Quant Investing and Multifactor Models

Financial Markets, Day 1, Class 4

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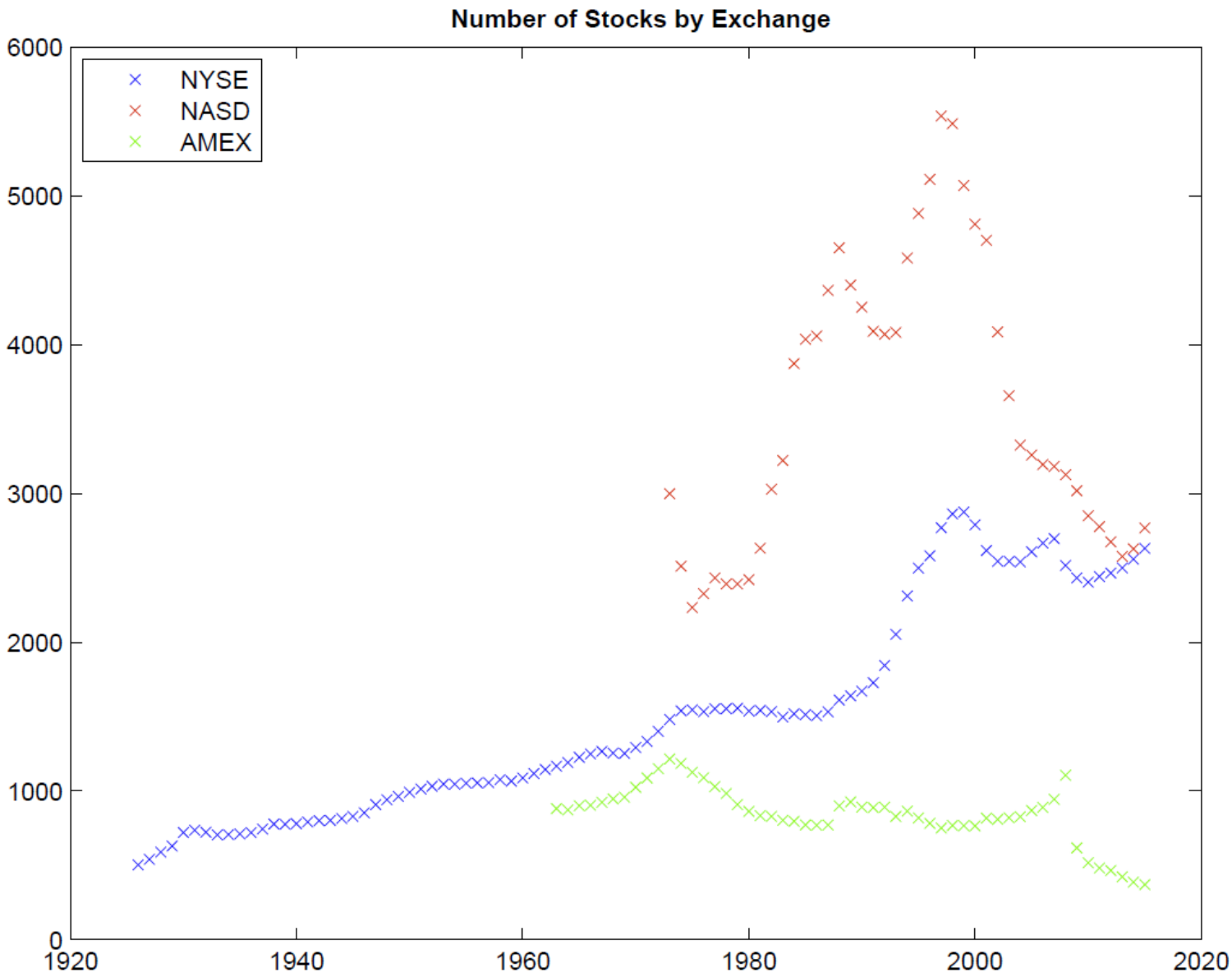
Outline

- Quant investing.
- Forming portfolios using quantitative signals.
- Testing the CAPM using size- and value-sorted portfolios.
- The Fama-French three factor model.

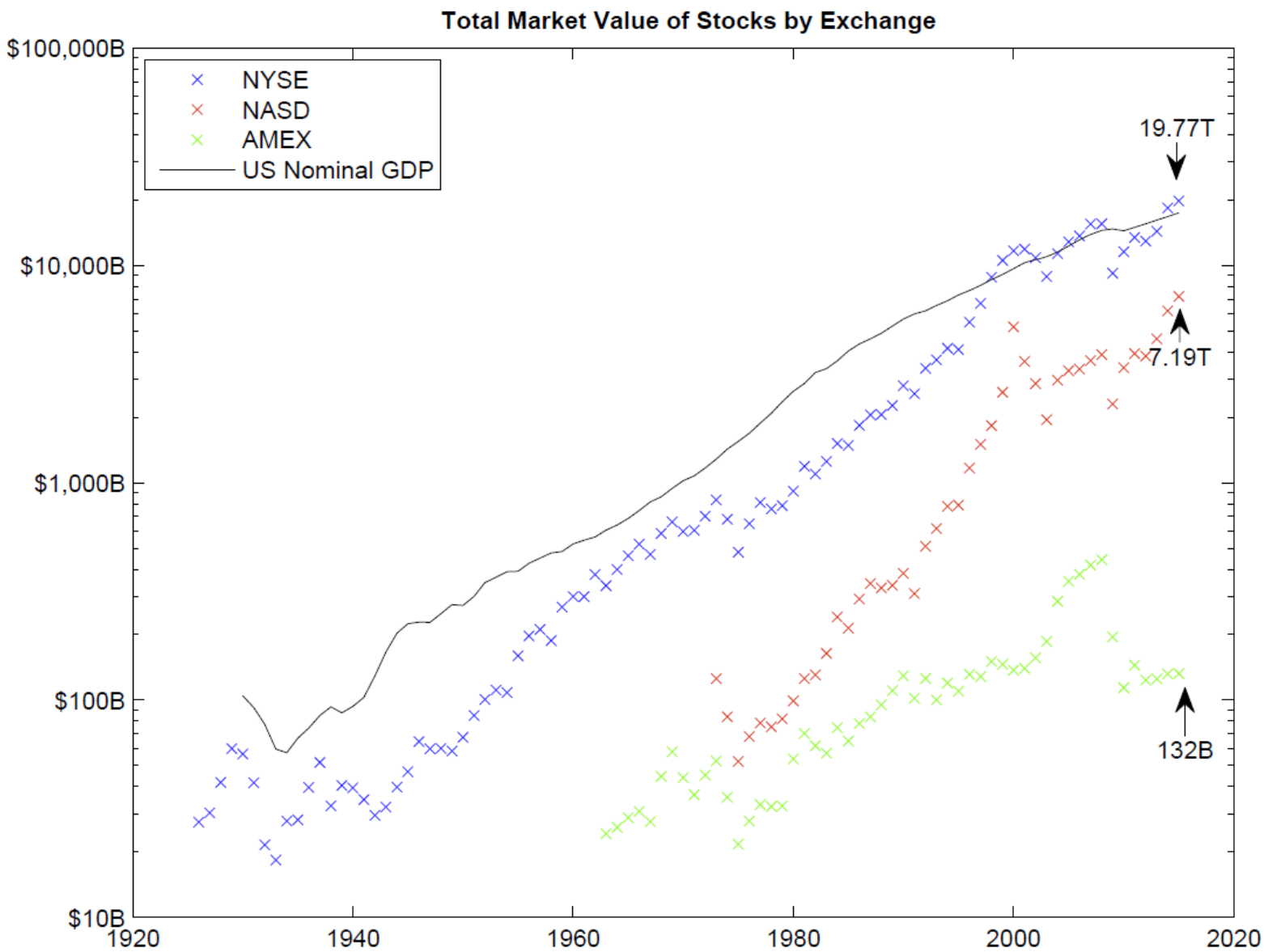
In Search for Alpha

- According to Theory
  - The CAPM: No way.
  - Believers of market efficiency: no true alpha, only beta in disguise.
  - Behavioral finance: true alpha caused by behavioral biases.
- In Practice
  - Stock picking: understand your stock, focus on the stories. (Examples: Warren Buffett, Peter Lynch)
  - Quant investing: understand your risk, focus on the numbers. (Examples: DFA, GSAM's Global Alpha, D.E. Shaw, BGI, LSV, AQR)

Quant Investing: Universe of Stocks



Quant Investing: Market Size



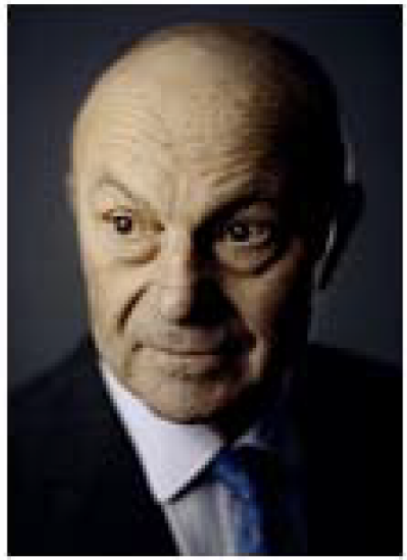
Data

Quant Investing

- Quant investing approaches the markets with an investment philosophy that is very different from stock picking.
- Instead of spending time to study each individual stock, it uses quantitative signals (e.g., market cap, profitability, book-to-market, and past returns) to form portfolios.
- The key insight is that such quantitative signals are useful in separating one group of stocks from another, exploiting the potential mis-pricing or differences in risk exposure.
- Quant investing has a razor sharp focus. For a given signal, the only risk it's interested in taking is the target risk factor. The portfolio approach helps diversify away unwanted idiosyncratic risk, and the long/short factor approach helps take out the unwanted systematic risk.

The Academic Influence

- Quant investing puts into practice ideas created and tested in academic research papers.
- The intellectual foundation and the framework of portfolio construction and factor building were provided mostly by papers written by Prof. Eugene Fama and his co-authors.
- In fact, many of the early quant investors were Prof. Fama's students at Chicago in the 1970s.
- The most creative part of quant investing is to come up with signals that could generate alpha. Most of the signals used today have their origin in academic papers.



Eugene F. Fama

Prize share: 1/3

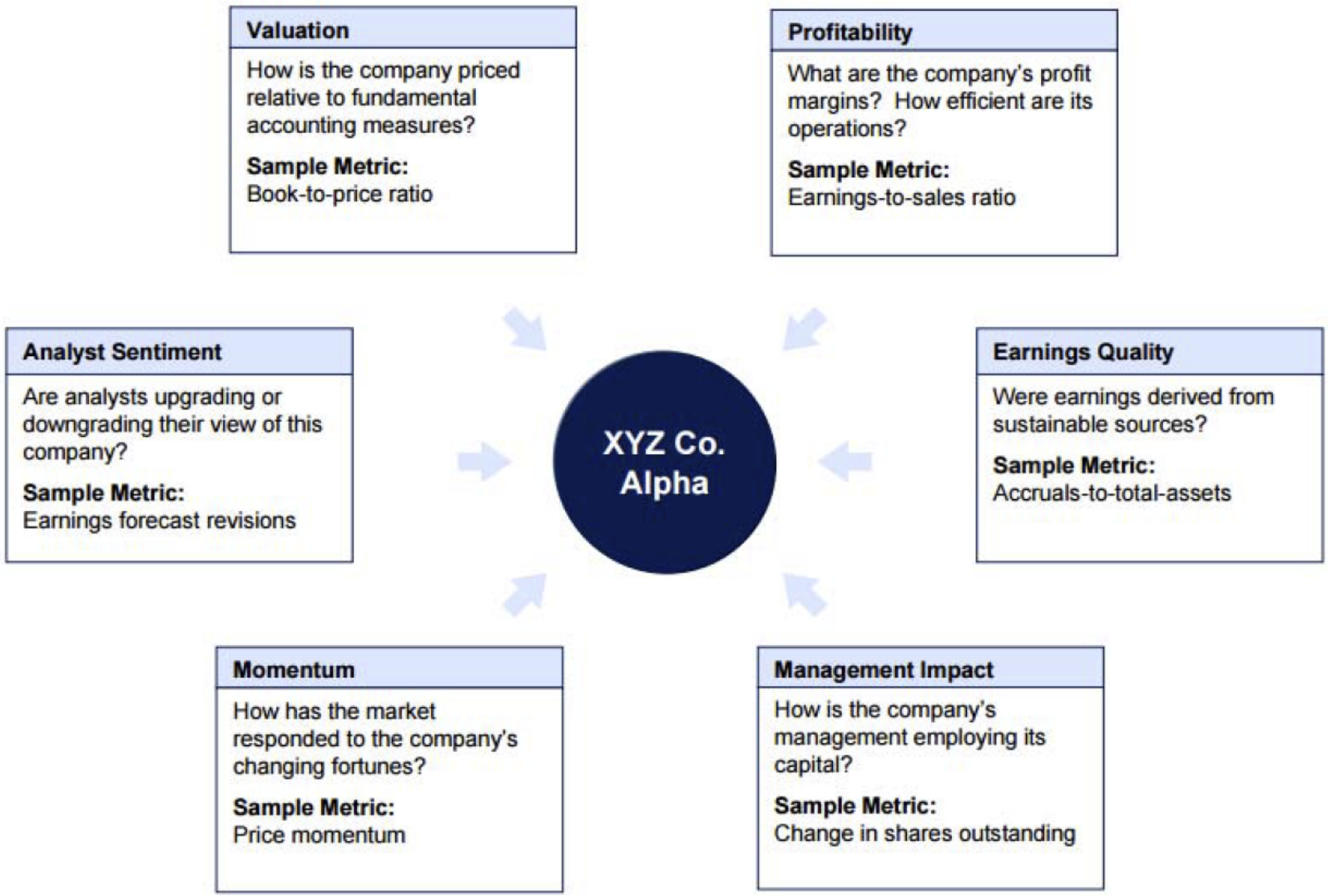
From Alpha to Beta

- Quant investing in the hedge fund space (long/short equity) started out in the 1990s, and grew quite rapidly in 2000s. Success led imitation.
- The "2007 quant meltdown" was a result of this space being over crowded: too many quant funds trading on too similar signals. The unwinding of "crowded trades" created large losses for many quant funds. Previously unrelated stocks suddenly started to move together during the unwind.
- In recent years, this idea of quant investing is showing up in the world of mutual funds and ETFs.
- While the sales pitch in the quant hedge fund world is all about Alpha, now the emphasis is on Beta: smart beta and factor investing.

Form Portfolios by Quant Signals

- Quant investing uses stock characteristics as signals. Some widely used stock characteristics are:
  - size: measured by market capitalization.
  - value: measured by the ratio of book equity to market value of equity.
  - momentum: measured by past stock performance.
- Stocks with the same characteristics are considered to be indistinguishable from one another and are sorted into the same portfolio.
- It is typical to sort stocks into terciles, quintiles, and deciles.
- It is also typical to identify two characteristics and do a double sort (e.g., the 5×5 Fama-French portfolios).

Quant Signals



Source: Prof. Kent Daniel

Size Sorted Portfolios

Market Capitalization = Stock Price $\times$ Number of Shares Outstanding

	Size Decile	Size (m$)	# of Stocks
Small	1	116	1362
	2	472	470
	3	912	378
	4	1,509	304
Med	5	2,308	233
	6	3,378	207
	7	5,212	225
	8	8,890	182
	9	17,244	182
Big	10	83,791	173

As of July 2015. Source: Prof. Ken French's Website.

Book-to-Market Sorted Portfolios

$$\textbf{BtM}\text{= book-to-market ratio} = \frac{\text{book value of equity}}{\text{market value of equity}}$$

	BtM Decile	BtM	# of Stocks	Size (m$)
Growth	1	0.095	432	8,440
	2	0.196	338	9,895
	3	0.269	330	10,430
	4	0.348	276	10,210
Neutral	5	0.431	314	4,726
	6	0.547	319	7,310
	7	0.654	333	2,586
	8	0.817	327	5,728
	9	0.972	378	2,878
Value	10	1.339	371	2,359

As of 2015. Source: Prof. Ken French's Website.

Sorting is Done Dynamically

- Stock characteristics fluctuate over time. Need to periodically update this information and re-sort stocks by their new characteristics. The sorting frequency depends on the variability of the signals.
- For example, Fama and French resort their size-sorted portfolios at the end of each June. A stock that was in the top size decile last year might have shrunk in size and gets re-sorted into a lower decile this year.
- So the stock composition of a characteristics-sorted portfolio changes over time. The turnover rate is higher for characteristics that move more frequently.
- For example, the momentum strategy requires you to re-sort stocks every month using past returns. Compared with the size-sorted portfolio, the momentum sorting is more frequent (once a month vs. one a year) and the sorting signal is also more variable (past returns vs. market cap).

The Fama French 25 Portfolios

- Size labels: A (small), B, C, D, and E (big).
- BtM labels: 1 (low), 2, 3, 4, and 5 (high).

	1	2	3	4	5
A	A1				A5
B					
C					
D					
E	E1				E5

A1 $\rightarrow$ small growth A5 $\rightarrow$ small value

E1 $\rightarrow$ big growth E5 $\rightarrow$ big value

Number of Stocks in Each Portfolio

- Each month, we have a cross section of stocks.
- The size of the cross section varies from month to month.
- So our portfolio size also varies from month to month.

July 2015

	1	2	3	4	5
A	269	208	285	347	542
B	159	115	134	141	82
C	107	89	89	78	55
D	120	103	75	51	35
E	115	91	50	43	35

January 1962

	1	2	3	4	5
A	7	12	32	56	92
B	25	28	46	48	50
C	31	47	43	51	29
D	60	57	47	26	18
E	81	62	35	22	11

Average Market Capitalization

Average Size ($M) as of July 2015

	1	2	3	4	5
A	246	235	243	240	149
B	1,220	1,201	1,211	1,135	1,084
C	2,831	2,944	2,720	2,753	2,819
D	6,860	6,863	6,895	6,806	6,737
E	48,736	56,086	56,500	44,859	40,072

Average Book-to-Market Ratio of Each Portfolio

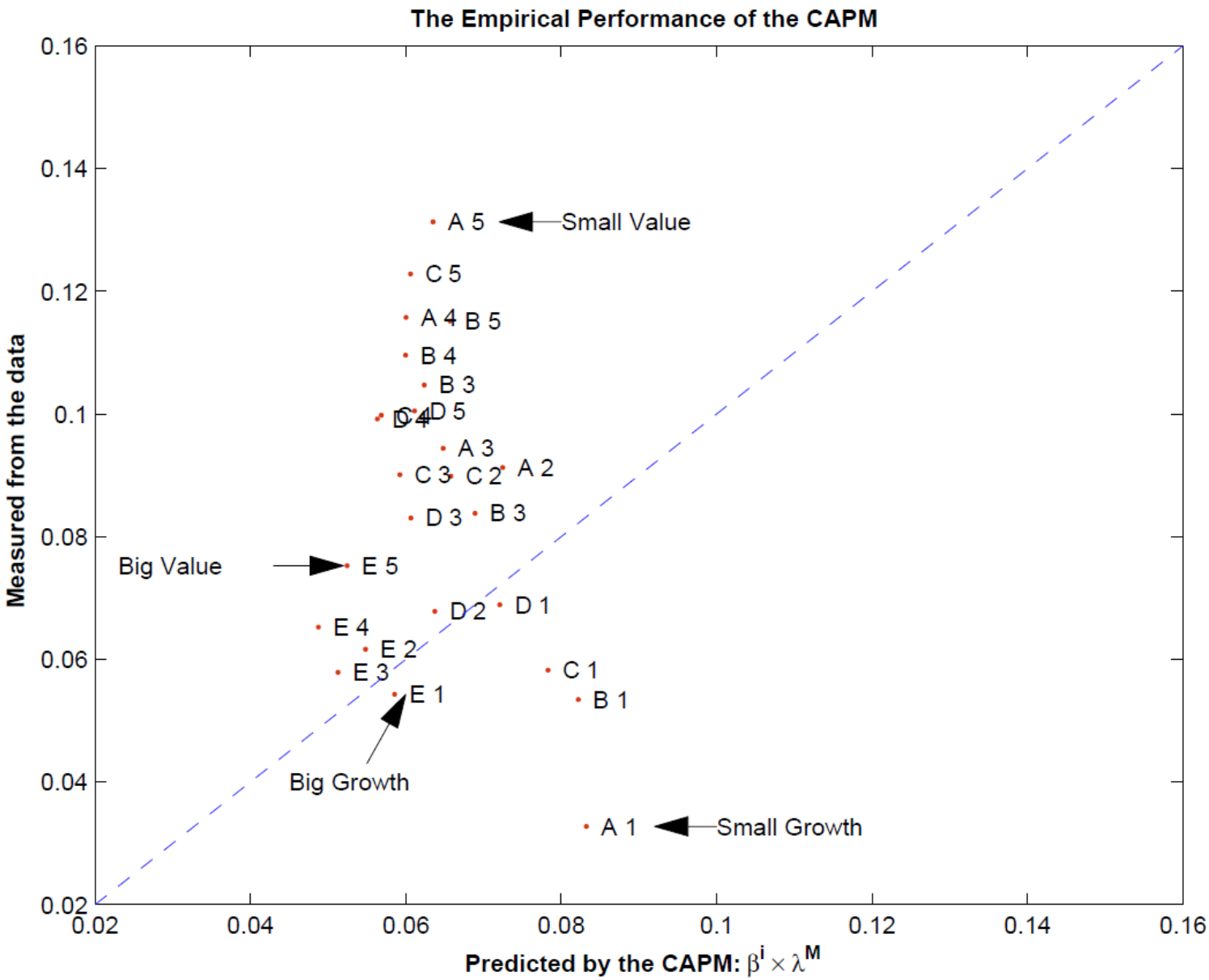
Book-to-Market as of July 2015

	1	2	3	4	5
A	0.15	0.31	0.49	0.72	1.36
B	0.14	0.32	0.49	0.71	1.18
C	0.13	0.30	0.48	0.73	1.33
D	0.15	0.31	0.49	0.72	1.11
E	0.14	0.30	0.51	0.78	1.10

Testing the CAPM using 25 Fama-French Portfolios

1. For each portfolio i, we perform regression to obtain an estimate for beta:
$$R_t^i - r_f = \alpha_i + \beta_i \left(R_t^M - r_f \right) + \epsilon_t^i$$
2. Estimate the market risk premium:
$$\lambda^M = \frac{1}{T} \sum_{t=1}^{T} \left(R_t^M - r_f \right)$$
3. The risk premium of portfolio i predicted by the CAPM:
$$\beta_i \lambda^M$$
4. Estimate the risk premium of portfolio i using realized returns:
$$\frac{1}{T} \sum_{t=1}^{T} \left(R_t^i - r_f \right)$$

The Empirical Performance of the CAPM



The CAPM Alphas of Fama-French 25 Portfolios

Annualized CAPM Alpha (in %) with t-stat's

	1	2	3	4	5
A	**-5.05** [-2.19]	1.88 [0.95]	2.95 [1.80]	**5.57** [3.46]	**6.78** [3.82]
B	-2.88 [-1.68]	1.49 [1.08]	**4.23** [3.27]	**4.96** [3.78]	**4.94** [3.06]
C	-2.01 [-1.41]	**2.40** [2.23]	**3.08** [2.83]	**4.29** [3.68]	**6.22** [4.31]
D	-0.32 [-0.30]	0.40 [0.45]	**2.24** [2.21]	**4.28** [3.96]	**3.94** [2.81]
E	-0.43 [-0.56]	0.68 [0.91]	0.66 [0.70]	1.65 [1.50]	2.28 [1.57]

Monthly data from January 1962 through July 2015.

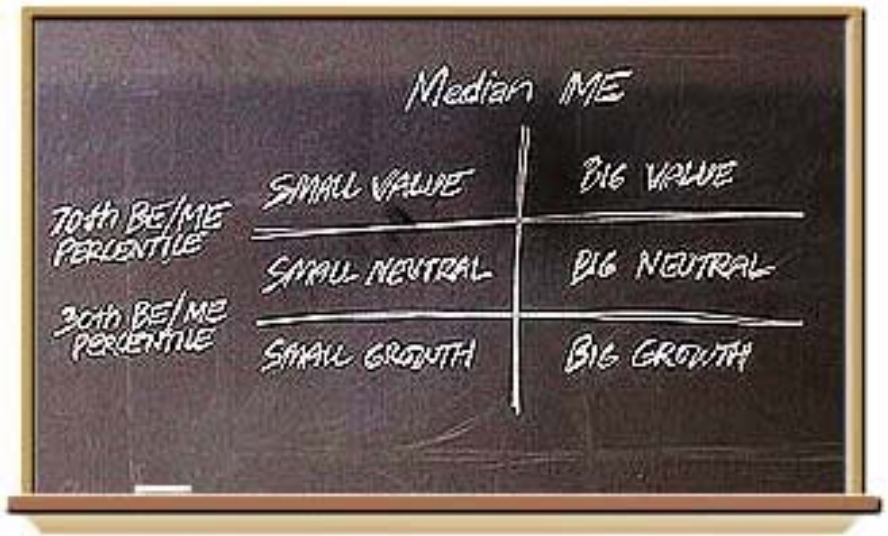
The Fama and French Factors

- Small Minus Big:

$$R^{\text{SMB}} = R^{\text{small}} - R^{\text{big}}$$

- High Minus Low:

$$R^{\text{HML}} = R^{\text{value}} - R^{\text{growth}}$$



R^{small}=1/3 (Small Value + Small Neutral + Small Growth)
R^{big} = 1/3 (Big Value + Big Neutral + Big Growth)
R^{value}=1/2 (Small Value + Big Value)
R^{growth}=1/2 (Small Growth + Big Growth)

The Fama-French Three-Factor Alpha and Beta's

$$R_t^i - r_f = \alpha_i + \beta_i \left(R_t^M - r_f \right) + s_i R_t^{\text{SMB}} + h_i R^{\text{HML}} + \epsilon_t^i$$

- β_i: the market beta.
- s_i: the size beta.
- h_i: the value beta.
- α_i: the Fama-French three-factor alpha.

Factor Exposures

$$R_t^i - r_f = \alpha_i + \beta_i \left(R_t^M - r_f \right) + s_i R_t^{\text{SMB}} + h_i R^{\text{HML}} + \epsilon_t^i$$

SMB beta s

	1	2	3	4	5
A	1.38	1.30	1.10	1.03	1.09
B	0.99	0.87	0.77	0.73	0.87
C	0.73	0.53	0.44	0.40	0.55
D	0.38	0.22	0.18	0.22	0.25
E	-0.24	-0.22	-0.23	-0.20	-0.08

HML beta h

1	2	3	4	5
-0.29	0.04	0.28	0.46	0.70
-0.39	0.13	0.39	0.56	0.81
-0.44	0.18	0.44	0.62	0.77
-0.42	0.21	0.45	0.57	0.81
-0.36	0.09	0.30	0.60	0.76

The Explanatory Power of the Factors

- One Factor:

$$R_t^i - r_f = \alpha_i + \beta_i \left(R_t^M - r_f \right) + \epsilon_t^i$$

- Three Factors:

$$R_t^i - r_f = \alpha_i + \beta_i \left(R_t^M - r_f \right) + s_i R_t^{\text{SMB}} + h_i R^{\text{HML}} + \epsilon_t^i$$

R2 (%) in one-factor

	1	2	3	4	5
A	63	64	67	64	62
B	75	76	75	73	68
C	80	83	79	75	70
D	85	87	82	78	71
E	89	88	80	72	63

R2 (%) in three-factor

	1	2	3	4	5
A	91	94	95	94	95
B	95	94	94	94	95
C	95	91	90	90	90
D	94	89	88	89	87
E	94	90	86	89	80

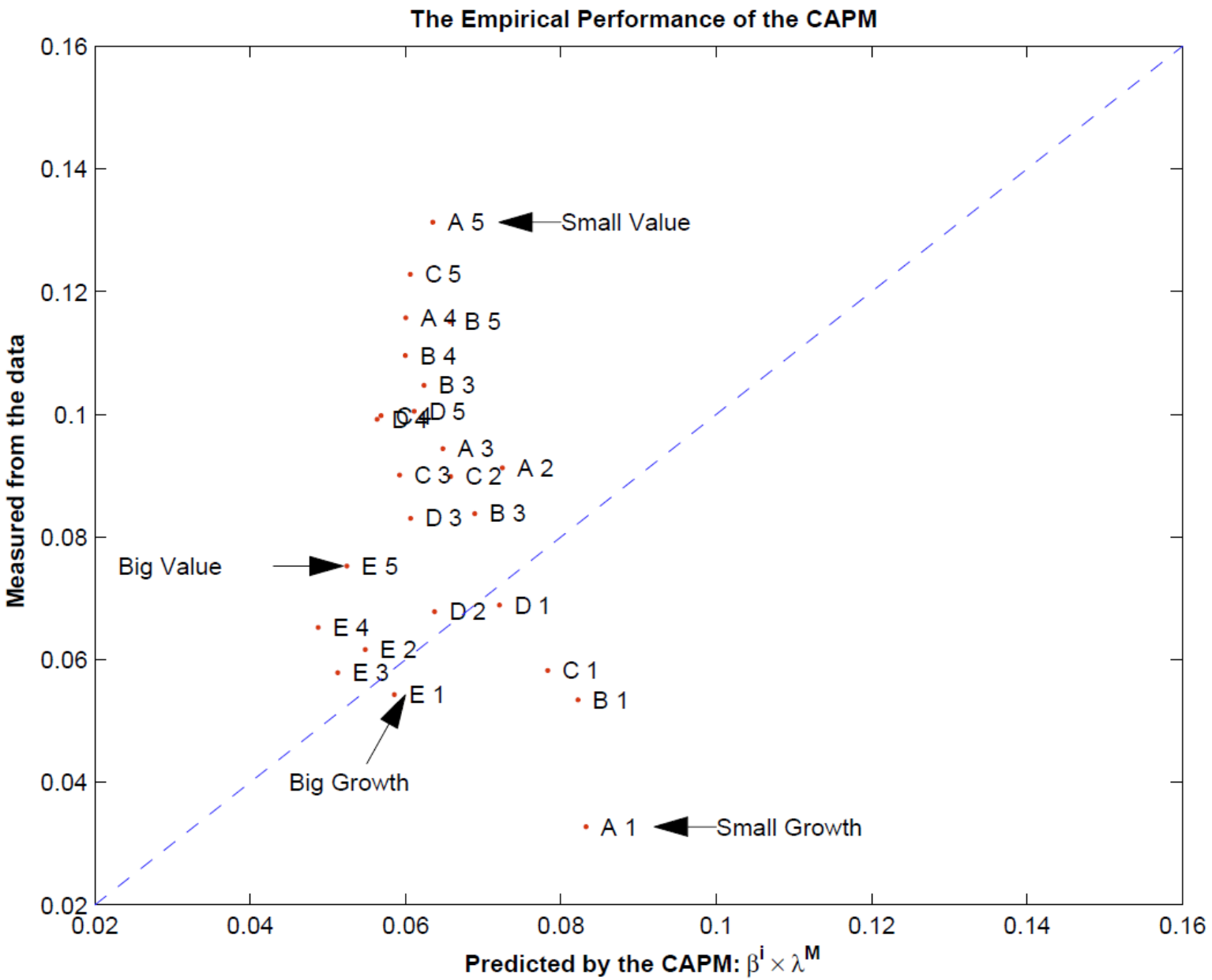
The Pricing Relation

$$E(R_t^i) - r_f = \beta_i \left(E\left(R_t^M\right) - r_f\right) + s_i E\left(R_t^{\text{SMB}}\right) + h_i E\left(R_t^{\text{HML}}\right)$$

	$E(R^M - r_f)$	$E(R^{\text{SMB}})$	$E(R^{\text{HML}})$
1962-2014	6.46% [2.64]	3.20% [1.68]	5.15% [2.78]
1927-2014	8.40% [3.81]	3.40% [2.28]	5.00% [3.33]

Fama-French 25 Portfolios and the Three-Factor Model

Fama-French 25 Portfolios and the CAPM



Peter Lynch and the Magellan Fund

$$R_t - R_t^f = \alpha + \beta \left(R_t^M - R_t^f \right) + s\, R_t^{SMB} + h\, R_t^{HML} + \epsilon_t$$

	Overall Period 76/6 – 98/12		Peter Lynch 76/6 – 90/5		Post-Lynch 90/6 – 98/12	
	estimate	s.e.	estimate	s.e.	estimate	s.e.
α	0.51	0.11	0.75	0.13	0.07	0.14
β	1.12	0.03	1.13	0.03	1.04	0.04
s	0.34	0.04	0.55	0.05	0.05	0.05
h	0.02	0.05	-0.01	0.06	0.005	0.06
R^2	0.91		0.94		0.90	

Warren Buffett and Berkshire Hathaway

Monthly returns of BRK.A from November 1976 through December 2008. The sample mean is 1.69% and the standard deviation is 7.29%.

alpha	1.36% [4.04]	1.11% [3.38]
Market beta	0.71 [9.50]	0.93 [11.60]
SMB beta		-0.26 [-2.42]
HML beta		0.58 [4.67]
R^2	19.10%	26.33%

Subsample Analysis

	First Half 197611-199212		Second Half 199301-200812	
alpha	1.83%	1.49%	0.84%	0.69%
	[3.69]	[2.99]	[1.91]	[1.74]
Market beta	0.93	1.04	0.46	0.70
	[8.70]	[8.38]	[4.53]	[7.16]
SMB beta		0.31		-0.57
		[1.54]		[-4.83]
HML beta		0.58		0.44
		[2.64]		[3.18]
R^2	28.28%	31.68%	9.72%	29.81%

Where Does Market Risk Premium Come from?

The market risk premium has its foundation in the CAPM:

- Investors are risk averse.
- Investors in aggregate cannot avoid holding the risk of the overall market.
- Negative beta stocks tend to do well when the market does badly.
- By contrast, positive beta stocks tend to do poorly when the market does badly.
- As a result, risk-averse investors are willing to pay a premium for negative beta stocks and demand a premium for positive beta stocks.
- The market risk premium is a reward for holding the market risk.

Where Do Size and Value Premiums Come from?

- Unlike the market portfolio, the Size and Value portfolios are empirically motivated.
- If we think of them as risk premiums, then we need to understand the *real, macroeconomic, aggregate, nondiversifiable* risk that is proxied by the SMB and HML portfolios.
- In particular, why are investors so concerned about holding stocks that do badly when the SMB and HML portfolios do badly, even though the market does not fall?
  - We know that small stocks are riskier because they have higher betas. The reward demanded for holding small stocks, however, is larger than what can be justified by the CAPM.
  - Similarly, after controlling for the CAPM, why do investors still consider value stocks risky and demand an additional premium?

Why Do We Care?

- The prevalent usage of size and value as "risk factors."
- Morningstar.com classifies stocks and mutual funds based on these factors.
- Index funds and ETFs are being offered based on the three factor model.
- Nevertheless, we know very little about the nature of these factors:
  - Are they risk factors?
  - If so, what risk?
  - If not, then what are they?
- Stock pickers: know your stock. Quant investors: know your risk.

Explaining the Size and Value "Anomalies"

- The Rational Camp
  - Value: proxies for the "distress risk."
  - Size: proxies for the illiquidity of the stock.
  - HML and SMB contain information above and beyond that in the market return for forecasting GDP growth.
  - Proxies for variables that forecast time-varying investment opportunities or time-varying risk aversion.
- The Behavioral Camp
  - Expectational errors made by investors
- The Critics
  - Survival bias
  - Data snooping

"A million monkeys banging on a million typewriters for a million years will eventually reproduce the entire works of Shakespeare."