Rational Roots of Irrational Markets: Game Theory and Financial Bubbles

Arjun Maneesh Agarwal

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Chennai Mathematical Institute

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- At its peak, one Viceroy tulip was traded for:

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- A silver cup, clothes, a bed with bedding, and even a ship!

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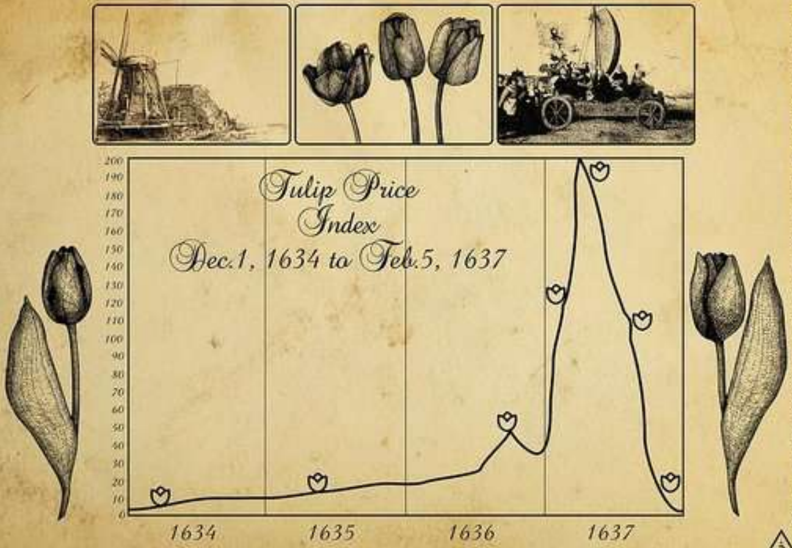
- The market collapsed, leaving many bankrupt.

Tulipomania



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    - The tipping point when rationality returns.

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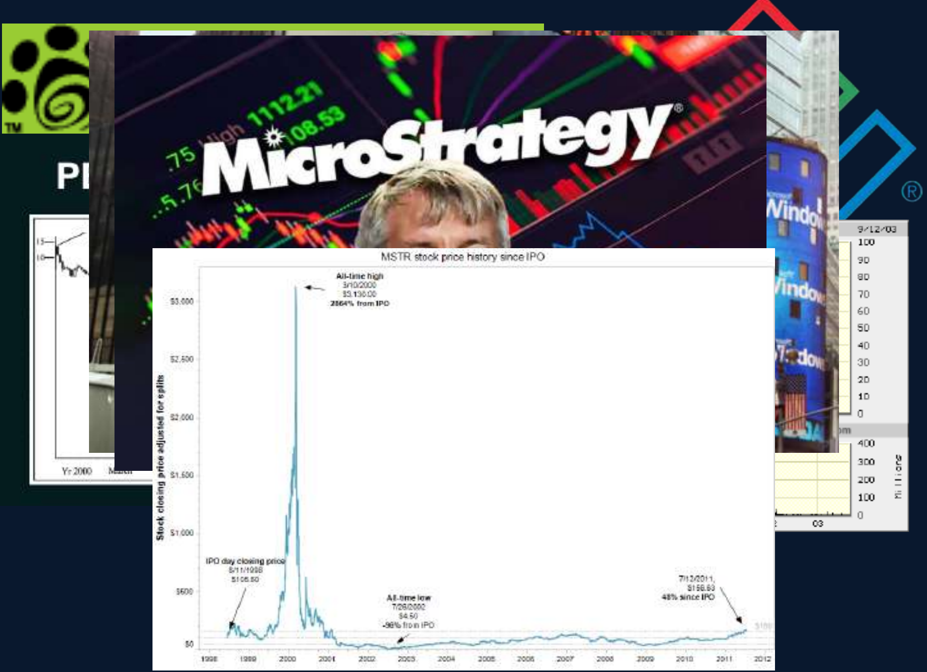
MicroStrategy®
MSTR stock price history since IPO
Stock closing price adjusted for splits
All-time high
3/10/2000
$3,130.00
2864% from IPO
IPO day closing price
6/11/1998
$105.50
All-time low
7/26/2002
$4.50
-96% from IPO
7/12/2011,
$156.63
48% since IPO
Yr 2000
9/12/03
Millions


TIME
SPECIAL REPORT
GetRich
.com
SECRETS OF THE NEW SILICON VALLEY
Sep 27, 1999
NASDAQ 2737
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- "Do the best you can given how you perceive the game and how you evaluate its various possible outcomes."
- In theory…but in practice?

Advertising War: Coke vs. Pepsi

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- What will the Cola companies do?
- Is there a better feasible outcome?

Laws of Game Theory

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- Second Law of Game Theory: Rational Choice may lead to outcomes which suck.

Connection to Prisoner's Dilemma

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Hint: Look for repeated interactions!

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Cocaine Oligopoly

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From one coke to another, cocaine is controlled by oligopolies. Let's work with a small case: two cartels have about 100 tons each. Let's say the cost per gram is $200 - q_1 - q_2$, where q_1 and q_2 are the amounts of cocaine the cartels(in tons) let into the market. Here, 200 is just a constant representing the maximum someone will pay per gram(in USD).

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- What does the price converge to?

Best Response Analysis

Let's say if my opponent is producing q_2, my best response is to produce q_1'. Using simple differentiation, for a given q_2, cartel 1's best response is:

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This is called the Cournout Price!

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- Voters go for the closest candidate.
- Play to win the election!

Median Voter Theorem

Proof.

- Suppose not.
- Without loss of generality, suppose that p_1 has more votes than p_2 and that $p_1 < b_{median}$.
- Then p_2 will deviate and instead choose $p_2 = p_1 + \varepsilon$, with ε small, so that $p_2 < b_{median}$.
- From single-peakedness, all the voters with ideal points in the interval $[p_2, \infty)$ prefer p_2 to p_1.
- Since $p_2 < b_{median}$, this is more than half of the voters.
- So p_2 would win, and thus would prefer to deviate.So it is not an equilibrium for p_1 to win with $p_1 < b_{median}$.
- Thus the only equilibrium where there is no profitable deviation is $p_1 = p_2 = b_{median}$.

$\square$

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- Why doesn't this always happen? That's deeper voting theory, which we won't cover today.

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- Firms locate to maximize sales!

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Branding can solve this problem. Explore the candidate-voter model and branding on a line for more insights.

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Should you accept this challenge?

Nash Equilibrium

Coming back to our topic, Nash Equilibriums are these magical stalemate points. The formal definition is:

Definition

Given a strategy profile $a_1, a_2, a_3, \ldots, a_n$; $b_1, b_2, b_3, \ldots, b_n$ and onwards for agents,

WLOG, $(a_1, b_1, c_1, \ldots)$ is a Nash equilibrium if and only if:

$$U(a_1 \mid b_1, c_1, \ldots) \geq U(a_i \mid b_1, c_1, \ldots) \quad \forall i$$

and the same for b and c and so on.

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Limitations of Nash Equilibrium

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- Many interesting games have more than one Nash Equilibrium!

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There is no pure strategy Nash equilibrium. However, if A chooses PNT with probability p and MTP with probability $1 - p$, then we can solve for p to find a mixed Nash equilibrium.

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- It can be a probability distribution over options.
- This is called a mixed equilibrium, and it always exists.
- The reason for existence is due to Brouwer's Fixed Point Theorem(and hence will not be covered).
- Although the algorithm to find it is much simpler, just assign probabilities to all non-dominated choices of A and solve so that B's choices are equal. It is a bunch of linear equations really.

Application: Sports Statistics

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- We'll see a poker theory example later down the line.

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- The first is Pareto dominant, but we often converge to the bad equilibrium.

Coordination Games and Bank Runs

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- Banks rely on depositors not withdrawing money simultaneously.
- A loss of trust can trigger massive withdrawals, leading to collapse.

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  - And we are still getting data on this one, Celsius’s 12 billion dollar collapse(2024).


SAFE DEPOSIT VAULTS
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W 37 ST


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    - It played a key role in providing liquidity to FTX and executing complex arbitrage strategies.

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  - In November 2022, a leaked Alameda balance sheet revealed that much of its assets were FTT-based, raising concerns about FTX's solvency.

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    - Binance initially considered acquiring FTX but backed out after conducting due diligence, citing "mishandled customer funds."

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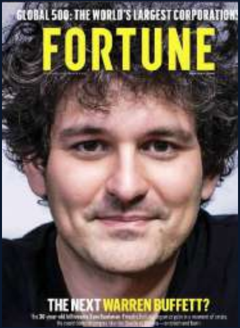
  - If SBF had managed to restore trust and survive the crisis, not declare bankruptcy, this investment could have been a financial lifeline.

FTX Case Study

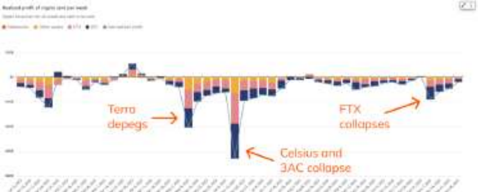
FTX

BINANCE



ALAMEDA RESEARCH

CoinDesk



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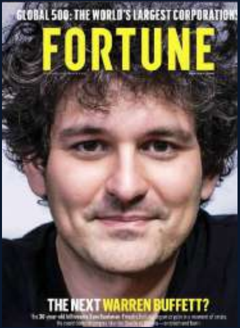
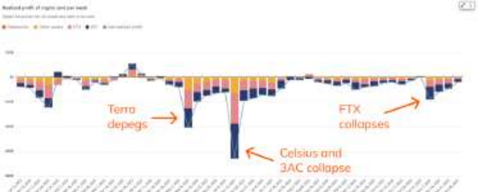
- What is the moral of this story?





Sequential Games

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Due to my inability to fit a tikz diagram in a slide, we will make the game tree on the board!

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- This is called a morel hazard.

- The classic problem is car insurance. What should the the terms be so that you don't mistreat your car?
- This process is called incentive design. If we change the payoffs in such a way that it is no longer a good idea to mistreat your car, well people won't.

Let's look at what all we need to consider here

- p = insurance premium
- r = recovery if car crashes
- c = cost of car
- ρ = probability of a car crash given you were driving recklessly
- κ = probability of a car crash given you were driving carefully

Are these enough?

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Car Insurence Cont.

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These kind of analysis are studied a lot in contract theory and policy design. You will also see them appear time and again in risk management and investment work.

Recap

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- Note perfect rationality has been assumed.

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First, some context. Marvel Snap employs poker-like betting mechanics. Players enter a match wagering 1 point and can "Snap!" on any turn to double their wager. Their opponent is given the option to either match the raise, or to retreat and forfeit the pot. Additionally, the game will always double the wager on the final turn. If you snap on this final turn, you are effectively re-raising to quadruple your wager. This is the notorious "boomer snap".

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  The nodes of decision tree are:

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  - The game is zero-sum, so B's payout is the negative of A's payout
  - The stake is initially set to 1
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  The nodes of decision tree are:

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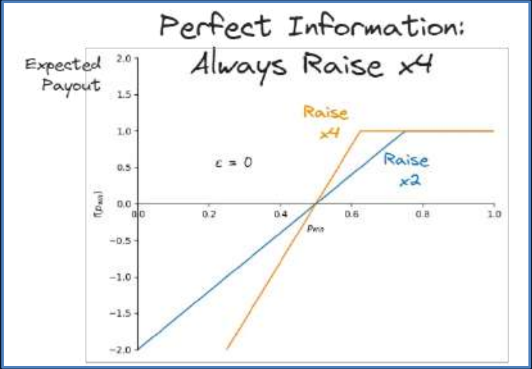
  - B: Call or Fold

To prevent me from needing to type math, we shall move to the black board now.



Why is then boomer snap bad?

Boomer Snap

- Of course, Marvel Snap is not a perfect information game. Opponents cannot see the cards in your hand. Additionally, players are not perfect computers. They might misjudge the situation and miscalculate P(win), which can be interpreted as hidden information. Given the variety of cards and decks, Snap seems to have even more hidden information than Poker. Let's add this to our model.

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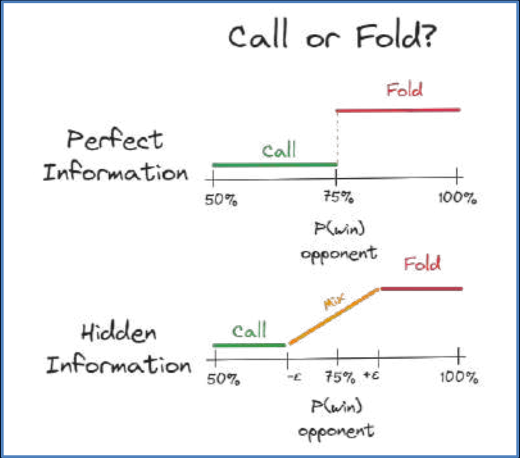
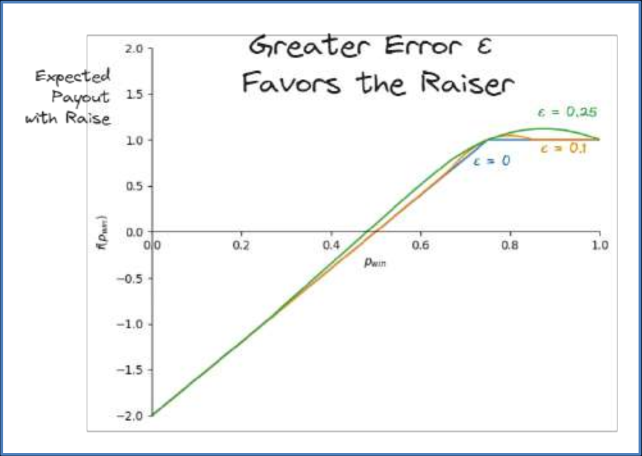
  - Note that $\hat{p}$(win) is unbiased. The expected value of $\hat{p}$(win) is the true value P(win). Payouts are still calculated based on P(win)

Boomer Snap



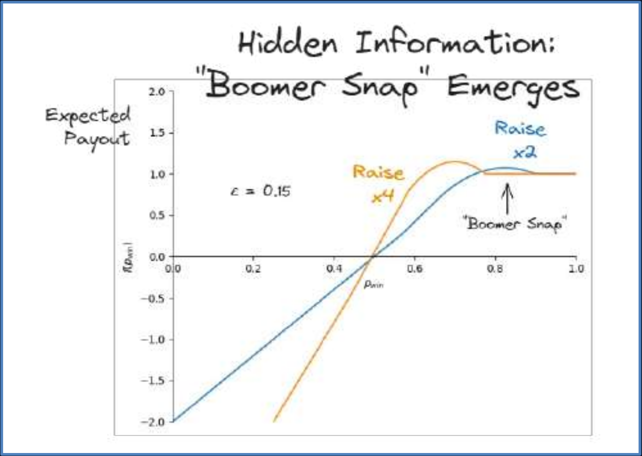
Call or Fold?
Perfect Information
Call
Fold
50%
75%
100%
P(win) opponent
Hidden Information
Call
Mix
Fold
50%
-ε
75%
+ε
100%
P(win) opponent

Boomer Snap



Greater Error ε
Favors the Raiser
Expected
Payout
with Raise
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
0.0
0.2
0.4
0.6
0.8
1.0
ε = 0.25
ε = 0.1
ε = 0

Boomer Snap



Hidden Information:
"Boomer Snap" Emerges
Expected
Payout
ε = 0.15
Raise
x4
Raise
x2
"Boomer Snap"
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
0.0
0.2
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1.0

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- Notably, this also suggests there is a correct time to boomer snap – if your P(win) is close to 62.5%(in our model), you have a lot of potential to gain from a x4 raise, as it will encourage opponents to fold decent hands.
- But this is also not a complete model? What are some hidden assumptions and simplifications we are making?

Boomer Snap

- Signals: Bets and play patterns signal about your hand state, which in-turn update the p(win) in a Bayesian fashion. While we will not talk about signalling here, note Spence's education game is a good introduction.

- Signals: Bets and play patterns signal about your hand state, which in-turn update the p(win) in a Bayesian fashion. While we will not talk about signalling here, note Spence's education game is a good introduction.
- Asymmetric information. We assumed that both players had the same error ε. However, if your opponent has more information than you, then that further muddies the decision. This scenario often arises, as one player may have played more cards to create a winning board state, but the other player may have more cards in hand or have been preparing a powerful combo for the final turn. 'Market for Lemons' by Akerlof is a great start to talk about such asymmetric scenarios.

Boomer Snap

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Other than that, such analysis is part of an intersection field of Probability, combinatorics, behavioural psychology and Game theory called Poker Theory

Bubbles

Schelling's Model

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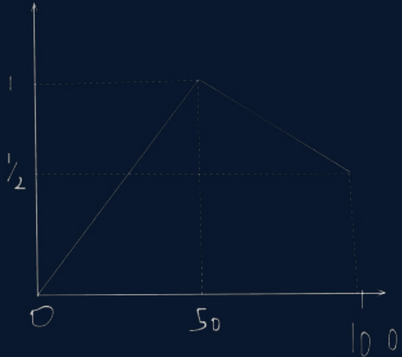

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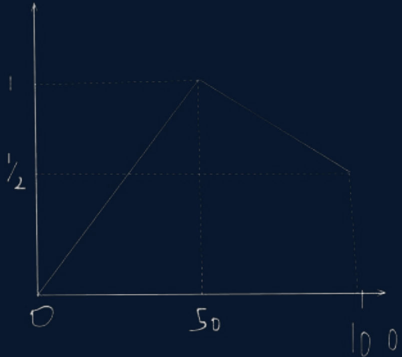

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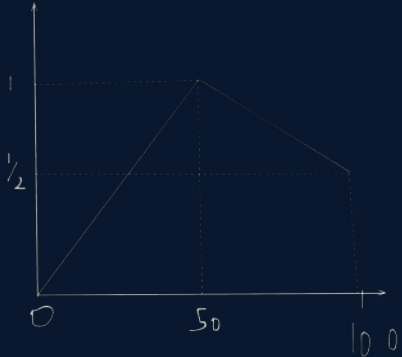

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- They just prefer to not be the minority which is justifiable.

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- What do we observe here?

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- Coming back to the model, what are the Nash Equilibriums here?

Discussion Contd.

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- Note: The last one is not something that really happens. It is induced by our method of modelling. We should be aware of such things when modelling the world!

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In reality, we can only be sure about our neighbours.

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- An excellent resource for this and policy methods to solve this is Vi Hart and Nicky Case’s polygons simulation.

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- But one has to ask, what does this have to do with Bubbles?

The Trend of Trading

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  - In fashion: Innovating or adopting trends early creates a unique identity and sets new trends.
  - In trading: Exiting before the trend reverses or identifying undervalued assets gives a competitive edge.

The Fashion Game

$$u(x_i) = -\|x - x_i\| - \lambda n(x_i)$$

The Fashion Game

- We model the expression of social identity as a game played by a population of N individuals. Let us say there are d aspects (or dimensions) of identity. Each person i chooses an expression of his identity xi ∈ {a..b}^d , i.e., represented as a tuple of d integers from some interval. For example, in the case of choosing a colour to wear, three integers between 0 and 255 might correspond to shades of red, green, and blue that mix together to form any colour.

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- We define the utility of an agent to be

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- Every player keeps changing their xi to get better payoffs.
- As it turns out, we can prove that this game converges to a Nash equilibrium. But that would mean some people would always follow a trend and others never follow it. This is false from our experience in fashion and finance.

Discussion contd.

$$u(x_i) = -||x_i - x_{\eta(u)}|| - \lambda n_{\eta u}(x_i)$$

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- And this much, is enough for there to exist networks with no Nash equilibrium. The proof is by construction, can anyone get it?

Discussion contd.

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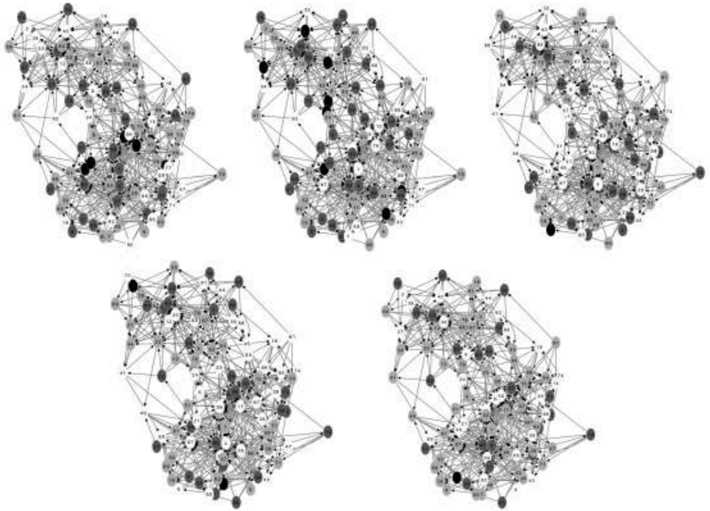
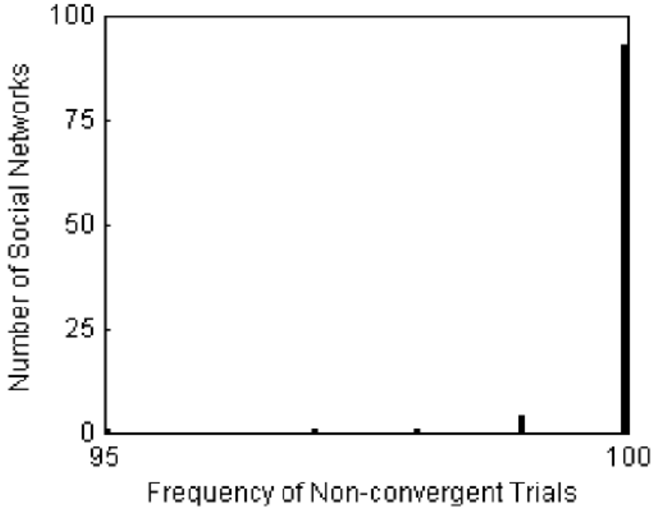
- We need to make some changes here to fit a financial market. I shall do them on the board.




100
75
50
25
0
95
100
Number of Social Networks
Frequency of Non-convergent Trials

Discussion contd.

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- This is true both sides. Despite many trends coming and going, people still wear Polo's.
- Similarly, despite market ups and downs, Tata, ITC etc are always dependable investments.
- Finally, We can now begin to understand the role of networks and local interaction. Popularity cycles(bubbles), perpetual change(bursts), and novel expressions(arbitrages) of social identity(makes) should be expected when people observe their neighbours in realistic, directed social networks and care about being unique(not being the last man holding the dollar) as well as fitting in(riding the momentum).

Conclusion

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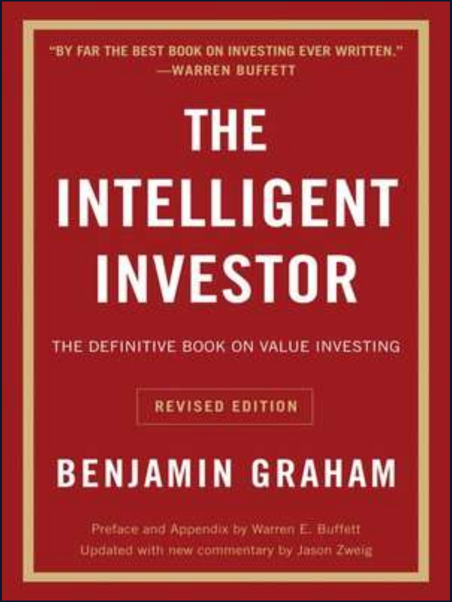
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Updated with new commentary by Jason Zweig

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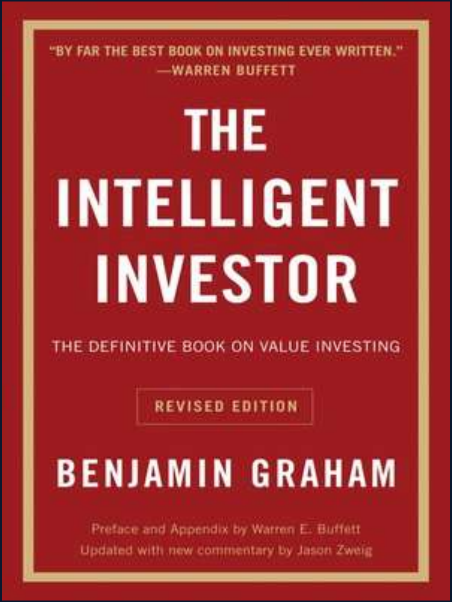

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"prime bank"
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"exclusive"
"You should focus on performance, not fees."
"Don't you want to be rich?"
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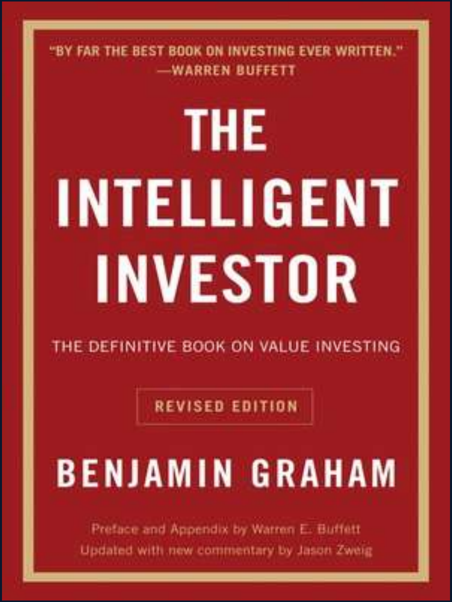

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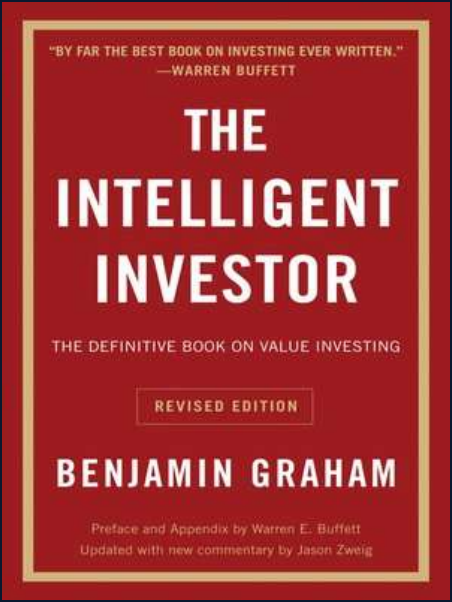

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We hear this, about every thing nowadays!
So is the greatest book on investing just wrong in 21st century?

Conclusion

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Over centuries, we've seen people—smart people, rich people, entire economies—fall for the same trap. Whether it was tulips, dot-com stocks, crypto, or AI, the game has always been the same: hype inflates, logic evaporates, and then—boom—gravity wins.

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So, what’s the lesson here? Markets aren’t rational. People aren’t rational. But you? You can choose to be.

Game Theory and the Art of Not Being an Idiot

- Every Bubble Has a Max Stupid Point – When prices stop being about value and start being about speculation, you’re playing chicken with reality. Don’t be the last fool holding the bag.

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- Understanding the Game is More Important Than Playing It – Everyone wants to win, but few understand why the game works the way it does. Study incentives. Study behavior. That's where the real power is.

Conclusion contd.

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I am sure some of you want to tell me that “Crypto is the future” or “AI is not a bubble” or “Have fun staying poor!”, and I want to tell you to beware.

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But if you feel this was all too much ado about nothing, then well I have a tulip to sell you!

PS: Keep Playing the Game

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Game Theory, market design, poker theory, contract theory, incentive design, voting theory, mathematical economics, and behavioural finance are gold mines of useful insights. If today made you think, dive deeper. Because the more you understand the game, the better your odds of not getting played.

Thank You!

Questions? Arguments? Outrage? Bring it on.