Summary

- GARCH models explain asset class and factor returns
- GARCH parameters determine performance of target volatility strategies
- Monte Carlo simulations can be used to investigate the impact of GARCH parameters
- Historical simulations can be used to confirm theoretical expectations

R. Perchet, R. Leote de Carvalho, T. Heckel, P. Moulin. "Predicting the success of volatility targeting strategies: Application to equities and other asset classes.", *The Journal of Alternative Investments*, Vol. 18, No. 3 (Winter 2016), pp. 21-38.

R. Perchet, R. Leote de Carvalho, P. Moulin. "Inter-temporal risk parity: a constant volatility framework for factor investing.", *Journal of Investment Strategies*, Vol. 4, No. 1 (2014), pp. 1-23.

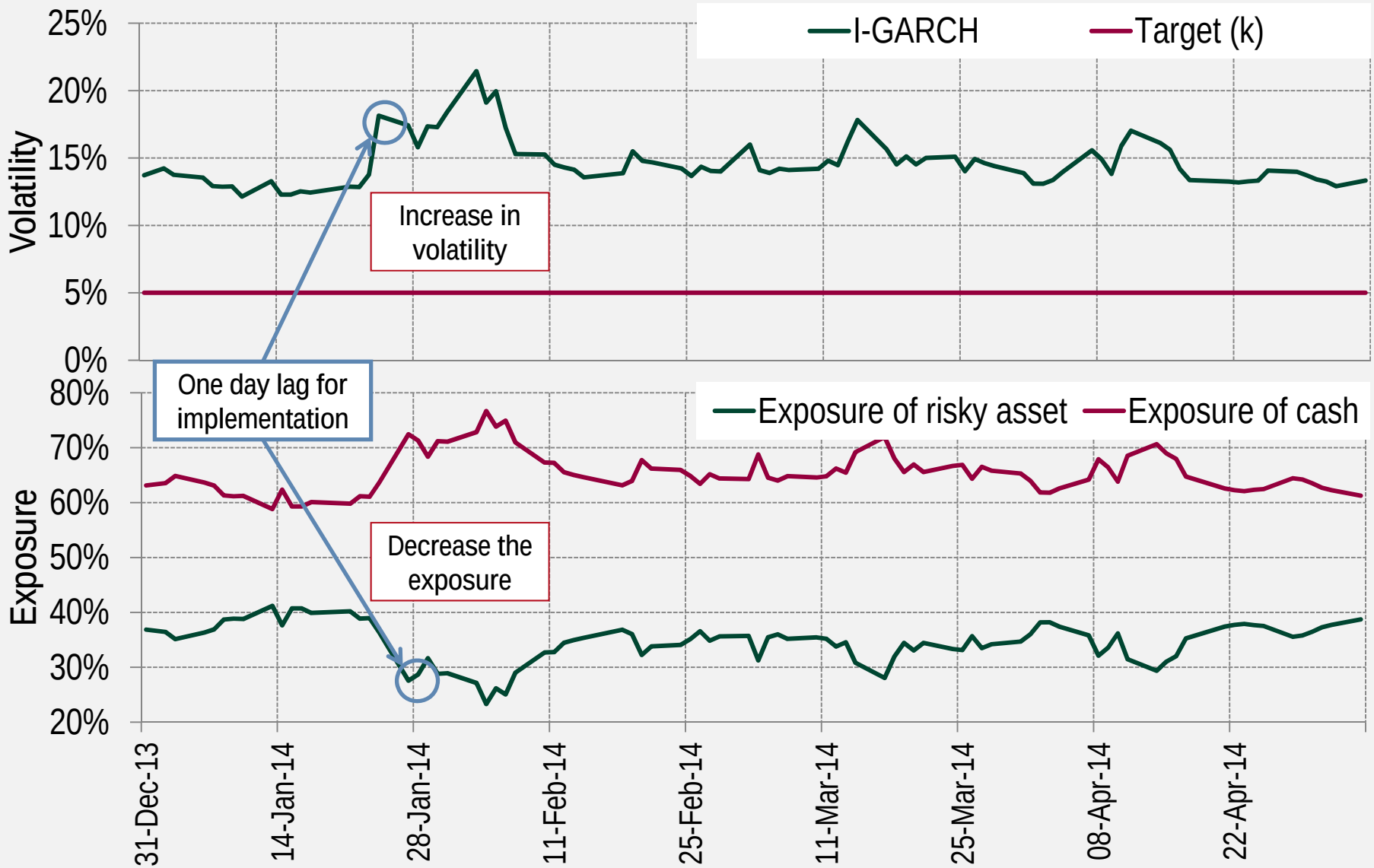
Target volatility strategy (TVS)

- ✓ Systematic strategy rebalancing between a risky asset and cash
- ✓ Weight of risky asset is chosen so that ex-ante risk is kept constant

$$r^{TVS}{}_t = r_t \frac{\kappa}{\sigma_t} + r_c\left(1 - \frac{\kappa}{\sigma_t}\right)$$

$r^{TVS}{}_t$	target volatility strategy returns	σ_t	ex-ante volatility at *t -1*
r_t	risky asset returns	κ	pre-defined target volatility
r_c	cash returns	κ / σ_t	weight of risky asset

Target volatility strategy in practice for S&P 500 index



What if risky asset returns were Gaussian distributed?

Gaussian distributed returns	Buy and Hold	Target Volatility
Average annualized excess return	7.5%	7.7%
Average annualized volatility	18.8%	19.3%
Sharpe ratio	0.40	0.40
Maximum drawdown (MDD)	-37.6%	-38.5%
Ratio MDD / volatility	-2.0	-2.0
Average exposure	100.0%	101.8%*
Improvement in Sharpe ratio	-	0.00
Std Dev of improvement in Sharpe ratio	-	3.5%

R. Perchet, R. Leote de Carvalho, T. Heckel, P. Moulin. "Predicting the success of volatility targeting strategies: Application to equities and other asset classes.", The Journal of Alternative Investments, Vol. 18, No. 3 (Winter 2016), pp. 21-38.

Substantial effort for nothing

But no losses either before transaction costs

Target volatility strategies for equities

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

Higher Sharpe ratio and smaller drawdowns with constant volatility strategies.

- But no consensus regarding why
  - Hallerbach (2012)

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

- Little known about application of target volatility strategies to other asset classes

Understanding target volatility Strategies

Monte Carlo framework

Scenarios generated from parametric models

Stochastic models [1] for risky asset returns

Risk premium μ 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 $$\sigma_t{}^2 = \omega + \alpha(r_t - \mu)^2 + \beta\sigma_{t-1}{}^2$$

ω long-term volatility level

α volatility clustering

higher alpha => larger clustering effect

β persistency of past volatility

~ 1 => few changes in the day-to-day volatility

$\alpha + \beta$ must be < 1 for stationary

Features like leverage effect, i.e. volatility more impacted by negative returns, can also be modelled

3 $$Z \sim N(\dots)$$

Compare average behaviour observed over many simulated scenarios with buy and hold

Volatility clustering explains higher risk-adjusted returns

Standard GARCH model

Simulate volatility clustering

- Increases predictability of volatility

Keep risk premium μ constant over time

- Higher Sharpe ratio in lower volatility regimes
- Lower Sharpe ratio in higher volatility regimes

Target volatility strategy

- Increases exposure in lower volatility regimes
- Decreases exposure in higher volatility regimes

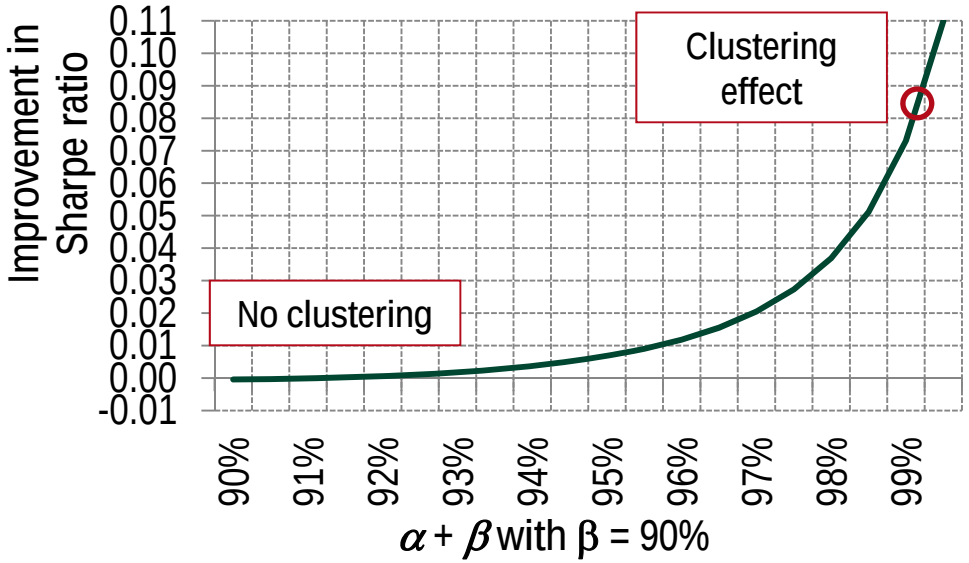
GARCH with α = 9% and β = 90%	Buy and Hold	Target Volatility
Average annualized excess return	7.5%	9.1%
Average annualized volatility	18.8%	18.9%
Sharpe ratio	0.40	0.48
Average exposure	100.0%	121.6%
Improvement in Sharpe ratio	-	0.08
Std Dev of improvement in Sharpe ratio	-	11.4%

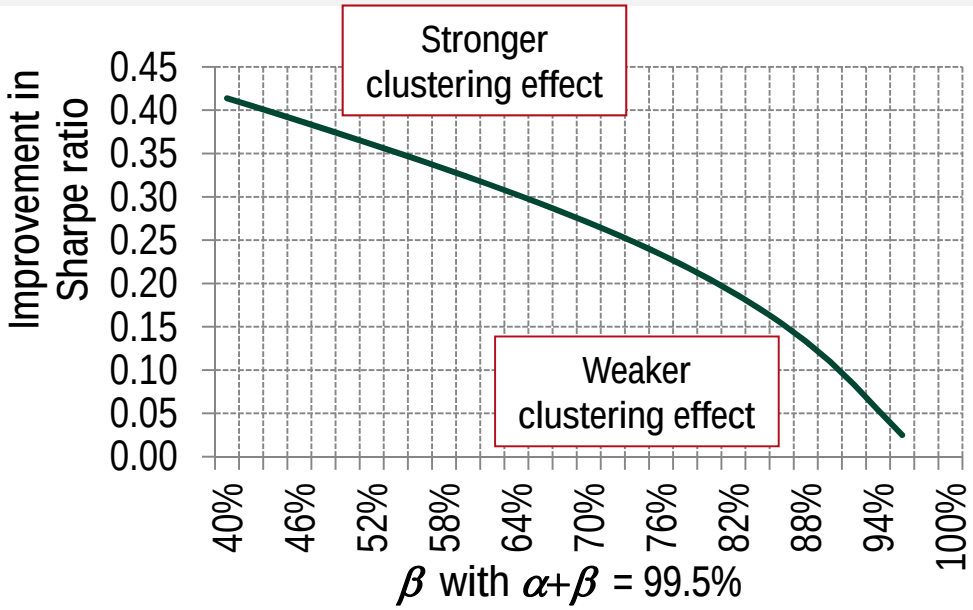
Source R. Perchet, R. Leote de Carvalho, T. Heckel, P. Moulin. "Predicting the success of volatility targeting strategies: Application to equities and other asset classes.", The Journal of Alternative Investments, Vol. 18, No. 3 (Winter 2016), pp. 21-38.

Volatility clustering explains higher risk-adjusted returns

Standard GARCH model

Impact of changing clustering parameters on risk-adjusted returns





Source R. Perchet, R. Leote de Carvalho, T. Heckel, P. Moulin. "Predicting the success of volatility targeting strategies: Application to equities and other asset classes.", The Journal of Alternative Investments, Vol. 18, No. 3 (Winter 2016), pp. 21-38.

Strong clustering leads to higher risk-adjusted returns

Adding fat tails

Fat tails: GARCH with t-student noise

Increase the probability of extremes events

Increases risk-adjusted returns

Reduces largest drawdowns

GARCH with t-Student noise	Buy and Hold	Target Volatility
Average annualized excess return	7.4%	10.3%
Average annualized volatility	17.8%	18.8%
Sharpe ratio	0.41	0.55
Maximum drawdown (MDD)	-37.2%	-35.2%
Ratio MDD / volatility	-2.1	-1.9
Improvement in Sharpe ratio	-	0.13
Std Dev of improvement in Sharpe ratio	-	13.9%

Source R. Perchet, R. Leote de Carvalho, T. Heckel, P. Moulin. "Predicting the success of volatility targeting strategies: Application to equities and other asset classes.", The Journal of Alternative Investments, Vol. 18, No. 3 (Winter 2016), pp. 21-38.

Adding leverage effect and skewness

✓ **Leverage effect: GJR-GARCH**

Negative correlation between returns and volatility

✓ **Skewed-GARCH**

Larger probability of negative returns

Reduces largest drawdowns

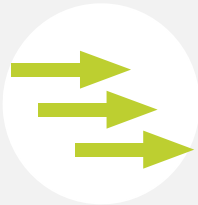
	GJR-GARCH		Skewed-GARCH	
	Buy and Hold	Target Volatility	Buy and Hold	Target Volatility
Average annualized excess return	7.7%	9.4%	7.2%	9.0%
Average annualized volatility	19.1%	18.8%	18.4%	18.9%
Sharpe ratio	0.40	0.50	0.39	0.48
Maximum drawdown (MDD)	-42.7%	-38.3%	-38.7%	-36.8%
Ratio MDD / volatility	-2.2	-2.0	-2.1	-2.0
Improvement in Sharpe ratio	-	0.10	-	0.08
Std Dev of improvement in Sharpe ratio	-	13.4%	-	11.9%

Source R. Perchet, R. Leote de Carvalho, T. Heckel, P. Moulin. "Predicting the success of volatility targeting strategies: Application to equities and other asset classes.", The Journal of Alternative Investments, Vol. 18, No. 3 (Winter 2016), pp. 21-38.

Impact of rebalancing frequency

GARCH	Buy and Hold Risk Asset	Target Volatility			
		Daily	Weekly	Monthly	Semiannual
Average annualized excess return	7.5%	9.1%	9.1%	9.0%	9.2%
Average annualized volatility	18.8%	18.9%	19.0%	19.3%	21.0%
Sharpe ratio	0.40	0.48	0.48	0.47	0.47
Maximum drawdown (MDD)	-39.0%	-36.8%	-37.0%	-38.0%	-41.4%
Ratio MDD / volatility	-2.1	-2.0	-2.0	-2.0	-2.0
Average exposure	100.0%	121.6%	121.7%	121.6%	121.7%
Improvement in Sharpe ratio	-	0.08	0.08	0.07	0.04
Std Dev of improvement in Sharpe ratio	-	11.4%	11.5%	11.3%	11.4%

Source R. Perchet, R. Leote de Carvalho, T. Heckel, P. Moulin. "Predicting the success of volatility targeting strategies: Application to equities and other asset classes.", The Journal of Alternative Investments, Vol. 18, No. 3 (Winter 2016), pp. 21-38.



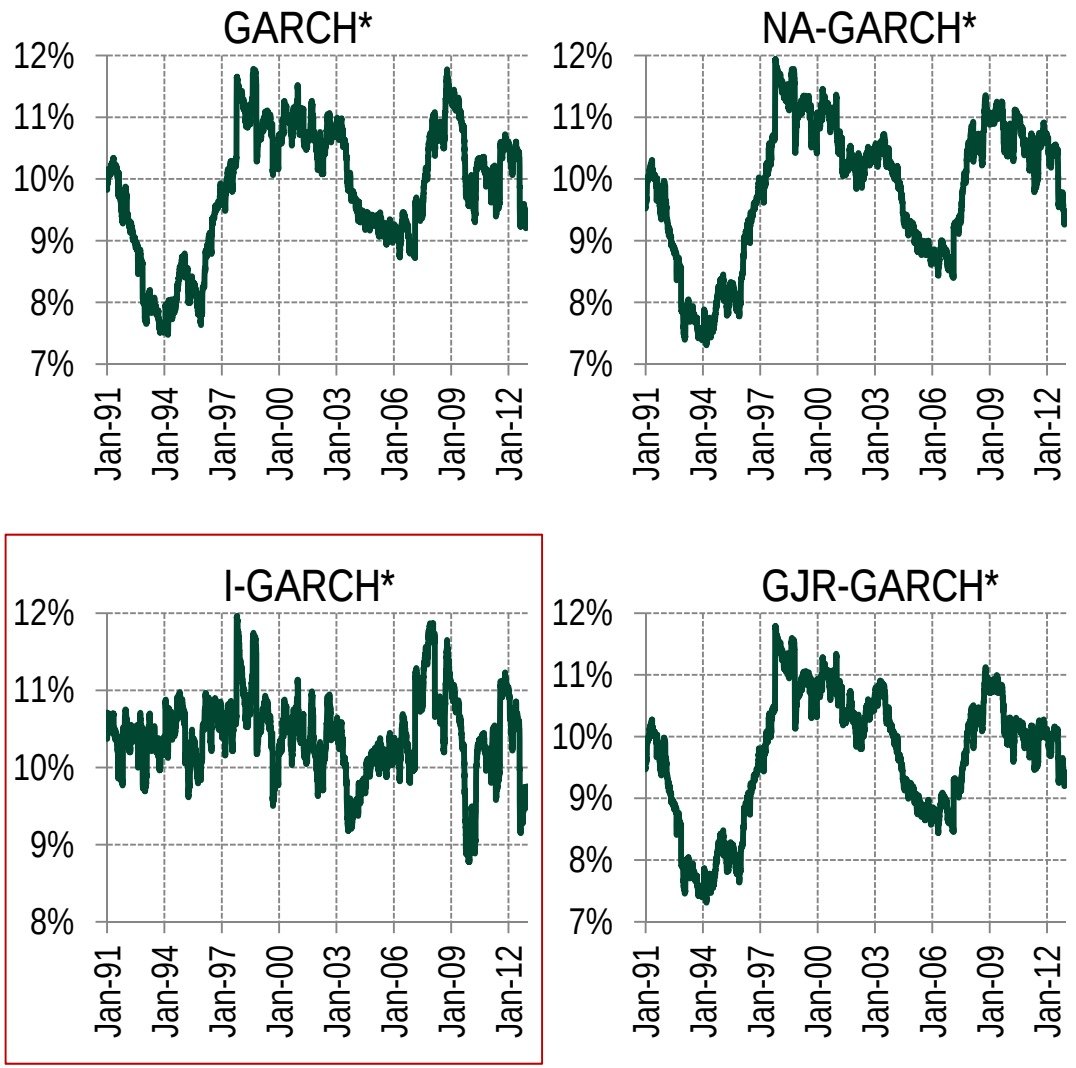
Strong turnover reduction at lower frequencies

Most of the effect still captured lower frequencies

EMPIRICAL FRAMEWORK

Forecasting volatility: S&P500

- Volatility forecasts using GARCH
  - Target 10% volatility
- Standard GARCH model
  - Volatility clustering
  - Long-term volatility
- NA-GARCH and GJR-GARCH models
  - Volatility clustering
  - Long-term volatility
  - Leverage effect
- I-GARCH
  - Volatility clustering
- 1-year ex-post volatility is measured



Comparison of the 1-year rolling ex-post volatility for the target volatility strategy applied to the S&P 500. The target volatility is 10% and the forecast volatility is based on different GARCH models with parameters estimated from maximum likelihood estimation using an expanding window of historical returns, once every year at the start of each year.

Source: R. Perchet, R. Leote de Carvalho, T. Heckel, P. Moulin. "Predicting the success of volatility targeting strategies: Application to equities and other asset classes.", The Journal of Alternative Investments, Vol. 18, No. 3 (Winter 2016), pp. 21-38.

Markov chain regime switching model

	S&P 500	Russell 1000	MSCI Emerging Markets	S&P GSCI Commodity	US High Yield Bonds	US Investment Grade Bonds	US 10Y Government Bonds
Regime 1							
Annulalized excess return over cash	-13.7%	-15.2%	-40.3%	-4.6%	-7.8%	0.0%	-2.3%
Annulalized volatility	29.2%	29.1%	30.8%	30.4%	7.7%	6.6%	11.4%
Sharpe Ratio	-0.47	-0.52	-1.31	-0.15	-1.01	0.00	-0.20
% of observations identified with regime	27.3%	27.1%	24.1%	37.3%	25.0%	34.4%	20.2%
Probability that return at t+1 is in this regime	97.1%	97.1%	95.4%	97.3%	85.3%	96.6%	96.7%
Regime 2							
Annulalized excess return over cash	17.4%	18.7%	34.3%	9.8%	10.3%	6.0%	4.7%
Annulalized volatility	11.3%	11.0%	12.0%	13.8%	1.7%	3.6%	6.2%
Sharpe Ratio	1.54	1.69	2.85	0.71	6.21	1.67	0.76
% of observations identified with regime	72.7%	72.9%	75.9%	62.7%	75.0%	65.6%	79.8%
Probability that return at t+1 is in this regime	98.9%	98.9%	98.5%	98.5%	94.5%	98.2%	99.0%

Jan-1990 – Dec-2012

Source: Bloomberg, BNP Paribas Investment Partners

Larger clustering effect in riskier asset classes

Application to other asset classes

Clustering effect and fat tails

- Large α for Equities, in particular Emerging, and for US high yield
  - more volatility clustering
- Smaller α 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

	Russell 1000	MSCI Emerging Markets	S&P GSCI Commo.	US high yield Bonds	US Invest. Grade bonds	US 10Y Gov. Bonds
ω	7.0E-7	1.6E-6	8.0E-7	2.0E-7	1.0E-7	3.0E-7
α	6.1%	9.6%	5.4%	21.7%	4.0%	4.3%
(t-stats)	(9.90)	(11.4)	(11.0)	(12.7)	(8.7)	(8.7)
β	93.3%	89.3%	94.1%	75.7%	95.0%	94.5%
(t-stats)	(132.3)	(89.5)	(171.9)	(38.0)	(162.1)	(136.7)
$\alpha + \beta$	99.4%	98.9%	99.5%	97.4%	99.0%	98.9%
t-Student	5.6	7.1	7.4	3.7	6.7	7.6
(t-stats)	(16.8)	(13.2)	(12.7)	(33.9)	(12.8)	(12.7)

Source: R. Perchet, R. Leote de Carvalho, T. Heckel, P. Moulin. "Predicting the success of volatility targeting strategies: Application to equities and other asset classes.", The Journal of Alternative Investments, Vol. 18, No. 3 (Winter 2016), pp. 21-38.

Historical simulations for different asset classes

Application to 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

	Russell 1000	MSCI EM Markets	S&P GSCI Commo	US high yield Bonds	US Invest. Grade bonds	US 10Y Gov. Bonds
			Buy and hold strategy			
Average annual. Excess return	8.0%	6.7%	2.3%	4.8%	3.7%	3.2%
Average annual. Volatility	19.0%	19.2%	21.6%	4.4%	5.1%	8.0%
Sharpe ratio	0.42	0.35	0.11	1.09	0.73	0.40
Maximum drawdown (MDD)	-55.8%	-65.2%	-73.4%	-29.1%	-16.7%	-14.1%
Ratio MDD / volatility	-2.9%	-3.4	-3.4	-6.6	-3.3	-1.8
I-GARCH			Inter-temporal risk parity strategy			
Average annual. Excess return	2.9%	3.0%	0.8%	8.5%	3.9%	2.1%
Average annual. Volatility	5.2%	5.4%	5.2%	5.5%	5.1%	5.2%
Sharpe ratio	0.56	0.56	0.15	1.55	0.76	0.40
Maximum drawdown (MDD)	-10.4%	-19.1%	-16.7%	-28.5%	-11.2%	-10.2%
Ratio MDD / volatility	-2.0	-3.5	-3.2	-5.2	-2.2	-2.0
Improv. in Sharpe ratio	0.14	0.21	0.05	0.45	0.04	0.00

* Comparison of a buy-and-hold strategy for different asset classes with target volatility strategies based on historical simulations. The target volatility was set to 5%. Volatility forecasts are based on I-GARCH models. The I-GARCH model parameters were estimated from maximum likelihood estimation using an expanding window of historical returns once every year at the start of each year.

Source: R. Perchet, R. Leote de Carvalho, T. Heckel, P. Moulin. "Predicting the success of volatility targeting strategies: Application to equities and other asset classes.", The Journal of Alternative Investments, Vol. 18, No. 3 (Winter 2016), pp. 21-38.

Factor investing

- Factor investing has been gaining attention since Fama & French (1992,1993)
  - Value and Size premiums in equity markets
- Carhart (1997) extended Fama & French model
  - Momentum premium was added
- Qian, Sorensen & Hua (2009) found value premium in other asset classes
  - Government bonds
  - Foreign exchange
- Asness, Moskowitz & Pedersen (2013) generalise 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

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

* 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

Markov chain regime switching model

	Equity		Foreign Exchange		Governments bonds	
	Momentum	Value	Momentum	Value	Momentum	Value
Regime 1						
Annulalized excess return over cash	18.0%	2.8%	10.6%	12.9%	4.0%	4.9%
Annulalized volatility	7.1%	5.6%	6.2%	5.9%	3.8%	4.4%
Information Ratio	2.55	0.50	1.70	2.20	1.05	1.11
% of observations identified with regime	74.8%	75.0%	80.5%	78.7%	62.8%	76.9%
Probability that return at t+1 is in this regime	99.0%	99.4%	97.9%	98.1%	98.0%	97.1%
Regime 2						
Annulalized excess return over cash	-16.1%	6.5%	-24.6%	-21.0%	-5.2%	0.5%
Annulalized volatility	24.9%	16.5%	15.5%	14.6%	8.1%	10.0%
Information Ratio	-0.65	0.40	-1.59	-1.44	-0.65	0.05
% of observations identified with regime	25.2%	25.0%	19.5%	21.3%	37.2%	23.1%
Probability that return at t+1 is in this regime	97.2%	98.1%	92.2%	93.7%	96.5%	92.2%

Jan-1995 – Dec-2013

Source: R. Perchet, R. Leote de Carvalho, T. Heckel, P. Moulin. "Predicting the success of volatility targeting strategies: Application to equities and other asset classes.", The Journal of Alternative Investments, Vol. 18, No. 3 (Winter 2016), pp. 21-38.

Historical simulations for value and momentum factors

Application to factors

Higher information ratios for target volatility

Larger impact for underlying risky asset classes

Equities and foreign exchange

Lower impact for government bonds

Also robust to rebalancing frequency

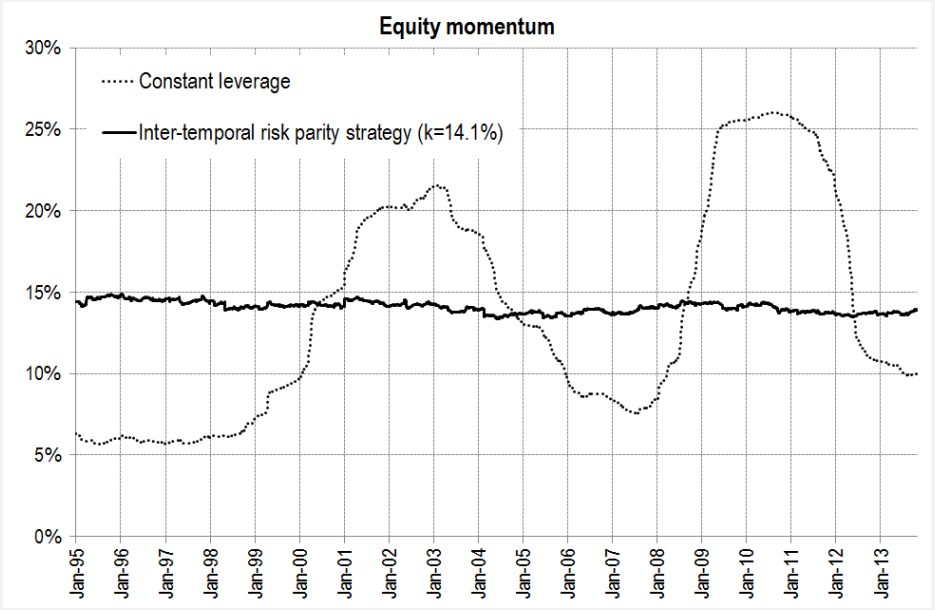
	Momentum Equity	Value Equity	Momentum Foreign Exchange	Value Foreign Exchange	Momentum Fixed Income	Value Fixed Income
			Constant leverage			
Average annual. Excess return	8.4%	3.3%	1.7%	3.9%	-0.3%	3.1%
Average annual. Volatility	14.1%	9.5%	9.1%	8.8%	5.7%	6.1%
Information ratio	0.59	0.34	0.19	0.44	-0.06	0.52
Maximum drawdown (MDD)	-63.0%	-44.5%	-27.8%	-34.0%	-28.9%	-11.4%
Ratio MDD / volatility	-4.5	-4.7	-3.0	-3.9	-5.1	-1.9
I-GARCH			Target volatility			
Average annual. Excess return	7.7%	2.2%	2.5%	3.3%	0.8%	2.9%
Average annual. Volatility	5.4%	5.3%	5.3%	5.3%	5.2%	5.2%
Information ratio	1.43	0.42	0.46	0.63	0.16	0.57
Maximum drawdown (MDD)	-13.9%	-22.1%	-14.9%	-17.1%	-18.1%	-9.1%
Ratio MDD / volatility	-2.6	-4.2	-2.8	-3.2	-3.5	-1.7
Improv. in information ratio	0.83	0.08	0.27	0.19	0.22	0.05

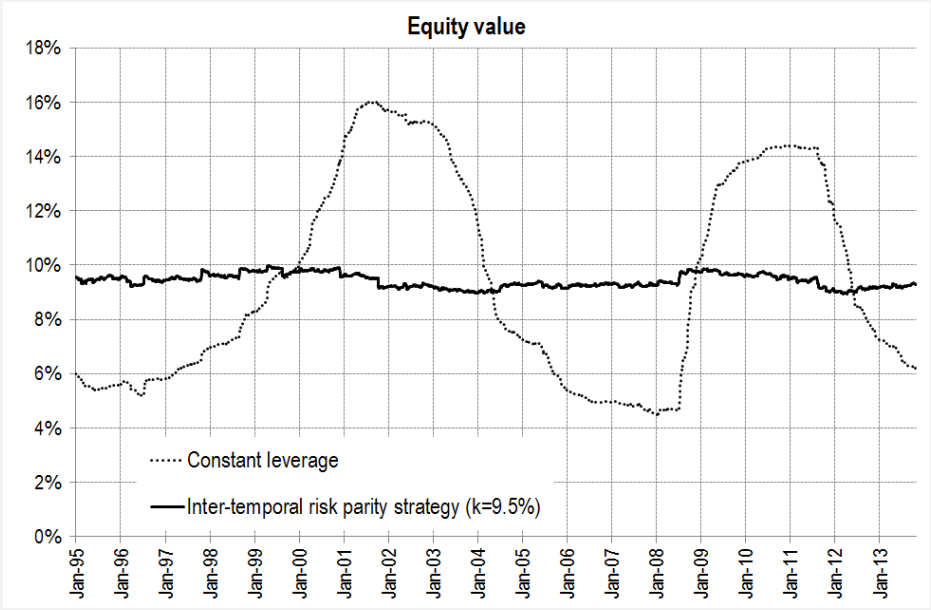
* Comparison of a constant leverage strategy for different factor with target volatility strategies based on historical simulations. The target volatility was set at 5%. Volatility forecasts as based on I-GARCH models. The I-GARCH model parameters were estimated from maximum likelihood estimation using an expanding window of historical returns once every year at the start of each year.

Source: R. Perchet, R. Leote de Carvalho, T. Heckel, P. Moulin. "Predicting the success of volatility targeting strategies: Application to equities and other asset classes.", The Journal of Alternative Investments, Vol. 18, No. 3 (Winter 2016), pp. 21-38.

Target risk strategies successfully manage factor volatility

Ex-post volatility (3 years rolling)





Volatility forecasts as based on I-GARCH models with parameters estimated from expanding window once each year at the start of the year.
Equity based on MSCI World Index. G10 FX against USD and 7 most liquid treasury 10 year futures.

Source: R. Perchet, R. Leote de Carvalho, T. Heckel, P. Moulin. "Predicting the success of volatility targeting strategies: Application to equities and other asset classes.", The Journal of Alternative Investments, Vol. 18, No. 3 (Winter 2016), pp. 21-38.

Conclusions

- Higher risk-adjusted returns from target volatility strategies explained by
  - Volatility clustering in time series of
  - Negative correlation between returns and volatility
- Presence of fat tails events increase volatility clustering effect
- Investors should think in terms of risk budget allocation rather than fixed weights
- Clear benefit for risky asset classes
  - Equities
  - High yield
  - Foreign exchange rates

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Thought Leadership: Financial Engineering contributions

Investors Corner blog (www.investors-corner.bnpparibas-ip.com/)

Illiquid assets: the latest from academia

Prudence paid with a low-volatility strategy in January 2016

What's hot: A report on the Axioma Quant Forum 2015 in London

Bye-bye "Smart Beta". Hello "Factor Investing"

What's hot: 25th anniversary seminar of Inquire Europe

Pension funds: understanding funding ratio risk better (2 posts)

How active is your fund manager? Should you really care about active share?

Europe's leading quantitative finance conference – as if you were there…

Making the moves toward clear outcomes at retirement

Low-risk equity strategies without interest rate sensitivity

Low-volatility anomalies in the time series of factor premia

What's hot: a report on the Axioma Quant Forum

To be at risk parity or not to be, that is the question

How to earn more in a world of low interest rates

What returns can be expected from investing in low-volatility equities?

What's hot: a report on the Nomura Global Quantitative Equity Conference

Models tell us equities are still the best game in town

How to make money from managing risk

The BNP Paribas Investment Partners and EDHEC partnership on ALM and institutional investment management

Gaining more by losing less in global bonds

Low volatility equities: now I see it, now I don't!

Smart Beta or Factor Investing?

INVESTORS' corner

A blog by BNP Paribas Investment Partners

Asset management

regular and timely analysis

Research Papers: Financial Engineering @ BNPPIP

Academic papers:

Romain Perchet, Xiao Lu, Raul Leote de Carvalho, Thomas Heckel
Insights into robust Robust Portfolio Optimization:
Decomposition into Mean-Variance and Risk-Based Portfolios
Submitted, August 2015

Erik Kroon, Anton Wouters, Raul Leote de Carvalho
Decomposing Funding Ratio Risk: Providing pension funds with key insights into their liabilities hedge mismatch and other factor exposures
Forthcoming in the Journal of Portfolio Management, 2016

Romain Perchet, Raul Leote de Carvalho, Thomas Heckel, Pierre Moulin
Predicting the success of volatility targeting strategies:
Application to equities and other asset classes
The Journal of Alternative Investments, 2016

François Soupé, Thomas Heckel, Raul Leote de Carvalho
Portfolio insurance with adaptive protection (PIWAP)
Submitted, January 2015

Romain Perchet, Raul Leote de Carvalho, Pierre Moulin
Inter-temporal risk parity: a constant volatility framework for factor investing
Journal of Investment Strategies, 2014

Raul Leote de Carvalho, Patrick Dugnolle, Xiao Lu, Pierre Moulin
Low-risk anomalies in global fixed income: Evidence from major broad markets
Journal of Fixed Income, 2014

Academic papers (continued):

Raul Leote de Carvalho, Xiao Lu, Pierre Moulin
An integrated risk-budgeting approach for multi-strategy equity portfolios
Journal of Asset Management, 2014

Raul Leote de Carvalho, Xiao Lu, Pierre Moulin
Demystifying Equity Risk-Based Strategies: an Alpha plus Beta description
Journal of Portfolio Management, 2012

Francois Ogliaro, Robert K Rice, Stewart Becker, Raul Leote de Carvalho
Explicit coupling of informative prior and likelihood functions in a Bayesian multivariate framework and application to a new non-orthogonal formulation of the Black–Litterman model
Journal of Asset Management, 2012

Investment books

Raul Leote de Carvalho, Majdouline Zakaria, Xiao Lu, Pierre Moulin
Low risk anomaly everywhere: evidence from equity sectors
In “Risk Based and Factor Investing”, ISBN 978-1-78548-008-9, Elsevier, 2015

Raul Leote de Carvalho, Xiao Lu, Pierre Moulin
Towards second generation risk-based strategies
In “Nuove (e vecchie) idee d’investimento per rispondere alla crisi”, PF Holding srl, 2013

Research Papers: BNPPIP and Sponsored (Edhec-Risk Inst.)

White papers (published)

Xiao Lu, Raul Leote de Carvalho, Shaun Stevens, Jan Willem Vis
The case for Listed Real estate Equity investing.
BNP Paribas Investment Partners, 2016

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