15.415x Foundations of Modern Finance 2

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CAPM and Beyond

CAPM: implementation issues

market portfolio: portfolio held by the investors. there is no reason to limit it to just equities
price of equity: high frequency, precisely measured
other asset (corporate bonds, real estate): less liquid, low frequency. ETF: liquidize the illiquid

- What are the implications of the benchmark used as Market portfolio in CAPM?
  - A multi-asset benchmark?
  - Geographic focus of this benchmark?
- Estimation of parameters:

CAPM is used to predict future, look forward by using spot rate. do estimate by using historical rates

  - Risk-free rate (historical rates or spot rates? maturities?)

CAPM is one-period static model, not multi-period dynamic model, long/short horizon predict: long/short-term interest rate

  - Market risk premium (historical? periodicity? implicit MRP?)= rmkt - rf

use implied risk premium from Gordon Growth Model (estimate of growth rates of cash flows), not historical average

  - I would like to know what are the possible approaches to increase the accuracy of the market premium (market excess return)? Since the risk premium could include volatile risk free rates and is relying on historical returns that are backwards looking.

- more samples
- cross section (other market)
- use implied number

CAPM: limitations

- How is the CAPM model used in practice, and what are the practical limitations of using CAPM?

  static model
  strong assumption
  more reliable to liquid and broadly held security

- How is CAPM applied to firms at an early stage?

  project are compared to comparable-risk project, but young firm may not be able to implement the project to the end

- Does CAPM work for financial markets outside of the US? What are the features of such markets (if any) where CAPM breaks down?

  CAPM assumptions in emerging market fail because of market friction and constrain, less liquidity, limited participation

- What additions one should consider to apply CAPM or APT in developing countries for capital budgeting purposes?

- My understanding is that the CAPM is widely adopted because of its effectiveness and "easy implementation". With finance becoming more and more data driven, will there be other models that could compete with the CAPM in the near future? What are the latest in this area?

  long horizon: traditional tools

CAPM vs APT

- Would like to hear more detail about CAPM vs. APT and how it fits in today's financial firms?
- How is CAPM applied to firms at an early stage? liquid factor, credit factor
- Does CAPM work for financial markets outside of the US? What are the features of such markets (if any) where CAPM breaks down?
- Do radical changes in money supply have implications for CAPM or is it orthogonal because the entire market is exposed to any effects?

  monetary policy shocks can be priced directly via a second factor, or through exposure to the market factor

CAPM vs APT

- Hi, in this video, from 16:57, https://youtu.be/GwyHCub7u4w?t=1017, Professor Andrew Lo derived CAPM from single-factor APT based on Stephen A. Ross's paper. In this derivation, there are not assumptions that we have made in the derivation of CAPM, it's purely based on the arbitrage argument. Then why do we say that CAPM is an equilibrium model and not that it's a special case of multifactor APT? Do Equilibrium and Arbitrage Conditions coincide in this case? Do they differ in general?
- Given that it is MIT, why was Intertemporal Capital Asset Pricing Model (ICAPM) of Robert Merton not discussed? Should a person of finance delve deeper into CAPM extensions or is the base theory fundamentally sufficient?

Merton's I-CAPM

- ICAPM is mathematically equivalent to APT:

$$\bar{r}_i - r_F = \beta_M^i(\bar{r}_M - r_F) + \sum_{k=1}^{K} \beta_k^i(\bar{r}_k - r_F)$$

- Market factor and K factor-mimicking portfolios.
- What factors do they mimic?
  - APT is silent on that.
  - ICAPM is specific: mimic shocks to the investment opportunity set (e.g., interest rates, expected returns, volatility, …)

Merton's I-CAPM: intuition

- Original derivation uses dynamic programming and stochastic calculus.
- Consider a motivating example instead:
  - Alice is *highly* risk averse.
  - The market consists of two bonds only: 1-year and 20-year discount bonds.
  - If Alice has a 1-year horizon, how will she invest?

over 1-year horizon, a 20 year bond is risky. We don't know at what price you'll be able to sell it a year from now, when the bond has 19 years left to go. Long duration bond has interest rate risk. One year bond is risk-free.

    - 100% in the 1-year bond.
  - If Alice has a 20-year horizon, how will she invest?

20-year: pre-set interest rate, risk-free
1-year roll over and over: future spot interest rate is random, risky

    - 100% in the 20-year bond. Why?
    - What about short-term volatility of the 20-year bond, isn't Alice highly averse to risk?

Merton's I-CAPM: intuition

long horizon investor does not consider short-term decline, because he does not liquidate asset at that time

- With a long horizon, short-term mean and variance is not the whole story.

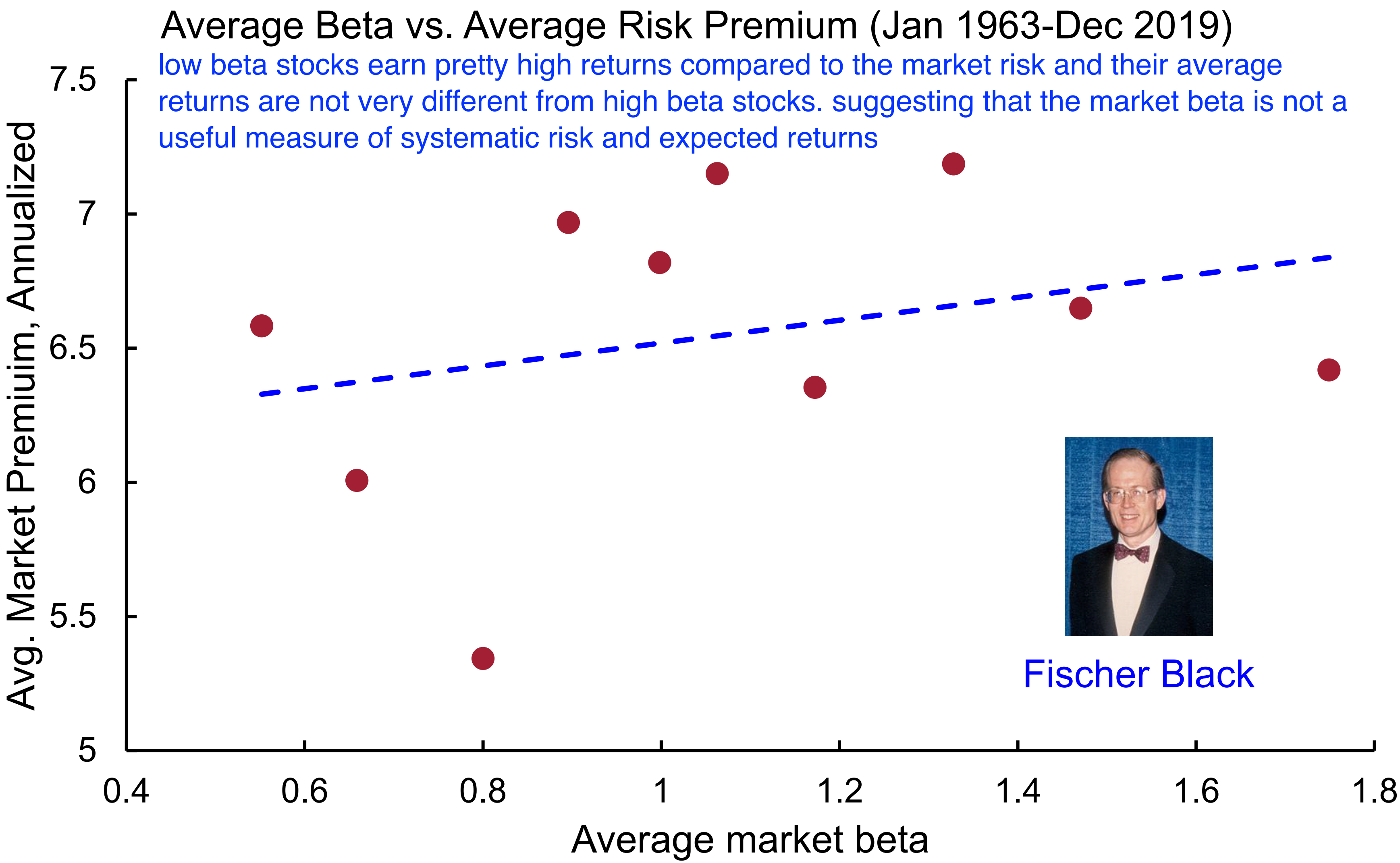
at the end of the first period, you consider how to reinvest your money

- Shocks to investment opportunities matter:
  - When the 20-year bond declines in price, its return to maturity (19-year interest rate) rises.
- In equilibrium, investors no longer hold portfolios that are short-term mean-variance efficient – they deviate to manage (hedge) shocks to investment opportunities.

$$\bar{r}_i - r_F = \beta_M^i(\bar{r}_M - r_F) + \sum_{k=1}^{K} \beta_k^i(\bar{r}_k - r_F)$$

- Additional factors are hedging portfolios: they best approximate (hedge) unexpected changes in investment opportunities.

Flat SML: a failure or an opportunity?



First, let's start with a narrative for why SML may be flat. This story made a recent resurgence in the context of betting-against-beta, which is a "smart beta" strategy (a quant strategy) consisting of buying low-beta stocks and selling high-beta stocks. The argument for why such a strategy may earn abnormal risk-adjusted returns goes like this. Many stock market investors (including mutual funds) are limited in their ability to use leverage. As a result, they cannot pick a high Sharpe-ratio portfolio and lever it up to their desired expected return. They need to find stocks with sufficiently high average returns and, as a result, don't like holding low-beta stocks, which produce lower average returns. They overvalue high-beta stocks, which have higher risk levels and higher expected returns. As a result, in equilibrium, low-beta stocks are undervalued relative to CAPM (have higher expected returns than their market betas imply), and high-beta stocks are over-valued (have lower expected returns that predicted by the CAPM). This narrative provides a particularly strong interpretation of the flat SML. It is causal: if a firm raises its equity beta, then, by this argument, the risk premium of its equity will not rise in proportion to the equity beta, because investors like higher market betas and are willing to accept lower expected returns than implied by the CAPM.

Fischer Black noted that in this situation, those low-risk firms that are able to issue corporate debt have an opportunity to increase their value by levering up. The underlying reason is that while some investors cannot use leverage, firms can do it for them and benefit as a result.

Finally, an alternative interpretation of the flat SML line is that CAPM fails in a different way: there exist systematic factors distinct from the market portfolio, and high- and low-market-beta firms have different exposures to such factors (two factor APT model). It so happens that missing factors result in a flat SML line (while the slope of market excess return is positive, the slope of second factor is negative).

CAPM and Beyond: CAPM vs APT

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FIRM CHARACTERISTICS AND STOCK RETURNS: THE ROLE OF INVESTMENT-SPECIFIC SHOCKS

Sorting firms on 'characteristics' leads to

1. Differences in average returns

   ↪ Return differences not captured by the CAPM: (in most cases) negative relation between average returns and market betas

2. Long-short portfolios that are 'return factors'

   ↪ These return factors are not spanned by the market portfolio

MARKET BETA

Long-short portfolio: go long high beta firms and short low beta firms for dollar

	Lo	2	3	8	9	Hi	Hi-Lo
$E(R) - r_f(\%)$	5.81	6.40	5.42	5.04	3.98	3.84	-1.97
	(2.51)	(3.04)	(2.72)	(1.95)	(1.19)	(0.98)	(-0.52)
$\sigma(\%)$	18.20	16.21	17.50	21.02	25.47	30.98	26.47
β^{mkt}	0.71	0.64	0.78	1.10	1.27	1.46	0.75
	(5.19)	(5.42)	(5.33)	(24.42)	(14.65)	(11.75)	(4.26)
$\alpha(\%)$	2.24	3.21	1.53	-0.44	-2.39	-3.47	-5.71
	(1.11)	(2.09)	(1.32)	(-0.43)	(-1.64)	(-1.48)	(-1.87)
$R^2(\%)$	49.70	50.28	64.13	88.09	81.13	72.10	25.93

- Estimate market beta using past 1 year of weekly data.
- Use only the firms producing consumption goods (motivated by the model below). Exclude investment-good producers, utilities, financial firms.
- 1965-2008 period.

Enterprise market-to-book (Tobin's Q)

	Lo	2	3	8	9	Hi	Hi-Lo
$E(R)-r_f(\%)$	10.26	9.48	7.43	5.13	4.94	1.47	-8.79
	(4.43)	(5.01)	(3.91)	(1.91)	(1.93)	(0.58)	(-3.26)
$\sigma(\%)$	19.06	19.74	16.87	20.85	20.31	24.94	20.75
β^{mkt}	0.86	0.92	0.82	1.06	0.99	1.15	0.29
	(7.25)	(7.27)	(8.82)	(13.78)	(15.13)	(9.61)	(1.66)
$\alpha(\%)$	5.98	4.90	3.35	-0.17	-0.00	-4.29	-10.27
	(3.25)	(3.68)	(3.22)	(-0.14)	(-0.00)	(-2.25)	(-3.64)
$R^2(\%)$	65.33	69.79	75.77	83.85	76.71	69.02	6.55

- Define Tobin's Q (Q) as market cap of common equity plus long-term debt (DLTT) plus preferred equity (PSTKRV) minus deferred taxes (TXDB), divided by book value of capital (PPEGT)
- Use only the firms producing consumption goods (motivated by the model below). Exclude investment-good producers, utilities, financial firms.
- 1965-2008 period.

Past investment rate (IK)

	Lo	2	3	8	9	Hi	Hi-Lo
$E(R) - r_f(\%)$	7.46	6.98	7.25	4.07	3.28	2.51	-4.94
	(3.00)	(3.42)	(4.40)	(1.67)	(1.30)	(0.65)	(-1.42)
$\sigma(\%)$	20.60	17.04	15.15	19.50	23.00	33.30	24.86
β^{mkt}	0.94	0.82	0.73	0.99	1.16	1.56	0.62
	(7.79)	(10.05)	(10.61)	(14.18)	(14.69)	(9.52)	(2.91)
$\alpha(\%)$	2.77	2.87	3.61	-0.89	-2.52	-5.27	-8.04
	(1.40)	(2.16)	(4.13)	(-0.89)	(-2.02)	(-1.85)	(-2.41)
$R^2(\%)$	67.02	75.49	75.24	83.89	82.52	70.80	20.13

- Define investment rate (IK) as capital expenditures (CAPX) divided by lagged gross property, plant and equipment (PPEGT)
- Use only the firms producing consumption goods (motivated by the model below). Exclude investment-good producers, utilities, financial firms.
- 1965-2008 period.

Enterprise Earnings-to-Price (EP)

	Lo	2	3	8	9	Hi	Hi-Lo
$E(R) - r_f(\%)$	2.28	1.65	2.23	8.23	8.95	11.19	8.91
	(0.72)	(0.84)	(1.13)	(3.33)	(3.98)	(4.25)	(3.00)
$\sigma(\%)$	25.72	16.90	16.24	19.05	19.76	20.96	19.72
β^{mkt}	1.21	0.86	0.85	0.92	0.81	0.97	-0.25
	(10.72)	(12.44)	(15.67)	(10.37)	(4.85)	(9.59)	(-1.62)
$\alpha(\%)$	-3.80	-2.63	-2.00	3.64	4.88	6.35	10.15
	(-2.24)	(-2.67)	(-3.02)	(2.88)	(2.50)	(3.15)	(3.51)
$R^2(\%)$	72.25	83.28	88.35	75.21	55.15	68.98	5.11

- Table shows results sorted on Earnings to total firm value.
- Define earnings to price (EP) as operating income (IB) plus interest payments (XINT) divided by market cap of common equity plus long-term debt (DLTT) plus preferred equity (PSTKRV) minus deferred taxes (TXDB)
- Use only the firms producing consumption goods (motivated by the model below). Exclude investment-good producers, utilities, financial firms.
- 1965-2008 period.

Idiosyncratic volatility

	Lo	2	3	8	9	Hi	Hi-Lo
$E(R) - r_f(\%)$	5.02	5.96	6.40	3.42	1.01	-0.84	-5.86
	(2.45)	(2.60)	(3.23)	(0.87)	(0.20)	(-0.14)	(-0.95)
$\sigma(\%)$	15.35	17.38	17.82	32.75	39.33	42.44	37.05
β^{mkt}	0.77	0.92	0.93	1.53	1.67	1.76	0.98
	(12.71)	(44.95)	(18.91)	(9.59)	(9.23)	(8.20)	(3.97)
$\alpha(\%)$	1.14	1.34	1.73	-4.24	-7.34	-9.64	-10.78
	(1.12)	(1.65)	(2.10)	(-1.43)	(-1.71)	(-1.90)	(-1.83)
$R^2(\%)$	82.67	91.64	89.14	70.99	58.41	55.65	22.85

- Estimate idiosyncratic volatility using past 1 year of weekly data from a two-factor model using market portfolio and IMC returns.
- Use only the firms producing consumption goods (motivated by the model below). Exclude investment-good producers, utilities, financial firms.
- 1965-2008 period.

Some new stylized facts

- The above patterns are related.
- Extract first principal component from market-residuals.
- Return factors from each cross-section are correlated.
  - ↪ I.e. not only do high-IK firms comove with other high-IK firms, but they also comove with high-β^{mkt}, high-Q, low-EP and high-IVOL firms
  - ↪ Not mechanically driven by common membership ($\rho(sort) \approx 20 - 30\%$).

PCA

	Cross-sections					Eigenvalue
	IK	EP	IVOL	β^{mkt}	Q	$\lambda_1 / \sum \lambda_i$
ALL (IK, EP, IVOL, β^{mkt}, Q)	92.0	77.9	46.8	89.7	74.2	33.2
(p-value)	(0.00)	(0.00)	(0.03)	(0.00)	(0.00)	(0.00)

The empirical factor model

	10 minus 1 decile portfolios				
	Tobin's Q	IK	PE	MBETA	IVOL
α (%)	–2.18	1.32	–3.17	3.21	–4.44
	(–1.00)	(0.62)	(–1.41)	(1.27)	(–0.94)
β^{mkt}	0.29	0.62	0.25	0.75	0.98
	(3.83)	(5.16)	(2.66)	(6.94)	(4.24)
β^{PC1}	0.63	0.73	0.54	0.69	0.49
	(7.32)	(10.01)	(5.83)	(8.16)	(3.75)
R^2 (%)	66.13	75.75	54.24	70.47	34.32

Pricing errors

- Common principal component prices all these five cross-sections

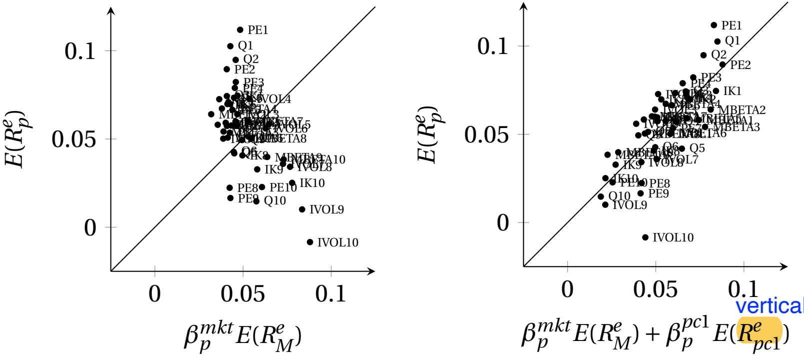
	Lo	2	3	8	9	Hi	Hi-Lo
α (Q)	1.76	1.77	0.73	0.57	0.93	-0.42	-2.18
	(1.48)	(1.16)	(0.61)	(0.35)	(0.56)	(-0.21)	(-1.00)
α (IK)	-0.96	0.03	0.53	-0.82	0.56	0.37	1.32
	(-0.63)	(0.03)	(0.91)	(-0.61)	(0.46)	(0.16)	(0.62)
α (EP)	-0.28	-2.49	-1.96	1.10	0.17	2.89	3.17
	(-0.12)	(-1.82)	(-2.48)	(0.80)	(0.11)	(2.05)	(1.41)
α (β^{mkt})	-1.64	-1.71	-2.37	0.66	1.11	1.57	3.21
	(-0.93)	(-2.13)	(-2.51)	(0.56)	(0.92)	(0.67)	(1.27)
α (IVOL)	-0.81	0.88	1.44	-0.76	-1.13	-5.25	-4.44
	(-0.82)	(1.10)	(1.46)	(-0.28)	(-0.26)	(-1.26)	(-0.94)

AVERAGE RETURNS VERSUS MODEL-IMPLIED PREMIA

Common principal component prices all five cross-sections

A. CAPM

B. Factor model (MKT, PC1)



vertical to R_M

two factor model APT