

Panic on Wall Street

Introduction to behavioral finance

Anton Antonov

<https://github.com/tonytonov/talks>

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Don't panic

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Efficient market
hypothesis

Behavioral effects
in economics and
trading

Detour: Bayesian
thinking

Model of investor
sentiment

Financial markets

■ Many exchanges

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Financial markets

- Many exchanges
- Many asset classes

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Financial markets

- Many exchanges
- Many asset classes
- Significant impact on daily lives

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- Many exchanges
- Many asset classes
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- Huge experimental field, *but*

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- Many exchanges
- Many asset classes
- Significant impact on daily lives
- Huge experimental field, *but*
- No control, no repeatability

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EMH statement

Definition (Fama, 1970)

Financial market is *efficient*, if security prices always fully reflect available information.

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Financial market is *efficient*, if security prices always fully reflect available information.

Definition (Efficient Market Hypothesis)

Real-world financial markets *are* efficient.

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Evidence supporting EMH

- Theoretical
 - Investors are rational

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■ Empirical

- (*Reaction to information*)
News arrive \Rightarrow price quickly and correctly adjusts

Evidence supporting EMH

■ Theoretical

- Investors are rational
- Prices are random walks (i.e., unpredictable)
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■ Empirical

- *(Reaction to information)*
News arrive \Rightarrow price quickly and correctly adjusts
- *(Non-reaction to non-information)*
No news about fundamentals \Rightarrow no significant price movements

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Evidence against EMH

- *“Limited rationality”* (discussed further)

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Evidence against EMH

- *“Limited rationality”* (discussed further)
- *“Physical reality”*:
 - Arbitrage opportunities are limited

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Evidence against EMH

- *“Limited rationality”* (discussed further)
- *“Physical reality”*:
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Evidence against EMH

- *“Limited rationality”* (discussed further)
- *“Physical reality”*:
 - Arbitrage opportunities are limited
 - Excess volatility puzzle
 - Momentum and other factors are consistent predictors
 - Flash Crash (reaction to non-news)

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Flash Crash

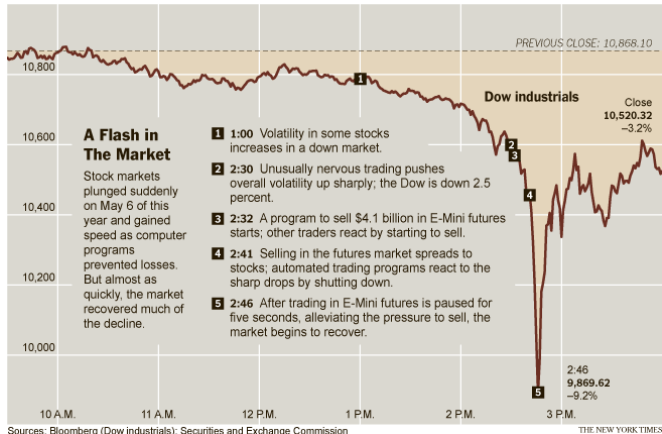


Figure 1: A trillion-dollar drop on May 6, 2010

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Effect: noise trading

- Trading agents tend to
 - look for patterns in random data

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 - ignore survivorship bias

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- Trading agents tend to
 - look for patterns in random data
 - ignore survivorship bias
 - systematically fail in absorbing new information

Effect: herding

- Traders, portfolio managers and algorithms
 - tend to mimic each other

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 - react on what others around them do
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- During stress periods
 - correlations increase sharply
 - event cascades are triggered
 - nonlinearity kicks in

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Other effects

- Win-loss asymmetry, influence of framing

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- Distortion by “gurus”, portfolio managers

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- Distortion by “gurus”, portfolio managers



Figure 2: The Economist, November 1997

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Model building approach

John von Neumann

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- *Derive* quantifiable conclusions using mathematics

Model building approach

John von Neumann

The sciences do not try to explain, they hardly even try to interpret, they mainly make models. [...]

- *Observe* existing phenomena
- *Construct* a model using domain knowledge
- *Derive* quantifiable conclusions using mathematics
- *Test* conclusions on real (simulated) data

Coin flipping

- “Unfair” coin:

$$P(Heads) = \theta, P(Tails) = 1 - \theta$$

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$$P(Heads) = \theta, P(Tails) = 1 - \theta$$

- Coin flips are *independent and identically distributed*, then e.g.

$$\begin{aligned} P(HHTHT) &= P(H)^3 P(T)^2 = \\ &= \theta^3 (1 - \theta)^2 \end{aligned}$$

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- Coin flips are *independent and identically distributed*, then e.g.

$$\begin{aligned} P(HHTHT) &= P(H)^3 P(T)^2 = \\ &= \theta^3 (1 - \theta)^2 \end{aligned}$$

- Given a set D of K_H heads and K_T tails

$$P(D|\theta) = \theta^{K_H} (1 - \theta)^{K_T}$$

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- By observing data D , how we can estimate unknown parameter θ ?

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- By observing data D , how we can estimate unknown parameter θ ?
- Idea: pick θ , s.t. the probability of observing sample D is as high as possible

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- Idea: pick θ , s.t. the probability of observing sample D is as high as possible
- This is *maximum likelihood estimation (MLE)*:

$$\hat{\theta}_{MLE} = \operatorname{argmax}_{\theta} P(D|\theta) = \operatorname{argmax}_{\theta} \ln P(D|\theta)$$

Problem with MLE

- Calculation yields (derive for bonus points!)

$$\hat{\theta}_{MLE} = \frac{K_H}{K_H + K_T}$$

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— makes sense!

Problem with MLE

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$$\hat{\theta}_{MLE} = \frac{K_H}{K_H + K_T}$$

- Take $D = \{3 \text{ Heads}, 2 \text{ Tails}\}$, then $\hat{\theta} = 60\%$ — makes sense!
- Take $D = \{5 \text{ Heads}\}$, then $\hat{\theta} = 100\%$ (!?)

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Coin tossing experiment

- Go to **bit.ly/pgi-math** to follow on-line!

Coin tossing experiment

- Go to **bit.ly/pgi-math** to follow on-line!
- The first coin is *heads-oriented*: H in 70% of outcomes, T in 30%. The second one is *tails-oriented*: 70% T, 30% H. I pick one randomly, the remaining coin is removed. At each step I'm telling you how the coin landed. Your task is to *estimate the probability of my coin being heads-oriented* as percentage from 0% to 100%. Let's go!

Bayes to the rescue!

- Reverend Thomas Bayes, 1702–1761:

$$P(\theta|D) = \frac{P(D|\theta)P(\theta)}{P(D)}$$

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$$P(\theta|D) = \frac{P(D|\theta)P(\theta)}{P(D)}$$

- Here $|$ means “given”, “conditioned by”: a probabilistic way to express *known information*
- This is *maximum a posteriori* estimation:

$$\hat{\theta}_{MAP} = \operatorname{argmax}_{\theta} P(\theta|D) = \operatorname{argmax}_{\theta} P(D|\theta)P(\theta)$$

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- Our case: two mutually exclusive events:
 H^* (head-oriented coin was chosen) and
 T^* (tail-oriented was chosen). $Data$ is what we
observe: $Data = \{K_H Heads, K_T Tails\}$

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$$\begin{aligned} P(Data) &= P(Data|H^*)P(H^*) + \\ &\quad P(Data|T^*)P(T^*) = \\ &= 0.7^{K_H}0.3^{K_T}0.5 + 0.7^{K_H}0.3^{K_T}0.5 \end{aligned}$$

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$$P(H^*|Data) = \frac{P(Data|H^*)P(H^*)}{P(Data)}$$

- Count K_H and K_T from $Data$, and ~~(0.5)~~

$$P(H^*|Data) = \frac{0.7^{K_H}0.3^{K_T}}{0.7^{K_H}0.3^{K_T} + 0.7^{K_H}0.3^{K_T}}$$

Results in theory

Roll	Outcome	History	Estimate
0			50%
1	H	H	70%
2	H	HH	84.5%
3	H	HHH	92.7%
4	H	HHHH	96.7%
5	H	HHHHH	98.6%
6	T	HHHHHT	96.7%

Table 1: Coin-tossing experiment, bayesian answers

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Results from studies

- Edwards (1968): excess conservatism, *underreaction*
- Kahneman, Tversky (1974): representativeness heuristic, *overreaction*

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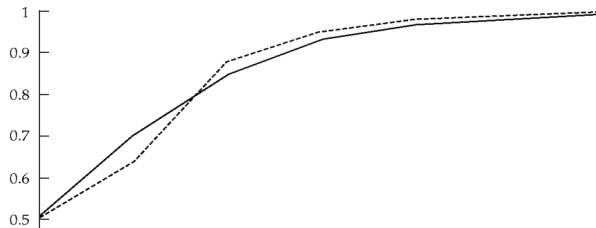


Figure 3: Bayesian (solid) and average response (dashed).
Source: [Shleifer, 2000]

Our results

- Total respondents: 43
- Group 1: no reaction to information (all answers 50%)
- Group 2: non-Bayesian after one throw (all answers 70%)
- Group 3: Bayesian congregation
- Underreaction, no overreaction

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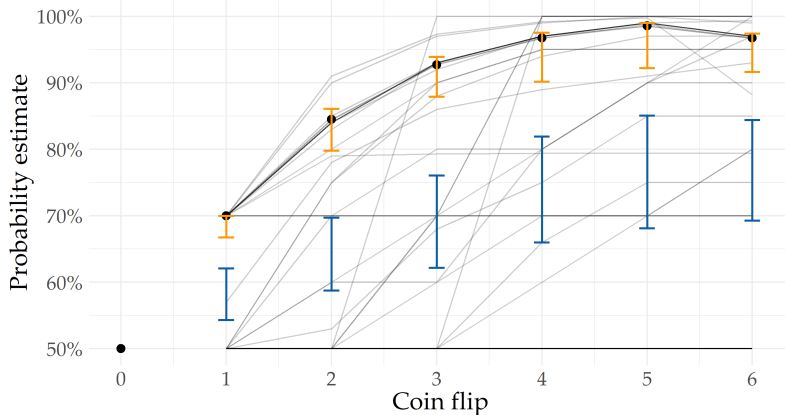
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Our results

A coin flipping experiment: survey results

Error bars are 99% bootstrapped confidence intervals



| All responses | "Bayes-oriented" responses • Fully rational Bayesian

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Barberis et al. (1998)

- Featured in *Inefficient Markets* [Shleifer, 2000]

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- The stock price is driven by a random process $N_t = N_{t-1} + y_t$, where N_t is company's earnings, y_t is "shock"

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- Featured in *Inefficient Markets* [Shleifer, 2000]
- The stock price is driven by a random process $N_t = N_{t-1} + y_t$, where N_t is company's earnings, y_t is "shock"
- Here y_t is either $+y$ or $-y$, i.e. positive or negative shock

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- y_t is generated by a *regime-switching* model

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- There are two states, M1 and M2, both are *Markov processes*
- M1:

$$\begin{array}{cc} y_{t+1} = y & y_{t+1} = -y \\ y_t = y & \pi_L \quad 1 - \pi_L \\ y_t = -y & 1 - \pi_L \quad \pi_L \end{array}$$

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- M2 is similar, with π_H instead of π_L

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Barberis et al. (1998)

■ $\pi_L < 0.5 < \pi_H$, e.g. $\pi_L = 1/3$, $\pi_H = 3/4$

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- M1: “reversion”, M2: “long memory”

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- $\pi_L < 0.5 < \pi_H$, e.g. $\pi_L = 1/3$, $\pi_H = 3/4$
- M1: “reversion”, M2: “long memory”
- Regime switching M1/M2 is also Markovian

$$\begin{array}{cc} & s_{t+1} = 1 & s_{t+1} = 2 \\ s_t = 1 & 1 - \lambda_1 & \lambda_1 \\ s_t = 2 & \lambda_2 & 1 - \lambda_2 \end{array}$$

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- $\pi_L < 0.5 < \pi_H$, e.g. $\pi_L = 1/3$, $\pi_H = 3/4$
- M1: “reversion”, M2: “long memory”
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$$\begin{array}{cc} s_{t+1} = 1 & s_{t+1} = 2 \\ s_t = 1 & 1 - \lambda_1 \quad \lambda_1 \\ s_t = 2 & \lambda_2 \quad 1 - \lambda_2 \end{array}$$

- λ_1 and λ_2 are small, $\lambda_1 + \lambda_2 < 1$, $\lambda_1 < \lambda_2$

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Proposition

Under some conditions on $\pi_L, \pi_H, \lambda_1, \lambda_2$, the price exhibits both under- and overreaction to N_t .

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- Pick two portfolios: “winners” and “losers”

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- Calculate difference in performance (returns)
 $r_+^n - r_-^n$ for $n = 1, 2, 3, 4$ years

Proposition

Under some conditions on $\pi_L, \pi_H, \lambda_1, \lambda_2$, the price exhibits both under- and overreaction to N_t .

- Pick two portfolios: “winners” and “losers”
- Calculate difference in performance (returns)
 $r_+^n - r_-^n$ for $n = 1, 2, 3, 4$ years
- It *decreases monotonically*

Barberis et al. (1998)

- It *decreases monotonically*:

$r_+^1 - r_-^1$	0.0391
$r_+^2 - r_-^2$	0.0131
$r_+^3 - r_-^3$	-0.0072
$r_+^4 - r_-^4$	-0.0309

Figure 4: Difference between portfolios. Source:
[Shleifer, 2000]

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Reproducing in R

R code:

https://github.com/tonytonov/talks/blob/master/behfin_intro/R/shleifer.R

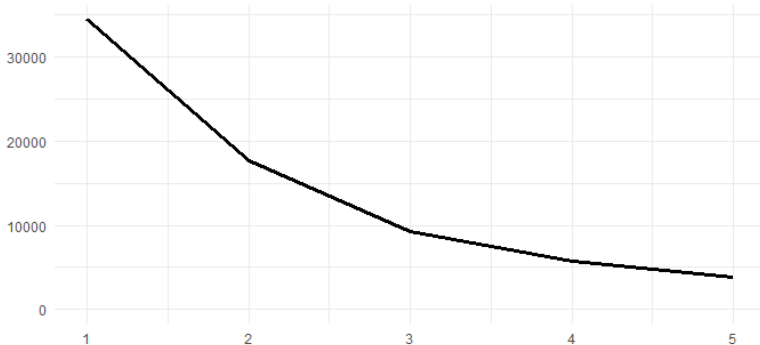


Figure 5: Difference between portfolios decays with n

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Takeaway

- Efficient market hypothesis
- Behavioral effects in finance
- Model of investor sentiment
[Barberis et al. (1998)]

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Key takeaway

Don't panic and become a Bayesian!






- Efficient market hypothesis
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[Barberis et al. (1998)]

Key takeaway

Don't panic and become a Bayesian!

Thanks! Questions?

References

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