Trend-following, Risk-Parity and the influence of Correlations

Risk-Based and Factor Investing Conference
Imperial College Business School

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November 2015

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Introduction – Motivation

• Trend-following:
  – Long-short systematic strategy
  – Across multiple asset classes
  – Signals: buy rising assets, sell falling assets
  – Weighting scheme: inverse-volatility

• Poor performance during 2009-2013 (following double-digit returns in 2008)
  – The post-crisis period has been characterised by substantial asset co-movement
  – Inverse-volatility weights ignore pairwise correlations
  – Accounting for correlations would require the use of risk-parity

• Extend risk-parity to a long-short framework
  – Significant improvement in the performance of a trend-following strategy
  – Especially during periods of extreme correlation
Related Literature

- **Trend-Following:**
  - **UBS Research Notes:**

- **Risk Parity & Low-Risk investing:**
  - **UBS Research Notes:**
    5. "Correlation, De-correlation and Risk-Parity", 27 June 2014

- **Volatility Targeting:**
  - **UBS Research Notes:**
    1. "Understanding Volatility Targeting", October 4, 2011
    2. "Beyond Volatility Targeting", June 18, 2012
Data Description

• Futures Data
  – Source: Bloomberg [see the Appendix A for details on the construction of continuous series]
  – Daily closing futures prices for 35 assets over the period January 1987 – December 2013:

• 6 Energy contracts:
  - Brent Crude Oil, Gas Oil, Gasoline,
  - Heating Oil #2, Light Crude Oil, Natural Gas

• 10 Commodity contracts:
  - Metals: Cooper, Gold, Silver
  - Meat: Live Cattle
  - Grains: Corn, Soybeans, Wheat
  - Softs: Coffee "C", Cotton #2, Sugar

• 7 Equity contracts:
  - DAX, Eurostoxx 50, FTSE 100, KOSPI 200,

• 6 Currency contracts:
  - AUD, CAD, CHF, EUR, GBP, JPY.

• 6 Government Bond contracts:
  - US T-Note 5Yr, US T-Note 10Yr, US T-Bond 30Yr,
  - German Bobl (5Yr), German Bund (10Yr), JGB 10Yr.
Unconditional Asset Volatilities

- Large cross-sectional dispersion of volatilities...
- Must be taken into account when constructing a cross-asset portfolio.

Source: UBS Quantitative Research
Trend-Following Strategies

- Trend-Following (TF) strategy:
  - Assume $N_t$ available assets at the end of month $t$.
  - Look-back 12 months
  - Buy/sell signal = sign of past return.
  - Hold the portfolio for 1 month and rebalance:

  $$\frac{r_{t,t+1}^{TF}}{r_{t,t+1}^{Net}} = \sum_{i=1}^{N_t} \operatorname{sign}(r_{t-12,t}^i) \cdot w_{t,Net}^i \cdot r_{t,t+1}^i$$

  where $\sum_{i=1}^{N_t} w_{t,Gross}^i = \sum_{i=1}^{N_t} |w_{t,Net}^i| = 100\%$ and $\sum_{i=1}^{N_t} w_{Net,i}^t \leq 100\%$.

- Constant-Volatility Trend-Following (CV: TF) strategy:
  - Assuming a desirable target level of volatility $\sigma_{TGT}$ (10% for our purposes):

  $$\frac{r_{t,t+1}^{CV:TF}}{\sigma_T^{TF}} = \frac{\sigma_{TGT}}{\sigma_t^{TF}} \sum_{i=1}^{N_t} w_{t,Net}^i \cdot r_{t,t+1}^i$$
• **Volatility Parity Trend-Following** (*VP: TF*) strategy:
  
  – **Standard approach:** inverse-volatility weighted portfolio, aka "volatility-parity":

  \[
  w_{t,i,\text{Gross,VP}} = \frac{(\sigma_t^i)^{-1}}{\sum_{j=1}^{N_t}(\sigma_t^j)^{-1}}, \forall i
  \]

  \[
  \Rightarrow r_{t+1}^{VP:TF} = \frac{\sigma_{TGT}}{\sigma_t^{TF}} \sum_{i=1}^{N_t} \text{sign}(r_{t-12,t}^i) \cdot \frac{(\sigma_t^i)^{-1}}{\sum_{j=1}^{N_t}(\sigma_t^j)^{-1}} \cdot r_{t,t+1}^i
  \]

  – All assets enter the portfolio with the same volatility (hence "volatility-parity")
  – However, the portfolio construction ignores all pairwise correlations

• **Benchmark:** Volatility Parity Long-Only (*VP: LO*) strategy:

  \[
  r_{t+1}^{VP:LO} = \frac{\sigma_{TGT}}{\sigma_t^{LO}} \sum_{i=1}^{N_t} (+1) \cdot \frac{(\sigma_t^i)^{-1}}{\sum_{j=1}^{N_t}(\sigma_t^j)^{-1}} \cdot r_{t,t+1}^i
  \]

- Target volatility level $\sigma_{TGT} = 10\%$

Source: UBS Quantitative Research
And then trend-following stopped working...


- Volatility-Parity Long-Only
- Volatility-Parity Trend-Following

Source: UBS Quantitative Research
Correlation Event Study – Do correlations matter?

- Split months in correlation buckets and estimate Sharpe ratio per correlation regime

**Source:** UBS Quantitative Research

- Could this be due to the recent increases in correlations? "Risk On – Risk Off"…?
- **Volatility-Parity** ignores the effect of pairwise correlations, hence "Naïve Risk Parity"
Volatility Parity ignores the Pairwise Correlations

- Let's look into *gross weight allocation* and respective *risk allocation* per asset class

There is No Equal Contribution to Risk
- ...clearly due to *asset pairwise correlations* not being equal
Volatility Parity ignores the Pairwise Correlations

- We next plot 90-day rolling estimates of average pairwise correlation over time.
Volatility Parity ignores the Pairwise Correlations

- We next plot 90-day rolling estimates of *intra and inter asset-class correlations* over time.

Source: UBS Quantitative Research
Intra and Inter Asset-Class Correlations

Source: UBS Quantitative Research
Intra and Inter Asset-Class Correlations

Source: UBS Quantitative Research
Intra and Inter Asset-Class Correlations

- The degree of co-movement has dramatically increased post-2004
- However, fixed income assets have been become de-correlated after 2007
- Two rough clusters: Fixed Income and non-Fixed Income → "Risk on/Risk off"
- Pairwise correlations are ignored by a Volatility-Parity allocation.
- How to account for such information in portfolio construction?... "True Risk Parity"
Risk-Parity (aka Equal Risk Contribution - ERC)

- Define Marginal Contribution to Risk (MCR): \( MCR_i = \frac{\partial \sigma_p}{\partial w_i} \), where \( \sigma_p \) denotes portfolio volatility.
- It can be trivially shown that:
  \[
  \sum_{j=1}^{N} w_j \cdot MCR_j = \sigma_p
  \]
  ❖ Contrast this with: \( \sum_{j=1}^{N} w_j \cdot \sigma_j \geq \sigma_p \)
- RP Objective: equate the weighted MCR's:
  \[
  w_{i}^{RP} \cdot MCR_i = constant, \forall i
  \]
- Optimisation:
  Maximise: \( \sum_{i=1}^{N} \log(w_i) \)
  Subject to: \( \sigma_p(w) = \sqrt{w' \cdot \Sigma \cdot w} \leq \sigma_{TGT} \)
- Initial weights: \( w_{i}^{RP,init} = w_{i}^{VP} = \frac{(\sigma_i)^{-1}}{\sum_{j=1}^{N}(\sigma_j)^{-1}}, \forall i \)
- Post-optimisation rescaling of weights is permitted so to get weights in [0,1].
- Logarithmic weights are also used by Kaya (2012), Kaya and Lee (2012) and Roncalli (2014).

Note: For comparison between VP and RP see Appendix B.
Risk-Parity

• Advantages:
  – Attractive risk-return profile
  – True equal distribution of risk across portfolio constituents
  – Robust against parameter estimation error (acts like shrinkage)
  – Naturally constrained (the optimisation does not allow negative weights or position flips)
  – Lower turnover than minimum-variance or mean-variance portfolios

• Criticisms:
  – No information about expected returns is used
  – Substantial leverage for low-volatility assets (e.g. bonds)
  – Does not offer guidance as to which assets should be included in the portfolio; whatever enters the optimisation will bear a non-zero weight.
  – Highly correlated assets will bear a larger aggregate weight than what a single asset would bear ("identical asset problem")
Extending Risk-Parity to a Long-Short Framework

- The risk-parity formulation that has been presented only applies to long-only portfolio
  - If anything, log($w_i$) can only be defined for positive weights.

- How to go from long-only risk-parity to a long-short one:
  1. Start with **long-only risk-parity**
  2. Introduce/extend to **long-only risk-budgeting**
  3. Extend **long-only risk-budgeting** to **long-short risk-budgeting**
  4. Simplify **long-short risk-budgeting** down to **long-short risk-parity**
Long-Only Risk-Budgeting

- Risk-parity equates the weighted marginal contribution to risk from all assets
- **Risk-budgeting** (RB) allocates weights so that the assets contribute an amount to the overall portfolio volatility that is proportional to a certain positive asset-specific score, $s_i$
- From RP objective:

  $$w_i^{RP} \cdot MCR_i = \text{constant, } \forall i$$

- To RB objective:

  $$w_i^{RB} \cdot MCR_i \propto s_i, \forall i$$

- Optimisation (also shown in Kaya and Lee, 2012):

  Maximise: $\sum_{i=1}^{N} s_i \cdot log(w_i)$

  Subject to: $\sigma_p(w) = \sqrt{w' \cdot \Sigma \cdot w} \leq \sigma_{TGT}$

- Initial weights:

  $$w_{i,\text{init}}^{RB} = \frac{S_i \cdot (\sigma_i)^{-1}}{\sum_{j=1}^{N} S_j \cdot (\sigma_j)^{-1}}, \forall i$$
Long-Short Risk-Budgeting

- Can we allow for negative asset-specific scores?
  - Positive scores → Long positions
  - Negative scores → Short positions

- The resulting net weights must agree with the asset-specific scores in their sign:
  \[ \text{sign}(w_{i}^{\text{Net},RB}) = \text{sign}(s_{i}), \quad \forall i \]

- The RB objective becomes:
  \[ w_{i}^{\text{Net},RB} \cdot \text{MCR}_{i} \propto |s_{i}|, \forall i \]

- Optimisation:
  
  **Maximise:** \[ \sum_{i=1}^{N} |s_{i}| \cdot \log(|w_{i}|) \]

  **Subject to:** \[ \sigma_{p}(w) = \sqrt{w' \cdot \Sigma \cdot w} \leq \sigma_{TGT} \]

- Initial weights:
  \[ w_{i}^{\text{Net},RB,init} = \frac{s_{i} \cdot (\sigma_{i})^{-1}}{\sum_{j=1}^{N} |s_{j}| \cdot (\sigma_{j})^{-1}} \]
Long-Short Risk-Parity and Trend-Following

- Notice that if all asset-specific scores are equal in absolute value, we are back to risk-parity:

\[
if \ |s_i| = |s_j|, \forall i, j
\]

\[\Rightarrow \text{Long-Short Risk-Budgeting: } w_{i}^{Net,RB} \cdot MCR_i \propto 1\]

\[\Rightarrow w_{i}^{Net,RB} \cdot MCR_i = \text{constant}, \forall i \Rightarrow \text{Risk – Parity}\]

- However, this framework now allows for long and short positions!

- Trend-following signal: \( s_i = \text{sign}(ret_{i}^{12M}) = \pm 1 \Rightarrow |s_i| = |s_j|, \forall i, j\)

- Long-Short risk-budgeting optimisation boils down to a long-short risk-parity optimisation.

- Optimisation:

\[
\text{Maximise: } \sum_{i=1}^{N} \log(|w_i|) \\
\text{Subject to: } \sigma_p(w) = \sqrt{w' \cdot \Sigma \cdot w} \leq \sigma_{TGT}
\]

- Initial weights:

\[
w_{i}^{Net,RP,init} = \text{sign}(ret_{i}^{12M}) \cdot \frac{(\sigma_i)^{-1}}{\sum_{j=1}^{N}(\sigma_j)^{-1}}
\]

- Risk-Parity Trend-Following \((RP:TF)\) strategy:

\[
r_{t,t+1}^{RP:TF} = \frac{\sigma_{TGT}}{\sigma_{TF}} \sum_{i=1}^{N_t} w_{t}^{i,Net,RP} \cdot r_{t,t+1}^{i}
\]

UBS
Trend-following: Performance Statistics


Note: For rolling Sharpe ratio see Appendix C.
Correlation Event Study – Revisited

- How do RP portfolios perform in extreme-correlation regimes?

- **RP constitutes a genuine improvement** to naïve VP, especially in periods of high correlations.

- **Word of Caution**: In an environment that markets do not trend at all, a more sophisticated weighting scheme like Risk-Parity can only do so much.
From VP to RP – Weight vs. Risk Allocation

- Gross weight allocation and respective risk allocation per asset class.

- From Volatility-Parity…
From VP to RP – Weight vs. Risk Allocation

- **Gross weight allocation** and respective **risk allocation** per asset class.

- From Volatility-Parity…to **Risk-Parity**

- **Equal Risk Contribution** across assets and consequently asset classes.
From VP to RP – Unconditional Weight Distribution

- Similar distribution, but RP has larger interquartile ranges
- … → larger turnover, but this was expected
- The two weighting schemes are only different because of correlations.
Concluding Remarks

- One reason for the underperformance of trend-following strategies in the post-crisis period has been the substantial co-movement of assets and asset classes.

- Trend-following can benefit significantly from a risk-parity allocation, especially in periods of substantial co-movement.

- Risk-parity is generally considered a long-only allocation scheme.

- We extend risk-parity to a long-short framework and show that it can significantly improve the risk-adjusted performance of trend-following in periods of high correlation.
Appendix A - Working with Futures Contracts

- Building continuous futures price-series:
  - Futures contracts are short-lived instruments, only active until the delivery date.
  - In theory, unfunded investments; in practice, initial margin payment is required.
  - We use Bloomberg's custom-made continuous generic price-series using backwards-ratio price adjustment, so that no "price jump" (fictitious return) occurs on a roll-over day.
  - Screen <GFUT> in Bloomberg provides a number of choices regarding the construction of the generic futures series.

- Construction of “excess” returns:
  - Assume a “front” futures contract priced at $F_{t,T}$ at the end of month $t$ maturing at $T$.
  - Assume the contract is not within its delivery month, i.e. $t < t + 1 < T$.
  - At the end of month $t + 1$, it is priced at $F_{t+1,T}$.
  - Entering the contract at time $t$ involves initial margin of $M_t$, which, in turn, grows at $r_t^f$.
  - The excess return of the futures contracts in $[t, t + 1]$ is (assuming no variation margin):

$$r_{x}^{s,t+1} = \frac{[M_t(1 + r_t^f) + (F_{t+1,T} - F_{t,T})] - M_t}{M_t} - r_t^f = \frac{F_{t+1,T} - F_{t,T}}{M_t}$$

  - For a "fully-collateralised" position, $M_t = F_{t,T}$:

$$r_{t,t+1}^{x,c} = r_{t+1,t}^{x} = \frac{F_{t+1,T} - F_{t,T}}{F_{t,T}}$$

  - We use this formula to calculate monthly holding returns for the strategy backtesting.
Appendix B: Volatility-Parity versus Risk-Parity

• Volatility-parity weights:

\[ w_{i}^{VP} \propto \frac{1}{\sigma_i} \]

• Risk-parity weights are such that: \( w_{i}^{RP} \cdot MCR_i = constant, \forall i \)

It can be shown that: 
\[ MCR_i = \frac{\partial \sigma_P(w)}{\partial w_i} = \sigma_i \cdot \rho_{i,P}(w) \]

\( \rho_{i,P}(w) \): correlation of asset \( i \) with the overall portfolio.

\[ \Rightarrow \ w_{i}^{RP} \propto \frac{1}{MCR_i} = \frac{1}{\sigma_i} \cdot \frac{1}{\rho_{i,P}(w^{RP})} \]

Caution: the above result is not a closed-form solution...

• Risk-parity over-weights:
  – Low-volatility assets
  – De-correlated assets (i.e. assets with lower correlation with the rest of the universe)
Appendix B: Volatility-Parity versus Risk-Parity

• Divide by parts:

\[
\frac{w_{i}^{RP}}{w_{i}^{VP}} \propto \frac{1}{\rho_{i,P}(w^{RP})}
\]

Caution: this result is a proportionality statement \(\rightarrow\) qualitative conclusions only

- When an asset correlates more with the universe, its RP weight falls relative to \(\frac{1}{\sigma}\)
- When an assets de-correlates, its RP weight increases relative to \(\frac{1}{\sigma}\)

• Using the weight normalisation (sum of weights is 100%), we deduce the following illustrative comparison:

\[
\begin{align*}
    w_{i}^{VP} &= \frac{(\sigma_{i})^{-1}}{\sum_{j=1}^{N}(\sigma_{j})^{-1}} \\
    \text{Closed-form Solution} \\
\end{align*}
\]

\[
\begin{align*}
    w_{i}^{RP} &= \frac{(MCR_{i})^{-1}}{\sum_{j=1}^{N}(MCR_{j})^{-1}} \\
    \text{non-closed-form expression} \rightarrow \text{Numerical Solution}
\end{align*}
\]

• The two weighting schemes are identical if all correlations are equal [see next page]
Appendix B: Volatility-Parity versus Risk-Parity

• The Marginal Contribution to Risk \((MCR)\) is defined as the change in portfolio volatility \(\sigma_p(w)\) for a marginal change in the weight of each asset \(i, w_i:\)

\[
MCR_i = \frac{\partial \sigma_p(w)}{\partial w_i} = \frac{(\Sigma \cdot w)_i}{\sigma_p(w)}
\]  
(1)

• If the pairwise correlation is constant across all pairs and equal to \(\bar{\rho}\) then (1) simplifies to:

\[
MCR_i(\bar{\rho}) = \frac{\sigma_i}{\sigma_p(w)} \left[ w_i \cdot \sigma_i \cdot (1 - \bar{\rho}) + \bar{\rho} \sum_{j=1}^{N} w_j \cdot \sigma_j \right]
\]  
(2)

• The Risk-Parity objective is:

\[
w_i^{RP} \cdot MCR_i = constant, \forall i \iff w_i^{RP} \cdot MCR_i = w_j^{RP} \cdot MCR_j, \forall i, j
\]  
(3)

• Combining (2) – for \(i\) and \(j\) – and (3) leads to:

\[
\frac{(w_i \cdot \sigma_i - w_j \cdot \sigma_j)}{A} \cdot \left[ (w_i \cdot \sigma_i + w_j \cdot \sigma_j)(1 - \bar{\rho}) + \bar{\rho} \sum_{m=1}^{N} w_m \cdot \sigma_m \right] = 0, \forall i, j
\]  
(4)

• Under reasonable assumptions for \(B (\ldots)\) the solution to (4) is \(A = 0\), hence:

\[
\frac{w_i}{w_j} = \frac{1/\sigma_i}{1/\sigma_j}, \forall i, j \iff Volatility Parity
\]
Appendix C: 36-month Rolling Sharpe Ratio

The picture is similar (in terms of RP relative benefit) for long-only strategies.

Source: UBS Quantitative Research
Appendix D: Distribution of Pairwise Correlations

- We plot below the certain percentiles of the cross-sectional distribution of 90-day pairwise correlations between all the assets of our universe.

Source: UBS Quantitative Research
Related Literature (1/2)

- Baltas, A. N., & Kosowski, R. (2013), Momentum Strategies in Futures Markets and Trend-Following Funds. *Available at SSRN 1968996*.
Related Literature (2/2)

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<table>
<thead>
<tr>
<th>12-Month Rating</th>
<th>Definition</th>
<th>Coverage1</th>
<th>IB Services2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buy</td>
<td>FSR is &gt; 6% above the MRA.</td>
<td>49%</td>
<td>33%</td>
</tr>
<tr>
<td>Neutral</td>
<td>FSR is between -6% and 6% of the MRA.</td>
<td>40%</td>
<td>26%</td>
</tr>
<tr>
<td>Sell</td>
<td>FSR is &gt; 6% below the MRA.</td>
<td>12%</td>
<td>18%</td>
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<table>
<thead>
<tr>
<th>Short-Term Rating</th>
<th>Definition</th>
<th>Coverage1</th>
<th>IB Services2</th>
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</thead>
<tbody>
<tr>
<td>Buy</td>
<td>Stock price expected to rise within three months from the time the rating was assigned because of a specific catalyst or event.</td>
<td>less than 1%</td>
<td>less than 1%</td>
</tr>
<tr>
<td>Sell</td>
<td>Stock price expected to fall within three months from the time the rating was assigned because of a specific catalyst or event.</td>
<td>less than 1%</td>
<td>less than 1%</td>
</tr>
</tbody>
</table>

Source: UBS. Rating allocations are as of 30 September 2015.
1:Percentage of companies under coverage globally within the 12-month rating category. 2:Percentage of companies within the 12-month rating category for which investment banking (IB) services were provided within the past 12 months. 3:Percentage of companies under coverage globally within the Short-Term rating category. 4:Percentage of companies within the Short-Term rating category for which investment banking (IB) services were provided within the past 12 months.

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