The Investment CAPM

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and NBER

Keynote
The EFM Symposium on "Finance and Real Economy"
April 8, 2017, Xiamen

Theme

A new class of capital asset pricing models arises from the first principle of real investment for individual firms

Three defining characteristics of neoclassical economics:

- Rational expectations
- Consumers maximize utility, and firms maximize market value
- Markets clear

A representative household maximizes:

$$U(C_t) + \rho E_t[U(C_{t+1})]$$

subject to:

$$\begin{aligned} C_t + \sum_i P_{it} S_{it+1} &= \sum_i (P_{it} + D_{it}) S_{it} \\ C_{t+1} &= \sum_i (P_{it+1} + D_{it+1}) S_{it+1} \end{aligned}$$

The first principle of consumption:

$$E_t[M_{t+1} r^S_{it+1}] = 1 \quad \Rightarrow \quad \overbrace{E_t[r^S_{it+1}] - r_{ft} = \beta^M_{it} \lambda_{Mt}}^{\textbf{The Consumption CAPM}}$$

An individual firm i maximizes:

$$P_{it} + D_{it} \equiv \max_{\{I_{it}\}} \left[\Pi_{it} K_{it} - I_{it} - \frac{a}{2} \left(\frac{I_{it}}{K_{it}} \right)^2 K_{it} + E_t \left[M_{t+1} \Pi_{it+1} K_{it+1} \right] \right]$$

The first principle of investment:

$$1 = E_t \left[M_{t+1} \frac{\Pi_{it+1}}{1 + a(I_{it}/K_{it})} \right]$$

$$\frac{P_{it+1} + D_{it+1}}{P_{it}} \equiv \underbrace{r^S_{it+1} = \frac{\Pi_{it+1}}{1 + a(I_{it}/K_{it})}}_{\textbf{The Investment CAPM}}$$

The investment CAPM: Cross-sectionally varying expected returns

The consumption CAPM and the investment CAPM deliver identical expected returns in general equilibrium:

$$r_{ft} + \beta_{it}^{M} \lambda_{Mt} = E_t[r_{it+1}^{S}] = \frac{E_t[\Pi_{it+1}]}{1 + a(I_{it}/K_{it})}$$

- Consumption: Covariances are sufficient statistics of $E_t[r_{it+1}^{S}]$
- Investment: Characteristics are sufficient statistics of $E_t[r_{it+1}^{S}]$

Outline

1. The q-Factor Model

2. The Multiperiod Investment CAPM

3. The Big Picture
   - A Historical Perspective
   - Complementarity with the Consumption CAPM
   - The Aggregation Critique
   - An Efficient Markets Counterrevolution
   - Revisiting the Joint-Hypothesis Problem

Outline

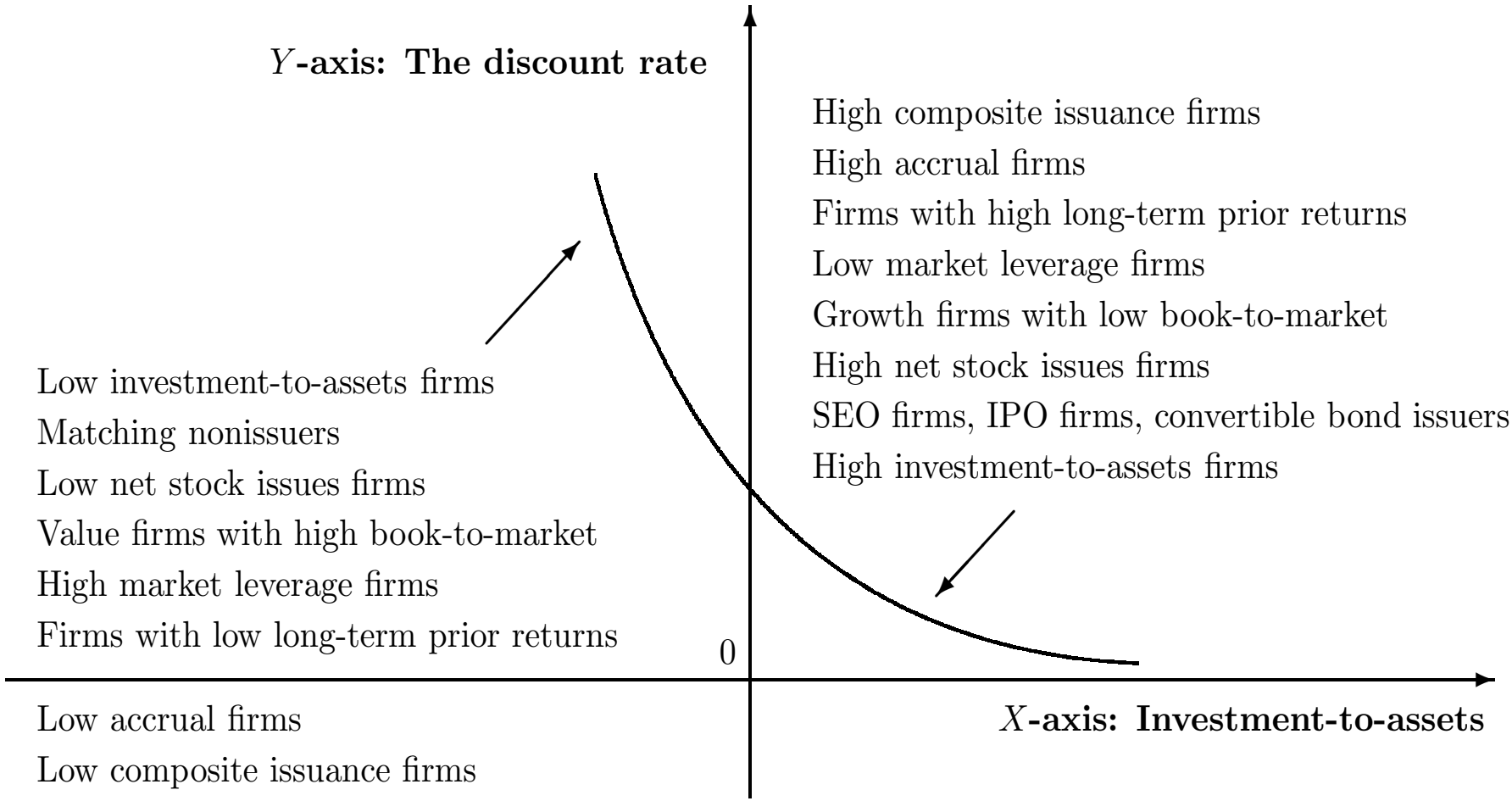
The q-Factor Model

Hou, Xue, and Zhang (2015, RFS)

$$E[r_{it} - r_{ft}] = \beta^i_{\text{MKT}} E[\text{MKT}_t] + \beta^i_{\text{ME}} E[r_{\text{ME},t}] + \beta^i_{\text{I/A}} E[r_{\text{I/A},t}] + \beta^i_{\text{ROE}} E[r_{\text{ROE},t}]$$

- MKT_t, $r_{\text{ME},t}$, $r_{\text{I/A},t}$, and $r_{\text{ROE},t}$ are the market, size, investment, and profitability (return on equity, ROE) factors, respectively
- β^i_{MKT}, β^i_{ME}, $\beta^i_{\text{I/A}}$, and β^i_{ROE} are factor loadings

The q-factor model largely summarizes the cross section of average stock returns, capturing most (but not all) anomalies that plague the Fama-French 3-factor model and Carhart 4-factor model


Y-axis: The discount rate
High composite issuance firms
High accrual firms
Firms with high long-term prior returns
Low market leverage firms
Growth firms with low book-to-market
High net stock issues firms
SEO firms, IPO firms, convertible bond issuers
High investment-to-assets firms
Low investment-to-assets firms
Matching nonissuers
Low net stock issues firms
Value firms with high book-to-market
High market leverage firms
Firms with low long-term prior returns
0
Low accrual firms
Low composite issuance firms
X-axis: Investment-to-assets

High ROE relative to low investment means high discount rates:

- Suppose the discount rates were low
- Combined with high ROE, low discount rates would imply high net present values of new projects and high investment
- So discount rates must be high to counteract high ROE to induce low investment

Price and earnings momentum winners and less financially distressed firms have higher ROE and earn higher expected returns

The Fama-French 5-factor model:

$$E[r_{it} - r_{ft}] = b_i\, E[\mathrm{MKT}_t] + s_i\, E[\mathrm{SMB}_t] + h_i\, E[\mathrm{HML}_t] + r_i\, E[\mathrm{RMW}_t] + c_i\, E[\mathrm{CMA}_t]$$

- $\mathrm{MKT}_t, \mathrm{SMB}_t, \mathrm{HML}_t, \mathrm{RMW}_t$, and CMA_t are the market, size, value, profitability, and investment factors, respectively
- b_i, s_i, h_i, r_i, and c_i are factor loadings

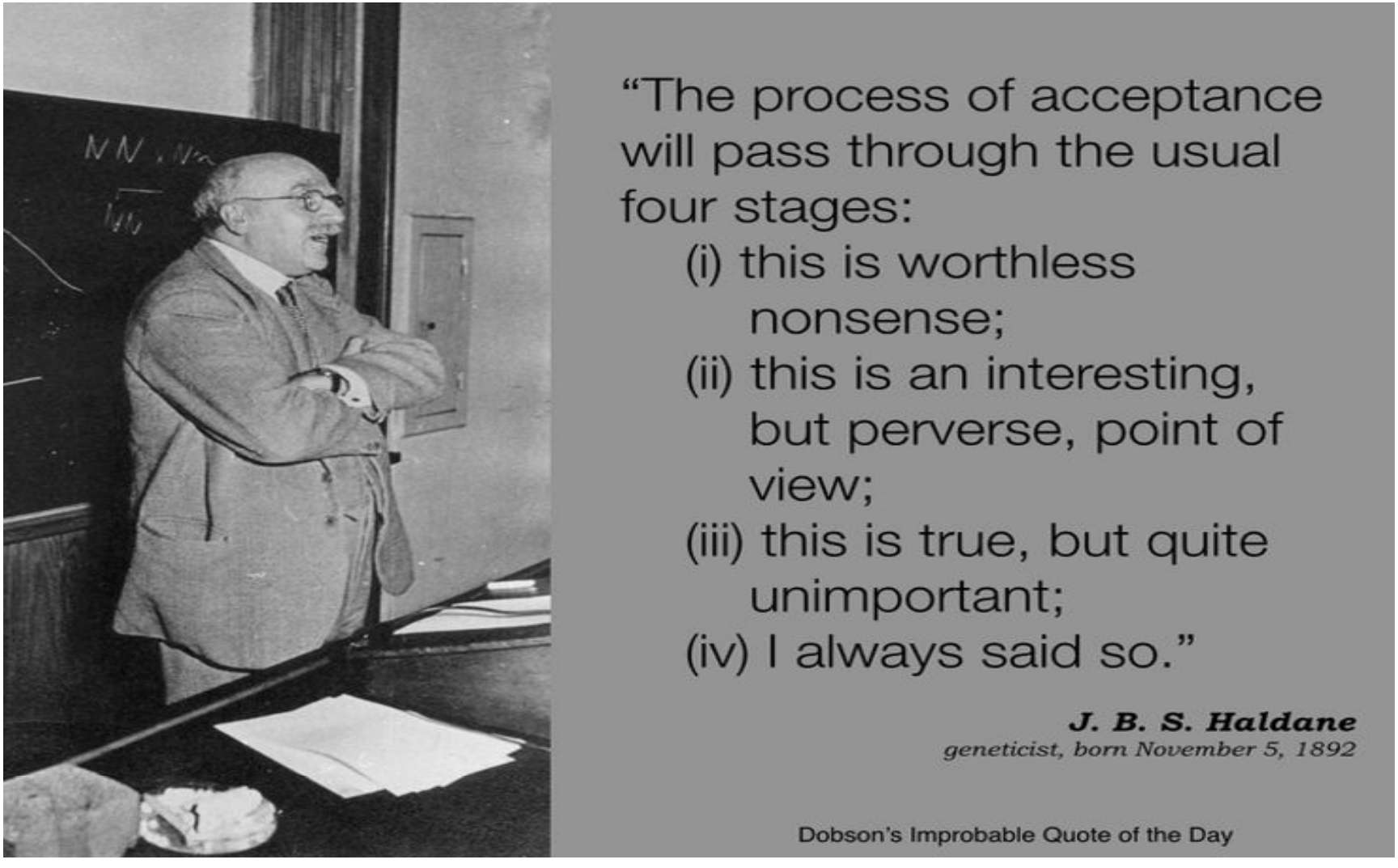
The q-Factor Model

Predating the Fama-French 5-factor model by 3–6 years

Neoclassical factors	July 2007
An equilibrium three-factor model	January 2009
Production-based factors	April 2009
A better three-factor model that explains more anomalies	June 2009
An alternative three-factor model	April 2010, April 2011
Digesting anomalies: An investment approach	October 2012, August 2014
Fama and French (2013): A four-factor model for the size, value, and profitability patterns in stock returns	June 2013
Fama and French (2014): A five-factor asset pricing model	November 2013, September 2014

The q-Factor Model

A quote from John B. S. Haldane



The q-Factor Model

Hou, Xue, and Zhang (2016): Factor spanning tests, 1/1967–12/2014

	m	α_C	β_{MKT}	β_{SMB}	β_{HML}	β_{UMD}
r_{ME}	0.32	0.01	0.01	0.97	0.17	0.03
	(2.42)	(0.25)	(1.08)	(67.08)	(7.21)	(1.87)
$r_{I/A}$	0.43	0.29	−0.06	−0.04	0.41	0.05
	(5.08)	(4.57)	(−4.51)	(−1.88)	(13.36)	(1.93)
r_{ROE}	0.56	0.51	−0.04	−0.30	−0.12	0.27
	(5.24)	(5.58)	(−1.39)	(−4.31)	(−1.79)	(6.19)
	a	b	s	h	r	c
r_{ME}	0.05	0.00	0.98	0.02	−0.01	0.04
	(1.39)	(0.39)	(68.34)	(1.14)	(−0.21)	(1.19)
$r_{I/A}$	0.12	0.01	−0.05	0.04	0.07	0.82
	(3.35)	(0.73)	(−2.86)	(1.60)	(2.77)	(26.52)
r_{ROE}	0.45	−0.04	−0.11	−0.24	0.75	0.13
	(5.60)	(−1.45)	(−2.69)	(−3.54)	(13.46)	(1.34)

The q-Factor Model

Factor spanning tests, 1/1967–12/2014

	m	α_C	β_{MKT}	β_{SMB}	β_{HML}	β_{UMD}
SMB	0.26	−0.02	0.00	1.00	0.13	0.00
	(1.92)	(−1.24)	(0.96)	(89.87)	(8.07)	(0.11)
HML	0.36	−0.00	0.00	−0.00	1.00	−0.00
	(2.57)	(−1.79)	(1.79)	(−1.69)	(13282.85)	(−0.87)
RMW	0.27	0.33	−0.04	−0.28	−0.00	0.04
	(2.58)	(3.31)	(−1.32)	(−3.20)	(−0.03)	(0.81)
CMA	0.34	0.19	−0.09	0.03	0.46	0.04
	(3.63)	(2.83)	(−4.42)	(0.86)	(13.52)	(1.51)

The q-Factor Model

Factor spanning tests, 1/1967–12/2014

	α_q	β_{MKT}	β_{ME}	$\beta_{\text{I/A}}$	β_{ROE}
SMB	0.05	−0.00	0.94	−0.09	−0.10
	(1.48)	(−0.17)	(62.40)	(−4.91)	(−5.94)
HML	0.03	−0.05	0.00	1.03	−0.17
	(0.28)	(−1.33)	(0.03)	(11.72)	(−2.17)
RMW	0.04	−0.03	−0.12	−0.03	0.53
	(0.42)	(−0.99)	(−1.78)	(−0.35)	(8.59)
CMA	0.01	−0.05	0.04	0.94	−0.11
	(0.32)	(−3.63)	(1.68)	(35.26)	(−3.95)

Outline

The Multiperiod Investment CAPM

Liu, Whited, and Zhang (2009), building on Cochrane (1991)

$E_t[M_{t+1} r^I_{it+1}] = 1$, in which r^I_{it+1} is the investment return:

$$r^I_{it+1} \equiv \frac{\overbrace{\left[\underbrace{(1-\tau_{t+1})\left[\kappa \frac{Y_{it+1}}{K_{it+1}} + \frac{a}{2}\left(\frac{I_{it+1}}{K_{it+1}}\right)^2\right]}_{\text{Marginal product plus economy of scale (net of taxes)}} + \tau_{t+1}\delta_{it+1} + \underbrace{(1-\delta_{it+1})\left[1 + (1-\tau_{t+1})a\left(\frac{I_{it+1}}{K_{it+1}}\right)\right]}_{\text{Expected continuation value}}\right]}^{\text{Marginal benefit of investment at time } t+1}}{\underbrace{1 + (1-\tau_t)a\left(\frac{I_{it}}{K_{it}}\right)}_{\text{Marginal cost of investment at time } t}}$$

$E_t\left[M_{t+1} r^{Ba}_{it+1}\right] = 1$, in which $r^{Ba}_{it+1} = (1-\tau_{t+1}) r^{B}_{it+1} + \tau_{t+1}$

r^{I}_{it+1} = the weighted average of stock and after-tax bond returns:

$$r^{I}_{it+1} = w_{it} r^{Ba}_{it+1} + (1-w_{it}) r^{S}_{it+1} \;\Rightarrow\; r^{S}_{it+1} = r^{Iw}_{it+1} \equiv \frac{r^{I}_{it+1} - w_{it} r^{Ba}_{it+1}}{1-w_{it}}$$

in which w_{it} is the market leverage

Expected stock returns = expected levered investment returns?

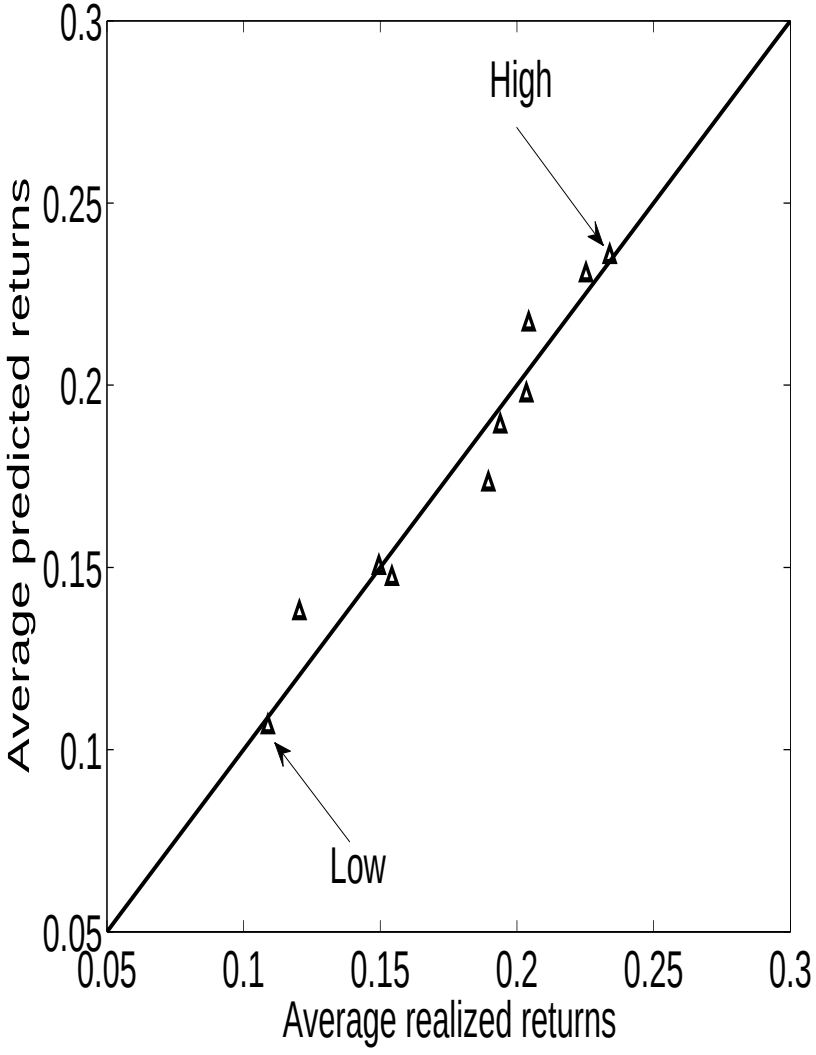
$$E\left[r^{S}_{it+1} - \underbrace{\frac{r^{I}_{it+1}(a,\kappa) - w_{it} r^{Ba}_{it+1}}{1 - w_{it}}}_{r^{lw}_{it+1}} \right] = 0,$$

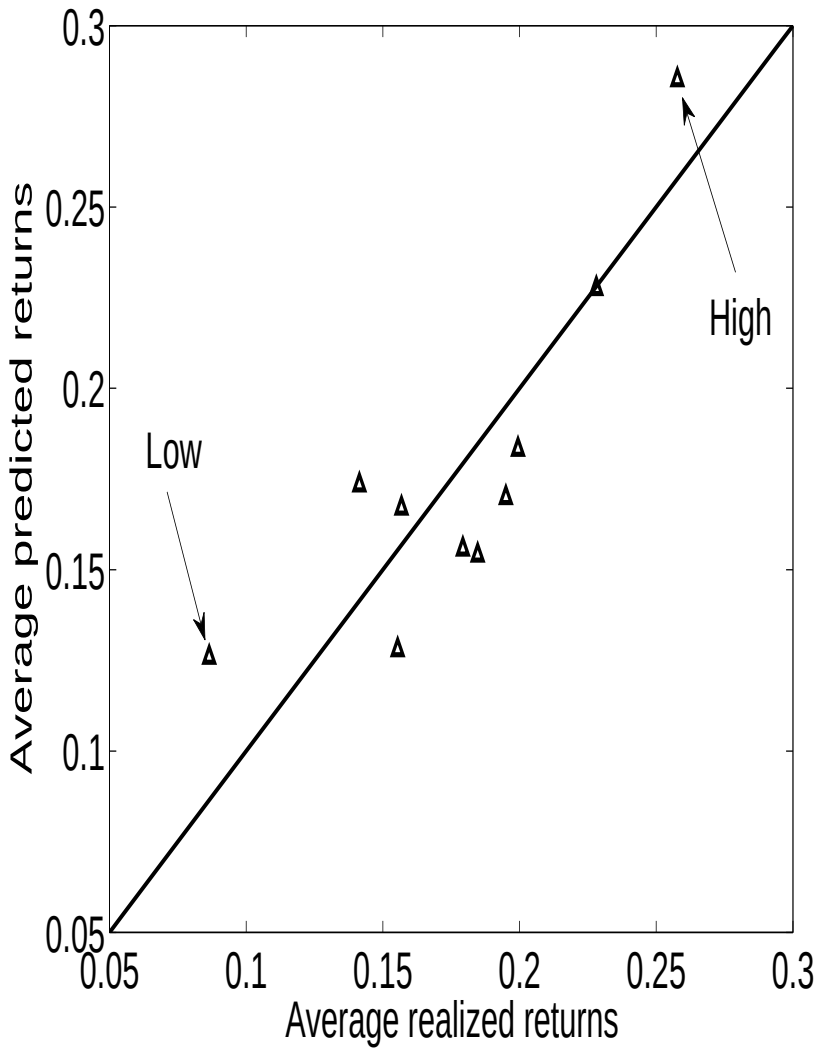
with the model error, α^{i}_{q}, as the sample average of the difference

The model fits well across price and earnings momentum and B/M deciles, explains short-lived nature of momentum (Liu and Zhang 2014), but cannot explain value and momentum simultaneously

The Multiperiod Investment CAPM

Estimation results, ten SUE and B/M deciles

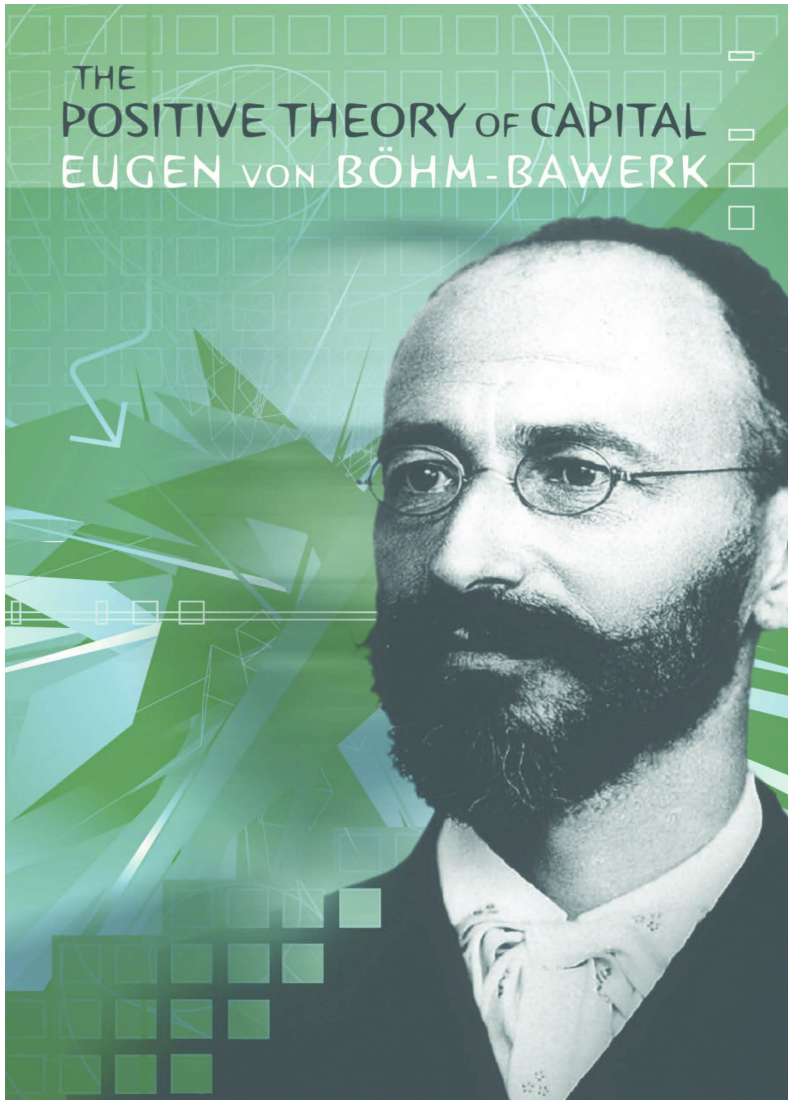




Outline

The Big Picture

A historical perspective: Böhm-Bawert (1891, The positive theory of capital)



1st generation Austrian School economists, with Carl Menger and Friedrich von Wieser

Why the interest rate > 0?

1. The falling marginal utility of income over time
2. Consumers tend to underestimate future needs
3. "Roundabout" production: Production per worker rises with the production length

"It is an elementary fact of experience that methods of production which take time are more productive. That is to say, given the same quantity of productive instruments, the lengthier the productive method employed the greater the quantity of products that can be obtained (p. 260, my emphasis)."

A positive interest rate offsets benefits from a long production period, giving rise to a negative interest rate-investment relation

The Big Picture

Fisher (1930, The Theory of Interest)

THE THEORY
OF INTEREST

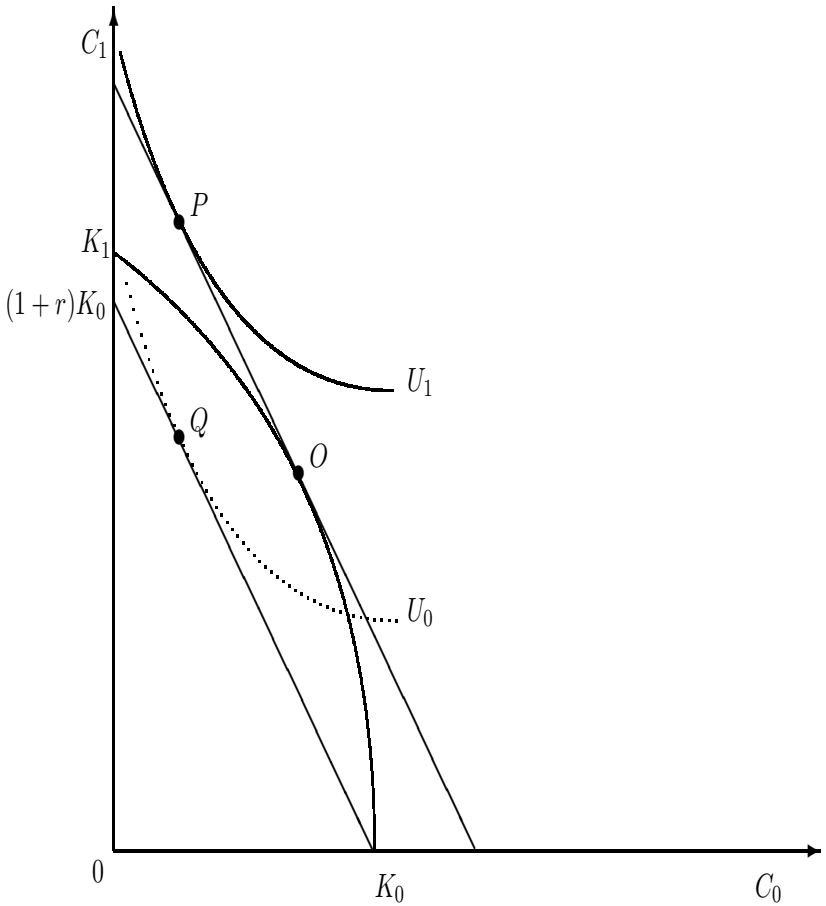
AS DETERMINED BY IMPATIENCE TO SPEND INCOME
AND OPPORTUNITY TO INVEST IT

BY

IRVING FISHER

[1930]

AUGUSTUS M. KELLEY • PUBLISHERS
CLIFTON 1974



The first general equilibrium model with both intertemporal consumption and production

Fisher Separation Theorem: Maximizing the present value of free cash flows as the objective of the firm, without any dependence on shareholder preferences

The Big Picture

Jack Hirshleifer's (1958, 1965, 1966, 1970) seminal work

Revives and extends Fisher's (1930) general equilibrium analysis to uncertainty

A pioneer in applying the Arrow-Debreu state-preference approach in finance, including capital budgeting and capital structure

The Big Picture

Cochrane (1991)

"The logic of the production-based model is exactly analogous [to that of the consumption-based model]. It ties asset returns to marginal rates of *transformation*, which are inferred from data on investment (and potentially, output and other production variables) through a *production* function. It is derived from the *producer's* first order conditions for optimal intertemporal *investment* demand. Its testable content is a restriction on the joint stochastic process of *investment* (and/or other production variables) and asset returns. This restriction can also be interpreted in two ways. If we fix the return process, it is a version of the q theory of investment. If we fix the investment process, it is a production-based asset pricing model. For example, the production-based asset pricing model can make statements like 'expected returns are high because (a function of) *investment* growth is high' (p. 210, original emphasis)."

The Big Picture

Modern asset pricing thoroughly dominated by the consumption CAPM

In hindsight, thanks to Arrow-Debreu, asset pricing theory is just the standard price theory extended to uncertainty and over time

- Fisher (1930) did the extension over time; Debreu (1959), Arrow (1964), and J. Hirshleifer (1970) did uncertainty

Asset pricing theorists, led by Markowitz (1952), started with investors' problem under uncertainty, and never looked back

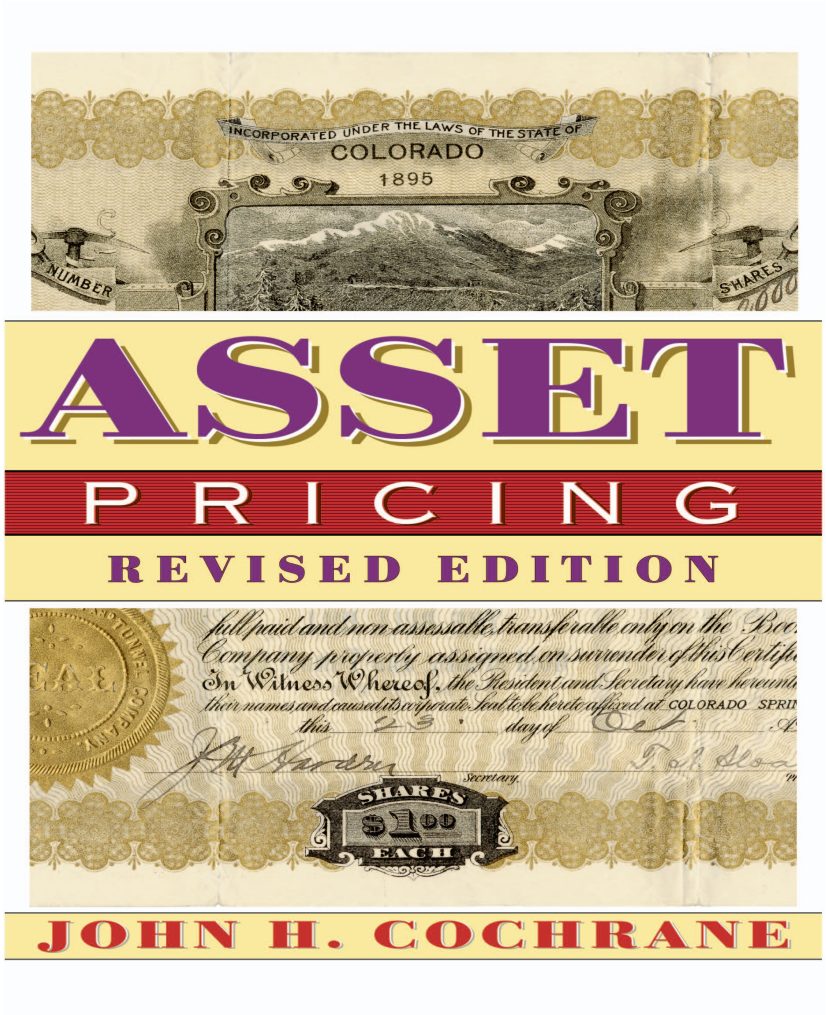
- Markowitz (1952); Roy (1952)
- Treynor (1962); Sharpe (1964); Lintner (1965); Mossin (1966)
- Merton (1973); Long (1974)

Empirical work reinforced the investors-centered CAPM, by favoring the mean variance approach over the state-preference approach

- Fama and Miller (1972); Fama (1976)

The Big Picture

Böhm-Bawert's, Fisher's, and J. Hirshleifer's investment opportunity approach to the interest rate/discount rate all disappeared from modern asset pricing



Rubinstein (1976); Lucas (1978); Breeden (1979)

Hansen and Singleton (1982); Breeden, Gibbons, and Litzenberger (1989)

Cochrane (2005): "*All* asset pricing models amount to alternative ways of connecting the stochastic discount factor to data (p. 7, original emphasis)."

Bodie, Kane, and Marcus; Berk and DeMarzo

The Big Picture

Inspired by Cochrane (1991), I recognize in Zhang (2005a) that the neoclassical q-theory of investment allows a different reduction of the general equilibrium problem

NBER WORKING PAPER SERIES

ANOMALIES

Lu Zhang

Working Paper 11322
http://www.nber.org/papers/w11322

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
May 2005

I was intrigued by anomalies but disturbed by behavioral finance

The investment CAPM expresses expected returns in terms of firm characteristics without any dependence on shareholder preferences, the latest incarnation of Fisher Separation Theorem

The first principle of consumption and the first principle of investment are two key optimality conditions in general equilibrium

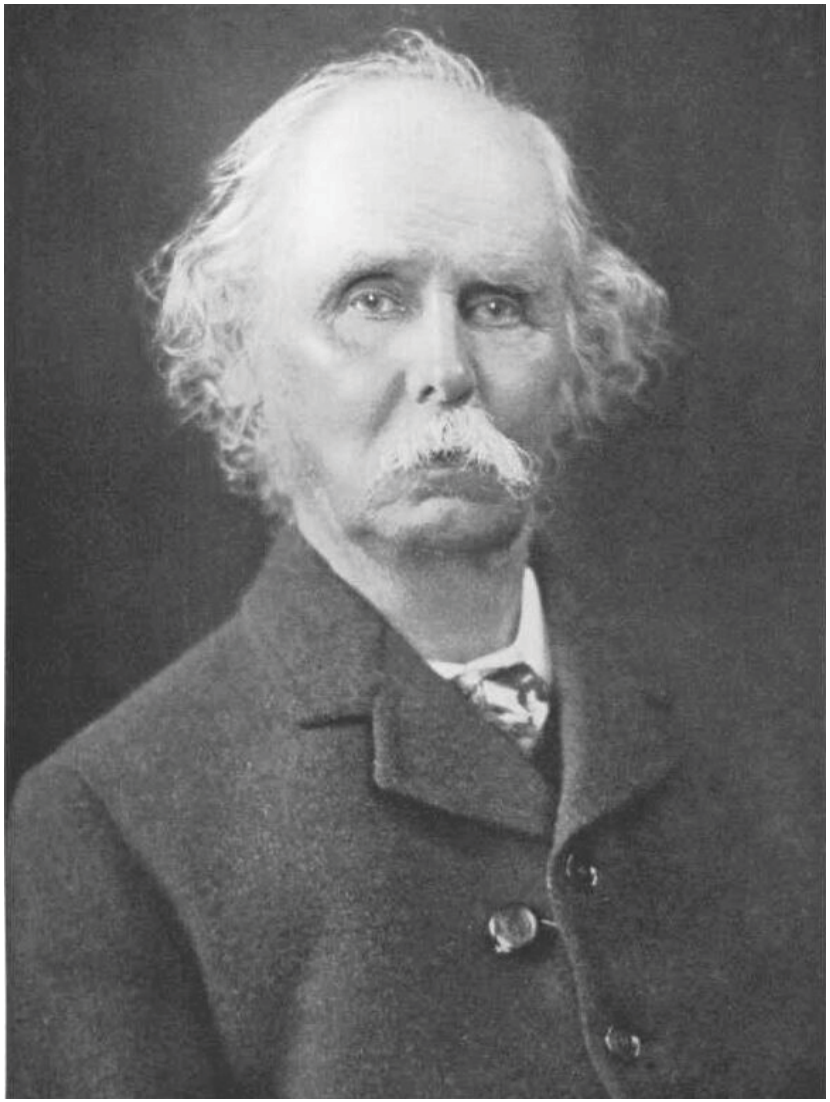
- The investment CAPM as "causal" as the consumption CAPM

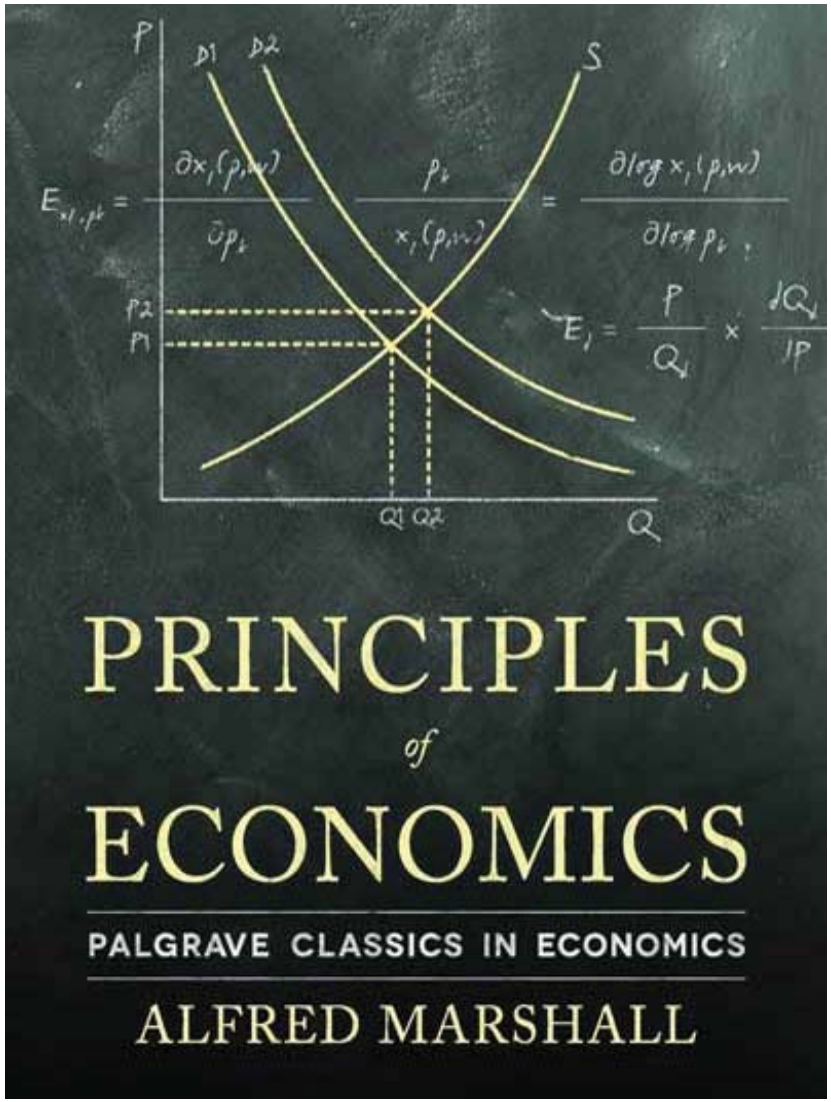
Consumption risks, expected returns, and firm characteristics are all endogenously determined by a system of simultaneous equations, with no causality running in any direction

The consumption CAPM predicts time-varying risk premiums; the investment CAPM cross-sectionally varying risk premiums

The Big Picture

Marshall's "scissors:" Marshall (1890, Principles of Economics)





Ricardo and Mill: Costs of production determine value, but Jevons, Menger, and Walras: Marginal utility determines value

- The water versus diamond example

"We might as reasonably dispute whether it is the upper or under blade of a pair of scissors that cuts a piece of paper, as whether value is governed by utility or costs of production. It is true that when one blade is held still, and the cutting is affected by moving the other, we may say with careless brevity that the cutting is done by the second; but the statement is not strictly accurate, and is to be excused only so long as it claims to be merely a popular and not a strictly scientific account of what happens (Marshall 1890 [1961, 9th edition, p. 348], my emphasis)."

If the investment CAPM and the consumption CAPM are complementary, why does the former perform better in the data?

What explains the empirical failure of the consumption CAPM?

Most consumption CAPM studies assume a representative investor

The Sonnenschein-Mantel-Debreu theorem in general equilibrium theory: The aggregate excess demand function is not restricted by the standard rationality assumption on individual demands

The Big Picture

Kirman's (1992) four objections to a representative investor

- Individual maximization does not imply collective rationality; collective maximization does not imply individual rationality
- The response of the representative to a parameter change might not be the same as the aggregate response of individuals
- It is possible for the representative to exhibit preference orderings that are opposite to all the individuals'.
- The aggregate behavior of rational individuals might exhibit complicated dynamics, and imposing these dynamics on one individual can lead to unnatural characteristics of the individual

Is it possible to assign rational preferences to "the representative voter" in the U.S. that picked Trump after Obama?

Insisting on assigning would yield highly irrational preferences

Analogously, assigning irrational preferences on the representative investor is not particularly illuminating

The Big Picture

The consumption CAPM (with a representative investor) is not testable

The failure of the consumption CAPM might have nothing to say about individual rationality

The consumption CAPM studies with heterogeneous consumers face severe data limitations (Ludvigson 2013)

The investment CAPM, derived for individual firms, is relatively immune to the aggregation critique

The investment CAPM offers a powerful defense of efficient markets

"Research in experimental psychology suggests that, in violation of Bayes' rule, most people tend to 'overreact' to unexpected and dramatic news events. This study of market efficiency investigates whether such behavior affects stock prices. The empirical evidence, based on CRSP monthly return data, is consistent with the overreaction hypothesis. Substantial weak form market inefficiencies are discovered (De Bondt-Thaler 1985, p. 793)."

"[It] is possible that the market underreacts to information about their short-term prospects of firms but overreacts to information about their long-term prospects. This is plausible given that the nature of the information available about a firm's short-term prospects, such as earnings forecasts, is different from the nature of the more ambiguous information that is used by investors to assess a firm's longer-term prospects (Jegadeesh-Titman 1993, p. 90)."

"While the behavior of the aggregate stock market is not easy to understand from the rational point of view, promising rational models have nonetheless been developed and can be tested against behavioral alternatives. Empirical studies of the behavior of *individual* stocks have unearthed a set of facts which is altogether more frustrating for the rational paradigm. Many of these facts are about the *cross-section* of average returns: they document that one group of stocks earn higher average returns than another. These facts have come to be known as 'anomalies' because they cannot be explained by the simplest and most intuitive model of risk and return in the financial economist's toolkit, the Capital Asset Pricing Model, or CAPM (Barberis-Thaler 2003, p. 1087, original emphasis)."

The argument for inefficient markets based on the failure of the CAPM represents, to paraphrase Shiller (1984), "one of the most remarkable errors in the history of economic thought"

The Big Picture

Evidence rejects the consumption CAPM, but (largely) conforms to the investment CAPM

Why are investors more psychologically biased than managers?

Why are managers of sophisticated institutional investors more biased than managers of nonfinancial firms?

Why would individuals exhibit biases at home picking portfolio, but switch them off readily at work picking investment projects?

More plausible: Aggregation renders the consumption CAPM untestable, but the investment CAPM is immune to this problem

The investment effect is stronger in developed than emerging markets, as shown in Titman, Wei, and Xie (2013)

The Big Picture

Griffin, Ji, and Martin (2003) and Chui, Titman, and Wei (2010): Momentum stronger in developed than emerging markets

Panel A: Developed markets			Panel B: Emerging markets		
	WML	t		WML	t
Australia	1.08	4.76	Argentina	0.08	0.12
Austria	0.63	2.70	Bangladesh	1.68	2.75
Belgium	0.89	5.50	Brazil	0.46	0.96
Canada	1.35	6.29	Chile	0.99	3.60
Denmark	0.96	4.29	China	0.26	0.92
Finland	0.98	2.62	Greece	0.59	1.49
France	0.94	4.68	India	1.14	2.91
Germany	0.99	4.41	Indonesia	0.14	0.30
Hong Kong	0.77	3.18	Israel	0.32	1.19
Ireland	0.88	3.06	Korea	−0.34	−0.81
Italy	0.90	4.47	Malaysia	0.10	0.26
Japan	−0.04	−0.18	Mexico	0.69	2.00
Netherlands	0.83	4.40	Pakistan	0.46	1.05
New Zealand	1.58	5.01	Philippines	0.37	0.68
Norway	1.05	3.77	Poland	1.76	3.33
Singapore	0.14	0.47	Portugal	0.31	0.93
Spain	0.63	2.24	South Africa	0.94	3.29
Sweden	0.71	2.27	Taiwan	−0.20	−0.48
Switzerland	0.82	4.39	Thailand	0.48	1.10
United Kingdom	1.13	7.08	Turkey	−0.41	−0.96
United States	0.79	3.44			
Average	0.86		Average	0.49	

The Big Picture

Cross-country variation of anomalies, explanations?

Why are U.S. investors more biased than Chinese investors? Why does the U.S. have higher limits to arbitrage than China?

Behavioral finance relies on dysfunctional, inefficient markets for biases and limits to arbitrage to work, contradicting the evidence

The investment CAPM relies on well functioning, efficient markets for its mechanisms to work, consistent with the evidence

The Big Picture

A tribute to Fama and French (1993)

The three-factor model has served its historical purpose, admirably.

Filled the vacuum left by the CAPM after its rejection in Fama and French (1992) as the workhorse model in efficient markets

Alas, ad hoc, vulnerable to the data mining critique

The relative distress interpretation refuted by the distress anomaly

The risk factors interpretation in the ICAPM-APT unconvincing

Characteristics-based factor models as linear approximations to the investment CAPM

The investment CAPM predicts all kinds of relations between characteristics and expected returns:

- Characteristics forecasting returns not necessarily mispricing
- No need to insist on risk factors to defend efficient markets

Time series and cross-sectional regressions are two different ways of summarizing correlations, largely equivalent in economic terms

"Most of the available work is based only on the assumption that the conditions of market equilibrium can (somehow) be stated in terms of expected returns. In general terms, like the two parameter model such theories would posit that conditional on some relevant information set, the equilibrium expected return on a security is a function of its 'risk.' And different theories would differ primarily in how 'risk' is defined (Fama 1970, p. 384, my emphasis)."

Only describes the consumption CAPM

Does not apply to the investment CAPM, in which characteristics are sufficient statistics for expected returns, and after characteristics are controlled for, risks should not matter

Neither risks nor characteristics "determine" expected returns

Risks as driving forces: A relic and illusion from the CAPM

"[The] really pressing problems, e.g., a cure for cancer and the design of a lasting peace, are often not puzzles at all, largely because they may not have any solution. Consider the jigsaw puzzle whose pieces are selected at random from each of two different puzzle boxes. Since that problem is likely to defy (though it might not) even the most ingenious of men, it cannot serve as a test of skill. In solution in any usual sense, it is not a puzzle at all. Though intrinsic value is no criterion for a puzzle, the assured existence of a solution is (Kuhn 1962, p. 36–37, my emphasis)."

Conclusion

Like any prices, asset prices are equilibrated by supply and demand

The consumption CAPM and behavioral finance, both of which are demand-based, cannot possibly be the whole story

Anomalies doom the consumption CAPM, but behavioral finance is not the answer; the investment CAPM as a new paradigm

Make Finance Great Again!