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Diversification of Equity Factors

Hierarchical Clustering for better risk allocation

Diversifying equity exposure when building quantitative factor models can be done in many ways – from a simple equal weighting, or with volatility adjustments, right through to a full mean-variance optimization (we test 10 different weighting schemes in all). No matter the scheme we show that they all seem to benefit by first incorporating the hierarchical cluster relationships between the factors.

Some of the more modern risk allocation techniques like Hierarchical Risk Parity (Lopez de Prado, 2016) and Hierarchical Cluster Parity (Raffinot, 2016) already have this cluster information built in and our tests confirm they tend to do better. But we find that the hierarchical relationship between factors can be included as a preprocessing step with *any* allocation scheme and it almost always improves the model performance (especially for the more naïve ones like equal weighting).

We can introduce this cluster information by applying the risk allocation scheme onto the hierarchical dendrogram at *different distance thresholds* (as shown below). First we test the scheme on the full set of 70 factors, and then as we increase the distance threshold the number of clusters will reduce and we can apply the allocation across the clusters instead. Doing so can remove collinear asset returns and redundant factors and in some scenarios greatly increase the risk adjusted returns (but only up to a point after which the reduced cluster number becomes too coarse to fully represent the exposures present in the original returns set).

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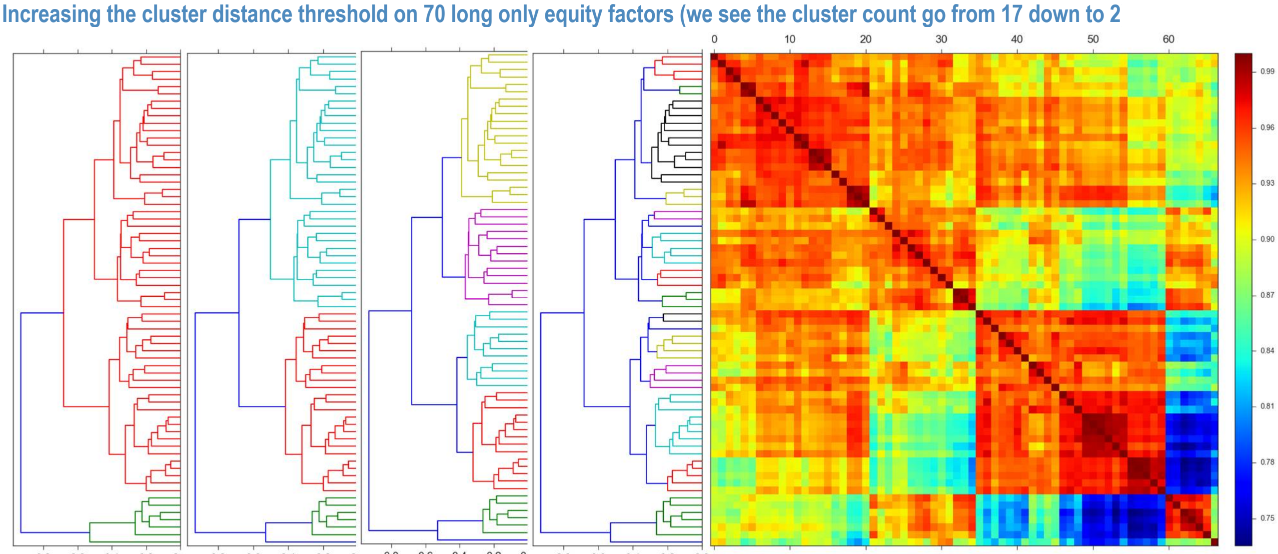
Increasing the cluster distance threshold on 70 long only equity factors (we see the cluster count go from 17 down to 2



Source: J.P. Morgan Quantitative and Derivatives Strategy (QDS)

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Table of Contents

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Diversification of Factors

In this report we investigate the effects of various risk allocation techniques on factors attempting to capture different Equity Risk Premia or Smart Beta. These include the typical more traditional approaches such as Equal Weight, Minimum Variance, and Risk Parity, as well as some more recent additions that incorporate the hierarchical clustering i.e. Hierarchical Risk Parity (HRP) and Hierarchical Cluster Parity (HCP).

The return sets are equity factors coming from the usual Equity Risk Premia families – in all we use 70 of our core factors, in long-only and long-short forms, plus some market hedges (either short the market or the short the beta of Value, Earnings, Momentum and Quality).

We iteratively step through different distance cut-offs of a hierarchical dendrogram to test if there is an optimal cluster count to apply the risk allocation schemes.

The main focus is how the different allocation schemes perform not just across all the single factors, but also across clusters formed at different hierarchical distance thresholds. We make a stepped scan of the hierarchical structure of the clusters with the allocation schemes applied to the clusters at every step (see the front cover diagram).

In general we note that as we reduce the asset count by allocating grouping more factors into clusters and THEN applying the risk allocation scheme, we get better risk/return profiles up to a point. The added benefit is a simplified portfolio construction as there are fewer assets to consider and manage.

Clustering is already embedded in the HRP and HCP approaches, but we show how it can also be added to any other weighting schemes as a preprocessing step to improve performance and it almost always does to some degree. We explore the pros and cons of the different approaches applied before and after clustering.

We find that almost all risk allocation schemes can benefit from first clustering the single factors.

In both MSCI GEM and GDM we conclude that clustering before applying most risk allocation techniques can improve risk adjusted returns. We see it removes redundant exposures that can unfairly bias the allocation when applied across all the single assets. This is especially the case for some of the simpler allocation schemes like Equal Weight and Inverse Vol.

Our favoured approach is to use HCP with cluster weights adjusted for volatility.

Our preferred approach is to use inverse vol but at the cluster level by taking into account hierarchical distance as well. We call this Cluster Risk Parity (CRP) and it is essentially the HCP approach but adjusted for cluster variance. HRP adjusts for variance but does not take into account cluster size or distance between clusters.

We also explore alternative ways to implement each clusters return i.e. not just the average of the returns across the cluster membership. For example we could choose the best performing factor in each cluster, or perhaps the most liquid or best Value spread. In general doing this also boosts performance.

Lastly we test an expected return momentum overlay on the cluster selection and see that it significantly improves risk adjusted returns. This can be done through Mean Variance Optimization, and we also test the Term Structure weighting scheme as described in our report "Mitigating Equity Index Risk Using Term Structure of Price Momentum".

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Static is really Dynamic

Allocating across equity factors to extract risk premia is a key part of quantitative investing in equities. Static weighting is often proposed as a simpler and diversified approach however it does not take into account concentrations of exposures can build up as some factors 'change their spots' through time.

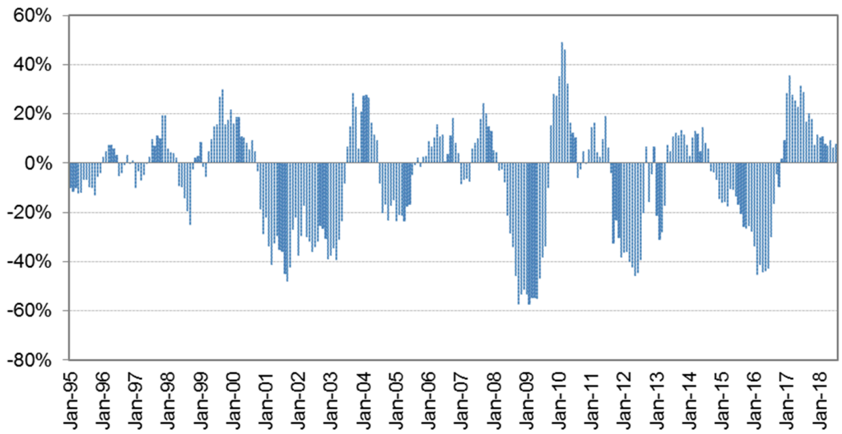
Probably the most effected factors are those in the momentum family. At some points in the cycle they are more like high beta factors (such as Value) and at other points more like low beta factors (like Quality).

Ironically, an equal weight to Momentum, Quality and Value in fact will give us a dynamic loading between Quality and Value depending on the market cycle.

Pairwise correlations between factors can vary greatly through time.

Price Momentum is probably one of the worst affected because of its dynamic (trending) nature. Not only that but it's a popular factor simply due to its potency.

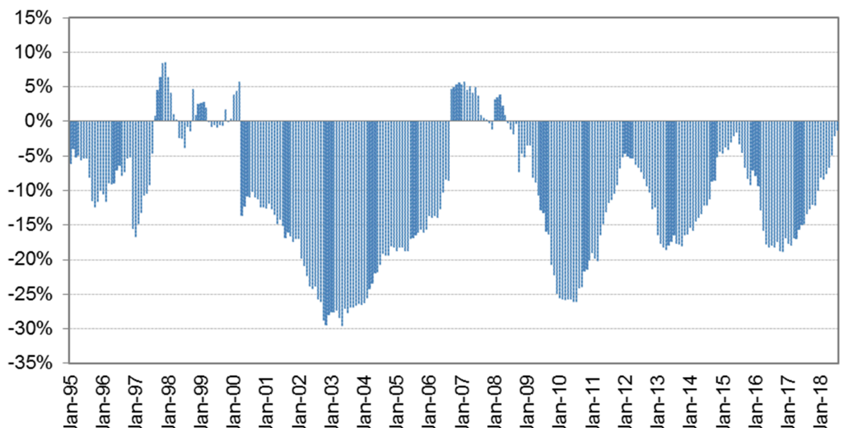
Figure 1: Pairwise correlations between 12-month Price Momentum and Beta through time



Source: MSCI, Factset, J.P. Morgan QDS

We would like to dynamically adjust both traditional and modern weighting schemes to allow for these correlation changes.

Figure 2: Pairwise correlations between ROE and Beta through time



Source: MSCI, Factset, J.P. Morgan QDS

In this report we take a look at the pairwise correlation between 70 or so quantitative equity factors in MSCI GDM and MSCI GEM. We use a hierarchical clustering approach to explore ways to make risk allocation and diversification across these factors more robust.

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Our approach

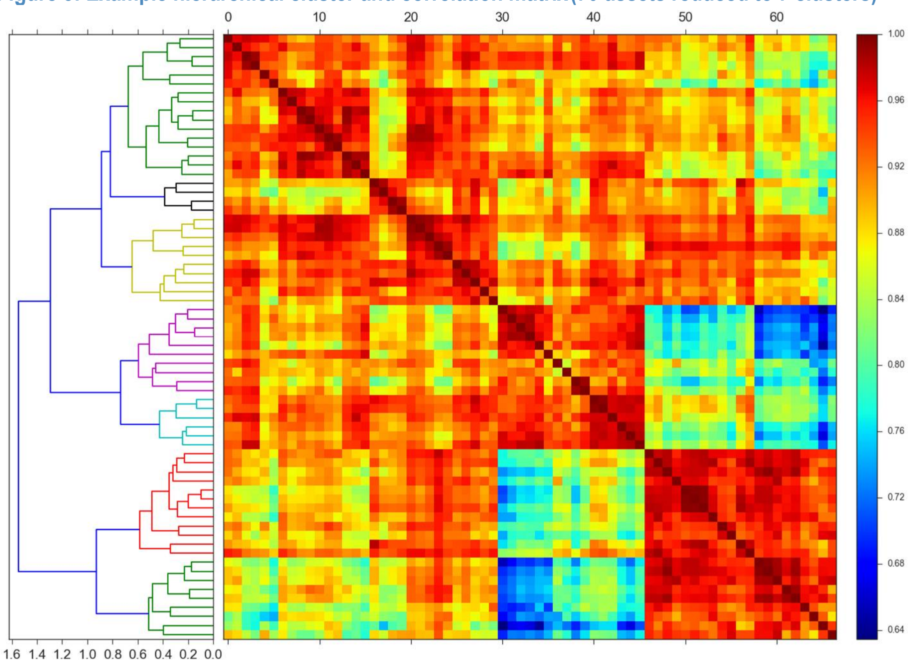
We will take a look at ten different weighting schemes and demonstrate how in general they can all be improved by first finding the hierarchical clusters, and *then* weighting the clusters. The approach is fairly robust to the parameters used in the pair-wise correlations or the clustering technique.

The clusters can be formed aggressively or mildly by changing the threshold for dendrogram cutoff and we will explore the sensitivity of the results to this parameter in particular.

Instead of allocating to each and every single asset (~70 in this example) we allocate to the clusters at a certain distance threshold (7 in this example).

The cluster returns can be implemented through a simple average or for better performance and easier implementation a single asset selection strategy within each cluster could also be used (i.e. performance, volatility, liquidity or value driven).

Figure 3: Example hierarchical cluster and correlation matrix (70 assets reduced to 7 clusters)



Source: J.P. Morgan QDS

Our main measure of the success of the technique is risk-adjusted returns. But the approach also benefits from:

- Better handles collinearity as it removes the effects of redundant assets that are effectively the same as others. This can also help remove pre-selection bias for a universe of assets in more naïve weighting schemes;
- Includes more information about the hierarchical structure which can be used to make more informed asset substitution decisions;
- Flexible in implementation so we can get performance boosts on asset selection within each cluster;
- Can make implementation simpler (less assets to manage); and
- Fewer assets make any optimization process much faster to run.

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Weighting schemes

The goal of risk-based allocations lies in the concept of diversification: Since we do not have an idea of expected returns, we would rather focus our attention to either minimize and/or diversify risk. As highlighted in Jean-Charles et al (2015), one can define different measures of diversification, and each measure could lead to a particular risk-based portfolios. For instance, an equal-weighted portfolio diversifies in terms of asset weights; a portfolio built to have equal risk contributions diversifies in terms of risk budgets, etc.

These are the different weighting schemes we tested both on the individual factors as wells as the cluster groups. None of them require any forward return estimation except for the Mean Variance optimization and the Term Weighting approach.

Equal Weight (EW)

All assets have the same weighting which is 1 / N (number of assets). This is the simplest allocation but a useful benchmark no less.

Inverse Vol (IV)

This strategy allocates weights inversely proportional to asset volatility (we use the variance). It is a "naïve" form of risk parity which does not take into account correlations. This aligns with the approach used in Hierarchical Risk Parity by Lopez de Prado (2016).

Hierarchal Risk Parity (HRP)

Lopez de Prado (2016) introduced a new and interesting idea of allocation called Hierarchical Risk Parity. It is termed "Hierarchical" because it makes use of the hierarchical clustering algorithm to assign assets into similar groups, and then apply the (naïve) Risk Parity allocations recursively across asset groups. As such, HRP also considers correlations among assets instead of simply looking at asset volatilities. Actually, rather than trying to improve upon the naïve Risk Parity approach, Lopez de Prado (2016) comes up with the idea of HRP so as to improve upon the Minimum Variance strategy.

The rationale behind HRP is to avoid the instability and concentration in Minimum Variance (MV) portfolios that rely on the inversion of covariance matrix, which is problematic when there are highly correlated assets that render the covariance matrix close to singular.

The rationale behind HRP is to avoid the instability and concentration in Minimum Variance (MVP) portfolios that rely on the inversion of covariance matrix, which is problematic when the matrix is close to singular – this happens when there are highly correlated assets. Furthermore, estimations of full covariance matrices could be noisy or spurious, especially when the number of assets is large and the number of observations is relatively small6. HRP comes as a solution to get around the above issues by allocating to clusters of similar assets. For a full overview of the algorithm please refer to our report "Hierarchical Risk Parity: Enhancing Returns at Target Volatility".

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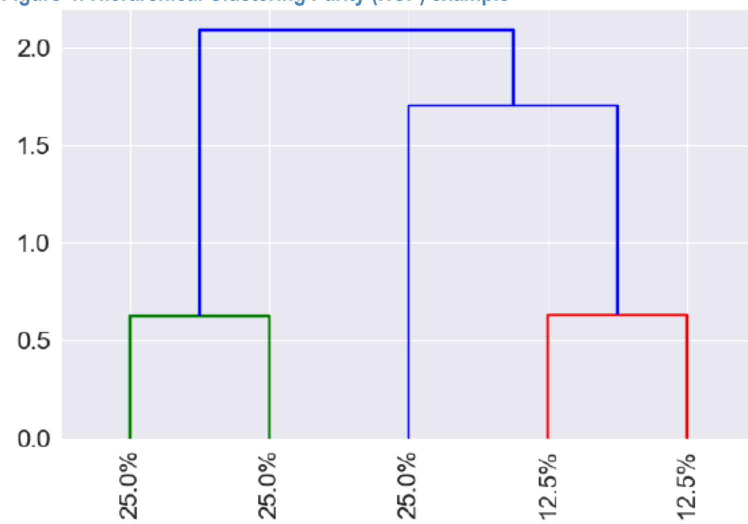
Hierarchical Cluster Parity (HCP)

Another method to create a diversified weighting is to distribute the capital across each cluster hierarchy such that many correlated assets receive the same total allocation as a single uncorrelated one. This idea was recently published by Thomas Raffinot in his paper "Hierarchical Clustering based Asset Allocation".

In the dendrogram are five assets and three clusters. The first cluster is made up of assets 1 and 2, asset 3 constitutes the second cluster and the third cluster consists of assets 4 and 5. Based on the hierarchical clustering, making a split at vertical distance measure of 1.5 (say), the weights for cluster number one is 0.5 (simply a 1/2 = 0.5) and weights for clusters 2 and 3 are 0.25 (0.5/2 = 0.25) each. Since there are two assets in the cluster number one, the final weights for assets 1 and 2 are 25%. Asset 3 has been assigned a weight of 25% while, assets 4 and 5 would get a weight of 0.25 divided equally between them (12.5%).

Figure 4: Hierarchical Clustering Parity (HCP) example



Source: J.P. Morgan QDS, Thomas Raffinot "Hierarchical Clustering based Asset Allocation"

In his paper, Raffinot highlights that complex systems, such as financial markets, have a structure and are usually organized in a hierarchical manner, with separate and separable sub-structures (Simon 1962). The hierarchical structure of interactions among elements strongly affects the dynamics of complex systems.

Raffinot (and Lopez de Prado) notes that correlation matrices lack the notion of hierarchy, which allows weights to vary freely in unintended ways. A correlation matrix makes no difference between assets yet, some assets seem closer substitutes of one another, while others seem complementary to one another.

Cluster Risk Parity (CRP)

This is our preferred approach, in which the cluster weight is determined by the cluster distances AND the variance of the averaged asset returns inside each cluster. This hybrid approach then accounts for cluster size, distance between clusters AND is volatility adjusted.

Minimum Variance (MVP)

Minimum Variance portfolios have a very simple objective, which is to minimize the expected portfolio variance. Such portfolios have been documented to have high out-of-sample returns, especially in equities (Clarke et al 2011). Together with the low volatility (provided that one does not leverage), Minimum Variance portfolios tend to have high information ratios. However, if we look at a very large universe (e.g. hundreds of stocks), the performance of Minimum Variance usually deteriorates. This is largely due to two issues in Minimum Variance portfolios

Sensitivity to inputs: To obtain the optimal weights in an MV portfolio, one has to invert the covariance matrix. Such inversion makes it very sensitive to the noises in the covariance estimates, especially when there are highly correlated assets that render the covariance matrix close to singular.

Concentrated positions: MV tends to assign concentrated weights to only a few assets, and as such, even within a large universe, the actual uncorrelated number of exposures is low. Concentrated portfolios tend to be more prone to sudden drawdowns and have higher realized volatilities.

Maximally Diversified Portfolio (MDP)

Maximum Diversification (MD): Maximize the diversification ratio (Choueifaty and Coignard 2008), defined as the ratio of weighted volatility to portfolio volatility. An interesting property of the Maximum Diversification portfolio is that all assets have the same positive correlation with the portfolio. This is intuitive, because if one asset has a higher correlation with the portfolio, that asset is deemed to be “over-represented”. We will then increase the diversification ratio by decreasing the weight of that asset, hence its correlation with the portfolio will decrease – see Choueifaty et al (2011) which provides more insightful analysis on the properties of this Most Diversified portfolio.

Mean-Variance Optimization (MVO)

The Markowitz's Mean-Variance Optimization (MVO) also requires expected returns so it is not quite the same as the pure risk allocation methods but we wanted to examine it regardless. Mean-Variance analysis trades off risk against expected return and we aimed to maximize the Sharpe ratio in the portfolio.

Equal Contribution to Risk (ECR)

This strategy assigns weights so that all assets have the same contribution to total portfolio risk (Maillard et al 2010). If Total Risk Contribution (TRC) is the proportion of risk of an asset contributed to the final portfolio volatility, then a strategy with Equal Risk Contribution means that risk budgets (i.e. TRC) are equal for all assets.

Term Weighting (TW)

This is a momentum overlay using the differing look back periods for momentum. The term weightings we use are 25% allocation per 4 different lookback periods – 1, 3, 6 and 12 months. The way it works is that if all 4 lookback periods have positive returns, then the weight is 100%. If no lookback period had a positive return then the allocation weight to that asset is 0%. Partial allocations of 25%, 50% and 75% are then possible too.

Please see our report “Mitigating Equity Index Risk Using Term Structure of Price Momentum” for a full overview of this approach.

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Assumptions

We tested various parameters for the pairwise correlations and clustering process.

Look back period

We tested *12, 36 and 60 month* look back periods for the pairwise correlations. The longer periods were naturally more stable and tended to have better risk-adjusted returns.

Distance metric

We always transformed the correlation matrix into *distances* before clustering using the following:

$$d_{i,j} = \sqrt{(1 - \rho_{i,j})/2}$$

Correlation type

Pearson correlations are the most popular and this is what we used.

Cluster linkages

All our clustering was done using Python's Sci-Kit Learn package.

We are only looking at Hierarchical Agglomerative Clustering (HCA) methods (see our report "Dynamic Cluster Neutralisation in Global Equity Markets") so that we can scan the dendrogram and examine clusters at different thresholds. This is a "bottom up" approach: each observation starts in its own cluster and pairs of clusters are merged as we move up the hierarchy.

Cluster linkage methods for the HAC tested were:

- Single (minimum distance between members of the clusters) – a drawback of this method is that it tends to produce long thin clusters in which nearby elements of the same cluster have small distances. Clusters do not merge readily at lower distance thresholds.
- Complete (maximum distance) – looking for the largest difference between all members of joined clusters.
- Average (unweighted pair group simple average distance across all members) – typically we had the best results with this method.
- Ward (finds the next pair of clusters to merge that leads to minimum increase in total within-cluster variance after merging) – this techniques produces clusters with small distances between them nearer the leaves, but large distances further up the branches. Equal step sizes up the hierarchy tend to reduce the cluster numbers too quickly.

See Appendix III for examples of their structures.

Cluster Returns

To start we simply *average* the returns of all factors in each cluster. Later in this report we demonstrate the effects of using other criteria to form the returns – see the section 'Best in Cluster'.

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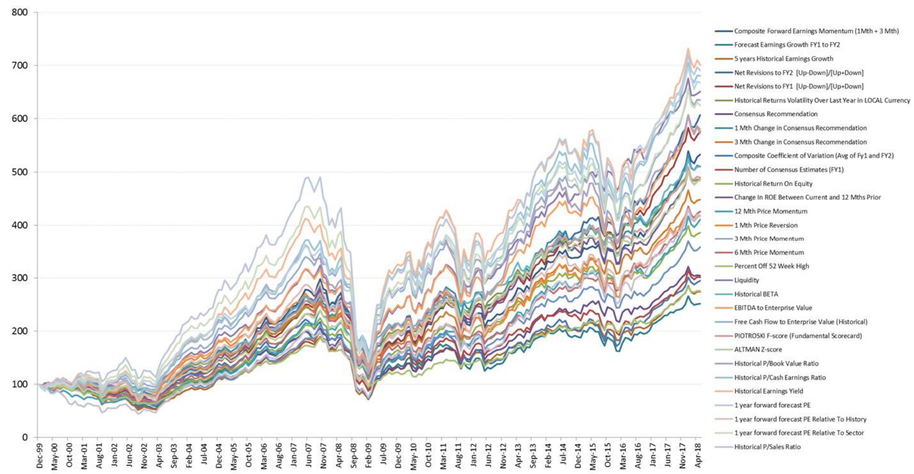
Backtests

Our test assets are equity factors representing various equity risk premia. We look at MSCI GDM and MSCI GEM separately. Below are performances of the last ~20 years of a sample selection from the full suite of 67 factors we tracked.

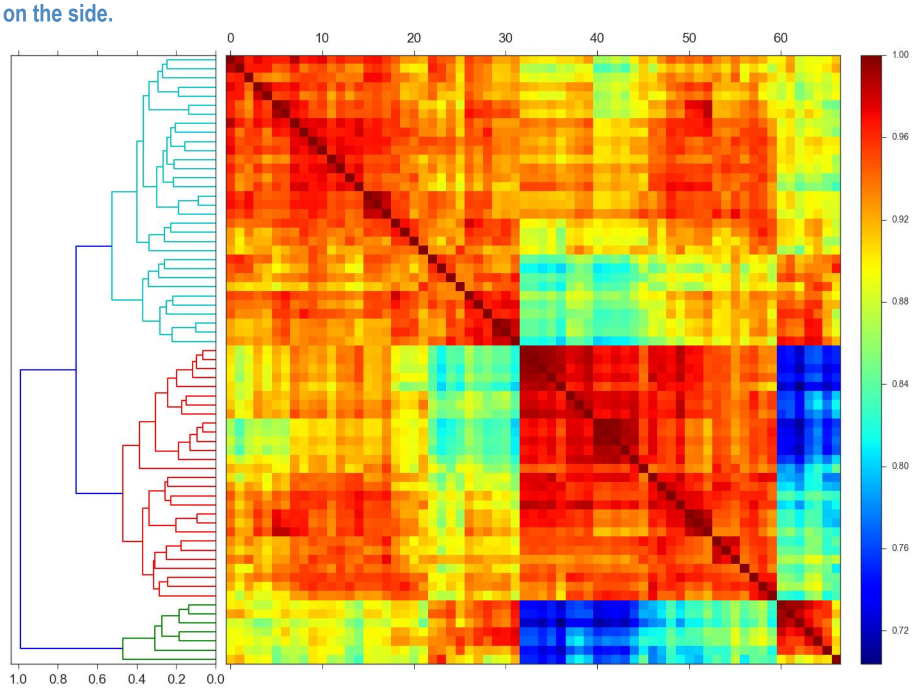
The test period runs monthly from January 2000 to May 2018.

Figure 5: MSCI GDM, Long Only Factor performance – the market beta effect can be clear see on each factor



The pairwise correlations of these LO factors look like this – with hierarchical clustering shown on the side.

Note these are Long Only and so have a significant market beta exposure. Hence the correlations are broadly 75% or more.



Source: MSCI, Bloomberg, Factset, J.P. Morgan QDS (Clusters on 36 months correlations, Average method)

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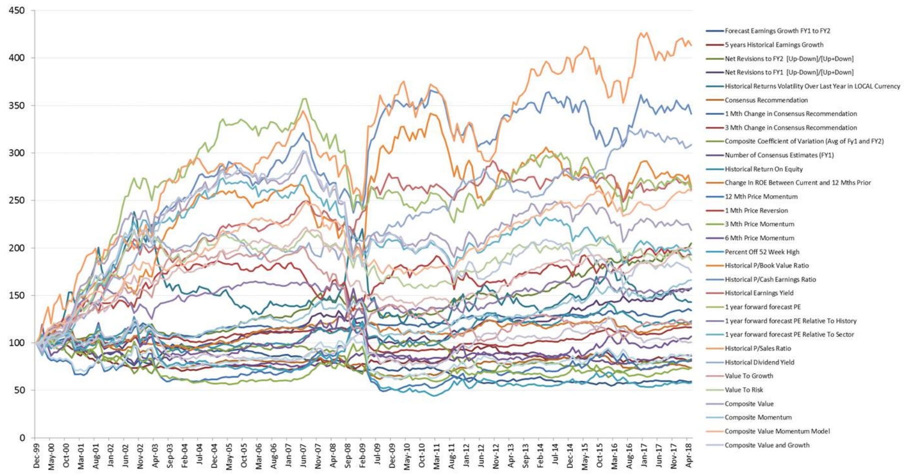
We also want to look at the long-short space which is commonly used with equity factors – see the chart below.

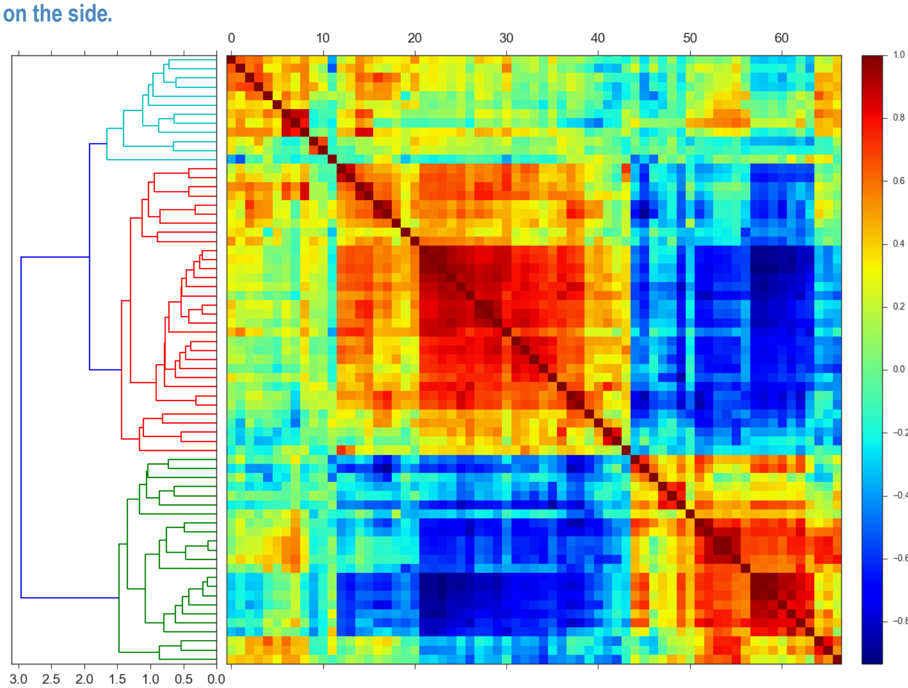
Note how with the Long-Short factors the distance between clusters is on average 3x that of the Long-Only.

Much more diversification is possible when available asset return correlations are negative.

Figure 6: MSCI GDM, Long Short Factor performance – we have neutralized the market beta somewhat by being long-short



The pairwise correlations of these LS factors look like this – with hierarchical clustering shown on the side.



Source: MSCI, Bloomberg, Factset, J.P. Morgan QDS (Clusters on 36 months correlations, Average method)

A final test we run will be again looking at the Long-Only factors but with some smart beta hedges. This will help demonstrate the benefits of the approach even more in a scenario where some correlations are negative.

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Equal weight

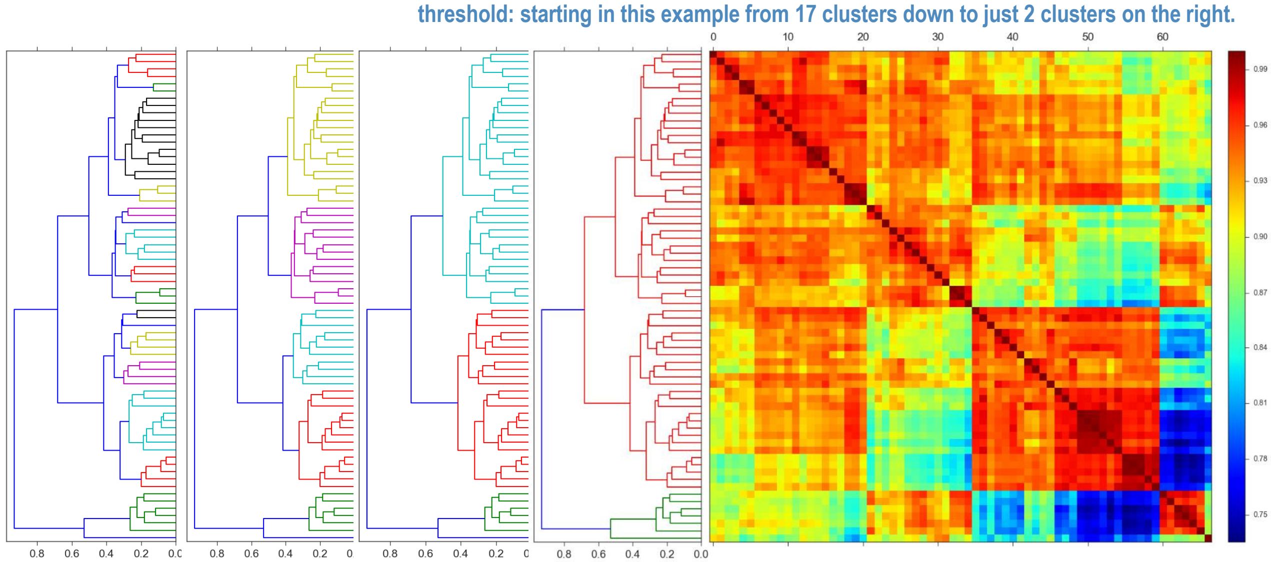
If we were to equal weight the risk premia shown above, it would look something like this below. Of course this is probably the simplest and most naïve approach and it is prone to survivorship bias as we have pre-selected these factors over many years of working with them, but it serves as a handy benchmark.

Figure 7: Equal weight exposure to all Long Only factors, MSCI GDM

Source: MSCI, Bloomberg, Factset, J.P. Morgan QDS

If we cluster the factors before applying the weighting, then we can allocate the equal weighting to each cluster. We can run the sensitivities to the cluster distances by gradually increasing the distance threshold as shown below.

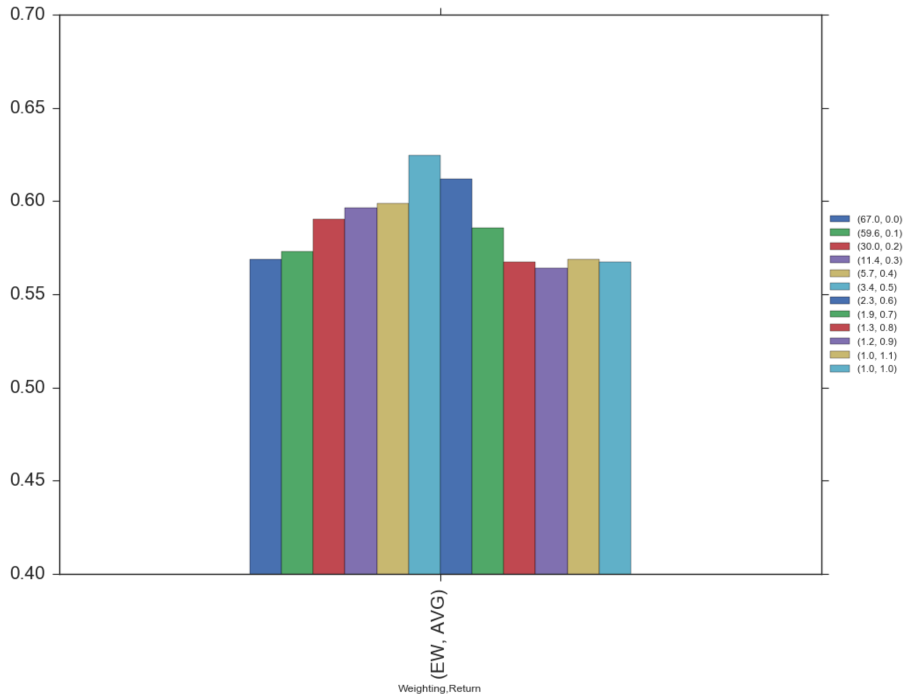
Figure 8: Correlation clusters on the 67 Long Only factors in MSCI GDM – increasing the distance threshold: starting in this example from 17 clusters down to just 2 clusters on the right.



Source: MSCI, Bloomberg, Factset, J.P. Morgan QDS (Clusters on 60 months correlations, Average method)

A subtle effect occurs as we increase the distance thresholds: collinear factor returns are averaged which effectively removes them from the returns set. This allows more even weight to be given to the actual factor exposures present and not just across whatever factor selection happens to be thrown into the pot. This works up until a point of course, after which the number of clusters are too few to capture the set of factor representations present in the returns.

Figure 9: Risk Adjusted returns when using EW on the cluster (distance threshold increases from 0.0 (67 clusters with 1 factor per cluster) to 1.0 (just 1 cluster that contains all 67 factors)



Weight	Return	Distance	AvgN	Sharpe	Ret	Vol	MDD	Hitrate	tStat
EW	AVG	0	67.0	0.57	9.7%	17.0%	(82.3%)	63.0%	2.10
EW	AVG	0.1	59.6	0.57	9.6%	16.8%	(81.9%)	61.7%	2.11
EW	AVG	0.2	30.0	0.59	9.7%	16.4%	(80.7%)	62.3%	2.18
EW	AVG	0.3	11.4	0.60	9.5%	15.9%	(79.1%)	62.3%	2.20
EW	AVG	0.4	5.7	0.60	9.2%	15.4%	(75.0%)	63.0%	2.21
EW	AVG	0.5	3.4	0.62	9.7%	15.6%	(75.7%)	63.0%	2.30
EW	AVG	0.6	2.3	0.61	9.8%	16.1%	(78.8%)	62.3%	2.25
EW	AVG	0.7	1.9	0.59	9.6%	16.4%	(81.7%)	61.1%	2.16
EW	AVG	0.8	1.3	0.57	9.5%	16.8%	(82.1%)	61.7%	2.09
EW	AVG	0.9	1.2	0.56	9.6%	17.0%	(82.3%)	61.7%	2.08
EW	AVG	1.1	1.0	0.57	9.7%	17.0%	(82.3%)	63.0%	2.10

Source: MSCI, Bloomberg, Factset, J.P. Morgan QDS

The real benefit is that we can use this approach across all the many and varied risk allocation schemes from Equal Weight to Mean Variance Portfolios – as we show in the next section.

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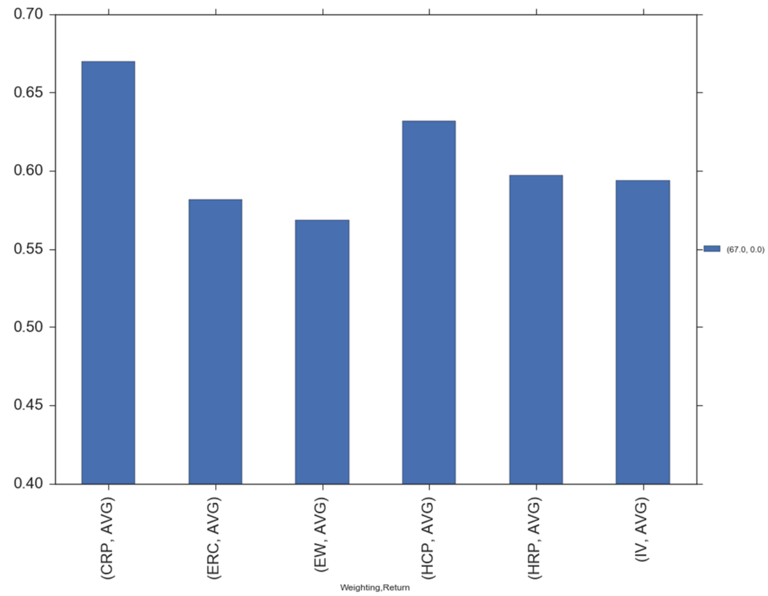
Long Only

We next test all the LO factors, under all the different weighting schemes, and then introduce different cluster distances on the weighting schemes to show the improvements. The distance is increased for each step giving us fewer clusters with larger memberships.

CRP	**Cluster Risk Parity**
ERC	**Equal Contribution to Risk**
EW	**Equal Weight**
HCP	**Hierarchical Cluster Parity**
HRP	**Hierarchical Risk Parity**
IV	**Inverse Volatility**

CRP does the best because it takes into account *both* the volatility and the hierarchy. HRP does this too but does not consider the cluster sizes or distances between them.

Figure 10: Risk adjusted returns of Long-Only factors under different weighting schemes (no clustering), MSCI GDM

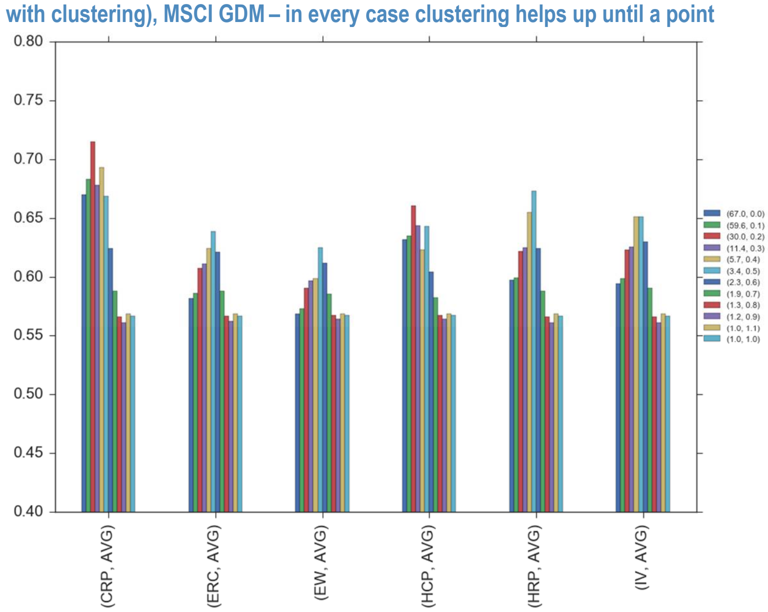


Source: MSCI, Bloomberg, Factset, J.P. Morgan QDS (67 factors in each test)

The benefit is clear: clustering before weighting helps every scheme (up to a point) even when these are highly correlated return sets.

The benefits are even more apparent when the correlations are lower or negative as we will see in the next sections.

Figure 11: Risk adjusted returns of Long-Only factors under different weighting schemes (now with clustering), MSCI GDM – in every case clustering helps up until a point



Source: MSCI, Bloomberg, Factset, J.P. Morgan QDS; Cluster scheme: Average method on 60 month distance matrix (0.0 to 1.1 distance thresholds with 1 factor to 67 factor member counts respectively)

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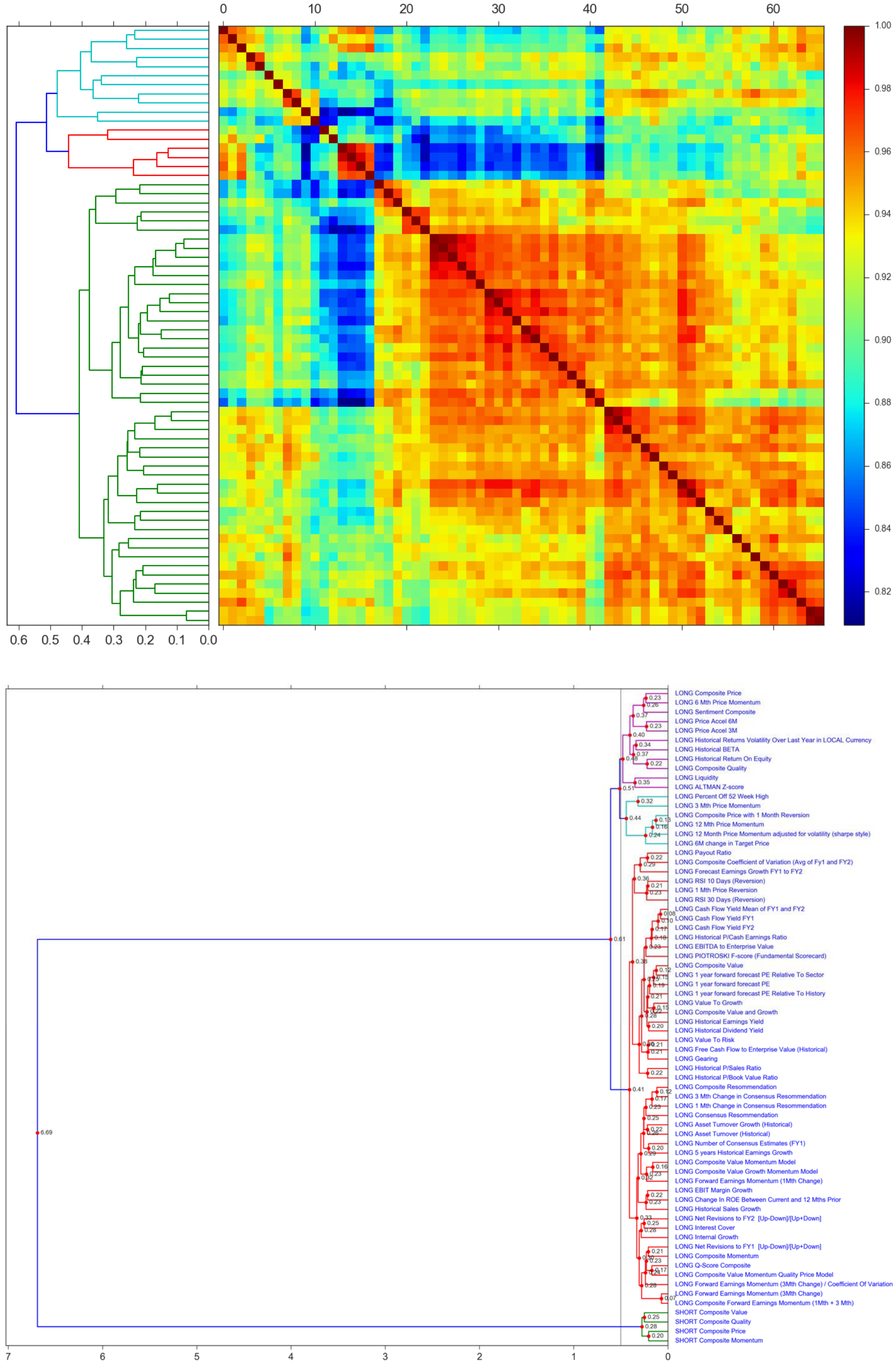
Inverse Volatility

In this section we use GEM long only factors with some smart-beta hedges (with negative correlations). We cluster the factors before applying the inverse volatility weighting and test the performance gained by gradually increasing the distance threshold.

We can add some hedges to better demonstrate the effects of clustering on the weighting schemes.

The hedges are much further away in distance and so will remain in their distinct cluster for longer. This allows even the more naïve weighting algorithms (such as Inverse Volatility) to better access their hedging properties after clustering.

Figure 12: Correlation matrix and dendrogram for GEM long only factors



Source: MSCI, Bloomberg, Factset, J.P. Morgan QDS

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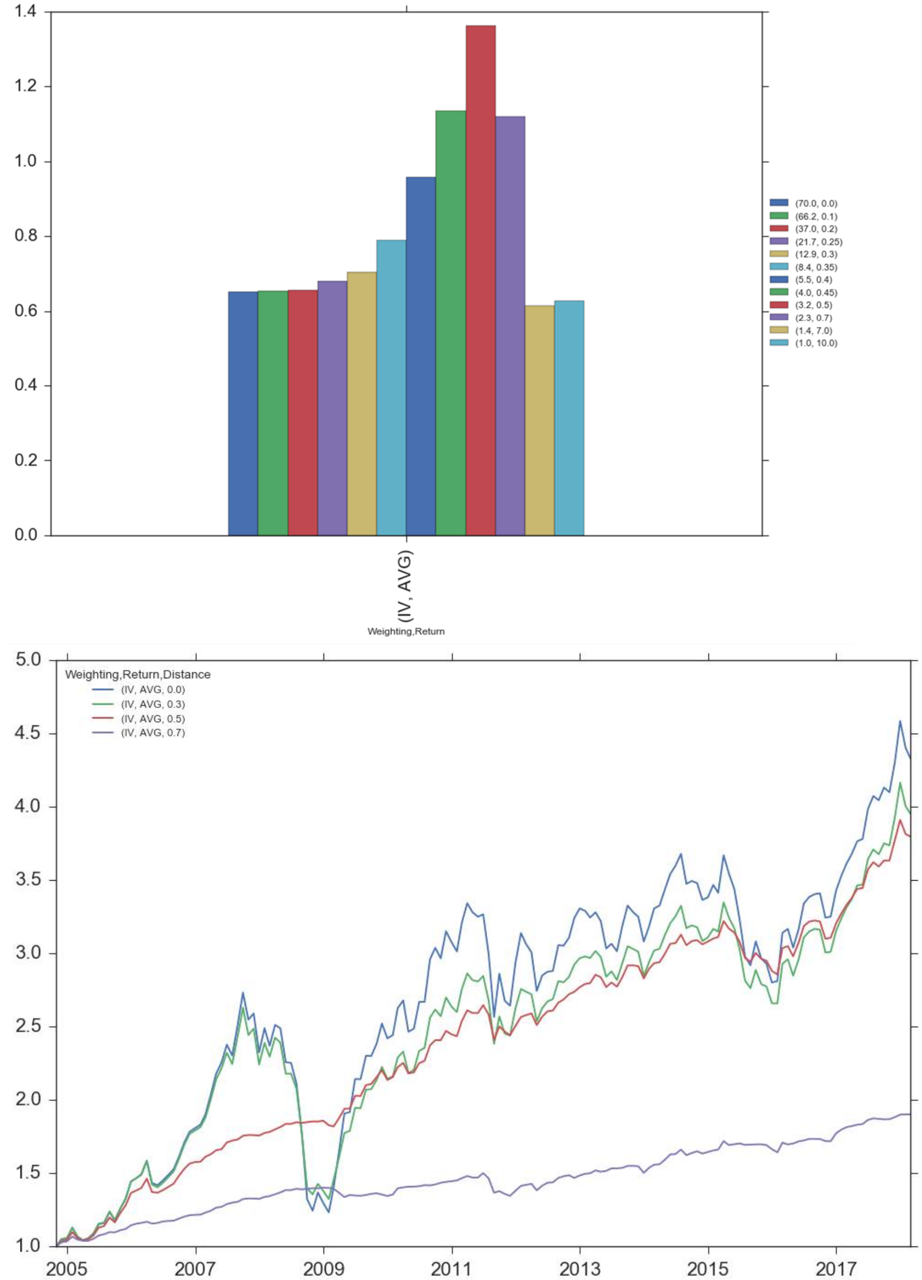
Clearly the performance improves if we use the clusters instead of the single factors as shown in the performance charts.

Figure 13: Risk adjusted and cumulative returns using the Inverse Volatility weighted exposure to various clusters combinations in MSCI GEM



Source: MSCI, Bloomberg, Factset, J.P. Morgan QDS

The benefit of using IV weighted clusters improves as the Hedge cluster becomes more dominant (i.e. when the cluster count comes down and only up to a point). We are introducing the cluster information explicitly into the IV weighting. Compare this with HCP and HRP in the next section which have the cluster structure built into their weighting schemes and so do better at the outset before any clustering.

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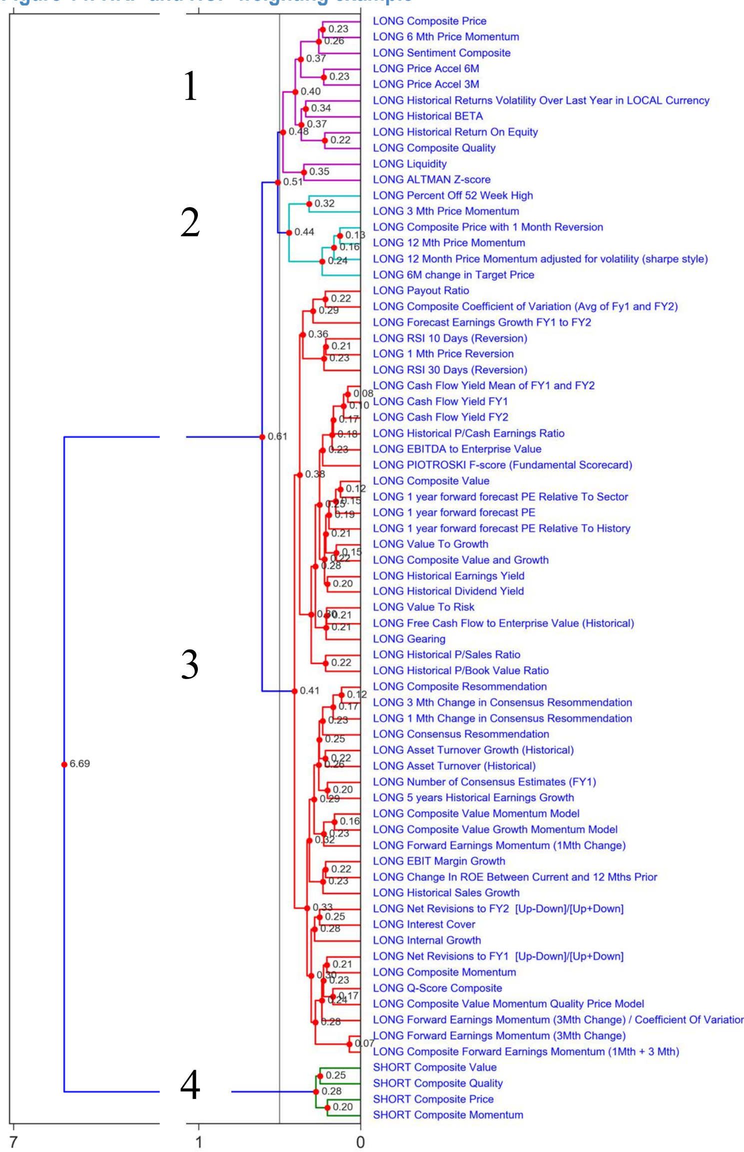
HCP and HRP

This time we apply the HCP and HRP to the GEM long only factors with hedges. These two techniques are special as they directly involve the cluster hierarchy in the weighting scheme. What we observe is they start already strong and don't benefit as much by subsequent clustering – although there is still an improvement.

HCP has the highest weight of 50% to cluster 4 because it is furthest away from the other LO factors, with only one branch split to the top. The other branch shares 50% between clusters 1, 2 and 3 according to the number of branch splits (12.5%, 12.5% and 25% respectively).

HRP uses recursive bisection to allocate weights according to the cluster volatility. The four clusters are firstly split 1 & 2 vs 3 & 4. Because 3 & 4 includes the Hedge cluster its combined volatility will be very small giving it the bigger weight. Then each component cluster is allocated a volatility adjusted weight and because cluster 3 has less standard deviation than cluster 4 it will have a higher weight. Similarly clusters 1 and 2 divide their share and cluster 1 has lower vol and so a higher weight than cluster 2.

Figure 14: HRP and HCP weighting example



Cluster	Count	EW	HCP	HRP	Std Dev
1	11	25%	12.5%	3.8%	3.7%
2	6	25%	12.5%	2.5%	3.9%
3	49	25%	25%	56.7%	4.7%
4	4	25%	50%	37.0%	5.0%

Source: J.P. Morgan, MSCI, Factset, Bloomberg

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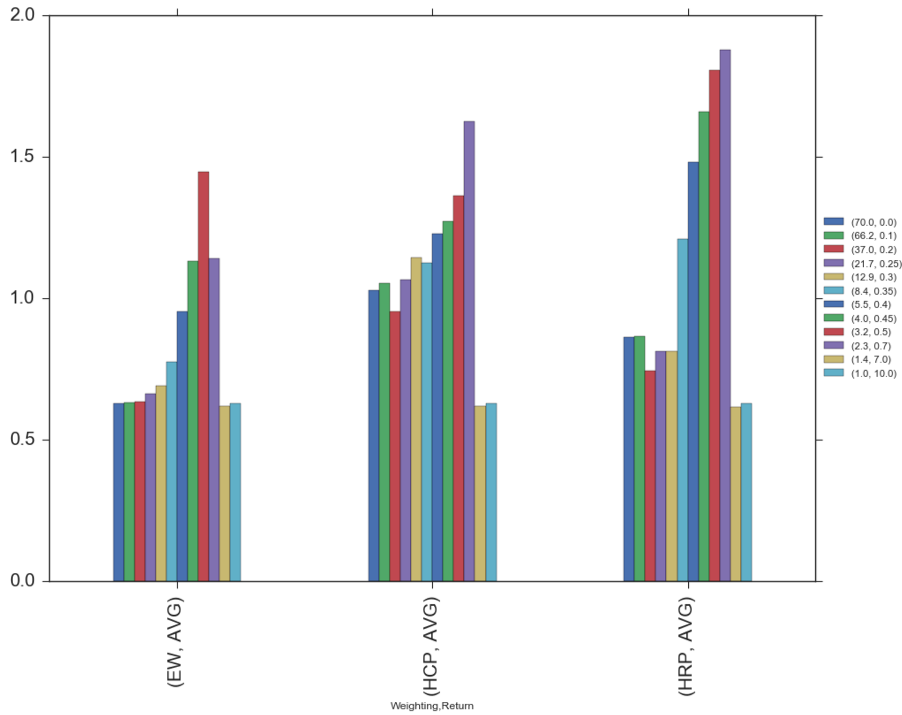
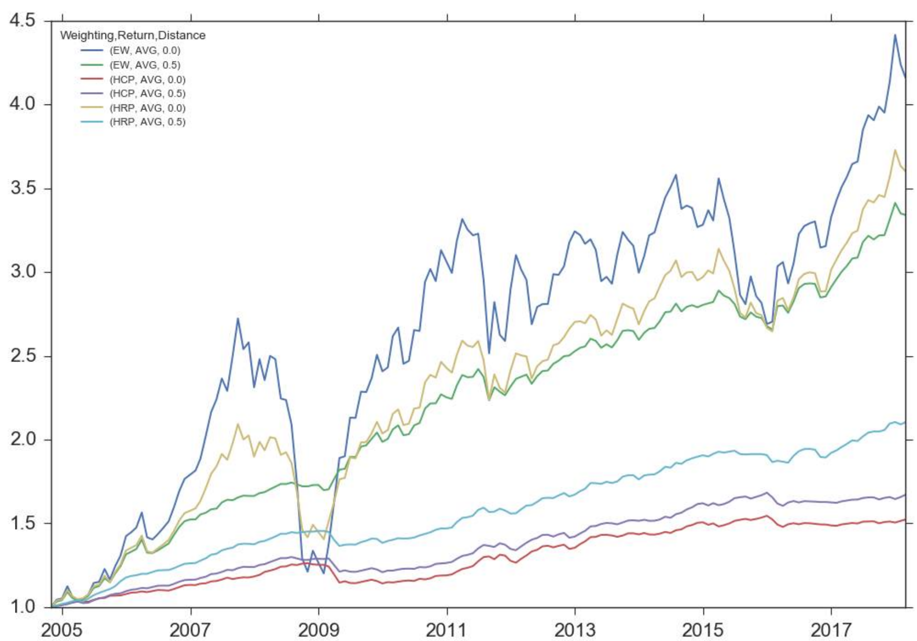
Figure 15: HCP and HRP weighted exposure to various cluster formations in MSCI GEM





Source: MSCI, Bloomberg, Factset, J.P. Morgan QDS

In summary, HCP and HRP have the cluster structure built into their weighting schemes which puts them in a better position right away to exploit the pairwise distances between the LO factors and the hedges (due to the negative correlations). However they also still benefit from factor grouping via increased clusters sizes.

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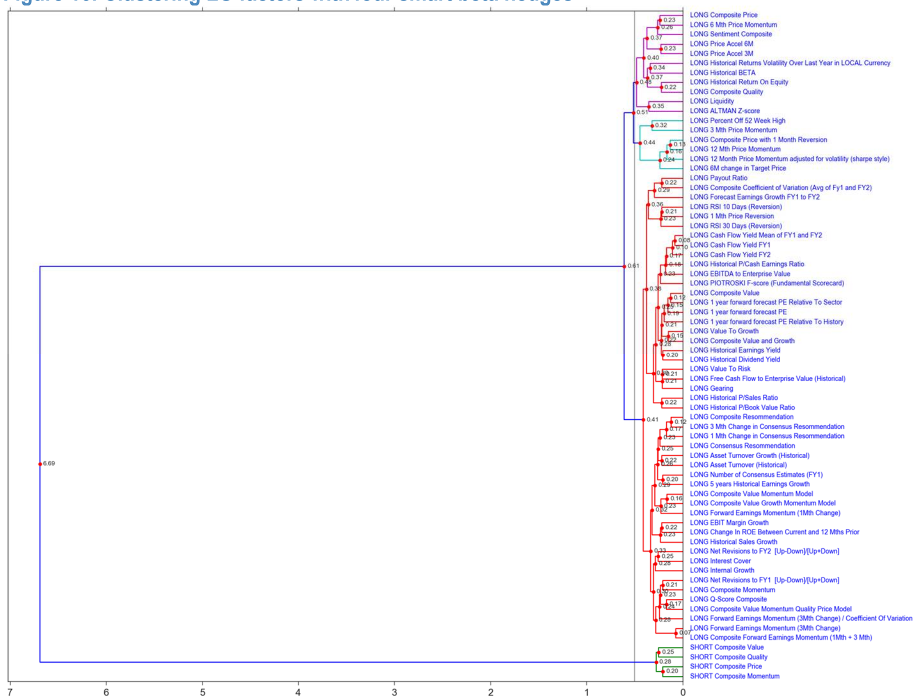
Long Only with Hedges

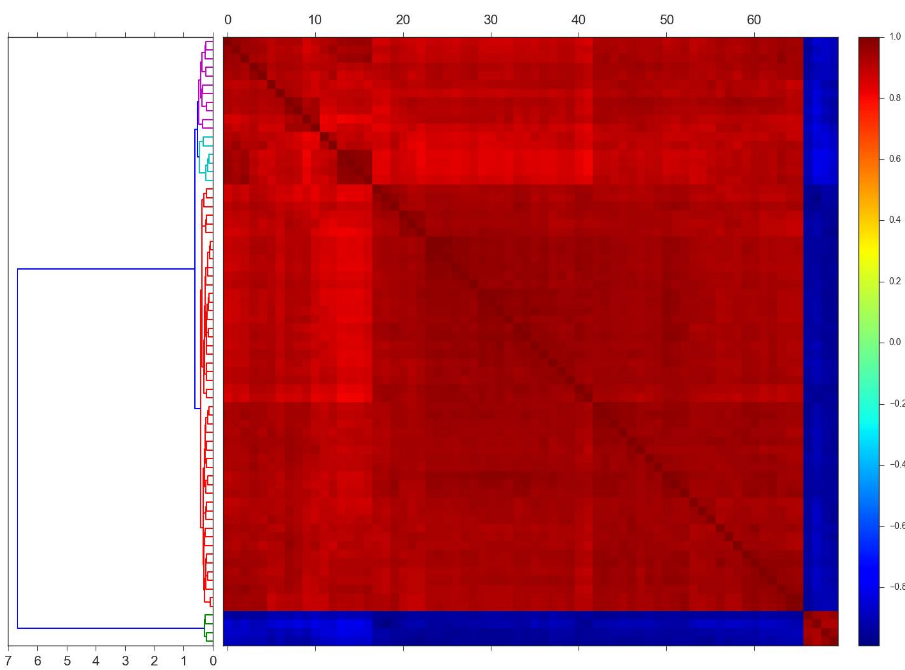
Again we take the GEM LO factors and with the smart beta hedges under different weighting schemes. The hedges are the short legs of the Momentum, Value, Quality and Earnings smart-beta composites.

The correlations between the LO factors and Hedges are negative so the distance measure has them very far apart.

Figure 16: Clustering LO factors with four smart-beta hedges



The correlations are extreme with the LO vs Hedges at near -1.0



Source: MSCI, Bloomberg, Factset, J.P. Morgan QDS (67 factors in each test); Correlations are on 60mnths, Average method clusters

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The best result is with the CRP allocation scheme which is volatility adjusted HCP. It has the advantage of using both the hierarchical cluster distances AND adjusts for volatility.

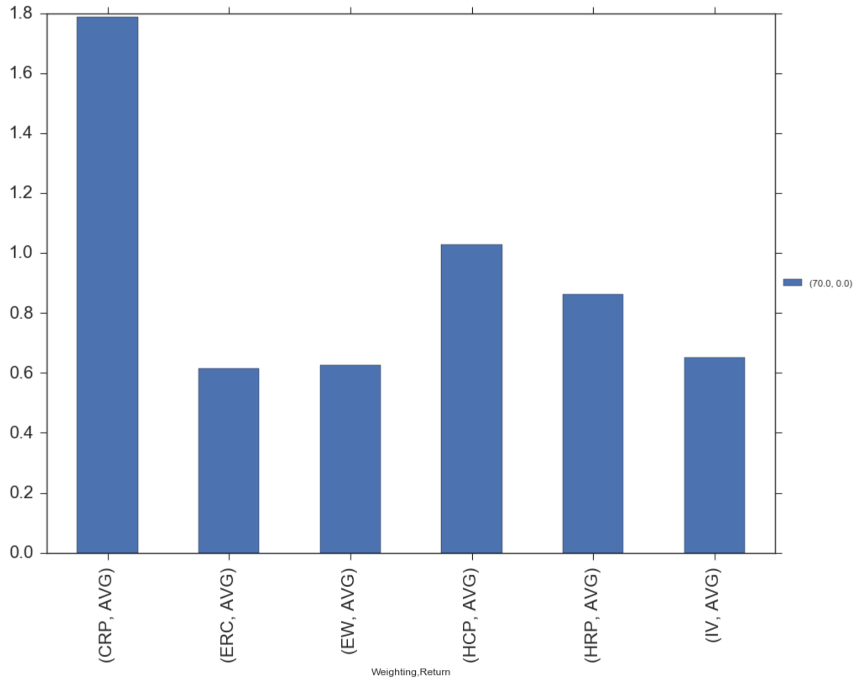
CRP Cluster Risk Parity
ERC Equal Contribution to Risk
EW Equal Weight
HCP Hierarchical Cluster Parity
HRP Hierarchical Risk Parity
IV Inverse Volatility

Cluster Risk Parity can use both the hierarchical distance AND the volatility.

HCP does not use any volatility adjustment.

HRP does adjust for volatility, but the distance information is more coarsely applied using recursive bisection after ordering by distance between assets, and not directly on the clusters (i.e. it ignores cluster sizes).

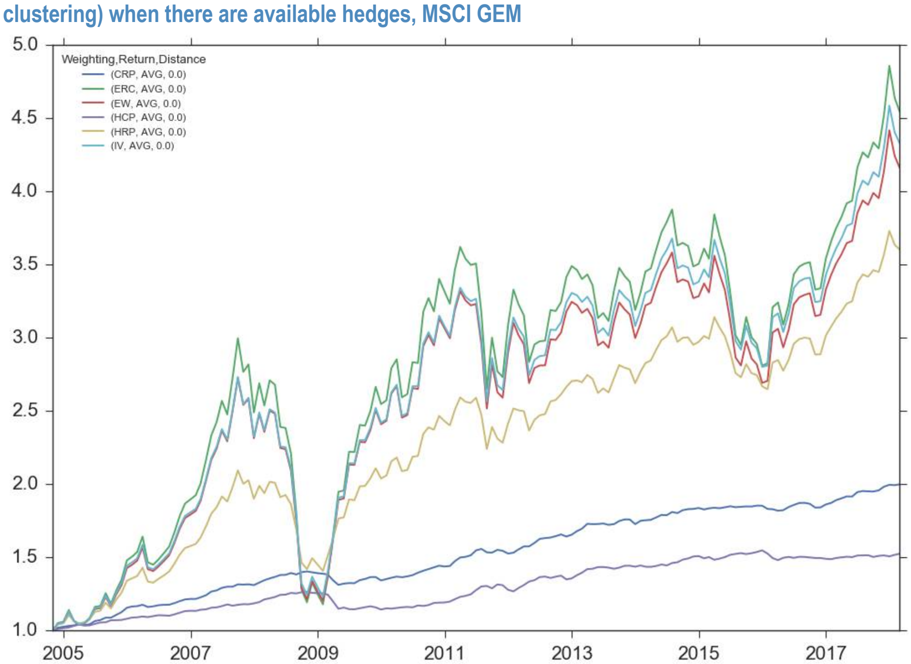
Figure 17: Risk adjusted returns of Long-Only factors under different weighting schemes (no clustering) when there are available hedges, MSCI GEM



Source: MSCI, Bloomberg, Factset, J.P. Morgan QDS (67 factors in each test); Correlations are on 60mnths, Average method

The CRP and HCP are able to allocate 50% to the Hedges because of how far they are from the LO returns. HRP can also to a lesser degree because the hedge distances are only applied through recursive bisection.

Figure 18: Cumulative returns of Long-Only factors under different weighting schemes (no clustering) when there are available hedges, MSCI GEM



Source: MSCI, Bloomberg, Factset, J.P. Morgan QDS (67 factors in each test)

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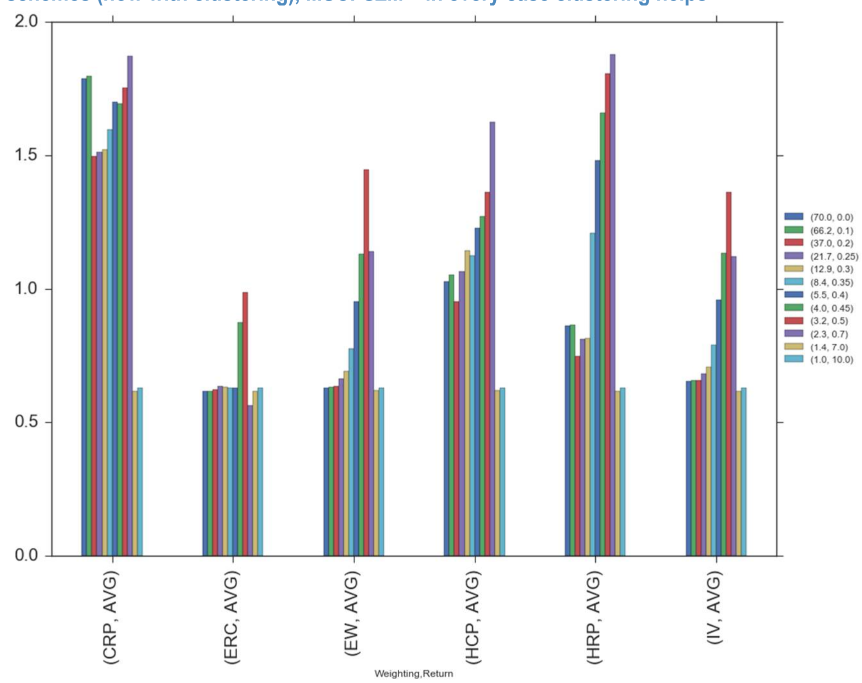
In every allocation scheme, forming clusters beforehand can improve the risk adjusted returns as shown in the chart below. Beyond a point however, the clusters become unable to adequately reflect the risk premia contained in the factors.

Figure 19: Risk adjusted returns of Long-Only factors and Four Hedges under different weighting schemes (now with clustering), MSCI GEM – in every case clustering helps



Weight	Return	Distance	AvgN	Sharpe	Ret	Vol	MDD	Hitrate	tStat
CRP	AVG	0	70.0	1.79	5.2%	2.9%	(6.7%)	73.8%	6.54
CRP	AVG	0.25	21.7	1.51	4.8%	3.2%	(9.2%)	71.9%	5.54
CRP	AVG	0.4	5.5	1.70	5.3%	3.1%	(6.9%)	73.8%	6.23
CRP	AVG	0.5	3.2	1.75	5.3%	3.0%	(6.8%)	73.8%	6.42
ERC	AVG	0	70.0	0.61	14.1%	22.9%	(82.4%)	61.3%	2.25
ERC	AVG	0.25	21.7	0.63	13.7%	21.5%	(81.0%)	61.3%	2.33
ERC	AVG	0.4	5.5	0.63	13.3%	21.2%	(84.0%)	62.5%	2.30
ERC	AVG	0.5	3.2	0.99	17.0%	17.2%	(28.0%)	64.4%	3.62
EW	AVG	0	70.0	0.63	12.9%	20.6%	(73.1%)	61.3%	2.29
EW	AVG	0.25	21.7	0.66	12.3%	18.6%	(69.6%)	61.9%	2.42
EW	AVG	0.4	5.5	0.95	10.9%	11.5%	(31.3%)	63.8%	3.49
EW	AVG	0.5	3.2	1.44	9.3%	6.4%	(8.3%)	71.3%	5.29
HCP	AVG	0	70.0	1.03	3.2%	3.1%	(9.9%)	69.4%	3.76
HCP	AVG	0.25	21.7	1.06	3.3%	3.1%	(9.7%)	67.5%	3.90
HCP	AVG	0.4	5.5	1.23	3.4%	2.8%	(6.5%)	73.1%	4.50
HCP	AVG	0.5	3.2	1.36	3.9%	2.9%	(7.1%)	70.6%	4.99
HRP	AVG	0	70.0	0.86	10.4%	12.0%	(37.4%)	63.8%	3.16
HRP	AVG	0.25	21.7	0.81	9.0%	11.0%	(33.2%)	63.1%	2.97
HRP	AVG	0.4	5.5	1.48	7.0%	4.8%	(5.4%)	68.1%	5.42
HRP	AVG	0.5	3.2	1.81	5.6%	3.1%	(6.3%)	73.8%	6.61
IV	AVG	0	70.0	0.65	13.1%	20.1%	(71.4%)	61.3%	2.39
IV	AVG	0.25	21.7	0.68	12.5%	18.4%	(68.5%)	61.9%	2.49
IV	AVG	0.4	5.5	0.96	11.6%	12.1%	(29.8%)	64.4%	3.51
IV	AVG	0.5	3.2	1.36	10.3%	7.6%	(11.9%)	70.6%	4.99

Source: MSCI, Bloomberg, Factset, J.P. Morgan QDS; Cluster scheme: Average method on 60 month distance matrix (0.0 to 1.1 distance thresholds with 1 factor to 67 factor member counts respectively)

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Cluster weights using optimizations

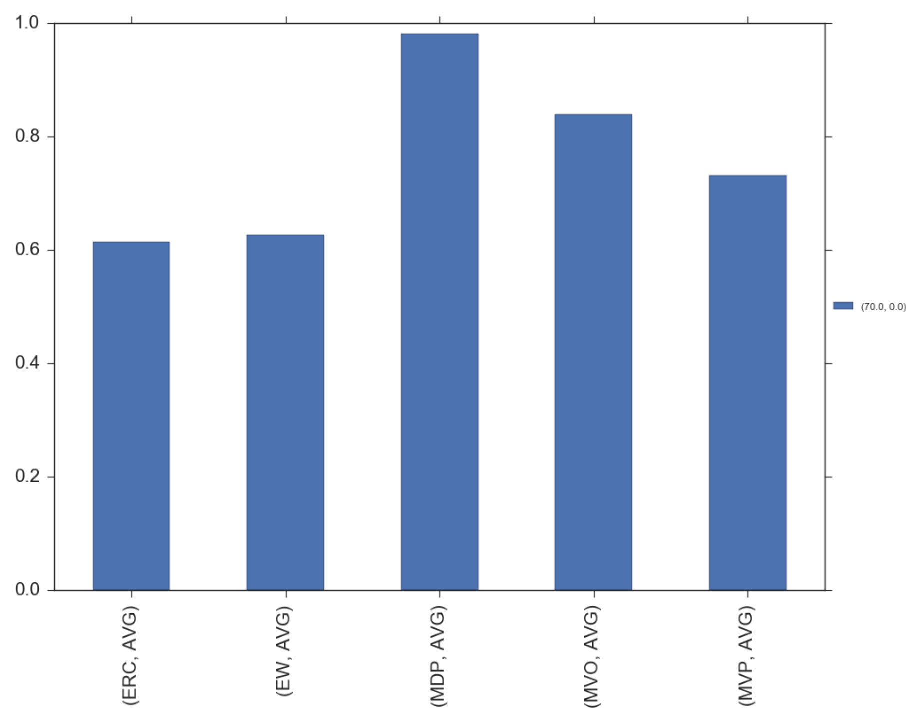
We can also improve the performance of the usual optimized portfolios approaches by using clusters. We tested the following optimization schemes against Equal Weight (EW) again for comparison:

- Equal Risk Contribution (ERC)
- Minimum Variance (MV),
- Mean Variance Optimization (MVO), and
- Maximally Diversified Portfolio (MDP).

We only allowed positive weights in the optimizations and they must sum to one. Additionally we limited the single asset holdings to be a maximum of 3x the equal weight benchmark or else it has a tendency to allocate heavily into single assets.

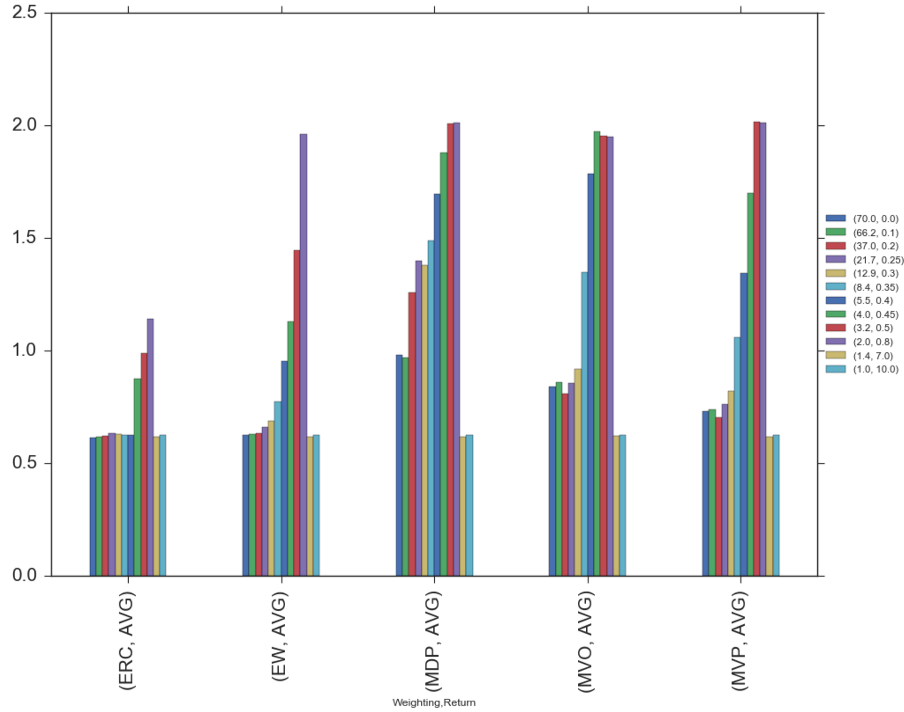
Figure 20: MSCI GEM risk adjusted returns of Long-Only factors and Hedges under different weighting schemes

	Sharpe	Ret	Vol	MDD	Hitrate	tStat
ERC	0.61	14.1%	22.9%	(82.4%)	61.3%	2.25
EW	0.63	12.9%	20.6%	(73.1%)	61.3%	2.29
MDP	0.98	1.3%	1.3%	(3.4%)	60.0%	3.60
MVO	0.84	11.7%	14.0%	(52.4%)	65.0%	3.07
MVP	0.73	11.8%	16.1%	(57.9%)	62.5%	2.68



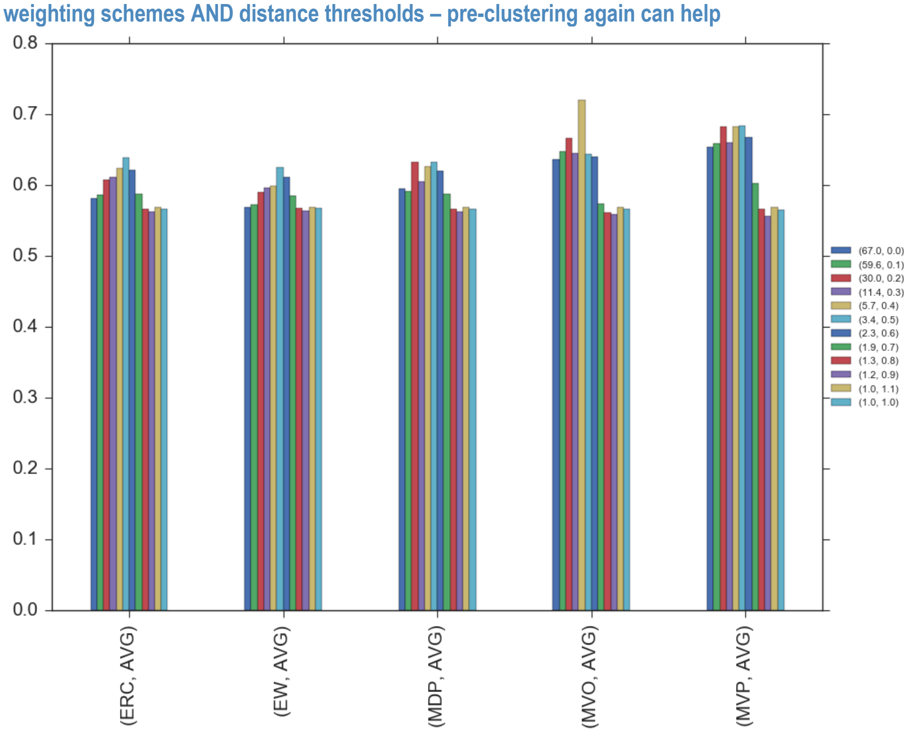
Source: MSCI, Bloomberg, Factset, J.P. Morgan QDS; Cluster scheme: Average method on 60 month distance matrix

Figure 21: MSCI GEM risk adjusted returns of Long-Only factors + HEDGEs under different weighting schemes AND distance thresholds – pre-clustering helps traditional optimization



Source: MSCI, Bloomberg, Factset, J.P. Morgan QDS; Cluster scheme: Average method on 60 month distance matrix

Figure 22: MSCI GDM risk adjusted returns of Long-Only factors (NO Hedge) under different weighting schemes AND distance thresholds – pre-clustering again can help



Source: MSCI, Bloomberg, Factset, J.P. Morgan QDS; Cluster scheme: Average method on 60 month distance matrix

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Another more direct way to look at the effects of Momentum is to use what we call a Term Weighted (TW) approach, using the momentum of different lookback periods.

Term weighting uses a 25% allocation on 4 different lookback periods – 1, 3, 6 and 12 months. If all 4 lookback periods have positive returns, then the weight is 100%.

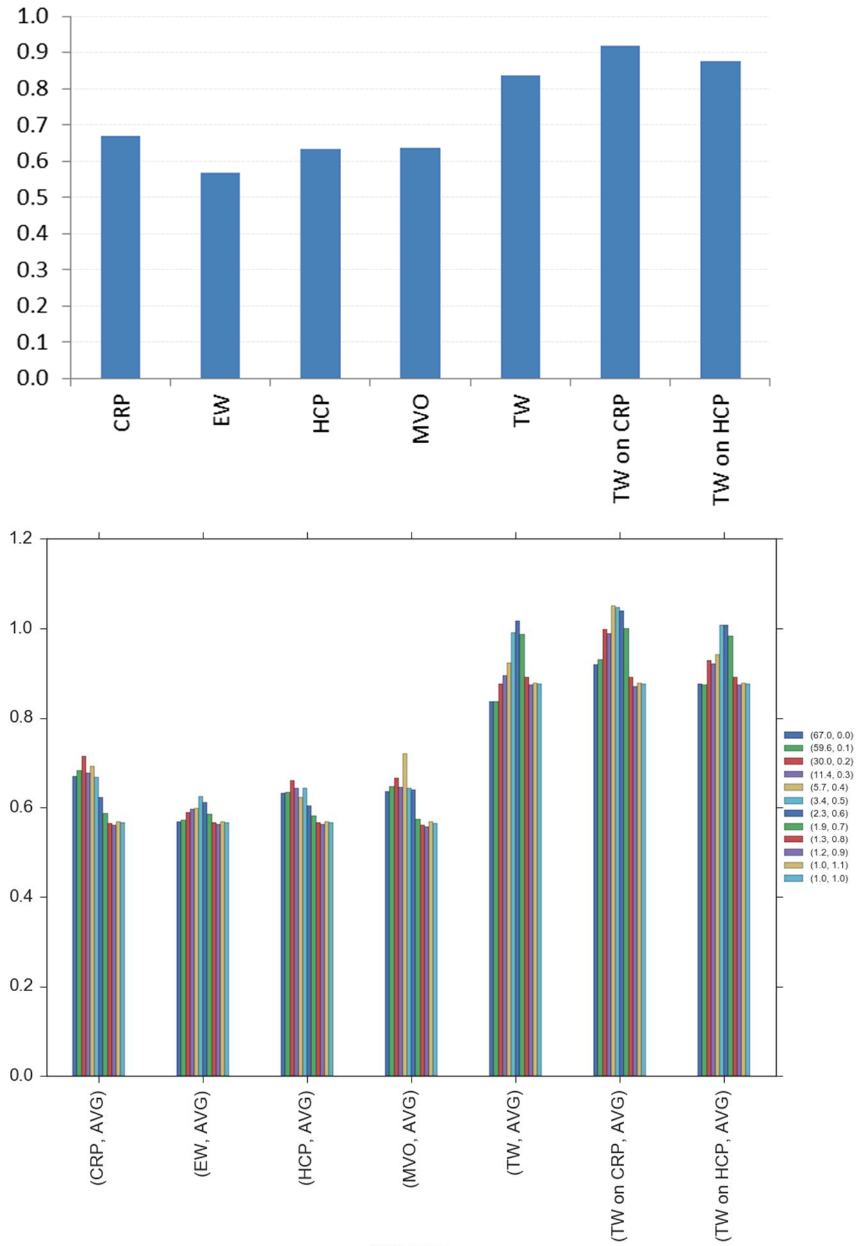
We also apply the TW to HCP and CRP for a momentum overlay on both.

See our full report on TW: "[Mitigating Equity Index Risk Using Term Structure of Price Momentum]"

Momentum Overlays

Next we investigate the use of a returns estimate (in addition to the volatility and correlations estimate). We already included the Mean-Variance Optimization (MVO) in optimizations comparison previously and it tended to do better as in some ways it is using factor momentum in its allocations.

Figure 23: Optimization first with no clustering, then using different cluster distances thresholds (MSCI GDM Long Only)



Source: MSCI, Bloomberg, Factset, J.P. Morgan QDS; Cluster scheme: Average method on 60 month distance matrix

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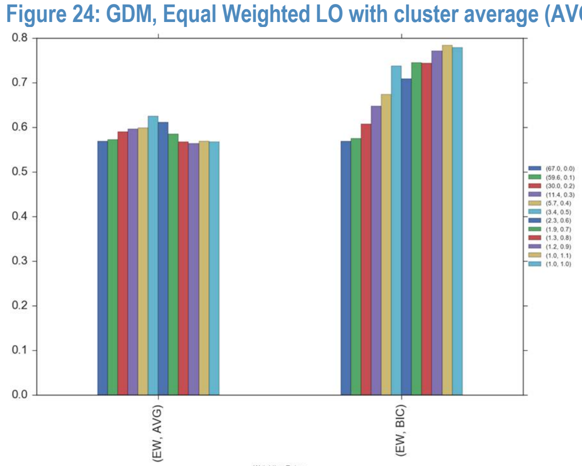
Best in Cluster

Lastly we look at how alternative implementation of the cluster exposure can affect the strategy returns. So far we have been only using the simple average return of all assets in each cluster. However we could choose to implement the cluster by selecting the asset or factor with the best:

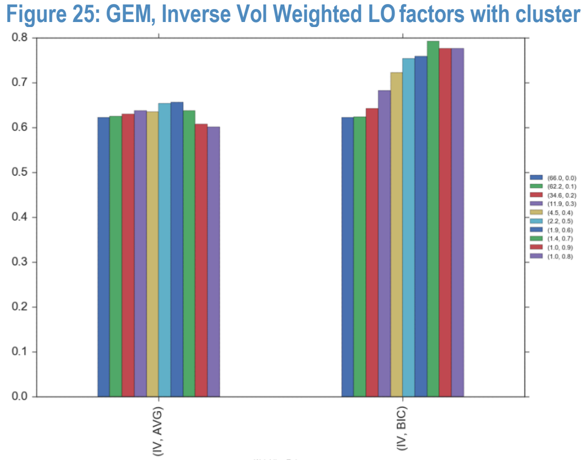
- 12-month risk adjusted return (Sharpe)
- Prior 1 month return
- Prior year (12 month) return
- Most Volume/Liquidity
- Cheapest Value spreads (in the case of factors)
- Market cap (if applicable)

Figure 24: GDM, Equal Weighted LO with cluster average (AVG) vs 12mth 'Best in Cluster' (BIC)



Source: MSCI, Bloomberg, Factset, J.P. Morgan QDS; Average linkage on 60 month distance matrix

Figure 25: GEM, Inverse Vol Weighted LO factors with cluster average (AVG) vs 12mth (BIC)



Source: MSCI, Bloomberg, Factset, J.P. Morgan QDS; Average linkage on 60 month distance matrix

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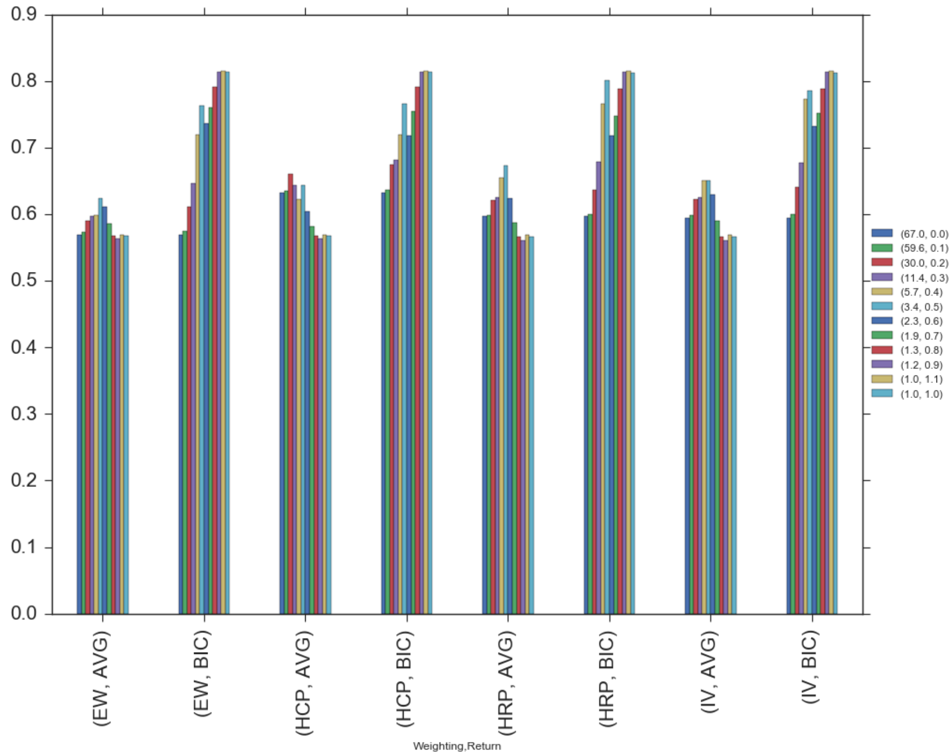
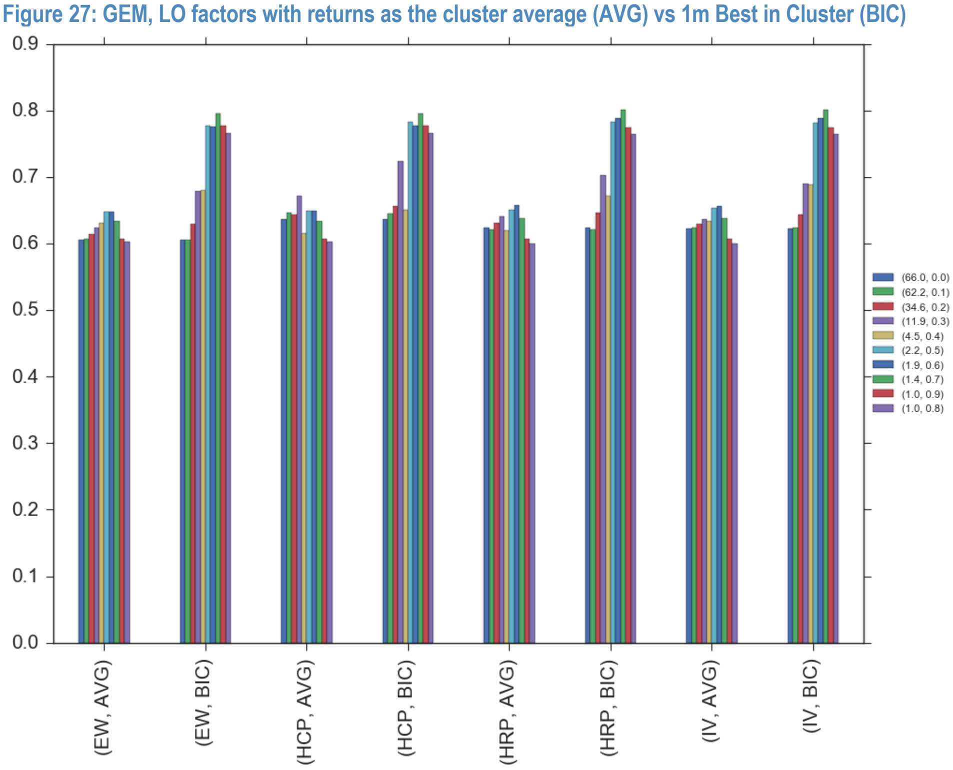
Figure 26: GDM, LO factors with returns as the cluster average (AVG) vs 1m Best in Cluster (BIC)



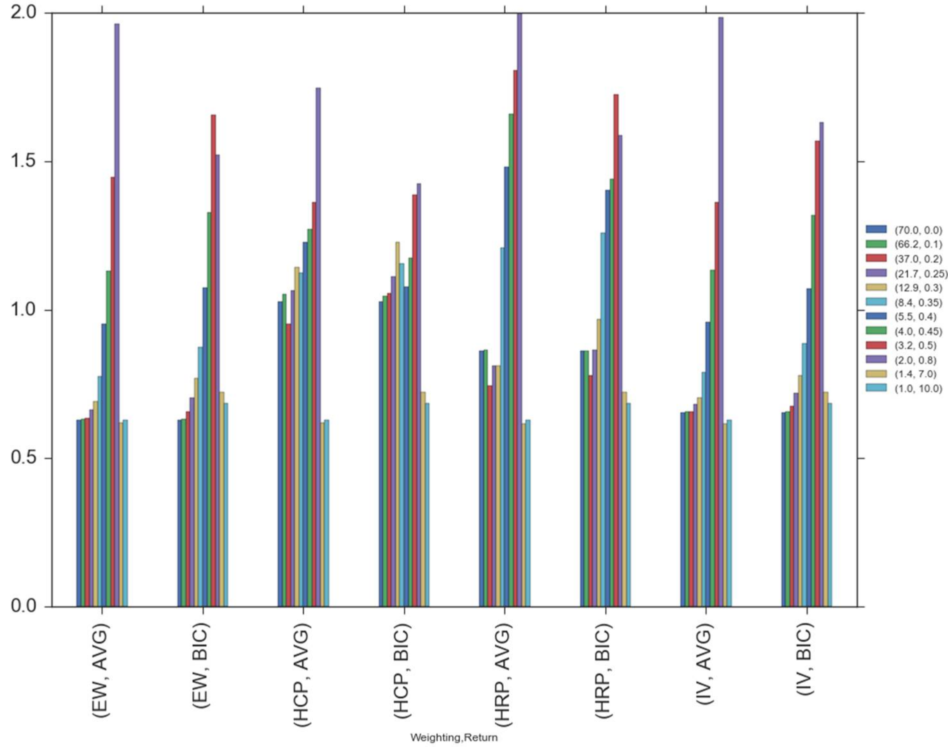
Source: MSCI, Bloomberg, Factset, J.P. Morgan QDS; Average linkage on 60 month distance matrix

Figure 27: GEM, LO factors with returns as the cluster average (AVG) vs 1m Best in Cluster (BIC)



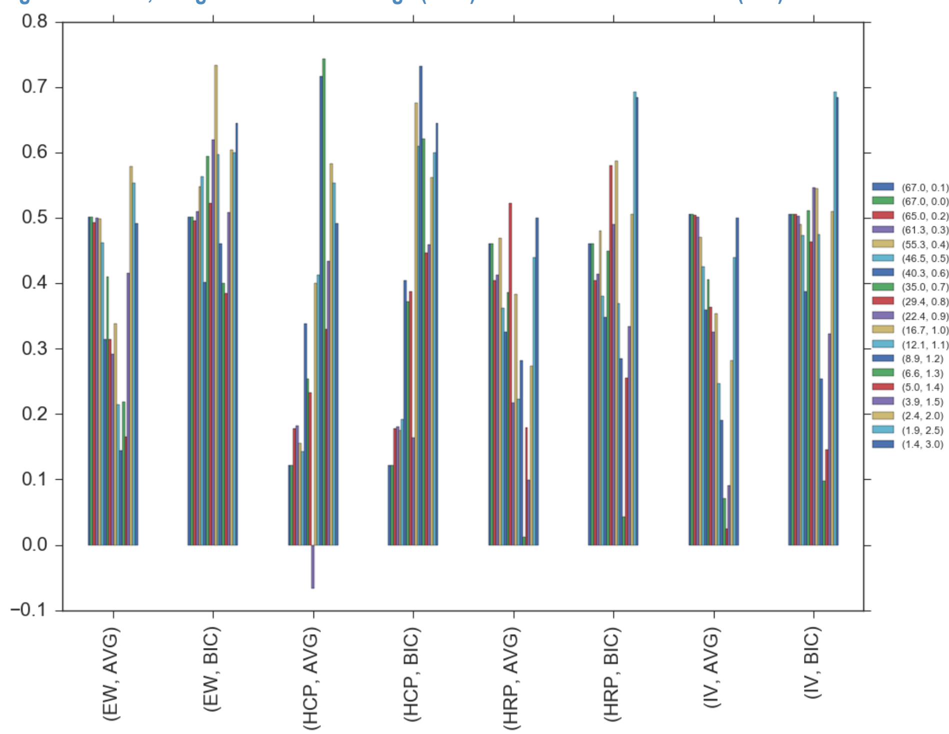
Source: MSCI, Bloomberg, Factset, J.P. Morgan QDS; Average linkage on 60 month distance matrix

Figure 28: GEM, LO + HEDGE cluster average (AVG) vs 1 month Best in Cluster (BIC)



Source: MSCI, Bloomberg, Factset, J.P. Morgan; Average linkage on 60 month distance matrix; BIC is the best past 1 month return

Figure 29: GDM, Long Short cluster average (AVG) vs 1 month Best in Cluster (BIC)



Source: MSCI, Bloomberg, Factset, J.P. Morgan; Average linkage on 60 month distance matrix; BIC is the best past 1 month return

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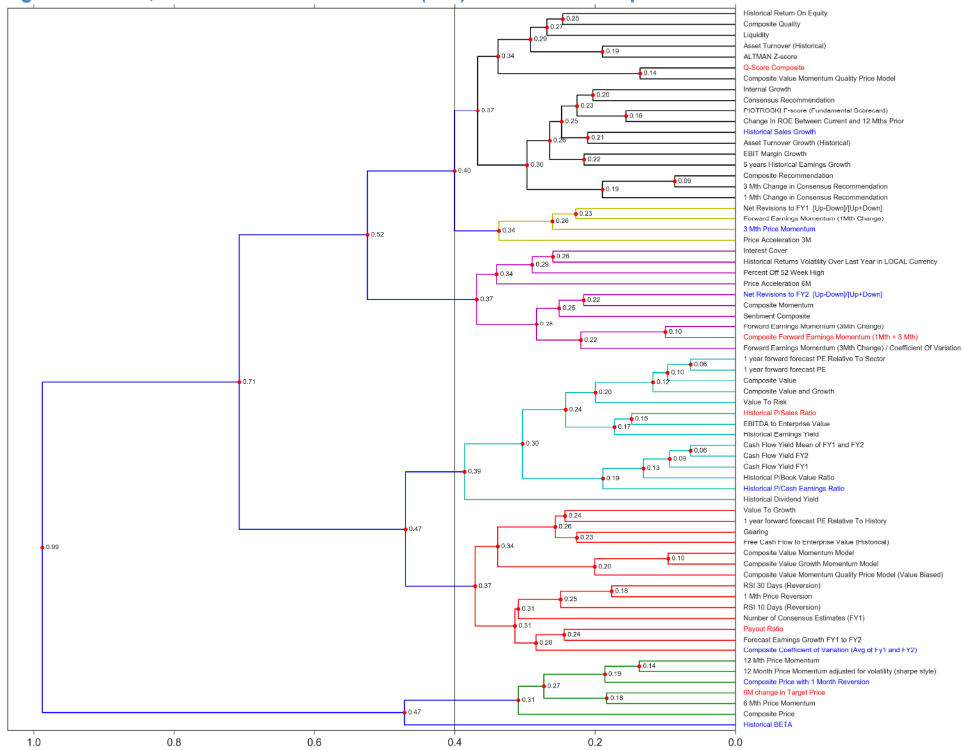
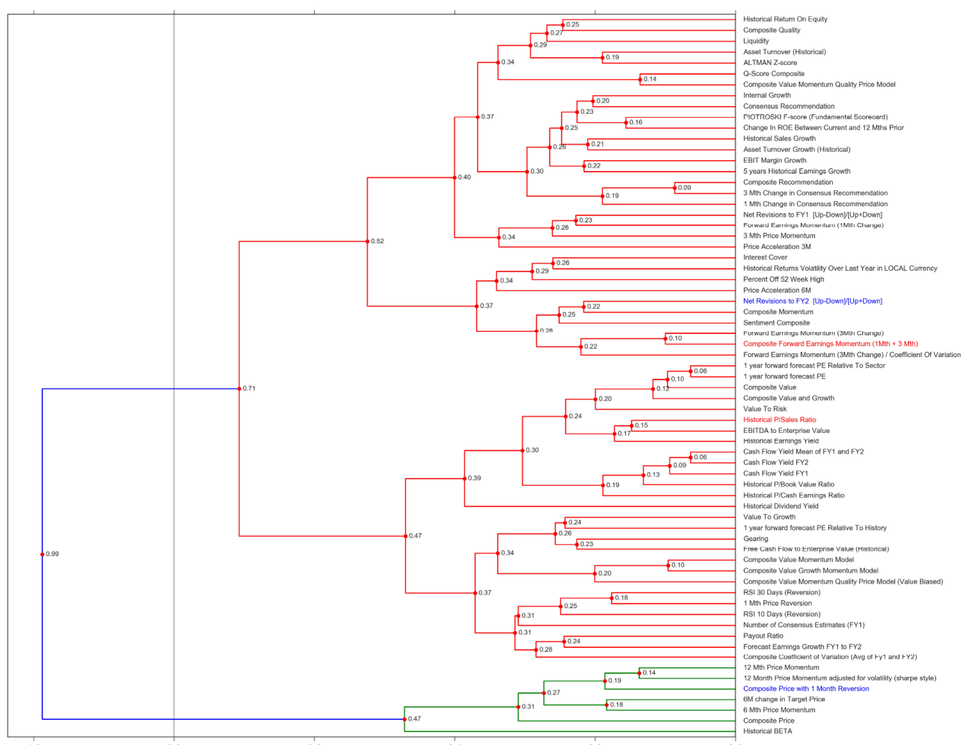
Blue factors are the current months selection and red are the prior month (if there is no red factor in a cluster then the selection did not change month on month).

Figure 30: GDM, LO 1 month Best in Cluster (BIC) at different example thresholds





Source: MSCI, Bloomberg, Factset, J.P. Morgan; Average linkage on 60 month distance matrix; BIC is the best past 1 month return

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Figure 31: GEM, LO 1 month Best in Cluster (BIC) at different example thresholds

Source: MSCI, Bloomberg, Factset, J.P. Morgan; Average linkage on 60 month distance matrix; BIC is the best past 1 month return

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Appendix I: Full Backtesting Results

In this appendix we have all the results for the following backtests:

- MSCI GEM equity factors
- MSCI GDM equity factors
- Long Only
- Long + HEDGE
- Long Short
- 60 month pairwise correlations
- Average method for cluster dendrogram

- Allocation methods
  - Cluster Risk Parity (CRP)
  - Equal Weight (EW)
  - Hierarchal Cluster Parity (HCP)
  - Hierarchal Risk Parity (HRP)
  - Inverse Vol (IV)
  - Maximally Diversified Portfolio (MDP)
  - Mean Variance Optimized (MVO)
  - Minimum Variance Portfolio (MVP)
  - Term Weighted (TW)

We step the cluster cut-off thresholds from 0.0 (all assets) up to a point where there is just a single cluster (this threshold varies depending on the parameters used).

Cluster returns are formed by average the returns of all the single assets inside each cluster.

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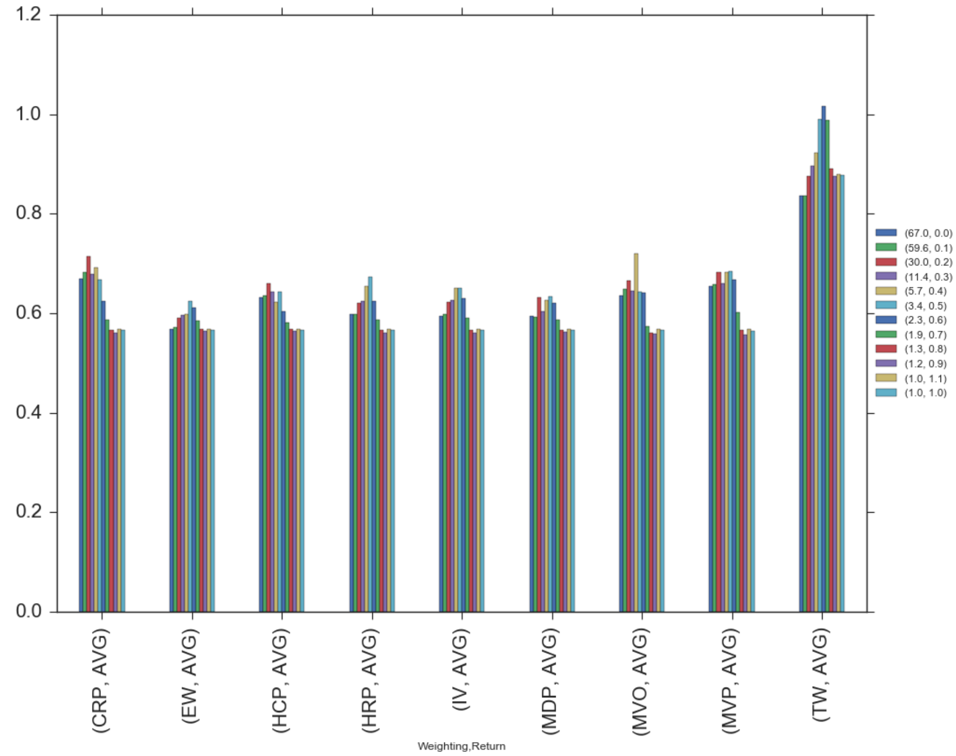
MSCI GDM, Long Only, 60 months, Average



Wght	Return	Distance	AvgN	Sharpe	Ret	Vol	MDD	Hitrate	tStat
CRP	AVG	0	67	0.67	9.3%	13.9%	(68.7%)	63.6%	2.47
CRP	AVG	0.5	3.4	0.67	9.8%	14.7%	(70.7%)	61.7%	2.46
CRP	AVG	1	1.0	0.57	9.6%	17.0%	(82.3%)	62.3%	2.09
EW	AVG	0	67.0	0.57	9.7%	17.0%	(82.3%)	63.0%	2.10
EW	AVG	0.5	3.4	0.62	9.7%	15.6%	(75.7%)	63.0%	2.30
EW	AVG	1	1.0	0.57	9.7%	17.0%	(82.3%)	62.3%	2.09
HCP	AVG	0	67.0	0.63	9.5%	15.1%	(73.0%)	62.3%	2.33
HCP	AVG	0.5	3.4	0.64	9.8%	15.2%	(73.2%)	61.7%	2.37
HCP	AVG	1	1.0	0.57	9.7%	17.0%	(82.3%)	62.3%	2.09
HRP	AVG	0	67.0	0.60	9.7%	16.3%	(79.8%)	61.7%	2.20
HRP	AVG	0.5	3.4	0.67	9.9%	14.7%	(71.9%)	62.3%	2.48
HRP	AVG	1	1.0	0.57	9.6%	17.0%	(82.3%)	62.3%	2.09
IV	AVG	0	67.0	0.59	9.7%	16.3%	(79.9%)	62.3%	2.19
IV	AVG	0.5	3.4	0.65	9.8%	15.0%	(73.0%)	61.7%	2.40
IV	AVG	1	1.0	0.57	9.6%	17.0%	(82.3%)	62.3%	2.09
MDP	AVG	0	67.0	0.60	9.6%	16.1%	(81.1%)	59.9%	2.19
MDP	AVG	0.5	3.4	0.63	9.6%	15.2%	(74.0%)	61.1%	2.33
MDP	AVG	1	1.0	0.57	9.6%	17.0%	(82.3%)	62.3%	2.09
MVO	AVG	0	67.0	0.64	9.8%	15.5%	(76.9%)	64.2%	2.35
MVO	AVG	0.5	3.4	0.64	9.0%	14.0%	(64.8%)	63.0%	2.37
MVO	AVG	1	1.0	0.57	9.6%	17.0%	(82.3%)	62.3%	2.09
MVP	AVG	0	67.0	0.65	10.0%	15.2%	(75.3%)	63.0%	2.41
MVP	AVG	0.5	3.4	0.68	9.5%	14.0%	(69.5%)	61.1%	2.52
MVP	AVG	1	1.0	0.57	9.6%	17.0%	(82.3%)	62.3%	2.08
TW	AVG	0	67.0	0.84	12.1%	14.5%	(46.3%)	63.7%	3.08
TW	AVG	0.5	3.4	0.99	13.0%	13.1%	(30.0%)	64.5%	3.65
TW	AVG	1	1.0	0.88	12.5%	14.2%	(32.6%)	63.7%	3.23

Source: MSCI, Bloomberg, Factset, J.P. Morgan QDS; Cluster scheme: Average method on 60 month distance matrix

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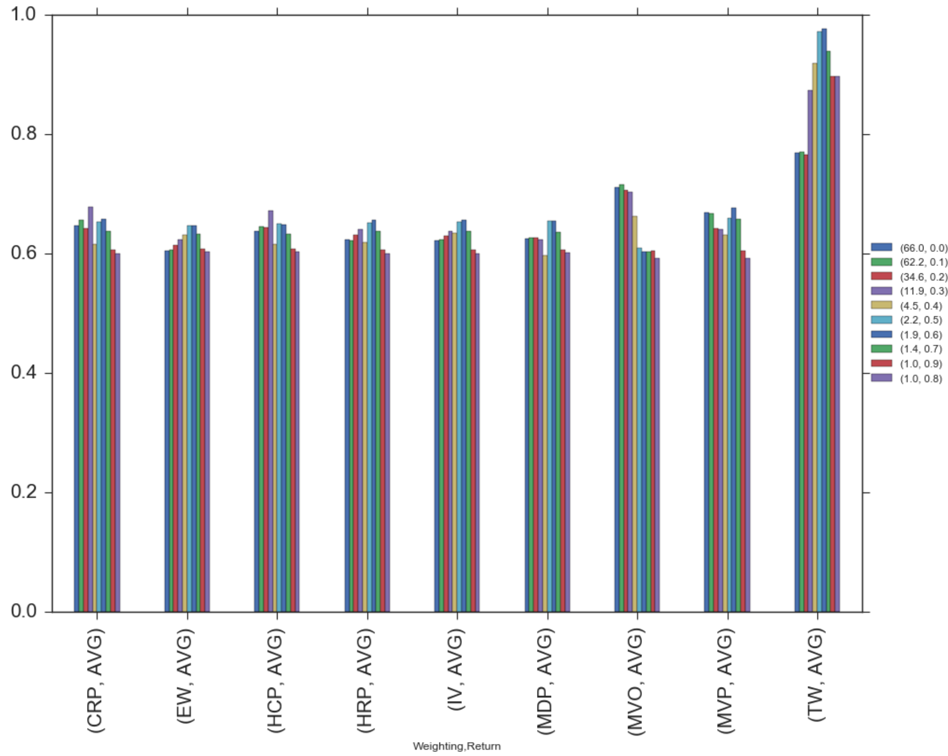
MSCI GEM, Long Only, 60 months, Average



Wght	Return	Distance	AvgN	Sharpe	Ret	Vol	MDD	Hitrate	tStat
CRP	AVG	0	66.0	0.65	13.1%	20.3%	(76.9%)	62.5%	2.37
CRP	AVG	0.5	2.2	0.65	14.5%	22.2%	(83.0%)	61.3%	2.39
CRP	AVG	0.9	1.0	0.61	14.1%	23.3%	(83.1%)	61.3%	2.22
EW	AVG	0	66.0	0.61	14.1%	23.3%	(83.1%)	61.3%	2.22
EW	AVG	0.5	2.2	0.65	14.5%	22.4%	(83.0%)	60.6%	2.37
EW	AVG	0.9	1.0	0.61	14.1%	23.3%	(83.1%)	61.3%	2.23
HCP	AVG	0	66.0	0.64	13.4%	21.0%	(78.7%)	61.3%	2.33
HCP	AVG	0.5	2.2	0.65	14.5%	22.4%	(83.0%)	60.6%	2.38
HCP	AVG	0.9	1.0	0.61	14.1%	23.3%	(83.1%)	61.3%	2.23
HRP	AVG	0	66.0	0.62	14.1%	22.6%	(81.6%)	61.3%	2.28
HRP	AVG	0.5	2.2	0.65	14.4%	22.2%	(83.0%)	61.3%	2.39
HRP	AVG	0.9	1.0	0.61	14.1%	23.3%	(83.1%)	61.3%	2.22
IV	AVG	0	66.0	0.62	14.1%	22.6%	(81.6%)	61.3%	2.28
IV	AVG	0.5	2.2	0.65	14.5%	22.2%	(83.0%)	61.3%	2.39
IV	AVG	0.9	1.0	0.61	14.1%	23.3%	(83.1%)	61.3%	2.22
MDP	AVG	0	66.0	0.63	13.3%	21.3%	(76.8%)	61.3%	2.29
MDP	AVG	0.5	2.2	0.65	14.6%	22.3%	(83.0%)	60.6%	2.40
MDP	AVG	0.9	1.0	0.61	14.1%	23.3%	(83.1%)	61.3%	2.22
MVO	AVG	0	66.0	0.71	15.6%	22.0%	(82.1%)	62.5%	2.60
MVO	AVG	0.5	2.2	0.61	13.3%	21.9%	(83.0%)	61.9%	2.24
MVO	AVG	0.9	1.0	0.61	14.1%	23.3%	(83.1%)	61.3%	2.22
MVP	AVG	0	66.0	0.67	14.3%	21.4%	(77.5%)	63.1%	2.45
MVP	AVG	0.5	2.2	0.66	14.1%	21.3%	(83.0%)	64.4%	2.42
MVP	AVG	0.9	1.0	0.61	14.1%	23.3%	(83.1%)	61.3%	2.22
TW	AVG	0	66.0	0.77	16.6%	21.6%	(61.1%)	61.9%	2.82
TW	AVG	0.5	2.2	0.97	18.9%	19.5%	(34.4%)	63.3%	3.56
TW	AVG	0.9	1.0	0.90	18.2%	20.3%	(37.8%)	63.7%	3.29

Source: MSCI, Bloomberg, Factset, J.P. Morgan QDS; Cluster scheme: Average method on 60 month distance matrix

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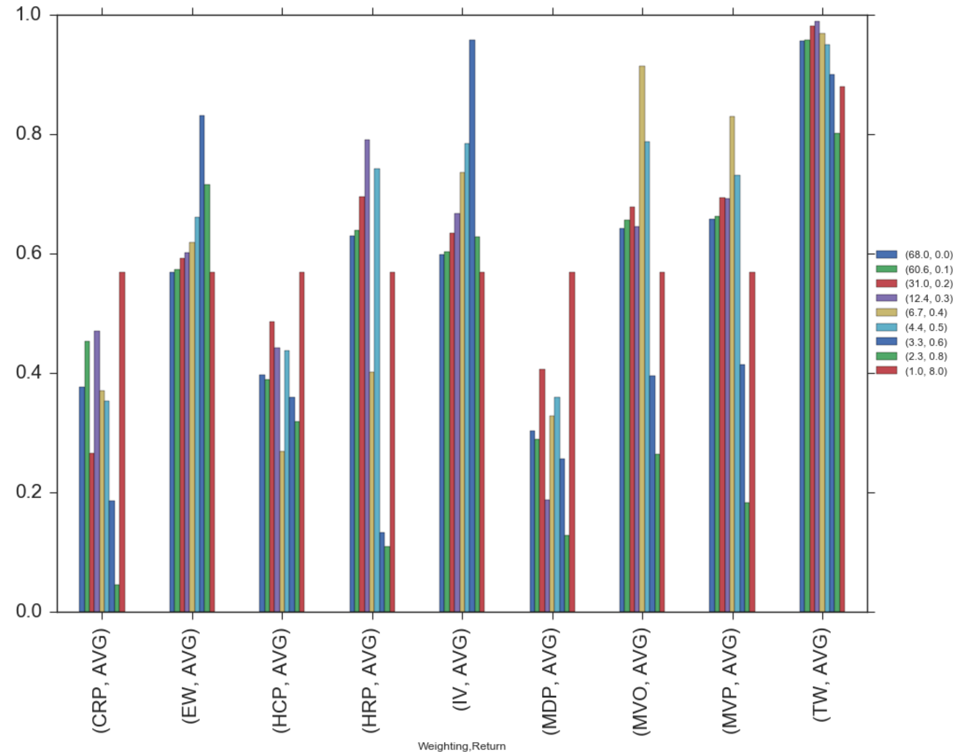
MSCI GDM, Long Only + HEDGE, 60 months, Average



Weight	Return	Distance	AvgN	Sharpe	Ret	Vol	MDD	Hitrate	tStat
CRP	AVG	0	68.0	0.38	0.7%	1.9%	(4.9%)	54.9%	1.39
CRP	AVG	0.5	4.4	0.35	0.8%	2.3%	(8.1%)	54.9%	1.30
CRP	AVG	0.8	2.3	0.05	0.1%	2.1%	(12.5%)	51.9%	0.17
EW	AVG	0	68.0	0.57	9.4%	16.6%	(80.1%)	63.0%	2.10
EW	AVG	0.5	4.4	0.66	5.4%	8.2%	(38.3%)	61.7%	2.44
EW	AVG	0.8	2.3	0.72	2.3%	3.2%	(8.7%)	59.9%	2.64
HCP	AVG	0	68.0	0.40	0.6%	1.5%	(3.5%)	54.9%	1.46
HCP	AVG	0.5	4.4	0.44	0.7%	1.7%	(3.8%)	54.3%	1.61
HCP	AVG	0.8	2.3	0.32	0.6%	1.9%	(7.3%)	57.4%	1.18
HRP	AVG	0	68.0	0.63	8.3%	13.2%	(63.3%)	62.3%	2.32
HRP	AVG	0.5	4.4	0.74	2.0%	2.7%	(6.6%)	58.6%	2.74
HRP	AVG	0.8	2.3	0.11	0.2%	2.1%	(11.6%)	51.9%	0.40
IV	AVG	0	68.0	0.60	9.4%	15.6%	(76.4%)	62.3%	2.20
IV	AVG	0.5	4.4	0.78	5.4%	6.9%	(28.2%)	61.1%	2.89
IV	AVG	0.8	2.3	0.63	1.8%	2.8%	(8.2%)	55.6%	2.32
MDP	AVG	0	68.0	0.30	0.4%	1.2%	(2.4%)	54.3%	1.12
MDP	AVG	0.5	4.4	0.36	0.6%	1.6%	(4.0%)	54.3%	1.32
MDP	AVG	0.8	2.3	0.13	0.2%	1.6%	(5.9%)	50.6%	0.47
MVO	AVG	0	68.0	0.64	9.1%	14.1%	(70.0%)	64.2%	2.37
MVO	AVG	0.5	4.4	0.79	3.0%	3.8%	(15.8%)	63.6%	2.91
MVO	AVG	0.8	2.3	0.26	2.1%	8.0%	(34.3%)	61.7%	0.98
MVP	AVG	0	68.0	0.66	9.4%	14.3%	(70.8%)	63.0%	2.42
MVP	AVG	0.5	4.4	0.73	1.8%	2.5%	(5.1%)	57.4%	2.70
MVP	AVG	0.8	2.3	0.18	0.3%	1.6%	(5.8%)	52.5%	0.67
TW	AVG	0	68.0	0.96	13.9%	14.5%	(24.9%)	64.8%	3.53
TW	AVG	0.5	4.4	0.95	11.3%	11.9%	(19.6%)	62.3%	3.50
TW	AVG	0.8	2.3	0.80	9.5%	11.9%	(22.2%)	62.3%	2.95

Source: MSCI, Bloomberg, Factset, J.P. Morgan QDS; Cluster scheme: Average method on 60 month distance matrix

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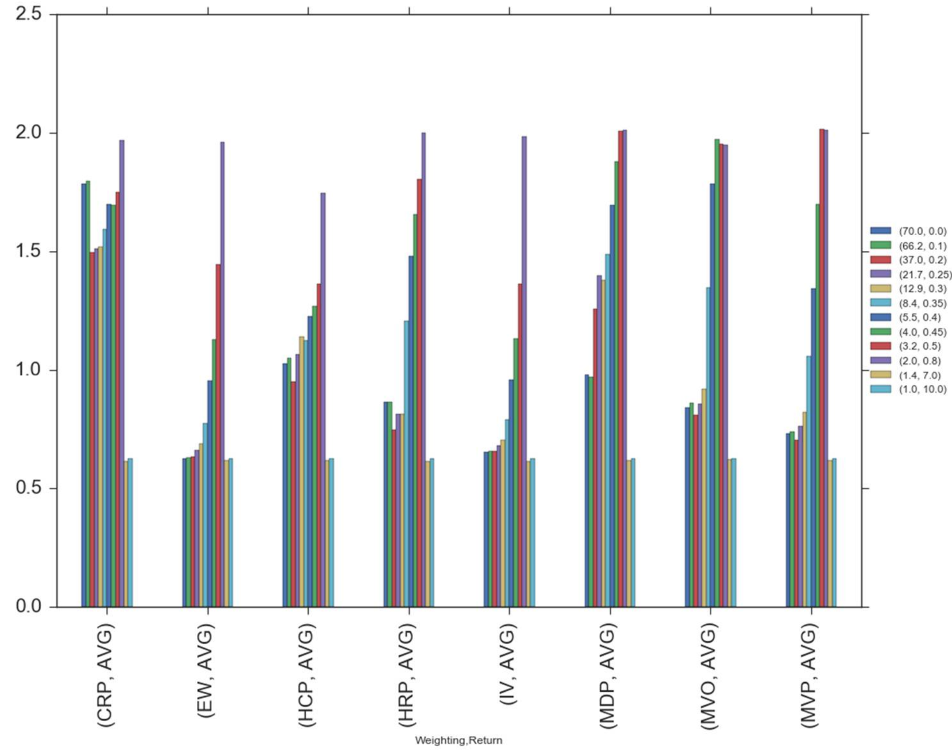
MSCI GEM, Long Only + HEDGE, 60 months, Average



Weight	Return	Distance	AvgN	Sharpe	Ret	Vol	MDD	Hitrate	tStat
CRP	AVG	0	70.0	1.79	5.2%	2.9%	(6.7%)	73.8%	6.54
CRP	AVG	0.5	3.2	1.75	5.3%	3.0%	(6.8%)	73.8%	6.42
CRP	AVG	7	1.4	0.61	8.2%	13.4%	(44.8%)	67.5%	2.25
EW	AVG	0	70.0	0.63	12.9%	20.6%	(73.1%)	61.3%	2.29
EW	AVG	0.5	3.2	1.44	9.3%	6.4%	(8.3%)	71.3%	5.29
EW	AVG	7	1.4	0.62	8.2%	13.3%	(44.2%)	66.9%	2.26
HCP	AVG	0	70.0	1.03	3.2%	3.1%	(9.9%)	69.4%	3.76
HCP	AVG	0.5	3.2	1.36	3.9%	2.9%	(7.1%)	70.6%	4.99
HCP	AVG	7	1.4	0.62	8.2%	13.3%	(44.2%)	66.9%	2.26
HRP	AVG	0	70.0	0.86	10.4%	12.0%	(37.4%)	63.8%	3.16
HRP	AVG	0.5	3.2	1.81	5.6%	3.1%	(6.3%)	73.8%	6.61
HRP	AVG	7	1.4	0.61	8.2%	13.4%	(44.8%)	67.5%	2.25
IV	AVG	0	70.0	0.65	13.1%	20.1%	(71.4%)	61.3%	2.39
IV	AVG	0.5	3.2	1.36	10.3%	7.6%	(11.9%)	70.6%	4.99
IV	AVG	7	1.4	0.61	8.2%	13.4%	(44.8%)	67.5%	2.25
MDP	AVG	0	70.0	0.98	1.3%	1.3%	(3.4%)	60.0%	3.60
MDP	AVG	0.5	3.2	2.01	3.9%	1.9%	(3.5%)	74.4%	7.35
MDP	AVG	7	1.4	0.62	8.2%	13.3%	(44.5%)	67.5%	2.26
MVO	AVG	0	70.0	0.84	11.7%	14.0%	(52.4%)	65.0%	3.07
MVO	AVG	0.5	3.2	1.95	4.1%	2.1%	(4.3%)	76.3%	7.15
MVO	AVG	7	1.4	0.62	8.3%	13.3%	(44.6%)	69.4%	2.27
MVP	AVG	0	70.0	0.73	11.8%	16.1%	(57.9%)	62.5%	2.68
MVP	AVG	0.5	3.2	2.02	4.1%	2.0%	(3.5%)	75.0%	7.38
MVP	AVG	7	1.4	0.62	8.2%	13.3%	(44.5%)	67.5%	2.26

Source: MSCI, Bloomberg, Factset, J.P. Morgan QDS; Cluster scheme: Average method on 60 month distance matrix

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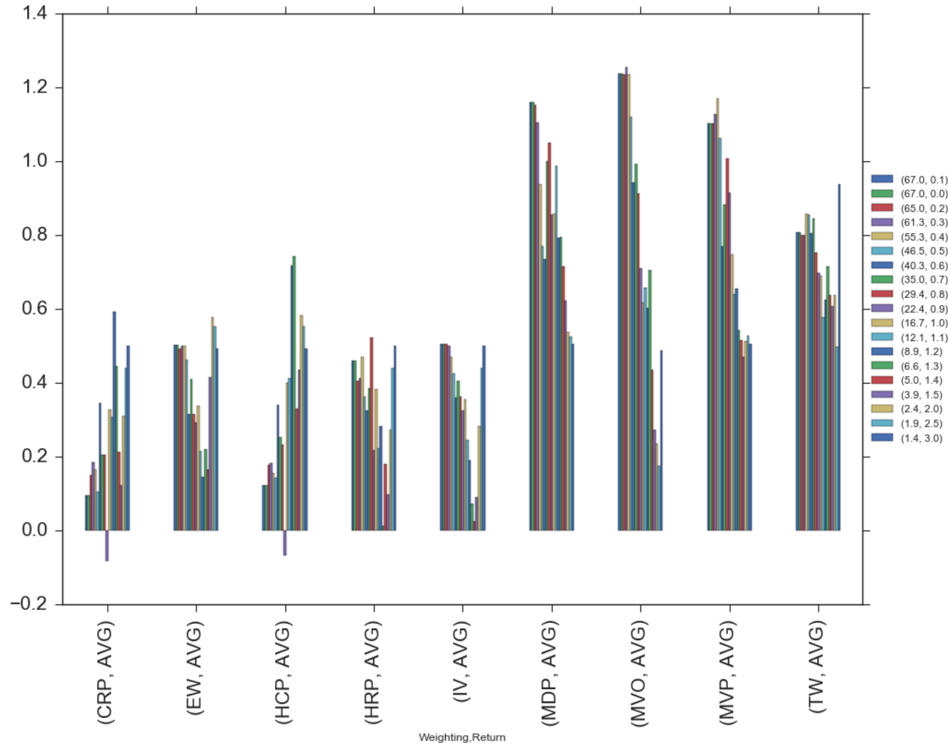
MSCI GDM, Long-Short, 60 months, Average



Weight	Return	Distance	AvgN	Sharpe	Ret	Vol	MDD	Hitrate	tStat
CRP	AVG	0	67.0	0.10	0.2%	2.1%	(9.8%)	53.7%	0.35
CRP	AVG	1	16.7	0.33	0.6%	1.8%	(7.5%)	56.8%	1.21
CRP	AVG	3	1.4	0.50	1.3%	2.5%	(10.6%)	59.3%	1.84
EW	AVG	0	67.0	0.50	1.2%	2.5%	(12.0%)	60.5%	1.85
EW	AVG	1	16.7	0.34	0.7%	2.1%	(7.7%)	62.3%	1.25
EW	AVG	3	1.4	0.49	1.2%	2.5%	(11.4%)	61.1%	1.81
HCP	AVG	0	67.0	0.12	0.3%	2.3%	(10.2%)	58.0%	0.45
HCP	AVG	1	16.7	0.40	0.8%	1.9%	(6.0%)	54.9%	1.48
HCP	AVG	3	1.4	0.49	1.2%	2.5%	(11.4%)	61.1%	1.81
HRP	AVG	0	67.0	0.46	0.8%	1.8%	(8.3%)	60.5%	1.70
HRP	AVG	1	16.7	0.38	0.7%	1.8%	(6.1%)	58.6%	1.41
HRP	AVG	3	1.4	0.50	1.3%	2.5%	(10.6%)	59.3%	1.84
IV	AVG	0	67.0	0.51	1.1%	2.1%	(8.8%)	61.1%	1.86
IV	AVG	1	16.7	0.35	0.7%	2.0%	(6.6%)	60.5%	1.30
IV	AVG	3	1.4	0.50	1.3%	2.5%	(10.6%)	59.3%	1.84
MDP	AVG	0	67.0	1.16	1.2%	1.0%	(1.0%)	69.8%	4.28
MDP	AVG	1	16.7	0.86	1.1%	1.3%	(2.5%)	68.5%	3.16
MDP	AVG	3	1.4	0.50	1.2%	2.4%	(10.0%)	59.9%	1.86
MVO	AVG	0	67.0	1.24	1.5%	1.2%	(2.3%)	69.1%	4.56
MVO	AVG	1	16.7	0.62	1.1%	1.8%	(4.3%)	64.8%	2.28
MVO	AVG	3	1.4	0.49	1.6%	3.3%	(10.4%)	56.8%	1.80
MVP	AVG	0	67.0	1.10	1.3%	1.2%	(2.2%)	67.9%	4.07
MVP	AVG	1	16.7	0.75	0.9%	1.2%	(2.1%)	64.2%	2.76
MVP	AVG	3	1.4	0.50	1.2%	2.5%	(10.0%)	59.9%	1.86
TW	AVG	0	67.0	0.81	3.1%	3.8%	(6.1%)	64.8%	2.98
TW	AVG	1	16.7	0.69	1.9%	2.8%	(4.5%)	59.9%	2.55
TW	AVG	3	1.4	0.94	2.4%	2.5%	(4.4%)	63.5%	3.46

Source: MSCI, Bloomberg, Factset, J.P. Morgan QDS; Cluster scheme: Average method on 60 month distance matrix

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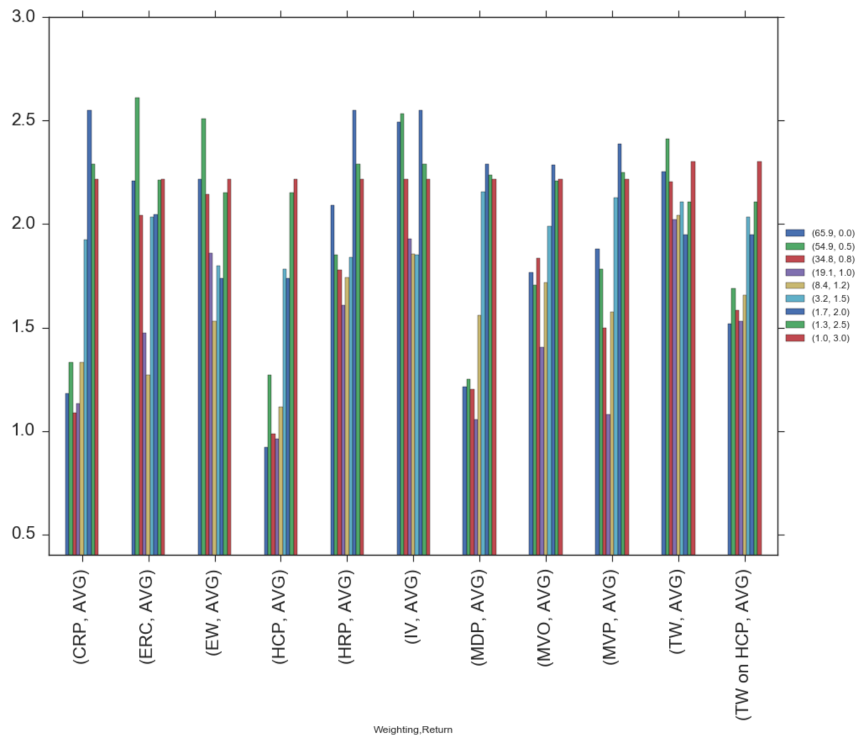
MSCI GEM, Long-Short, 60 months, Average

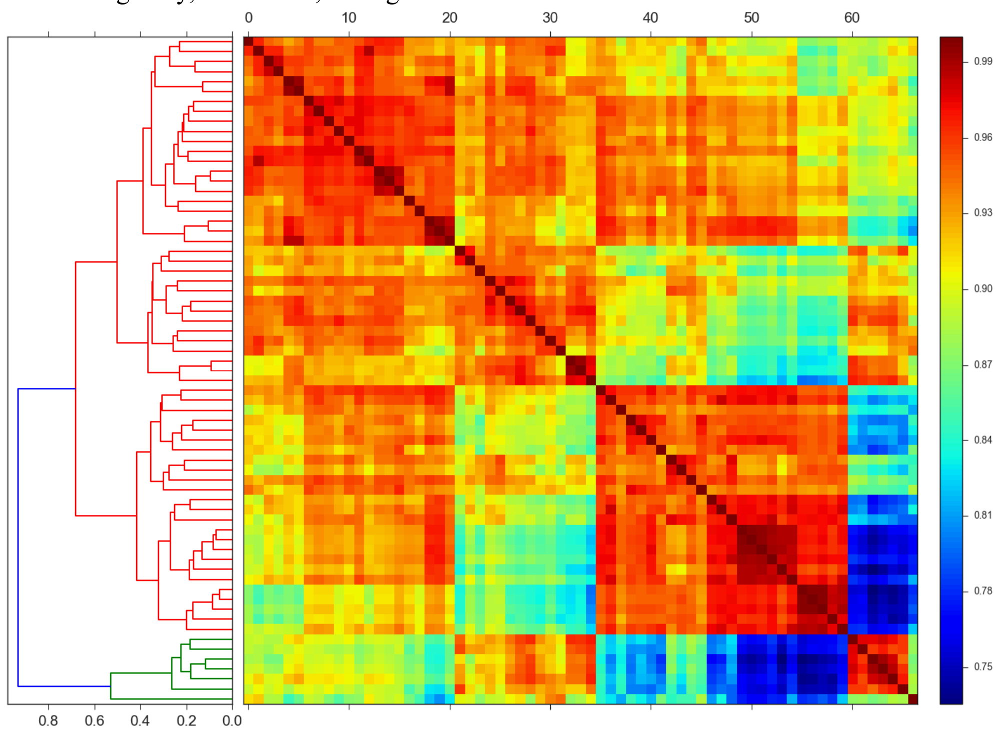


Weight	Return	Distance	AvgN	Sharpe	Ret	Vol	MDD	Hitrate	tStat
CRP	AVG	0	65.9	1.18	3.2%	2.7%	(8.8%)	69.4%	4.33
CRP	AVG	1.5	3.2	1.93	4.1%	2.1%	(3.1%)	72.5%	7.05
CRP	AVG	3	1.0	2.22	5.6%	2.5%	(6.4%)	78.8%	8.12
ERC	AVG	0	65.9	2.21	5.2%	2.3%	(3.7%)	76.9%	8.09
ERC	AVG	1.5	3.2	2.04	4.6%	2.3%	(4.4%)	74.4%	7.46
ERC	AVG	3	1.0	2.22	5.6%	2.5%	(6.4%)	78.8%	8.12
EW	AVG	0	65.9	2.22	5.6%	2.5%	(6.4%)	78.8%	8.12
EW	AVG	1.5	3.2	1.80	4.6%	2.6%	(7.0%)	73.1%	6.58
EW	AVG	3	1.0	2.22	5.6%	2.5%	(6.4%)	78.8%	8.12
HCP	AVG	0	65.9	0.92	2.9%	3.2%	(13.4%)	69.4%	3.37
HCP	AVG	1.5	3.2	1.78	4.3%	2.4%	(3.7%)	72.5%	6.52
HCP	AVG	3	1.0	2.22	5.6%	2.5%	(6.4%)	78.8%	8.12
HRP	AVG	0	65.9	2.09	4.0%	1.9%	(2.3%)	71.9%	7.65
HRP	AVG	1.5	3.2	1.84	4.0%	2.2%	(3.5%)	71.3%	6.73
HRP	AVG	3	1.0	2.22	5.6%	2.5%	(6.4%)	78.8%	8.12
IV	AVG	0	65.9	2.49	5.4%	2.2%	(3.1%)	82.5%	9.14
IV	AVG	1.5	3.2	1.85	4.0%	2.2%	(4.1%)	73.1%	6.78
IV	AVG	3	1.0	2.22	5.6%	2.5%	(6.4%)	78.8%	8.12
MDP	AVG	0	65.9	1.21	1.8%	1.5%	(2.2%)	63.8%	4.45
MDP	AVG	1.5	3.2	2.16	4.5%	2.1%	(4.4%)	75.0%	7.90
MDP	AVG	3	1.0	2.22	5.6%	2.5%	(6.4%)	78.8%	8.12
MVO	AVG	0	65.9	1.77	3.4%	1.9%	(3.5%)	73.1%	6.48
MVO	AVG	1.5	3.2	1.99	4.2%	2.1%	(6.0%)	75.6%	7.29
MVO	AVG	3	1.0	2.22	5.6%	2.5%	(6.4%)	78.8%	8.12
MVP	AVG	0	65.9	1.88	2.6%	1.4%	(2.2%)	73.8%	6.88
MVP	AVG	1.5	3.2	2.13	4.2%	2.0%	(3.6%)	74.4%	7.79
TW	AVG	0	65.9	2.25	7.9%	3.5%	(3.8%)	78.1%	8.26
TW	AVG	1.5	3.2	2.11	6.2%	2.9%	(3.2%)	78.8%	7.72
TW	AVG	3	1.0	2.30	5.7%	2.5%	(4.9%)	79.1%	8.44
TW on HCP	AVG	0	65.9	1.52	5.4%	3.6%	(4.2%)	74.4%	5.56
TW on HCP	AVG	1.5	3.2	2.04	5.9%	2.9%	(3.6%)	75.6%	7.46

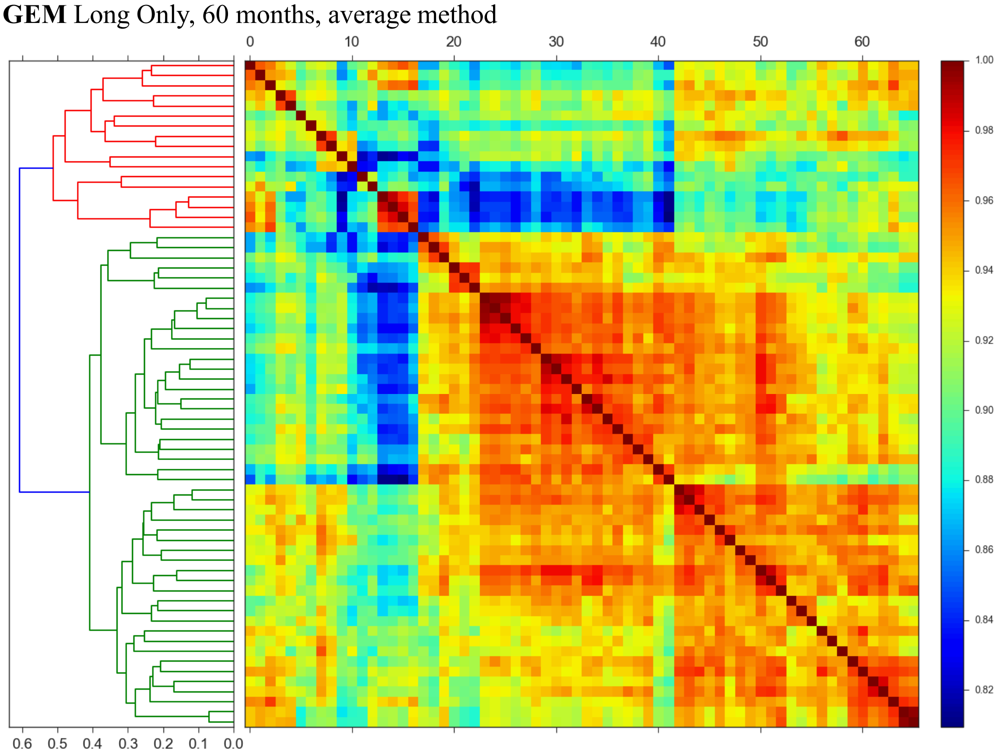
Source: MSCI, Bloomberg, Factset, J.P. Morgan QDS; Cluster scheme: Average method on 60 month distance matrix

Appendix II: Correlation Matrices

GDM Long Only, 60 months, average method



GEM Long Only, 60 months, average method



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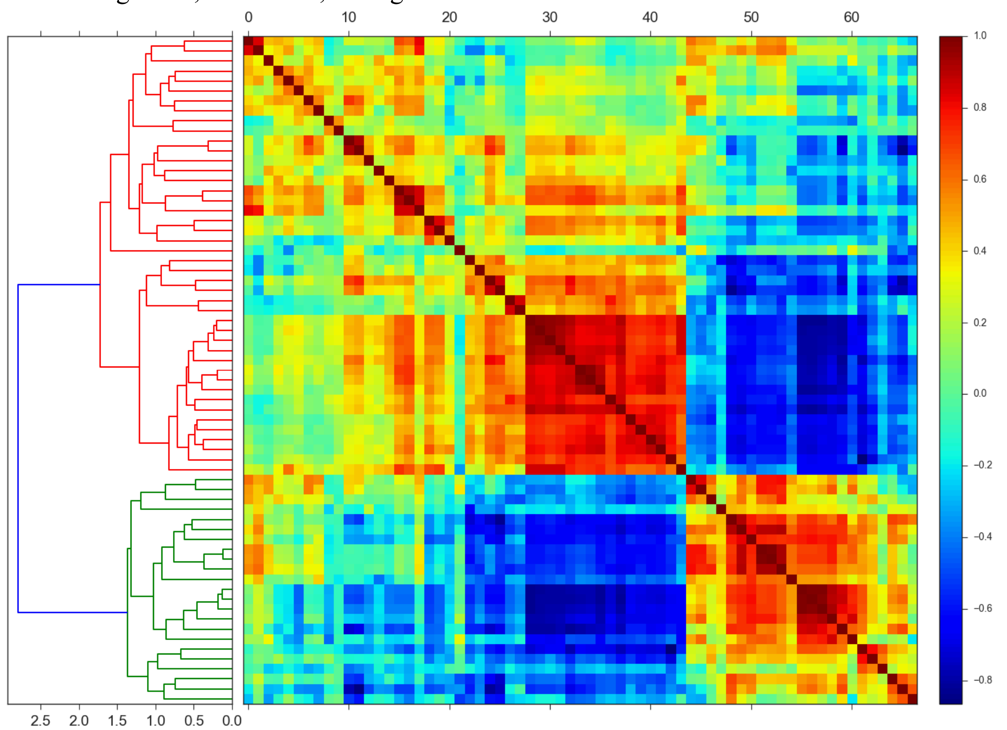
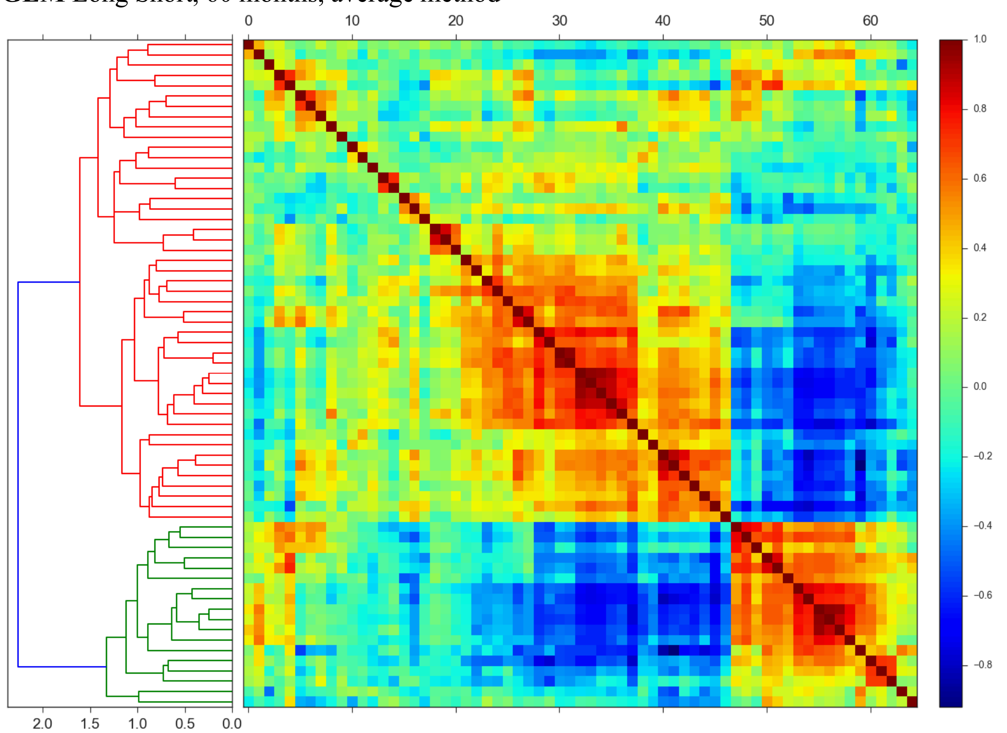
GDM Long Short, 60 months, average method



GEM Long Short, 60 months, average method



Source: MSCI, Bloomberg, Factset, J.P. Morgan QDS; Cluster scheme: Average method on 60 month distance matrix

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Appendix III: Different Linkage methods

Universe: MSCI GDM long only factors (67)

We use a 60 month lookback for pairwise correlations and distance matrix.

Four different linkage methods on the above are shown in this order:

- Single
- Complete
- Average
- Ward

Source: MSCI, Bloomberg, Factset, J.P. Morgan QDS

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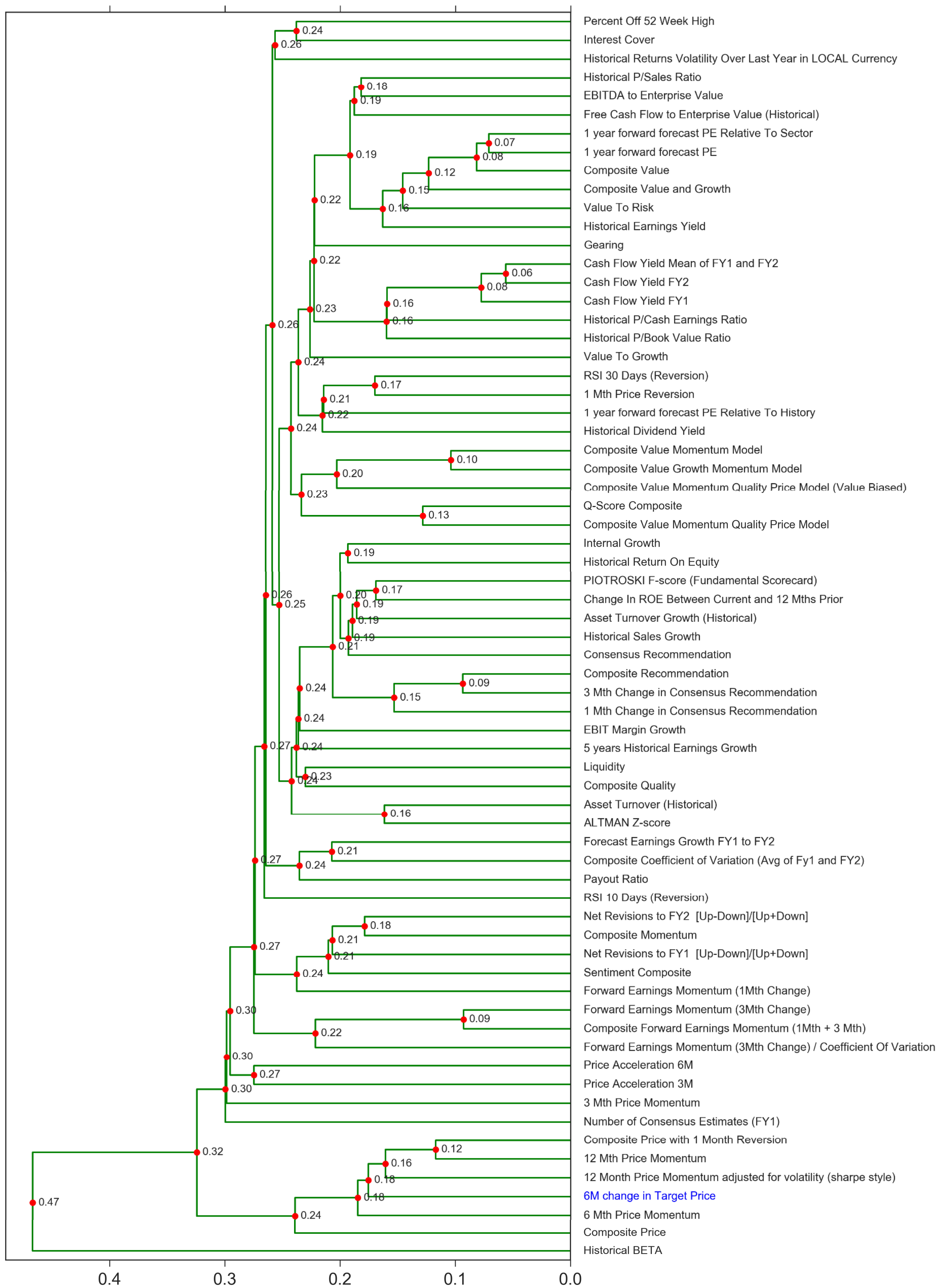

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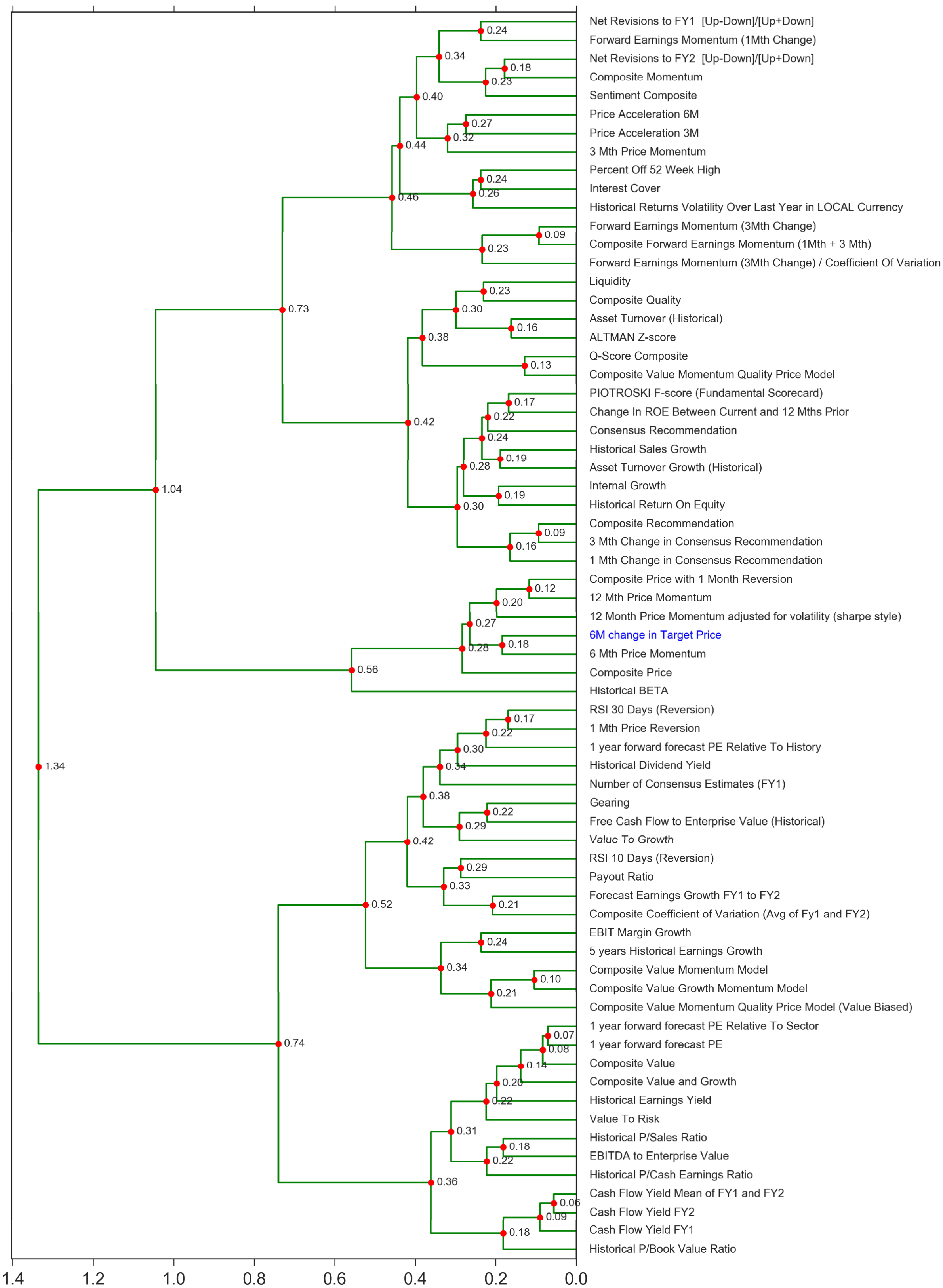

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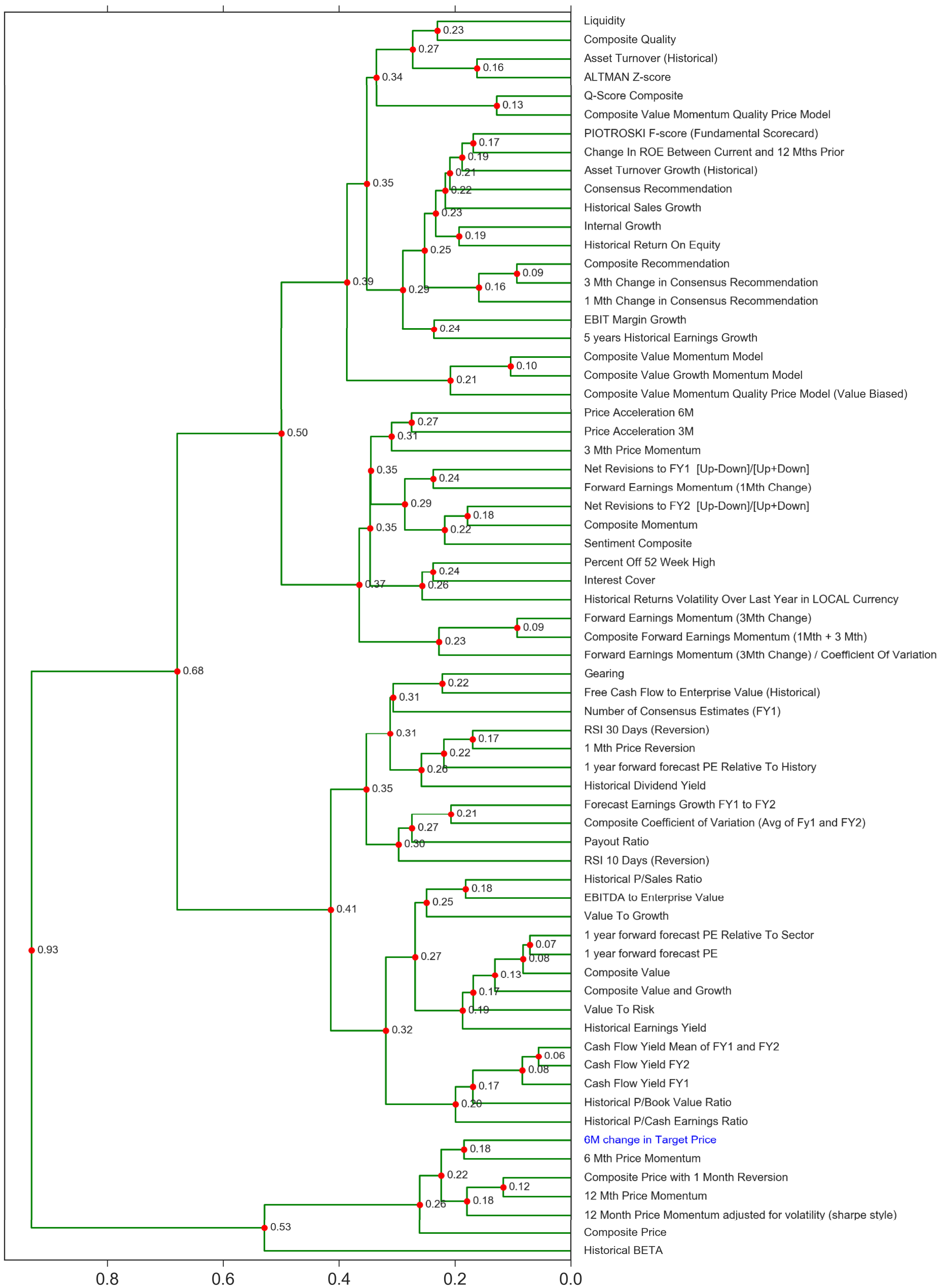

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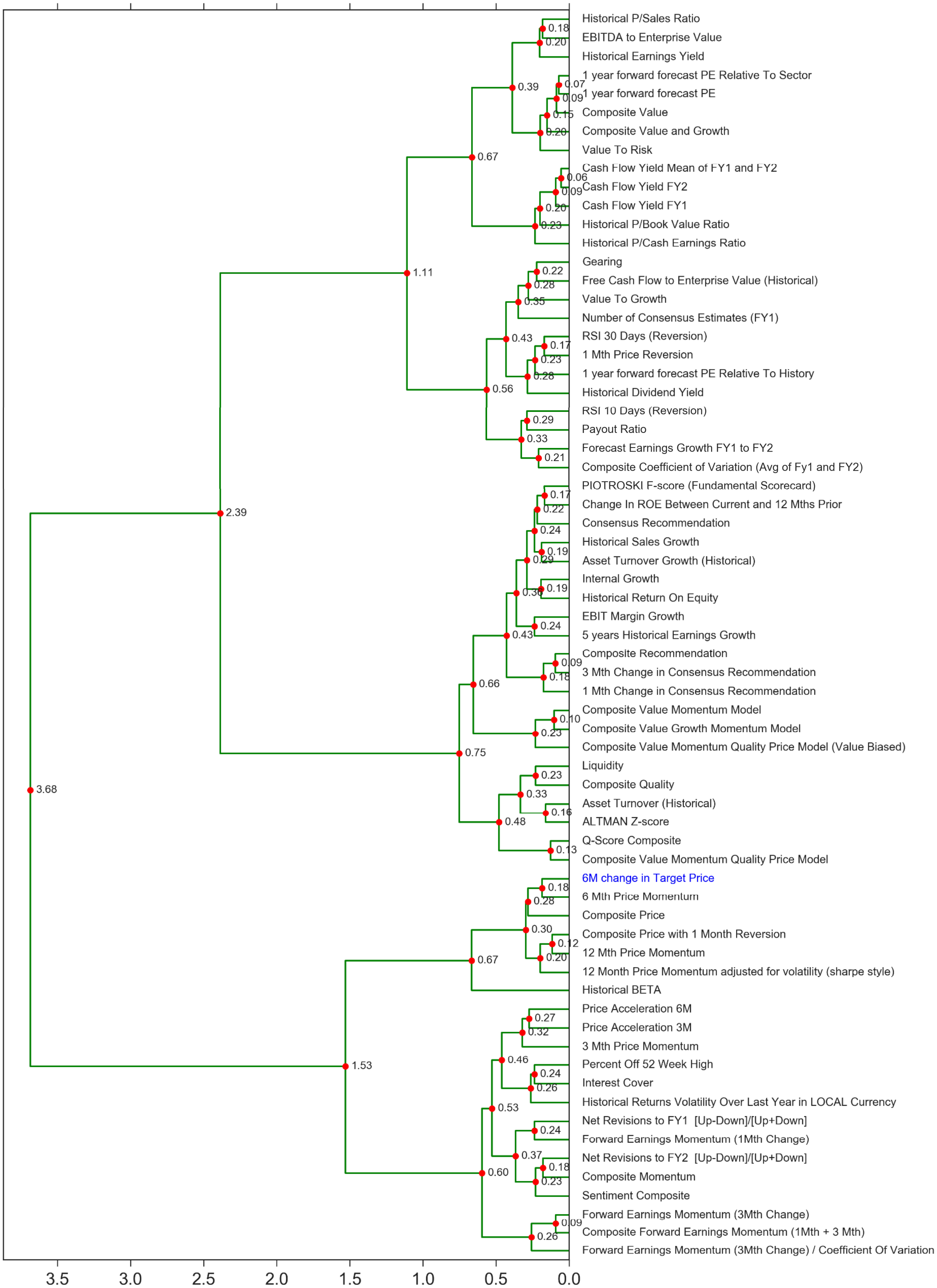

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Appendix IV: Iterative Step through

MSCI GEM long only factors (66)

We use a 60 month lookback for pairwise correlations.

We use the AVERAGE linkage method.

We show the one month 'Best in Cluster' as of 31 May 2018 in blue (and the month before that is in red which will not be present if it was the same as the current month).

We iterate through the distance thresholds to demonstrate the convergence of the cluster hierarchy and how the factor selection would look under the past 12 month returns for the Best in Cluster approach:

[0.0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7]

Source: MSCI, Bloomberg, Factset, J.P. Morgan QDS

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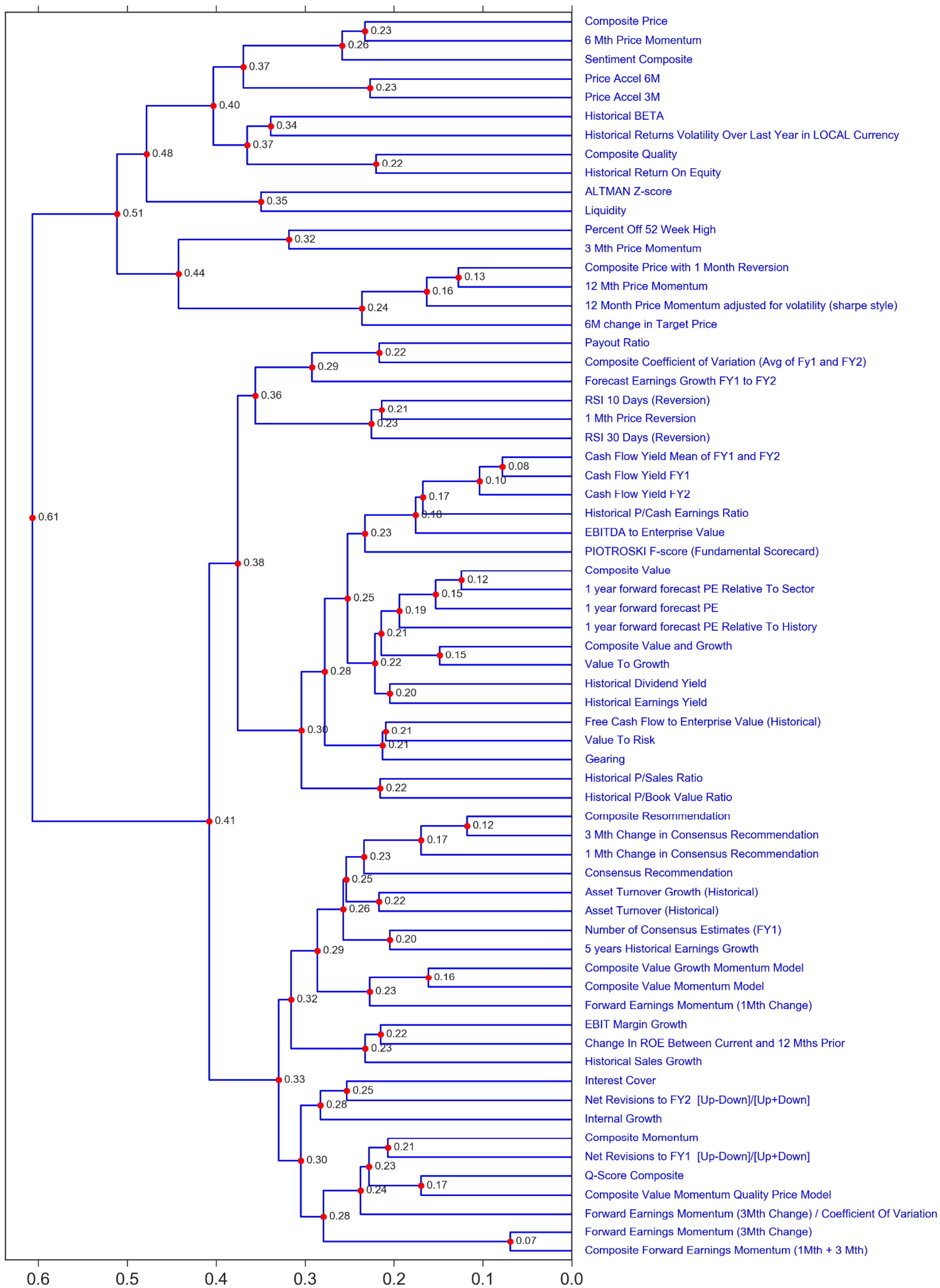

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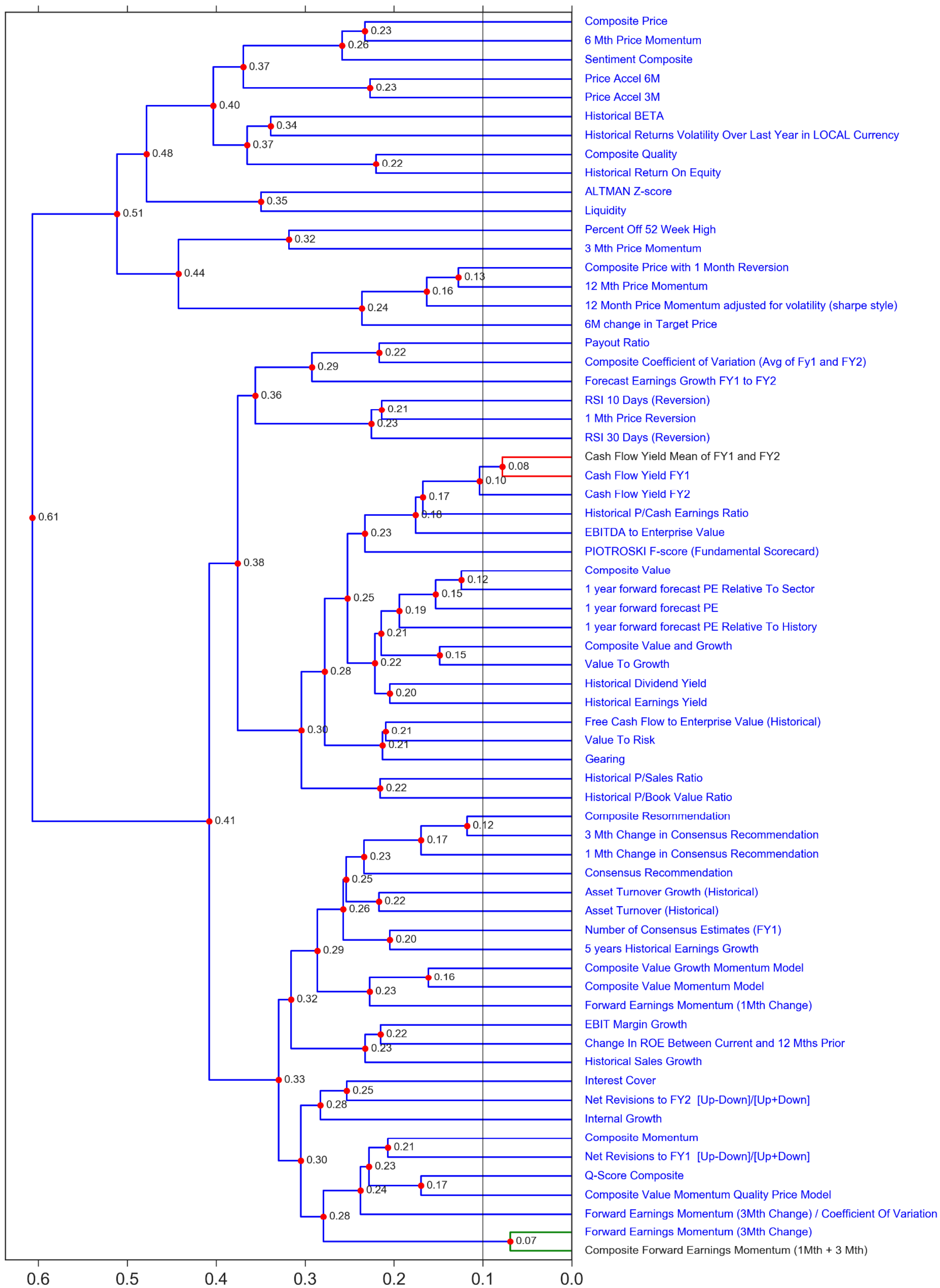

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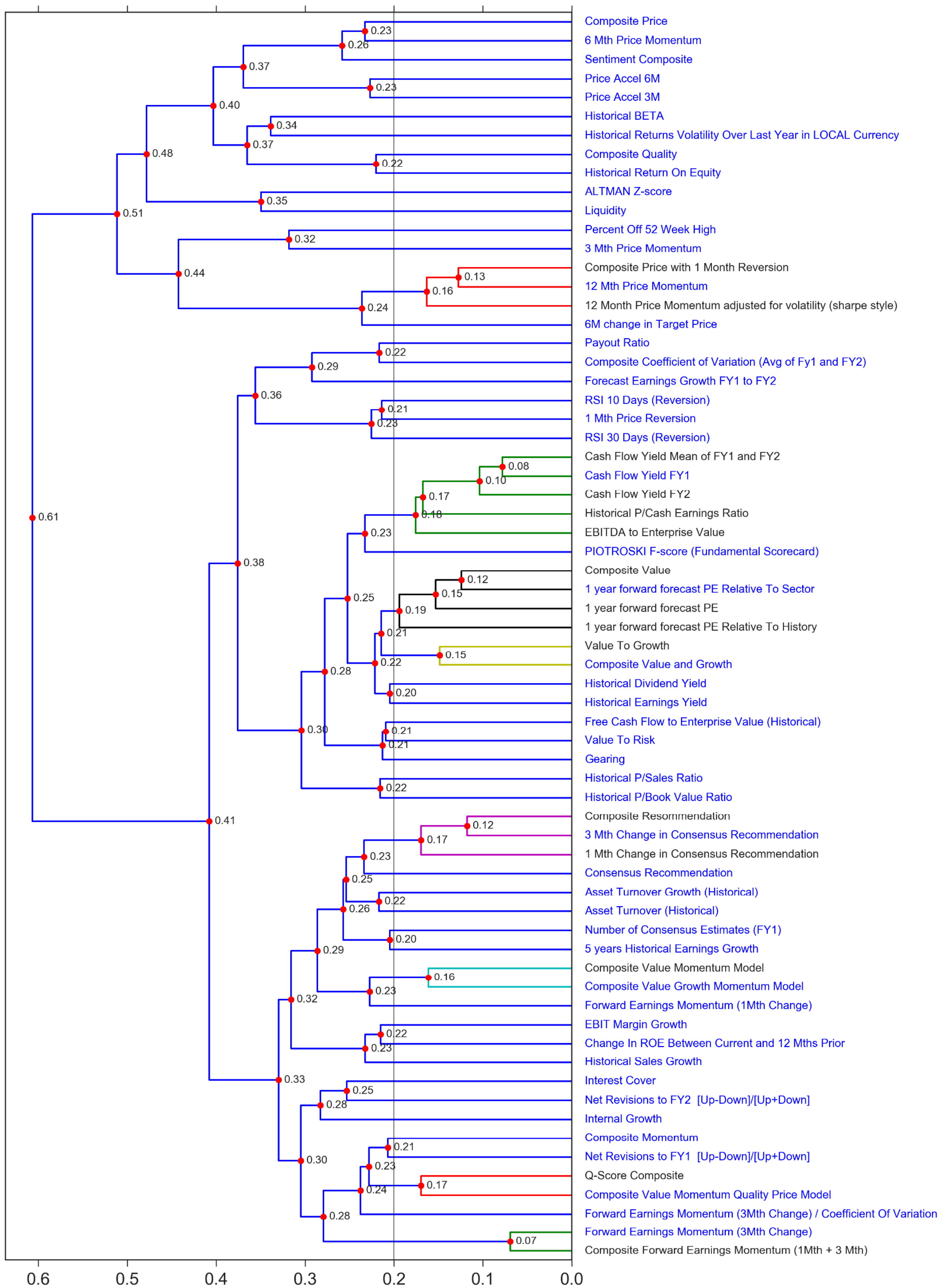

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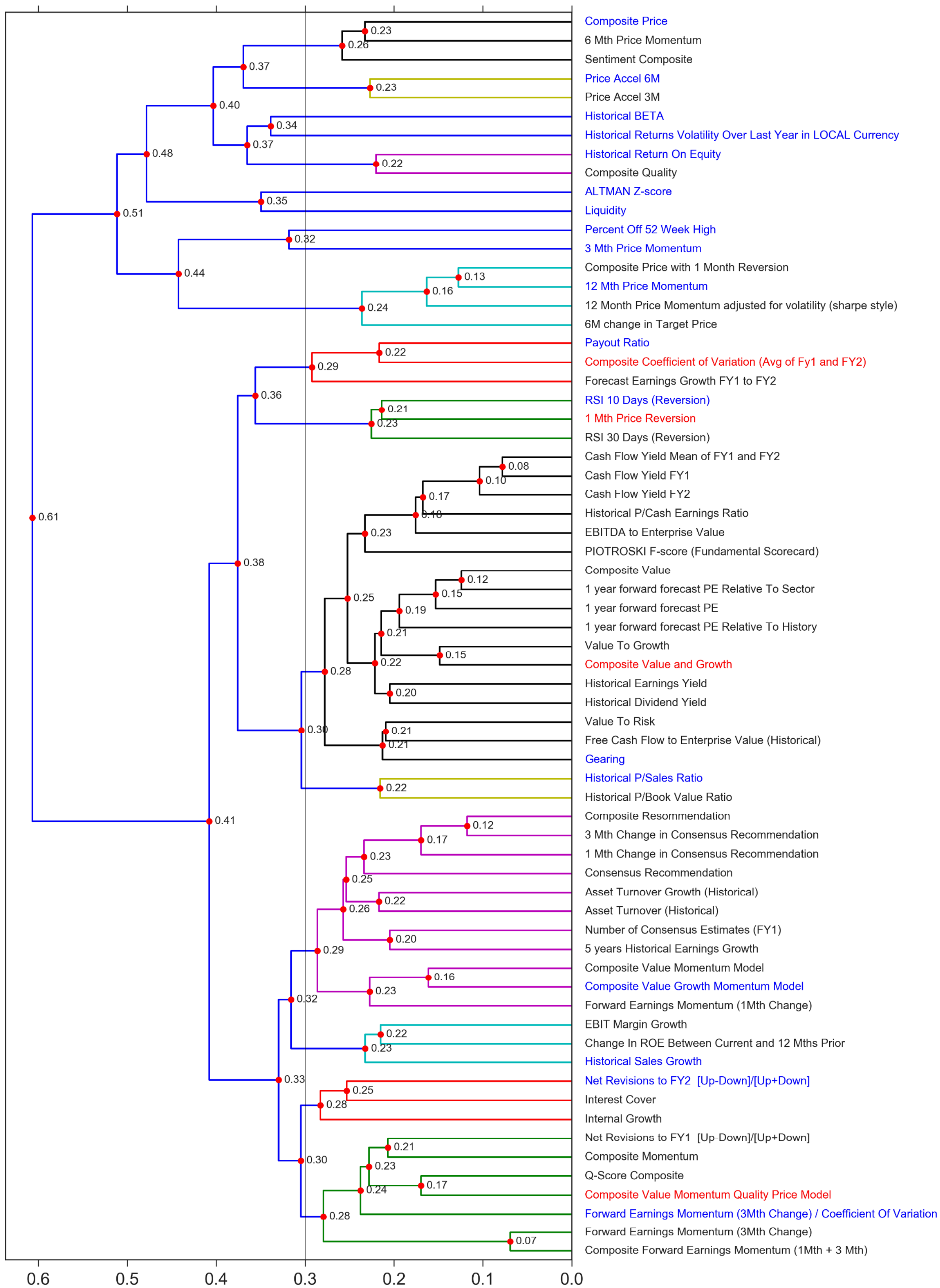

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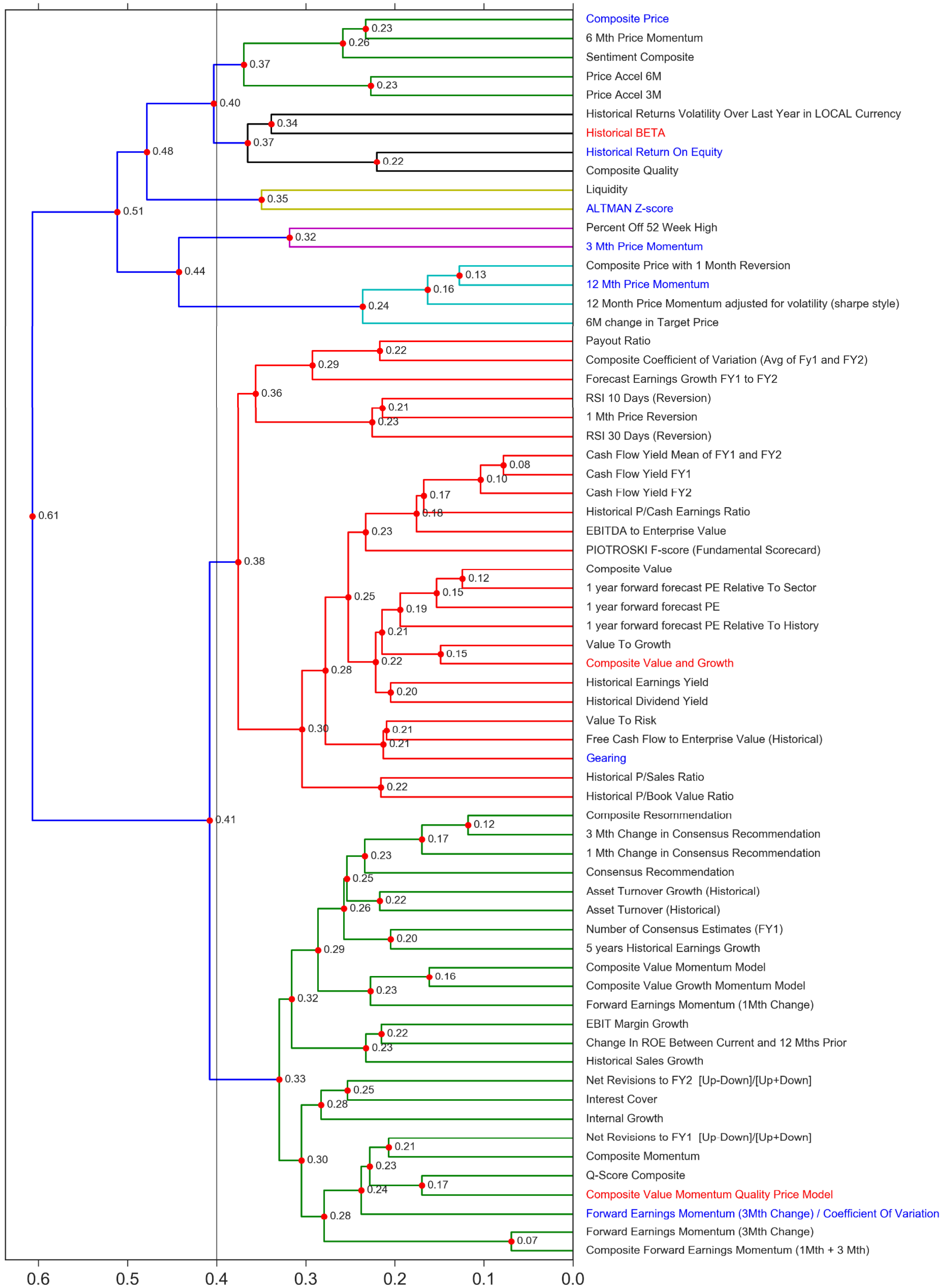

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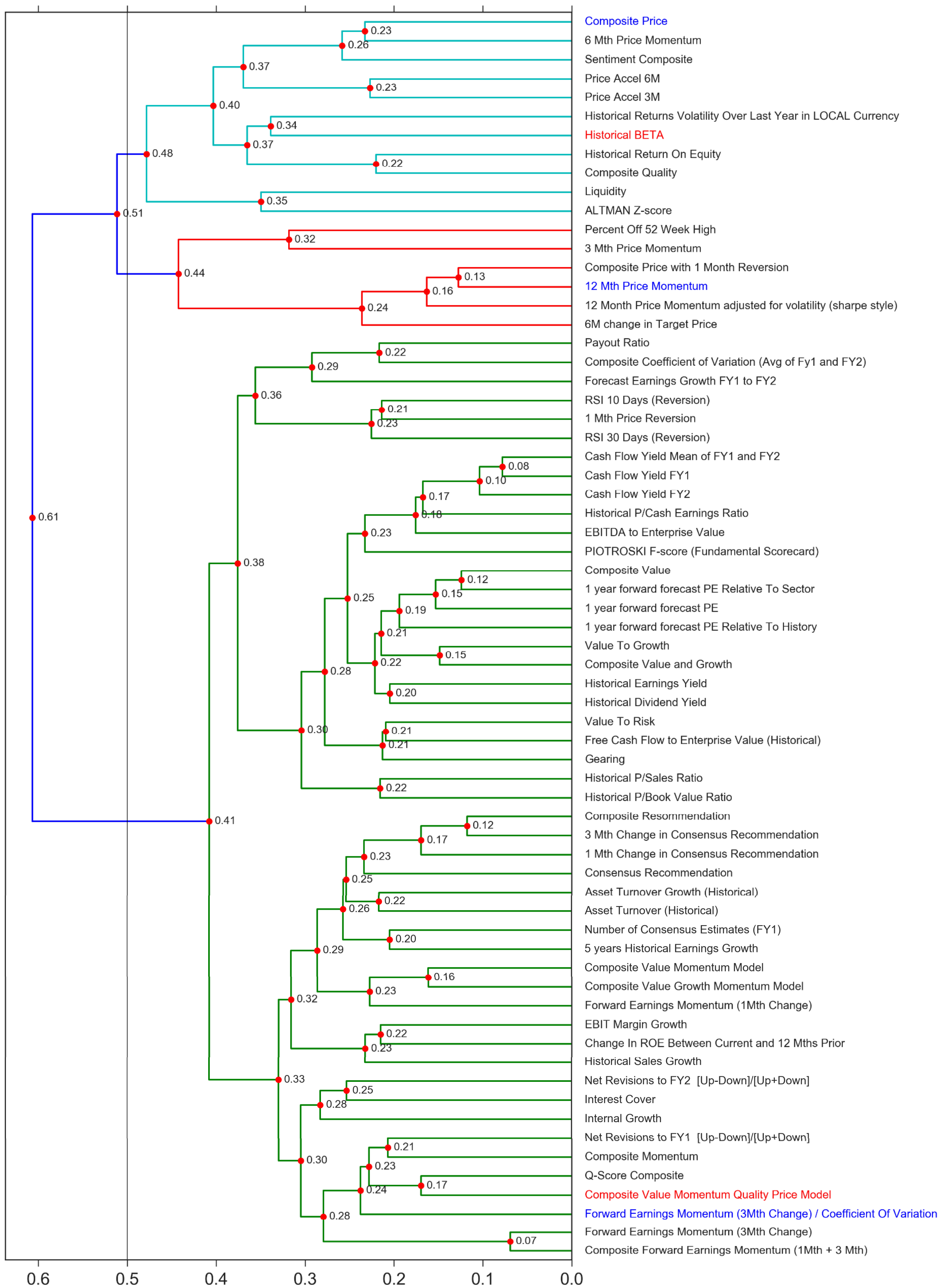

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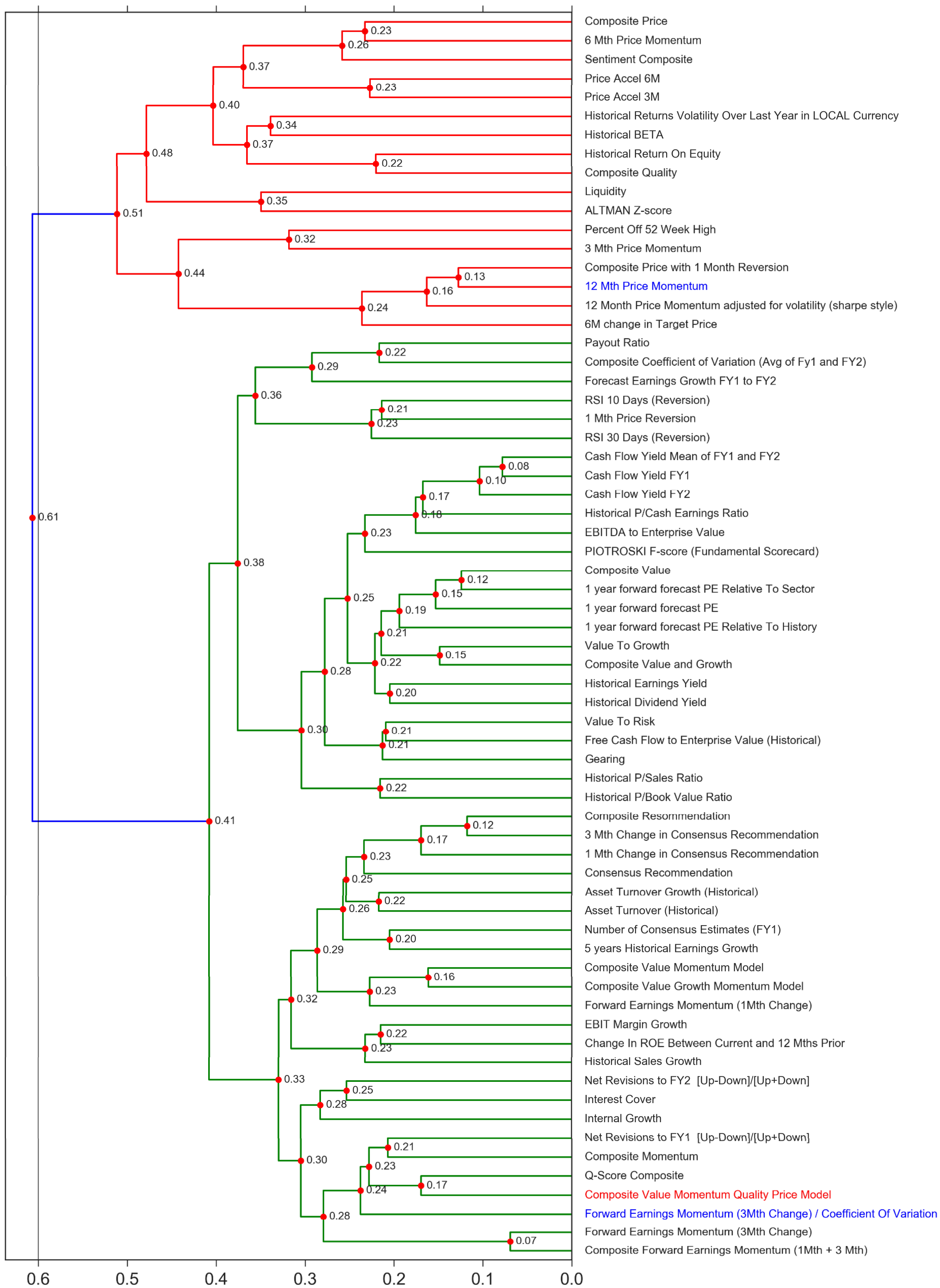

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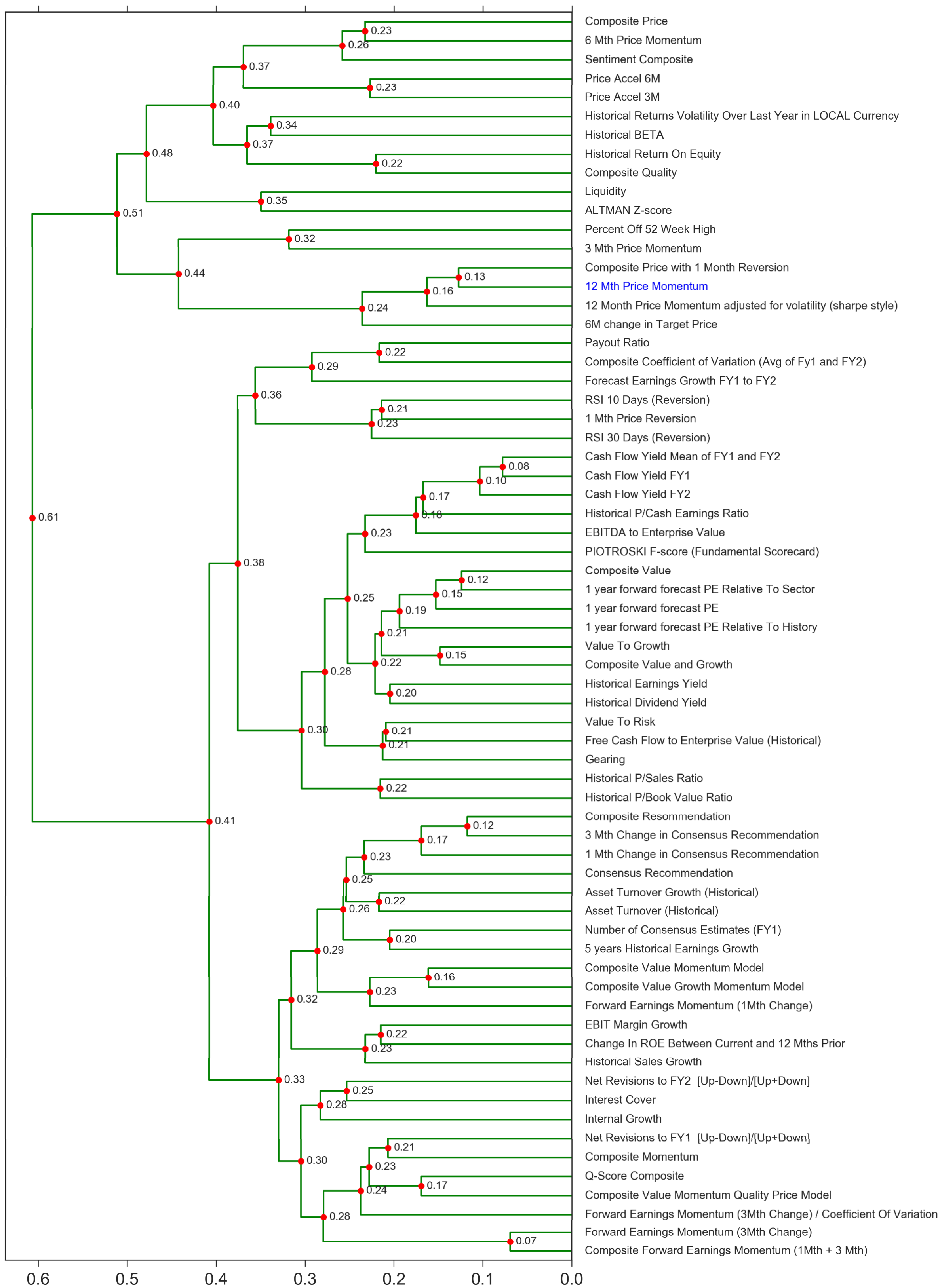

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