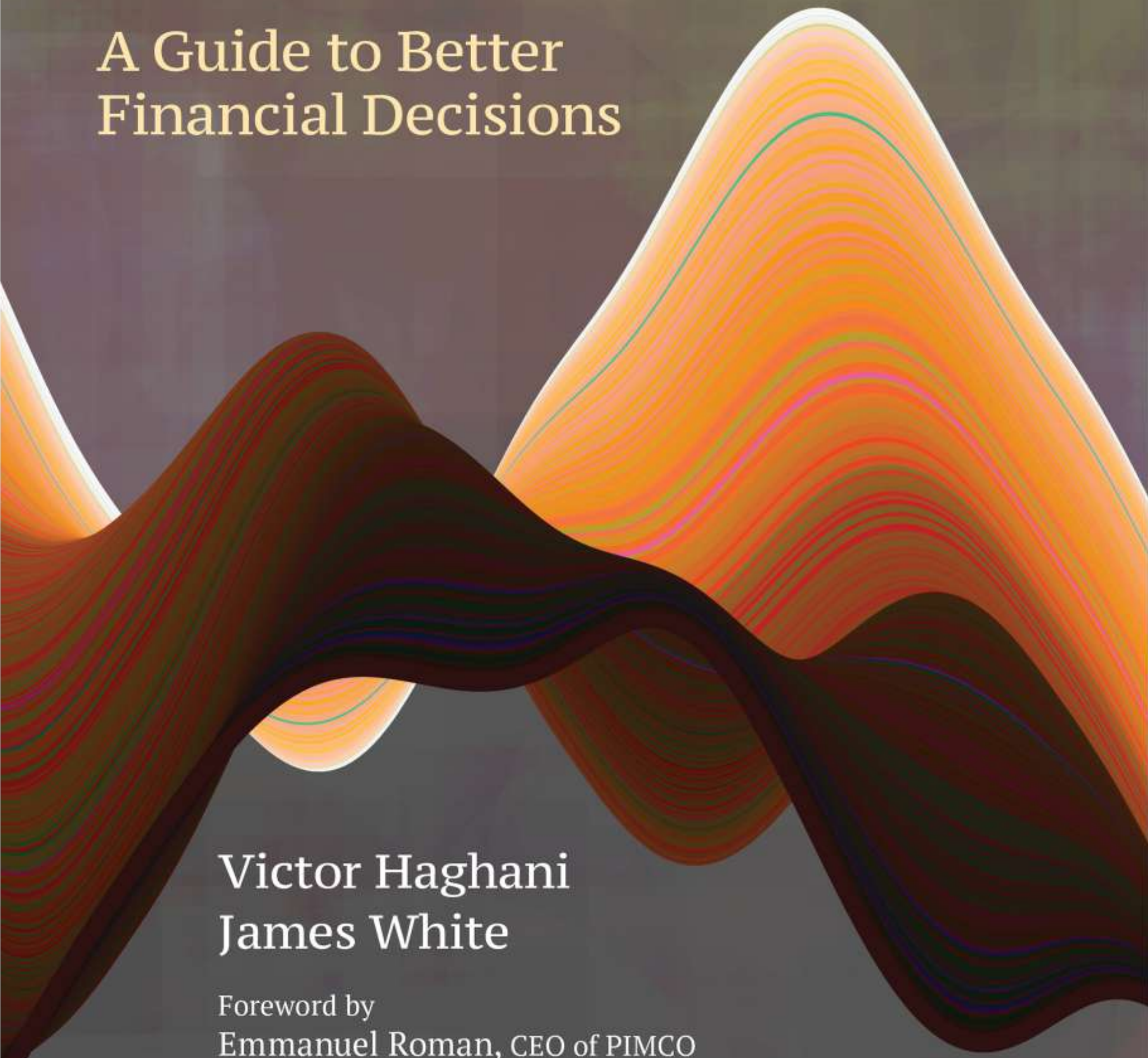
The Missing Billionaires

A Guide to Better Financial Decisions



Victor Haghani
James White

Foreword by
Emmanuel Roman, CEO of PIMCO

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Praise for The Missing Billionaires

"How much investment risk should I take? How much should I spend, and how much should I save? We all want answers to these questions, and financial economists have them, but the answers need to be translated into practical language. That's exactly why you should read this enjoyable and insightful book, to understand and apply the best thinking about risk-taking and lifetime financial planning."

—**John Y. Campbell,** Morton L. and Carole S. Olshan Professor of Economics at Harvard University

"Through years of dialogue with Victor and James, I have put into practice the ideas described in this book, and to great effect. They present a framework which encompasses many of the important principles I have learned through my nearly four decades of trading experience. *The Missing Billionaires* should be required reading at every bank, hedge fund and investment firm focused on enduring success."

—**Alan Howard,** Founder of Brevan Howard

"This book provides a thought-provoking, straightforward introduction to some of the most important questions in personal finance, and an engaging, non-technical description of some of the answers provided by financial economists over the past fifty years."

—**Robert C. Merton,** MIT Sloan School of Management Distinguished Professor of Finance, Nobel Laureate in Economic Sciences

"Haghani and White persuasively explain that to make good decisions under uncertainty, not only must we think probabilistically, but also we must apply those probabilities to the appropriate objective function. Thinking beyond the plight of the 'missing billionaires,' perhaps human history would have followed a gentler and more peaceful path if our leaders had made decisions with the ideas of this book in mind."

—**Philip E. Tetlock,** Annenberg University Professor at the University of Pennsylvania, and co-founder of The Good Judgment Project

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Preface

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Introduction: The Puzzle of the Missing Billionaires

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Befuddled Betting on a Biased Coin

Table 2.1

Betting Strategy	Bet Size	Expected Outcome	Probability of Hitting Max Payout	Probability of Going Bust
Constant Fractional	5%	$218	70%	0%
Constant Fractional	10%	$241	94%	0%
Constant Fractional	20%	$237	94%	0%
Constant Fractional	40%	$176	70%	0%
Constant Absolute	$4	$213	59%	7%
Doubling Down	$2.5	$72	29%	40%

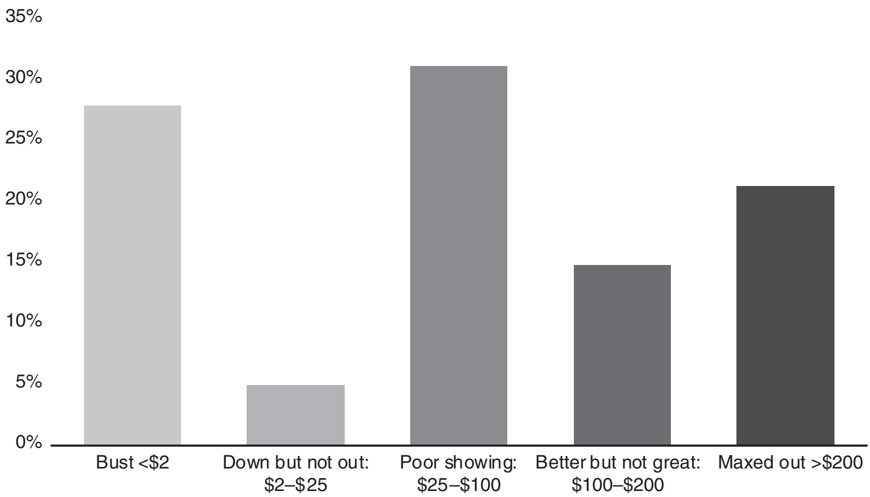

Exhibit 2.1 Summary of Coin Flipper Performance: Betting on a Coin with Disclosed Bias Toward Heads of 60%, $25 Starting Stake, $250 Maximum Payout

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Size Matters When It's for Real

Table 3.1 Calculating Expected Payout

Number of "Heads" Flips	Number of "Tails" Flips	Probability	Ending Wealth	Probability × Wealth
0	5	1.0%	$590,490	$6,047
1	4	7.7%	$721,710	$55,427
2	3	23.0%	$882,090	$203,234
3	2	34.6%	$1,078,110	$372,595
4	1	25.9%	$1,317,690	$341,565
5	0	7.8%	$1,610,510	$125,233
Expected Payout		100.0%		$1,104,081

Table 3.2 Expected Wealth Over a Range of Betting Fractions

Betting Fraction	Expected Wealth After 25 flips
1%	$1,051,219
5%	$1,282,432
10%	$1,640,606
20%	$2,665,836
30%	$4,291,871
40%	$6,848,745
50%	$10,834,706
75%	$32,918,953
100%	$95,396,217

Table 3.3 Most Likely Wealth Over a Range of Betting Fractions

Betting Fraction	Most Likely (Median) Wealth After 25 flips
1%	$1,049,960
5%	$1,244,731
10%	$1,456,516
20%	**$1,654,316**
30%	$1,445,875
40%	$940,661
50%	$427,631
75%	$4,217
100%	$0

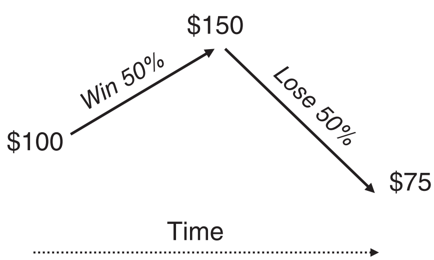

Exhibit 3.1 Illustration of volatility drag

Table 3.4 Betting "Heads" on 25 Flips of a 60/40 Biased Coin, $1mm Starting Wealth

Bet Size (% of Wealth)	1%	5%	10%	20%	40%
Probability of losing 80% or more of starting wealth	Impossible	Impossible	0.005%	3%	27%
Probability of losing 50% or more of starting wealth	Impossible	0.03%	3%	15%	41%
End wealth from winning 13/25 flips	$1,008,789	$1,018,930	$975,023	$732,252	$172,774
End wealth from winning 15/25 flips (median outcome)	$1,049,960	$1,244,731	$1,456,516	$1,654,316	$940,661
Expected final wealth	$1,051,219	$1,282,432	$1,640,606	$2,665,836	$6,848,475

Equation 3.1 Optimal Bet Size

$\gamma = \dfrac{\hat{k}\mu}{\left(\hat{k}\sigma\right)^2}$, which we can simplify and rearrange as:

$$\hat{k} = \frac{\mu}{\gamma\sigma^2}$$

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A Taste of the Merton Share

Equation 4.1 The Merton Share

$\hat{k} = \dfrac{\mu}{\gamma\sigma^2}$ *where* μ *is the expected excess return of the risky investment you're considering,* σ *is the riskiness of that investment expressed as standard deviation of returns, and* γ *is your personal degree of risk-aversion.*

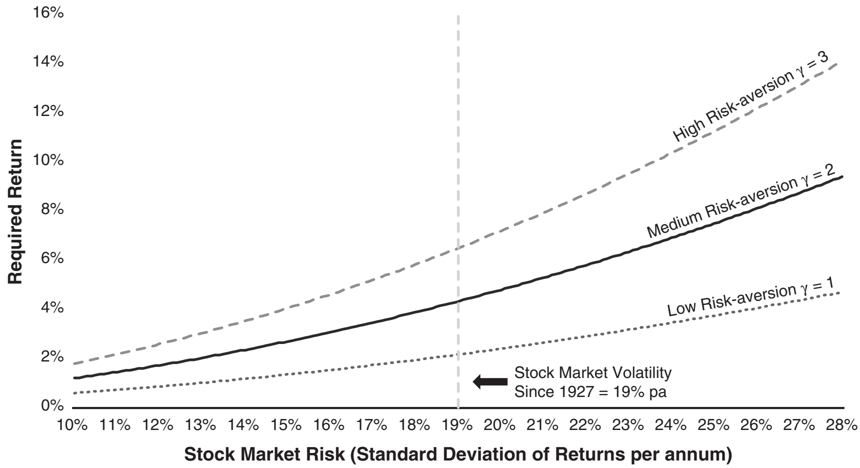

Exhibit 4.1 Return Versus Risk Trade-offs to Justify 60/40 Stock/Bond Allocation Using Merton Share Formula

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How Much to Invest in the Stock Market?

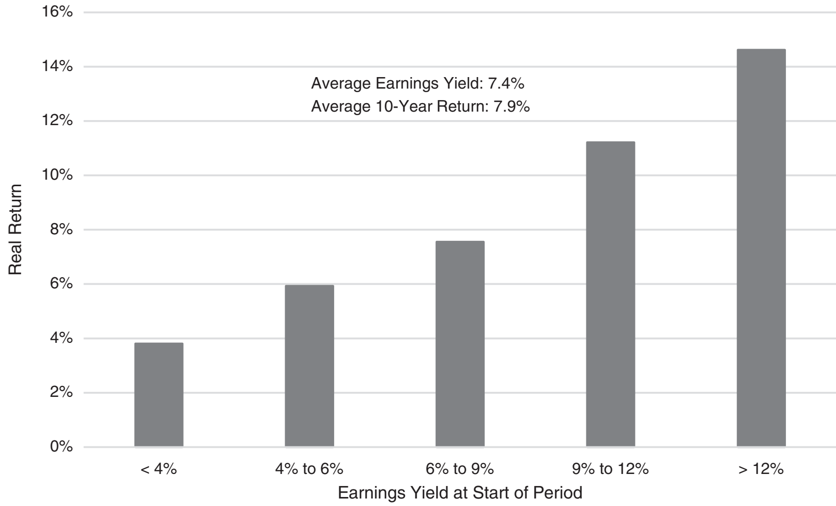


Exhibit 5.1 Next 10-year Realized Real Return Versus Earnings Yield at Start: US Equities 1900–2022

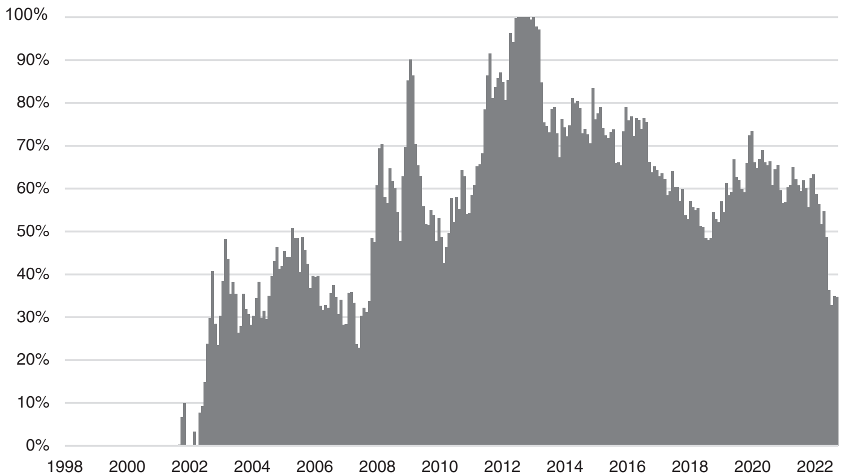


Exhibit 5.2 Allocation to US Equities Based on Merton Share Using Excess Earnings Yield 1997–2022

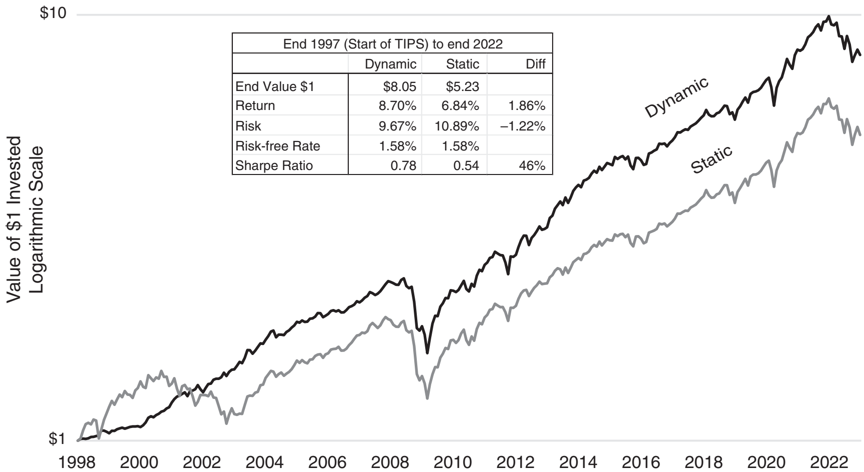


Exhibit 5.3 Excess Earnings Yield Dynamic Versus Static Asset Allocation, US Equities and 10-Year TIPS 1998–2022

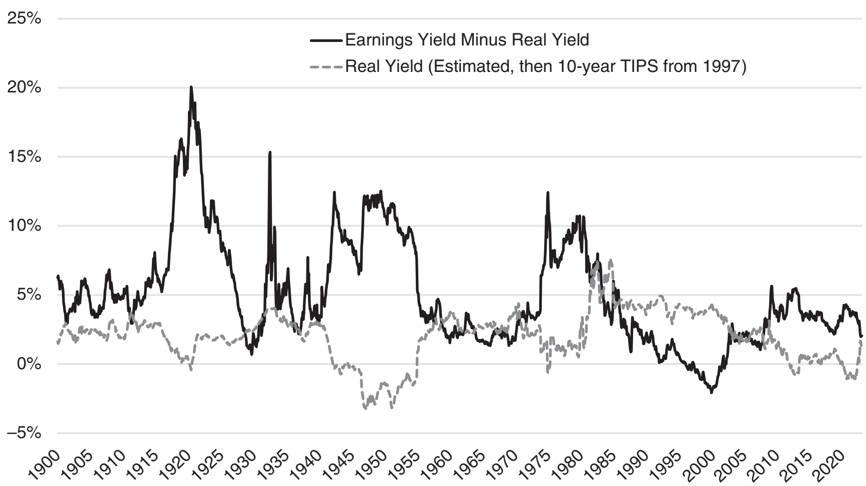
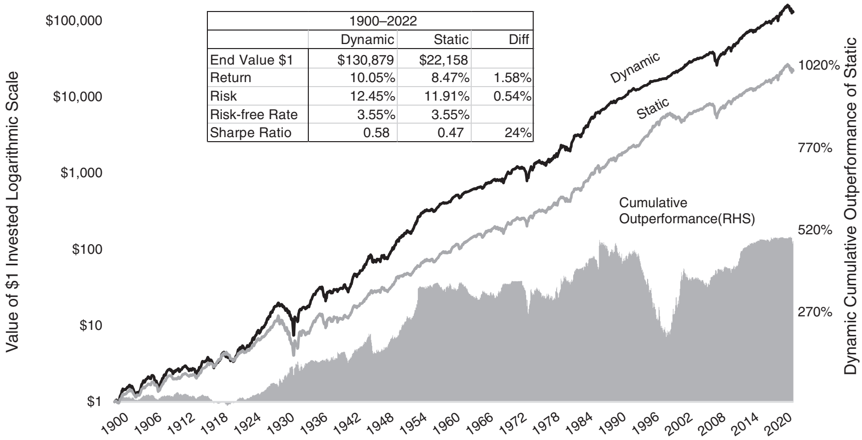
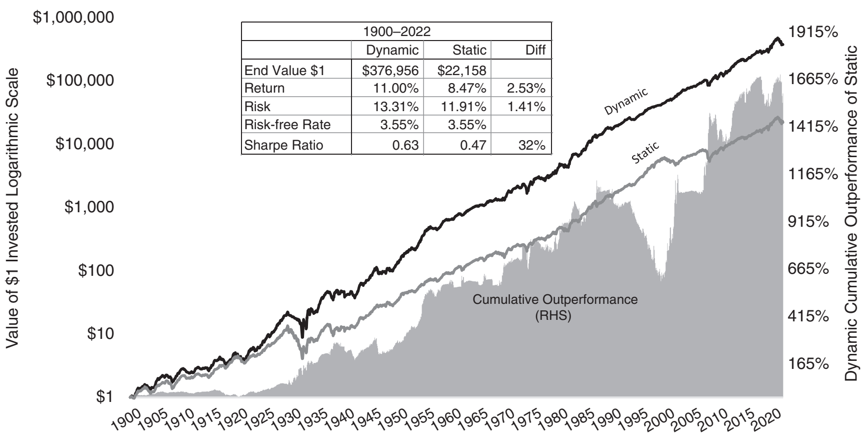


Exhibit 5.4 US Equities: Earnings Yield Minus Real Yield and Real Yield 1900–2022



1900–2022			
	Dynamic	Static	Diff
End Value $1	$130,879	$22,158	
Return	10.05%	8.47%	1.58%
Risk	12.45%	11.91%	0.54%
Risk-free Rate	3.55%	3.55%	
Sharpe Ratio	0.58	0.47	24%

Exhibit 5.5 Excess Earnings Yield Dynamic Versus Static Asset Allocation: US Equities and 10-year TIPS 1900–2022



1900–2022			
	Dynamic	Static	Diff
End Value $1	$376,956	$22,158	
Return	11.00%	8.47%	2.53%
Risk	13.31%	11.91%	1.41%
Risk-free Rate	3.55%	3.55%	
Sharpe Ratio	0.63	0.47	32%

Exhibit 5.6 Excess Earnings Yield Dynamic Versus Static Asset Allocation Using Momentum as Risk Proxy: US Equities and 10-year TIPS 1900–2022

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The Mechanics of Choice

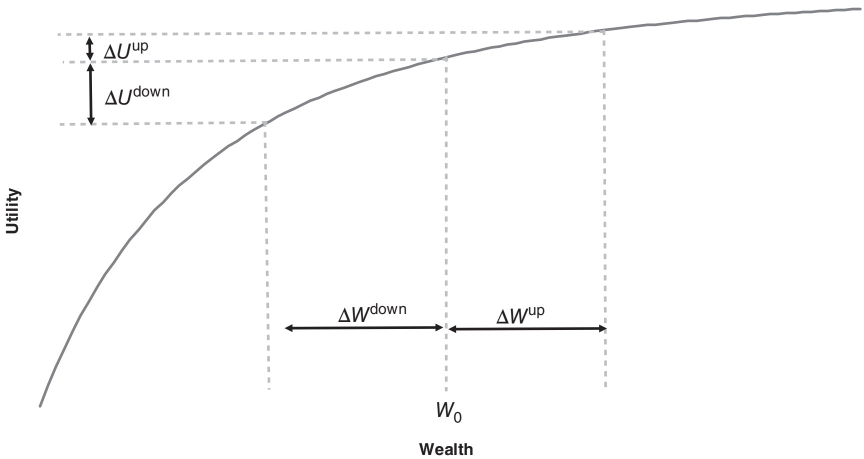

Exhibit 6.1 Concave Utility Curve and Decreasing Marginal Utility of Wealth

Table 6.1 Expected Utility of St. Petersburg Game

Num Heads in a Row	Probability	Payoff	Prob × Payoff	Wealth	Util(W) = ln(W)	Prob × Utility
0	50%	$2	$1	$100,002	11.5129	5.75647
4	3.125%	$32	$1	$100,032	11.5132	0.35979
10	0.049%	$2,048	$1	$102,048	11.5332	0.00563
20	0.000048%	$2.1 mm	$1	$2.2 mm	14.6027	0.00001
40	0.00000000005%	$2.2 tn	$1	$2.2 tn	28.4190	0.00000000001
Sum of Probability × Payoff			Infinity			
Sum of Probability × Utility						11.51310
Wealth Equivalent to Expected Utility: $e^{11.51310}$						$100,018
Starting Wealth						$100,000
Utility of Starting Wealth: ln(100,000)						11.51293
Increase in Utility from Playing						0.00018
Maximum Amount Willing to Pay to Play						$18

Equation 6.1 CRRA Utility

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

where γ is the parameter that dials the level of risk-aversion and W is your wealth.

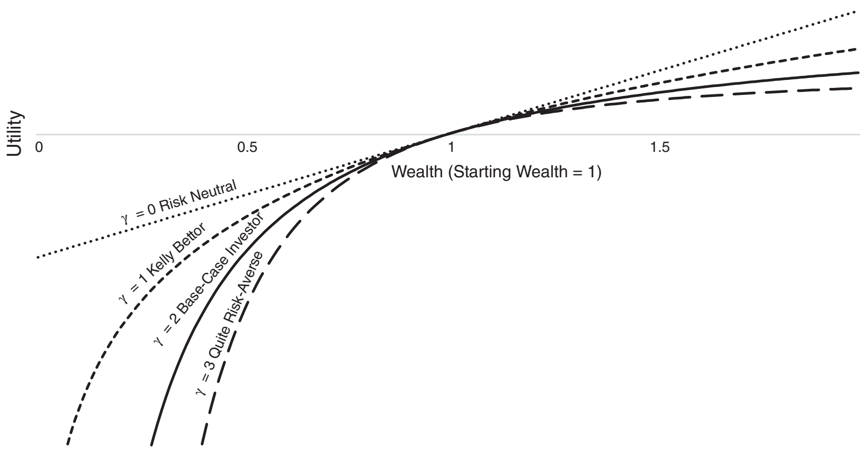

Exhibit 6.2 Constant Relative Risk-aversion Utility With Different Levels of Individual Risk-aversion

Table 6.2

Probability of heads	60%
Number of Bets	25
Starting Wealth ($mm)	1
Bet Size	10%
Risk-aversion (CRRA)	2

Number of Winning Bets (Heads)	**Probability**	**Profit ($mm)**	**End Wealth ($mm)**	**Utility of End Wealth**
0	0.00000001%	(0.93)	0.07	–12.930
1	0.0000004%	(0.91)	0.09	–10.397
2	0.00001%	(0.89)	0.11	–8.325
3	0.0001%	(0.87)	0.13	–6.629
4	0.0007%	(0.84)	0.16	–5.242
5	0.005%	(0.80)	0.20	–4.107
6	0.023%	(0.76)	0.24	–3.179
7	0.092%	(0.71)	0.29	–2.419
8	0.312%	(0.64)	0.36	–1.797
9	0.884%	(0.56)	0.44	–1.289
10	2.122%	(0.47)	0.53	–0.873
11	4.341%	(0.35)	0.65	–0.532
12	7.597%	(0.20)	0.80	–0.254
13	11.395%	(0.02)	0.98	–0.026
14	14.651%	0.19	1.19	0.161
15	16.116%	0.46	1.46	0.313
16	15.109%	0.78	1.78	0.438
17	11.998%	1.18	2.18	0.540
18	7.999%	1.66	2.66	0.624
19	4.420%	2.25	3.25	0.692
20	1.989%	2.97	3.97	0.748
21	0.710%	3.86	4.86	0.794
22	0.194%	4.93	5.93	0.831
23	0.038%	6.25	7.25	0.862
24	0.005%	7.86	8.86	0.887
25	0.0003%	9.83	10.83	0.908
Expectation		0.64	1.64	0.224

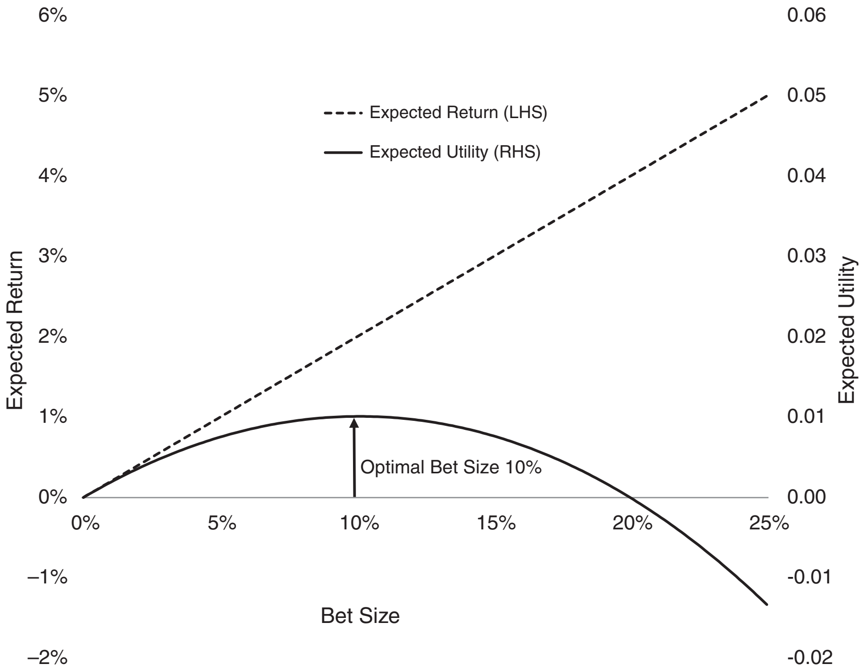

Exhibit 6.3 Expected Return and Utility over a Range of Bet Sizes For a Single Toss

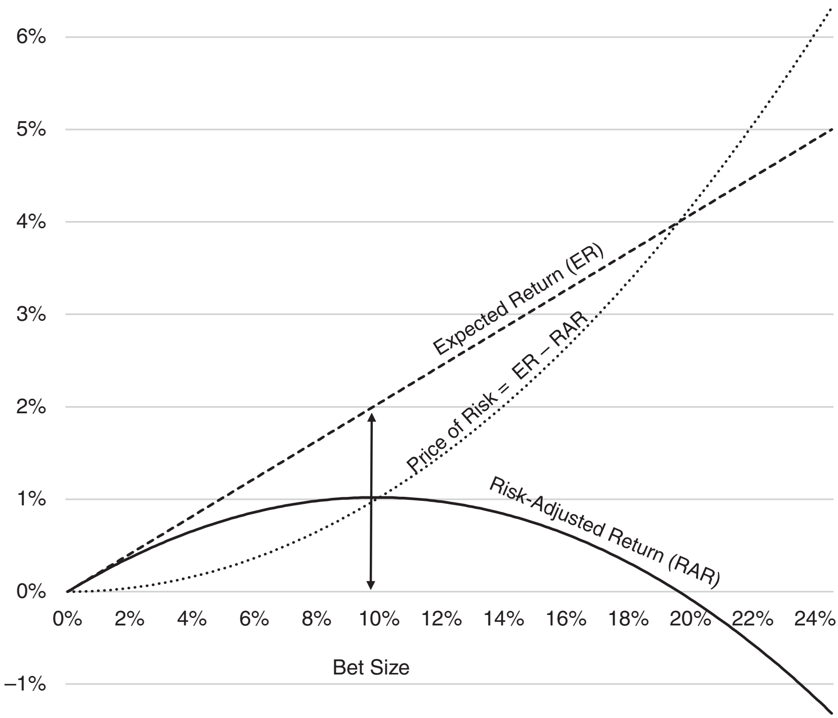

Exhibit 6.4 Expected Return, RAR and Price of Risk Over Range of Bet Sizes For One Toss

Equation 6.2 Risk-Adjusted Return

$$\textit{Risk-adjusted Excess Return} = k\mu - \frac{\gamma\left(k\sigma\right)^2}{2}$$

Equations 6.3 and 6.4 Restating optimal investment size and Risk-adjusted Excess Return in terms of Sharpe ratio

$\hat{k} = \frac{SR}{\gamma\sigma}$ where $\hat{k}$ is the optimal fraction of wealth to invest in the risky asset, SR is the Sharpe ratio, σ is the risk measured in standard deviation and γ is the investor's coefficient of risk-aversion.

And for the risk-adjusted excess return of the optimal portfolio, we get:

$$Risk\text{-}adjusted\ \ Excess\ \ Return = \frac{SR^2}{2\gamma}$$

Table 6.3 Three Investments with Same Expected Gain and Risk but Varying Symmetry of Payoffs

	Positively Asymmetric	**Symmetric**	**Negatively Asymmetric**
Probability of Profit	20%	50%	80%
Probability of Loss	80%	50%	20%
Profit	45%	25%	15%
Loss	–5%	–15%	–35%
Expected Gain	5%	5%	5%
Risk	20%	20%	20%
Sharpe Ratio	0.25	0.25	0.25

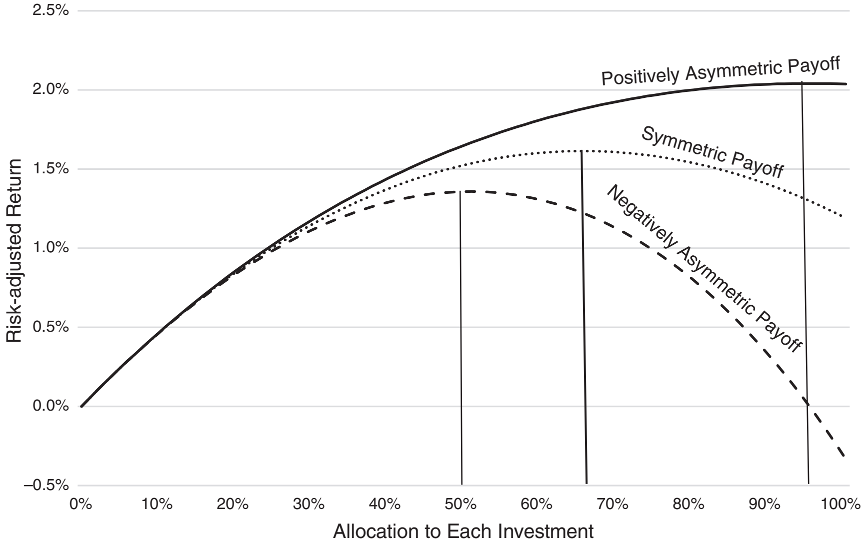

Exhibit 6.5 Impact of Investment Symmetry on Risk-adjusted Return

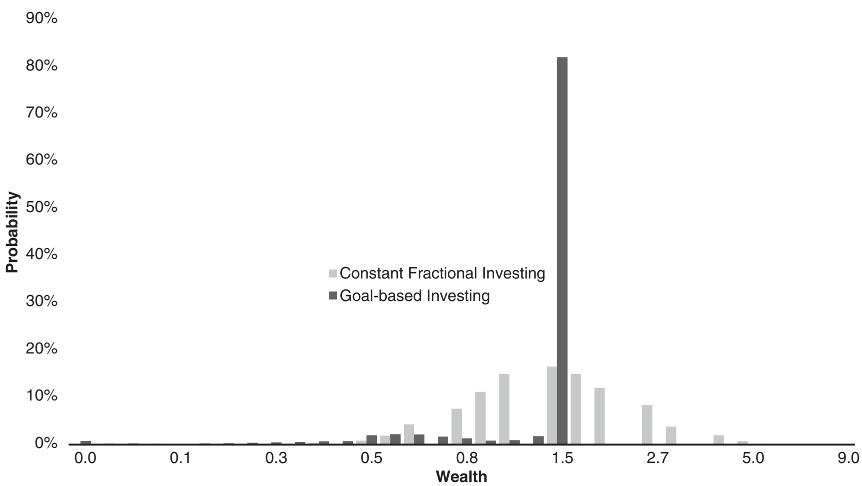

Exhibit 6.6 Comparing Wealth Outcomes for Goal-based Investing Versus Constant Risk Investing, Starting Wealth = 1

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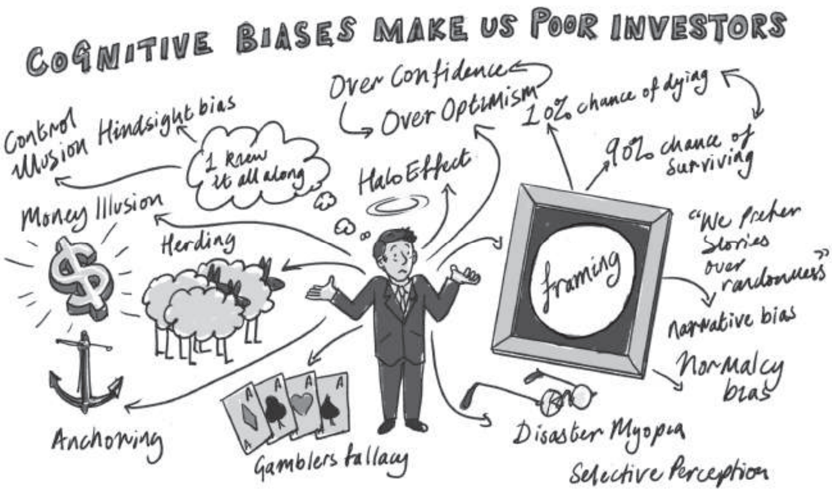
Criticisms of Expected Utility Decision-making



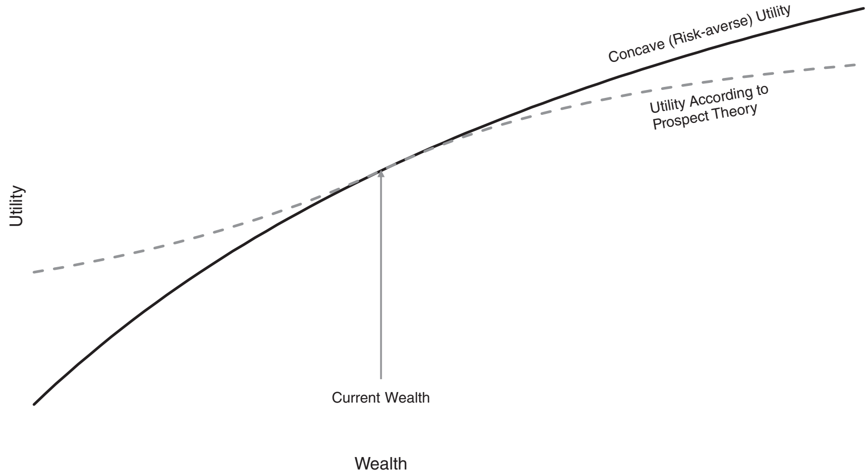


Exhibit 7.1 Prospect Theory Versus Classical Utility Preferences

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Reminiscences of a Hedge Fund Operator

Table 8.1 Assumptions Needed for Expected Utility Analysis

Assumptions	
Risk-free rate	5%
Expected fund return with no incentive fee	20%
Standard deviation of fund return in normal times	15%
Annual probability of 90% fund loss	0.5%
Management company expected return	15%
Standard deviation of management company in normal times	25%
Loss in value of management company if fund loses 90%	100%
Fraction of total net worth in the management company	50%
Victor's personal degree of CRRA risk-aversion	2

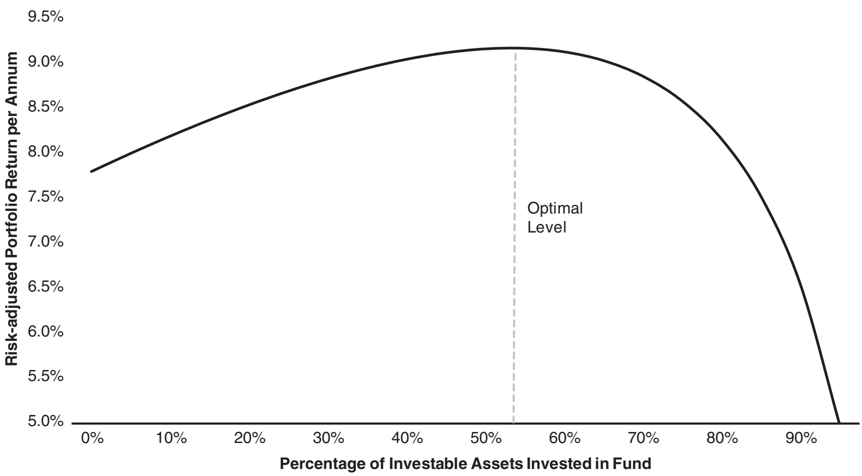

Exhibit 8.1 Risk-adjusted Return as Function of Percentage of Liquid Wealth Invested in Fund

9

Spending and Investing in Retirement

Table 9.1 Sam Case Study: 65 Years Old, Retired, $1mm of Savings, 20 Years to Live, Can Only Invest in a Risk-Free Asset Paying 3% After-tax and Above Inflation, Discounts Future Utility of Consumption by 2% per Year, Has CRRA Utility with γ = 2 Risk-aversion

Age	Wealth ($)	Risk-Free Income ($)	Spending (%)	Spending ($)	Utility of Spending	Discounted Utility of Spending
65	1,000,000					
66	965,547	30,000	6.3%	64,453	0.8448	0.8283
67	929,744	28,966	6.5%	64,769	0.8456	0.8128
68	892,551	27,892	6.8%	65,084	0.8464	0.7975
69	853,925	26,777	7.1%	65,403	0.8471	0.7826
70	813,820	25,618	7.5%	65,723	0.8478	0.7679
71	772,189	24,415	7.9%	66,045	0.8486	0.7535
72	728,986	23,166	8.3%	66,369	0.8493	0.7394
73	684,163	21,870	8.9%	66,693	0.8501	0.7255
74	637,669	20,525	9.5%	67,019	0.8508	0.7119
75	589,453	19,130	10.3%	67,346	0.8515	0.6985
76	539,462	17,684	11.1%	67,675	0.8522	0.6854
77	487,641	16,184	12.2%	68,005	0.8530	0.6725
78	433,932	14,629	13.6%	68,338	0.8537	0.6599
79	378,278	13,018	15.4%	68,672	0.8544	0.6475
80	320,617	11,348	17.7%	69,009	0.8551	0.6353
81	260,888	9,619	21.0%	69,347	0.8558	0.6234
82	199,028	7,827	25.9%	69,687	0.8565	0.6117
83	134,972	5,971	34.2%	70,028	0.8572	0.6002
84	68,652	4,049	50.6%	70,369	0.8579	0.5889
85	0	2,060	100.0%	70,711	0.8586	0.5778
Total Lifetime Spending				$1,350,745		
Sum of Discounted Annual Utility of Spending						13.9207

Equation 9.1 Optimal spending to a very long horizon

$$\hat{c}_\infty = r_{ra} - \frac{r_{ra} - r_{tp}}{\gamma}$$

where

$\hat{c}_\infty$ is the long (infinite) horizon optimal spending rate,
r_{ra} is the Risk-Adjusted Return of the optimal portfolio,
r_{tp} is the investor's rate of time preference, and
γ is the investor's level of constant relative risk-aversion.

Equation 9.2 Optimal spending for finite horizon

$$\hat{c}_t = \frac{\hat{c}_\infty}{1-\left(1+\hat{c}_\infty\right)^{-T}}$$

Equation 9.3 Bequest function

$$U(Bequest) = \frac{b\left(1-\left(\frac{w}{b}\right)^{(1-\gamma)}\right)}{\gamma - 1}.$$

Table 9.2 Assumptions Behind Sam's Optimal Investment and Spending Policy

Starting wealth	$1,000,000
Fraction in Roth IRA	40%
Risk-aversion level	2
Rate of time preference	2%
Average tax rate	20%
Safe asset return	4%
Stock market expected return	9%
Stock market risk	20%
Inflation Rate	2%

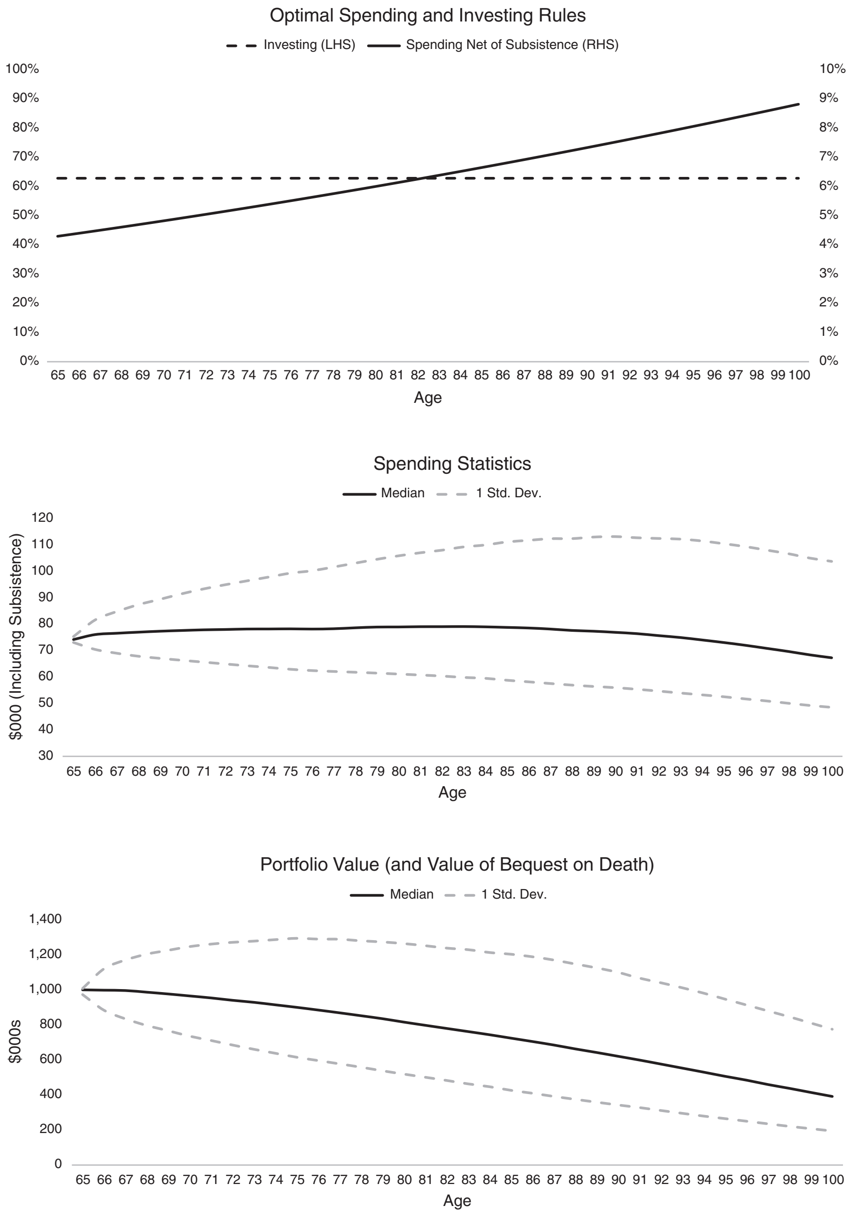

Exhibit 9.1 Spending and Investing Rules and Spending and Portfolio Value Statistics

Table 9.3 Sam: Fixed Spending vs Utility Optimal Variable Spending (60% in US Stocks, 40% in T-Bills)

	S&P 500 Return	**Wealth 5% Spending Rule**	**Fixed Real Spend per 5% Rule**	**Wealth Utility Opt Plan**	**Utility Opt Spend**	**Utility Opt Spend**
1999		$1,000,000		$1,000,000		
2000	-9.7%	$916,247	$50,000	$923,019	**4.3%**	$42,979
2001	-11.8%	$809,334	$51,693	$826,041	**4.4%**	$40,618
2002	-21.6%	$662,400	$52,496	$690,400	**4.5%**	$37,211
2003	28.2%	$713,782	$53,743	$772,316	**4.6%**	$31,831
2004	10.7%	$707,082	$54,753	$789,537	**4.7%**	$36,436
2005	4.8%	$679,762	$56,536	$785,175	**4.8%**	$38,108
2006	15.8%	$692,503	$58,467	$831,956	**4.9%**	$38,765
2007	5.1%	$660,027	$59,952	$824,263	**5.0%**	$42,007
2008	-36.8%	$465,904	$62,399	$609,412	**5.2%**	$42,555
2009	26.4%	$467,423	$62,456	$668,782	**5.3%**	$32,164
2010	15.1%	$439,705	$64,156	$689,873	**5.4%**	$36,078
2011	1.9%	$378,901	$65,116	$659,343	**5.5%**	$38,032
2012	16.0%	$341,855	$67,045	$682,056	**5.6%**	$37,139
2013	32.3%	$326,729	$68,212	$767,510	**5.8%**	$39,247
2014	13.5%	$278,446	$69,236	$781,187	**5.9%**	$45,108
2015	1.2%	$210,632	$69,760	$741,150	**6.0%**	$46,885
2016	12.0%	$151,759	$70,269	$752,218	**6.1%**	$45,417
2017	21.7%	$90,889	$71,727	$800,819	**6.3%**	$47,056
2018	-4.6%	$17,272	$73,239	$733,649	**6.4%**	$51,131
2019	31.2%	$0	$17,272	$814,514	**6.5%**	$47,802
2020	18.3%	$0	$0	$844,134	**6.6%**	$54,149
2021	28.7%	$0	$0	$922,212	**6.8%**	$57,249
2022	-18.2%	$0	$0	**$884,418**	**6.9%**	$56,344
Avg Equity Return	7.84%					
Avg T-Bill Return	1.36%					
Avg Inflation	2.51%					
Total Spending			$1,198,528			$984,314
Total Spending + Wealth at End			$1,198,528			$1,868,733

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Spending Like You'll Live Forever

Table 10.1 Investment Environment and Policy Assumptions

Long-term risk-free real rate	0%
Expected real return on a well-chosen mix of public and private market risky assets	6%
Risky assets annual variability of returns	18%
Endowment asset allocation	90% in risky assets 10% in risk-free assets
Endowment expected return	5.4%

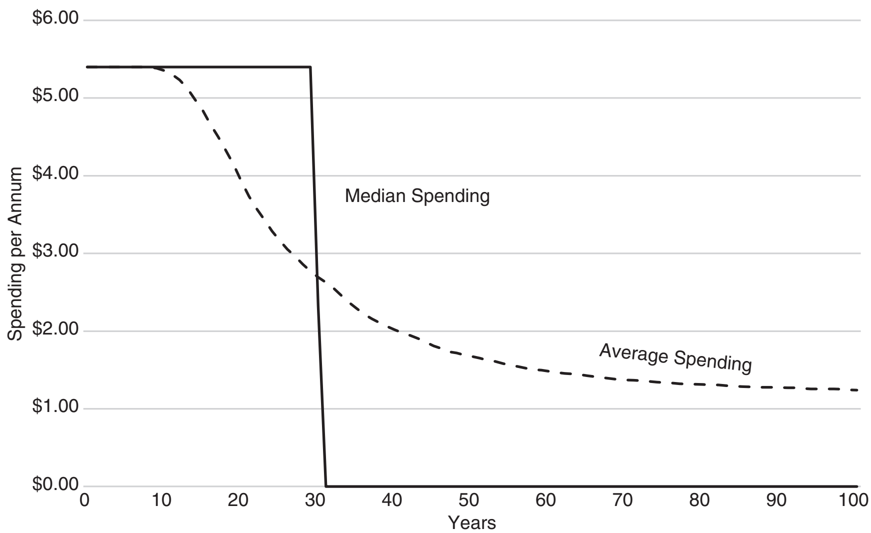

Exhibit 10.1 Policy 1: Spend a Fixed Annual Amount Equal to the Expected Simple Return of the Portfolio

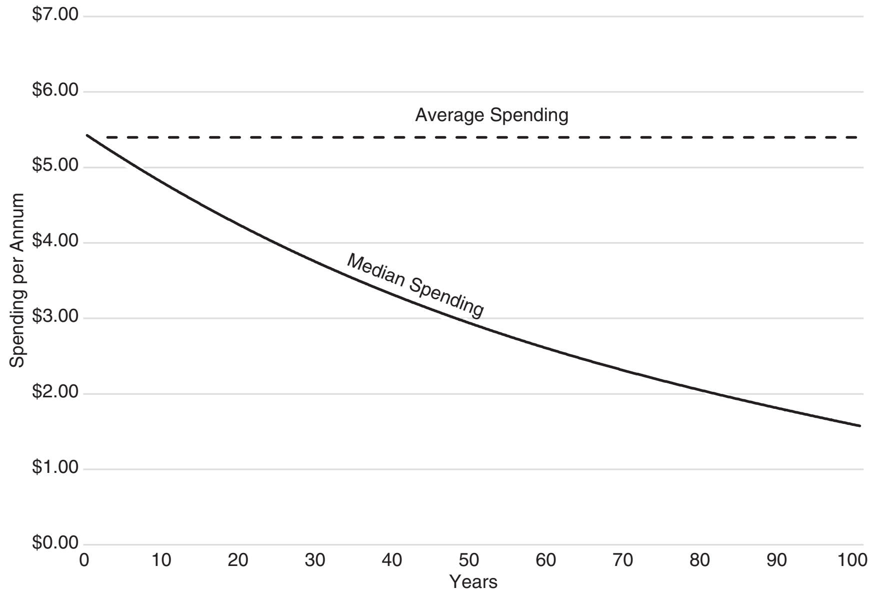

Exhibit 10.2 Policy 2: Spend a Fixed Annual Percentage of the Endowment Value Equal to the Expected Return of the Portfolio

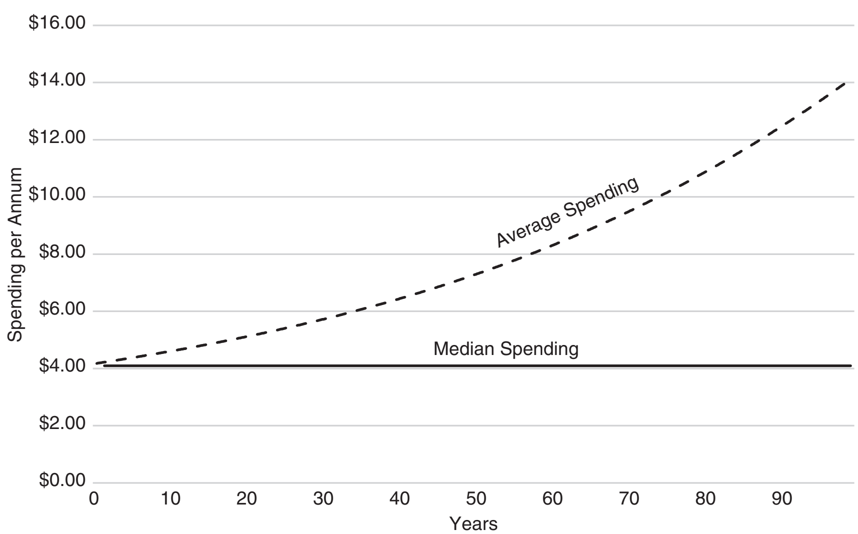

Exhibit 10.3 Policy 3: Spend a Fixed Annual Percentage of the Endowment Value Equal to the Expected Compound Return of the Portfolio

Table 10.2 Comparing Spending Rules: Size of Endowment Needed to Generate Equal Welfare Over 100 Years Under Different Spending Policies

Rule 1: Spend $5.40 per annum	Rule 2: Spend 5.4% per annum	Rule 3: Spend 4.1% per annum
$172	$152	$100

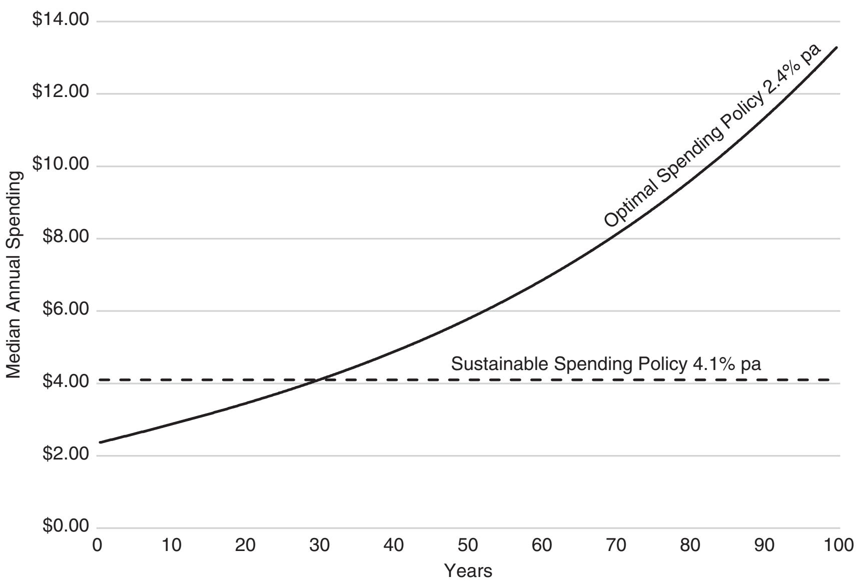

Exhibit 10.4 Median Spending Under Optimal and Sustainable Spending Policies

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Spending Like You Won't *Live Forever*

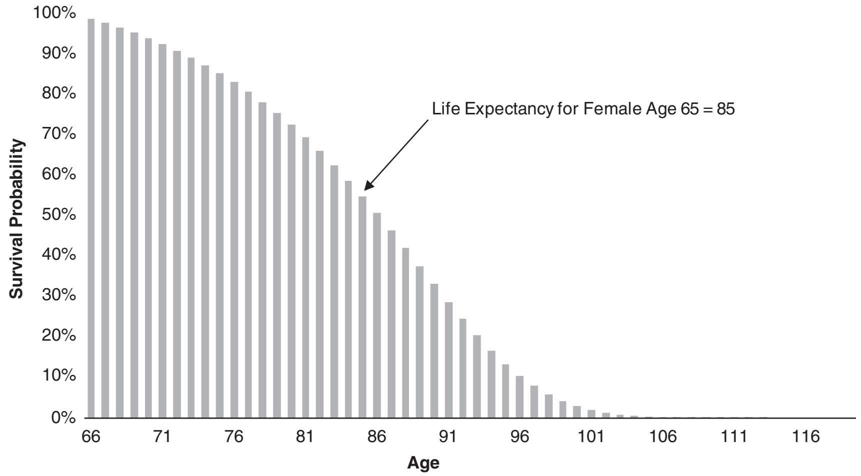

Exhibit 11.1 Longevity Probabilities for 65-year-old Female From US Social Security Mortality Tables (2015)

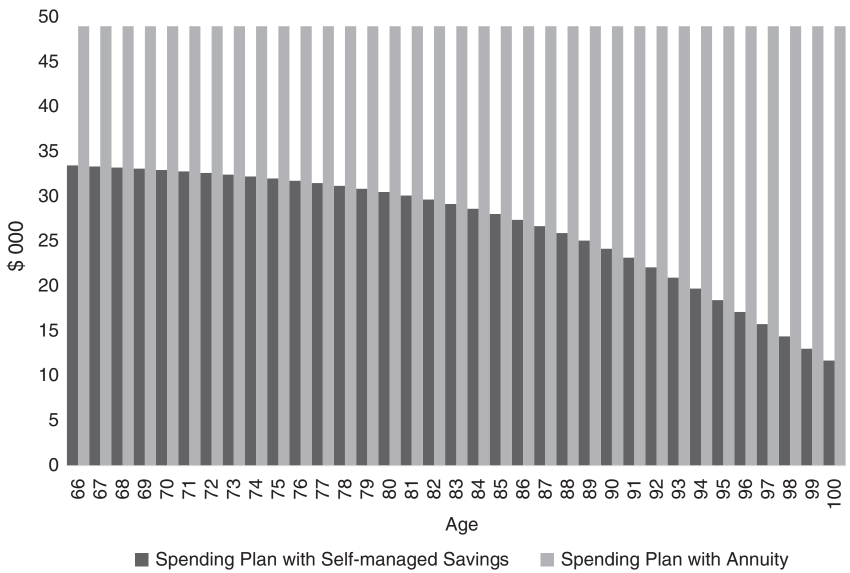

Exhibit 11.2 Comparing Self-Managed Versus Annuity Annual Expenditure for Sam Age 65

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Measuring the Fabric of Felicity

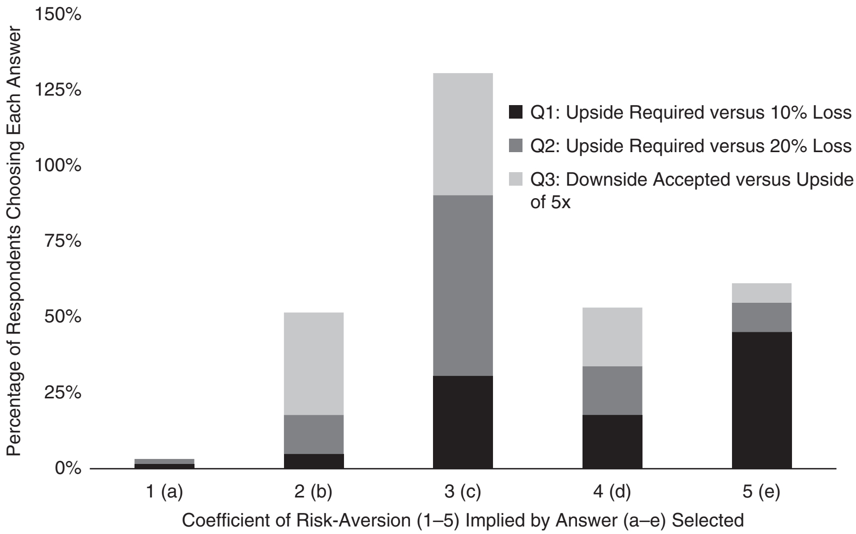

Exhibit 12.1 Survey Responses

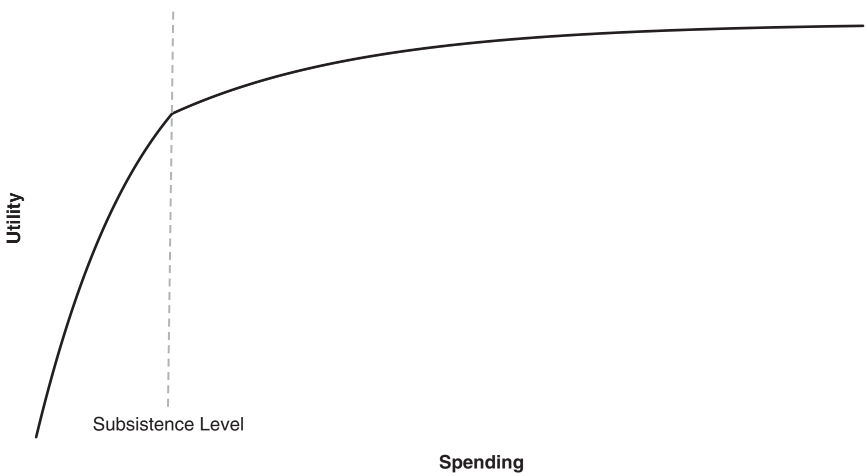

Exhibit 12.2 Utility Curve With Higher Risk-aversion Below Subsistence Level

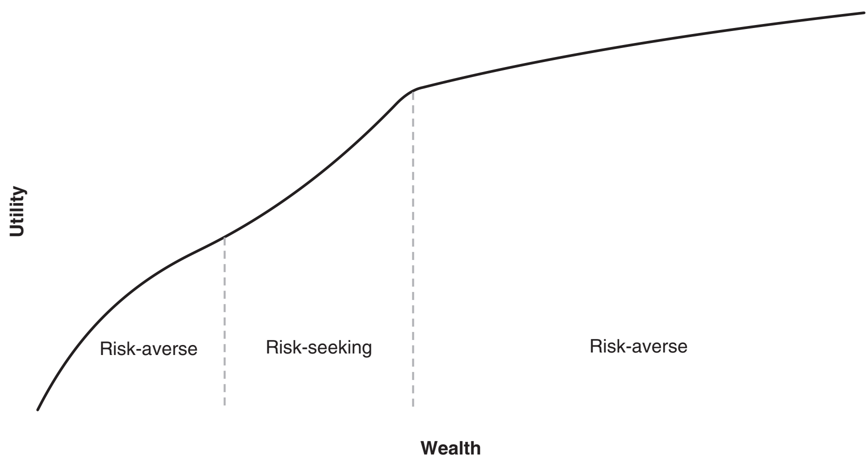

Exhibit 12.3 Friedman-Savage Utility Curve Incorporating Intermediate Range of Risk-seeking

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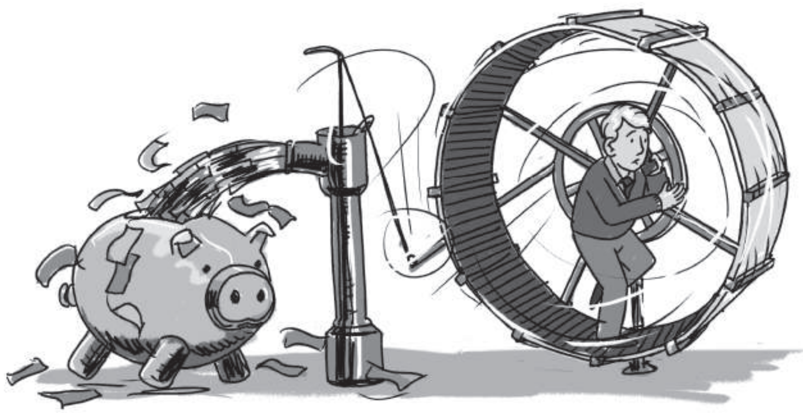
Human Capital



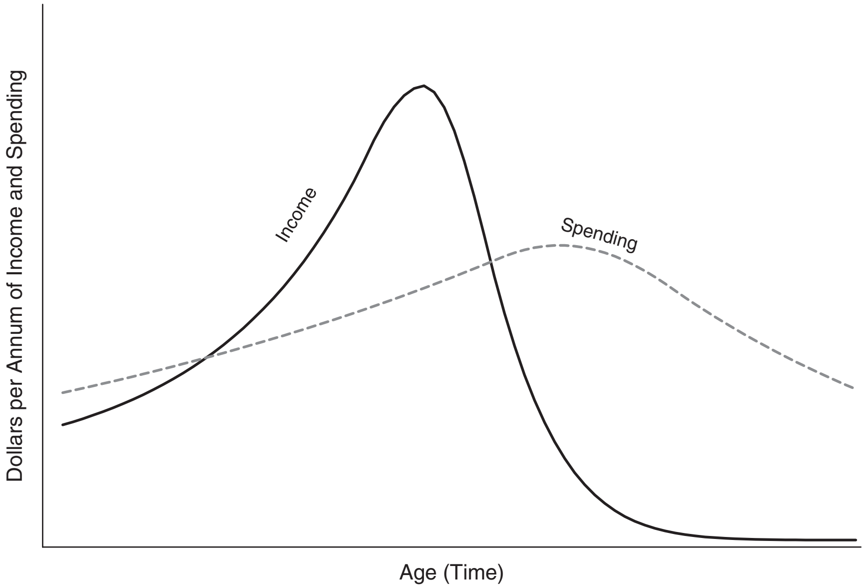


Exhibit 13.1 Typical Lifetime Earning and Spending Pattern

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Into the Weeds: Characteristics of Major Asset Classes

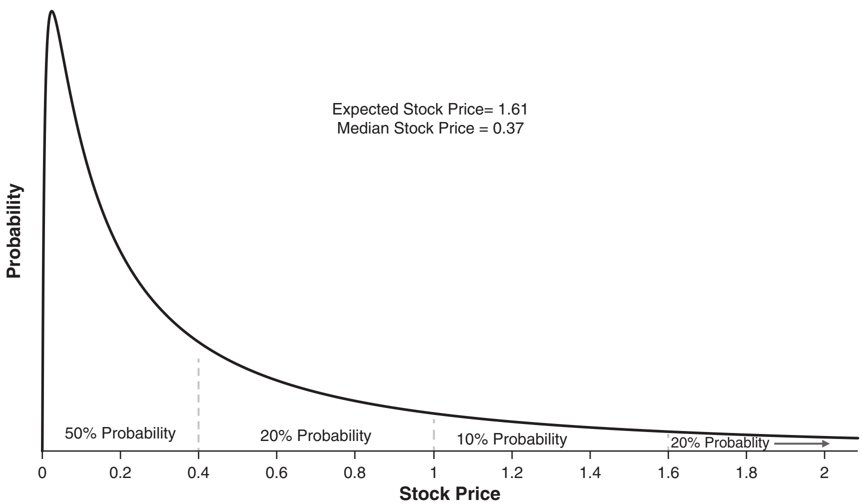

Exhibit 14.1 Stock Price Probability Distribution: 10% per Annum Expected Excess Return, 75% Annual Standard Deviation, 5-year Horizon

15

No Place to Hide: Investing in a World with No Safe Asset

Exhibit 15.1 US T-bills Are Far from Risk-free: Constant Standard of Living 30-year Annuity in 1997 Dollars (1997–2022)

16

What About Options?

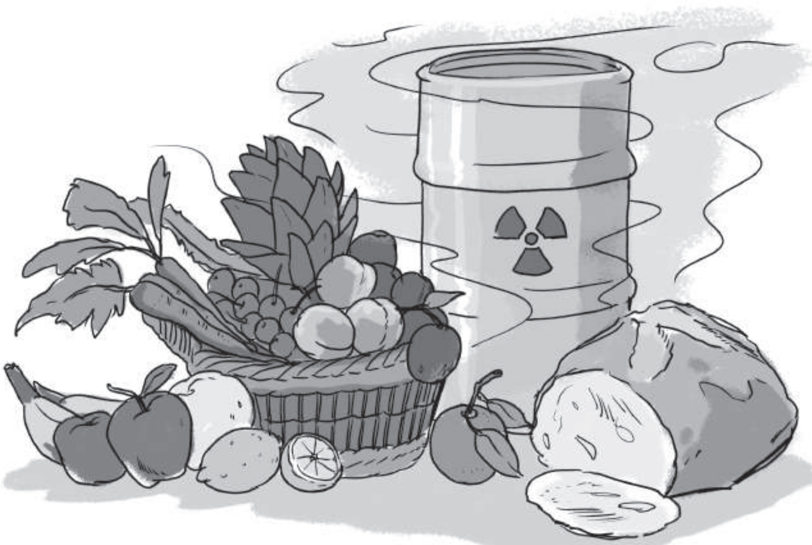

Table 16.1 Base-Case Investor Assumptions

Equities Expected Arithmetic Return	5%
Equities Annual Volatility	20%
Safe Asset Return	0%
Investor CRRA Risk-Aversion	2

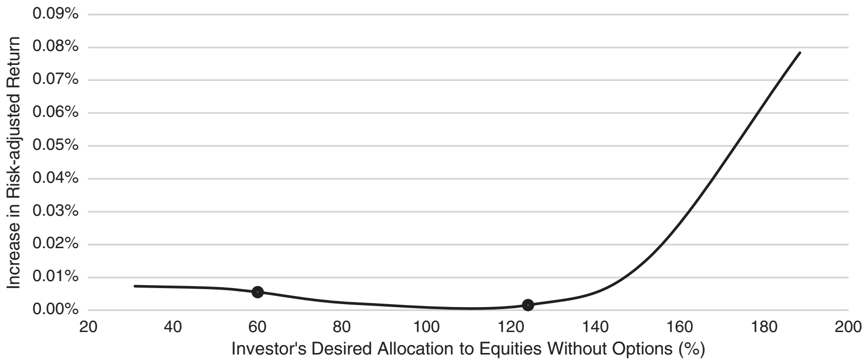

Exhibit 16.1 Contribution of Puts Versus Portfolio Leverage: Increase in Risk-adjusted Return for Optimal Portfolios With Versus Without Put Options

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Tax Matters

Table 17.1 Assumptions for Capital Gains Tax Realization Decision

Current Equity Allocation	75%	Horizon (years)	20
Unrealized Gains % of Portfolio	50%	Risk-free Rate	3%
Capital Gains Tax Rate Today	30%	Stock Market Expected Return	6%
Capital Gains Tax Rate at Horizon	30%	Stock Market Risk	20%
Tax on Equity Dividends	30%	Stock Market Dividend Rate	2%
Tax on Interest	50%	Investor Risk-Aversion (CRRA)	2
Future Value of Capital Losses*	0		

*If a capital loss arises at the horizon, for simplicity we assume the investor derives no future value from this loss as a carryforward.

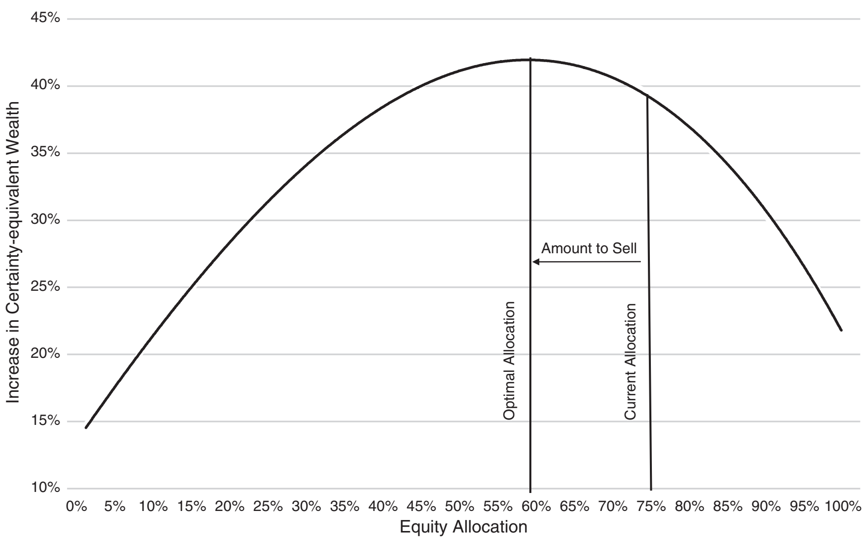

Exhibit 17.1 How Much Appreciated Asset to Sell?

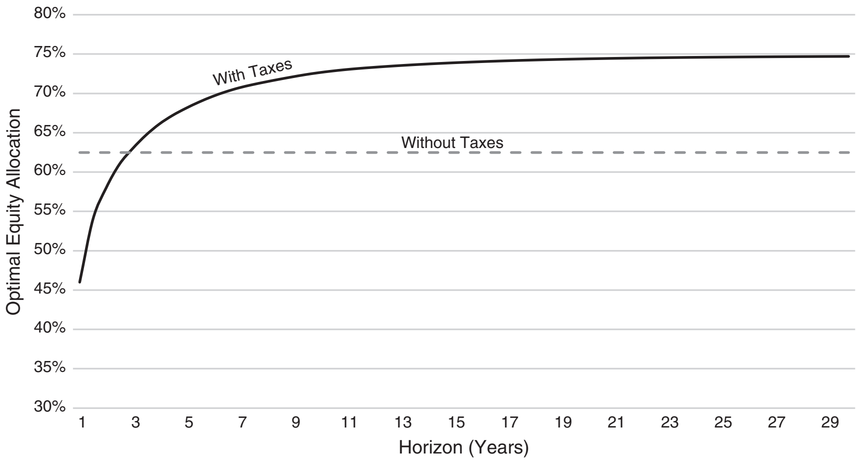

Exhibit 17.2 Optimal Equity Allocation With and Without Taxes for Different Horizons

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Risk Versus Uncertainty

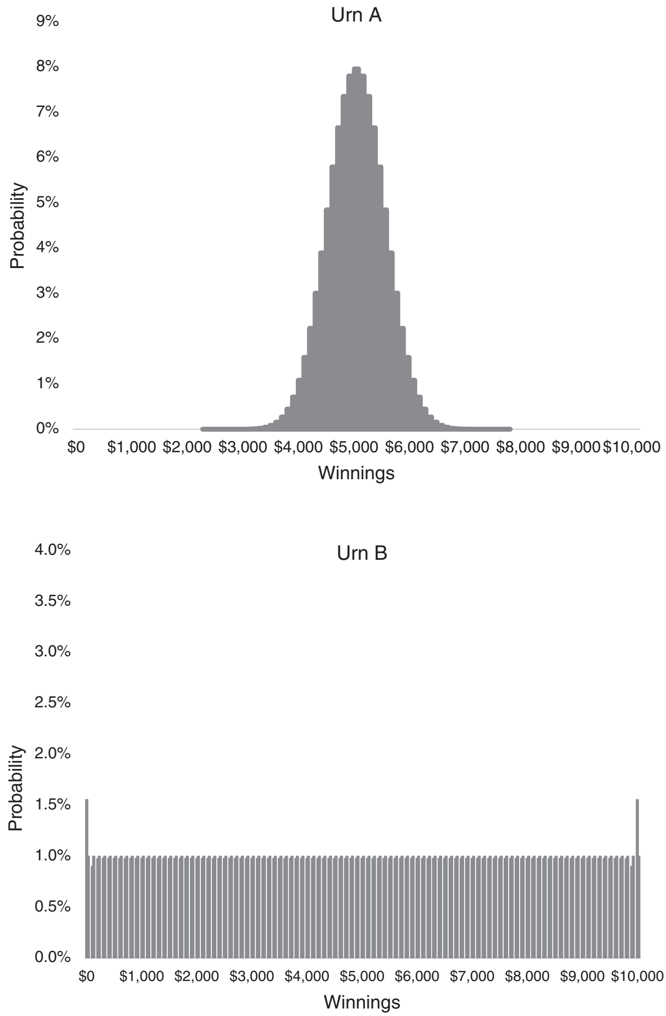

Exhibit 18.1 Multi-Round Ellsberg Experiment: $100 Prize for Choosing Red Ball, Choosing 100 Rounds from Urn A or from Urn B, Urn A: 50 Red and 50 Black Balls, Urn B: 100 Balls, Uniformly Likely Combinations of 0—100 Red and Rest Black

Table 18.1

	Asset A				Asset B			
Horizon	**Opt Alloc**	**Return of Exp Price**	**Exp Comp Return**	**Vol**	**Opt Alloc**	**Return of Exp Price**	**Exp Comp Return**	**Vol**
1y	62.5%	5.0%	3.0%	20.0%	62.2%	5.0%	3.0%	20.1%
5y	62.5%	5.0%	3.0%	20.0%	60.9%	5.1%	3.0%	20.5%
10y	62.5%	5.0%	3.0%	20.0%	59.5%	5.2%	3.0%	21.0%
30y	62.5%	5.0%	3.0%	20.0%	54.5%	5.6%	3.0%	22.8%
100y	62.5%	5.0%	3.0%	20.0%	44.5%	6.3%	3.0%	28.2%

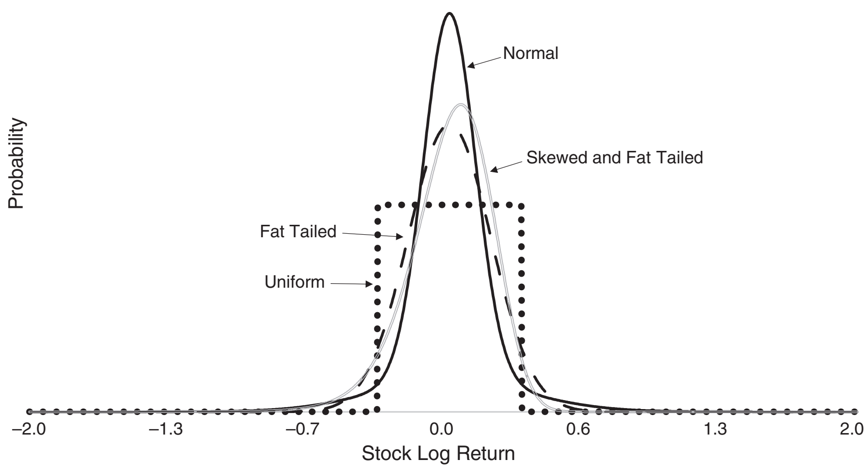

Exhibit 18.2 Less than 1% Difference in Optimal Allocation to Equities Under These Four Different Probability Distributions of Stock Price Returns, All with the Same Expected Return (5%) and Risk (20%) for Investor with Risk-aversion of 2

19

How Can a Great Lottery Be a Bad Bet?

20

The Equity Risk Premium Puzzle

Equations 20.1, 20.2 and 20.3 Equilibria in fish economy

$$r_{bond} = \delta + \gamma\left(\mu - (1+\gamma)\frac{\sigma^2}{2}\right)$$

$$r_{stock} = \delta + \gamma\left(\mu - (\gamma - 1)\frac{\sigma^2}{2}\right)$$

$$Equity\ Risk\ Premium = r_{stock} - r_{bond} = \gamma\sigma^2$$

μ is the expected growth of the economy, σ is the variability in that growth, γ is the coefficient of risk-aversion, and δ is the time preference of the representative individual.

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The Perpetuity Paradox and Negative Interest Rates

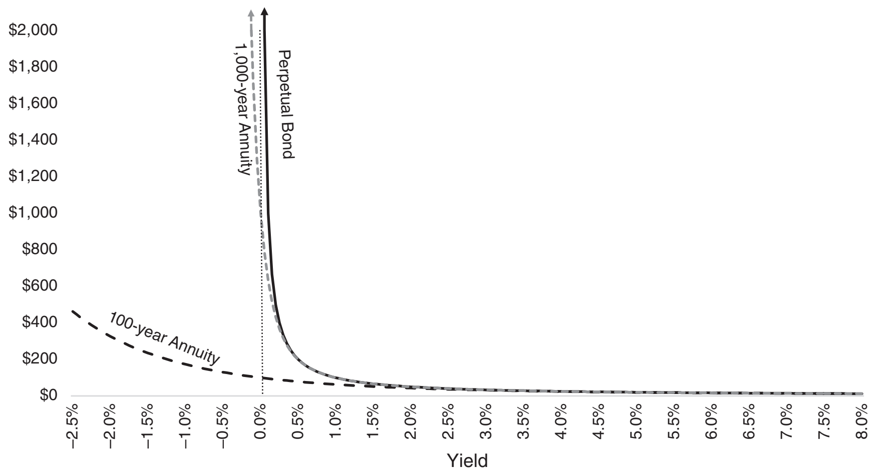

Exhibit 21.1 Price of 100-year, 1,000-year and Perpetual Annuities: Present Value of $1 per Year

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When Less Is More

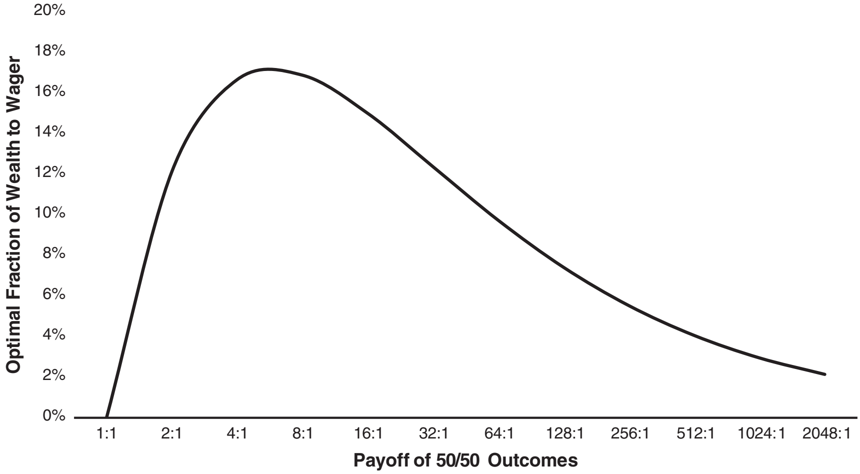

Exhibit 22.1 How Much to Wager on a Digital Asset as Payout Becomes More Favorable: Investor with CRRA Utility Risk-aversion 2

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The Costanza Trade

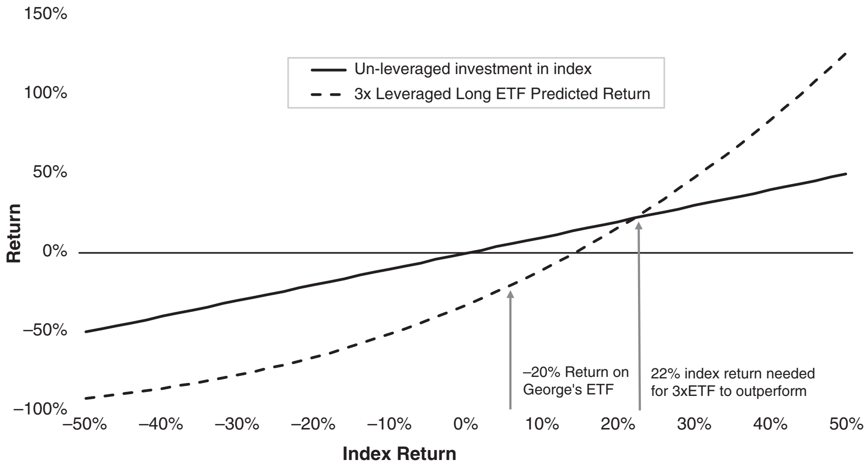

Exhibit 23.1 3x Leveraged Long ETF Predicted Return Versus Unleveraged Index Return: George's 1.25-year horizon. S&P 500 Volatility = 28%

Table 23.1

Leverage Ratio	Compound Return per Annum (nominal)	Risk per Annum	End Value of $1	Maximum Peak-to-Trough Drawdown
0.50	7.1%	9.5%	$682	–55%
0.75	8.6%	14.2%	$2,437	–73%
1.00	**9.8%**	**19.0%**	**$7,059**	**–84%**
1.50	11.0%	28.5%	$19,503	–95%
2.00	11.1%	38.1%	$22,882	–98.5%
3.00	8.5%	57.7%	$2,233	–99.9%
4.00	1.7%	78.4%	$4.79	–99.999%
5.00	–infinity	170.7%	$0.00	–100.000%

The table assumes daily rebalancing, no transaction costs, no fees, no market impact, borrowing at 3-month T-bill rates +1%. Attentive readers will notice the maximum loss of 84% in the case of the 1.0 leverage ratio, which is smaller than the near 90% loss we have referred to previously. The difference is that here we are measuring total returns including dividends, while the near 90% loss is exclusive of dividends.

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Conclusion: U and Your Wealth

Bonus Chapter: Liar's Poker and Learning to Bet Smart


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THIS CERTIFICATE IS LEGAL TENDER
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SERIES 1957
ONE DOLLAR
IN SILVER PAYABLE TO THE BEARER ON DEMAND

A Few Rules of Thumb

Constant relative risk-aversion (CRRA) utility

$$U(W) = \frac{1 - W^{1-\gamma}}{\gamma - 1} \text{ for } \gamma \neq 1$$

$$U(W) = ln(W) \text{ for } \gamma = 1$$

Merton share for asset allocation, risk-taking, and bet-sizing

$$\hat{k} = \frac{\mu}{\gamma\sigma^2}$$

$\gamma = 1$ is equivalent to the Kelly criterion

Risk-adjusted Return (r_{ra}), a.k.a., Certainty-equivalent Return

$$r_{ra} = r_{rf} + \frac{\hat{k}\mu}{2} \text{ for optimal } \hat{k}\text{, or more generally}$$

$$r_{ra} = r_{rf} + k\left(\mu - \frac{k\gamma\sigma^2}{2}\right)$$

$$Cost\ \ of\ \ Risk = \frac{\gamma\left(k\sigma\right)^2}{2}$$

Optimal spending

$$\hat{c}_\infty = r_{ra} - \frac{r_{ra} - r_{tp}}{\gamma} \text{ for infinite life and}$$

$$\hat{c}_t = \frac{\hat{c}_\infty}{1 - \left(1 + \hat{c}_\infty\right)^{-T}} \text{ for finite life } T\text{, i.e., wealth annuitized over}$$

T at rate $\hat{c}_\infty$. For $\hat{c}_\infty = 0,\ \hat{c}_t = \frac{1}{T}$.

Symbols and assumptions

- W is wealth
- c is consumption as a fraction of wealth per unit time
- k is the fraction of wealth allocated to the risky asset
- $\hat{k}$ is the optimal allocation
- γ is coefficient of risk-aversion in CRRA utility (for wealthy investors above subsistence typically 2–3, the higher the more risk-averse)
- r_{rf} is safe asset return (for long-term US investors, real yield of long-term TIPS)
- r_{tp} is the investor's rate of time preference (typical values 0%–4%)
- μ is expected excess return of risky asset above safe asset return (for broad equity markets typically 3%–6%, expressed as arithmetic expected return)
- σ is the variability of risky asset expressed as standard deviation of returns (for broad equity markets typically 15%–20%)

About the Authors

Victor Haghani has spent four decades actively involved in markets and financial innovation. He started his career in 1984 at Salomon Brothers in bond research. He moved to the trading floor in 1986 and shortly after became a managing director in the bond arbitrage group run by John Meriwether. In 1993, Victor was a cofounding partner of Long-Term Capital Management (LTCM). He established and co-ran its London office. His participation in the failure of LTCM was a life-changing experience that led him to question and revise much of the way he thought about the economy, markets, and investing.

Through a careful study of the academic literature on investing and many thought-provoking discussions with friends, colleagues, and investors of all backgrounds, Victor concluded that savers can and should do much better. He founded Elm Wealth in 2011 to help investors, including his own family, manage their savings in a disciplined, research-based, cost-effective manner and to capture the long-term returns they ought to earn.

In his 2013 TEDx talk, *Where Are All the Billionaires and Why Should We Care?,* Victor shared his perspective on the synthesis of active and passive investing, which forms the basis of the Dynamic Index Investing® approach offered by Elm Wealth. Over the years, Victor became fascinated with the challenge of making good decisions on broader questions about wealth and personal finances, including sound spending policies, tax decisions, and retirement choices.

Victor was born in New York City in 1962 and grew up in New York, Pennsylvania, Tehran, and London. As an adult, he has resided in New York City and London and, more recently, has been based in Jackson Hole, Wyoming. Victor graduated from the London School of Economics (LSE) in 1984 with a B.Sc. (economics). He has been a prolific contributor to the academic and practitioner finance literature.

Victor has been involved in a variety of other activities, including research and lecturing at the LSE, where he was a senior research associate in the Financial Markets Group, as well as consulting and board assignments and acting as a "name" in the Lloyd's of London insurance market. He loves the outdoors and is an avid skier, hiker, and fisherman and enjoys taking long walks with his dog Milo. He has always been fascinated by airplanes, flying model ones as a boy and full-size ones as an adult.

James White has spent two decades working in finance, covering the gamut of quantitative research, market-making, hedge fund investing, private equity investing, and wealth management. He has been the chief executive officer (CEO) of Elm Wealth since 2018, working with Victor to help friends, family, and clients sensibly and efficiently invest their wealth. After meeting through a mutual friend, James and Victor began working on research and writing together, sharing ideas, and collaborating regularly. After James built the next generation of Elm's portfolio management systems, he and Victor were talking and working together every day so joining Elm as the CEO just seemed natural.

Since then James has moved to Philadelphia to establish Elm's headquarters and has seen the business grow to serve hundreds of families and manage around $1.5 billion of their assets. He splits his time between working with clients, continuing to develop and improve Elm's systems, and research and writing.

After studying math at the u niversity of Chicago, James lived and worked all over the world, first for Nationsbank/Cr T and Bank of America, then for Citadel Investment Group, then as a partner at PAC Partners, a boutique private investment firm. His interest in optimal trade-sizing and risk-taking arose from each of these experiences and has culminated in the way Elm Wealth advises and invests for clients today.

James is an avid rock climber, classical guitarist, cook, and lover of renaissance history and music. When not in Elm's office or visiting clients, he can usually be found out climbing, hiking, eating, or traveling somewhere that nicely incorporates all three.

Praise for *The Missing Billionaires*

This is a marvelous book that importantly extends the literature on financial decision-making. The authors creatively weave together the essence of practical considerations with insightful academic theory. One of a small handful of books that is timeless and should be read and reread over a lifetime for enjoyment and substance.

—Gary P. Brinson, CFA, Author, and
Founder of Brinson Partners

The missing billionaires in the book's title allude to the difficulty of keeping already-made fortunes. Believing that nobody should get rich twice, Victor and James arm investors with lessons galore, drawn from their long practitioner careers. Yet the core lessons come from academia, and this wonderful book gives the best shot for Expected Utility and lifecycle models to finally become widely used in real-world investment decision-making. Uniquely, this book puts position sizing in the center, showing through many illustrations how "too much of a good thing" can be just too much.

—Antti Ilmanen, Principal at AQR Capital,
Author of *Expected Returns*

The Missing Billionaires addresses a topic that gets far too little attention in the investment community: how much to invest. The book is a terrific blend of theory, practice, and stories from the front lines. This is must-reading for anyone seeking to invest and spend wisely.

—Michael Mauboussin, Author and Head of
Consilient Research, Morgan Stanley

I enjoyed and learned from Victor and James' book on incorporating uncertainty directly into making better financial decisions. Rightly so, for them, risk is front and center. This book is a great education for all of us, seamlessly marrying sophisticated theory with applications, demonstrating the beauty of a risk architecture that combines specificity with illuminating implementations into the lifetime wealth management problem.

—Myron S. Scholes, Frank E. Buck Professor of Finance,
Emeritus, Stanford Graduate School of Business,
Nobel Laureate in Economic Sciences