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The underestimated edge

How machine learning is enhancing macro investing

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Summary

- Macro investing has historically had only limited adoption of machine learning due to low-asset breadth. This paper challenges that skepticism. It shows that, with purpose-built techniques, machine learning can add robust, scalable value.
- By pooling data across countries and markets, and applying regularized models, macro signal detection becomes more adaptive and accurate. By improving robustness of learners on low breadth data, this approach can outperform traditional models that analyze a single variable over time, especially during regime shifts — like the post-Covid inflation surge.
- Advanced machine learning mapping techniques — including geospatial mapping and language model-enhanced embeddings — allow investors to translate hyper-local economic insights into tradable macro exposures. This transforms once-unusable datasets (e.g., foot traffic, local GDP) into alpha-generating strategies.
- Traditional linear regressions fall short in low-breadth environments. Learn-to-rank models, inspired by recommender systems, offer a better alternative for macro relative value strategies, proving more stable and adaptable across changing economic conditions.
- Finally, this research emphasizes that macro investing demands customized machine-learning solutions. Success lies not in applying off-the-shelf models, but in designing approaches tailored to the structural realities of macro — limited assets, regime shifts and signal fragility.

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BSYSM0925E/S-4850157-2/12

Reframing machine learning in macro investing

Machine learning has reshaped many corners of the investment landscape — especially in fast-moving, high-breadth arenas like equity and credit security selection. Yet in macro investing, its impact has been more muted. The challenge? Macro markets have fewer distinct return streams to model, making it harder to apply traditional machine-learning techniques effectively.

Too often, naive applications of machine learning in macro investing gravitate toward a narrow set of dominant factors. This overconcentration can lead to overfitting, reducing robustness and limiting practical deployment. As a result, many macro hedge funds have approached machine learning cautiously, often reserving it for small, ancillary roles, such as enhancing investment narratives rather than driving core decisions.

In contrast, machine learning has thrived in long/short equity and corporate bond strategies, where the breadth of instruments and insight variety is far greater.[1] These successes have fueled significant investments in data infrastructure, computational resources and modeling capabilities across quantitative investment platforms.[2]

At BlackRock, for instance, a single data store for alphas allows for modular applications of machine learning across diverse use cases. This foundation has now laid the groundwork to unlock machine learning's potential in macro strategies.

A new path forward for machine learning in macro

Instead of forcing machine learning into the mold of direct return prediction for individual macro assets — a task fraught with statistical and practical challenges — we believe the key lies in reframing the problem. Our approach focuses on how machine learning can deliver genuine value when tailored to the structural realities of macro: sparse signals, temporal fragility and low asset granularity.

The aim of this paper is to challenge the prevailing belief that machine learning doesn't belong in macro. By showcasing techniques specifically designed for challenges present in macro investing, we demonstrate that it's not only possible — but increasingly practical — for machine learning to become a core component of modern macro investing.

To overcome the limitations of traditional macro modeling, we highlight three key machine-learning applications that target the core constraints of low breadth, weak signal generalizability, and sparse data environments:

- **Pooling macro assets and datasets** to strengthen time-series models
- **Translating complex macroeconomic insights** into tradable asset exposures
- **Deploying specialized learning techniques** within relative value frameworks

While additional frontiers — such as those involving large language models — are the subject of a forthcoming white paper, this paper focuses on the foundational innovations already reshaping how macro strategies are built, tested, and scaled.

1 Examples of academic literature that support the notion that machine learning can be effectively used in stock and bond prediction are as follows (1) Gu, S., Kelly, B., & Xiu, D. (2020). *Empirical Asset Pricing via Machine Learning.* The Review of Financial Studies, 33(5), 2223–2273. https://doi.org/10.1093/rfs/hhaa009, (2) Bell, S., Kakhbod, A., Lettau, M., & Nazemi, A. (2025). Glass Box Machine Learning and Corporate Bond Returns. SSRN. https://ssrn.com/abstract=5076023. **2** See for example, https://www.bloomberg.com/professional/insights/data/data-trends-that-shaped-investment-strategies-in-2024/.

BSYSM0925E/S-4850157-3/12

Pooling macro assets and datasets to strengthen time-series models

In macro investing, the true edge comes not just in identifying signals, but from learning when and where those signals matter. Traditional time series models, trained in isolation, often suffer from sparse data, structural breaks, and limited ability to adapt across regimes.[3] Machine learning offers a more powerful approach: pooling data across countries, assets, and markets to train regularized models that extract shared patterns and boost robustness.

One example is our approach to equity and bond market timing. By training a model on a cross-sectional library of macro signals, and imposing a non-negative constraint, we can systematically time a combination of signals that best predicts returns over time.

The benefit of this approach is twofold:

1 Greater regime diversity

A single market may experience only a few turning points or regime shifts and requires a long time-series of observations to adapt, but a global panel provides a richer set of regimes, increasing the model's learning efficiency.

2 Higher generalizability

Cross-sectional pooling helps the model to recognize consistent, shared macro relationships rather than idiosyncratic noise — boosting forecast robustness and adaptability across market cycles.

To avoid overfitting — a common pitfall in unconstrained regression — we incorporate informative priors rooted in economic intuition. Just as unconstrained portfolio optimizations can produce unstable results, so too can unconstrained optimization of a regression task — that is, overfitting. Applying a non-negative constraint to our signal library is a sensible and powerful regularization technique. As a result, our equity and bond market timing views are capable of identifying and responding to macro regime shifts in a rapid and robust manner.

Real-world impact: Duration timing in a post-Covid world

The practical power of this method was clearly demonstrated in our duration timing model during the post-Covid inflation regime. The pooled model swiftly adapted by significantly upweighting inflation-sensitive signals outperforming both:

- **Univariate time-series models, which lagged in recognizing the regime shift**
- **Naïve 1/N signal approaches, which lacked adaptability**

Importantly, the pooled model's larger signal weight variation isn't just noise — it corresponded to increased information content across the board, confirming strong predictive value.

3 For a comparison of the challenges facing traditional methods and the benefits of model combination, see Giannone, D. Lenza, M. & Primiceri, G.E. (2021). *Economic Predictions with Big Data: The Illusion of Sparsity.* Econometric 89(5), 2409-2437. For a discussion of regularization using Bayesian priors, see Giannone, D., Lenza, M., & Primiceri, G. E. (2015). *Prior Selection for Vector Autoregressions.* Review of Economics and Statistics, 97(2), 436–451.

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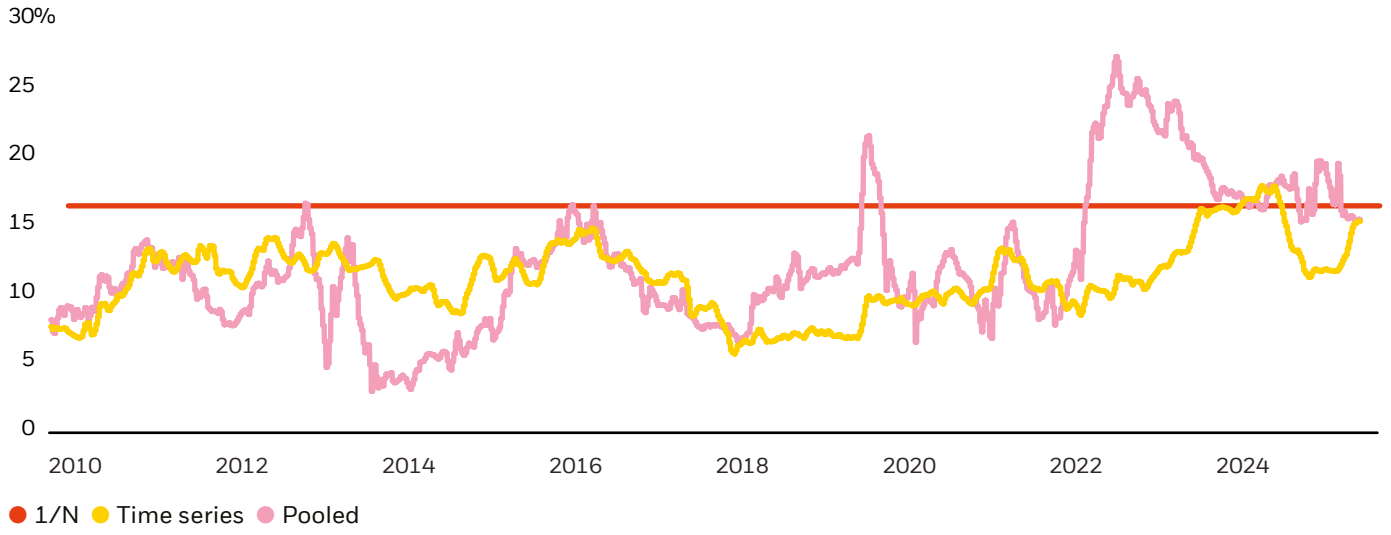
Figure 1: Relative signal weights

Inflation signals weights



Duration timing signal cumulative returns

Source: BlackRock Systematic, with data from Aladdin, Bloomberg, Price Stats, Thomson Reuters. Signal weights are rescaled to sum to 100% at each point in time. The yellow line shows the relative signal weights attributed to inflation signals from fitting a rolling five-year elastic net regression on a single univariate target, averaged across each market. The pink line shows the same relative signal weights from fitting a pooled elastic net regression on all targets simultaneously. Calculated as of May 2025.

The top chart in Figure 1 shows relative signal weights to inflation insights in our duration timing model for a naïve 1/N benchmark in orange, learned weights from univariate regressions averaged across DM bond future universe in yellow, and the pooled learner's weights in pink. Bottom chart shows our cumulative duration timing signal returns scaled to 1% risk for the three approaches.

This pooling-based approach reframes macro signal timing into a **systematic, scalable and forward-looking process**. Rather than being constrained by the narrow histories of individual markets, machine learning can tap into the **empirical breadth of the global macro landscape**, elevating the likelihood that investors can detect and respond to structural shifts with agility and precision.

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Translating complex macroeconomic insights into tradable asset exposures

A core challenge in macro investing lies in bridging the gap between rich, high-dimensional datasets and tradeable macro instruments. Many macroeconomic signals, especially geospatial or local economic indicators, hold valuable insights, but are difficult to map to investable asset classes in a consistent, scalable way.

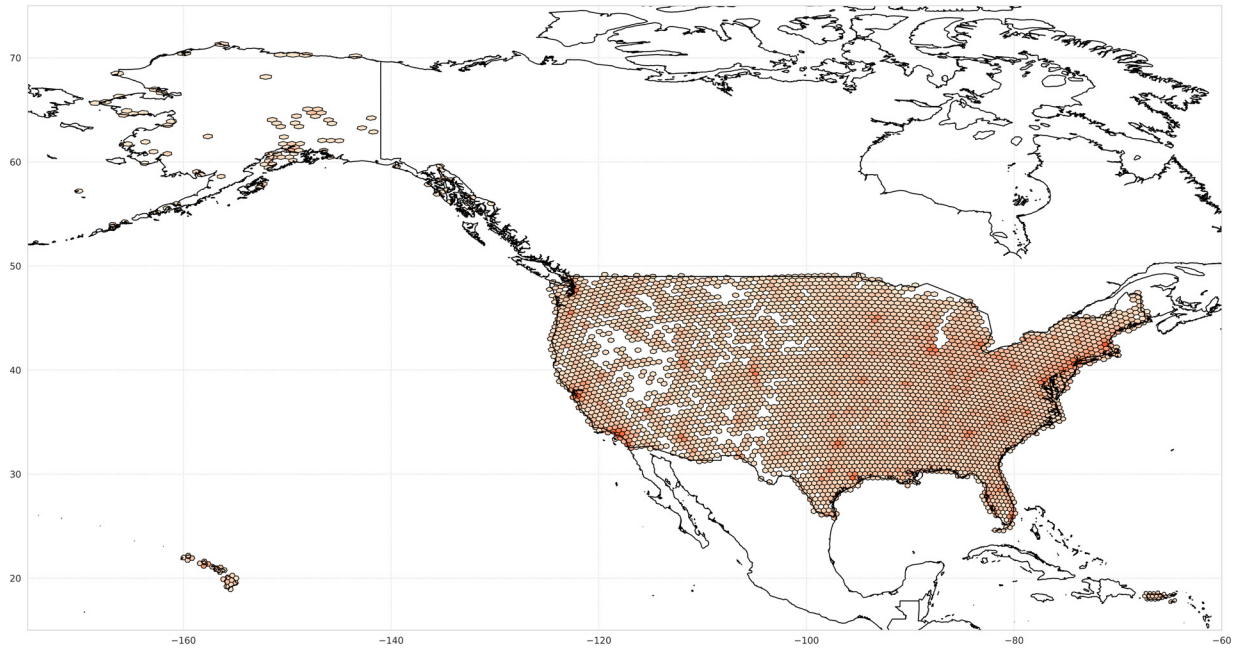
Advances in machine learning and AI techniques are helping solve this problem. Through automated, robust mapping frameworks, we can now extract investment signals from complex, previously underutilized datasets and systematically link them to baskets of tradable securities. We illustrate this through two applied use cases in our macro strategies:

Mapping points of interest to tradable equity exposures

In our research processes, we've leveraged hyper-local geospatial data — such as foot traffic, extreme weather events, and measures of local economic activity — as novel alpha signals.[4] The key challenge? Understanding which securities are most exposed to these localized impulses. This goes beyond tracking companies solely by their headquarters — across the U.S. large-cap equity universe, approximately 80% of a company's footprint, as measured by location presence, is situated outside its home state.[5]

To tackle this, we developed an AI-driven mapping system using **Points of Interest** (POI) data — defined by precise longitude-latitude coordinates of company physical locations globally. These POIs are linked to public companies and tradable exposures. We leverage both purchased and publicly available datasets that include one or more identifiers, such as company name, business type, or associated website. Then, we leverage machine-learning techniques and AI to map to companies based on a 'knowledge-graph' of all known characteristics, leveraging known corporate subsidiary relationships, name matching, probabilistic techniques and artificial intelligence agents.

Figure 2: 1.8 million U.S. company locations mapped to 8,750 tradeable companies

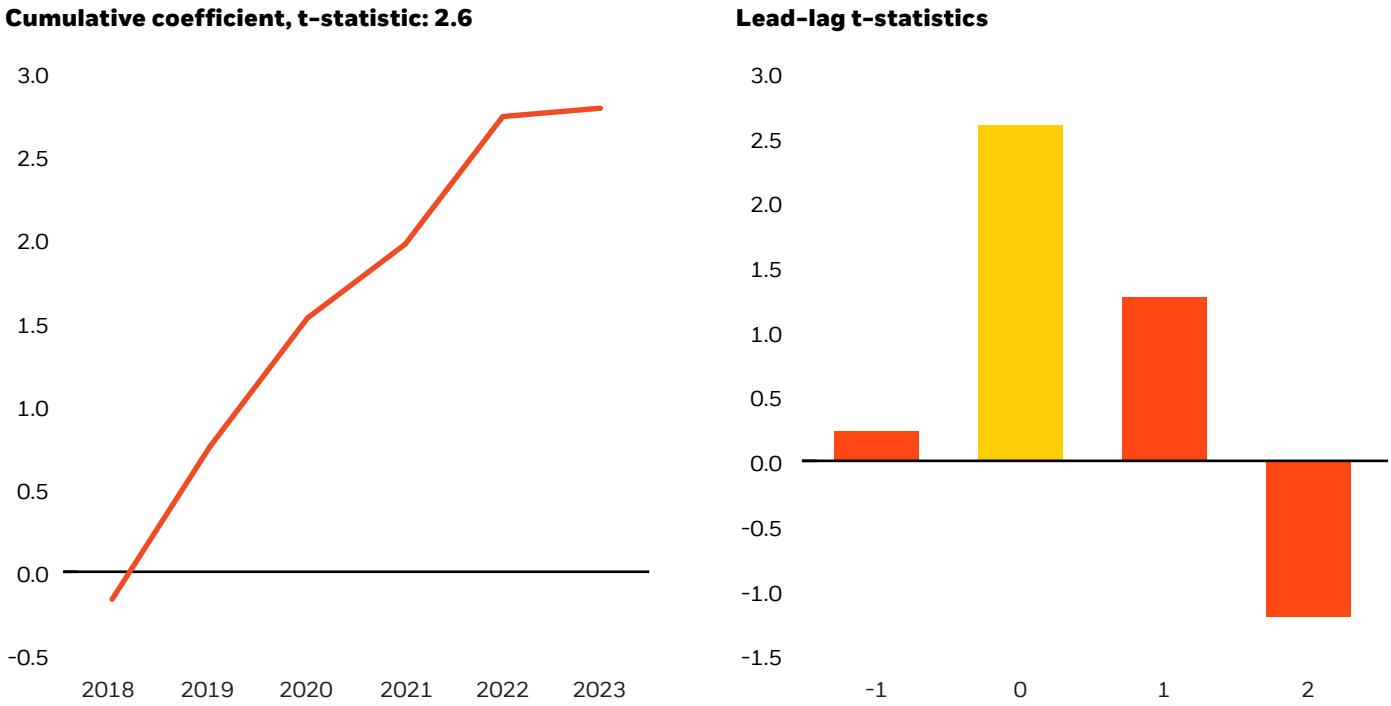


4 Source: "How Geospatial Data Can Inform Investing," The Bid podcast hosted by Oscar Pulido, featuring analysts Joshua Kazdin and Mike Pensky discussing how BlackRock leverages geospatial data in their investment process. https://www.blackrock.com/us/individual/podcasts/the-bid/geospatial-data. **5** Source: BlackRock, Precisely. Based on analysis of Points of Interest (locations) for S&P 500 and Russell 1000 companies. Company exposure is calculated as the percentage of locations inside versus outside the state of headquarters. Data as of January 2025.

BSYSM0925E/S-4850157-6/12

For example, (as shown in Figure 2) in North America, we've mapped over 1.8 million physical company locations to 8,750 publicly traded entities, enabling the construction of region-specific investment baskets, which are effectively tradable exposures mapped to hyper-local areas. For example, (as shown in Figure 3) the co-movement between these state- or city-level baskets and the local GDP growth surprises, offers highly targeted macro expressions for our insights.

Figure 3: Concurrent relationship between relative performance of locally-mapped baskets (states) to innovations in state-level GDP



Source: Precisely, Bureau of Economic Analysis (BEA), BlackRock. Calculated as of May 2025.

Another area where machine learning is transforming macro investing is in the mapping of **foreign industry-level economic data** — such as business sentiment surveys, sector activity indices, and regional production statistics — to relevant asset exposures. Prior to the emergence of improved mapping techniques through machine learning, these processes could be highly labor intensive and error-prone due to human efforts.

With the advent of large language models, such mapping procedures have become more streamlined, allowing us to make use of more local and granular data on sectors and industries around the world with varying identifying schema and evolving exposures. For example, to map Japanese macroeconomic time series to industries, we use a two-step approach that combines embedding-based similarity with language model refinement. First, we generate embeddings, or numerical vector representations, for both industry descriptions (based on representative company products) and for the economic series names, and identify top matches based on similarity. Then, we use a language model to refine those mappings by reviewing the context and selecting the most relevant series for each industry. This process allows us to efficiently create many-to-many mappings at scale, and delivers performance comparable to — or even better than manual mapping — especially helpful when dealing with large, fragmented datasets.

Together, these techniques are turning formerly "hard-to-trade" macro insights into powerful components of systematic investment strategies. By **automating the translation of economic information into investable exposures**, we enable a more responsive, nuanced, and data-rich approach to macro investing — one that adapts dynamically to regional shifts and localized disruptions.

BSYSM0925E/S-4850157-7/12

Deploying specialized learning techniques within relative value frameworks

Traditional return methods in macro — most notably linear regression methods — have typically been designed to predict an individual asset's returns. While effective in some settings, this approach is often misaligned with the goal of relative value ("RV") investing, where the primary objective is not to predict precise return magnitudes, but rather rank a set of assets' forecasted returns from best-to-worst. In this context, learn-to-rank methodologies — originally developed in the machine learning domain for recommendation systems and search engine optimization — offer a more applicable framework. These methods are designed to generate ranked outputs directly, making them especially well-suited to address RV investment problems.

Ranking G5 sovereign bonds with macroeconomic predictors

To illustrate the power of this approach, we examine a simple forecasting problem using two classical predictors of developed-market sovereign bond returns — Consumer Price Index ("CPI") and GDP analyst revisions. As can be seen in the simulated backtests in Figure 4, these two measures have historically been robust predictors of bond futures returns, but their explanatory power has diminished over the past decade due to evolving macroeconomic regimes.

We compare two distinct learning methods:

1 Traditional multivariate linear regression

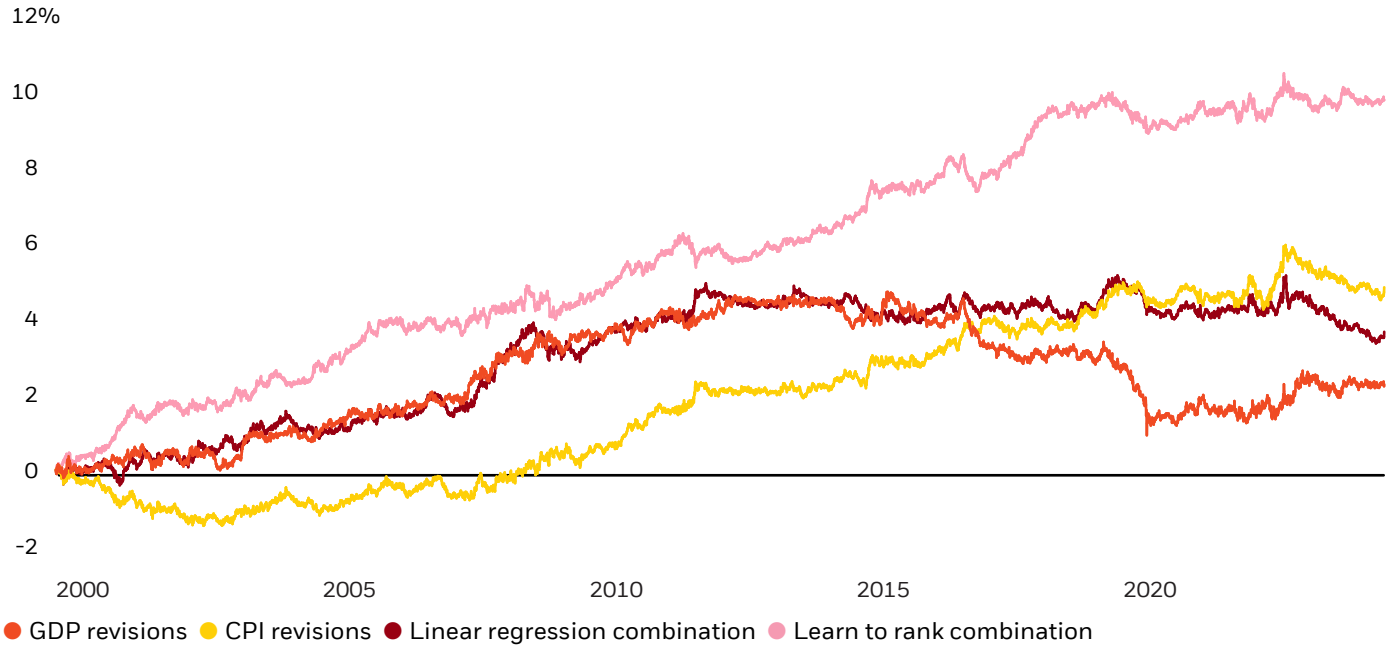
Each G5 bond is modeled individually using multivariate regression, where the learner is trained on each asset's 20-day returns using the two predictors. Forecasted returns are treated as predictions, which are then backtested to evaluate performance.

2 Learn-to-rank "LambdaRank"[6]

Instead of predicting returns directly, the model learns to rank bonds at each point in time by comparing asset pairs. These rankings are then standardized using cross-sectional z-scores and evaluated through backtests to assess effectiveness.

Figure 4: Comparison of strategy performance simulation using alternate machine-learning approaches in combining macroeconomic signals across bond returns

Explanatory backtest G5 bond returns



Source: Consensus Economics, BlackRock. For illustrative purposes only. As of June 30, 2025.

6 Christopher J. C. Burges, Robert Ragno, and Quoc Viet Le. 2006. Learning to rank with non-smooth cost functions. In Proceedings of the 20th International Conference on Neural Information Processing Systems (NIPS'06). MIT Press, Cambridge, MA, USA, 193–200.

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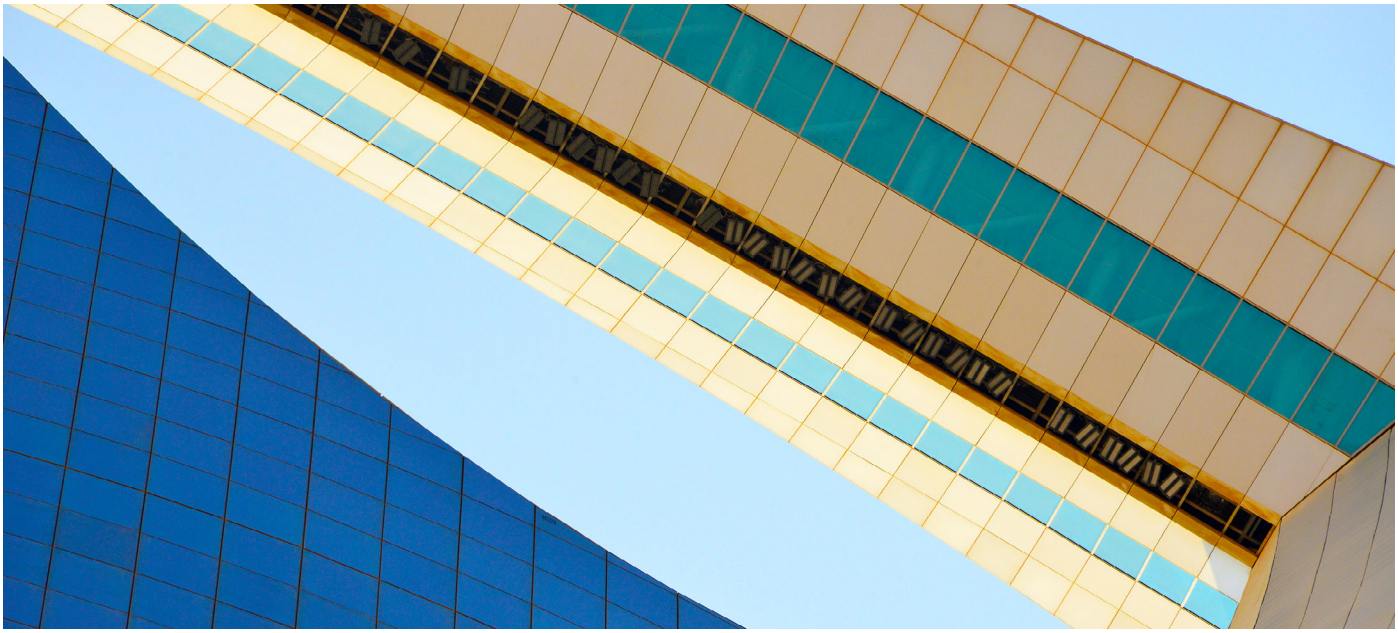

The results (shown in Figure 4) are telling. While the linear regression model has been able to predict asset returns historically, its predictive power declines substantially along with the predictive power of the underlying features. In contrast, the learn-to-rank approach maintains stronger performance consistency, even in the face of macroeconomic regime changes and increased return volatility.

Why does this happen? As macro regimes shift, global factors increasingly dominate, reducing the idiosyncratic component of returns and making magnitudes harder to forecast — but relative rankings remain relevant, even in low-breadth environments where macro assets move together under common global influences. Selecting an appropriate forecasting methodology tailored to the specific investment scenario is crucial. Direct return prediction via traditional regression may be suitable in stock selection contexts, characterized by numerous assets and significant idiosyncratic variation. Conversely, macroeconomic forecasting — typically constrained to a small set of highly correlated assets driven by dominant global factors — may benefit most from methods designed to optimize relative rankings.

Fit-for-purpose machine learning in macro

Across all three examples, a common theme emerges: machine learning in macro must be purpose-built for the challenges of low breadth and complex signal mapping. In the first example, we demonstrate that forecasting a low breadth global factor can be improved by including a broader swath of data with exposure to the same latent factor. In the second example, we take advantage of ML techniques, creating synthetic breadth at the point of interest level, before aggregating to macro factors — harnessing fragmented big data and applying it to top-down views. Finally, we demonstrate that the choice in learners can lead to material differences in explanatory power when it comes to low-breadth systematic investment problems. These innovations demonstrate how modern machine-learning methods, when tailored to macro's structural characteristics, may unlock new alpha sources and bring greater precision to systematic macro research.

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