Do Factor Models Explain Stock Returns When Prices Behave Explosively? Evidence from China

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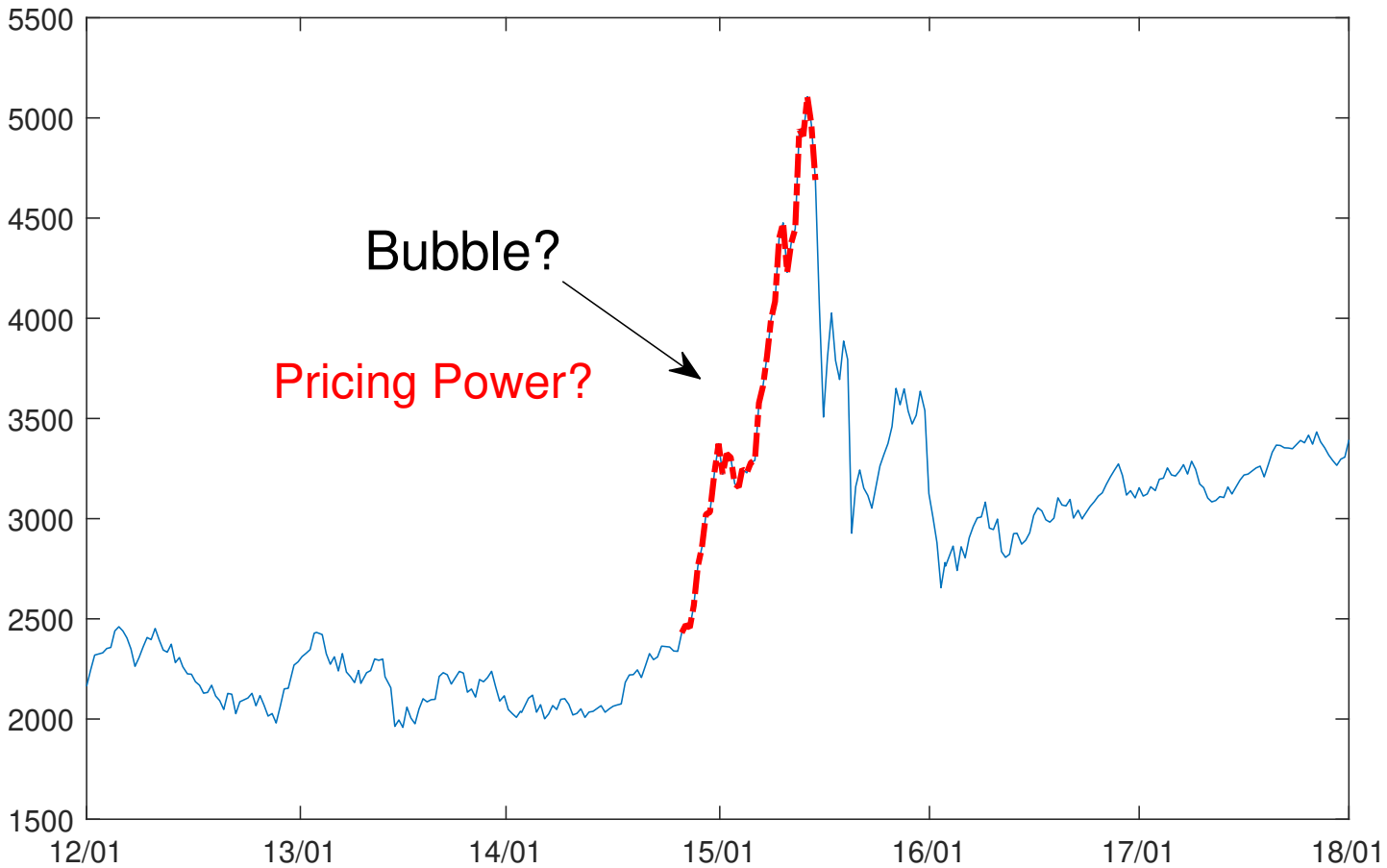
June 19, 2024

Outline

Motivation

- The Fama-French factor models provide a powerful tool for understanding asset prices and guide the way for all subsequent research.
- However, literature on asset pricing models generally assumes the market is weak efficient, where stock prices follow random walks.
- Do the Fama-French factor models still work when stock prices follow explosive (or bubble) processes?

The Shanghai Stock Exchange Composite Index



What We Do

- We test the Fama-French five-factor (FF5) model when stock prices follow explosive processes.
  - We use the bubble test of Phillips, Shi and Yu (PSY, 2015) to identify bubbles in China's stock market.
  - We estimate the FF5 model in the random walk and bubble periods separately.
  - We compare the performance of the model between the two subsample periods.
- We investigate the marginal pricing ability of each factor in the FF5 model.
  - We examine which factor shows the strongest ability in explaining stock returns.
  - We analyze the dynamics of the factor's pricing ability from the random walk period to the bubble period.

Fama-French Five-Factor Model I

The FF5 model centers on the following time-series regression.

$$R_{it} - R_{ft} = \alpha_i + \beta_i(R_{mt} - R_{ft}) + s_i SMB_t + h_i HML_t + r_i RMW_t + c_i CMA_t + \varepsilon_{it} \quad (1)$$

At each time t, the excess returns on portfolio i can be explained by five factors:

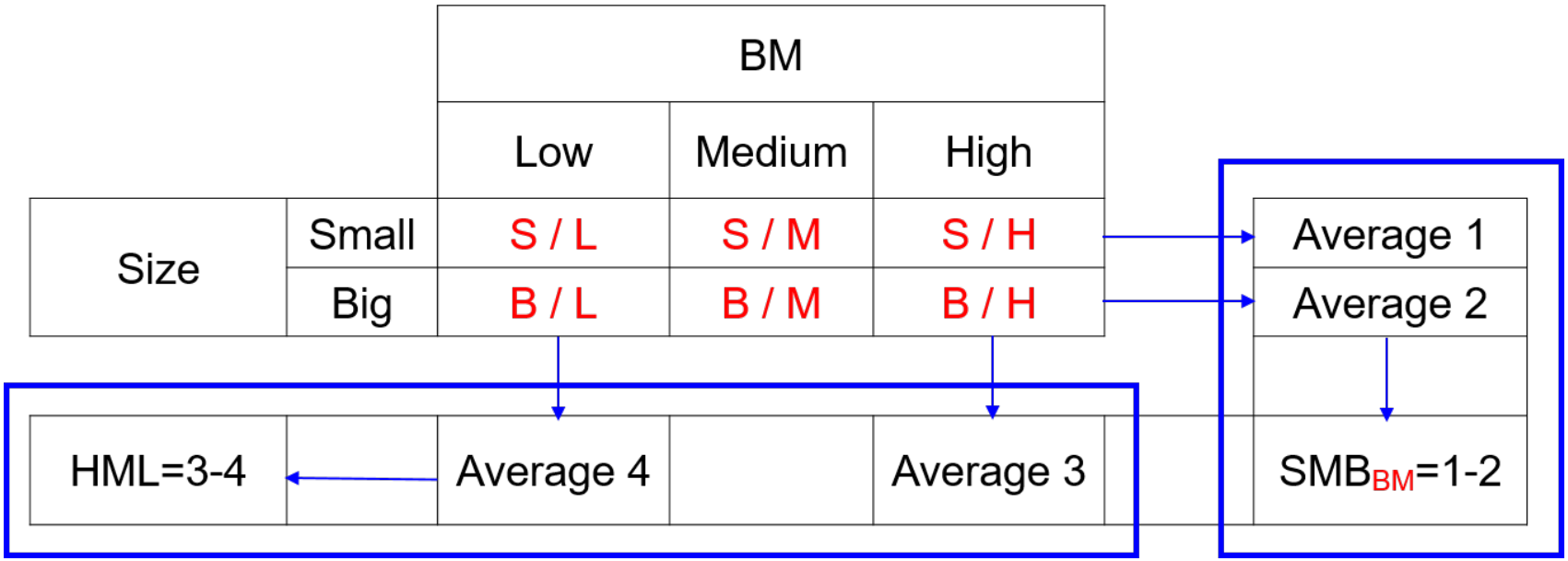
- $R_m - R_f$: market factor, the excess returns on the market portfolio
- SMB: size factor, (Small Minus Big) Market Value
- HML: value factor, (High Minus Low) Book-to-Market Equity
- RMW: profitability factor, (Robust Minus Weak) Operating Profitability-to-Book Equity
- CMA: investment factor, (Conservative Minus Aggressive) Total Asset Growth Rate

Fama-French Five-Factor Model II

- Factor Construction
  - Stocks are sorted independently into TWO size groups and THREE BM, OP or INV groups.
  - The 2×3 Sorts are held for ONE year, and reconstructed every year.
  - Follow Fama and French (2015) to calculate the five factors.
- Portfolio Formation
  - Stocks are sorted independently into FIVE size groups and FIVE BM groups.
  - The 5×5 Sorts are held for ONE year, and reconstructed every year.
  - Follow Fama and French (2015) to calculate the portfolio returns.

Factor Construction

2×3 double sorts by Size and BM



$$SMB_{BM} = 1/3(S/L + S/M + S/H) - 1/3(B/L + B/M + B/H) \quad (2)$$

$$HML = 1/2(S/H + B/H) - 1/2(S/L + B/L) \quad (3)$$

Similarly,

- Replace BM by OP or INV, get RMW, CMA, SMB_{OP}, SMB_{INV}
- SMB=1/3(SMB_{BM}+SMB_{OP}+SMB_{INV})

Portfolio Formation

5×5 double sorts by Size and BM

Size	Book-to-Market Equity (BM)				
	Low	2	3	4	High
Small	1.02	1.00	0.85	0.81	0.57
2	0.70	0.79	0.76	0.72	0.46
3	0.58	0.64	0.60	0.55	0.49
4	0.47	0.46	0.51	0.50	0.38
Big	0.45	0.24	0.20	0.17	0.29

Portfolio Return Calculation

- An Example: Small-Low-BM Portfolio

$$R_{S/L} = \sum_{i=1}^{n} w_i R_i \tag{4}$$

Portfolio return is the weighted average returns of the stocks contained in that portfolio.

PSY(2015): Bubble Test I

Price series will be explosive when bubbles exist. Phillips, Shi and Yu (2015) develop a bubble detection method, which is based on a double recursive right-tailed ADF test. The PSY method tests whether the price follows a random walk (H_0) or an explosive process (H_1).

- Data Generating Process

$$y_t = dT^{-\eta} + \rho y_{t-1} + \varepsilon_t \tag{5}$$

- Test Equation

$$\Delta y_t = \alpha_{r_1 r_2} + \delta_{r_1 r_2} y_{t-1} + \sum_{i=1}^{k} \psi^i_{r_1 r_2} \Delta y_{t-i} + \varepsilon_t \tag{6}$$

- Test Statistic

$$GSADF(r_0) = \sup_{r_2 \in [r_0,1], r_1 \in [0, r_2 - r_0]} \{ADF^{r_2}_{r_1}\} = \sup_{r_2 \in [r_0,1], r_1 \in [0, r_2 - r_0]} \{\frac{\hat{\delta}_{r_1 r_2}}{se(\hat{\delta}_{r_1 r_2})}\} \tag{7}$$

If GSADF statistic value exceeds the critical value, then bubbles exist.

PSY(2015): Bubble Test II

The PSY method can also locate the origination and termination date of bubbles.

- BSADF Test

$$BSADF_{r_2}(r_0) = sup_{r_1 \in [0, r_2 - r_0]} \{ADF_{r_1}^{r_2}\} \tag{8}$$

- Origination Date

$$\hat{r}_e = \inf_{r_2 \in [r_0, 1]} \{r_2 : BSADF_{r_2}(r_0) > CV_{r_2}^{SADF}\} \tag{9}$$

- Termination Date

$$\hat{r}_f = \inf_{r_2 \in [\hat{r}_e + \delta log(T)/T, 1]} \{r_2 : BSADF_{r_2}(r_0) < CV_{r_2}^{SADF}\} \tag{10}$$

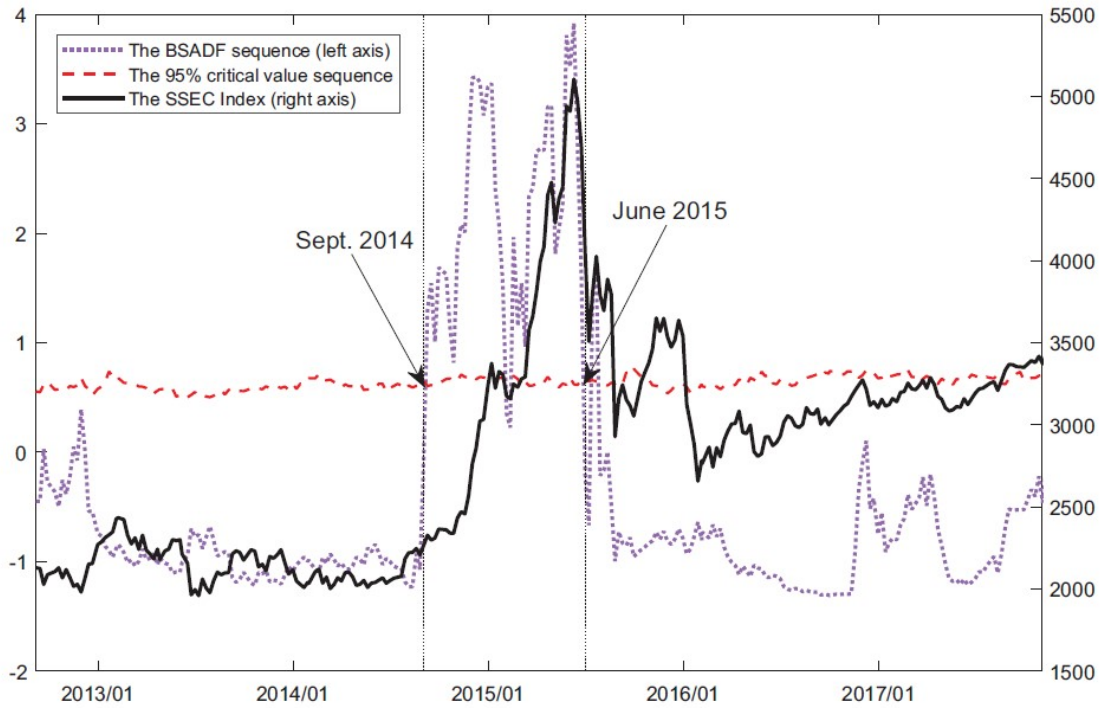
Data and Sample

- Data
  - CSMAR database
  - Shanghai A-share stock market
  - Focus on 2012-2018, covering the period before and after the 2015 stock market crash
- Sample

  Excludes-
  - Financial firms
  - "ST" firms
  - Firms with negative Book Values
  - Firms that lacks necessary financial information

The Identified Bubble Period

Shanghai Stock Exchange Composite Index (weekly data)



- Bubble period: Sept.2014-June 2015
- Random walk period: Jan.2012-Aug.2014

The results are consistent with the intuitive observation of the rapid expansion and collapse in China's stock market around 2015.

Portfolio Returns in Two Periods I

Table: Average weekly excess returns for 25 size-BM portfolios

Size	Book-to-Market Equity (BM)				
	Low	2	3	4	High
	Panel A: The random walk period (Jan. 2012-Aug. 2014)				
Small	0.76	0.83	0.57	0.60	0.51
2	0.53	0.49	0.56	0.66	0.26
3	0.44	0.45	0.42	0.40	0.29
4	0.41	0.40	0.37	0.37	0.27
Big	0.16	0.03	0.07	0.00	-0.01
	Panel B: The bubble period (Sept. 2014-June 2015)				
Small	2.71	2.83	2.68	2.68	2.05
2	2.41	2.41	2.71	2.23	2.35
3	2.52	2.64	2.31	2.34	2.73
4	2.12	2.04	1.90	2.66	2.42
Big	1.66	1.56	2.13	1.70	2.07

Notes: All the returns are expressed in percent per week.

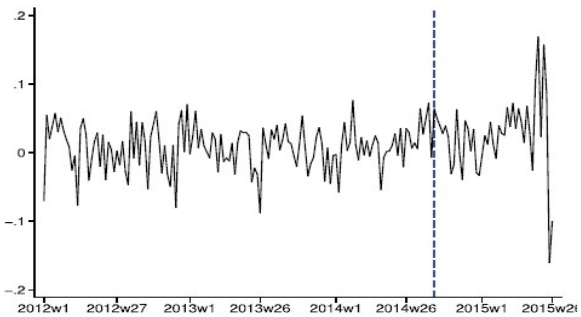
Portfolio Returns in Two Periods II

The returns patterns in China's stock market.

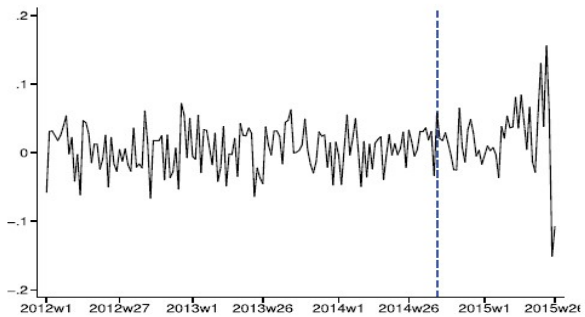
- Higher excess returns in the bubble period.
- Size Effect Exists in both periods.
  - Stock returns show size-related differences. Smaller stocks have higher average excess returns than bigger stocks. (0.76>0.16, 2.71>1.66.)
- Size Effect Weakens in the bubble period.
  - The difference between the returns of small and big portfolios shrinks in the bubble period. (0.76>>>>0.16, 2.71>>1.66.)
- Value Effect does not exist in both periods.
  - Value (high BM) stocks do not show higher average returns than growth (low BM) stocks.

Portfolio Returns in Two Periods III

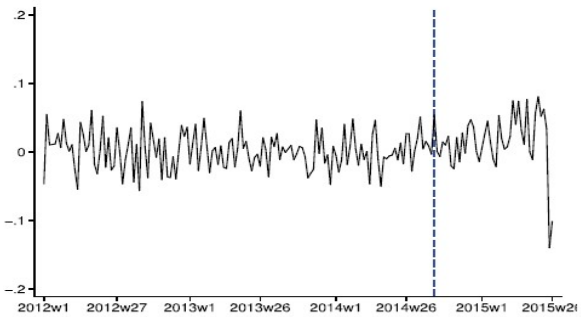
Dynamics of the Representative Portfolio Excess Returns



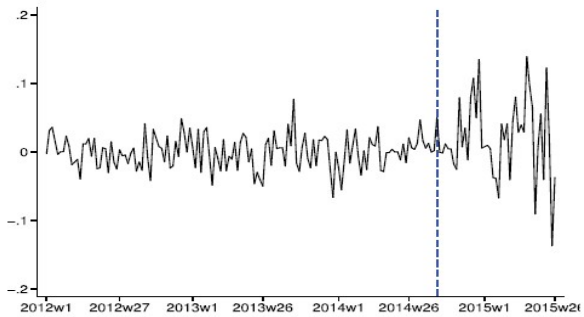
(a) Small-low-BM portfolio



(b) Small-high-BM portfolio



(c) Big-low-BM portfolio

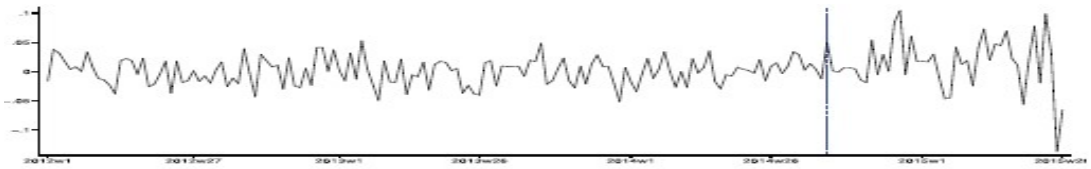


(d) Big-high-BM portfolio

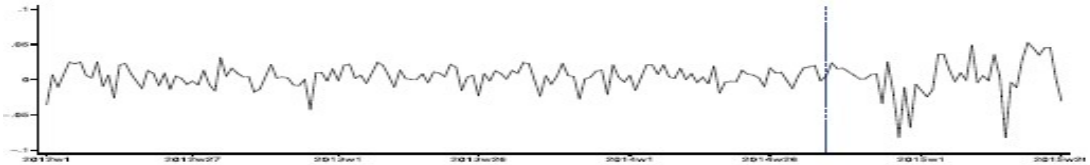
- The Volatility of the excess returns increases from the random walk period to the bubble period.
- The returns of Small portfolios are more volatile than that of the Big portfolios.

Five Factors in Two Periods I

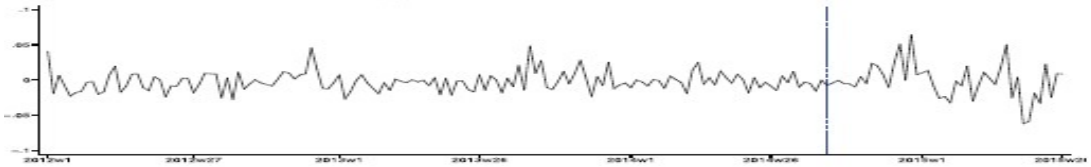
Dynamics of the Five Factors



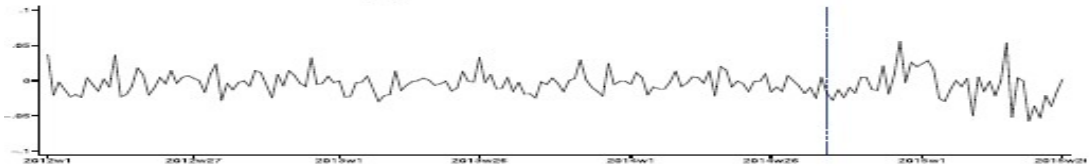
(a) The market factor



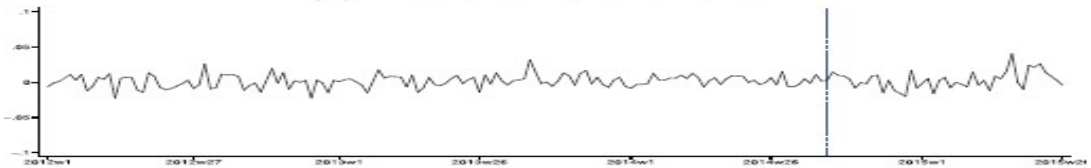
(b) The size factor SMB



(c) The value factor HML



(d) The profitability factor RMW



(e) The investment factor CMA

Five Factors in Two Periods II

Dynamics of the Five Factors.

- The Five Factors are more volatile in the bubble period than in the random walk period.
- The average standard deviation of $R_m - R_f$, SMB, HML, RMW, CMA increase 109.6%, 137.8%, 87.5%, 86.2% and 41.9% in the bubble period, respectively.
- The market factor, $R_m - R_f$ is more volatile than the other four factors.

Compare the Perfomance of FF5 Model in Two Periods I

We use Gibbons, Ross and Shanken (GRS, 1989) test to examine the Overall Explanatory Power of the FF5 Model. The GRS method tests whether the intercepts of all portfolios returns are jointly zero (H_0) or not (H_1).

$$GRS = \frac{T-N-K}{N}[1+\bar{f}'\hat{\Omega}^{-1}\bar{f}]^{-1}\hat{\alpha}'\hat{\Sigma}^{-1}\hat{\alpha} \sim F_{N,T-N-K} \qquad (11)$$

$$H_0 : \alpha_i = 0, \forall i = 1, ...N,\ H_1 : \text{at least one } \alpha_i \neq 0$$

Here, T is the number of time periods, N is the number of portfolios, K is the number of factors included in the model. $\hat{\alpha}$ is a vector of the estimated intercepts ($\hat{\alpha}$=$[\hat{\alpha_1}\hat{\alpha_2}...\hat{\alpha_N}]'$). $\hat{\Sigma}$ is the residual covariance matrix. $\bar{f}$ is the mean of the factors and $\hat{\Omega}$ is the covariance matrix of the factors.

- If an asset pricing model explains the cross-sectional expected returns, then the intercept, α_i, is insignificant from zero for all portfolios i. Fail to reject H_0.

Compare the Perfomance of FF5 Model in Two Periods II

Table: Overall explanatory power of the FF5 model in two periods

	GRS	p-value	Mean $\|\alpha\|$	Mean $\|t\|$	Mean adj.R^2	Mean SE
The random walk period (Jan. 2012-Aug. 2014)	1.05	0.41	0.09	0.56	0.864	0.10
The bubble period (Sept. 2014-June 2015)	1.47	0.24	0.29	0.68	0.857	0.36

Notes: The means of absolute alphas and the corresponding standard errors are expressed in percent per week.

The GRS statistic fails to reject H_0 in both period. However, the explanatory power of the FF5 model declines in the bubble period.

- Lower probability to pass the test. (0.24<0.41)
- Larger pricing errors. (0.29>0.09)
- Lower fraction of returns variation explained by the model. (0.857<0.864)

Marginal Pricing Ability of the Five Factors I

Ross (2017): Two Desiderata for a Parsimonious Factor Model

- Explaining the cross section of average stock returns.
- Explaining the expected returns on stocks. (This inspires us!)

We examine the ability of each factor in explaining stock returns.

- Expected returns can be estimated from the loadings on the factors.
- If a portfolio has a significant loading on the factor, then it has the risk of that factor, enjoys the factor risk premium.
- The factor has Marginal Pricing Ability for that portfolio.

Thus, we investigate the marginal pricing ability of the Five Factors, and make comparisions between the two periods.

Marginal Pricing Ability of the Five Factors II

The Random Walk Period: Jan. 2012-Aug. 2014

Size	Book-to-market equity (BM)									
	Low	2	3	4	High	Low	2	3	4	High
			β					$t(\beta)$		
Small	0.93	0.99	0.97	0.94	0.93	19.91	16.91	18.56	14.47	16.69
2	1.06	0.98	1.01	0.99	1.08	23.25	22.87	19.41	19.05	21.39
3	0.94	0.94	1.03	1.03	1.09	17.03	21.03	22.49	23.18	22.46
4	0.98	1.15	1.07	1.12	1.07	17.63	20.52	21.31	23.92	23.48
Big	0.89	1.28	1.12	0.89	0.99	18.37	22.09	25.16	31.87	28.42
			s					$t(s)$		
Small	0.74	0.68	1.10	0.70	1.02	5.07	3.76	6.75	3.44	5.84
2	0.74	0.99	1.25	1.21	1.26	5.23	7.42	7.66	7.50	7.99
3	0.38	1.02	0.71	1.18	0.72	2.19	7.30	4.97	8.54	4.75
4	0.30	0.44	0.53	0.82	0.53	1.71	2.51	3.36	5.58	3.70
Big	0.13	0.00	−0.34	−0.12	−0.35	0.83	−0.01	−2.45	−1.43	−3.20
			h					$t(h)$		
Small	−0.50	−0.24	0.12	−0.23	0.07	−5.36	−2.04	1.17	−1.76	0.65
2	−0.45	−0.32	−0.07	0.43	0.11	−5.05	−3.75	−0.69	4.21	1.11
3	−0.54	−0.26	−0.27	0.09	0.22	−4.92	−2.96	−2.98	0.99	2.35
4	−0.81	−0.48	−0.30	0.16	0.34	−7.42	−4.37	−3.06	1.69	3.84
Big	−0.95	−0.49	−0.06	0.14	0.27	−9.97	−4.31	−0.67	2.46	4.00
			r					$t(r)$		
Small	−0.27	−0.38	−0.21	−0.32	−0.24	−1.86	−2.09	−1.26	−1.58	−1.34
2	−0.14	0.04	0.01	−0.49	0.14	−0.99	0.26	0.06	−3.07	0.89
3	−0.53	−0.09	−0.14	−0.16	−0.13	−3.08	−0.68	−1.01	−1.18	−0.83
4	−0.26	−0.38	−0.41	−0.12	−0.25	−1.49	−2.20	−2.59	−0.78	−2.01
Big	0.05	−0.24	−0.42	0.24	−0.40	0.31	−1.31	−3.04	2.81	−3.65
			c					$t(c)$		
Small	0.53	0.24	0.01	0.04	−0.39	3.52	1.29	0.07	0.22	−2.18
2	0.20	−0.04	−0.13	−0.29	−0.46	1.34	−0.31	−0.75	−1.72	−2.85
3	−0.37	−0.44	−0.23	−0.42	−0.34	−2.08	−3.08	−1.56	−2.93	−2.17
4	−0.07	−0.35	−0.39	−0.38	−0.35	−0.42	−1.98	−2.39	−2.50	−2.36
Big	−0.78	−0.43	−0.18	0.35	−0.06	−5.02	−2.29	−1.27	3.96	−0.53

Marginal Pricing Ability of the Five Factors III

The Bubble Period: Sept. 2014-June 2015

Size	Book-to-market equity (BM)									
	Low	2	3	4	High	Low	2	3	4	High
			β					$t(\beta)$		
Small	1.05	0.96	1.00	0.90	1.04	13.56	13.98	13.68	13.01	20.55
2	0.94	1.01	1.02	0.96	1.02	12.84	14.44	12.70	11.41	11.49
3	1.06	1.02	0.94	0.92	0.95	13.73	13.87	13.22	14.27	8.96
4	0.97	0.97	1.06	1.01	0.92	13.19	11.85	16.59	14.84	11.21
Big	0.95	0.94	1.03	1.05	0.98	16.76	13.52	11.50	11.27	14.02
			s					$t(s)$		
Small	0.75	0.71	0.85	0.86	0.76	3.02	3.24	3.63	3.87	4.71
2	0.30	0.13	0.87	0.99	0.46	1.25	0.56	3.39	3.66	1.63
3	0.17	0.34	0.62	0.33	0.18	0.68	1.43	2.74	1.58	0.54
4	0.35	0.28	0.45	0.23	−0.12	1.48	1.05	2.18	1.06	−0.45
Big	−0.48	−0.50	−0.46	−0.18	−0.84	−2.63	−2.24	−1.61	−0.59	−3.73
			h					$t(h)$		
Small	−0.52	−0.35	−0.25	−0.08	−0.08	−2.34	−1.77	−1.22	−0.40	−0.52
2	−0.16	−0.81	−0.25	0.10	0.27	−0.76	−4.03	−1.08	0.41	1.06
3	−1.22	−0.80	0.06	0.06	0.76	−5.51	−3.82	0.28	0.34	2.52
4	−0.98	−0.52	−0.35	0.39	0.40	−4.65	−2.21	−1.90	2.02	1.70
Big	−1.02	−0.85	−0.15	−0.36	0.35	−6.29	−4.29	−0.58	−1.37	1.75
			r					$t(r)$		
Small	−0.13	−0.38	−0.11	−0.23	−0.09	−0.37	−1.26	−0.35	−0.77	−0.39
2	−0.65	−0.41	−0.16	−0.21	−0.83	−1.99	−1.31	−0.45	−0.57	−2.12
3	−0.13	−0.33	−0.81	−0.63	−0.87	−0.38	−1.01	−2.59	−2.23	−1.85
4	0.08	−0.37	−0.23	−0.64	−0.97	0.26	−1.03	−0.82	−2.13	−2.69
Big	−0.68	−0.48	−0.73	1.16	−0.75	−2.70	−1.56	−1.85	2.82	−2.43
			c					$t(c)$		
Small	0.60	0.70	0.82	0.74	0.55	1.66	2.21	2.40	2.31	2.35
2	0.28	0.86	0.81	0.02	0.00	0.82	2.63	2.17	0.04	0.00
3	0.48	0.46	−0.33	0.13	−0.31	1.32	1.33	−1.01	0.42	−0.64
4	0.25	0.30	−0.03	0.01	−0.07	0.74	0.78	−0.08	0.03	−0.19
Big	−0.16	−0.21	0.02	1.34	0.37	−0.59	−0.65	0.04	3.09	1.14

Marginal Pricing Ability of the Market Factor

The **market factor** shows the strongest pricing ability of the five factors.

- The market βs are positive and highly significant for all the 25 portfolios in both periods.
- But its pricing ability declines in the bubble period.(shown by t-statistics)

An Example: Portfolio of small-low-BM

- In the Random Walk period: β=0.93, $t(\beta)$=19.91
- In the Bubble period: β=1.05, $t(\beta)$=13.56
- Its average excess returns increase significantly by 0.93% and 1.05% in the Random Walk and Bubble periods, respectively, when the market premium increases by 1%.

Marginal Pricing Ability of SMB

The **size factor, SMB**, its pricing ability

- Less stronger than the market factor.
- Declines in the bubble period.
- Stronger for small and medium-sized portfolios.
- Limited for big portfolios.

Examples:

- Portfolio of small-low-BM
  - In the Random Walk period: s=0.74, $t(s)$=5.07
  - In the Bubble period: s=0.75, $t(s)$=3.02
  - Its excess returns can be explained by SMB in both periods.
- Portfolio of big-low-BM
  - In the Random Walk period: s=0.13, $t(s)$=0.83
  - Its excess returns cannot be explained by SMB in the Random Walk period.

Marginal Pricing Ability of HML

The **value factor, HML**, its pricing ability

- Less stronger than the market factor and the size factor
- Disappears for most portfolios in the bubble period.
- Mainly in the growth (low BM) portfolios.

Examples:

- Portfolio of big-high-BM
  - In the Random Walk period: h=0.27, $t(h)$=4.00
  - In the Bubble period: h=0.35, $t(h)$=1.75
  - Its average excess returns can be explained by HML in the Random Walk period, but cannot in the Bubble period.
- Portfolio of big-low-BM
  - In the Random Walk period: h=-0.95, $t(h)$=-9.97
  - In the Bubble period: h=-1.02, $t(h)$=-6.29
  - Its average excess returns can be explained by HML in both periods.

Marginal Pricing Ability of RMW

The **profitability factor, RMW**

- Does not show strong pricing ability.
- The coefficients of RMW are not significant for most portfolios.
- Only 1/3 of portfolios can be priced by RMW.

Examples:

- Portfolio of small-high-BM
  - In the Random Walk period: r=-0.24, $t(r)$=-1.34
  - In the Bubble period: r=-0.09, $t(r)$=-0.39
  - Its average excess returns cannot be explained by RMW in both periods.
- Portfolio of big-high-BM
  - In the Random Walk period: r=-0.40, $t(r)$=-3.56
  - In the Bubble period: r=-0.75, $t(r)$=-2.43
  - Its average excess returns can be explained by RMW in both periods.

Marginal Pricing Ability of CMA

The **investment factor, CMA**, its pring ability

- Stronger than RMW, but less stronger than the market factor, SMB and HML.
- Declines in the bubble period.

An Example: Portfolio of small-low-BM

- In the Random Walk period: c=0.53, $t(c)$=3.52
- In the Bubble period: c=0.60, $t(c)$=1.66
- Its average excess returns can be explained by CMA in the Random Walk period, but cannot in the Bubble period.

Why Do Factor Models Perform Less Well During the Bubble?

The FF5 Model explains the stock returns in China' A share market, but the explanatory power of the model declines during the bubble.
WHY?

- All versions of the FF models are based on the Efficient Market Hypotheis. (Not surprising!)
- Significant changes in the data characteristics of portfolio returns and the factors.
- Trading motives of investors is more speculative than rational during the bubble.

An Explanation From Behavioral Finance I

- Extrapolation Theory: Extrapolators, a type of investors, "waver" between two conflicting motives.
  - Speculating the prices continue to go up.
  - Fearing the prices go back to its rational valuation.
  - Good news of fundamentals push them in favor of the First motive. (Barberis et al.,2018)
- Facts: In 2015, before the stock market crash in China,
  - Bullish news about future stock market movement appear.
  - Various media, including Official media, report the news.
  - Investors have increased and easier access to leverage-financed capital. (Bian et al.,2018)

Thus, extrapolators are stimulated to increase their demand for stocks, buying stocks from rational traders, pushing prices to a high level.

An Explanation From Behavioral Finance II

The Speculative trading motives of investors

- Lead to less effcient market and larger pricing errors.
- Is witnessed by the higher Turnover during the bubble.

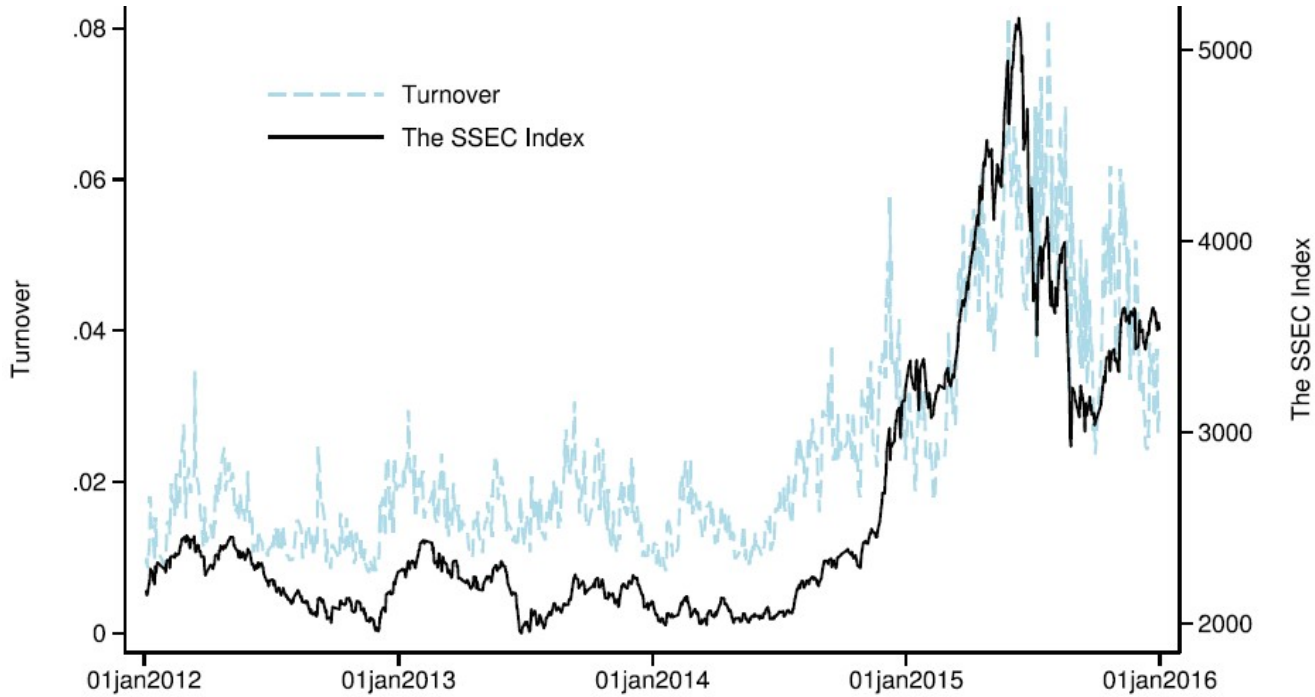


Fig. 4. Average daily turnover of the sample stocks.

Conclusion

- The FF5 model explains cross-sectional stock returns when prices follow explosive processes, but the explanatory power of the FF5 model declines in the bubble period.
- The marginal pricing ability of the Five factors decreases as prices change from the random walk period to the bubble period.
- The speculative behavior of investors may explain the declined explanatory power of the model during the bubble.

Thank you !