Automated Navel Gazer 1.0

Trading signals and a Research Duration Sentiment Index (RDSI) from NLP modeling of sell-side research

US Fixed Income Strategy

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- We have had some success in producing high quality, statistically significant returns from trading signals automated using machine learning on market observables …
- … but these input features miss more qualitative drivers, which can at times dominate price action and have become particularly important in recent years
- A corpus drawn from sell-side research is arguably preferable to traditional news in NLP models for fixed income in that it is targeted at practitioners and is less focused on equity markets
- We train machine learning classifiers on a curated subset of terms from more than 200,000 pages of research across economics, fixed income, and FX to generate long/short duration signals form "reading" that text, weighted by the level of confidence our algorithm has in its prediction
- We then test its predictions on a weak (validation) and strong (quarantine) out-of-sample over three years covering another roughly 200,000 pages of research
- Though transparently self-serving in this context, the data speaks for itself: automated trading signals generated in this way produce attractive and statistically significant Sharpe ratios in both validation and quarantined samples
- We can use the same models to produce a Research Duration Sentiment Index (RDSI), which can be used to complement existing traditional fair value frameworks based off of fundamentals and positioning

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To date most of our work has been focused on generating trading signals from *ex-ante* market and economic variables. The assumption underlying this work is that these features, which are all readily observable either in the market or from public sources, contain enough information to inform future price action—at least over sufficiently short horizons. After applying rigorous statistical significance and generalizability tests, we have found some techniques are able to produce reasonably attractive and reliable risk-adjusted returns through a range of regimes. **This suggests that there is some truth to our assumptions, and that when armed with a sufficiently flexible modeling approach—often referred to in broad strokes as machine learning (ML)—there is sufficient "information" in readily and publically observable features to automate short-term trading decisions**.

That said, **this approach is necessarily missing more qualitative information**. As every market participant is well aware, there are frequently unobservable factors which play an important role in price action. We can broadly characterize these as market sentiment, which includes shifts in perceptions of positioning or the economic or policy outlook driven by more anecdotal factors rather than hard data. These are often spun into narratives that can become self-reinforcing, whether or not they end up playing out as expected in the end. This presumption is the basis for the relatively new field of narrative economics (e.g., Shiller 2017).

How do we capture this effect and incorporate it into an automated trading strategy? We recently made a preliminary attempt to do so via tracking the impact of presidential tweets on volatility (see *Introducing the Volfefe Index*, M. Salem et al., 9/6/19). This is, however, a fairly narrow application, both in its focus (volatility) and corpus (a very influential, but singular Twitter feed). We are likely to be better served, particularly in modeling and forecasting directional moves in interest rates, by capturing a much broader dataset.

This motivates relying on a much broader corpus, for which many have used the news and social media. Doing so is compelling in principle, but the content and tone of popular discussion will not necessarily track that of the narrative followed by market participants. This is arguably truer of fixed income than equities, given the disproportionate popular press and social media focus on the latter. **Sell-side research, which in contrast to popular media is intended for specialist professional investors, is an attractive source of news-type data that is potentially more directly applicable to fixed income markets**.

This piece presents the results of an experiment which applies NLP and machine learning to this alternative data set. We start by collecting roughly nine years of textual data from J.P. Morgan Research publications covering Fixed Income Strategy, Global Economics, and Global FX Strategy. **To complete this experiment the computer has "read" more than 33,000 individual research articles totaling 130 million words (more than 400,000 pages in standard novel format) back to early-2010**. The mix has, interestingly, varied over time, with economics recently

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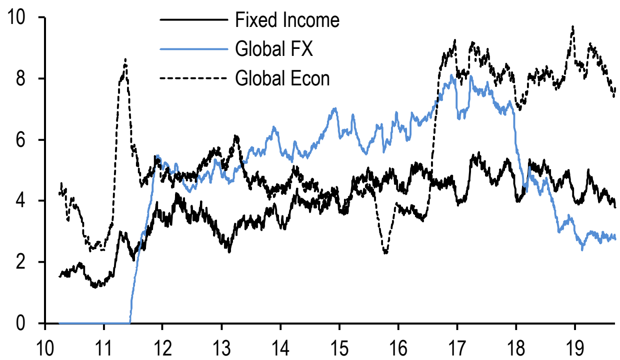
increasing significantly and FX dropping nearly at the same time, while fixed income has remained relatively constant (**Exhibit 1**).

Exhibit 1: Our sample consists of fixed income, FX, and economics publications over the past few years, though the split between the three has evolved …

Rolling 3-month average of daily publications split by coverage group; count



Source: J.P. Morgan

Exhibit 2: … which we split into training, validation, and quarantine for model selection and benchmarking purposes

Publication statistics for our sample of research, total as well as split by group and into the training, validation, and quarantine periods

		Fixed Income	Global FX	Global Econ	Total
Training 1/10- 12/15	Publications	4,766	6,110	6,575	17,451
	Words	30,149,510	8,860,239	30,734,192	69,743,941
	Pages	100,498	29,534	102,447	232,479
Validation 1/16- 9/17	Publications	2,096	3,160	3,104	8,360
	Words	10,117,051	5,025,234	13,116,854	28,259,139
	Pages	33,723	16,750	43,722	94,195
Quarantine 10/17- 9/19	Publications	2,141	1,804	3,892	7,837
	Words	11,817,882	3,837,374	16,623,692	32,278,948
	Pages	39,392	12,791	55,412	107,595
Total	Publications	9,003	11,074	13,571	33,648
	Words	52,084,443	17,722,847	60,474,738	130,282,028
	Pages	173,614	59,076	201,582	434,272

Note: To get an approximate page count we assume 300 words per page.

Source: J.P. Morgan

These data were then split into three periods along the same lines as our earlier automated trading signal generation experiments: a 5-year training period, 18-month validation period, and a 1–year quarantine period (**Exhibit 2**). We do not perform a proper cross-validation in this case simply because we lack sufficient history in our corpus to do so. As before, we limit our hyper-parameter search to the training and validation periods and confirm the statistical significance of the results before considering the performance of the optimal model specification in quarantine (for more details, see some of our prior work here, here, and here).

First, construct the daily word count matrix as raw feature set. From the roughly 130 million words in our corpus we remove stop and most 2-letter words—we retain “QE” for example—which in our corpus made up roughly half of the text. We then replace thematically and conceptually associated terms and phrases with categorical tokens using the Word2Vec algorithm. For example, all references to swap spreads or options structures, various descriptions of quantitative easing and tightening, references to growth and recessions, etc. Negations are concatenated into a single token as well: e.g., “not bullish” to “neg bullish”. We calculate the frequency of single words (1-gram) and two adjacent words (2-gram) in each document, and filter out tokens used in less than 1% of the publications. This forms a count matrix of 12,000 unique tokens, which we then group by publication date (defined as 3pm to align with desk closing marks) to track the total daily count of these tokens. Finally, we normalize these counts by the squared root of publications that day to account, among other things, for cyclicality—e.g., a preponderance of publications of Fridays—and variations in the overall rate of publications apparent in Exhibit 2.

Second, the easy part: tagging the data. We seek to predict returns on outright duration exposures, for which we use benchmark 10-year Treasuries as a proxy. Therefore the “y-variable” in our experiment is total returns over a 1-week holding period, incorporating term financing rates. By analogy to other NLP work, this can

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also be thought of as a form of sentiment tagging: instead of positive/negative were use *ex-post* price action to automatically generate bullish/bearish labels based on asset returns.

Third, the more complicated part: selecting features. We then perform a Chi-Squared test on the 12,000 unique tokens to identify the fifty most likely to be important features (see *2019 Alternative Data Handbook*, M. Kolanovic & R. Smith, 10/11/19 and *Extracting Sentiment from News*, R. Smith & B. Hlavaty, 10/9/17 for details). The final list is further reduced to 41 based on a manual review—the all-important domain knowledge step.

The day's research is then "read" in the sense that it is reduced to token frequencies among our selected features, and these counts are used to model *ex-post* returns on 10-year Treasuries over a 1-week holding period. We consider a variety of models, including classical techniques like multivariate logistic regression and Naïve Bayes, as well as ensemble machine learning techniques like gradient boosting (GBM) and random forest (RF). **We then perform a hyper-parameter search to maximize model performance in the validation period for various classifier specifications.** That said, model performance itself is a somewhat poorly defined concept. The definition of this metric is a key consideration in any experiment, and depends on our goals. For this exercise we have two related to in practice subtly different goals: first, to generate tradable signals, and second to measure and track sentiment. The quality of an automated trading strategy is best benchmarked, in our view, by risk-adjusted returns—the annualized Sharpe ratio. The utility of a sentiment index, however, is better measured by AUC (area under the curve), which quantifies the frequency of true relative to false positives at various probability thresholds. This makes AUC an indicative for how well the model is able to separate positive (or bullish) versus negative (bearish) sentiment.

Exhibit 3: After identifying and reducing the feature set using a mix of statistical techniques and domain knowledge, GBM produces the best model performance in both validation and quarantine

Performance statistics for unweighted and balanced models by technique, split into the validation and quarantine periods

		Unweighted			Balanced		
	Attribute	**GBM**	RF	Logistic	GBM	RF	Logistic
Hit Rate	Validation	**58%**	55%	57%	57%	57%	57%
	Stat sig	**99%**	15%	95%	98%	100%	99%
	Quarantine	**53%**	55%	54%	54%	49%	50%
	Stat sig	**82%**	92%	97%	90%	50%	80%
Sharpe	Validation	**0.83**	0.45	0.97	0.86	0.82	0.88
	Stat sig	**99%**	95%	100%	98%	100%	100%
	Quarantine	**0.88**	0.81	0.46	1.2	0.25	0.01
	Stat sig	**98%**	90%	96%	100%	94%	96%
AUC	Validation	**0.59**	0.57	0.58	0.57	0.57	0.58
	Stat sig	**100%**	100%	100%	100%	99%	100%
	Quarantine	**0.56**	0.53	0.55	0.56	0.53	0.55
	Stat sig	**98%**	88%	98%	99%	87%	98%

Note: Statistical significance is determined using a Monte Carlo simulation of 10,000 randomized trading strategies with the same distribution of confidence levels as the model for each period. A value of 100% indicates model performance exceeded all of these trials. Returns are defined as daily longs or shorts in 10-year hot-run Treasuries held for five business days including term financing costs. Forecasts based on *ex-ante* feature word and categorical counts, normalized by the sqrt of the number of publications on that date.

Source: J.P. Morgan

Exhibit 4: GBM models can produce feature importance measure which highlight the relative contribution of specific terms or groups of terms to separating the data

Feature importance measure for unweighted GBM model

Token	Imp	Token	Imp	Token	Imp	Token	Imp
end	0.04	outlook	0.031	riksbank	0.024	butterfly*	0.016
decrease	0.038	regulate	0.03	options*	0.022	steepen	0.016
trend	0.037	usd	0.03	issuance	0.021	FRA/OIS	0.014
long	0.036	forecast	0.03	QE*	0.021	BTP	0.012
rates	0.036	vol	0.028	bund	0.02	global rates	0.012
short	0.034	ccy	0.028	tips	0.02	ois curve	0.01
bullish	0.034	futs*	0.027	gilt	0.019	new issue	0.009
bearish	0.032	investor	0.026	yld crv*	0.018	schatz	0.006
boe	0.031	purch's	0.026	mkt outlook	0.018		
flatten	0.031	ECB	0.026	swap	0.017		
spread*	0.031	scenario	0.025	duration	0.017		

* Denotes tokens made up of categorical or symbolic members.

Source: J.P. Morgan

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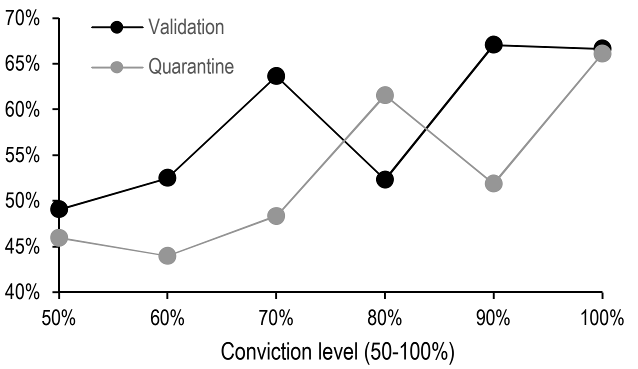
Results are summarized in **Exhibit 3**[1]. The hit rates are decent but not particularly impressive, and perhaps more importantly don't tend to generalize well when tested in quarantine. **However, when we incorporate confidence level into sizing the trade the Sharpe ratio is much more compelling and statistically significant, both in validation and quarantine**. This is similar to our results from prior experiments using market observables to generate automated trading signals with the same set of modeling techniques (references above). This suggests that applying NLP and machine learning to automate the processing of sell-side research content can produce high-quality risk-adjusted returns. We specifically select unweighted GBM owing to its superior performance over the validation period. Though a balanced approach outperforms in quarantine, we prefer to use quarantine simply to validate our hypothesis rather than to adjust it.

Having chosen this particular model, we can explore its underlying mechanics in a bit more detail. **First**, GBM in particular can be used to produce feature importance statistics to see which words and groups of words are most effective at splitting the data. The results, in our view, are rather intuitive (**Exhibit 4**), though it is important to note that this exercise does not account for interaction terms between these tokens. **Second**, we can confirm that the more detailed weak and strong out of sample behavior is consistent with good global statistics. In particular, we confirm that signals with higher conviction have higher hit rate, again in both validation and quarantine (**Exhibit 5**). In the past we have used this particular comparison to verify the intuitive behavior of model forecasts.

Exhibit 5: In addition to attractive aggregate performance statistics, higher levels of conviction are associated with higher hit rates in both validations and quarantine for GBM models

Hit rate in validation and quarantine periods for unweighted GBM model versus level of conviction in that trading signal (50-100%), long and short both included; %

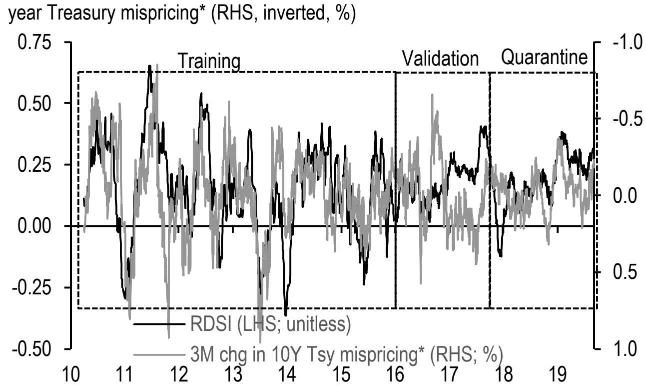


Note: See Exhibit 3 for details.

Source: J.P. Morgan

Exhibit 6: In addition to an automated trading strategy, we can use model probabilities to construct a Research Duration Sentiment Index which tracks the duration bias implied by a set of publications

3-month rolling average daily unweighted GBM model duration sentiment (LHS; unitless, >0 is bullish and implies declining yields) versus 3-month change in 10-year Treasury mispricing* (RHS, inverted, %)



* Difference between fair value and current 10-year Treasury yield. We estimate fair value using 5-year regression against 3Mx3M OIS rates, 1-year ahead GDP forecasts, 5Yx5Y inflation swap rates, share of negative yielding DM market debt, and CFTC spec positioning (3-year Z-score). For details, see *Tweaking out fair value framework*, J. Barry et al., 10/15/19.

Source: J.P. Morgan

Admittedly this is a transparently self-serving conclusion coming from the group that produced these publications in the first place. However, **the data speaks for itself**—not to mention the fact that this kind of study was not contemplated until very recently. It is also worth noting that the sentiment gauged from automated

[1] Naïve Bayes was examined as well, but is excluded due to poor performance.

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processing of the full research corpus leads to a noticeably different distribution of recommended positioning than the model portfolio.

As alluded to above, we can complement automated trading recommendations with variant on news sentiment measures. In contrast to most such trackers, our tags are based on tradeable market outcomes rather than qualitative interpretation or bias. **This is somewhat different from the performance of a trading strategy in that it measures the accumulated tendency or market bias over a longer period of time—a technique we have found useful under other circumstances (e.g., the Volefe Index)**. An example is shown in **Exhibit 6**, in which present a Research Duration Sentiment Index (RDSI) which is constructed from a trailing average of the past 3-months of text-based model probabilities. A positive number in this chart indicates a bullish bias, and the training, validation, and quarantine periods are labeled. Generally speaking, **this sentiment measure tracks well with changes in 10-year Treasury relative to fair value over the same period**. In other words, the RDSI can explain a significant fraction of the variation in 10-year Treasury yields versus the levels that one would infer from the current state of their drivers (e.g., inflation and growth expectations, speculative net positioning, etc.; for details, see *Tweaking our fair value framework*, J. Barry et al., 10/15/19). This is true, once again, out of sample in both the weak (validation) and strong (quarantine) form. Interestingly, performance by this measure is somewhat better in recent years, which is not particularly surprising given the increasing attention paid by markets to much less easily observable policy and geopolitical risk factors (e.g., Interest Rate Derivatives, *US Fixed Income Markets Weekly*, 10/11/19). To be clear, this is not an *ex-ante* indicator, and in that sense is not predictive. But it is useful descriptive statistic, and in that sense does provide a way to quantify and track the market bias implied by the broader content of sell-side research across related asset classes and subjects.

From this we can come to a few conclusions. **First**, the corpus of sell-side research can be effectively reduced to a manageable set of input words and categories. **Second**, applying machine learning techniques to this reduced feature set can produce high quality risk-adjusted returns as an automated trading strategy. Put a little differently, **the computer can be trained to "read" the day's research and synthesize its content into a long or short duration position based on its level of confidence**. Trading on the basis of those confidence estimates produces a high out-of-sample (validation *and* quarantine) Sharpe ratio. **And finally**, **the sentiment estimated through this exercise is a potentially useful complement to existing fundamental analysis** as well as other automated signals generated using market observables.

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