University of Zurich
Institute for Empirical Research in Economics

Advanced Portfolio Theory

NHH-Bergen

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6. Behavioral Portfolio Theory: Typical Pitfalls in Portfolio Choice

- Descriptive vs Prescriptive Theories
- Search for Information
- Framing of Information
- Processing of Information
- Prospect Theory

South Sea Bubble

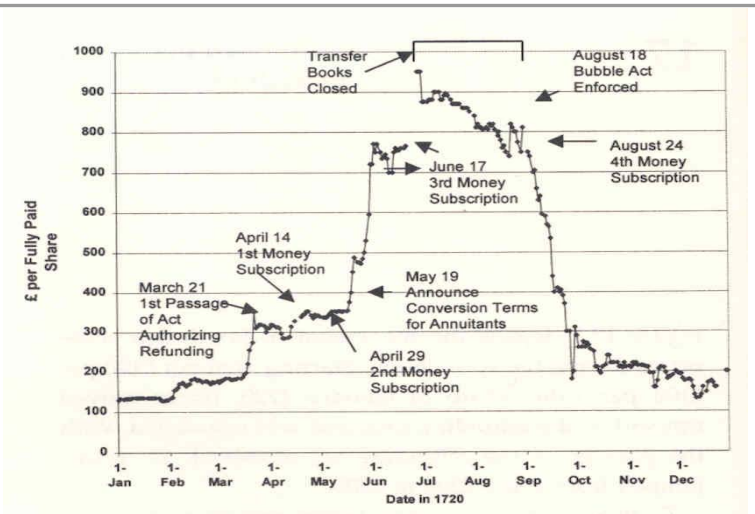
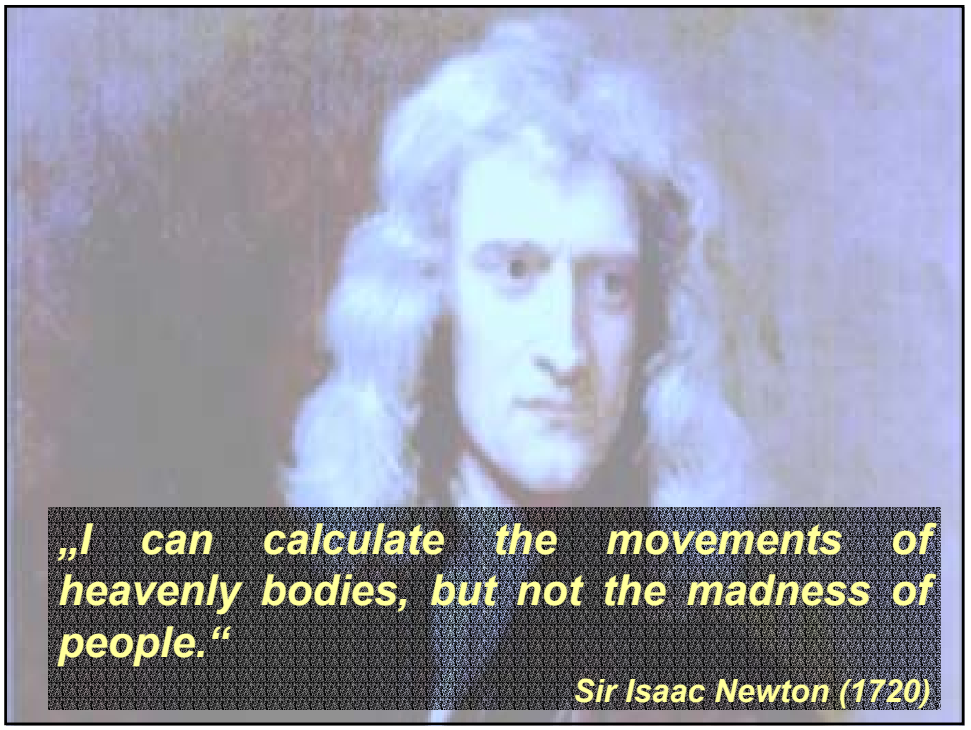


Figure 17.1
Daily South Sea Share Prices, 1720. Data courtesy of Larry Neal.



Keynes (1936) Animal Spirits

"Most… decisions to do something positive.. Can only be taken as a result of animal spirits-of a spontaneous urge to action rather than inaction, and not as the outcome of a weighted average of quantitative benefits multiplied by quantitative probabilities."

John Maynard Keynes (1936): The General Theory of Employment, Interest and Money, Harcourt.

Market values being a psychological outcome, it follows that pecuniary capital, an aggregate of market values, may vary in magnitude with a freedom which gives the whole an air of caprice – such as psychological phenomena, particularly the psychological phenomena of crowds, frequently present, and such as becomes strikingly noticeable in times of panic or of speculative inflation.

Veblen (1900), S. 310-311

In making predictions and judgments under uncertainty, people do not appear to follow the calculus of chance or the statistical theory of prediction. Instead, they rely on a limited number of heuristics which sometimes yield reasonable judgments and sometimes lead to severe and systematic errors.

Kahneman/Tversky (1982), S. 48

There is a lot of psychology that might be relevant for the formation of investor sentiment, and no obvious way of deciding which psychological biases are the most important.

Shleifer (2000), S. 25

De Bondt (1998)

*„For at least 40 years, psychologists have amassed evidence that '**economic man** (Edwards, The Theory of Decision-Making, 1954) –**is very unlike a real man'** and that reason – for now, defined by the principles that underlie expected utility theory, Bayesian learning, and rational expectations – is not an adequate basis for a descriptive theory of decision making."*

De Bondt (1998): Anatomy of the individual investor, European Economic Review.

(Raiffa, (1994), *Decision Theory and Decision Analysis: Trends and Challenges*)

Second, real people make errors;
they do no or poor analysis;
they use inappropriate heuristics.
What should be done about this?

Some of the answers are:

- Build better descriptive and predictive theories.
- Modify normative theories to include cognitive concerns.
- Provide better training and therapy.

Howard (1988) Normative and Descriptive

„Some decision theorists have questioned the normative concepts. They desire to weaken the norms until the normative behavior agrees with the desriptive behavior of human beings. A moments reflection shows that if we have a theory that is both normative and desriptive, we do not need a theory at all. If a process is natural like breathing, why would you even be tempted to have a normative theory?“(page 683).

R.A. Howard: “Decision Analysis: Practice and Promise“, Management Science (34), June 1988, p.679-695.

b) Search for Information

- Recognition Bias in Stock Picking
- Confirmation Bias
- Herding

Simon (1957) on Search

„Human thought consists of first, a great capacity, and second, a capacity for selective search“

H.A. Simon (1957): Models of Man: Social and Rational, Wiley.

The Recognitian Heuristic

If one of two objects is recognized and the other is not, then infer that the recognized object has the higher value.

Example:

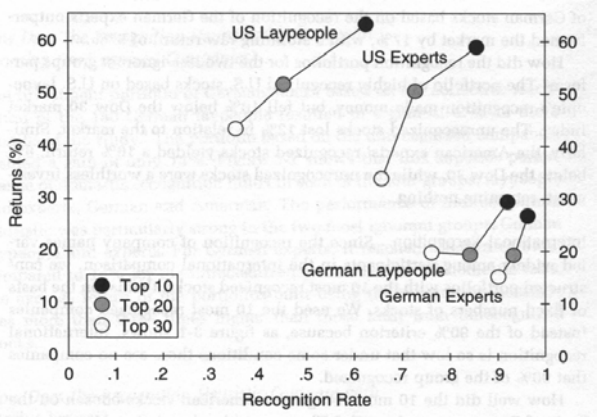
- Which US City has more inhabitants: San Diego or San Antonio?
- Which English Soccer Team will win?

Which English Soccer Team Will Win?

- 54 British Students
- 50 Turkish Students

The Turkish Students did not do worse on their predictions!

Recognition Rates and Returns

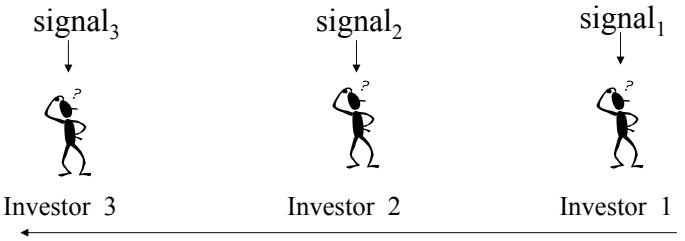


Gigerenzer and Todd (1999): „Simple Heuristics That Make us Smart“, Oxford University Press.

Herding

- Uncertainty induces imitative behavior.
- Everybody believes everybody else has better informationen.
- This may lead to information cascades.

Rational Herding (Banerjee (1992):



c) Framing of Information

- Win-Loss Framing
- Benartzi and Thaler 1/n
- Window Dressing in Broshures
- Names Matter

Win-Loss Framing

Decisions depend on the way they are presented!

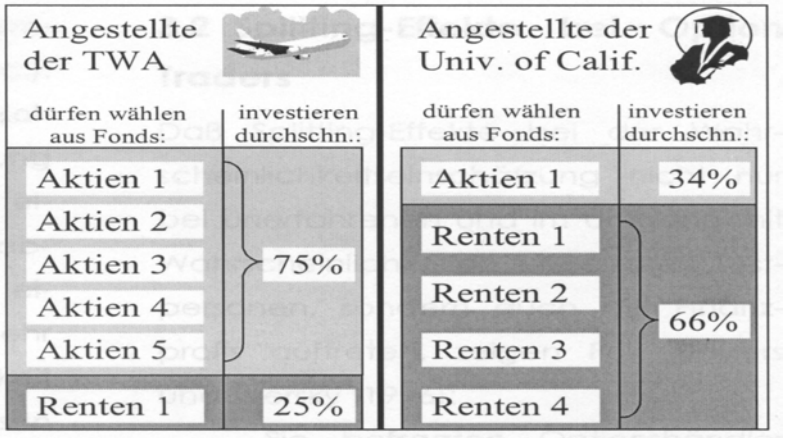
Framing: 40`000 CHF at risk

“positive” :
- A: rescue 20’000 CHF, loose 20’000 CHF
- B: probability 1/3 rescue the total amount,
  probability 2/3 loose the total amount.

“negative” :
- A: loose 20’000 CHF
- B: probability 1/3 loose nothing,
  probability 2/3 loose *all.*

Naive Diversification: 1/nWin-Loss Framing

Benartzi and Thaler (1998) observe tendency to equal splitting:



Window Dressing

A common end of the year practice of mutual funds is to buy those stocks that performed well during that year.

They want to dress their window, i.e. to show in their broshures that they have the winners in their portfolio.

Names Matter

- MCI
- Holderbank and Holcim

MCI

Massmutual Corporate Investors, a $200 Millionen Closed End Fund, is listed at the NYSE under the Ticker Symbol MCI.

The stock price of Massmutual Corporate Investors comoves with news on MCI Communications, a $20 Billion telecommunications firm. (MCI Communications does not have MCI or similar as its ticker symbol.)

Moreover the trading volumes of Massmutual Corporate Investors and of MCI Communications are much more closely related than those of MCI Communications and other telecommunication.

Rashes (2000) Journal of Finance.

The Case of MCI

The highest volume days of Massmutual Corporate Investors fund (MCI) for the sample period 11/1/96-11/13/97 are displayed in descending order. For each day, the trading volume of MCI is shown along with the return on MCI and MCI Communications (MCIC). The return for security j is defined as $\text{Log}[(P_{j,t+1} + D_{j,t+1})/P_{j,t}]$, where $P_{j,t}$ and $D_{j,t}$ are the price and dividend, respectively, for security j on day t. All returns are expressed in percentages. Any news from these days relevant to MCIC merger discussions is also displayed.

MCI Volume	Date	MCI Return	MCIC Return	Merger News
59200	11/1/96	0.68	18.56	British Telecom makes initial bid
45500	10/1/97	2.35	18.41	Worldcom makes initial bid
40200	8/21/97	-0.30	-18.27	British Telecom announces it is renegotiating original agreement
30000	11/10/97	0.70	11.82	Worldcom announces definitive acquisition agreement
25100	7/11/97	-0.31	-19.12	Rumors that British Telecom's bid may be renegotiated
24600	10/2/97	-0.73	3.65	See 10/1/97
24600	10/16/97	0.58	3.33	See 10/15/97
22800	5/12/97	-1.30	2.28	European Union deems Boeing/McDonnell Douglas merger unacceptable; may place restrictions on British Telecom/MCIC combination
21100	1/17/97	1.92	0.36	
17300	11/4/96	0.34	1.64	See 11/1/96
16600	4/30/97	-0.96	-0.33	See 4/29/97
16300	11/11/97	0.42	0.00	See 11/10/97
14600	5/30/97	-0.63	0.33	
14300	4/29/97	2.25	0.99	Global One executive announces British Telecom/MCIC combination poses competitive "danger"
13700	12/27/96	1.62	0.38	
13600	7/14/97	0.46	7.07	See 7/11/97
11900	7/28/97	0.30	-0.27	FCC says British Telecom acquisition should be approved
11900	10/28/97	0.00	0.71	MCIC shareholders file suit over mishandling of British Telecom bid
11700	12/26/96	0.63	0.77	
11300	6/17/97	0.63	-0.56	
10700	8/20/97	0.60	5.79	See 8/21/97
10100	10/15/97	0.00	4.33	GTE announces initial bid
10000	3/17/97	-2.56	-0.34	

Holderbank and Holcim

Holderbank is a Swiss construction firm.

Its stock price moved with that of the swiss banking sector up to the point when the name was changed to Holcim. From then on it co-moved with the construction sector.

When old news appear to be new: ENMD

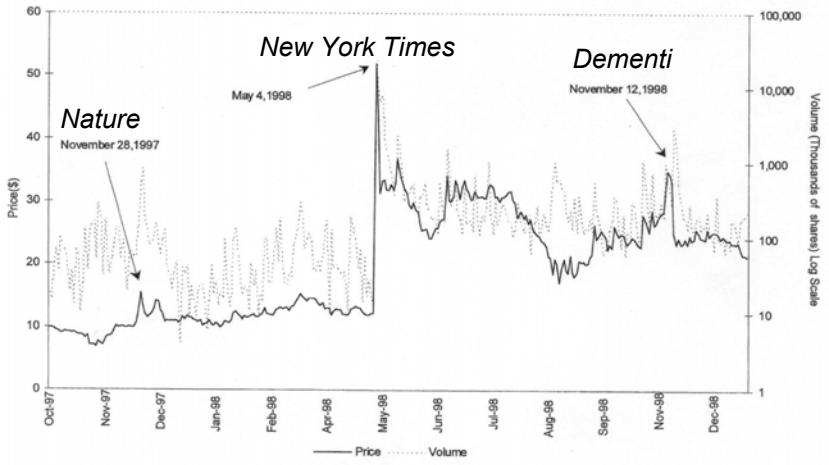


Figure 1. ENMD closing prices and trading volume, October 1, 1997, to December 30, 1998.

Quelle: Huberman, G., Regev, T., 2001

d) Processing of Information

- Availability Bias
- Gambler`s Fallacy
- Probability Matching
- Conditional Probabilities
- Conjunction Fallacy
- Representativeness Bias
- Violating Bayes Law
- Mental Accounting
- Self Control
- Home Bias
- Underdiversification

Availability Bias

„Which is a more likely death in the United States – being killed by falling airplane parts or by a shark? Most people rate shark attacks as more probable than death from falling airplane parts. Shark attacks certainly receive more publicity than do deaths from falling airplane parts, and they are far easier to imagine (thanks in part to Jaws). Yet the chances of dying from falling airplane parts are thirty times greater than the chances of being killed by a shark.“

Plous,S. (1993): *The Psychology of Judgement and Decision Making.* McGraw-Hill.

Availability Bias

„In a typical sample of text in the English Language, is it more likely that a word starts with the letter K or that K is its third letter?“

Kahneman and Tversky (1973): *On the Psychology of Prediction*, Psychological Review,80.

Availability Bias

„In a typical sample of text in the English Language, is it more likely that a word starts with the letter K or that K is ist third letter?“

There are approximately more than twice as many words with the letter K in the third position.

Kahneman and Tversky (1973): *On the Psychology of Prediction*, Psychological Review,80.

Gambler`s Fallacy

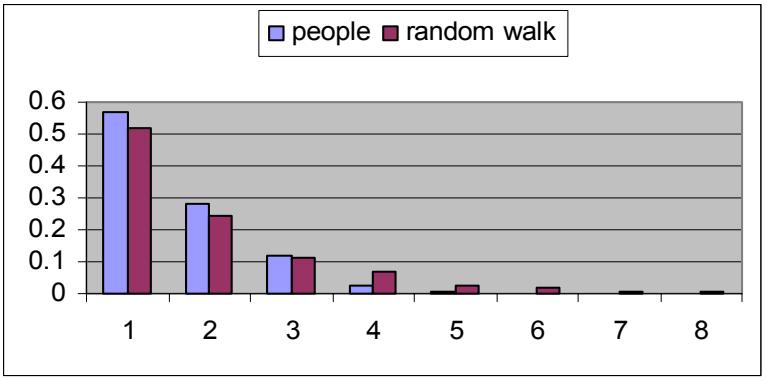
- Roullette: After a run of order at most 7 people think it is time for the other colour to come again.
- Violates i.i.d. feature of Roullette wheel.

Experiment (Runs of a RW)

Suppose you throw a fair coin 100 times

- How often does ist change sides immediately?
- How often does ist change sides after a run of order 2?
- How often does ist change sides after a run of order 3?
- How often does ist change sides after a run of order 4?
- How often does ist change sides after a run of order 5?
- How often does ist change sides after a run of order 6?

Frequency of Runs of the Coin Tossing Experiment



People underestimate the frequency of long runs of a random walk

Probability Matching

Example:

1) **Faire coin is tossed** 100 times
Task: Predict the result of each tossing.

Probability Matching

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Task: Predict the result of each tossing.
Typical Answer: On average 50 times Heads and 50 times Tails.

2) **Slightly worn coin** (51% H) is tossed 100 times
Task: Predict the result of each tossing.

Probability Matching

Example:

1) **Faire coin is tossed** 100 times
Task: Predict the result of each tossing.
Typical Answer: On average 50 times Heads and 50 times Tails.

2) **Slightly worn coin** (51% H) is tossed 100 times
Task: Predict the result of each tossing.
Typical Answer: On average 51 times Heads and 49 times Tails.

Probability Matching

Optimal Choice:
1) Fair Coin: Every answer is equally good.
2) Worn Coin: Always choose Heads!

Interpretation of the Examples:
Contemplate whether to invest in an asset whose price increase with „H“ and decreases with „T“.

Optimal Buy/Sell Decision (with transaction costs):
1) Fair Coin: D not invest.
2) Worn Coin: Buy and Hold!

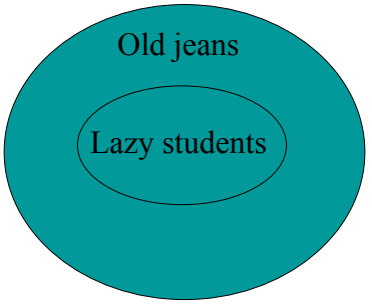
Observed behavior is *exessive trading*.

Conditional Probabilities

Lazy students wear old jeans. This student wears an old jeans. He must be lazy.

Conditional Probabilities

Lazy students wear old jeans. This student wears an old jeans. He must be lazy.



Conjunction Fallacy

Linda is 31, single, outspoken and very bright. She majored in philosopy. As a student she was deeply concerned with issues surrounding equality and discrimination.

It is more likely that Linda is:

A bank clerk

or

A bank clerk and active in the feminist movement?

Representativeness Bias (1)

(Overreaction)

Test

A fund manager is known to beat the market in 2 of 3 years.

Which of the following protocols is most likely?

a) BLBBB *b) LBLBBB* *c) LBBBBB*

Representativeness Bias (2)

Typical answer: *b)* *LBLBBB*

Explanation: Frequencies in are most representative for 2/3.

Representativeness Bias (3)

Typical answer: *b)* *LBLBBB*

Correct answer: *a)* *BLBBB*

Explanation: Frequencies in are most representative for 2/3.

But b) is the protocol a) and the condition that L comes before.

Self Control (1)

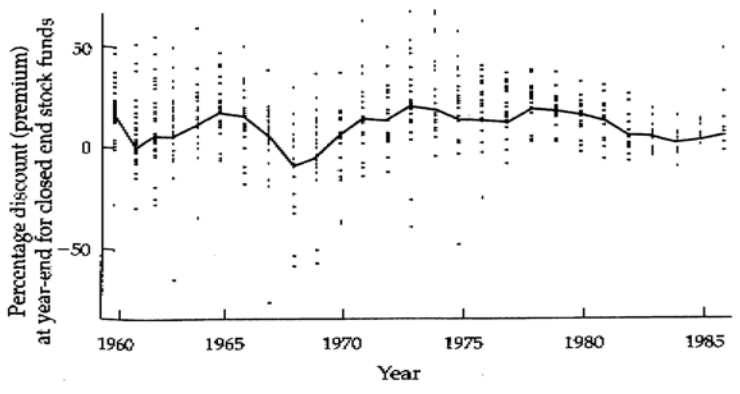
Example:
- Hand over the car keys to the barkeeper.
- Set the alarm clock.
- Have the stomach removed.

Application in Finance:
„Don`t dip into capital!“

Closed End Fund Puzzle

(Mutual Fund of fixed composition and size that is traded)

Price of shares in Mutual Funds $\neq$ Sum of the prices of its components.



Self Control (2)

Example: Closed End Fund Puzzle

Problem: Closed End Funds trade at a significant discount.

Analysis: Self Control

Dividends versus Capital Gains:

„Don`t dip into capital“.

Solution: M. Zweig (1986) in Forbes Magazine:

„Pay the dividend, whether you earn it or not.“

Summary: Self Control

Helps to explain:

- Closed End Fund Puzzle
- Dividend Payments
- Equity Premium Puzzle

Home Bias

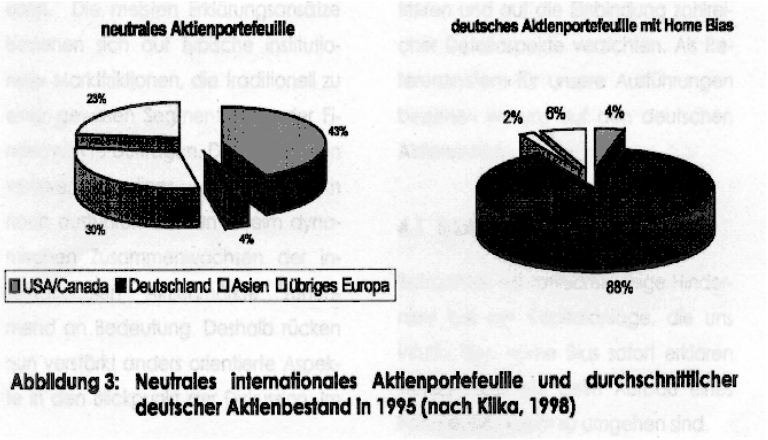


Abbildung 3: Neutrales internationales Aktienportefeuille und durchschnittlicher deutscher Aktienbestand in 1995 (nach Klika, 1998)

Home Bias

- Investors may find their national stock market to be more familiar than foreign stock markets
- French and Poterbra (1991):
  - Investors in the U.S., Japan and the U.K. allocate 93%, 98% and 82% of their overall equity investments, respectively, to domestic equities
- Other studies confirm this insufficient diversification

➔ people like familiar situations, where they feel they are in a better position than others to evaluate a lottery

Ambiguity Aversion

People feel more comfortable in situations of risk than in situations of uncertainty.

Lottery A:
„Draw a ball from urn with 50 red and 50 blue balls“.
Pay off:
(100 if blue, 0 if red)

Lottery B:
„Draw a ball from urn with unknown proportion of red and blue balls“.
Pay off:
(100 if blue, 0 if red)

Ambiguity Aversion helps to explain:

- Home Bias
- Equity Premium Puzzle

FIN 417- Assignment

Home Bias & Ambiguity Aversion

Experiment

1. 20 people had to choose between the two following lotteries:

Lottery A:	Lottery B:
”Draw a ball from a urn with 50 red and 50 blue balls.”	”Draw a ball from a urn with 50 an unknown proportion of red and blue balls.”
Pay off:	Pay off:
100 if blue, 0 if red	100 if blue, 0 if red

2. The same people were asked how many domestic and how many foreign stocks they have hold during the last 5-10 years.

Experimental Results

- 16 out of 20 chose lottery A
- 11 out of them have hold domestic stocks during the last 5-10 years
- All the 4 who chose lottery B have hold foreign stocks during the last 5-10 years

Explanation

- People obviously dislike situations where they are not sure what the probability distribution of a game is
- helps to explain:
  - Home Bias
  - Equity Premium Puzzle

Bedre å tape store penger på kjente selskaper enn på "eksotiske" aksjer.

„Når amerikanske investorer velger å selge aksjer, så dumper de heller sine marginale investeringer i utlandet og beholder de aksjene man kjenner best i hjemmemarkedet, selv om dette kanskje ikke er den mest rasjonelle beslutningen. Det er lettere for en amerikansk fondsforvalter å bortforklare et stortap i kjente selskaper som Cisco eller IBM, fremfor et tap i "eksotiske" aksjer som EDB eller Nera.“

Source: Finansavisen, 25.09.2002

Under Diversification

Real man tends not to diversify.

Blume,Crocket & Friend (1974):
17.056 individual investors
only $\leq$ 1 share is hold by 34,1% of the investors
$\geq$ 2 shares have 50% of the investors
10 share have only 10% of the investors

Starr-McCluer (1994): Federal Reserve Study
Average number of shares hold: 3.41

False Portfolio Diversification

Test:

Lottery	*Payoff in CHF*
A	(2.400; 100 %)
B	(10.000; 25 %, 0; 75 %)
C	(-7.500; 100 %)
D	(-10.000; 75 %, 0; 25 %)
Choose:	*A or B and C or D ?*

False Portfolio Diversification

Typical Answer: A and D

Lottery	*Payoff in CHF*
A and D	(-7.600; 75% , 2.400; 25%)
B and C	(-7.500; 75%, 2.500; 25%)

100 are left on the table!

Prospect Theory

- The four building blocs
- An Application to Product Development
- Prospect Theory and Mean-Variance

Kahneman, D. and A. Tversky (1979) : "Prospect Theory: An Analysis of Decisions Under Risk", *Econometrica*, 47, 263-291.

Prospect Theory: The Four Building Blocs

- Gains and Losses
- Loss Aversion
- Gambling to avoid Losses
- Probability Weighting

Gains and Losses

Would you pay for the lottery A for 150 CHF?

A= (100 CHF, 50%; 200 CHF, 50%)

Would you pay 150 CHF to avoid playing the lottery

B = (- 100 CHF, 50%; -200 CHF, 50%)

Gains and Losses

How much would you pay for the lottery

A= (100 CHF, 50%; 200 CHF, 50%)

How much would you pay to avoid to play the lottery

B = (- 100 CHF, 50%; -200 CHF, 50%)

Gains and Losses

Certainty equivalent

A= (100 CHF, 50%; 200 CHF, 50%)

CE(A) $\approx$ 140 CHF = E(A) –10.

Certainty equivalent

B = (- 100 CHF, 50%; -200 CHF, 50%)

CE(B) $\approx$ -175 CHF = E(B) –25.

Who plays A does not play B.

Expected Utility: Final Wealth

Lotteries are evaluated according to gains and losses

Initial wealth W = 10.000

A`= (10.100 CHF, 50%; 10.200 CHF, 50%)

CE(A) ≈ 10.149,88 CHF = E(A) – 0,12

B` = (9.900 CHF, 50%; 9.800 CHF, 50%)

CE(B) ≈ 9.837 CHF = E(B) – 13.

Who plays A` also plays B`.

Loss Aversion

Losses hurt by a factor 2.25 more than gains give pleasure.

Hence there is tendency not to realize losses:

Disposition Effect.

Dispositionseffect

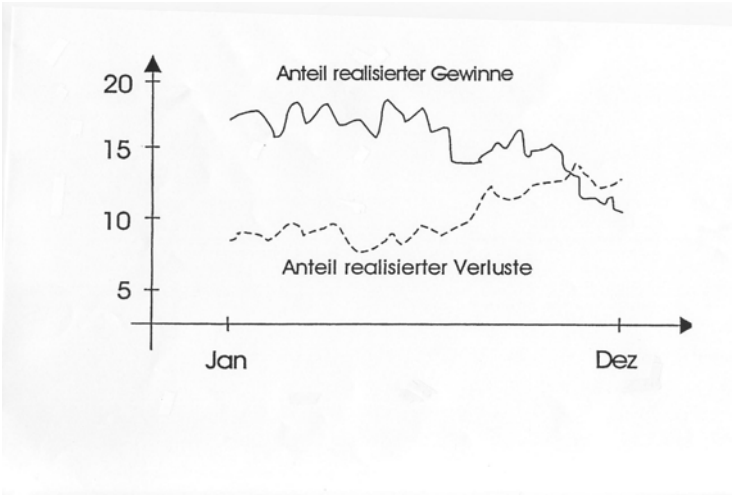
Odean (1998):

163.000 investors of a big broker house

Investors realize gains
1.68 times
more frequently than losses.

Dispositionseffect

Odean (1998):



Gambling: Get Eventis

A= (500 CHF, 50%; 700 CHF, 50%)

Are you ready to pay 600 CHF for playing lottery A?

B = (- 500 CHF, 50%; -700 CHF, 50%)

Are you ready to pay 600 CHF to avoid playing B?

Typical answer: A ⟶ NO! B ⟶ NO!

Nick Leeson: I gambled on the stock market to reverse my mistakes

Get Eventis

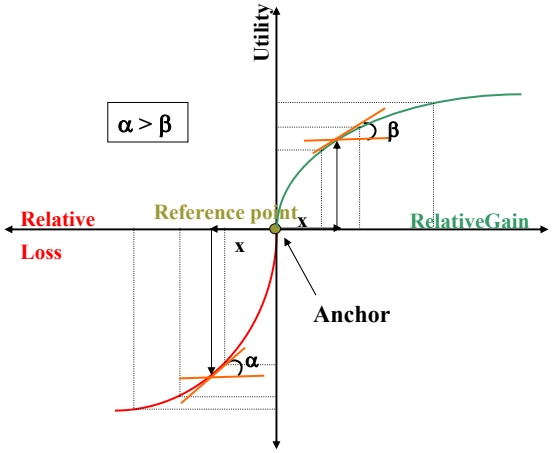
Example: Nicholas Leeson :

Lost 1,4 Mrd $ and broke 1995 Barings Bank PLC

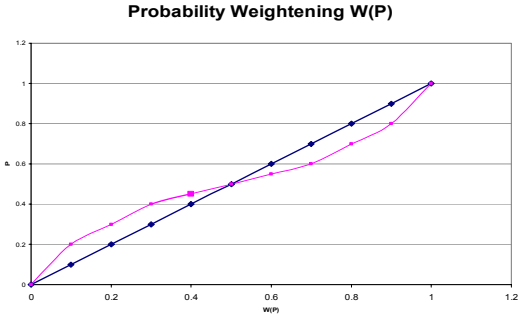
„I gambled on the stock market
to rescue my mistakes and
to save the bank.“

Prospect Theory

Von Neumann Morgenstern utility:



Probability Weighting



Product Strategy:

Sell Insurance Contracts.

Probability Weighting and Allais Paradox

	$0	$50	$250
A	0%	100%	0%
B	1%	89%	10%
A`	89%	11%	0%
B`	90%	0%	10%

$A \succcurlyeq B$

$1U(50)>0.01U(0)+0.89U(50)+0.1U(250)$

$0.11u(50)>0.01U(0)+0.1U(250)$

$B` \succcurlyeq A`$

$0.9u(0)+0.1u(250)>0.89u(0)+0.11u(50)$

$0.01u(0)+0.1u(250)>0.11u(50)$

Contradicts Expected Utility but can be explained with probability weighting

Probability Weighting and Allais Paradox

	$0	$50	$250
A	0%	100%	0%
B	1%	89%	10%
A`	89%	11%	0%
B`	90%	0%	10%

$A \succcurlyeq B$

$W(1)U(50)>W(0.01)U(0)+W(0.89)U(50)+w(0.1)U(250)$

$(w(1)-w(0.89))u(50)>w(0.01)U(0)+w(0.1)U(250)$

$B` \succcurlyeq A`$

$W(0.9)u(0)+w(0.1)u(250)>w(0.89)u(0)+w(0.11)u(50)$

$(W(0.9)-w(0.89))u(0)+w(o.1)u(250)>w(0.11)u(50)$

Contradicts Expected Utility but can be explained with probability weighting

Prospect Theory: Product Development

Product Development:

Examples of structured products with captial insurance:

- Ladder Pop (Bank Wegelin & Co.)
- Dax Sparbuch (Postbank)

Implikationen for repeated portfolio choice: **„Get-Eventis“**

After losses one starts gambling.

Example: Nicholas Leeson

Application of Prospect Theory

Die Bewertung und Analyse

des Ladder-POP

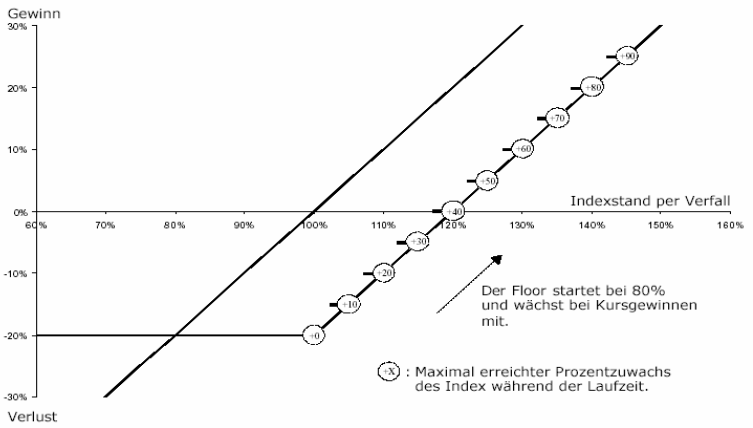
Diplomarbeit

Institut für Empirische Wirtschaftsforschung

Universität Zürich

Prof. Dr. Thorsten Hens

Ladder Pop (Bank Wegelin & Co.)



Ladder Pop (Bank Wegelin & Co.)

Underlying:	SMI
Issue Prices:	100%
Nominalvalue:	CHF 5'000
Floor:	80%
Bondfloor (*yield to maturity*):	68.07% (3.35%)
Participation:	50%
Start:	22. Januar 2002
Termination:	19. Dezember 2006
Time to Maturity:	ca. 4.9 Jahre

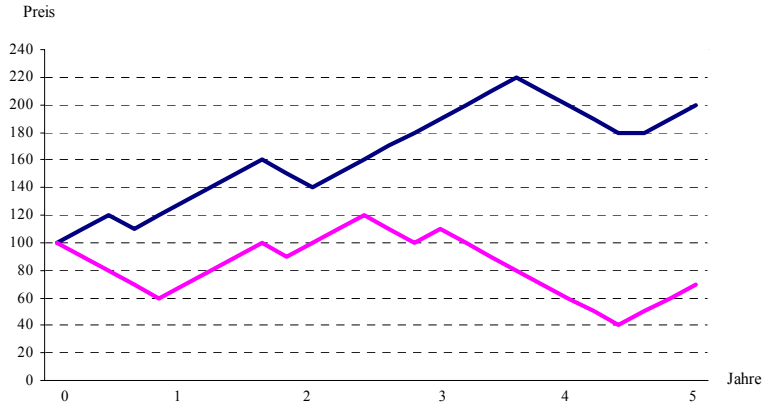
Ladder Pop (Bank Wegelin & Co.)

Arbitrage free-pricing of Ladder-POP:

Value Zero-Coupon-Bond	CHF 3’403.60
Value Call-Option	CHF 791.20
Value of the long up-and-in Put-Optionen	CHF 4'530.80
Value of short up-and-in Put-Optionen	CHF -3'725.60
Wert Ladder-POP	**CHF 5'000.00**

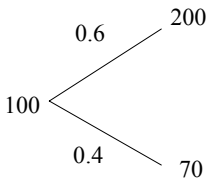
Ladder Pop (Bank Wegelin & Co.)

The investors` point of view given two Scenarios of the underlying:

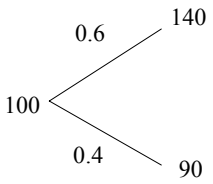


Expected Utility Theory

Underlying:



Ladder Pop:



Expected utility (underlying) = $0.6 \cdot \ln(200) + 0.4 \cdot \ln(70) = 4.8784$

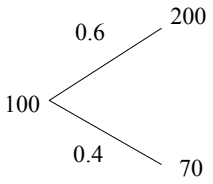
Expected utility (Ladder-POP) = $0.6 \cdot \ln(140) + 0.4 \cdot \ln(90) = 4.7649$

Expected utility (risk-free asset) = $0.6 \cdot (100) + 0.4 \cdot \ln(100) = 4.6052$

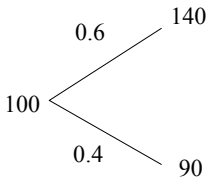
Choose the stock!

Expected Utility Theory

Underlying:



Ladder Pop:



Expected utility (underlying) = $0.6 \cdot 200^{0.6} + 0.4 \cdot 70^{0.6} = 19.5317$

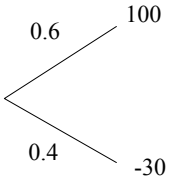
Expected utility (Ladder-POP) = $0.6 \cdot 140^{0.6} + 0.4 \cdot 90^{0.6} = 17.5878$

Expected utility (risk-free asset) = $0.6 \cdot 100^{0.6} + 0.4 \cdot 100^{0.6} = 15.8489$

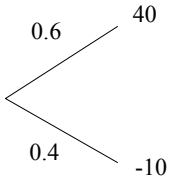
Choose the underlying!

Prospect Theory

Underlying:



Ladder Pop:



PT(Underlying) $= W(0.6)\cdot 100^{0.6} - W(0.4)\cdot 2.5\cdot 30^{0.6}$
$= 0.467\cdot 100^{0.6} - 0.366\cdot 2.5\cdot 30^{0.6}$
$= \mathbf{0.3569}$

PT(Ladder Pop) $= W(0.6)\cdot 40^{0.6} - W(0.4)\cdot 2.5\cdot 10^{0.6}$
$= 0.467\cdot 40^{0.6} - 0.366\cdot 2.5\cdot 10^{0.6}$
$= \mathbf{0.6276}$

PT(Bond) $= W(0.6)\cdot 0^{0.6} - W(0.4)\cdot 2.5\cdot 0^{0.6}$
$= \mathbf{0}$

Choose the Ladder Pop!

Prospect Theory and Mean-Variance Principle

Assumption 2 (CPT-preferences)

Every agent's utility function can be represented as

$$U^i(\Delta x) = \int_{\mathbb{R}} u^i(\Delta y)\, d\,(T^i \circ \Phi(\Delta y)) \quad \textit{for all} \quad \Delta x \in X, \qquad (1)$$

where

- u^i *is a two-times differentiable function on* $\mathbb{R} \setminus \{0\}$, *strictly increasing on* $\mathbb{R}$, *strictly concave on* $(0, \infty)$ *and strictly convex on* $(-\infty, 0)$,
- T^i *is a differentiable, non-decreasing function from [0,1] onto [0,1] with* $T^i(p) = p$ *for* $p = 0$ *and* $p = 1$ *and with* $T^i(p) > p$ $(T^i(p) < p)$ *for* p *small (large),*
- Φ *denotes the cumulative distribution function for the payoffs* Δx.

Levy, De Giorgi & Hens (2003): Prospect Theory and the CAPM, NCCR-working paper.

Prospect Theory and Mean-Variance Principle

Suppose returns are normally distributed then:

$$PT_{u^i}(\Delta x) = \int u^i(\Delta x) dT^i(N(\Delta x;\mu,\sigma)) = \int u^i(\frac{\Delta x - \mu}{\sigma}) dT^i(\Phi(\Delta x)) = V^i(\mu,\sigma)$$

Hence PT is consistent with the mean variance principle.

Moreover, since u^i is increasing in x, V^i is increasing in μ, and therefore Two-Fund-Separation holds which implies the Security Market Line Theorem of the CAPM.

Levy, De Giorgi & Hens (2003): Prospect Theory and the CAPM, NCCR-working paper.

Probability Weighting and FSD

Let there be three states, s=1,2,3.

Consider the three state contingent payoffs (100, 100, 90.25)

The true probabilities are: $p = (0.05,\ 0.05\ ,0.9)$

The perceived probabilities are: $w = (0.1,\ 0.1,\ 0.85)$

Let the Von Neumann-Morgenstern utility function be $u(x) = \sqrt{x}$

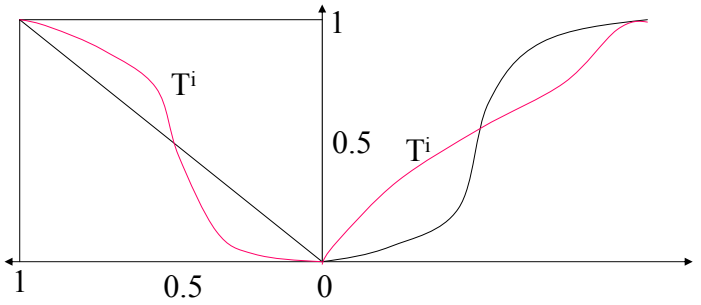
Then the Prospect Theory investor prefers the lottery (100, 100, 90.25)
to the certain payoff 100, violating First order Stochastic Dominance:

$$0.1\sqrt{100} + 0.1\sqrt{100} + 0.86\sqrt{90.25} = 2 + 8.075 \ > \ 10 \ = \ 1\sqrt{100}$$

Cumulative Prospect Theory

Tversky and Kahneman (1992) suggested

To transform the distribution functions:



Note that this transformation keeps FSD

since T^i is increasing: A FSD B $\Leftrightarrow$ T^i(A) FSD T^i(B).