Inter-temporal risk parity

Nomura Global Quantitative Equity Conference  8th May 2014
Inter-temporal risk parity strategy

- What is inter-temporal risk parity?
  - Systematic strategy rebalancing between a risky asset and cash
  - Weight of risky asset is chosen so that ex-ante risk is kept constant

\[ r^{IRP}_t = r_t \frac{\kappa}{\sigma_t} + r_c \left(1 - \frac{\kappa}{\sigma_t}\right) \]

- Other names: *constant risk*, *inverse volatility weighting* and *iso-vol* (France).
Inter temporal risk parity strategy in practice

Volatility

I-GARCH
Target (k)

Exposure

Exposure of risky asset
Exposure of cash

Increase in volatility
One day lag for implementation
Decrease the exposure

31-Dec-13  14-Jan-14  28-Jan-14  11-Feb-14  25-Feb-14  11-Mar-14  25-Mar-14  08-Apr-14  22-Apr-14
If returns of risky assets had Gaussian distributions

<table>
<thead>
<tr>
<th>Gaussian distributed returns</th>
<th>Buy and Hold</th>
<th>Inter-temporal Risk Parity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average annualized excess return</td>
<td>7.5%</td>
<td>7.7%</td>
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<tr>
<td>Average annualized volatility</td>
<td>18.8%</td>
<td>19.3%</td>
</tr>
<tr>
<td>Sharpe ratio</td>
<td>0.40</td>
<td>0.40</td>
</tr>
<tr>
<td>Maximum drawdown (MDD)</td>
<td>-37.6%</td>
<td>-38.5%</td>
</tr>
<tr>
<td>Ratio MDD / volatility</td>
<td>-2.0</td>
<td>-2.0</td>
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<tr>
<td>Average exposure</td>
<td>100.0%</td>
<td>101.8%*</td>
</tr>
<tr>
<td>Improvement in Sharpe ratio</td>
<td>-</td>
<td>0.00</td>
</tr>
<tr>
<td>Std Dev of improvement in Sharpe ratio</td>
<td>-</td>
<td>3.5%</td>
</tr>
</tbody>
</table>


Substantial effort for nothing. But, before transaction costs, no loss either.

- Returns of risky assets do not follow Gaussian distributions: clustering, fat tails, leverage effects, ...

* Average of $1 / \sigma_i > 1$ for an uniform function, thus average exposure > 100%
Inter-temporal risk parity applied to equities

- Evidence that managing equities at constant risk adds value:
  - Hocquard, Ng and Papageorgiou (2013)
  - Cooper (2010)
  - Kirby and Ostdiek (2012)
  - Ilmanen & Kizer (2012)
  - Giese (2012)

- But no consensus regarding where added value comes from:
  - Hallerbach (2012)

Better volatility forecast and less variability in volatility is sufficient to improve Sharpe ratio.

Higher Sharpe ratio and smaller drawdowns with constant volatility portfolio.
Understanding inter-temporal risk parity strategies

Monte Carlo simulations with scenarios generated from parametric models

- Apply different stochastic models [1] for risky asset returns
  - Keep risk premium $\mu$ constant over time
- Apply different volatility models [2]
  - GARCH family of models
  - Introduce effects, i.e. leverage effect
- Different noise [3]
  - Gaussian
  - t-student for higher probability of fat tail events
  - skewed for larger extreme events

1. $r_t = \mu + \sigma_t Z$

2. $\sigma_t^2 = \omega + \alpha (r_t - \mu)^2 + \beta \sigma_{t-1}^2$
   - $\omega$ long-term volatility level
   - $\alpha$ volatility clustering
     - higher alpha $\Rightarrow$ larger clustering effect
   - $\beta$ persistency of past volatility
     - $\sim 1$ $\Rightarrow$ few changes in the day-to-day volatility
   - $\alpha + \beta$ must be $< 1$ for stationarity
   - Features like leverage effect i.e. volatility more impacted by negative returns can also be added

3. $Z \sim N(\ldots)$

Compare buy and hold with the average behaviour observed over many simulated scenarios.
Volatility clustering explains better risk-adjusted performances

Using standard GARCH model

- Generate volatility clustering while keeping risk premium is constant:
  - Higher Sharpe ratio in lower volatility regimes
  - Lower Sharpe ratio in higher volatility regimes

- Clustering of volatility adds predictability while:
  - Increased exposure in lower volatility regimes
  - Decreased exposure in higher volatility regimes

- Market timing effect!

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<tr>
<td>Sharpe ratio</td>
<td>0.40</td>
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<td>Average exposure</td>
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<td>Std Dev of improvement in Sharpe ratio</td>
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<td>11.4%</td>
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</tbody>
</table>

Source: R Perchet, R Leote de Carvalho, T Heckel and P Moulin, “Inter-temporal risk parity: A constant volatility framework for equities and other asset classes” (2014)
Fat tails, leverage effect and skew

- Fat tails (GARCH with t-student noise)
  - Increase the probability of extremes events
  ⇒ Improvement of the Sharpe ratio
  ⇒ Reduces largest drawdown events

- Leverage effect (GJR-GARCH):
  - Volatility increases more with negative returns, i.e. negative correlation between volatility and returns
  ⇒ Reduces largest drawdown events

- Larger negative return (Skewed-GARCH)
  - Increase probability of larger negative return
  ⇒ Reduces largest drawdown events

Inter-temporal risk parity strategy improves returns and filters out fat tails thanks to predictability of volatility due to clustering. Negative correlation between return volatility add to the benefit.

### Table

<table>
<thead>
<tr>
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<td>Sharpe ratio</td>
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<td>Ratio MDD / volatility</td>
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<td>Maximum drawdown (MDD)</td>
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Source: R Perchet, R Leote de Carvalho, T Heckel and P Moulin, “Inter-temporal risk parity: A constant volatility framework for equities and other asset classes” (2014)
Impact of rebalancing frequency

- At weekly re-balancing, the benefits from an inter-temporal risk parity strategy remain strong.

Lower frequency means substantially lower turnover.
Optimal strategy with daily monitoring and rebalancing only when significant changes are observed.

Source: R Perchet, R Leote de Carvalho, T Heckel and P Moulin, “Inter-temporal risk parity: A constant volatility framework for equities and other asset classes” (2014)
Forecasting volatility (S&P500)

- Different GARCH models considered
  - Target 10% volatility ex-ante

- GARCH which includes
  - Volatility clustering
  - Long term volatility

- NA-GARCH & GJR-GARCH which include
  - Volatility clustering
  - Long term volatility
  - Leverage effect

- I-GARCH which includes
  - Volatility clustering

- 1-year ex-post volatility is measured

I-GARCH model does best at forecasting volatility

* Comparison of the 1-year rolling ex-post volatility for the inter-temporal risk parity strategy applied to the S&P 500. The target volatility is 10% and the forecast volatility is based on four different GARCH models with parameters estimated from an expanding window once every year at the start of each year. Source: R Perchet, R Leote de Carvalho, T Heckel and P Moulin, “Inter-temporal risk parity: A constant volatility framework for equities and other asset classes” (2014)
Larger clustering effect in riskier asset classes

- Estimation of clustering effect and fat tail events for main asset classes
  - Large $\alpha$ for Equities, in particular Emerging, and for US high yield more volatility clustering
  - Smaller $\alpha$ for government bonds and for investment grade bonds less volatility clustering
- $\alpha + \beta \sim 1$ for all assets
  - most of the volatility explain past volatility and new events
- Very small impact of long term volatility
- High probability of extremes events in US high yield and Russell 1000

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<td>1.6E-6</td>
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<td>2.0E-7</td>
<td>1.0E-7</td>
<td>3.0E-7</td>
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<td>6.1%</td>
<td>9.6%</td>
<td>5.4%</td>
<td>21.7%</td>
<td>4.0%</td>
<td>4.3%</td>
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<td>(t-stats)</td>
<td>(9.90)</td>
<td>(11.4)</td>
<td>(11.0)</td>
<td>(12.7)</td>
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<td>(8.7)</td>
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<td>89.3%</td>
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<td>(89.5)</td>
<td>(171.9)</td>
<td>(38.0)</td>
<td>(162.1)</td>
<td>(136.7)</td>
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<td>$\alpha + \beta$</td>
<td>99.4%</td>
<td>98.9%</td>
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<td>99.0%</td>
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<td>t-Student</td>
<td>5.6</td>
<td>7.1</td>
<td>7.4</td>
<td>3.7</td>
<td>6.7</td>
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<td>(t-stats)</td>
<td>(16.8)</td>
<td>(13.2)</td>
<td>(12.7)</td>
<td>(33.9)</td>
<td>(12.8)</td>
<td>(12.7)</td>
</tr>
</tbody>
</table>

Chunnel returns with Inter-temporal risk parity strategy

![Graphs of Russell 1000 (B&H), Russell 1000 (ITR), US 10Y Gov. Bonds (B&H), and US 10Y Gov. Bonds (ITR)]
### Historical simulations for different asset classes

- **Inter-temporal risk parity strategy** applied to equity indices and other asset classes
  - Higher Sharpe ratio for asset classes with stronger volatility clustering and fat tails
    - High yield bonds
    - Emerging Equities
    - Developed Equities
    - Less for commodities
  - Corporate bonds and government bonds
    - Low clustering in the last 20 years
    - No significant benefit

Source: R Perchet, R Leote de Carvalho, T Heckel and P Moulin, “Inter-temporal risk parity: A constant volatility framework for equities and other asset classes” (2014)

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<tbody>
<tr>
<td><strong>Average annual. Excess return</strong></td>
<td>8.0%</td>
<td>6.7%</td>
<td>2.3%</td>
<td>4.8%</td>
<td>3.7%</td>
<td>3.2%</td>
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<tr>
<td><strong>Average annual. Volatility</strong></td>
<td>19.0%</td>
<td>19.2%</td>
<td>21.6%</td>
<td>4.4%</td>
<td>5.1%</td>
<td>8.0%</td>
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<tr>
<td><strong>Sharpe ratio</strong></td>
<td>0.42</td>
<td>0.35</td>
<td>0.11</td>
<td>1.09</td>
<td>0.73</td>
<td>0.40</td>
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<td><strong>Maximum drawdown (MDD)</strong></td>
<td>-55.8%</td>
<td>-65.2%</td>
<td>-73.4%</td>
<td>-29.1%</td>
<td>-16.7%</td>
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<td><strong>Ratio MDD / volatility</strong></td>
<td>-2.9%</td>
<td>-3.4</td>
<td>-3.4</td>
<td>-6.6</td>
<td>-3.3</td>
<td>-1.8</td>
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<td><strong>I-GARCH</strong></td>
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<td><strong>Average annual. Excess return</strong></td>
<td>2.9%</td>
<td>3.0%</td>
<td>0.8%</td>
<td>8.5%</td>
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<td>2.1%</td>
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<tr>
<td><strong>Average annual. Volatility</strong></td>
<td>5.2%</td>
<td>5.4%</td>
<td>5.2%</td>
<td>5.5%</td>
<td>5.1%</td>
<td>5.2%</td>
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<tr>
<td><strong>Sharpe ratio</strong></td>
<td>0.56</td>
<td>0.56</td>
<td>0.15</td>
<td>1.55</td>
<td>0.76</td>
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<td><strong>Maximum drawdown (MDD)</strong></td>
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<td>-10.2%</td>
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<tr>
<td><strong>Ratio MDD / volatility</strong></td>
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<td>-3.5</td>
<td>-3.2</td>
<td>-5.2</td>
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<tr>
<td><strong>Improv. in Sharpe ratio</strong></td>
<td>0.14</td>
<td>0.21</td>
<td>0.05</td>
<td>0.45</td>
<td>0.04</td>
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</table>
Factor investing

- Factor investing has been gaining attention since Fama & French (1992, 1993)
  - Value and Size premiums in equity markets
- Carhart (1997) extended Fama and French model
  - Momentum premium was added
- Qian, Sorensen and Hua (2009) found value premium in other asset classes
  - Government bonds
  - Foreign exchange
- Asness, Moskowitz and Pedersen (2013) generalize value and momentum premiums
  - Government bonds
  - Foreign exchange
  - Commodities
- Capture premiums: long-short portfolios
  - E.g. long the cheapest securities and short the most expensive securities
Value and Momentum premiums

Inter-temporal risk parity strategy applied to Value and Momentum factors:

- **Equities**: daily data from Ken French’s web-site:
  - Value premium: HML (High-Minus-Low factor)
  - Momentum premium: Mom (Momentum)

- **Sovereign Government bonds based on 10 countries***:
  - Value premium: slope of the yield curve (10-year bond yields minus cash rates)
  - Momentum premium: past twelve month cumulative returns of total return indices

- **Foreign exchange based on 10 countries****::
  - Value premium: carry strategy using inter-bank rates
  - Momentum premium: past twelve month cumulative returns of forward returns

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* Australia, Canada, Germany, Japan, Denmark, Norway, Sweden, Switzerland, UK and US
** Australia, Canada, Germany or Euro zone after 1999, Japan, New Zealand, Norway, Sweden, Switzerland, UK and US
Improvement of information ratios in factor investing

Applying inter-temporal risk parity to factor investing also bring benefits

- Improvement of information ratios
- Larger impact for underlying risky asset classes
  - Equities and foreign exchange
- Lower impact for government bonds
- Also robust to rebalancing frequency
  - Weekly or monthly rebalancing

<table>
<thead>
<tr>
<th></th>
<th>Momentum Equity</th>
<th>Value Equity</th>
<th>Momentum Foreign Exchange</th>
<th>Value Foreign Exchange</th>
<th>Momentum Fixed Income</th>
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<tbody>
<tr>
<td>Buy and hold strategy</td>
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<td>6.1%</td>
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<tr>
<td>Information ratio</td>
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<td>0.34</td>
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<td>Ratio MDD / volatility</td>
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<td>Information ratio</td>
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<td>Improv. in information ratio</td>
<td>0.83</td>
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<td>0.19</td>
<td>0.22</td>
<td>0.05</td>
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</table>

* Comparison of a buy-and-hold strategy for different factor with inter-temporal risk parity strategies based on historical simulations. The target volatility was set at 5%. Volatility forecasts as based on I-GARCH models. The I-GARCH model parameters were estimated from an expanding window once every year at the start of each year. Bloomberg, BNP Paribas Investment Partners, January 2014

Conclusions

- No Gaussian behavior or returns explains why constant volatility strategy add value
- Investors should think in terms of risk budget allocation rather than fixed weights
- Improvement of Sharpe ratio and information ratio explained by volatility clustering
  - Volatility is not constant over time and is predictable to some extent
- Presence of fat tails events increase volatility clustering effect
- Benefit of risk management is larger if return and volatility are negatively correlated
- Clear benefit for risky asset classes: equities, high yield and foreign exchange rates
- Less added value but keep the risk exposure under control for less risky asset classes such as government bonds

Our research show how risk management can improve risk-adjusted returns!
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