Financial Markets And Empirical Regularities

An Introduction to Financial Econometrics

SAMSI Workshop 11/18/05

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Outline

I. Historical Perspective on Asset Prices

II. Predictability of Asset Returns

III. Asset Pricing Models

IV. Volatility Models

Essential Sources

- Campbell, Lo, & MacKinlay, “The Econometrics of Financial Markets”
- Cochrane, “Asset Pricing”
- Huang & Litzenberger, “Foundations for Financial Economics”
- Hamilton, “Time Series Analysis”
- Greene, “Econometric Analysis”

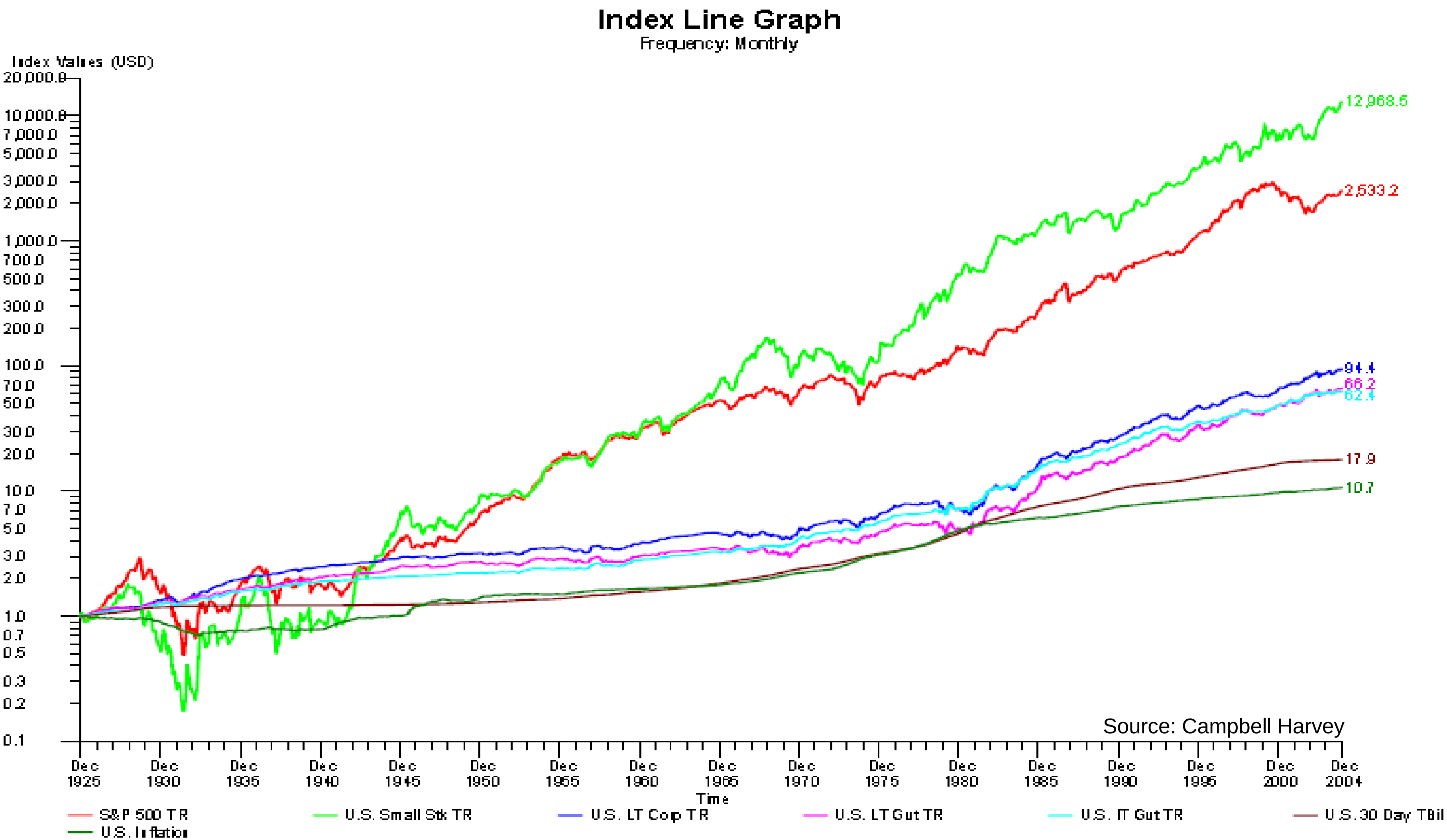
Types of Financial Assets:

Common: Stocks, Bonds, Commodities,
Foreign Exchange,…

Exotic: Derivatives; Options, Futures,…

I. Historical Perspective on Asset Prices

A History of Asset Prices



I. Historical Perspective on Asset Prices

Definitions:

- Simple Gross Return: $$R_t + 1 = \frac{P_t}{P_{t-1}}, \; P_t = \text{price of asset at time t.}$$
- Compound Gross Return: $$R_t(k) + 1 = (1 + R_t) * (1 + R_{t-1}) * ... * (1 + R_{t-k+1})$$
- Annualized Return: $$\left[\prod_{j=0}^{k-1} (1 + R_{t-j}) \right]^{1/k} - 1 \approx \frac{1}{k} \sum_{j=0}^{k-1} R_{t-j}$$
- Continuously Compounded Return: $$r_t = \log(1 + R_t) = \log P_t - \log P_{t-1}$$

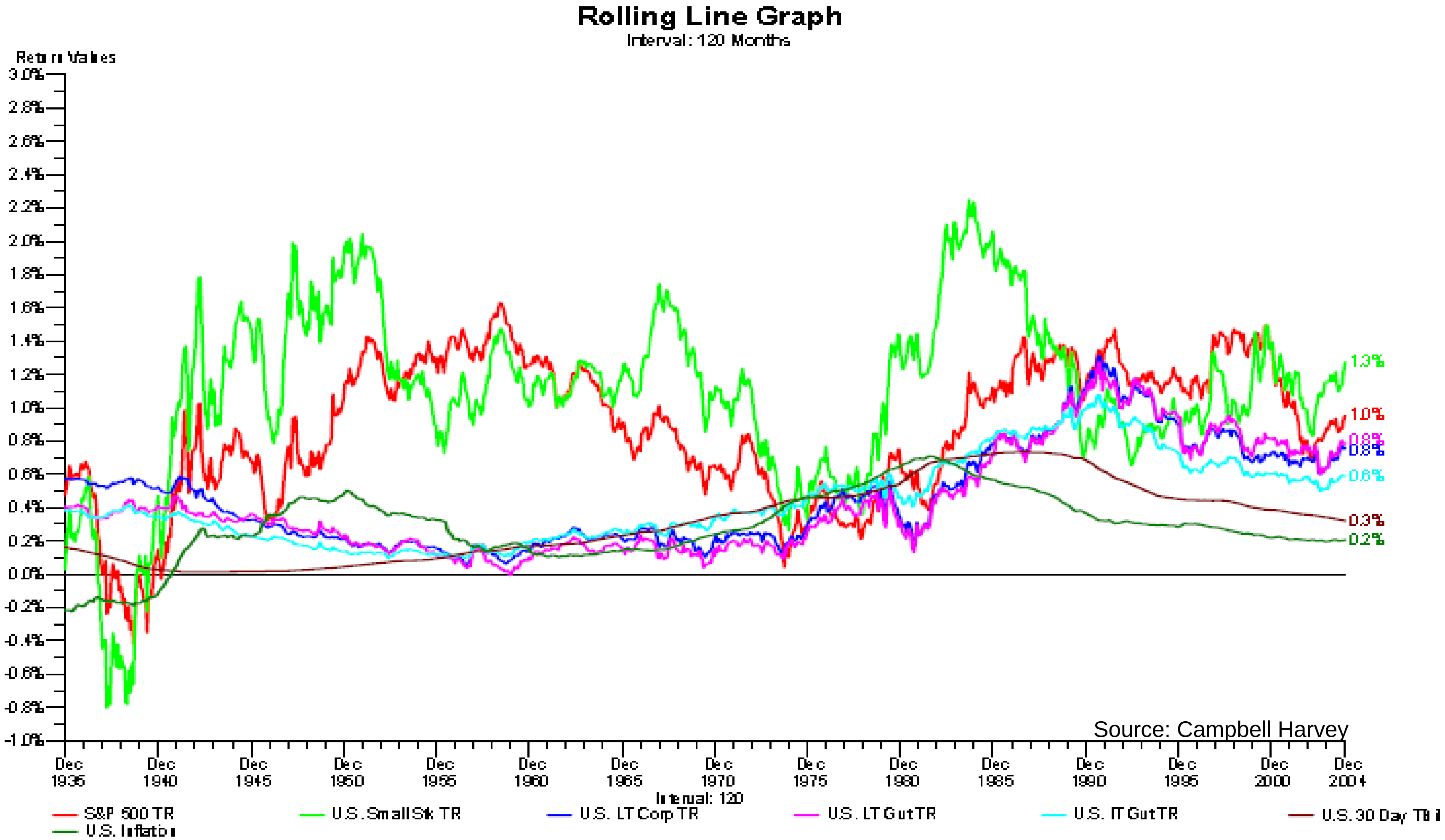
Why Returns?

…..Because returns tend to be stationary.

Stationary: The joint distribution between two returns x_t, x_{t-h} depends only on h and NOT on t.

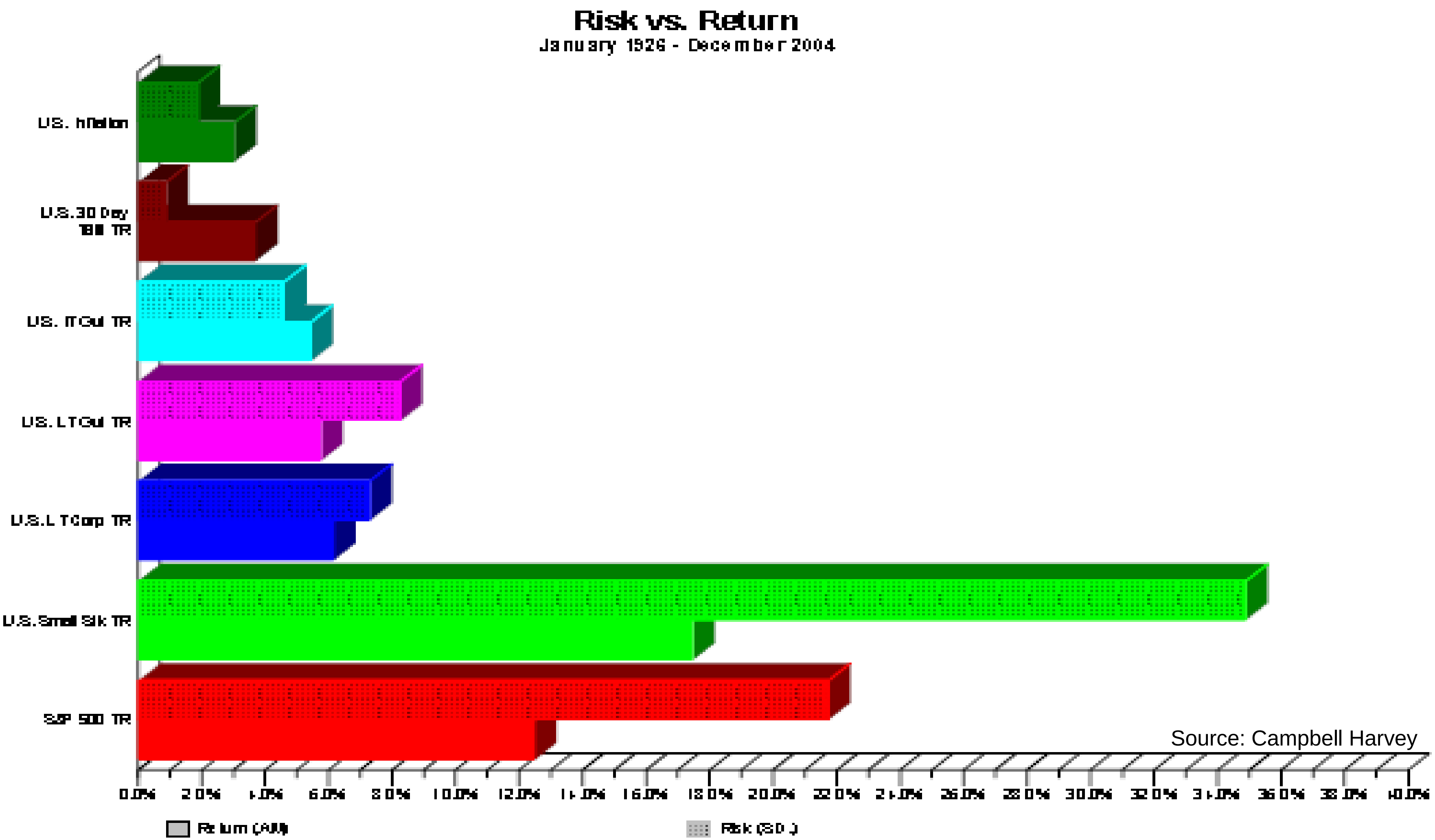
I. Historical Perspective on Asset Prices

A History of Asset Returns



Source: Campbell Harvey

I. Historical Perspective on Asset Prices



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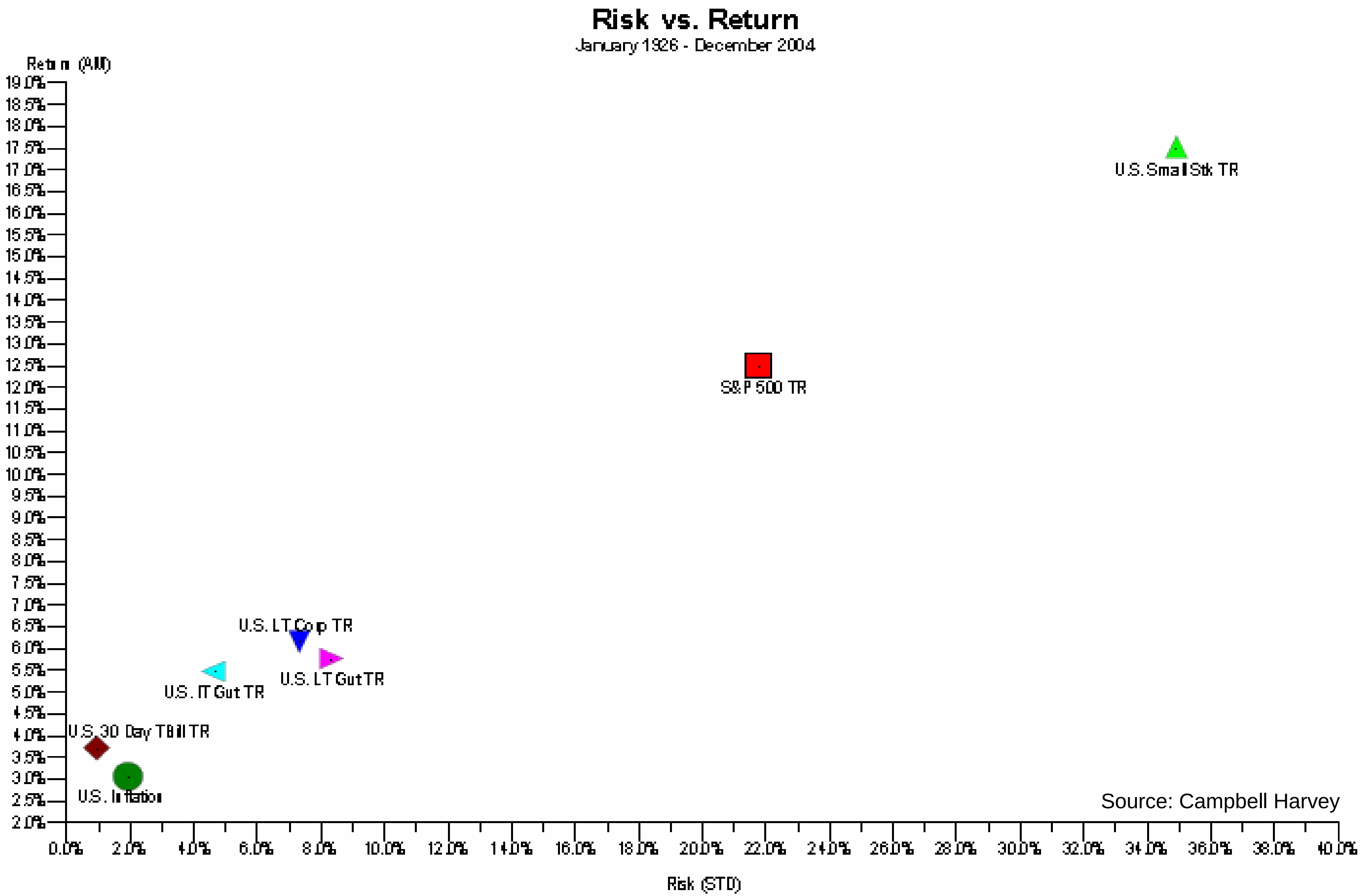

Source: Campbell Harvey

Observation:

- There exists a Risk / Return Tradeoff

Stats Reminder:

Consider a random variable x_t

- Mean: $$\hat{\mu} \equiv \frac{1}{T}\sum_{t=1}^{T} x_t$$
- Variance: $$\hat{\sigma}^2 \equiv \frac{1}{T}\sum_{t=1}^{T} (x_t - \hat{\mu})^2$$
- Skew: $$\hat{S} \equiv \frac{1}{T\hat{\sigma}^3}\sum_{t=1}^{T} (x_t - \hat{\mu})^3$$
- Kurtosis: $$\hat{K} \equiv \frac{1}{T\hat{\sigma}^4}\sum_{t=1}^{T} (x_t - \hat{\mu})^4$$

What is the Distribution of Returns?

- Normal?

I. Historical Perspective on Asset Prices

Table 1.1. Stock market returns, 1962 to 1994.

Security	Mean	Standard Deviation	Skewness	Excess Kurtosis	Minimum	Maximum
Panel A: Daily Returns						
Value-Weighted Index	0.044	0.82	−1.33	34.92	−18.10	8.87
Equal-Weighted Index	0.073	0.76	−0.93	26.03	−14.19	9.83
International Business Machines	0.039	1.42	−0.18	12.48	−22.96	11.72
General Signal Corp.	0.054	1.66	0.01	3.35	−13.46	9.43
Wrigley Co.	0.072	1.45	−0.00	11.03	−18.67	11.89
Interlake Corp.	0.043	2.16	0.72	12.35	−17.24	23.08
Raytech Corp.	0.050	3.39	2.25	59.40	−57.90	75.00
Ampco-Pittsburgh Corp.	0.053	2.41	0.66	5.02	−19.05	19.18
Energen Corp.	0.054	1.41	0.27	5.91	−12.82	11.11
General Host Corp.	0.070	2.79	0.74	6.18	−23.53	22.92
Garan Inc.	0.079	2.35	0.72	7.13	−16.67	19.07
Continental Materials Corp.	0.143	5.24	0.93	6.49	−26.92	50.00
Panel B: Monthly Returns						
Value-Weighted Index	0.96	4.33	−0.29	2.42	−21.81	16.51
Equal-Weighted Index	1.25	5.77	0.07	4.14	−26.80	33.17
International Business Machines	0.81	6.18	−0.14	0.83	−26.19	18.95
General Signal Corp.	1.17	8.19	−0.02	1.87	−36.77	29.73
Wrigley Co.	1.51	6.68	0.30	1.31	−20.26	29.72
Interlake Corp.	0.86	9.38	0.67	4.09	−30.28	54.84
Raytech Corp.	0.83	14.88	2.73	22.70	−45.65	142.11
Ampco-Pittsburgh Corp.	1.06	10.64	0.77	2.04	−36.08	46.94
Energen Corp.	1.10	5.75	1.47	12.47	−24.61	48.36
General Host Corp.	1.33	11.67	0.35	1.11	−38.05	42.86
Garan Inc.	1.64	11.30	0.76	2.30	−35.48	51.60
Continental Materials Corp.	1.64	17.76	1.13	3.33	−58.09	84.78

Summary statistics for daily and monthly returns (in percent) of CRSP equal- and value-weighted stock indexes and ten individual securities continuously listed over the entire sample period from July 3, 1962 to December 30, 1994. Individual securities are selected to represent stocks in each size decile. Statistics are defined in (1.4.19)–(1.4.22).

Stylized Facts on the Distribution of Returns:

1. Index Volatility < Stock Volatility
2. Negative Skewness
3. Excess Kurtosis

Can We Predict Returns?

- Day Traders Say Yes

- Efficient Market Hypothesis Says No

Efficient Market Hypothesis (EMH):

Fama (1970): “A market in which prices always ‘fully reflect’ available information is called ‘efficient’”.

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Malkiel (1992): "…the market is said to be efficient with respect to an *information set*…"

Probability Theory Reminder:

- The Information Set F_t is a sigma field said to contain all of the relevant information up to time t.

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- Martingale: $E[x_{t+1} | F_t] = x_t$

EMH:

Weak Form Efficiency:

Information Set: Asset's own history

Test via Random Walk

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Information Set: Weak Form + Publicly available data

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Information Set: Weak Form + Publicly available data

Test via Event Studies

Strong Form Efficiency:

Information Set: Weak + Semi + Private Info

Test via Performance Evaluation

Joint hypothesis problem: The EMH can't be tested directly. Even if we reject the hypothesis of efficiency, this could either be because the market is truly inefficient, or because we have assumed an incorrect equilibrium model.

Implication of Weak Form EMH:

- Expected Returns follow a martingale.
- Random Walk Hypothesis

II. Predictability of Returns

$$P_t = \mu + P_{t-1} + \varepsilon_t$$

Random Walk 1: i.i.d Increments

Random Walk 2: Independent, Not Indentical

Random Walk 3: Uncorrelated Increments

Time Series Econometrics Reminder:

Auto Correlation

Correlation between two observations of the same series at different dates

$$\text{AutoCovariance}: \gamma(\text{k}) \equiv Cov(x_t, x_{t-k})$$

$$\text{AutoCorrelation}: \rho(\text{k}) \equiv \frac{\gamma(k)}{\gamma(0)}$$

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$$\text{Box} - \text{Pierce Q Statistic}: \text{Q}_\text{m} = T(T+2)\sum_{k=1}^{m} \frac{\rho^2(k)}{T-k}$$

II. Predictability of Returns

Table 2.4. *Autocorrelation in daily, weekly, and monthly stock index returns.*

Sample Period	Sample Size	Mean	SD	$\hat{\rho}_1$	$\hat{\rho}_2$	$\hat{\rho}_3$	$\hat{\rho}_4$	$\hat{Q}_5$	$\hat{Q}_{10}$
A. Daily Returns									
			CRSP Value-Weighted Index						
62:07:03–94:12:30	8,179	0.041	0.824	17.6	−0.7	0.1	−0.8	263.3	269.5
62:07:03–78:10:27	4,090	0.028	0.738	27.8	1.2	4.6	3.3	329.4	343.5
78:10:30–94:12:30	4,089	0.054	0.901	10.8	−2.2	−2.9	−3.5	69.5	72.1
			CRSP Equal-Weighted Index						
62:07:03–94:12:30	8,179	0.070	0.764	35.0	9.3	8.5	9.9	1,301.9	1,369.5
62:07:03–78:10:27	4,090	0.063	0.771	43.1	13.0	15.3	15.2	1,062.2	1,110.2
78:10:30–94:12:30	4,089	0.078	0.756	26.2	4.9	2.0	4.9	348.9	379.5
B. Weekly Returns									
			CRSP Value-Weighted Index						
62:07:10–94:12:27	1,695	0.196	2.093	1.5	−2.5	3.5	−0.7	8.8	36.7
62:07:10–78:10:03	848	0.144	1.994	5.6	−3.7	5.8	1.6	9.0	21.5
78:10:10–94:12:27	847	0.248	2.188	−2.0	−1.5	1.6	−3.3	5.3	25.2
			CRSP Equal-Weighted Index						
62:07:10–94:12:27	1,695	0.339	2.321	20.3	6.1	9.1	4.8	94.3	109.3
62:07:10–78:10:03	848	0.324	2.460	21.8	7.5	11.9	6.1	60.4	68.5
78:10:10–94:12:27	847	0.354	2.174	18.4	4.3	5.5	2.2	33.7	51.3
C. Monthly Returns									
			CRSP Value-Weighted Index						
62:07:31–94:12:30	390	0.861	4.336	4.3	−5.3	−1.3	−0.4	6.8	12.5
62:07:31–78:09:29	195	0.646	4.219	6.4	−3.8	7.3	6.2	3.9	9.7
78:10:31–94:12:30	195	1.076	4.450	1.3	−6.3	−8.3	−7.7	7.5	14.0
			CRSP Equal-Weighted Index						
62:07:31–94:12:30	390	1.077	5.749	17.1	−3.4	−3.3	−1.6	12.8	21.3
62:07:31–78:09:29	195	1.049	6.148	18.4	−2.5	4.4	2.4	7.5	12.6
78:10:31–94:12:30	195	1.105	5.336	15.0	−1.6	−12.4	−7.4	8.9	14.2

Autocorrelation coefficients (in percent) and Box-Pierce *Q*-statistics for CRSP daily, weekly, and monthly value- and equal-weighted return indexes for the sample period from July 3, 1962 to December 30, 1994 and subperiods.

III. Asset Pricing Models

- Capital Asset Pricing Model (CAPM)

  Sharpe (1964) and Lintner (1965)

- Consumption Based-CAPM
- Inter-temporal-CAPM
- Arbitrage Pricing Theory

  Ross (1976)

CAPM: Differences in excess returns across assets are due to differences in the *riskiness* of each asset.

Beta: Measure of *riskiness*

Market Model: $(R_i - R_f) = \beta(R_m - R_f) + u$

$\Rightarrow$ There exists a linear Risk/Reward Tradeoff

$$\text{OLS} \Rightarrow \beta = \frac{Cov[(R_i - R_f),(R_m - R_f)]}{Var(R_m - R_f)}$$

CAPM Pricing Equation:

$$E[R_i] = R_f + \beta_{im}(E[R_m] - R_f)$$

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Testable Implications:

1) Only beta is required to price assets.

2) There is a linear risk/return relationship.

Testing the CAPM:

Fama & MacBeth (1973)

Step 1: For each time period estimate the cross-sectional regression:

$(R_i - R_f) = \theta_0 + \theta_1 \beta_{im} + \theta_2 \beta_{im}^2 + \theta_3 s_i + u_i$, where s is the standard deviation of u.

Step 2: Aggregate parameter estimates over time such that $\theta_k = E[\theta_k] \; \forall k = 0,1,2,3$

Fama & MacBeth cont'd

There is an errors-in-variables (EIV) problem because the β's must first be estimated.

<u>Fama & MacBeth solution</u>: Sort stocks into portfolios.

<u>Shanken solution</u>: correct variance of estimators post estimation.

$$H_0 : \theta_0 = \theta_1 = \theta_2 = \theta_3 = 0$$

$\Rightarrow \beta$ is the only factor necessary to price assets & there is a positive, linear risk-return tradeoff.

TABLE 3

SUMMARY RESULTS FOR THE REGRESSION

$$R_p = \hat{\gamma}_{0t} + \hat{\gamma}_{1t}\hat{\beta}_p + \hat{\gamma}_{2t}\hat{\beta}^2_p + \hat{\gamma}_{3t}\bar{s}_p(\hat{\epsilon}_i) + \hat{\eta}_{pt}$$

	Statistic																			
Period	$\bar{\hat{\gamma}}_0$	$\bar{\hat{\gamma}}_1$	$\bar{\hat{\gamma}}_2$	$\bar{\hat{\gamma}}_3$	$\overline{\hat{\gamma}_0 - R_f}$	$s(\hat{\gamma}_0)$	$s(\hat{\gamma}_1)$	$s(\hat{\gamma}_2)$	$s(\hat{\gamma}_3)$	$\rho_0(\hat{\gamma}_0 - R_f)$	$\rho_M(\hat{\gamma}_1)$	$\rho_0(\hat{\gamma}_2)$	$\rho_0(\hat{\gamma}_3)$	$t(\bar{\hat{\gamma}}_0)$	$t(\bar{\hat{\gamma}}_1)$	$t(\bar{\hat{\gamma}}_2)$	$t(\bar{\hat{\gamma}}_3)$	$t(\overline{\hat{\gamma}_0 - R_f})$	$\bar{r}^2$	$s(r^2)$
Panel C:																				
1935–6/68 ..	.0054	.0072	...	.0198	.0041	.052	.065	...	.868	.04	—.12	...	—.04	2.10	2.20	...	.46	1.59	.32	.31
1935–45	.0017	.0104	...	.0841	.0015	.073	.083	...	.921	—.00	—.26	...	—.08	.26	1.41	...	1.05	.24	.32	.31
1946–55	.0110	.0075	...	—.1052	.0100	.032	.056	...	.609	.08	.02	...	—.20	3.78	1.47	...	—1.89	3.46	.34	.32
1956–6/68 ..	.0042	.0041	...	.0633	.0016	.040	.052	...	.984	.12	.08	...	.03	1.28	.96	...	.79	.50	.30	.29
1935–40	.0036	.0119	...	—.0170	.0035	.082	.105	...	.744	—.03	—.26	...	—.18	.37	.97	...	—.19	.36	.25	.30
1941–45	—.0006	.0085	...	.2053	—.0009	.061	.052	...	1.091	.07	—.29	...	—.02	—.08	1.25	...	1.46	—.11	.41	.30
1946–50	.0069	.0081	...	—.0920	.0062	.034	.066	...	.504	.14	.06	...	—.02	1.56	.95	...	—1.41	1.40	.42	.33
1951–55	.0150	.0069	...	—.1185	.0138	.029	.043	...	.702	.06	—.18	...	—.32	4.05	1.24	...	—1.31	3.72	.27	.29
1956–60	.0127	—.0081	...	.0728	.0107	.037	.045	...	1.164	.15	.15	...	.21	2.68	—1.40	...	.48	2.26	.26	.30
1961–6/68 ..	—.0014	.0122	...	.0570	—.0044	.042	.055	...	.850	.10	.00	...	—.19	—.32	2.12	...	.64	—.98	.33	.27
Panel D:																				
1935–6/68 ..	.0020	.0114	—.0026	.0516	.0008	.075	.123	.060	.929	—.09	—.09	—.12	—.10	.55	1.85	—.86	1.11	.20	.34	.31
1935–45	.0011	.0118	—.0009	.0817	.0010	.103	.146	.079	1.003	—.20	—.23	—.24	—.15	.13	.94	—.14	.94	.11	.34	.31
1946–55	.0017	.0209	—.0076	—.0378	.0008	.042	.096	.038	.619	—.10	—.00	—.01	—.20	.44	2.39	—2.16	—.67	.20	.36	.32
1956–6/68 ..	.0031	.0034	—.0000	.0966	.0005	.065	.122	.055	1.061	.12	.03	.01	—.05	.59	.34	—.00	1.11	.10	.32	.29
1935–40	.0009	.0156	—.0029	.0025	.0008	.112	.171	.085	.826	—.16	—.23	—.26	—.12	.07	.78	—.29	.03	.06	.26	.30
1941–45	.0015	.0073	.0014	.1767	.0012	.092	.109	.072	1.181	—.28	—.21	—.22	—.18	.12	.52	.15	1.16	.10	.43	.31
1946–50	.0011	.0141	—.0040	—.0313	.0004	.047	.106	.042	.590	—.10	.03	—.01	—.12	.18	1.03	—.73	—.41	.07	.44	.33
1951–55	.0023	.0277	—.0112	—.0443	.0011	.037	.085	.034	.651	—.11	—.13	—.01	—.28	.48	2.53	—2.54	—.53	.23	.29	.30
1956–60	.0103	—.0047	—.0020	.0979	.0083	.049	.078	.032	1.286	—.16	.19	—.01	.02	1.63	—.47	—.49	.59	1.31	.28	.30
1961–6/68 ..	—.0017	.0088	.0013	.0957	—.0046	.073	.144	.066	.887	.20	.00	.01	—.15	—.21	.58	.19	1.02	—.60	.35	.29

CAPM Anomalies:

- Small Firm effect (Keim `81)
- P/E Ratio Effect (Ball `78 and Basu `83)
- Book-to-Market Effect (Stattman `80 and Rosenberg `85)
- Momentum Effect (Jegadeesh and Titman `93)

$\Rightarrow$ Is Beta Dead?

III. Asset Pricing Models - CAPM

Table III

Average Slopes (*t*-Statistics) from Month-by-Month Regressions of Stock Returns on β, Size, Book-to-Market Equity, Leverage, and E/P: July 1963 to December 1990

Stocks are assigned the post-ranking β of the size-β portfolio they are in at the end of June of year t (Table I). BE is the book value of common equity plus balance-sheet deferred taxes, A is total book assets, and E is earnings (income before extraordinary items, plus income-statement deferred taxes, minus preferred dividends). BE, A, and E are for each firm's latest fiscal year ending in calendar year $t - 1$. The accounting ratios are measured using market equity ME in December of year $t - 1$. Firm size ln(ME) is measured in June of year t. In the regressions, these values of the explanatory variables for individual stocks are matched with CRSP returns for the months from July of year t to June of year $t + 1$. The gap between the accounting data and the returns ensures that the accounting data are available prior to the returns. If earnings are positive, E(+)/P is the ratio of total earnings to market equity and E/P dummy is 0. If earnings are negative, E(+)/P is 0 and E/P dummy is 1.

The average slope is the time-series average of the monthly regression slopes for July 1963 to December 1990, and the t-statistic is the average slope divided by its time-series standard error.

On average, there are 2267 stocks in the monthly regressions. To avoid giving extreme observations heavy weight in the regressions, the smallest and largest 0.5% of the observations on E(+)/P, BE/ME, A/ME, and A/BE are set equal to the next largest or smallest values of the ratios (the 0.005 and 0.995 fractiles). This has no effect on inferences.

β	ln(ME)	ln(BE/ME)	ln(A/ME)	ln(A/BE)	E/P Dummy	E(+)/P
0.15 (0.46)						
	−0.15 (−2.58)					
−0.37 (−1.21)	−0.17 (−3.41)					
		0.50 (5.71)				
			0.50 (5.69)	−0.57 (−5.34)		
					0.57 (2.28)	4.72 (4.57)
	−0.11 (−1.99)	0.35 (4.44)				
	−0.11 (−2.06)		0.35 (4.32)	−0.50 (−4.56)		
	−0.16 (−3.06)				0.06 (0.38)	2.99 (3.04)
	−0.13 (−2.47)	0.33 (4.46)			−0.14 (−0.90)	0.87 (1.23)
	−0.13 (−2.47)		0.32 (4.28)	−0.46 (−4.45)	−0.08 (−0.56)	1.15 (1.57)

Consumption Based Asset Pricing Model

$$U(C_t) = \frac{C_t^{1-\gamma}}{1-\gamma}$$

$$Max \sum_{t=0}^{\infty} \beta^t U(C_t) \text{ subject to } C_t + \sum_{i=0}^{N} P_{it} Q_{it} \le \sum_{i=0}^{N} P_{it} Q_{it-1} + W_t$$

$$\Rightarrow E_t[\beta(\tfrac{C_{t+1}}{C_t})^{-\gamma} R_{t+1}] - 1 = 0$$

U : Utility Function

C : Consumption

γ : Coefficient of Risk Aversion

β : Intertemporal Rate of Substitution

P : Value of asset

Q : Amount of assets owned

N : Number of assets in the economy

W : Real Labor Income

GMM Estimation

$$\theta = [\gamma, \beta]$$

$$e_t = [\beta(\tfrac{C_t}{C_{t-1}})^{-\gamma} R_t] - 1$$

z_t : Vector of instruments at time t

$$m(\theta) = \tfrac{1}{T} Z' e$$

GMM Estimation

$$\theta = [\gamma, \beta]$$

$$e_t = [\beta(\tfrac{C_t}{C_{t-1}})^{-\gamma} R_t]$$

z_t : Vector of instruments at time t

$$m(\theta) = \tfrac{1}{T} Z' e$$

$J_t = \text{Min } m(\theta)' W m(\theta)$ where $W = S^{-1}$

$$S = \tfrac{1}{T} \sum_{t=1}^{T} [e_t e_t' \otimes z_t z_t']$$

$TJ_t \approx \chi^2_{q-p}$; q = dim($e$) & p = dim($z$)

IV. Volatility Models

6 K.R. French et al., Expected stock returns and volatility

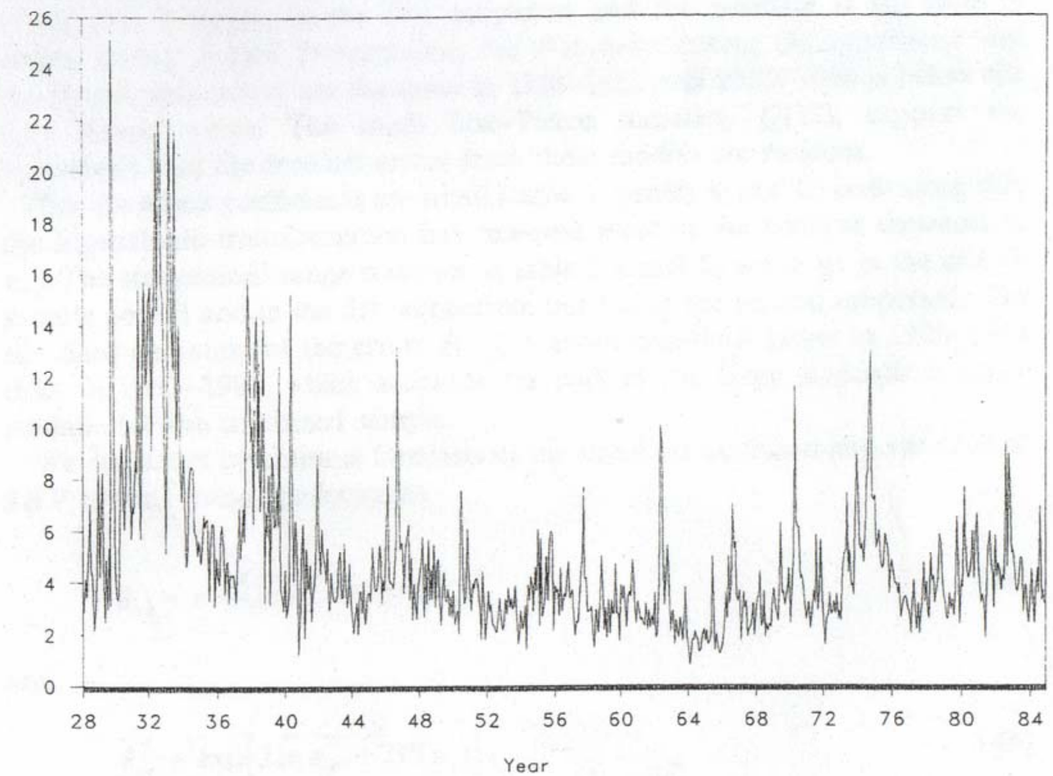

Fig. 1a. Monthly percent standard deviations of the returns to the Standard & Poor's composite portfolio, σ_{mt}, estimated from returns for days i within the month t, r_{it}, 1928–84.

ARCH–Autoregressive Conditional Heteroscedasticity

Engle (`82) & French, Schwert, Stambaugh (`87)

$$ARCH(q): \sigma_t^2 = \omega + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2$$

$$GARCH(p,q): \sigma_t^2 = \omega + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^{p} \beta_j \sigma_{t-j}^2$$

IV. Volatility Models

Table 2

Autoregressive conditional heteroskedasticity (ARCH) models for daily excess holding period returns to the Standard & Poor's composite portfolio.[a]

$$(R_{mt} - R_{ft}) = \alpha + \varepsilon_t - \theta\varepsilon_{t-1} \qquad (5c)$$

$$\sigma_t^2 = a + b\left(\sum_{i=1}^{22} \frac{\varepsilon_{t-1}^2}{22}\right) \qquad (5d)$$

$$\sigma_t^2 = a + b\sigma_{t-1}^2 + c_1\varepsilon_{t-1}^2 + c_2\varepsilon_{t-2}^2 \qquad (5e)$$

ARCH model equations	$\alpha \times 10^3$	$a \times 10^5$	b	c_1	c_2	θ	χ^2 test for stability
(A) January 1928 to December 1984, T = 15,369							
ARCH	0.265	1.006	0.938			−0.142	92.7
(5c), (5d)	(0.061)	(0.048)	(0.012)			(0.007)	
GARCH	0.324	0.062	0.919	0.121	−0.044	−0.157	86.7
(5c), (5e)	(0.063)	(0.005)	(0.002)	(0.007)	(0.007)	(0.007)	
(B) January 1928 to December 1952, T = 7,326							
ARCH	0.405	1.678	0.924			−0.080	
(5c), (5d)	(0.111)	(0.094)	(0.015)			(0.010)	
GARCH	0.496	0.149	0.898	0.106	−0.012	−0.090	
(5c), (5e)	(0.111)	(0.013)	(0.004)	(0.009)	(0.009)	(0.012)	
(C) January 1953 to December 1984, T = 8,043							
ARCH	0.218	0.947	0.856			−0.194	
(5c), (5d)	(0.076)	(0.069)	(0.023)			(0.010)	
GARCH	0.257	0.052	0.922	0.130	−0.060	−0.211	
(5c), (5e)	(0.080)	(0.008)	(0.004)	(0.010)	(0.010)	(0.012)	

[a] $(R_{mt} - R_{ft})$ is the daily excess holding period return to the Standard & Poor's composite portfolio (the percentage price change minus the yield on a short-term default-free government bond). Non-linear optimization techniques are used to calculate maximum likelihood estimates. Asymptotic standard errors are in parentheses under the coefficient estimates. The χ^2 test statistic is distributed χ_4^2 for the ARCH model (5d) and χ_6^2 for the generalized ARCH or GARCH model (5e) under the hypothesis that the parameters are equal in the subperiods.

Financial Econometrics is the Application of Econometric Methods to Financial Markets

- Econometrics: Time Series,GMM,ARCH,..
- Finance:
  - Returns not Predictable?
  - Volatility is Predictable?