# Momentum Crashes

Kent Daniel[†]

[†]Columbia University
Graduate School of Business

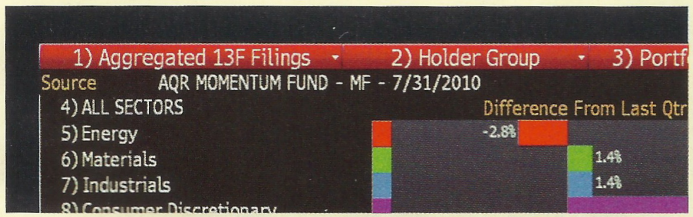
Columbia University
*Quantitative Trading & Asset Management Conference*

*9 November 2010*

# Quantitative Investing

# Quantitative Investing

**Bloomberg Tips** **AQR'S MUTUAL FUNDS**




For information on AQR Capital's seven mutual funds, type **FL <Go>** for the Fund Look Up function. Tab in to the field, enter *AQR* and press <Go>. Click on a fund name, such as AQR Momentum Fund-L, in the list of results for a menu of analytics. Click on **HLDS**, for example, to display quarterly changes in the Momentum Fund's holdings as disclosed in regulatory filings. Type **BRSK <Go>** to access a group of applications for measuring risk, such as scenario analysis. Type **BAIF <Go>** to measure the fund's performance against a Bloomberg index. BETH WILLIAMS

# What do Quants do?

- Identify fundamental return-driving factors, and estimate their relationship with expected returns for the cross-section of securities:

$$\mathrm{E}_t[\tilde{\mathrm{r}}_{t+1}] = \mathbf{B}_t \boldsymbol{\lambda}_t$$

- Estimate a risk model $\Sigma_t$.
- Use an optimizer to maximize expected return, net of trading costs, subject to a risk budget and other constraints:

$$\max_{\mathrm{w}_t} \ \mathrm{w}_t' \mathbf{B}_t \boldsymbol{\lambda}_t \quad \text{s.t.} \quad \mathrm{w}_t' \Sigma_t \mathrm{w}_t \leq \sigma_t^2, \quad \text{s.t.} \quad \ldots$$

  - Absent constraints, t-costs, *etc.*, portfolio weights are:

$$\mathrm{w}_t = \kappa_t \Sigma_t^{-1} \mathbf{B}_t \boldsymbol{\lambda}_t$$

# Momentum

- This paper does a "deep-dive" into one particular factor/anomaly: price momentum.
- It is employed by many (most?) quantitative managers.
- Historically, momentum strategies deliver high premia.
- However momentum strategy returns exhibit significant negative skewness:
  - *e.g.*, in March-May 2009, equity momentum strategies suffered severe losses.
- Much like "carry-trade" strategies in currencies, momentum strategies are sometimes perceived like selling out-of-the money put options.

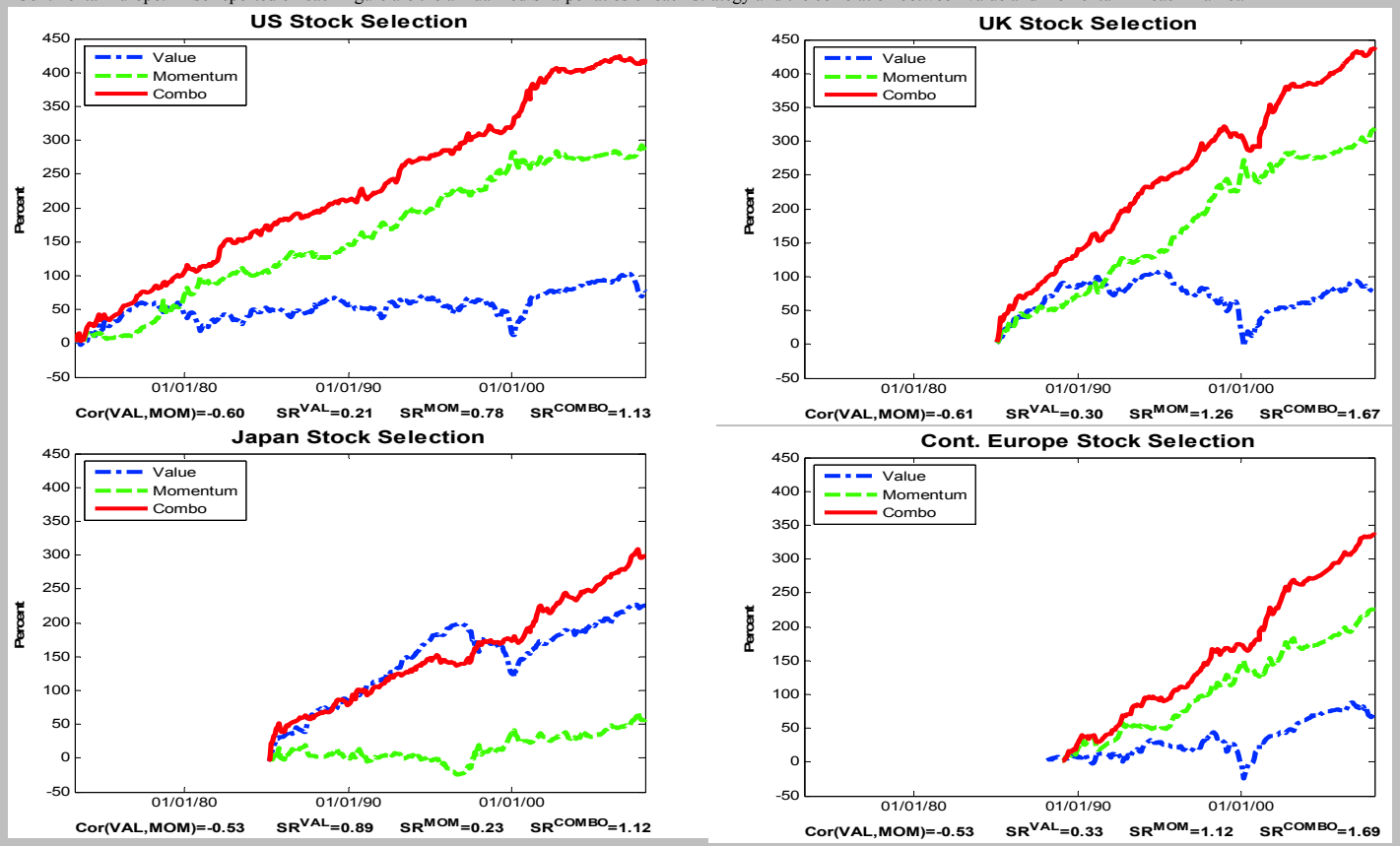
# Evidence of Momentum

- US Equities: Jegadeesh and Titman (1993, 2001).
- Developed Equities: Rouwenhorst (1998)
- Emerging Equities: Rouwenhorst (1999)
- Industries & Firm Specific (Equity): Moskowitz and Grinblatt (1999), Grundy and Martin (2001).
- Country Equity Indices: Asness, Liew, and Stevens (1997)
- Currencies: Okunev and White (2003)
- Commodities: Erb and Harvey (2006)
- Futures: Asness, Moskowitz, and Pedersen (2008), Moskowitz, Ooi, and Pedersen (2010).

# Momentum: *Stock-Selection*

*Asness, Moskowitz and Pedersen (2008), "Value and Momentum Everywhere," Figure 1:*

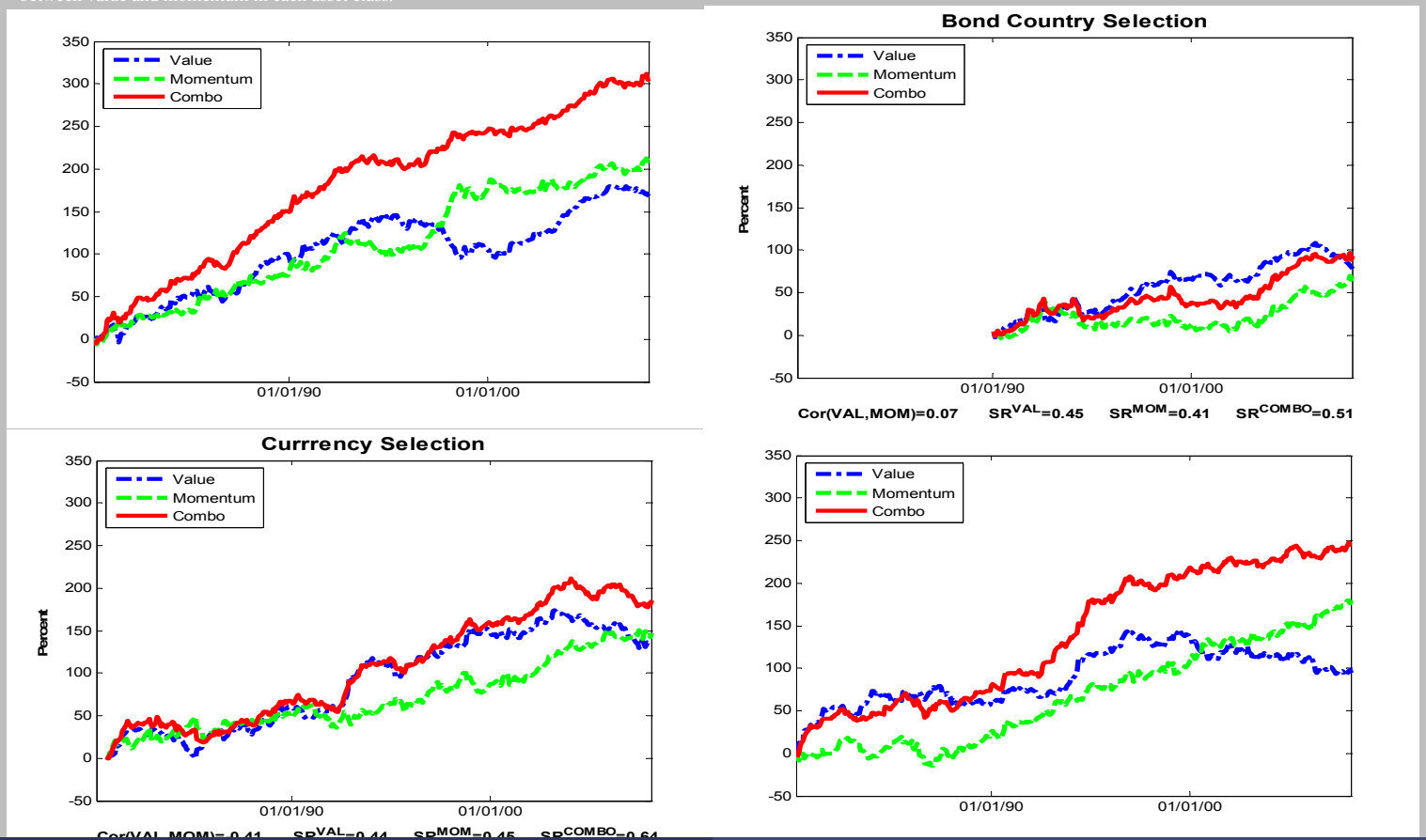
**Figure 1: Performance of value and momentum strategies for stock selection globally**
Plotted are the cumulative returns to value, momentum, and a 50-50 combination of value and momentum strategies among individual stocks in four markets: US, UK, Japan, and Continental Europe. Also reported on each figure are the annualized Sharpe ratios of each strategy and the correlation between value and momentum in each market.



# Momentum: *Non-Stock-Selection*

## *Asness, Moskowitz and Pedersen (2008), "Value and Momentum Everywhere," Figure 2:*

**Figure 2: Performance of value and momentum strategies for non-stock selection**
Plotted are the cumulative returns to value, momentum, and a 50-50 combination of value and momentum strategies among a cross-section of assets in four different asset classes: Country equity index futures, country bonds, currencies, and commodities. Also reported on each figure are the annualized Sharpe ratios of each strategy and the correlation between value and momentum in each asset class.

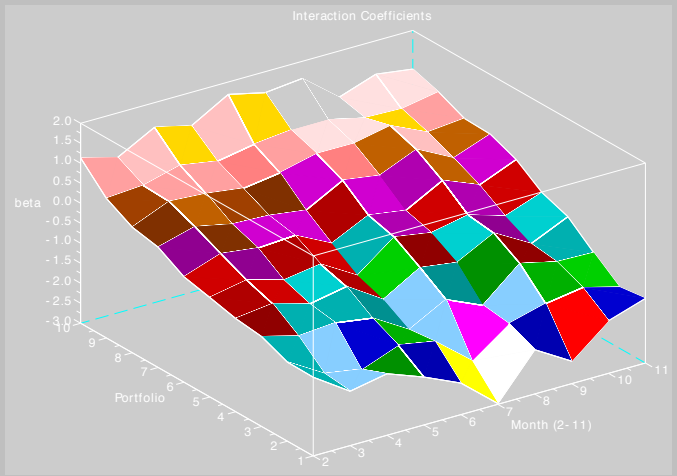


# Behavioral Theories of Momentum

- There is considerable debate in the academic literature on the source of the momentum premium.
- Daniel, Hirshleifer and Subramanyam (1998, 2001) propose a model in which momentum arises as a result of the *overconfidence* of agents.
  - Agents assess the precision of their private information as being higher than it actually is.
  - But they properly assess the precision of public information.
  - The result is that stock prices underreact to new, public information.
    - Consistent with evidence in Chan (2003).

# Time Variation in Momentum *Risk*

- Grundy and Martin (2001) evaluate time variation in the factor exposure of their EW momentum strategies.
- They show that the market beta of momentum strategies is highly dependent on the lagged market return.




- They further argue that a momentum portfolio which hedges out market & size risk exhibits consistently good performance.

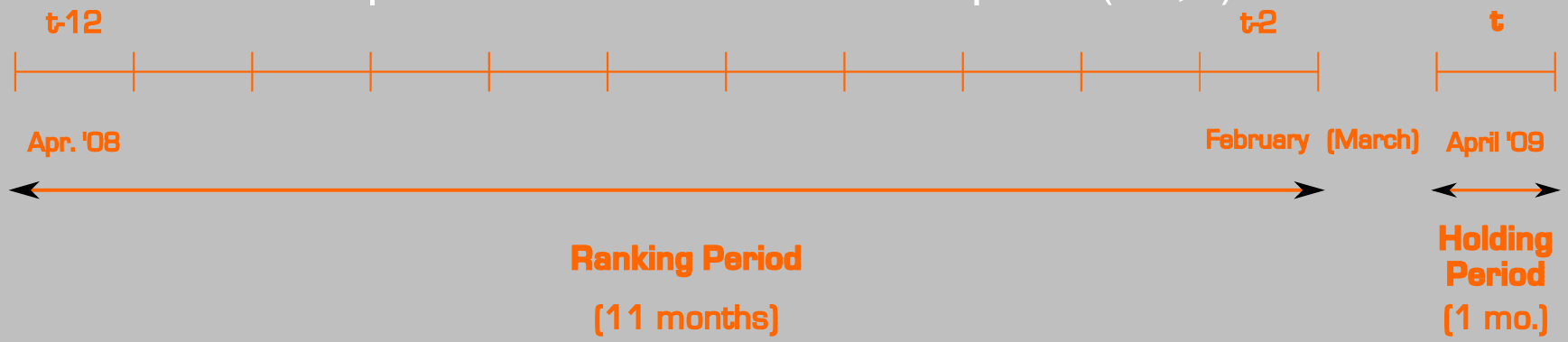
# Time Variation in Momentum *Returns*

Cooper, Gutierrez, and Hameed (2004) define UP and DOWN market states based on the lagged three-year return of the market:

- When the market has been UP, the historical mean return to a EW momentum strategy has been 0.93%/month.
- When the market has been DOWN, the mean return has been -0.37%/month.
- They find similar results, controlling for market, size & value
  - However, their controls are based on *unconditional* loadings on these factors.
  - They do not consider the variation in the conditional risk discussed in Grundy and Martin (2001).

# Momentum: *Portfolio Construction*

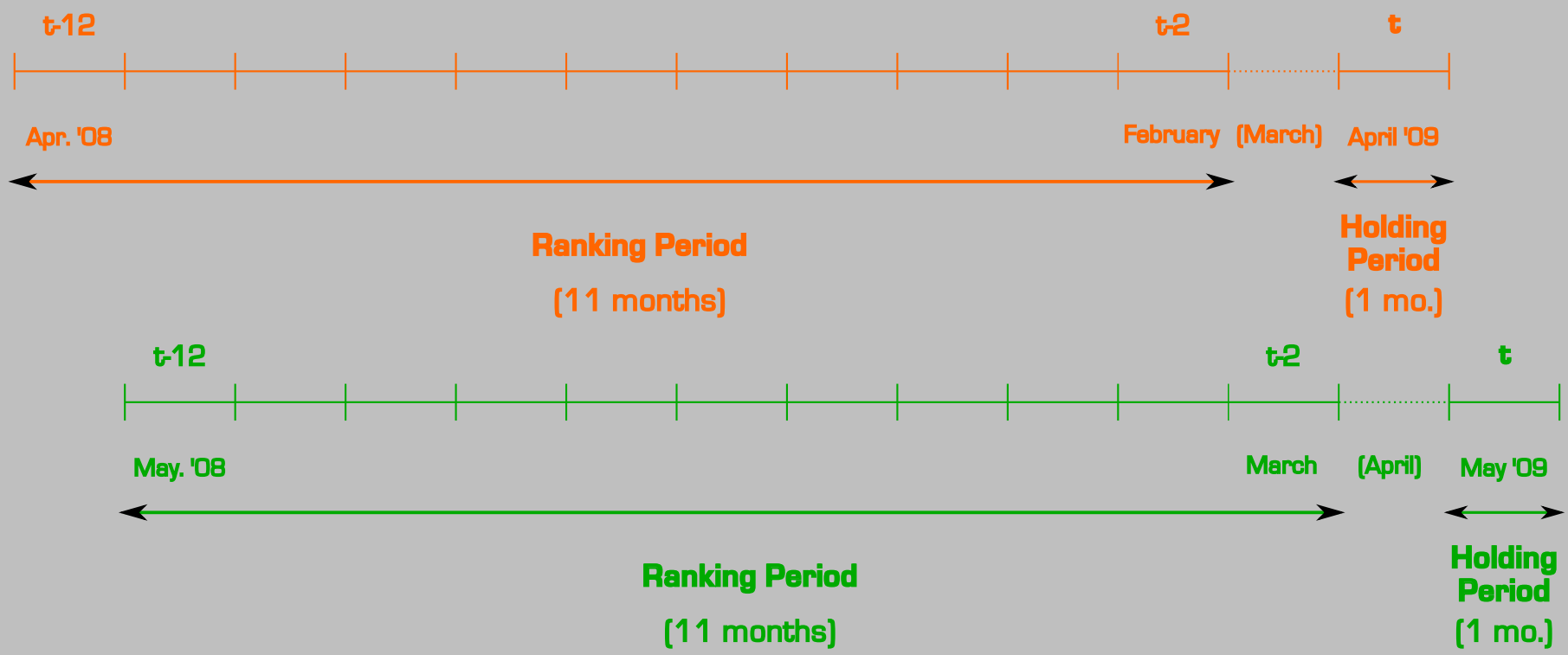
At the end of each month, we form 10 value-weighted momenutum portfolios on the basis of prior (12,2) return:




- Over the one-month *holding period*, we will evaluate the return of the top and bottom ("winner" and "loser") deciles.
- We also consider the long-short portfolio that invests $1 in the winner portfolio, and shorts $1 worth of the loser portfolio ( WML)

# Momentum: *Portfolio Construction*

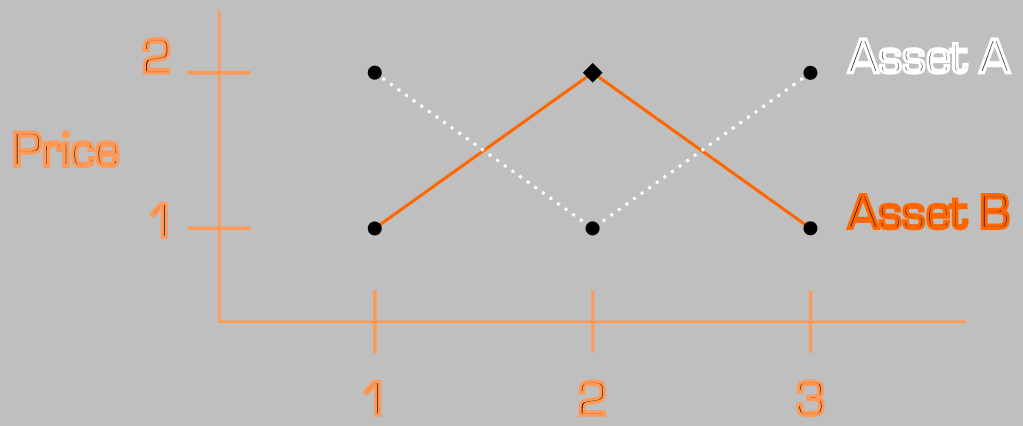
At the end of each month, we re-form the portfolios based on the updated ranking-period return:



# Momentum: *Portfolio Construction*

- While the portfolio are reblanced at the end of each month, we generate *daily* returns for each of the ten portfolios.
  - This is necessary to accurately estimate the conditional risk of the portfolios.
- For a firm to be included in the portfolio, we require that:
  - *The firm remain be listed on the NYSE, AMEX or NASDAQ.*
  - *The shares be common shares only (share-code 10 or 11)*
  - *The firm have valid prices and share data during the formation period (for value weighting).*

# EW Portfolio Return Bias

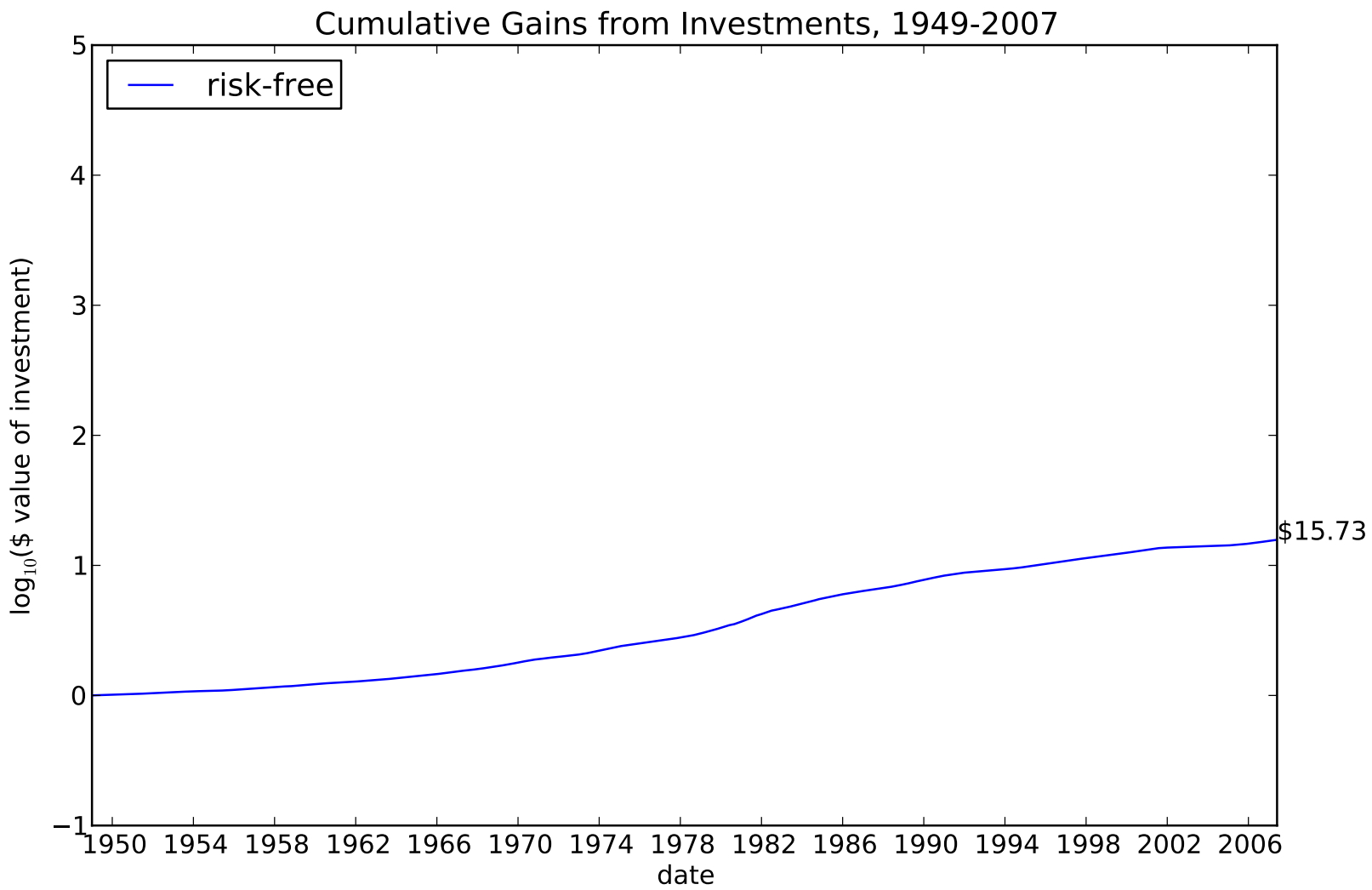



$$
\begin{array}{lll}
R_{EW,2} & (1/2)*(-50\%) + (1/2)*(+100\%) & 25\% \\
R_{EW,3} & (1/2)*(+100\%) + (1/2)*(-50\%) & 25\%
\end{array}
$$

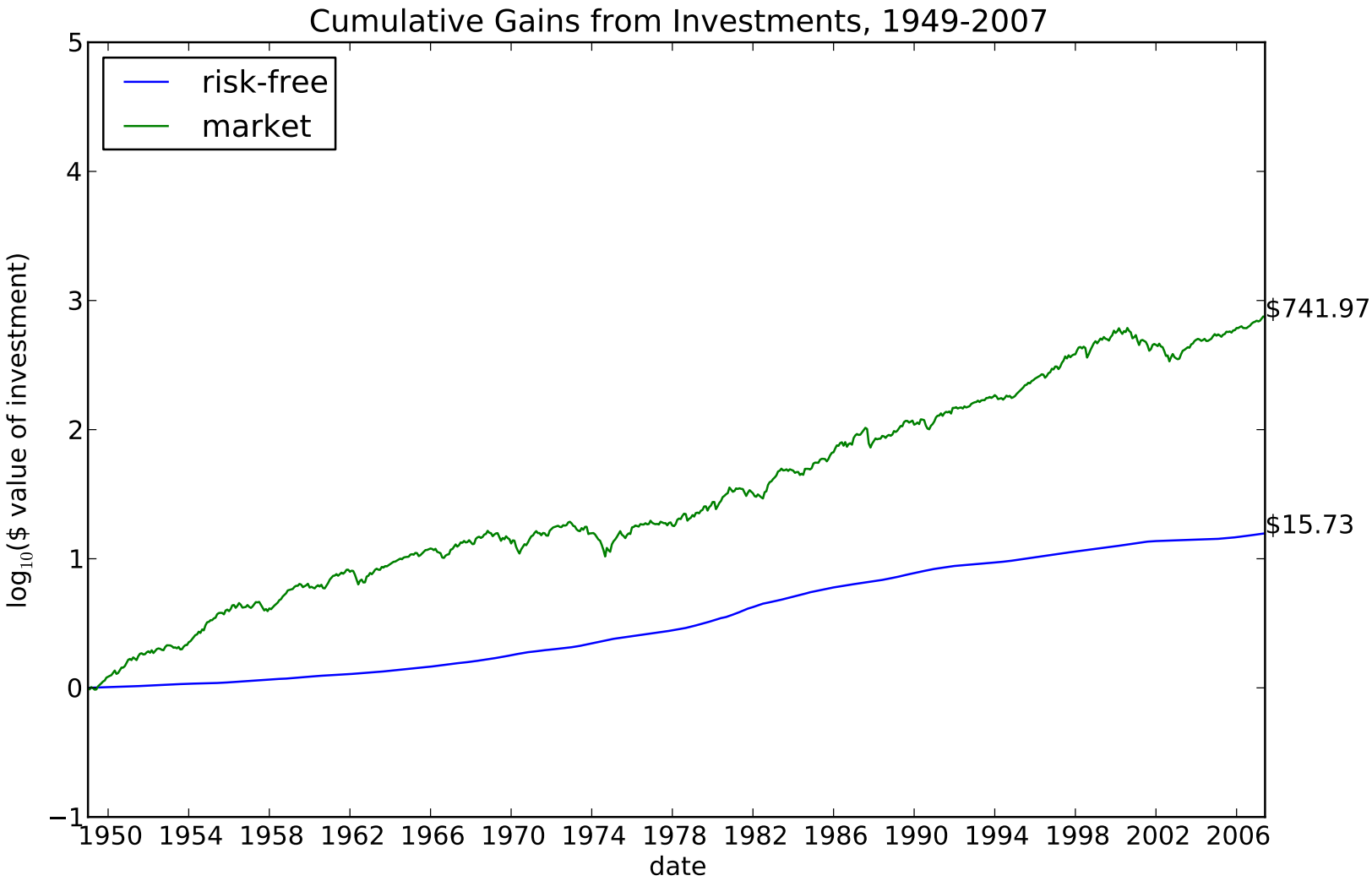
$$
\begin{array}{lll}
R_{EW,2} & \frac{Gain}{InitialCost} & \frac{(1/4)*(-1)+(1/2)*(+1)}{(1/4)*2+(1/2)*1} = 25\% \\
R_{EW,3} & \frac{Gain}{InitialCost} & \frac{(1/2)*(+1)+(1/4)*(-1)}{(1/2)*1+(1/4)*2} = 25\%
\end{array}
$$

- To avoid this bias, all portfolios here are value-weighted.

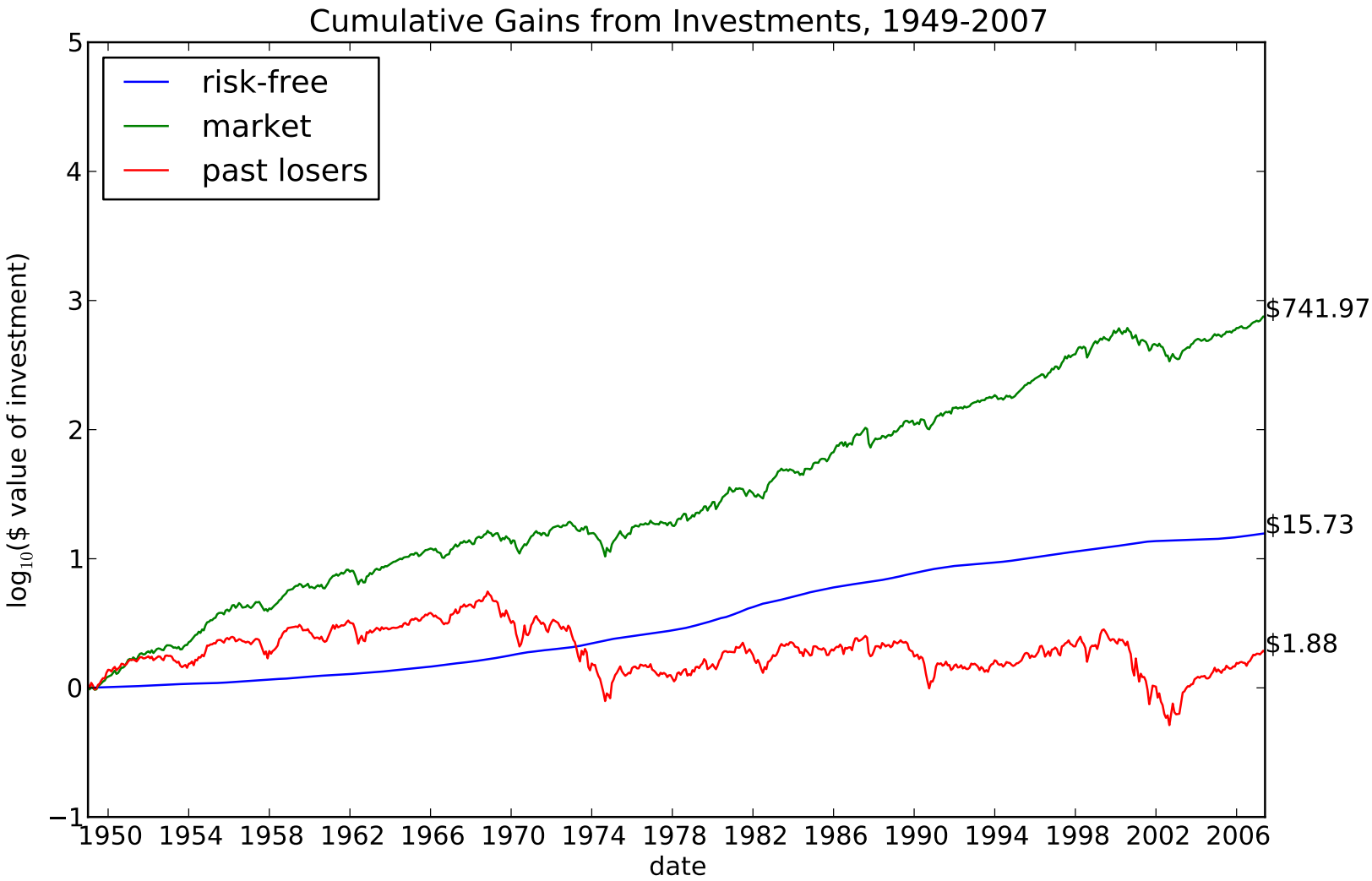
# Investment Strategy Returns



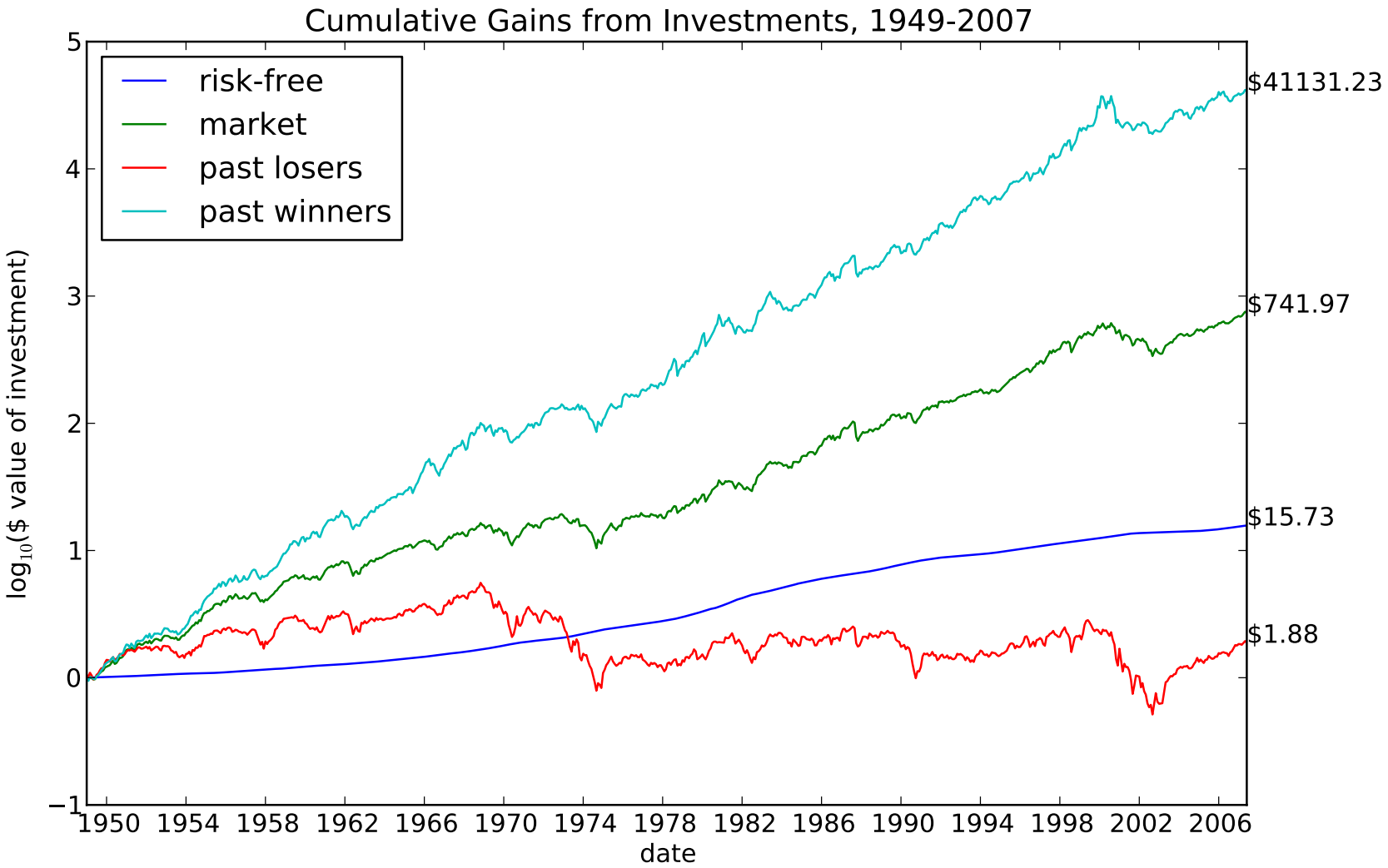
# Investment Strategy Returns



# Investment Strategy Returns



# Investment Strategy Returns

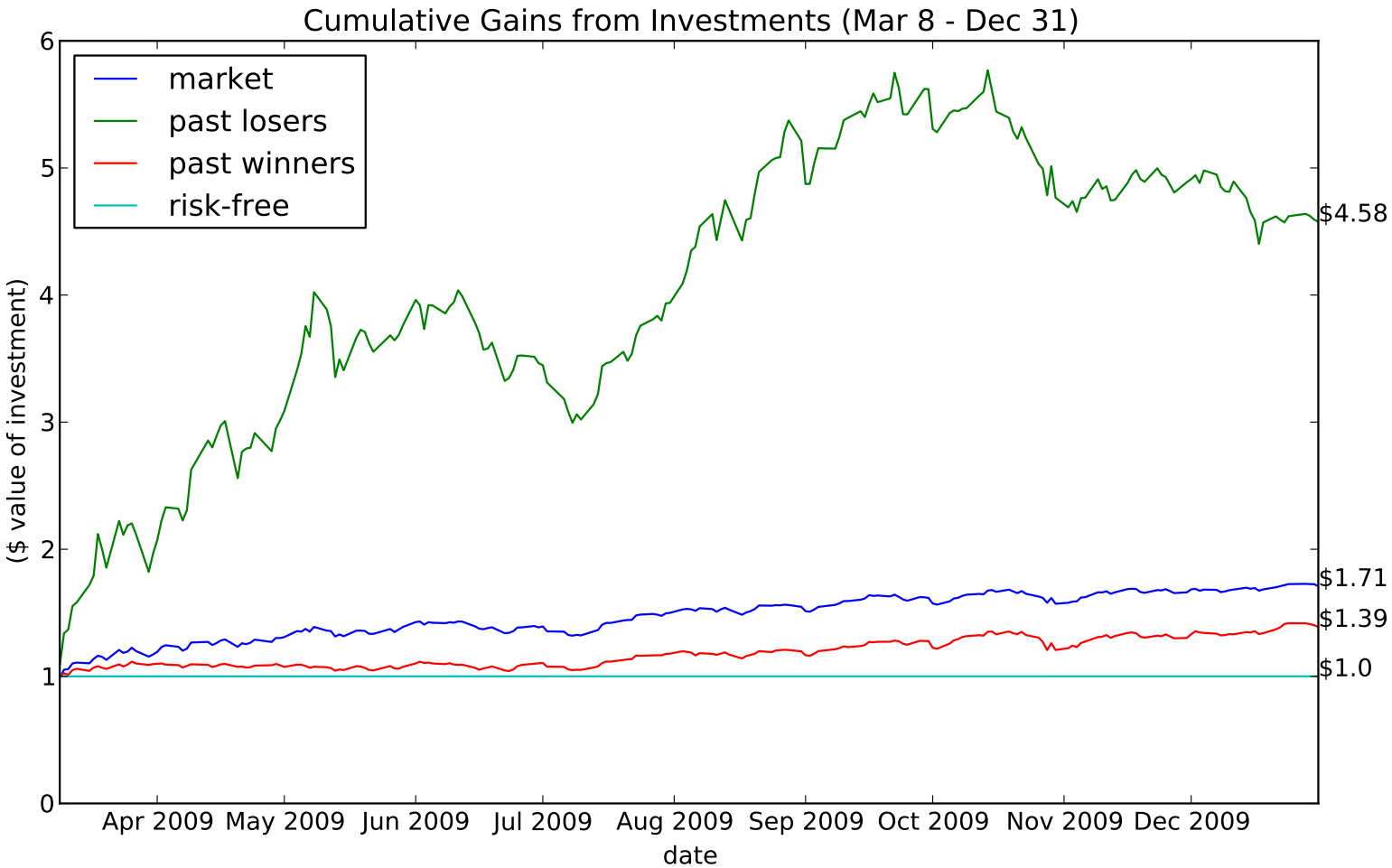


# Momentum Characteristics

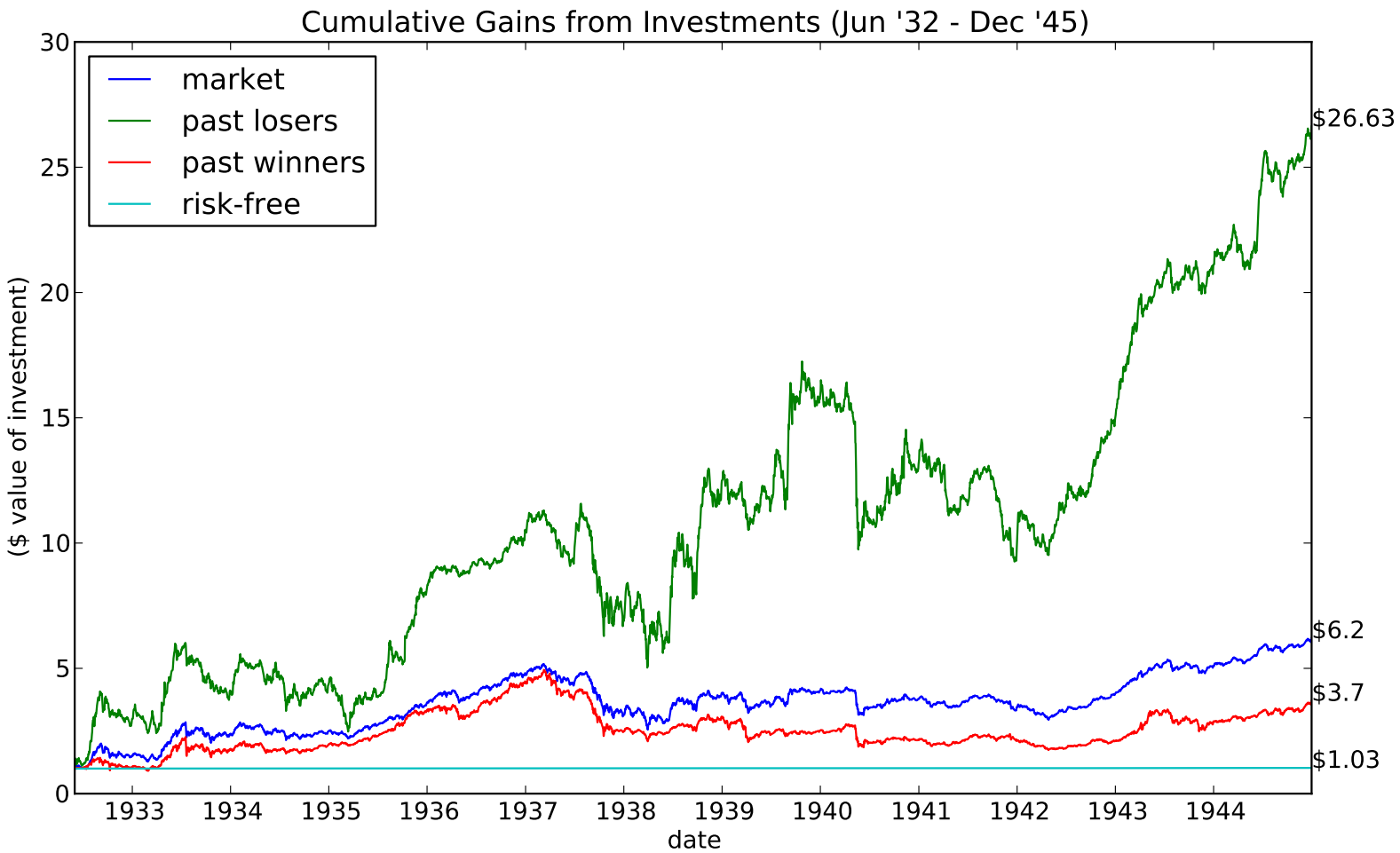
| | Portfolio Excess Return Characteristics | | | |
|---|---|---|---|---|
| | Mean (%/yr) | Annual. Vol. | Beta | S.R. |
| Momentum | 16.5% | 20.2% | -0.125 | 0.82 |
| Market | 7.7% | 14.4% | 1 | 0.53 |
| Combination* | 14.7% | 14.4% | – | 1.02 |

- The momentum portfolio achieved a higher Sharpe Ratio than the Market portfolio, and had a negative beta.
- The optimal combination of the market and momentum portfolios earned double the expected return, for the same volatility.

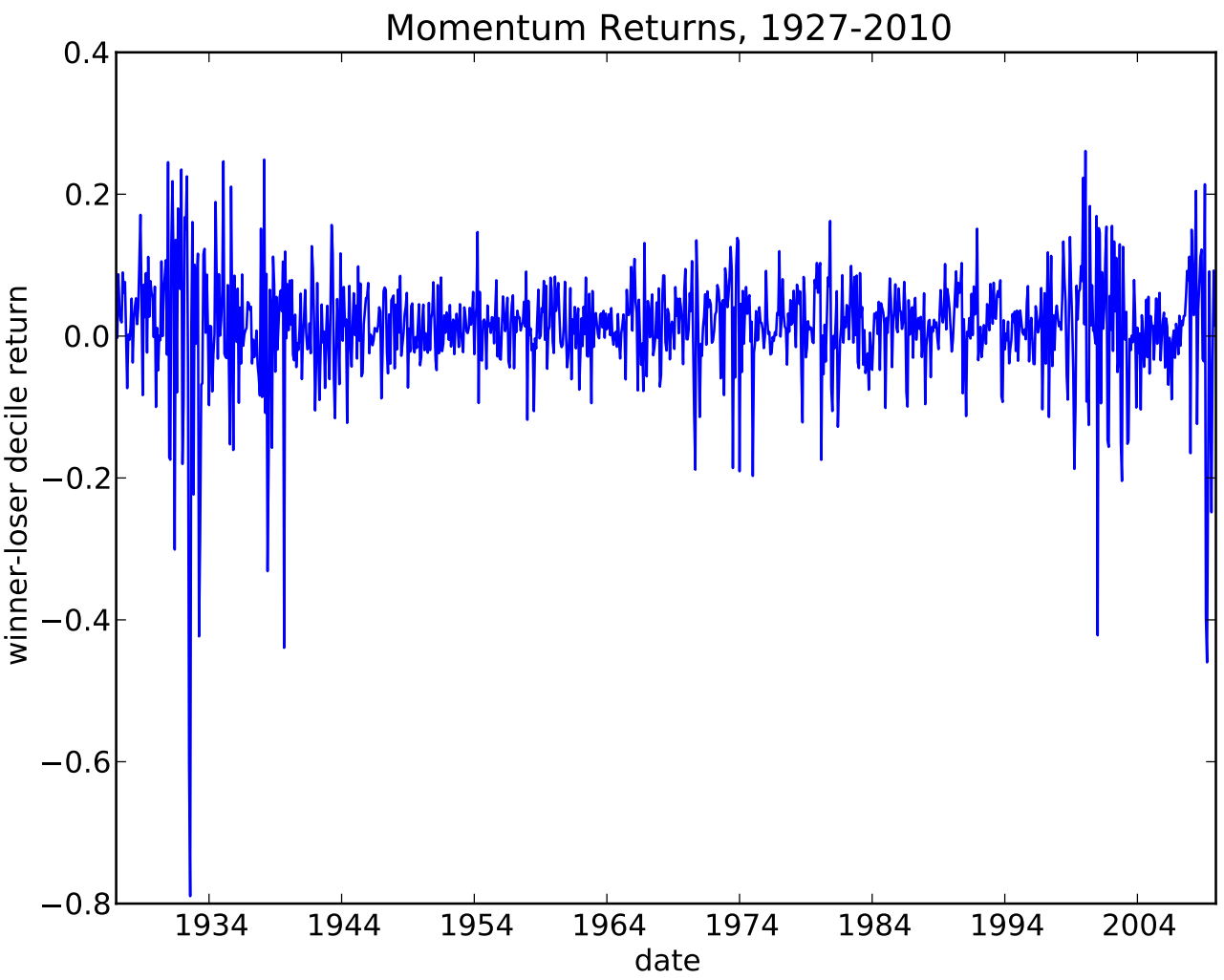
# 2009 Momentum Performance



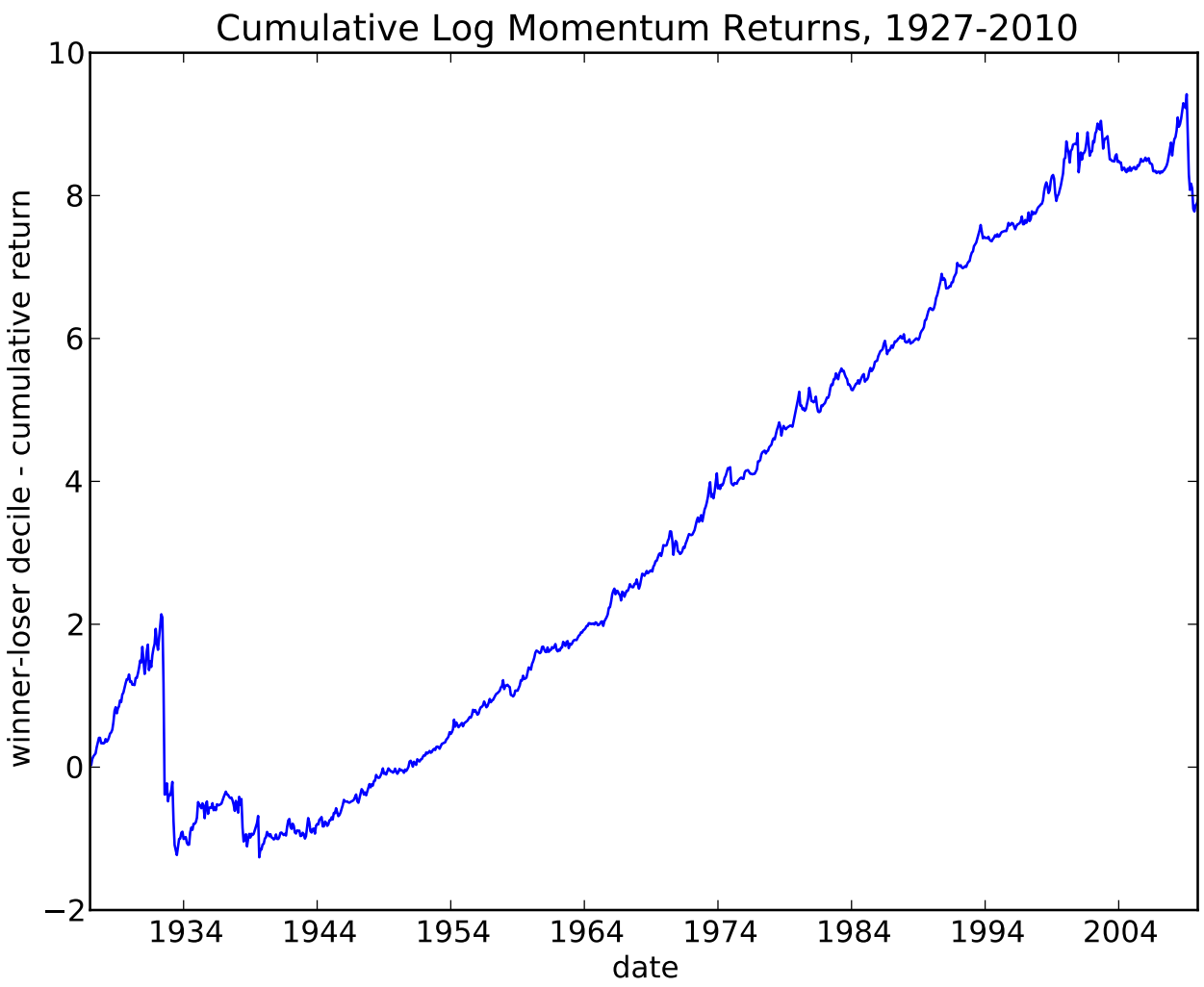
# Momentum in the Great Depression



# Monthly Momentum Returns



# Cumulative Momentum Returns



# 10 Worst Monthly Momentum Returns

Here, we add the lagged 2-year market return and the contemporaneous (1-month) market return.

| Rank | Month | $\text{Mom}_t$ | Mkt 2y | $\text{Mkt}_t$ |
|---|---|---|---|---|
| 1 | 1932-08 | -0.7896 | -0.6767 | 0.3660 |
| 2 | 1932-07 | -0.6011 | -0.7487 | 0.3375 |
| 3 | 2009-04 | -0.4599 | -0.4136 | 0.1106 |
| 4 | 1939-09 | -0.4394 | -0.2140 | 0.1596 |
| 5 | 1933-04 | -0.4233 | -0.5904 | 0.3837 |
| 6 | 2001-01 | -0.4218 | 0.1139 | 0.0395 |
| 7 | 2009-03 | -0.3962 | -0.4539 | 0.0877 |
| 8 | 1938-06 | -0.3314 | -0.2744 | 0.2361 |
| 9 | 1931-06 | -0.3009 | -0.4775 | 0.1380 |
| 10 | 1933-05 | -0.2839 | -0.3714 | 0.2119 |
| 11 | 2009-08 | -0.2484 | -0.2719 | 0.0319 |

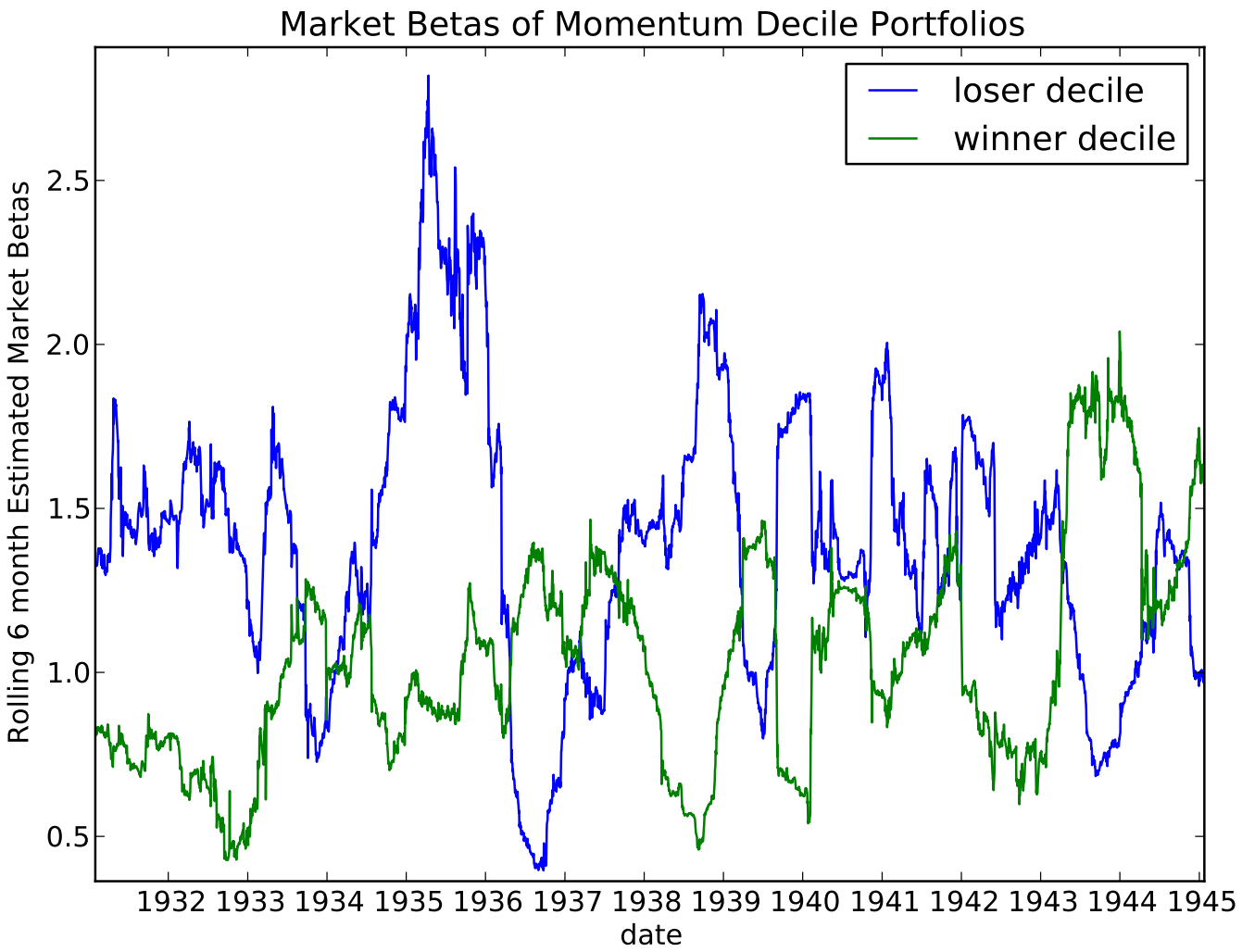
# Bear Market Momentum Performance

- This previous table shows that the momentum strategy suffers its worst performance at "turning points," following large market declines:
  - In June 1932, the market "bottomed.
    - in July-August 1932, the market rose by 82%.
    - Over these 2 months, losers outperform winners by 206%.
    - *losers gain 236%, winners gain 30%.*
  - On March 9, 2009 the US equity market bottomed.
    - In March-May 2009, the market was up by 29%.
    - losers outperform winners by 149%.
    - *losers gain 156%, winners gain 6.5%.*

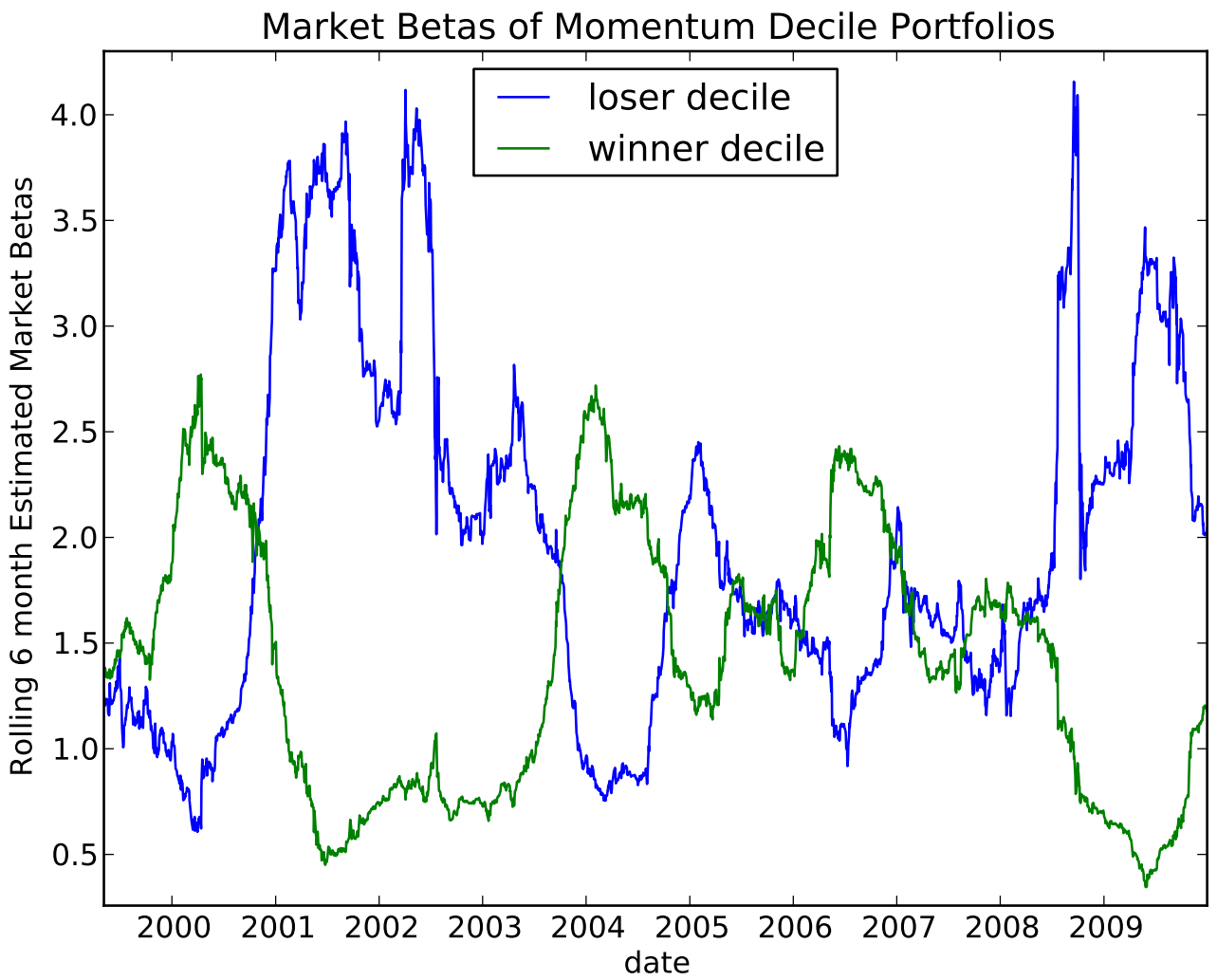
# Momentum Beta

- As of March 2009, many the firms in the Loser portfolio had fallen by 90% or more.
  - These were firms like Citigroup, Bank of America, Ford, GM, and International Paper (which was levered)
  - In contrast, the Winner portfolio was composed of defensive or counter-cyclical firms like Autozone.
- The loser firms, in particular, were often extremely levered, and at risk of bankruptcy.
  - Their common stock was effectively out-of-the-money options on the firm value.
- This suggests that there were potentially large differences in the market betas of the winner and loser portfolios

# Market Beta and Momentum - 1931-1945



# Market Beta and Momentum - 1999-2010



# Hedging market risk

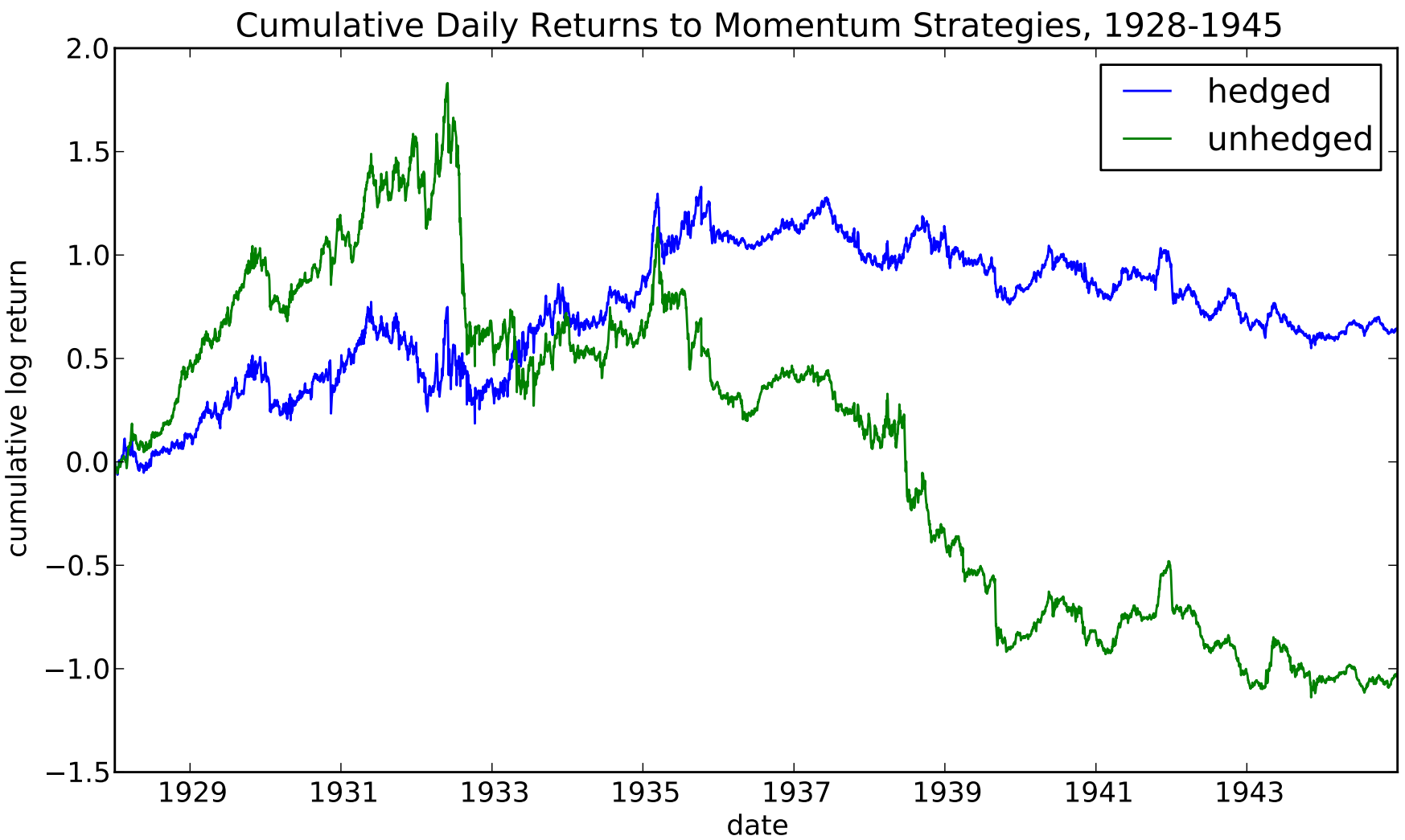
- This evidence suggests hedging out market risk could be beneficial.
- We estimate rolling 42-day (2-month) betas
  - We regress $r_{WML,t}$ on contemporaneous Market, and 10 lags of the market return.
  - This is particularly important in the early period, to address non-trading/illiquidity biases
- We then hedge the WML portfolio:

$$\tilde{r}^{h}_{WML,t} = \tilde{r}_{WML,t} - \beta_t \cdot \tilde{r}^{e}_{m,t},$$

where $\beta_t$ is the *forward-looking* rolling-beta estimate.

  - This follows the procedure of Grundy and Martin (2001).

# Hedged Momentum Portfolio Performance



# Estimating Beta

There is a strong Up- and Down-$\beta$ differential in bear markets:

$$\tilde{R}_{WML,t} = \alpha + \left[\beta_0 + \beta_1 \mathbf{I}_{Rm2y<0} + \beta_2 (\mathbf{I}_{Rm2y<0} \cdot \mathbf{I}_{R_{m,t}>0})\right] \tilde{R}^e_{m,t} + \tilde{\epsilon}_t$$

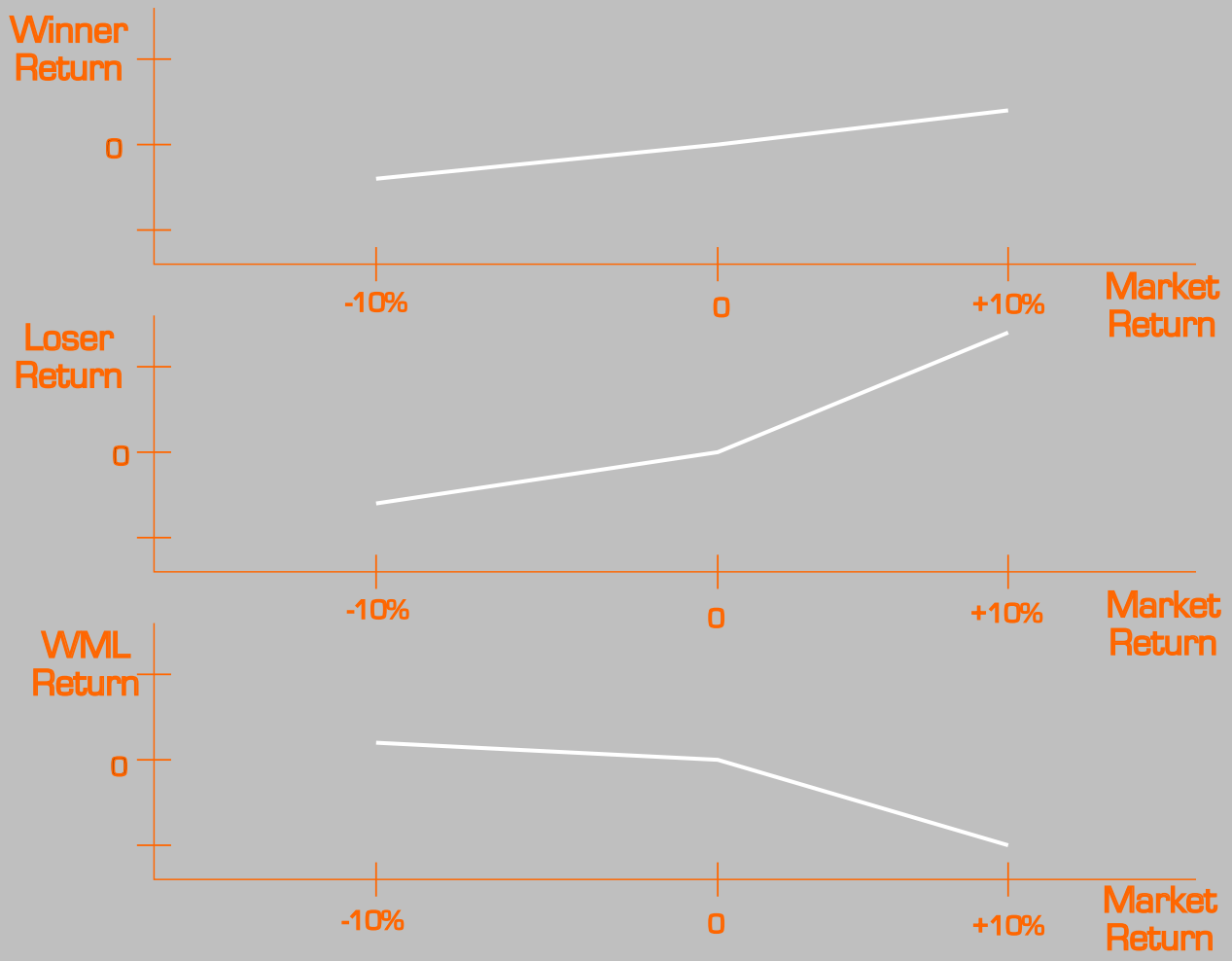
```
R-squared:            0.3394,          Adj R-squared:    0.3374
Rmse:                 0.0652
F-stat (3, 992):    169.8908,          p-value:          0.0000

Degrees of Freedom: model 3, resid 992
---------------Summary of Estimated Coefficients-------------
       Variable         Coef    Std Err      t-stat    p-value

             Rm       0.0359     0.0527        0.68     0.4958
     (m2y<0)*Rm      -0.7873     0.1050       -7.50     0.0000
(m2y<0)*(Rm>0)*Rm    -0.6978     0.1161       -6.01     0.0000
      intercept       0.0171     0.0022        7.72     0.0000
```

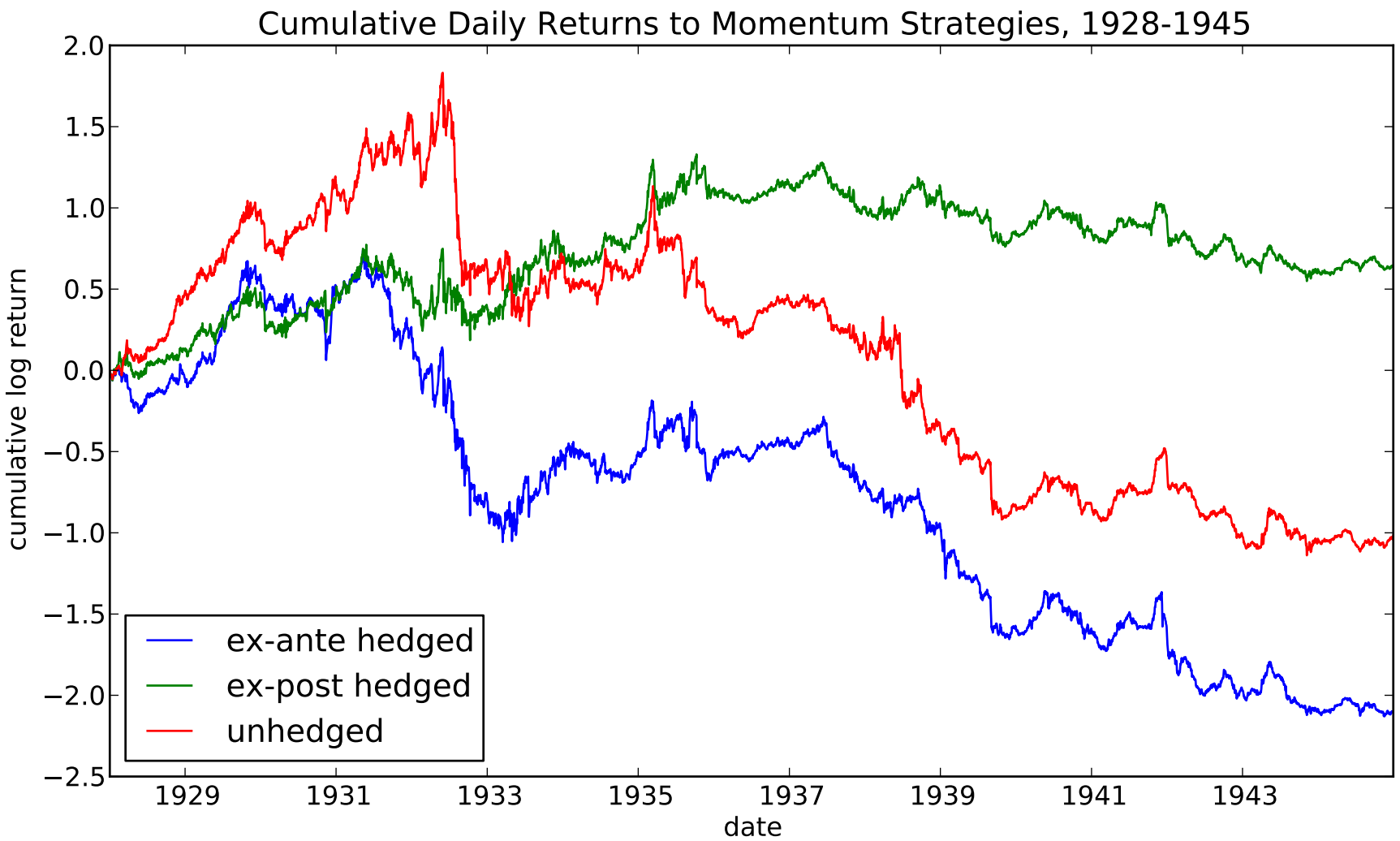
- Separate regressions show that the difference in up- and down-$\beta$s is driven by the "loser" portfolio.

# WML “Option”


Winner Return
0
-10%
0
+10%
Market Return
Loser Return
0
-10%
0
+10%
Market Return
WML Return
0
-10%
0
+10%
Market Return

- The regression results show that the up-beta of the WML portfolio is much more negative than the down-beta.
- This means, if you use a *forward looking* beta estimate:
  - You hedge more (i.e., buy more market) when then market is going to rise.
- This imparts a large *positve* bias to the estimate of the hedged portfolio returns.

# Hedged Momentum Portfolio Performance



# Forecasting Crashes

- We have seen that the payoff associated with the WML portfolio has short-option-like characteristics.
- It seems likely this this option will be more costly when market variance is higher
  - This is also consistent with behavioral motivations for the premium
- Based on this we investigate whether other variables associated with perceived risk affect the payoff to momentum strategies.
  - Specifically we look at a realized volatility related to the VIX.

# Forecasting Momentum Returns

$$\tilde{r}_{WML,t} = \gamma_0 + \gamma_{Rm2y} \cdot \mathbf{I}_{Rm2y<0} + \gamma_{\sigma_m^2} \cdot \hat{\sigma}_m^2 + \gamma_{int} \cdot \mathbf{I}_{Rm2y<0} \cdot \hat{\sigma}_{m,t}^2 + \tilde{\epsilon}_t$$

| | $\gamma_0$ | $\gamma_{Rm2y}$ | $\gamma_{\sigma_m^2}$ | $\gamma_{int}$ |
|---|---|---|---|---|
| 1 | 0.0006 | -0.0012 | | |
| | (5.59) | (-4.51) | | |
| 2 | 0.0008 | | -3.69 | |
| | (6.78) | | (-6.07) | |
| 3 | 0.0009 | -0.0006 | -3.07 | |
| | (6.98) | (-2.04) | (-4.54) | |
| 4 | 0.0006 | | | -4.75 |
| | (6.06) | | | (-7.17) |
| 5 | 0.0006 | -0.0004 | -0.54 | -4.50 |
| | (4.87) | (0.36) | (-0.53) | (-3.30) |

# Conclusions & Future Work

1. In “normal” environments, the market appears to underreact to public information, resulting in consistent price momentum.
2. However, in extreme market enviroments, the market prices of severe past losers embody a very high premium.
   - When market conditions ameliorate, these losers experience strong gains, resulting in a momentum crash.
     - The expected gains from the loser portfolio are related to both past market losses, and lagged market volatility.
3. Market risk of momentum portfolios varies dramatically, but does not appear to explain the variation in the premia earned by momentum.
4. Other Issues:
   - Increased Crowding in Quant Space
   - Transactions Costs

# References I

Asness, Clifford S., John M. Liew, and Ross L. Stevens, 1997, Parallels between the cross-sectional predictability of stock and country returns, *Journal of Portfolio Management* 23, 79–87.

Asness, Clifford S., Toby Moskowitz, and Lasse Pedersen, 2008, Value and momentum everywhere, University of Chicago working paper.

Chan, Wesley S., 2003, Stock price reactions to news and no-news: Drift and reversal after headlines, *Journal of Financial Economics* 70, 223–260.

Cooper, Michael J., Roberto C. Gutierrez, and Allaudeen Hameed, 2004, Market states and momentum, *Journal of Finance* 59, 1345–1365.

Daniel, Kent D., David Hirshleifer, and Avanidhar Subrahmanyam, 1998, Investor psychology and security market under- and over-reactions, *Journal of Finance* 53, 1839–1886.

———, 2001, Overconfidence, arbitrage, and equilibrium asset pricing, *Journal of Finance* 56, 921–965.

Erb, Claude B., and Campbell R. Harvey, 2006, The strategic and tactical value of commodity futures, *Financial Analysts Journal* 62, 69–97.

Fama, Eugene F., and Kenneth R. French, 1993, Common risk factors in the returns on stocks and bonds, *Journal of Financial Economics* 33, 3–56.

Grundy, Bruce, and J. Spencer Martin, 2001, Understanding the nature of the risks and the source of the rewards to momentum investing, *Review of Financial Studies* 14, 29–78.

# References II

Jegadeesh, Narasimhan, and Sheridan Titman, 1993, Returns to buying winners and selling losers: Implications for stock market efficiency, *Journal of Finance* 48, 65–91.

———, 2001, Profitability of momentum strategies: An evaluation of alternative explanations, *Journal of Finance* 56, 699–720.

Moskowitz, Tobias J., and Mark Grinblatt, 1999, Do industries explain momentum?, *The Journal of Finance* 54, 1249–1290.

Moskowitz, Tobias J., Yoa Hua Ooi, and Lasse H. Pedersen, 2010, Time series momentum, University of Chicago Working Paper.

Okunev, John, and Derek White, 2003, Do momentum-based strategies still work in foreign currency markets?, *Journal of Financial and Quantitative Analysis* 38, 425–447.

Rouwenhorst, K. Geert, 1998, International momentum strategies, *Journal of Finance* 53, 267–284.

———, 1999, Local return factors and turnover in emerging stock markets, *Journal of Finance* 54, 1439–1464.