J.P.Morgan

North America Fixed Income Strategy
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Automating asset allocation in fixed income

Incorporating machine learning into active management of investment-grade bond portfolios

- We introduce an automated asset allocation framework for investment-grade fixed income utilizing machine learning techniques
- We train classifiers to forecast the probability that corporates, MBS, and hard currency EM (corporates and sovereigns) outperform Treasuries
- These estimates are used to size recommended deviations from market weight (subject to a limit) for each asset class, with Treasuries as the residual
- We test the performance of this automated portfolio versus market weight allocations over a cross-validation (2000-15) and quarantine period (2016-18)
- The results show highly statistically-significant and consistent outperformance using automated weights
- We will be providing analytics based on the output of this asset allocation model, which will be updated daily on J.P. Morgan Markets.

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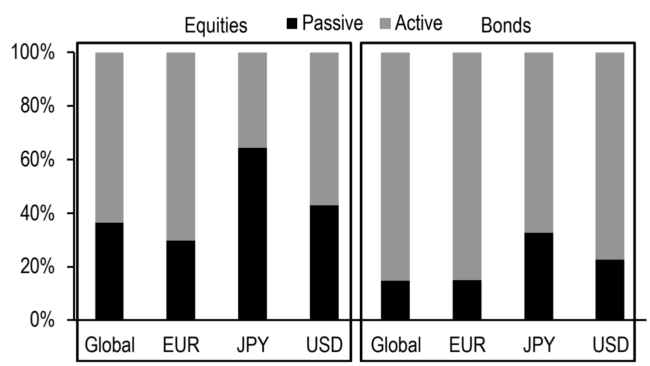
Automating asset allocation in investment-grade fixed income with machine learning

Rather than generating short-term trading signals, as has been our practice to date[1], we can alternatively incorporate machine learning techniques into asset allocation. To be more specific, we can interpret model projections, not as a buy/sell signal, but rather as a bias to be incorporated into diversified investment pools. In other words, we seek to deploy much of the same infrastructure developed in previous work to automate the process of active portfolio management. Our colleagues have done so very broadly across asset classes (see *Can Machine Learning help with Tactical Asset Allocation*, M. Inkinen et al., 11/1/18). **In this piece, we focus on the specific case of actively-managed portfolios of investment-grade fixed income in the U.S**.

Exhibit 1: Despite the rise of passive investing, the majority of assets as actively managed, particularly in fixed income

Fraction of funds adopting active versus passive strategies split into equities and bonds as well as by region



Note: Data taken from *The implications of passive investing for securities markets*, V. Sushko & G. Turner, BIS Quarterly Review, March 2018.

Source: J.P. Morgan, BIS

Exhibit 2: Classifiers for each asset class are trained on a number of features selected through a combination of domain knowledge and empirical testing …

Feature set for classifiers by asset class

Asset Class			
Corporates	MBS	EM corps	EM sovs
Yield	Corp yield	Yield to worst	Yield to worst
Spread to Tsy	Corp sprd	Spread to worst (vs Tsy)	Spread to worst (vs Tsy)
3M S&P 500 returns	MBS hedge-adj carry	Sprd vs high-grade corps	Sprd vs high-grade corps
1Y S&P 500 returns	Opt-adj convexity	1Yx1Y vs 1Y OIS crv	1Yx1Y vs 1Y OIS crv
VIX	Opt-adj spread (to Tsy)	Fed B/S size	3M chg in Fed B/S size
1Yx1Y/1Y OIS crv	Opt-adj duration	3M net supply	VIX
DB pension funded ratio	3Mx10Y swpn vol	Avg Credit quality	3M net supply
VA liability durations	10Yx10Y swpn vol	A/BBB spread crv	Avg Credit quality
Fed B/S size	3M net supply	USD NEER	EM EASI level
3M net supply	3M CPR	EM EASI Index	EM FX idx (EMCI) level
Financials/Non-fin ratio	1Yx1Y vs 1Y OIS crv	3M EM FX % chg	3M EM FX % chg
Avg credit quality	Fed B/S size	EM FX vol (VXY idx)	EM FX vol (VXY idx)
A/BBB spread crv	2s/10s Tsy crv	10Y Tsy yield	10Y ACM term premium
10Y term premium	10Y swap spread	2s/10s Tsy crv	10Y Tsy yield
2s/10s Tsy crv		3Mx10Y swpn vol	2s/10s Tsy crv
MBS hedge-adj carry			
MBS opt-adj sprd			
U.S. EASI Index			

Source: J.P. Morgan

We see two different but complementary applications of this experiment. The first, and most intuitive, usage would be determining the asset allocation itself. The second would be to infer positioning biases among active bond funds, under the assumption "human" managers will—in aggregate at least—react similarly to machines in response to changes in market observables. **Though much ink has been spilled on the rise of passive strategies, most assets are still managed actively**. This is particularly true of fixed income, both in the U.S. and across a range of jurisdictions (**Exhibit 1**). **As such, a well-calibrated asset allocation model could provide valuable advance indication of rising risks of reallocation flows owing to these shifts**.

[1] For details, see *Do Androids dream of electric bonds?*, M. Salem et al., 11/22/17; *TradeRunner*, M. Salem et al., 8/16/18; *#SquadGoals*, M. Salem et al., 9/21/18; *Where's the beef?* J. Younger et al., 1/25/19.

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Building an automated asset allocator

We begin by identifying the bond index to be used as our benchmark. For this purposes we use the U.S. subcomponent of the legacy Global Aggregate Bond Index (GABI), which covers the major U.S. fixed income asset classes: Treasuries, TIPS, Agency debentures, agency MBS, high-grade corporates, and hard currency emerging markets (both corporate and sovereign issuers).

We then construct classifier models for each asset class excluding Treasuries, seeking to project their relative performance (i.e., spread to Treasuries) over a typical rebalancing period (in this case, one month). **These models takes as input a limited number of drivers, drawn from an initial list generated by domain knowledge and pruned to leave only those features which clearly contain useful information**. The final lists for each asset class are summarized in **Exhibit 2**.

Exhibit 3: … which produce statistically significant projections from which we select our favorite classifier from a test/train split over the cross-validation period and confirm its performance in quarantine

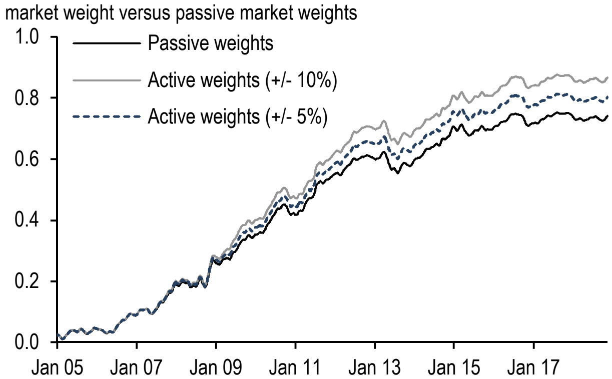
Classifier technique along with area under curve (AUC) and hit rate statistics for each asset class

		Cross Validation (2000/02-15)		Quarantine (2016-18)	
Asset class	Technique	AUC	Hit Rate	AUC	Hit Rate
HG corps	RF stacking	0.65	60%	0.60	60%
MBS	SVM stacking	0.59	57%	0.64	55%
EM sovs	LG stacking	0.56	56%	0.63	61%
EM corps	LG stacking	0.63	60%	0.64	57%

Source: J.P. Morgan

Exhibit 4: Automated monthly asset allocation decisions using model-based projections of the likelihood of over/underperformance have produced significantly better returns than passive weights

Cumulative returns for active management using two maximum deviations from market weight versus passive market weights



Note: Active weights are rebalanced monthly using the probability of outperformance estimated using our favorite classifiers, which were selected using a hyperparameter search and based on their performance during the cross-validation period (2000-16). The model specifications were then held fixed in the quarantine period (2016-18). Past performance is not indicative of future returns.

Source: J.P. Morgan

To train and select our models, we follow our now familiar approach to hyperparameter optimization. First, we split historical data into cross-validation and quarantine periods, in this case 2000-16 for the former and 2016-18 for the latter. We then consider a wide range of techniques (e.g., SVM, random forest, gradient boosting, stacking classifiers) and specifications, performing a time-based test/train split over the cross-validation period. Only once we settle on a model do we consider its performance in the quarantine period, hoping to find consistency over various measures. Finally, in both cases, we test the statistical significance of our results using a Monte Carlo simulation. **The results of this process for each asset class are summarized in Exhibit 3, and although we do not show it explicitly, we note that each model is highly (>99%) statistically significant**.

The question remains, however, how to use these classifiers to construct and rebalance an automated actively-managed bond portfolio. **To do so we start with the probability of outperformance produced by each of these models**. If we further assume a fixed maximum deviation from market weight, **we can use this probability to size the deviation from market weight for each asset class**. To use

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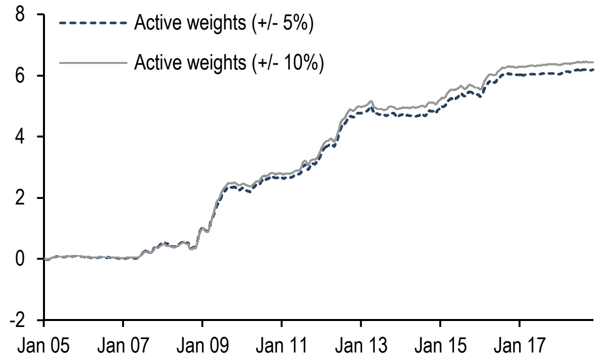
a concrete example, if our high-grade corporate spread model returns a 60% probability of outperformance versus Treasuries, then we would size our allocation to 20% of the maximum overweight; if that probability were 40%, we would size it to 20% of the maximum underweight. This is repeated for each asset class, and we treat Treasuries as a residual, allocating any unused funds. This process is repeated monthly.

The results are summarized in **Exhibit 4**, which show the relative performance of this approach to a passive, market value-weighted index of the same constituents. **The cumulative returns clearly favor active management, with larger caps on dynamic allocations (i.e., 10% versus 5% maximum deviation from market weight) showing better results**. In **Exhibit 5**, we also see that this outperformance is relatively clustered, with relatively short periods of time accounting for much of the deviations between active and passively managed simulated portfolios.

Exhibit 5: The outperformance of automated active weights is somewhat clustered over relatively short periods of time

Cumulative returns for active management using two maximum deviations from market weight minus cumulative returns for passive market weights



Source: J.P. Morgan. Note: Past performance is not indicative of future returns.

Exhibit 6: The outperformance of our automated active strategy are highly statistically significant

Annualized returns for cross-validation and quarantine results and automated active weights (5% and 10% max deviation) versus market weights, along with the results of a Monte Carlo simulation with 10,000 iterations

		Cross-validation (2004-15)	Quarantine (2016-19)
Ann. Return	Market Weight	4.81%	2.20%
	Active (+/-5%)	5.09%	2.59%
	Active (+/-10%)	5.38%	2.99%
Excess Return	Active (+/-5%)	0.28%	0.39%
	Active (+/-10%)	0.57%	0.79%
Significance Threshold	Median	4.90%	2.38%
	95th pct	4.96%	2.46%
	99th pct	4.98%	2.50%
	99.99 pct	5.04%	2.59%

Source: J.P. Morgan. Note: Past performance is not indicative of future returns.

Finally, we once again ask the question: are these results statistically significant? **To be sure, we have only performed hyperparemeter optimizations on each model individually, and have not considered every possible combination of input model specifications**. This significantly reduces the likelihood we have arrived at this results by luck. That said, it is not particularly computationally intensive to validate this intuition via another Monte Carlo simulation. We therefore consider 10,000 sets for random weights (subject to the same maximum deviation from market value; see **Exhibit 6**). **The results show that our 60-80 bp annualized excess returns are well above any generated via this randomized approach, and therefore highly statistically significant**.

Finally, we would be remiss not to dissect the results of the automated active strategy a bit more. **In Exhibit 7, we summarize the automated weights relative to market value, and find a long-run bias toward spread narrowers, specifically in high-grade and MBS**. This is reflected not only in the higher frequency of overweights in risky assets, but also the larger magnitude of these deviations from market weights (and *vice versa* in Treasuries). **It is also interesting to note that despite the fact that each asset class utilized an independently trained and**

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optimized classifier, the aggregate model recovered the longer-run counter-directionality of spreads with the level of rates (Exhibit 8). These correlations are also notably higher in recent years.

Exhibit 7: Automated asset allocations have covered a relatively wide range of over- and underweights, with a longer-run bias toward spread narrowing positions …

Statistics of automated active weights by asset class in cross-validation and quarantine

		HG corps		MBS		EM sovereigns		EM corps		Treasuries	
	Attribute	+/-5%	+/-10%	+/-5%	+/-10%	+/-5%	+/-10%	+/-5%	+/-10%	+/-5%	+/-10%
Cross-Validation	Freq of overweight	65%		78%		45%		43%		34%	
	Freq of underweight	35%		22%		55%		57%		66%	
	Avg weight	0.9%	1.9%	2.1%	4.3%	-0.3%	-1.1%	-0.4%	-0.8%	-2.4%	-4.2%
	Avg overweight	3.4%	6.8%	3.2%	6.5%	1.4%	1.7%	0.4%	0.6%	4.8%	9.7%
	Avg underweight	-2.0%	-3.9%	-0.5%	-1.0%	-2.1%	-4.2%	-1.3%	-2.6%	-11.9%	-21.8%
Quarantine	Freq of overweight	48%		68%		26%		60%		41%	
	Freq of underweight	52%		30%		74%		40%		58%	
	Avg weight	0.2%	0.3%	0.9%	1.9%	-1.4%	-3.0%	0.1%	-0.4%	0.1%	1.2%
	Avg overweight	3.3%	6.7%	2.5%	4.9%	1.5%	1.8%	1.2%	1.3%	8.0%	16.1%
	Avg underweight	-3.0%	-6.0%	-1.1%	-2.2%	-6.7%	-13.3%	-0.9%	-1.9%	-7.7%	-13.2%

Source: J.P. Morgan

Exhibit 8: … and these allocations roughly recover the negative correlation bewteen risky asset spreads and interest rates, with overall levels of correlation somewhat higher during the quarantine period

Correlation of deviation from market weight by asset class and period

	Cross-Validation (2004-16)					Quarantine (2016-18)				
Asset Class	HG Corps	MBS	EM corps	EM sovs	Tsy	HG Corps	MBS	EM corps	EM sovs	Tsy
HG Corps	100%	37%	33%	16%	-85%	100%	68%	54%	45%	-89%
MBS	37%	100%	33%	8%	-71%	68%	100%	53%	47%	-86%
EM corps	33%	33%	100%	34%	-56%	54%	53%	100%	67%	-75%
EM sovs	16%	8%	34%	100%	-43%	45%	47%	67%	100%	-71%
Treasuries	-85%	-71%	-56%	-43%	100%	-89%	-86%	-75%	-71%	100%

Source: J.P. Morgan

Conclusion

We outline our framework for deploying machine learning infrastructure to automate asset allocation decision within investment-grade fixed income. To start, we select the optimal model for each asset class in spread product using a variety of features selected using a combination of domain knowledge and empirical validation. We then select the optimal technique and hyperparameter set using a test/train split over a cross-validation period, and confirm the stability of its performance on quarantined data. These independently selected and trained models are then used to assign over/underweights versus market value on a monthly basis. **The resulting performance of this automated allocation is statistically-significant and material outperformance relative to a passive (i.e., market weight) strategy, both in cross-validation and quarantine**.

We will provide a report outlining the allocations suggested by this model. It will be made available daily on J.P. Morgan Markets.

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