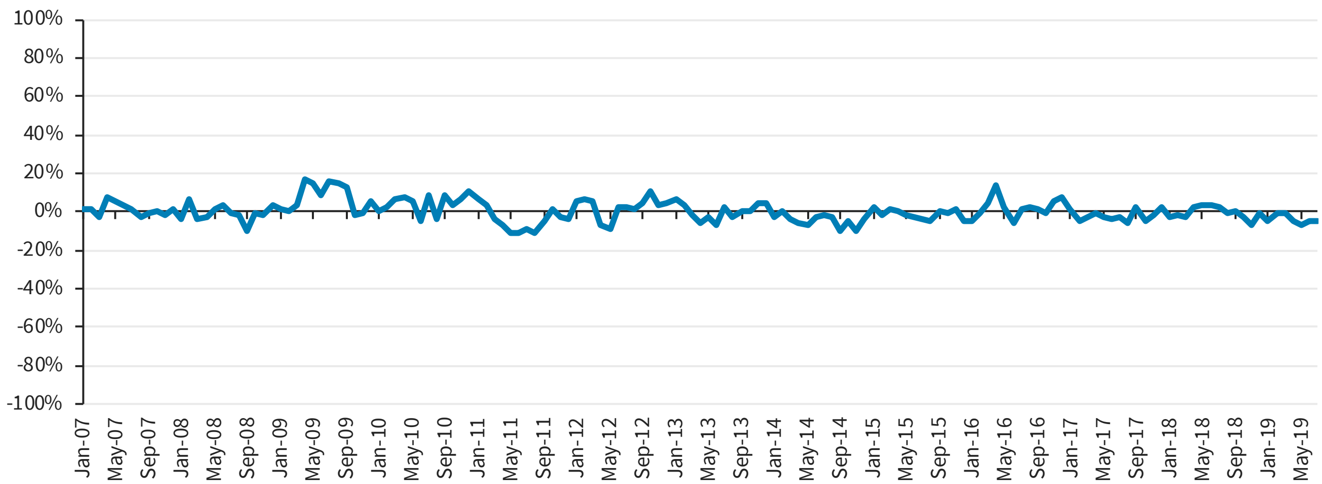
[9] In this report, all returns are *excess* returns over duration-matched treasury portfolios, as published by the index provider. Excess returns isolate the credit component of a bond return from the part associated with changes in Treasury yields. The duration exposure of a corporate bond portfolio can be managed separately using overlays of government bond futures or interest rate swaps (IRS).

While ESP and EMC scores constitute informative signals for issuer selection in isolation, their combination could be even more appealing. Indeed, ESP and EMC signals can complement each other in an investment process as shown by their low cross-sectional correlations[10] across index constituents.

Figure 4 shows that historical correlations between ESP and EMC scores remained low over time, oscillating around zero. Similar to other asset classes, value and momentum signals in credit tend to be uncorrelated.[11] Low correlations between ESP and EMC scores indicate that the signals are likely to complement each other without significantly reducing the investment opportunity set: there should always be a good chance to identify *undervalued* bonds with *strong issuer's equity momentum*. In contrast, positive correlations between ESP and EMC would mean that the signals overlap in terms of their information content, while large negative correlations would make signals mutually exclusive because investors would be forced to trade one signal for the other.

FIGURE 4

Monthly Cross-Sectional Rank Correlations Between ESP and EMC Scores



Source: Bloomberg, Barclays Research

Another way to illustrate that ESP and EMC signals tend to work well in combination, is to analyze the returns of top ESP and EMC portfolios[12] over the index during credit down-cycles. We define a credit down-cycle as a significant decline (top-to-trough) in cumulative excess returns of the US Corporate IG index in a rolling period of 12 months.

Figure 5 highlights seven such episodes associated with well-known market events: the 1998 Asian crisis, the 2001 telecom crisis, the 2008 financial crisis, the 2011 EU sovereign crisis, the 2015 energy crisis, and the market decline of 2018.

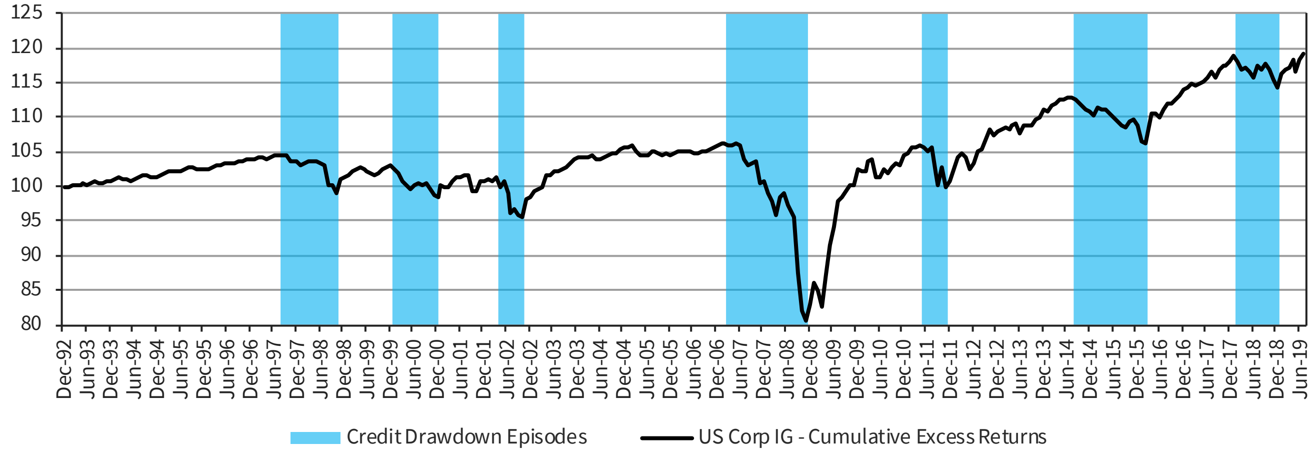
[10] We use Kendal tau rank correlation defined as the difference between concordant and discordant observation pairs normalized by the sample size. Similarly to the conventional correlation coefficient, Kendall tau varies in the range between -1 and 1.

[11] Please see , Asness, C., T. Moskowitz, and L. Pedersen *Value and Momentum Everywhere*.

[12] Top EMC and ESP score portfolios include bonds from the US Corp IG index with respective scores 9 and 10. The top ESP portfolio therefore includes top 20% of index *bonds* sorted on ESP. The top EMC portfolio includes top 20% of index *issuers* sorted on EMC.

FIGURE 5

Drawdown Episodes in Cumulative Excess Returns of the US Corporate IG Index



Source: Bloomberg, Barclays Research

Figure 6 shows the annualized returns of the index and the top scorecard portfolios during each of the market down-cycles. The first three columns report absolute average excess returns of the index and the strategy portfolios in each of the down-cycle episode. The last two columns report excess returns of the top EMC and top ESP portfolios over the index. The performance of the top ESP portfolios over the index tends to be pro-cyclical: top ESP portfolios underperformed the index in each down-cycle except for the market decline of 1998. This should not be surprising as the ESP strategy typically selects higher spread bonds in each rating-sector peer group, other things being equal. This often results in a positive net credit exposure (duration times spread, DTS[13]) relative to the index. In contrast, the relative performance of the top EMC portfolios over the index tends to be contra-cyclical as they outperformed the index in each down-cycle. The different performance of top ESP and EMC portfolios in credit down-cycles suggests that using the two signals jointly can potentially improve risk-adjusted performance.

FIGURE 6

Average Excess Returns of Top Scorecard Portfolios in Credit Down-Cycles Between January 1993 and July 2019

	Absolute			Over Index	
Down-Cycle Episodes	**US Corp**	**Top EMC**	**Top ESP**	**Top EMC**	**Top ESP**
Aug 1997 - Oct 1998	-4.2	-2.8	-3.8	1.4	0.4
Jan 2000 - Dec 2000	-4.5	-2.0	-7.0	2.5	-2.5
Apr 2002 - Oct 2002	-9.9	4.3	-19.8	14.2	-9.9
Mar 2007 - Nov 2008	-15.4	-11.6	-15.6	3.8	-0.2
May 2011 - Nov 2011	-9.9	-5.5	-12.5	4.5	-2.6
Aug 2014 - Feb 2016	-3.8	-1.6	-4.2	2.2	-0.5
Feb 2018 - Dec 2018	-4.3	-3.5	-4.4	0.8	-0.1
All Other Periods (71% of months)	***4.1***	***6.5***	***6.7***	***2.4***	***2.6***

Source: Bloomberg, Barclays Research

[13] DTS – duration times spread – is exposure to credit spreads that was introduced by Barclays Quantitative Portfolio Strategy in collaboration with Robeco in 2005, see a publically available version of the report in *DTS^{SM} (Duration Times Spread)*, The Journal of Portfolio Management, Winter 2007. DTS has been shown to track credit spread risk of corporate bond portfolios better than commonly used alternatives, see *A New Measure of Spread Exposure in Credit Portfolios*, Barclays Research , 3 February 2010.

To illustrate the benefit of jointly utilizing ESP and EMC signals, we create two additional sets of strategy portfolios. First, we build a combined portfolio by equally weighting the top ESP and EMC portfolios. Combining the two portfolios should help diversify risk and smooth the performance of the two strategies taken in isolation. Second, we build a portfolio based on a combination of the ESP and EMC signals. We calculate the equally weighted ESP-EMC score for each bond in the index universe, and then select bonds in the top quintile of the combined signal. This ensures that the strategy portfolio invests into undervalued securities issued by names with strong equity momentum.

Figure 7 reports the performance of the top ESP and top EMC portfolios, their equally-weighted combination (*Combined Portfolios 50/50*), and the portfolios based on the combined ESP-EMC signal (*Combined Signals 50/50*).

FIGURE 7

ESP and EMC Scorecards: Combining Signals Versus Combining Portfolios

	Absolute			Over US Corp Index		
Portfolios	**Avg. ExcRet, %/y**	**Volatility, %/y**	**Inf. Ratio**	**Avg. ExcRet, %/y**	**TEV, %/y**	**Inf. Ratio**
			March 2007 - July 2019			
Bloomberg Barclays US Corp IG	1.08	5.49	0.20	-	-	-
Top ESP (ESP = 9,10)	3.39	6.36	0.53	2.31	1.60	1.45
Top EMC (EMC = 9,10)	4.55	6.07	0.75	3.48	2.07	1.68
Combined Portfolios 50/50	3.97	6.13	0.65	2.89	1.51	1.92
Combined Signals 50/50	7.08	6.77	1.05	6.00	2.91	2.06
			March 2007 - December 2012			
Bloomberg Barclays US Corp IG	0.57	7.51	0.08	-	-	-
Combined Portfolios 50/50	4.81	8.31	0.58	4.24	2.02	2.10
Combined Signals 50/50	9.25	9.14	1.01	8.67	3.89	2.23
			January 2013 - July 2019			
Bloomberg Barclays US Corp IG	1.52	2.64	0.58	-	-	-
Combined Portfolios 50/50	3.23	3.08	1.05	1.70	0.67	2.54
Combined Signals 50/50	5.16	3.43	1.50	3.64	1.28	2.85

Source: Bloomberg, Barclays Research

The first three columns of Figure 7 report absolute average excess returns of US Corporate IG index and the strategy portfolios. The last three columns report the relative performance of strategy portfolios over the index.

Top ESP and EMC portfolios outperformed the index between 2007 and 2019 by 2.31%/yr and 3.48%/yr respectively. Despite higher tracking error volatility (TEV), the top EMC portfolios had a higher information ratio than the top ESP portfolios: 1.68 versus 1.45.

As expected, combining top ESP and EMC portfolios with equal weights resulted in a strategy portfolio with a lower TEV (1.51%/yr) and a higher information ratio (1.92). The strategy portfolio based on the combined signal delivered a similar information ratio (2.06) but outperformed the index by 6.00%/yr with a TEV of 2.91%/yr. The TEV of the strategy based on combined signals appears to be significantly higher than that based on combined strategies. This is because the former is significantly less diversified than the latter. Indeed, the number of bonds in a combined portfolio is by construction almost double that in a portfolio based on signal combination.

The strategy based on combining top portfolios and the one combining signals deliver similar information ratios. However, they differ in terms of return and risk. The outperformance of the combined portfolio over the index is always equal to the average outperformances of the top ESP and EMC portfolios in isolation, which limits the potential return upside of the strategy. In contrast, the strategy based on signal combination selects bonds that have attractive value and equity momentum characteristics. This boosts returns, as illustrated in Figure 7. Combining signals also has a practical advantage because strategies based on signal combination are likely to have higher returns per unit of transaction cost than strategies based on portfolio combination.

Figure 7 illustrates the benefits of combining value and momentum signals for credit selection. However, the strategies reported in Figure 7 are not practical due to high turnover and rebalancing costs. Indeed, quintile portfolios may have high turnover as rebalancing is triggered every time a bond crosses the percentile threshold. In addition, the quintile portfolios in Figure 7 might include highly illiquid bonds which were not available in the secondary market. Finally, most credit funds are designed to track a benchmark index. Therefore, broad alignment with index allocations and exposures might be required to limit portfolio TEV over the index.

In the following analysis, we explain how to integrate ESP and EMC signals into portfolio construction taking into account turnover, liquidity, transaction costs and the market structure of the underlying index.

Measuring Liquidity and Transaction Costs with Barclays Liquidity Cost Scores (LCS)

As mentioned in the introduction, measuring rebalancing costs is crucial when implementing systematic credit strategies. However, this can be a challenging task in the absence of bond-level transaction costs. Liquidity can vary across individual securities according to broad patterns. For example, recent large size issues tend to be reasonably liquid, while small seasoned issues are often illiquid and sometimes even impossible to source. In any case, detailed security-level data on liquidity is required to estimate portfolio transaction costs.

In 2009, Barclays launched a bond-level liquidity measure called Liquidity Cost Score (LCS),[14] which focuses on cost of trading, arguably one of the most important dimensions of liquidity. More specifically, LCS measures the cost of an immediate round-trip transaction of a typical institutional size and is expressed as a percentage of a bond price. LCS rely on simultaneous two-way quotes issued by Barclays traders to other market participants. Corporate bonds are quoted on either spread or price. For bonds quoted on spread, LCS is calculated as a product of bid-offer spread and spread duration. For lower quality bonds traded on price, LCS is calculated as the difference between offer and bid prices divided by the bid price.

Currently Barclays computes LCS for more than 20,000 fixed-income securities with a total amount outstanding of about $50trn, covering a very broad range of global fixed income markets.

Figure 8 summarizes the LCS coverage universe as of 31 July 2019. Historical bond-level LCS are available for constituents of the Bloomberg Barclays US Corporate IG and US Corporate HY indices since January 2007. LCS for Pan-European credit are available since May 2010.

[14] See *In Brief: Barclays Bond-Level Liquidity Measure – LCS*. A more detailed report describing LCS is available for subscribers to QPS Analytics – please see *Measuring Bond-Level Liquidity: Liquidity Cost Scores (LCS)*.

FIGURE 8

LCS Market Coverage, 31 July 2019

Bloomberg Barclays Index	Inception Date	July 2019 LCS, %
USD Credit IG	Jan-07	0.608
USD Credit HY	Jan-07	0.941
USD IG Credit 144A (no registration rights)	Jan-07	0.583
USD Treasuries	Nov-09	0.028
USD TIPS	Jul-10	0.137
USD Fixed Rate Agency MBS	Mar-10	0.084
USD Emerging Markets	Feb-12	0.601
Pan Euro Credit IG	May-10	0.427
Pan Euro Credit HY	May-10	0.954
Pan Euro Credit FRN	May-10	0.187
GBP Corporate 100-200mm Amt Outstand	May-10	1.208
Pan Euro Agencies	May-10	0.364
Pan Euro Local Authorities	May-10	0.243
Pan Euro Treasuries	Feb-11	0.097
Pan Euro Inflation Linked	Mar-11	0.201
Global Covered Bonds	Sep-12	0.218
JPY Treasuries	Sep-13	0.177

Source: Bloomberg, Barclays Research

Liquidity of the US corporate market varies a lot over time. Panel A of Figure 9 shows the evolution of the average LCS of the US Corporate IG index from 2007 to 2019. The average LCS of the corporate market overall increased from 0.4% in 2007 to 2.8% in 2008, and then declined to 0.6% in the recent period. Arguably, this large variation in market liquidity over time would make it difficult for investors to estimate historical rebalancing costs of a corporate bond portfolio.

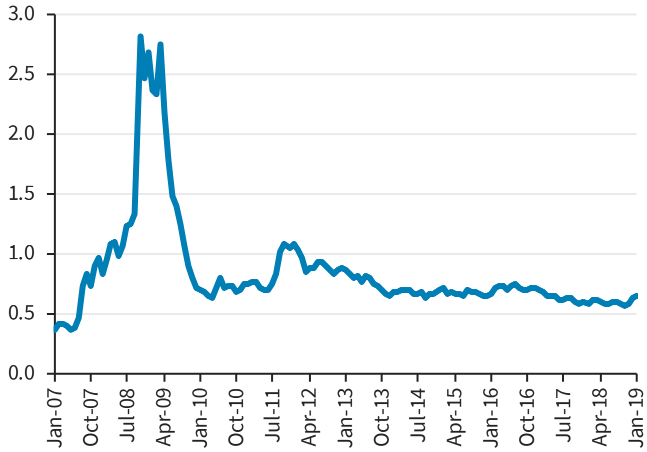
While index average LCS gives a broad indication of the evolution of market liquidity conditions over time, LCS of individual bonds also tend to vary significantly across index constituents. Panel B of Figure 9 shows distributions of bond LCS in December 2008 and December 2018. It shows significant variation of transaction costs across corporate bonds even at a given point in time. This implies that rebalancing costs of a strategy portfolio greatly depend on its composition at a given time. Accurate modeling of transaction costs can be a very difficult task without access to historical LCS data.

FIGURE 9

LCS of Corporate Bonds Over Time and in the Cross-section

PANEL A

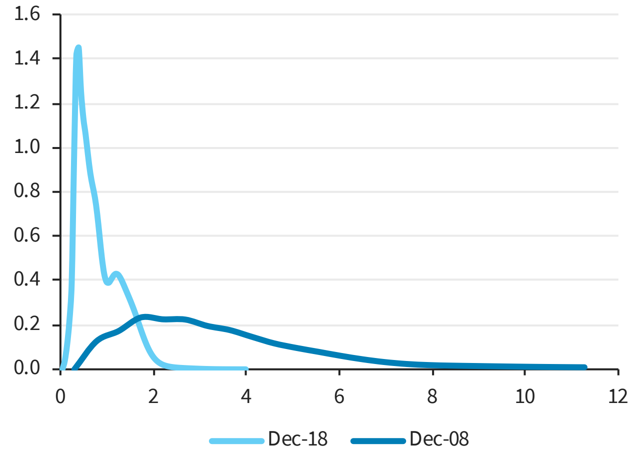
LCS of the US Corp. IG Index Over Time



Source: Bloomberg, Barclays Research

PANEL B

Distribution of LCS of Bonds in the US Corp. IG Index



Source: Barclays Research

Bond liquidity analytics provided by Barclays can also help identify corporate bonds that are actively traded at a particular point in time. It is important to avoid illiquid bonds with low trading volumes in a realistic portfolio simulation as those securities could be difficult or impossible to source.

In order to identify actively traded bonds with relatively low transaction cost, we use Trade Efficiency Scores (TES) published by Barclays alongside LCS. TES blend LCS[15] and trading volume of a bond into a single relative score that reflects both the cost and flow. Bonds with higher trading volume and lower LCS per unit of duration have lower TES. As a relative measure, TES can be used as a filter to help identify actively traded bonds available to investors at a given time and for a reasonably low bid-offer spread. Such a filter can help make a strategy portfolio more realistic and implementable in practice. Figure 10 shows cross-sectional distributions of monthly trading volumes as a percentage of amount outstanding and OASD-adjusted LCS for bonds falling into liquid (TES = 1-3) and illiquid (TES = 8-10) categories. The low TES category includes liquid, frequently traded bonds while the high TES category consists of illiquid, infrequently traded securities.

In the subsequent sections, we explain how to use TES to design realistic strategy portfolios of liquid bonds and estimate their rebalancing costs with LCS.

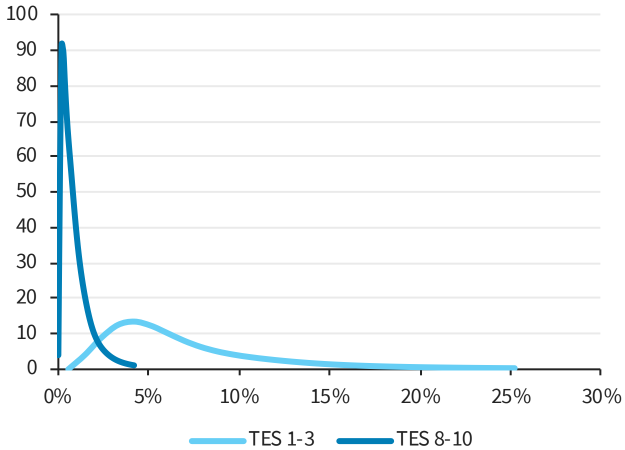
[15] In this case, LCS are adjusted for duration.

FIGURE 10

Volume and LCS Distributions of US IG Corporate Bonds, December 2018

PANEL A

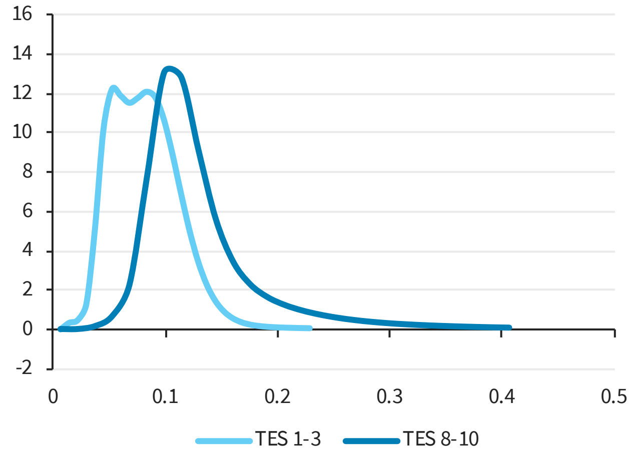
Trading Volume as % of Notional



Source: Bloomberg, Barclays Research

PANEL B

LCS per Unit of Duration



Source: Barclays Research

Strategy Portfolios with Turnover Buffers

Our early results suggest that a combination of relative value (ESP) and equity momentum (EMC) scores can be an informative signal for corporate bond selection (see Figure 7). Indeed, portfolios that include bonds with top combined score have significantly outperformed the index before transaction costs. However, the sorted portfolios used to illustrate usefulness of the signal are not practical due to high turnover and transaction costs. They can also include securities not actively traded and hence difficult to source.

A realistic strategy portfolio should control for turnover and transaction costs. One way to achieve this is to avoid trading securities with intermediate signal values. This can be done by introducing *turnover buffers*: ranges of ESP and EMC signals where bonds would not be traded in or out of the portfolio. Figure 11 illustrates example implementations of a turnover buffer for ESP and EMC scores, two dimensions in which buy and sell rules can be specified.

Panel A of Figure 11 shows a turnover buffer implemented using the combined equally weighted ESP-EMC signal. The strategy portfolio buys bonds with sufficiently strong signals, so buy candidates should have attractive relative value and equity momentum characteristics. The green area in Panel A highlights ranges of EMC and ESP scores corresponding to a buy decision. Similarly, the strategy sells bonds held in the portfolio when their combined ESP-EMC signal becomes sufficiently low. The red area highlights the region that corresponds to a sell decision. Bonds with intermediate signal values falling outside of buy and sell regions (the *turnover buffer*) are not traded but kept in the portfolio.

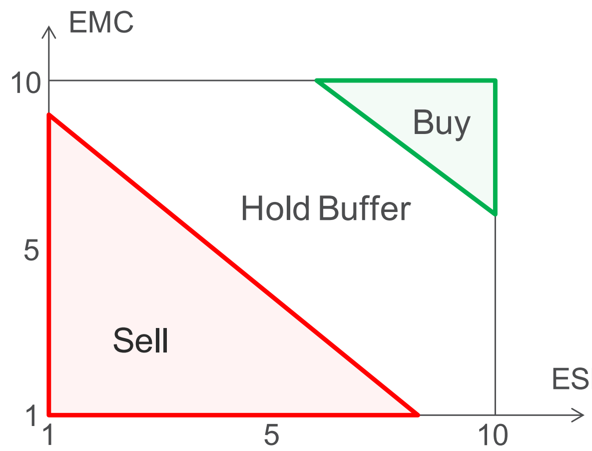
In the subsequent analysis, we use the implementation of the turnover buffer based on the combined equally-weighted ESP-EMC signal as illustrated in Panel A. However, alternative implementations that define separate buy and sell regions for ESP and EMC signals are also possible. Panel B of Figure 11 provides an illustration of this, where the primary objective of the strategy is to implement a relative value style based on ESP while the EMC signal is used as a "risk-control" mechanism to avoid issuers with too negative equity momentum (deemed "value trap" risks). The strategy buys bonds with high ESP signals as long as they don't have very low EMC scores. Bonds with too low ESP are sold from the portfolio. The green and red areas in panel B represent buy and sell regions respectively, while the remaining uncoloured area represents the turnover buffer.

FIGURE 11

Strategy Rules Designed Using Individual or Combined Scores

PANEL A

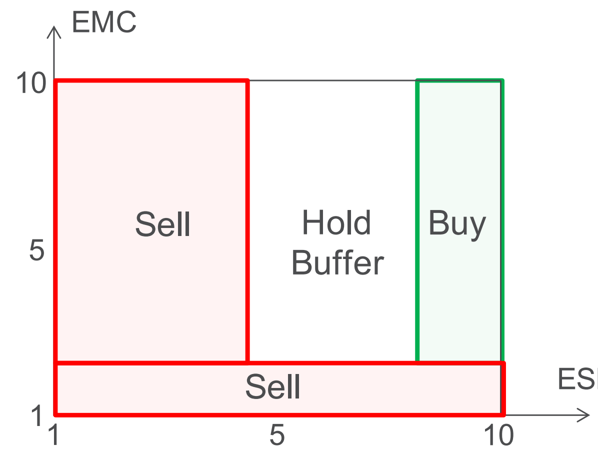
Based on Combined Scores: "Relative Value and Momentum"



Source: Bloomberg, Barclays Research

PANEL B

Based on Individual Scores: "Relative Value" Subject to Acceptable EMC Score



Source: Barclays Research

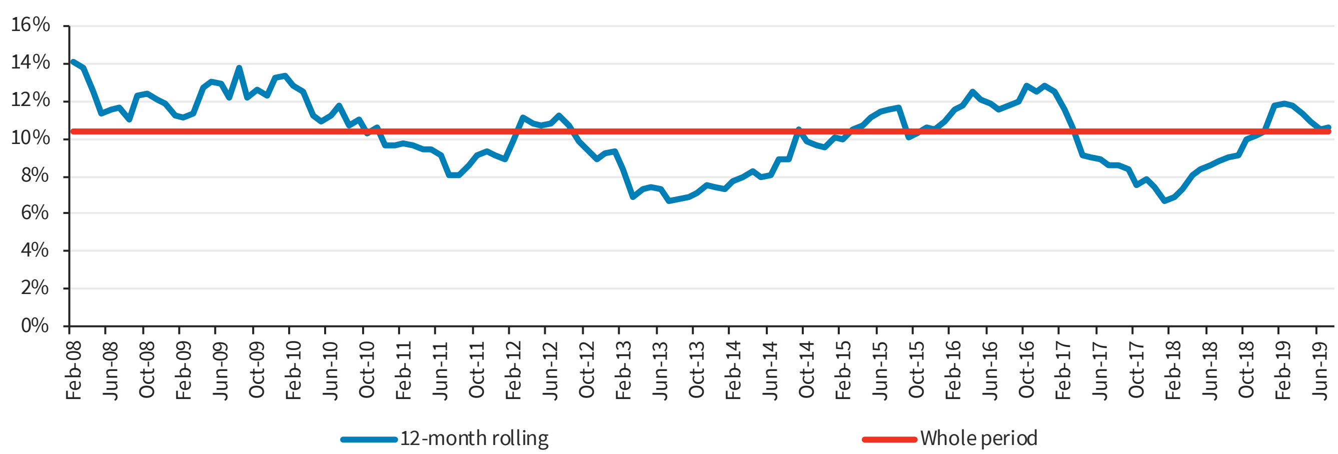
In the case study that follows, we implement strategy portfolios based on the turnover buffer for the combined signal, as illustrated in Panel A. Before this, we filter the universe of index bonds by identifying liquid actively traded securities with Trade Efficiency Scores (TES) of 3 and below. The filtered bonds should have relatively high trading volumes and low transaction costs (OASD-adjusted LCS).

From the actively traded bonds identified by the TES filter, our strategy portfolio buys bonds with the combined ESP-EMC signal in the top 20%. Positions are then kept unchanged unless the combined signal drops to or below the bottom 45%, triggering a sale. This separate implementation of buy and sell rules helps reduce portfolio turnover. Indeed, a bond added to the strategy portfolio can be kept for a number of months before its combined signal becomes sufficiently low to trigger its liquidation.

Figure 12 shows average monthly turnover of the strategy portfolio over 12-month rolling windows. Portfolio turnover varied significantly over time in the range between 7% and 14%, averaging at 10.4% for the entire period.

FIGURE 12

Average Turnover (in %/month) of the Strategy Portfolio with Turnover Buffer, 12 Months Rolling



Source: Bloomberg, Barclays Research

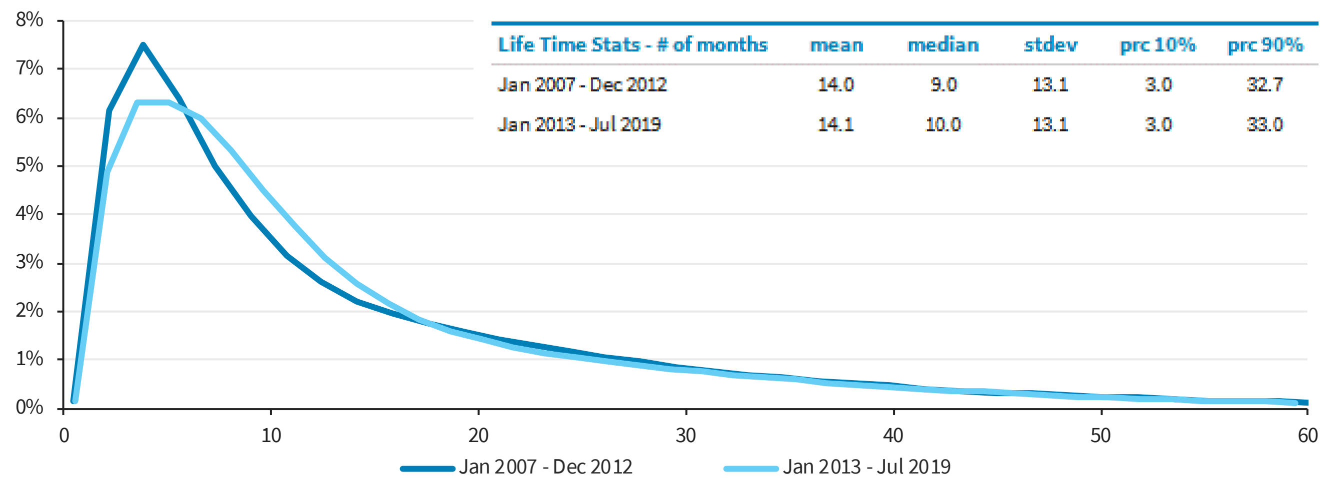
Strategy turnover cannot be controlled precisely as it is driven by the evolution of ESP and EMC signals. Relative value (ESP) scores typically change slowly because relative mispricing of corporate bonds tend to correct only gradually.[16] In contrast, equity momentum (EMC) scores can be volatile and change significantly month-on-month.

Investors frequently use a lower rebalancing frequency to reduce portfolio turnover. For example, portfolio turnover can be reduced by moving from monthly to quarterly or semi-annual rebalancing. In this approach quantitative signals are updated less frequently, leading to lower returns. Indeed, the speed of reversion of the combined ESP-EMC signal can vary across individual names. As a result, some bonds should be rebalanced faster than others. Imposing a low rebalancing frequency uniformly would prevent bonds with quickly reverting signals to be rebalanced in a timely manner, likely reducing strategy returns.

Figure 13 illustrates the variation in rebalancing speed across different bonds by plotting the distributions of time a bond spends in the strategy portfolio since its inclusion. The distributions, derived from portfolio compositions in 2007-2012 and 2013-2019, are remarkably similar. Positions are kept for 14 months on average. This is roughly consistent with the average portfolio turnover of 10.4% that we observe in the overall sample.[17] At the same time, there is a significant portion of bonds that remain in the portfolio for less than 6 months, which illustrates that imposing a uniform rebalancing frequency for all bonds in the portfolio might be suboptimal because it would prevent more frequent rebalancing required by the evolution of signals for some securities.

FIGURE 13

Distribution of Time (in Months) a Bond Spends in the Strategy Portfolio



Life Time Stats - # of months	mean	median	stdev	prc 10%	prc 90%
Jan 2007 - Dec 2012	14.0	9.0	13.1	3.0	32.7
Jan 2013 - Jul 2019	14.1	10.0	13.1	3.0	33.0

Source: Bloomberg, Barclays Research

As discussed previously, the strategy portfolio aims to buy only liquid actively traded corporate bonds by imposing a TES filter. Only bonds with TES of 3 or lower are eligible. However, while newly added bonds are liquid at the time of purchase, their liquidity tends to decline over time.[18]

[16] There are several channels for ESP scores to change over time. First, excess spreads over peers can converge, resulting in outperformance of high ESP names. This convergence would eventually occur in the absence of defaults as bond prices get pulled to par closer to maturity. Second, bonds can move to a different peer group over time as a result of a downgrade, so that the new excess spread to peers becomes low, which would typically lead to underperformance of the high ESP name. Finally, issuer fundamental characteristics can change over time, which can lead to changes in ESP scores. Given the historical performance of top ESP portfolios, convergence in relative spreads is likely to be the dominant factor affecting changes in ESP scores.

[17] An average holding period of 14 months would imply portfolio turnover of 7.14% (100%/14). However, since holding periods in a strategy portfolio vary significantly across individual bonds, the actual turnover is likely to be higher as implied by Jensen's inequality: E[100/T] ≥ 100/E[T].

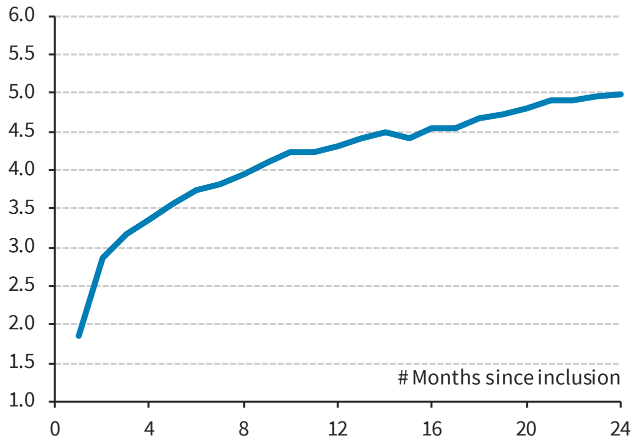
[18] See *Liquidity Dynamics of Newly Issued Bonds*, Barclays Research, 27 October 2016.

FIGURE 14

Evolution of Liquidity Characteristics of Bonds in the Strategy Portfolio over Holding Period, January 2007 – July 2019

PANEL A

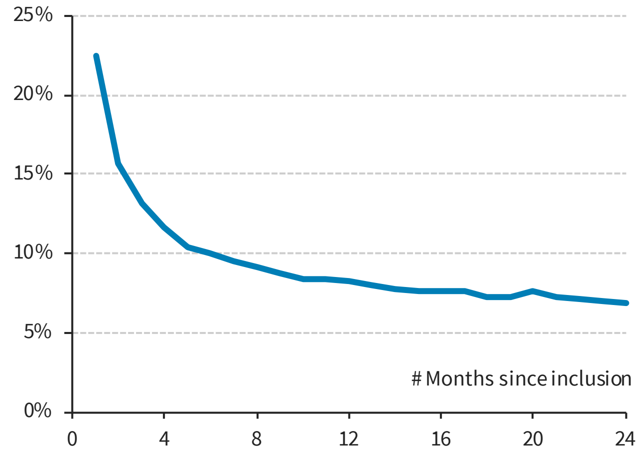
Average Trade Efficiency Score (TES)



Source: Barclays Research

PANEL B

Average Volume as % of Notional



Source: Barclays Research, TRACE

Figure 14 illustrates this by plotting the evolution of average liquidity characteristics as a function of time since inclusion. Panel A plots bonds' average trade efficiency score (TES) against the number of months passed since inclusion. The average TES gradually increases from 2 to the index average of 5 as the holding period increases. This increase in average TES occurs faster in the first few months after inclusion, and slower subsequently.

Panel B shows average monthly trading volume of portfolio bonds[19] as a function of their holding period. The average volume declines from 23% as bonds get included into the portfolio to 7% as the holding period increases to 24 months.

Using historical bond-level liquidity cost scores (LCS) as measures of transaction costs, we can quantify performance of the strategy portfolio net of rebalancing costs. Figure 15 shows the performance of the strategy portfolio *before* and *after* transaction costs. The strategy portfolio is likely to be investable, while transaction costs implied by LCS are likely to be conservative.[20]

[19] In this exercise we measure trading volume as percentage of bond's outstanding amount, so trading volumes of large and small size issues could be compared or aggregated on a fair basis.

[20] Liquidity cost scores (LCS) are based on bid-offer quotes provided by Barclays trading desks and, therefore, represent a relatively conservative measure of transaction costs. In practice, investors face competing bid-offer quotes from several broker dealers, so that effective market bid-offer spreads are usually tighter than those implied by LCS, resulting in lower costs. The ability to reduce transaction costs depends on the effectiveness of investor's execution team. Liquidity cost scores (LCS) can be used to benchmark costs incurred by an execution desk.

FIGURE 15

Performance of the Strategy Portfolio with Turnover Buffer

	Absolute			Over US Corp Index		
Portfolios	**Avg. ExcRet, %/y**	**Volatility, %/y**	**Inf. Ratio**	**Avg. ExcRet, %/y**	**TEV, %/y**	**Inf. Ratio**
			March 2007 - July 2019			
Bloomberg Barclays US Corp IG	1.08	5.49	0.20	-	-	-
Strategy w. Turn. Buffer before TC	3.74	6.10	0.61	2.66	1.48	1.80
Strategy w Turn. Buffer after TC	2.85	6.08	0.47	1.78	1.41	1.26
			March 2007 - December 2012			
Bloomberg Barclays US Corp IG	0.57	7.51	0.08	-	-	-
Strategy w. Turn. Buffer before TC	4.52	8.13	0.56	3.94	1.85	2.14
Strategy w Turn. Buffer after TC	3.37	8.10	0.42	2.79	1.75	1.59
			January 2013 - July 2019			
Bloomberg Barclays US Corp IG	1.52	2.64	0.58	-	-	-
Strategy w. Turn. Buffer before TC	3.04	3.41	0.89	1.52	0.94	1.62
Strategy w Turn. Buffer after TC	2.40	3.40	0.71	0.88	0.92	0.95

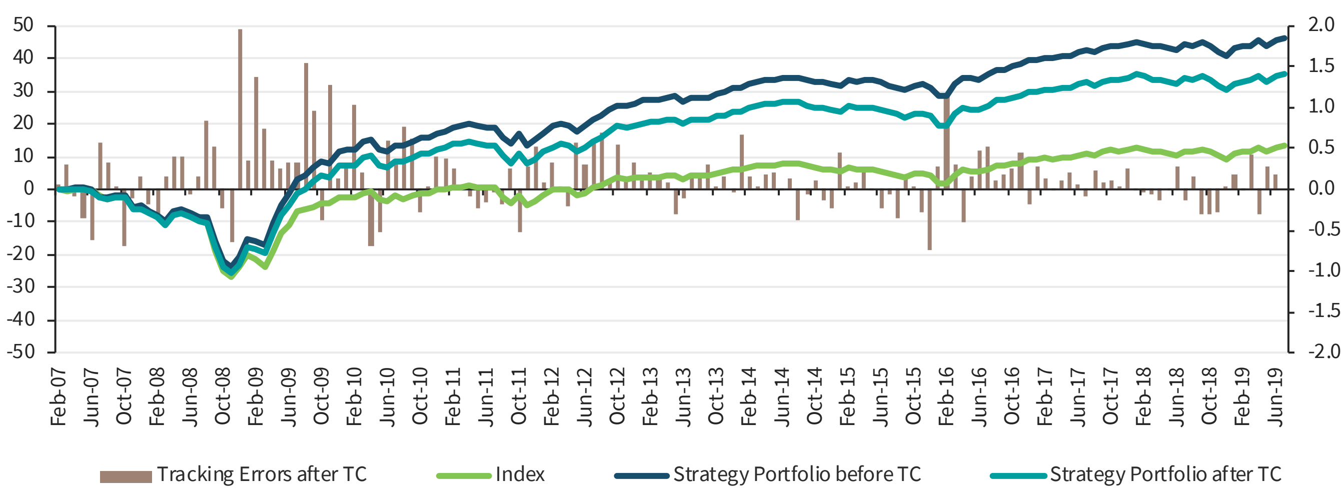
Source: Bloomberg, Barclays Research

The first three columns of the table report performance statistics of the strategy portfolio and the index in absolute terms. The last three columns report the relative performance of the strategy portfolio over the index. The strategy portfolio outperformed the index by 2.66%/yr before transaction costs between 2007 and 2019. Accounting for the rebalancing costs reduces relative returns from 2.66%/yr to 1.78%/yr, while the tracking error volatility remains virtually unchanged at 1.41%/yr. The impact of transaction costs is higher in the earlier period which includes the 2008 crisis. Indeed, portfolio relative return declines by 1.15%/yr (from 3.94%/yr to 2.79%/yr) in 2007-2012. In comparison, the drag from transaction costs in the 2013-2019 period is only 0.64%/yr.

Figure 16 plots cumulative portfolio returns before and after transaction costs alongside the index. The portfolio outperformed the index over the past decade even net of conservatively measured rebalancing costs. This suggests that a style portfolio based on value and equity momentum factors could have been successfully implemented in practice.

FIGURE 16

Cumulative Excess Returns of the Strategy Portfolio and of the US Corp. IG Index

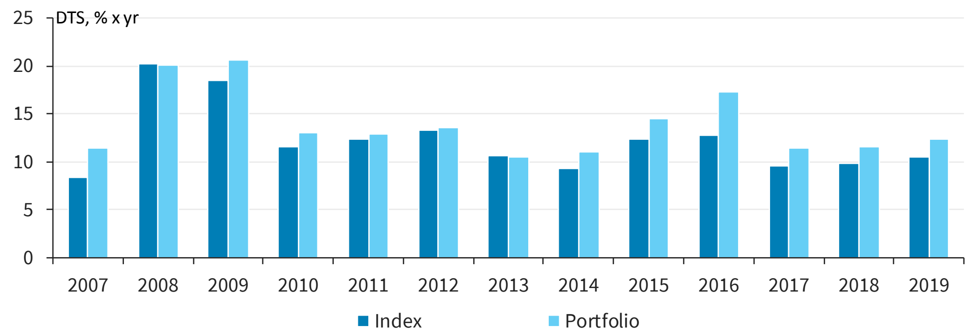


Source: Bloomberg, Barclays Research

Our portfolio performance is function of the evolution of the combined signal for each bond in the index universe. Whenever the signal is strong enough to trigger a buy order, a bond is added to the portfolio. If the signal of a portfolio bond becomes sufficiently negative, the bond is sold. In the strategy implementation via the turnover buffer, there is no explicit requirement to match index characteristics. Indeed, Figure 17 plots annual averages of the DTS[21] of the portfolio and of the index.

FIGURE 17

Average DTS Exposures of Strategy Portfolio and the US Corp. IG Index



Source: Bloomberg, Barclays Research

DTS exposures of the portfolio significantly exceed those of the index in recent years. This can lead to *unintended* systematic tracking error volatility (TEV) relative to the index. In practice, it might be desirable to avoid this and try to match index allocations and exposures explicitly.

In the next section, we introduce an alternative implementation of a strategy portfolio where we explicitly control exposures relative to the index by imposing broad allocation and exposure constraints.

Strategy Portfolios with Turnover Budgets

As shown in the previous section, a buffer based on the value taken by quantitative signals can be used to indirectly control turnover. The advantage of such an approach is that portfolio rebalancing is driven by changes in the underlying signals (a combination of ESP and EMC in our case).

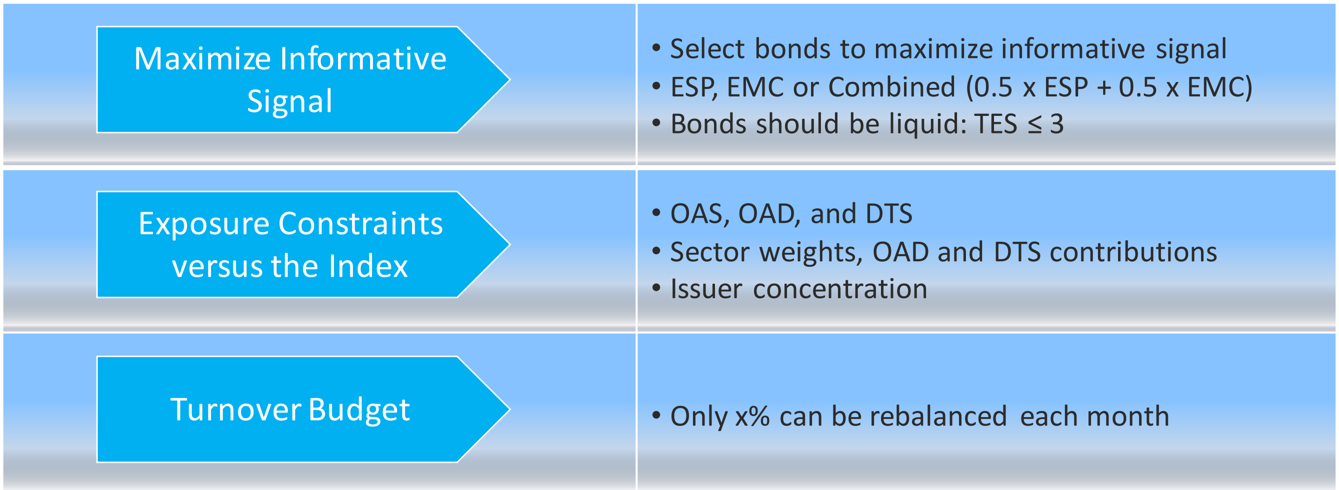
At the same time, a turnover buffer does not impose any explicit turnover constraints which leaves the possibility of large rebalancing events. For example, a large number of portfolio bonds could be sold if their combined ESP-EMC signals dropped sufficiently. Some investors might prefer to introduce a hard limit on portfolio turnover to avoid the risk of a very large rebalancing in a single month.

Another important limitation of the turnover buffer approach is that it makes it difficult to impose exposure and allocation constraints – either outright or relative to the index. As a result, a significant portion of TEV relative to the index can result from *unintended* systematic risk induced by mismatched exposures. It could be desirable to control portfolio exposures relative to the benchmark index explicitly.

To address these issues, we introduce a strategy portfolio with an explicit monthly turnover budget and exposure constraints relative to the index. As before, only sufficiently liquid bonds, with TES of 3 and below, are eligible to be included. The portfolio is built using a linear optimization programme according to the methodology outlined in Figure 18.

[21] See *DTS℠ (Duration Times Spread)*, The Journal of Portfolio Management, Winter 2007. DTS has been shown to track credit spread risk of corporate bond portfolios better than commonly used alternatives

FIGURE 18
Building a Strategy Portfolio with an Explicit Turnover Budget and Exposure Constraints Relative to the Index



Source: Barclays Research

Bonds included in a strategy portfolio are selected from index constituents subject to eligibility criteria. Bonds must be actively traded and sufficiently liquid: TES of 3 and below. In addition, the portfolio doesn't buy (but can keep) bonds with maturities below 3 years.

The bonds are selected to *maximize* an informative signal in the portfolio. In this case study, we use the combined ESP-EMC signal. Exposure and sector allocation constraints relative to the index ensure that portfolio's risk characteristics broadly match those of the index. Specifically, portfolio OAS, OAD, and DTS are required to be broadly consistent with those of the index. In addition, sector allocation and exposure constraints are used to emulate the index market structure, while issuer concentration limits make the portfolio sufficiently diversified.

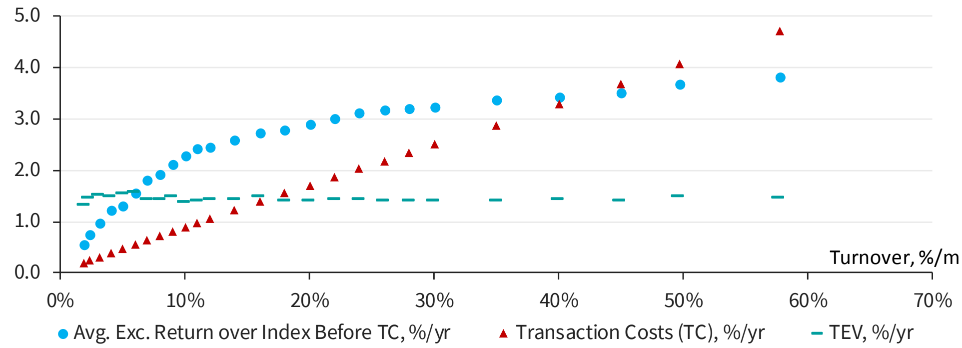
Portfolio rebalancing is controlled by an explicit *turnover budget*. This budget is defined as the maximum percentage of portfolio market value that can be rebalanced in a given month. Generally, the rebalancing process should replace bonds with the lowest signal by liquid bonds with the highest signal subject to turnover, exposure and issuer concentration constraints. Some rebalancing might also be required to ensure that portfolio allocation remains in line with that of the index as it changes over time due to new issuance, passage of time or rating migration. The turnover required to passively track the index is usually low, so it consumes only a small portion of the turnover budget.

The optimization outlined above is repeated every month to obtain a realistic dynamic allocation. We can compare different strategies by varying the *turnover budget*, while maximizing the combined ESP-EMC signal. The results for ESP and EMC signals in isolation are provided in the appendix.

Figure 19 reports the relative performance over the index alongside rebalancing costs as a function of turnover budget. Each point in the figure corresponds to a historical simulation with a given turnover budget.

FIGURE 19

Average Returns of Strategy Portfolios over the US Corp IG Index and Rebalancing Costs as a function of Turnover, March 2007 – July 2019



Source: Bloomberg, Barclays Research

Both average excess returns over the index and associated transaction costs increase as the turnover budget becomes larger. Outperformance increases faster than transaction costs for portfolios with moderate turnover but the increase in transaction costs outpaces the increase in returns for high turnover budgets.

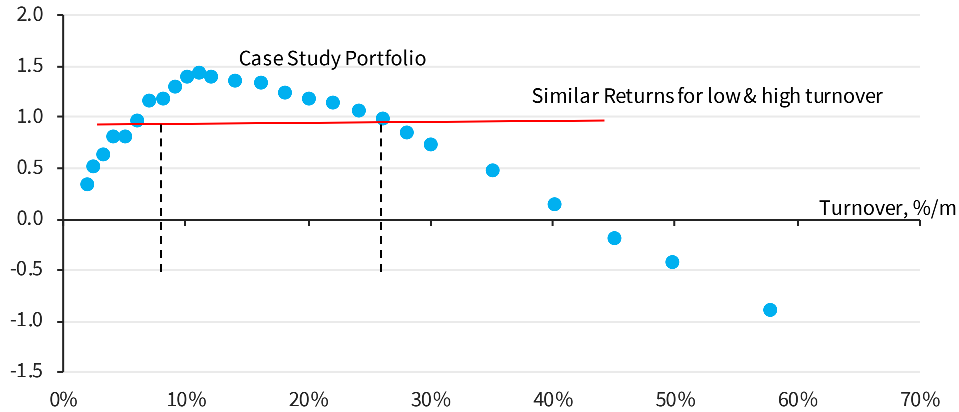
Figure 19 also shows annualised tracking error volatilities (TEV) of strategy portfolios over the index. TEV does not seem to vary significantly with turnover because all strategy portfolios remain subject to the same exposure and issuer concentration constraints irrespective of variations in turnover limits.

The transaction costs plotted in Figure 19 can be subtracted from returns to get portfolio average excess returns over the index *after* transaction costs. Figure 20 shows portfolio net performance over the index against turnover. Portfolio net returns remain low for small turnover budgets because signals cannot be fully implemented. The outperformance increases and reaches a peak for moderate turnover budgets. It then declines as turnover budget becomes so high that associated transaction costs outweigh the benefits of a more aggressive implementation of the strategy.

Figure 20 shows that *two* strategy portfolios with *low* and *high* turnover budget achieve the same net performance over the index. From a practical perspective, it is prudent for a portfolio manager to implement portfolios with the lower turnover budget.

FIGURE 20

Average Excess Returns of Strategy Portfolios over the US Corp. IG Index After Transaction Costs as a Function of Turnover, March 2007 – July 2019



Source: Bloomberg, Barclays Research

For the purpose of our analysis we chose (with hindsight) a strategy portfolio with 11% turnover budget and report its performance in Figure 21.[22] The first three columns show absolute performance statistics of the portfolio and of the index. The last three columns report the relative performance of the strategy portfolio over the index.

The average portfolio return between 2007 and 2019 was 3.49%/yr, significantly higher than the average return of the index: 1.08%/yr. Transaction costs reduced portfolio average return by almost 1%/yr to 2.52%/yr which is still significantly higher than that of the index.

FIGURE 21

Performance of Strategy Portfolio with 11% Turnover Budget

Portfolios	Absolute			Over US Corp Index		
	Avg. ExcRet, %/y	Volatility, %/y	Inf. Ratio	Avg. ExcRet, %/y	TEV, %/y	Inf. Ratio
			March 2007 - July 2019			
Bloomberg Barclays US Corp IG	1.08	5.49	0.20	-	-	-
Strategy Portfolio *before* TC	3.49	5.17	0.68	2.41	1.41	1.72
Strategy Portfolio *after* TC	2.52	5.16	0.49	1.45	1.38	1.05
			March 2007 - December 2012			
Bloomberg Barclays US Corp IG	0.57	7.51	0.08	-	-	-
Strategy Portfolio *before* TC	3.89	6.98	0.56	3.32	1.93	1.72
Strategy Portfolio *after* TC	2.69	6.98	0.39	2.12	1.90	1.12
			January 2013 - July 2019			
Bloomberg Barclays US Corp IG	1.52	2.64	0.58	-	-	-
Strategy Portfolio *before* TC	3.14	2.67	1.17	1.61	0.57	2.81
Strategy Portfolio *after* TC	2.37	2.67	0.89	0.85	0.57	1.50

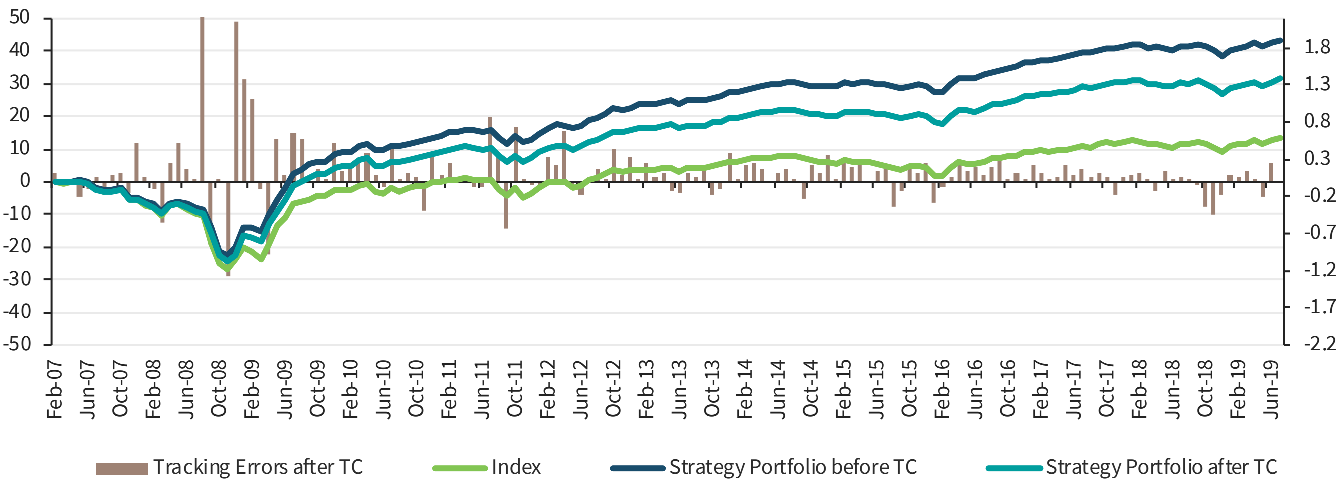
Source: Bloomberg, Barclays Research

[22] Turnover budget of 11% is also comparable to the average turnover of 10.4% achieved by the strategy portfolio with the turnover buffer in the previous section.

After transaction costs, the information ratio was 1.05. The outperformance was stronger in 2007-2012 than in 2013-2019: 2.12%/yr versus 0.85%/yr with respective information ratios of 1.12 and 1.50. Figure 22 shows that the strategy portfolio with a turnover budget of 11% persistently outperformed the index after rebalancing costs. Portfolio tracking errors and transaction costs were high in the 2008 crisis, but declined considerably in the subsequent period as the market stabilized.

FIGURE 22

Cumulative Excess Returns of the Strategy Portfolio with 11% Turnover Budget

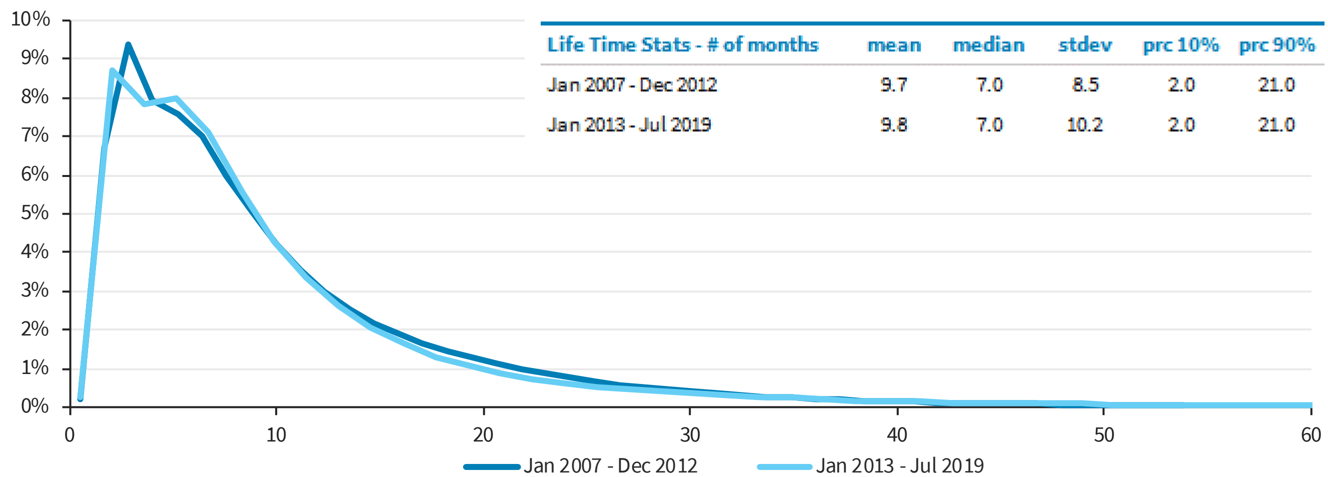


Source: Bloomberg, Barclays Research

As in the case of the strategy portfolio with a turnover buffer, we can analyse portfolio dynamics, including the distribution of bond lifetime in the portfolio, as reported in Figure 23. The average time a bond spends in the portfolio is 9.8 months, which is roughly consistent with the turnover budget of 11%.

FIGURE 23

Distribution of Time (in Months) a Bond Spends in the Strategy Portfolio



Life Time Stats - # of months	mean	median	stdev	prc 10%	prc 90%
Jan 2007 - Dec 2012	9.7	7.0	8.5	2.0	21.0
Jan 2013 - Jul 2019	9.8	7.0	10.2	2.0	21.0

Source: Bloomberg, Barclays Research

A significant portion of bonds remains in the strategy portfolio for more than 6 months. On the other hand, some bonds leave the portfolio relatively quickly. The average time spent in the portfolio is a function of the chosen turnover budget and of signal mean-reversion. The latter can vary greatly across individual bonds

We can finally compare the performance of our strategy portfolio with turnover budget with that of the portfolio using turnover buffer. Figure 24 summarises the performance statistics of the two portfolios after transaction costs.

FIGURE 24

Performance of Strategy Portfolios with Turnover Buffer and Turnover Budget

	Absolute			Over US Corp Index		
Portfolios	Avg. ExcRet, %/y	Volatility, %/y	Inf. Ratio	Avg. ExcRet, %/y	TEV, %/y	Inf. Ratio
			March 2007 - July 2019			
Bloomberg Barclays US Corp IG	1.08	5.49	0.20	-	-	-
Strategy w. Turn. Budget after TC	2.52	5.16	0.49	1.45	1.38	1.05
Strategy w Turn. Buffer after TC	2.85	6.08	0.47	1.78	1.41	1.26
			March 2007 - December 2012			
Bloomberg Barclays US Corp IG	0.57	7.51	0.08	-	-	-
Strategy w. Turn. Budget after TC	2.69	6.98	0.39	2.12	1.90	1.12
Strategy w Turn. Buffer after TC	3.37	8.10	0.42	2.79	1.75	1.59
			January 2013 - July 2019			
Bloomberg Barclays US Corp IG	1.52	2.64	0.58	-	-	-
Strategy w. Turn. Budget after TC	2.37	2.67	0.89	0.85	0.57	1.50
Strategy w Turn. Buffer after TC	2.40	3.40	0.71	0.88	0.92	0.95

Source: Bloomberg, Barclays Research

The two portfolios achieved qualitatively comparable results, outperforming the index by respectively 1.45%/yr and 1.78%/yr after transaction costs with information ratios above 1. The portfolio with the turnover budget underperformed the portfolio with the buffer by 0.67%/yr in 2007-2012. In the second sub-period, 2013-2019, the average returns of the two portfolios were similar.

Although average portfolio turnovers of the two implementations are close (10.4% and 11%), the two approaches are materially different. First, the turnover of the strategy portfolio based on the turnover buffer is dynamic and is driven by the evolution of the underlying signals. The portfolio is likely to rebalance more in periods of large changes in the combined signal and less in periods of small changes. In contrast, the turnover of the portfolio with the turnover budget is constant over time, so that the portfolio is likely to be less opportunistic in volatile periods. This explains the relatively weak performance of the turnover budget portfolio in 2008-2009. Second, the portfolio with the turnover budget is subject to exposure constraints relative to the index. These constraints can also be costly in terms of performance because they limit the scope for opportunistic rebalancing across sectors. In *Corporate Sector Timing Using Equity Momentum*, we showed that a significant part of added value of the EMC signal comes from timing sector allocation.

Conclusion

We find that systematic strategies that utilize relative value and equity momentum styles can be practically implemented in credit portfolios but this requires addressing several challenges.

First, transaction costs in credit are high, so a turnover control mechanism is required. Second, liquidity of corporate bonds can vary substantially over time and across individual issues. A practical strategy should focus on bonds that are actively traded in the market. Finally, credit portfolios usually refer to a benchmark index. This means that the primary objective of implementing informative signals should be balanced against the need to follow the benchmark index allocation and overall risk exposures.

We explain how to address these challenges through realistic case studies that leverage on two Barclays datasets: quantitative scorecards for selecting securities based on relative value (ESP) and equity momentum (EMC) signals; and Barclays liquidity analytics – Liquidity Cost Scores (LCS) and Trade Efficiency Scores (TES).

We explain how to build practical strategy portfolios while controlling turnover and investing in liquid, actively traded bonds, with positions rebalanced according to quantitative signals updated every month. The strategy portfolios are constructed using two separate approaches illustrated in two case studies.

The first approach utilises a turnover buffer that avoids trading bonds with intermediate signal levels. Consequently, individual bond positions result from separate buy and sell decisions based on a combined ESP-EMC signal. Rebalancing volume changes over time based on signal dynamics.

The second methodology uses an explicit turnover budget to avoid excessive rebalancing and sets exposure constraints relative the index to control tracking error risk. The rebalancing volumes in this implementation are exogenous and remain constant over time.

We use the two approaches to simulate strategy portfolios historically and report performances over time *net* of conservatively measured transaction costs.

We find that realistic portfolio strategies, based on ESP and EMC scores and implemented with liquid securities, significantly outperformed the benchmark index *after* transaction costs, with information ratios above 1 since 2007. In the absence of a long track record of actual portfolio returns, our portfolio simulations support the case for a systematic investment style in credit markets.

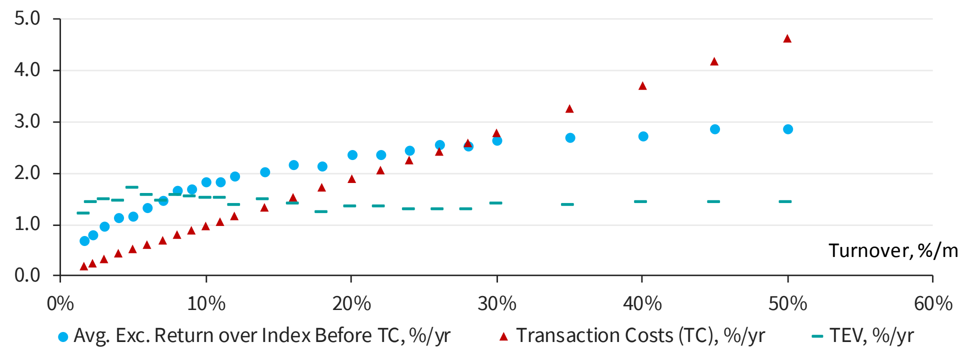
Appendix – Strategy Portfolios Based on ESP and EMC Signals in Isolation

We implement strategy portfolios with turnover budget for EMC and ESP signals in isolation. All other constraints and portfolio construction rules, including the liquidity filter, remain the same as in the case of the implementation based on the combined signal.

Figure 25 shows average excess returns over the index of portfolios based on the EMC signal as a function of the turnover budget. The outperformance is reported before transaction costs, shown separately.

FIGURE 25

Average Excess Returns of EMC-Based Portfolios over the US Corp IG Index and Transaction Costs as a Function Turnover, March 2007 – July 2019



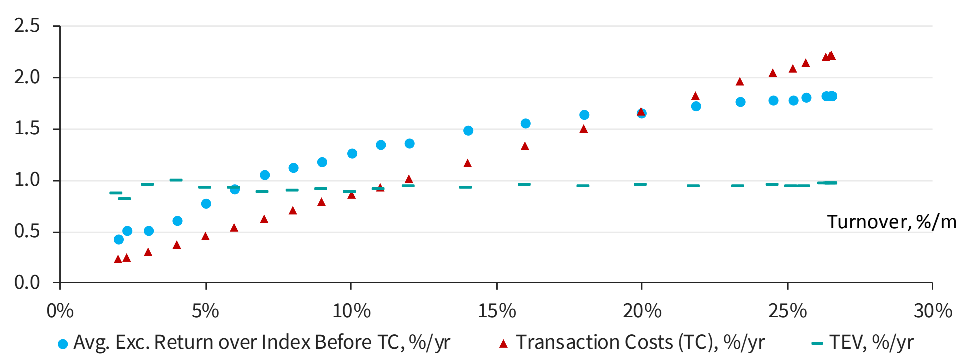
Source: Bloomberg, Barclays Research

We find that for a wide range of turnover budgets, EMC-based portfolios outperform the index net of conservatively measured transaction costs. However, the achievable net returns are significantly smaller than those of the strategy based on the combined signal discussed in the main text.

Figure 26 shows similar average excess returns over the index of portfolios based on the ESP signal as a function of the turnover budget. The outperformance is reported *before* transaction costs.

FIGURE 26

Average Excess Returns of ESP-Based Strategy Portfolios over the US Corp IG Index and Transaction Costs as a Function Turnover, March 2007 – July 2019



Source: Bloomberg, Barclays Research

Figure 27 reports the performance of the strategy portfolios with a turnover budget of 11%. The figure shows the performance of portfolios based on isolated and combined ESP and EMC signals *after* transaction costs. Portfolios based on isolated signals have lower average returns than that the strategy portfolio based on the equally-weighted combination of the two signals.

FIGURE 27

Performance of Strategy Portfolios with 11% Turnover Buffer *after* Transaction Costs

Portfolios	Absolute			Over US Corp Index		
	Avg. ExcRet %/y	Volatility %/y	Inf. Ratio	Avg. ExcRet %/y	TEV, %/y	Inf. Ratio
			March 2007 - July 2019			
US Corp IG Index	1.08	5.49	0.20	-	-	-
EMC w. Turn Budget after TC	1.83	5.12	0.36	0.75	1.50	0.50
ESP w. Turn Budget after TC	1.50	5.69	0.26	0.42	0.90	0.46
Combined w. Turn Budget after TC	2.52	5.16	0.49	1.45	1.38	1.05
			March 2007 - December 2012			
US Corp IG Index	0.57	7.51	0.08	-	-	-
EMC w. Turn Budget after TC	1.75	6.84	0.26	1.18	2.12	0.56
ESP w. Turn Budget after TC	0.90	7.81	0.11	0.32	1.19	0.27
Combined w. Turn Budget after TC	2.69	6.98	0.39	2.12	1.90	1.12
			January 2013 - July 2019			
US Corp IG Index	1.52	2.64	0.58	-	-	-
EMC w. Turn Budget after TC	1.90	2.83	0.67	0.37	0.49	0.76
ESP w. Turn Budget after TC	2.03	2.65	0.76	0.50	0.53	0.94
Combined w. Turn Budget after TC	2.37	2.67	0.89	0.85	0.57	1.50

Source: Bloomberg, Barclays Research

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