Using factors with different alpha decay times: The case for non-linear combination

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See Appendix A-1 for analyst certification, important disclosures and the status of non-US analysts.

Any authors named on this report are research analysts unless otherwise indicated.
Factors have different information decay times (e.g., Value vs Momentum)

We believe that these differences are highly persistent

Most quant models average across signals, thus discarding the information decay differences

Is there a better way to combine factors? Should it be linear?

We (quants) have mined for factors

Harvey, Liu and Zhu (2015) identify 314 factors from academic literature

We conclude: THERE. ARE. NO. NEW. FACTORS. TO. BE. DISCOVERED. (pace the possibilities of “big data”)

So, instead, maybe we should be looking to find more intelligent ways to combine the factors that we already have.

Let’s consider non-linear factor combinations

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Introduction

- Trees for global equity timing
- Trees for regional allocation
- Non-linear factor combination: rewarding agreement
At the stock level one can often afford to be lazy.

With 1,000 stocks to choose from, *on average* the stocks that pass the long and short horizon factors do ok

What happens as the number of tradable assets shrinks?

What does one do if there is only one asset: the global equity market?
Market timing factors have different information decay times: correlation with forward returns

Table shows the correlation of indicators with forward market returns over different horizons. Shiller P/E correlation measured since 1980, for other measures since February 1987.

<table>
<thead>
<tr>
<th></th>
<th>Shiller PE</th>
<th>Equity Risk Premium</th>
<th>Positioning</th>
<th>Composite Sentiment Indicator</th>
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<tbody>
<tr>
<td>1mth</td>
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</table>

Source: Nomura Quantitative Strategy research
Our framework – a three-level Bayesian tree structure

Equity Risk Premium
Positioning
Composite Sentiment Indicator

Predicted classes
- Top Quartile Returns
- Cash
- Bottom Quartile Returns
Market Timing: A tree approach

Equity Risk Premium

High

Positioning

High
CSI
High
Neutral
 CSI
High
Neutral
 CSI
High
Neutral
 CSI
High
Neutral
 CSI
High
Neutral
 CSI
Most bullish state

Neutral

Positioning

High
CSI
High
Neutral
 CSI
High
Neutral
 CSI
High
Neutral
 CSI
High
Neutral
 CSI
Most bearish state

Low

Positioning

High
CSI
High
Neutral
 CSI
High
Neutral
 CSI
High
Neutral
 CSI
High
Neutral
 CSI
Most bearish state

Neutral

Positioning

High
CSI
High
Neutral
 CSI
High
Neutral
 CSI
High
Neutral
 CSI
High
Neutral
 CSI
Most bearish state

Low

Positioning

High
CSI
High
Neutral
 CSI
High
Neutral
 CSI
High
Neutral
 CSI
High
Neutral
 CSI
Most bearish state

Source: Nomura Strategy research
Populating the tree

**Equity Risk Premium**

Cheap

- **P (bullish)**: 31%
- **P (neutral)**: 49%
- **P (bearish)**: 20%

Positioning

Low

- **P (bullish)**: 50%
- **P (neutral)**: 38%
- **P (bearish)**: 12%

Composite Sentiment Indicator

Low

- **P (bullish)**: 67%
- **P (neutral)**: 33%
- **P (bearish)**: 0%
Figure is a graphical representation of the probabilistic mapping between each possible combination of our inputs or predictors (as described by the values ERP, the combinations of the ERP and positioning and, lastly, the combinations of the ERP, positioning and the CSI) and forward equity returns with their associated probabilities. The green, yellow and red arrows refer to 'high', 'neutral' or 'low' values of our predictors while the probabilities refer to the probabilities of one-month forward returns being high (top quartile of historical distribution), low (bottom quartile) or neutral. The probabilities of the various outcomes are estimated using monthly historical returns on the MSCI World, and the monthly historical ERP, CFTC positioning and our Composite Sentiment Indicator series, from February 1987, with a 10-year out-of-sample period starting in October 2004 during which the model learns.

The top 'layer' of the tree is characterised by the level of the ERP, with a high level (a reading in the top quartile) denoted by the green arrow, low by the red arrow and a neutral level by the yellow arrow. The probabilities listed for each ERP 'state' denote, moving down from the top, the probabilities of high (top quartile), neutral or low (bottom quartile) equity returns on a one-month forward view. We can see that using the ERP in isolation tells us that returns are more likely to be high than low when the ERP is high (market is cheap) and vice-versa when the ERP is low, whereas with the neutral reading from the ERP the probability of high and low returns are very similar. As we would expect intuitively, the probability of high returns decreases in a monotonic fashion as we move from high to neutral to low ERP, while the probability of low returns increases monotonically. But, also as we would expect, the ERP alone finds it relatively hard to attach strong probabilities to 'high', 'neutral' or 'low' values of our predictors while the probabilities refer to the probabilities of one-month forward returns being high (top quartile of historical distribution), low (bottom quartile) or neutral.

As we move down the decision tree, our information set is enriched, and we are able to discriminate between the likely outcomes with greater confidence. Note that, importantly, the CFTC (positioning) reading and the CSI reading at high levels (and so accompanied by a green arrow) give a negative signal for equity returns and vice-versa, because we use both sentiment indicators in a contrarian manner. As an example, in an environment where the ERP is high (the market is cheap), while both CFTC and the CSI are low (sentiment is depressed), the probability of low market returns over the following month is zero, and there is a nearly 70% likelihood that returns will be 3% or above. (See the circled part denoted 'A', which denotes this state of the world.) In contrast, when sentiment is extended, ie, both positioning and sentiment as measured by the CSI are at high levels, then despite the fact that the market is cheap, the probability of high returns is very low (see the part of the tree denoted by 'B' on the diagram). When equities are expensive relative to bonds (the ERP is low), depressed sentiment does not help the return expectation and the probability of one-month forward returns exceeding 3% is low or zero across most scenarios (eg, node C).

Looking at different 'layers' of the diagram, we can see how the impact of positioning on forward returns varies depending on the valuation background and how the impact of the CSI is, in turn, dependent on the environment in which we find ourselves as determined by valuation and positioning. For example, low positioning implies very different likely market outcomes if the market is expensive (7% probability of high returns, circled and marked 'D' on the diagram) and if the market is cheap (50% probability of high returns, marked 'E' on the diagram). Similarly, looking at the next level down, CSI at extreme lows is associated with a zero probability of a bullish outcome when positioning is high (circled and marked 'F') and almost 70% when positioning is low (node A) even against the same valuation background. Being able to capture these interdependencies and the fact that the same reading from each input can act as a very different signal in different environments — ie, signals are conditional on the other variables — is a crucial advantage of this framework. Source: Nomura Quantitative Strategy research.
Chart shows the performance of the strategy based on going long equities when the model predicts 'high' one-month forward equity returns (top quartile of the historical range), going short equities when the model predicts 'low' returns, and holding cash when the model gives a neutral signal. The index is MSCI World. The model uses the Equity Risk Premium, the CFTC positioning data and our Composite Sentiment Indicator as performance signals. An out-of-sample period of 10 years (starting October 2004) is used.

Source: Nomura Quantitative Strategy research
Chart shows the performance of a long short strategy based on the monthly generated by our Market Timing model and compares it with performance of the model's individual components. For consistency of comparison, the performance shown here is the long short performance of each variable with one month holding period; the same 10 year out-of-sample period is used throughout.

Source: Nomura Quantitative strategy research
Chart compares the performance of our Market Timing model with learning during the out-of-sample period and without learning, i.e., with the parameters fixed at the end of the in-sample 'training' in October 2004. 
Source: Nomura Quantitative Strategy research
Our confidence measure, which we use to size the positions prescribed by the model, consists of three components:

1. **The diversity of predictions:** How much does the model discriminate between outcomes?
2. **Leaf error:** What is the likelihood of getting it wrong?
3. **Leaf frequency:** How often have we observed this state before?

We combine the three measures of confidence in one overall measure, attaching a 50% weight to leaf frequency and 25% each to the Gini Diversity measure and leaf error, reflecting a more distinct function performed by the former measure than by the latter two. The greater the value of the overall Confidence Measure, which ranges from 0 to 100%, the greater our confidence in the signal and the bigger the size of the position we take.
We can scale views given our confidence

### Performance of the MSCI World model with confidence scaling

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Benchmark</th>
<th>OS strategy</th>
<th>Benchmark</th>
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<td>Vol</td>
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<td>R/R</td>
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<td>Max Drawdown</td>
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<td>-7.70</td>
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<tr>
<td>Calmar ratio</td>
<td>70.89</td>
<td>9.58</td>
<td>114.35</td>
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<tr>
<td>Omega ratio</td>
<td>3.57</td>
<td>1.37</td>
<td>3.93</td>
</tr>
</tbody>
</table>

Source: Nomura Quantitative Strategy research
Using the tree for regional selection

- S&P
- Topix
- Eurostoxx

Equity Risk Premium

Regional Flows

Composite Sentiment Indicator
Using the tree for regional selection

Performance of the S&P model – out of sample

Performance of the Topix model – out of sample

Performance of the Eurostoxx model – out of sample

Source: Nomura Quantitative research
Bringing together the regions

Correlation matrix of the regional model performance

<table>
<thead>
<tr>
<th></th>
<th>Whole sample</th>
<th>Avg PC: 0.1</th>
<th>Out of sample</th>
<th>Avg PC: 0.1</th>
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<td>Eurostoxx</td>
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<td>1</td>
<td>0.0</td>
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</table>

Performance of the equal-weighted strategy – out of sample

Source: Nomura Quantitative research
We use a non-linear ‘cross-term’ factor that models the interaction of factors.

- The functional form of our multifactor model:

\[ r_{i,t:t+\delta} = \alpha + \beta_1 V_{i,t} + \beta_2 M_{i,t} + \gamma \cdot \Phi(V_{i,t} \cdot M_{i,t}) \]

- Certain non-linear interaction functions can have the economic interpretation of measuring agreement.

- Extra complexity should be added only with good reason, but we can show an empirical benefit to such a term.

- To defend against a charge of data mining, we impose an \textit{a priori} functional form that we believe is defendable.

- Non-linear interaction terms also have the benefit of lessening the impact of crowding if it brings together factors in ways that are not usually practiced.

- Model has been published and hence live since July 2009, based on an initial European version first published Sep 2008.
We use a cubic interaction factor as our favoured approach.

Alternative is a discontinuous interaction screen.

Interaction Score

Cheaper

Increasing momentum

Source: Nomura Strategy research
Non-linear global multifactor model: % weights of factors by sector. Result of a learning process

<table>
<thead>
<tr>
<th>Value</th>
<th>Basic Industries</th>
<th>Consumer Cyclicals</th>
<th>Capital Goods</th>
<th>Consumer Staples</th>
<th>Energy</th>
<th>Healthcare</th>
<th>Media</th>
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<td>35</td>
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<td>Div Yld (b'back adjusted)</td>
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<table>
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<tr>
<th>Interaction</th>
<th>(V+M)³</th>
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<th>Capital Goods</th>
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Source: Nomura Strategy research
Performance of Nomura global multifactor model

Dec 91 = 100

<table>
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<tr>
<th>Period</th>
<th>Return, % pa</th>
<th>Annualised monthly volatility</th>
<th>Annualised monthly IR</th>
</tr>
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<tr>
<td>Whole Period</td>
<td>9.0</td>
<td>6.8</td>
<td>1.3</td>
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<tr>
<td>Dec 91 - Jun 04</td>
<td>13.0</td>
<td>8.3</td>
<td>1.6</td>
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<tr>
<td>Jun 04 - Present</td>
<td>4.6</td>
<td>4.1</td>
<td>1.1</td>
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<tr>
<td>July 09 - Present</td>
<td>5.0</td>
<td>4.2</td>
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<tr>
<td>Jan 10 - Present</td>
<td>4.6</td>
<td>4.2</td>
<td>1.1</td>
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Out of sample

Dec 91 = 100

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<thead>
<tr>
<th>Start of Drawdown</th>
<th>Length of Drawdown (Days)</th>
<th>% Fall</th>
</tr>
</thead>
<tbody>
<tr>
<td>10/10/2005</td>
<td>368</td>
<td>-3.1</td>
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<tr>
<td>19/09/2007</td>
<td>135</td>
<td>-2.9</td>
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<td>13/10/2008</td>
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<td>23/04/2010</td>
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<td>-3.4</td>
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Live Period

Value added from non-linearity

Dec 91 = 100

<table>
<thead>
<tr>
<th>Performance during live period</th>
<th>Return, % pa</th>
<th>Annualised monthly volatility</th>
<th>Annualised monthly IR</th>
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</thead>
<tbody>
<tr>
<td>Non-linear model</td>
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<tr>
<td>Linear model</td>
<td>4.3</td>
<td>4.1</td>
<td>1.0</td>
</tr>
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</table>

Relative performance of non-linear and linear versions of our global multifactor model.

Source: Nomura Strategy research
Global multifactor (long-only version)

Absolute return performance (out-of-sample period)

Relative returns performance (out-of-sample period)

Absolute return statistics

<table>
<thead>
<tr>
<th></th>
<th>Return, % pa</th>
<th>Benchmark</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 yr</td>
<td>10.3</td>
<td>8.8</td>
</tr>
<tr>
<td>3 yr</td>
<td>17.5</td>
<td>13.3</td>
</tr>
<tr>
<td>5 yr</td>
<td>14.1</td>
<td>11.6</td>
</tr>
<tr>
<td>Out of sample Period</td>
<td>10.7</td>
<td>7.7</td>
</tr>
</tbody>
</table>

Relative return statistics

<table>
<thead>
<tr>
<th></th>
<th>Return, % pa</th>
<th>Annualised monthly volatility</th>
<th>Annualised monthly IR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 yr</td>
<td>1.4</td>
<td>2.9</td>
<td>0.5</td>
</tr>
<tr>
<td>3 yr</td>
<td>3.9</td>
<td>3.0</td>
<td>1.3</td>
</tr>
<tr>
<td>5 yr</td>
<td>2.5</td>
<td>3.2</td>
<td>0.8</td>
</tr>
<tr>
<td>Out of sample Period</td>
<td>3.0</td>
<td>3.2</td>
<td>0.9</td>
</tr>
</tbody>
</table>

Source: Datastream, IBES, Nomura Strategy research
To combine factors with different information decay times into a common signal, we think there are better approaches than simple linear combinations.

Trees can be used with the information decay time determining the factor order in the tree.

If there are indeed no new accounting factors to be discovered, then we should look for new ways to combine the factors that we have.

There is a case for using non-linear factor combinations in stock selection as well.
Appendix A-1

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STOCKS
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perform in line with the benchmark over the next 12 months. A rating of 'Reduce', indicates that the analyst expects the stock to underperform the Benchmark over the next 12 months. A rating of 'Suspended', indicates that the rating, target price and estimates have been suspended temporarily to comply with applicable regulations and/or firm policies. Securities and/or companies that are labelled as 'Not rated' or shown as 'No rating' are not in regular research coverage of the Nomura entity identified in the top banner. Investors should not expect continuing or additional information from Nomura relating to such securities and/or companies.

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