Lecture 3: Behavioral Finance and The Limits of Arbitrage

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Spring 2023

Question 1:

There is a hedge fund named Centennial that was founded in 1990 with $100 mln. It has now grown into one of the largest hedge funds in the world with over $45 bln in AUM.
In its 30 year history it has only down-year where it lost money. It runs in manner where it tries to be equity market neutral (e.g. it has a beta to the S&P 500 = 0).
Over the course of its history it has produced an average Sharpe Ratio of 2.2.
In your opinion does tis hedge fund Centennial have skill (e.g. “alpha”)? Does this hedge fund’s success make you make more skeptical about the markets being efficient

Question 2:

You want to test whether the ROE of a company has the power to predict the cross-section of stock returns? Both by itself and if has predictive power beyond the Size of a company.
ROE is defined at the trailing 12 months of net income for the firm divided by its current market capitalization.
How would you test this? Please describe the tests you would run?

Outline

- Exploring Heuristics and Biases
- Why Might Biases Effect Markets

Exploring Heuristics and Biases

Remember Market Efficiency

- Market efficiency in its most basic form is the simple statement that:

  "The market uses all information available to it to set prices."

In other words, market efficiency is stating that:

1. The market is aware of all available information.
2. The market uses the information correctly to set prices.

Remember Market Efficiency

- Does everyone need to be rational for market efficiency to hold?

No!

1. People do “dumb” things all the time but we can think of this as “noise”. One person’s dumb action is cancelled out by another’s person dumb action. So on average, there is just a lot of “noise” in the market but on average, prices are correct.

   Anecdotes of “silliness” or people behaving “irrationality” is not systematic evidence of inefficiency.

2. Even if you believe people make systematic mistakes, **professional arbitrageurs will be able to “capitalize” on those mistakes and earn large profits at the expense of the “irrational” traders.** Hence, driving prices to their correct value.

- So what’s the evidence on these two points?

Psychological Behavior

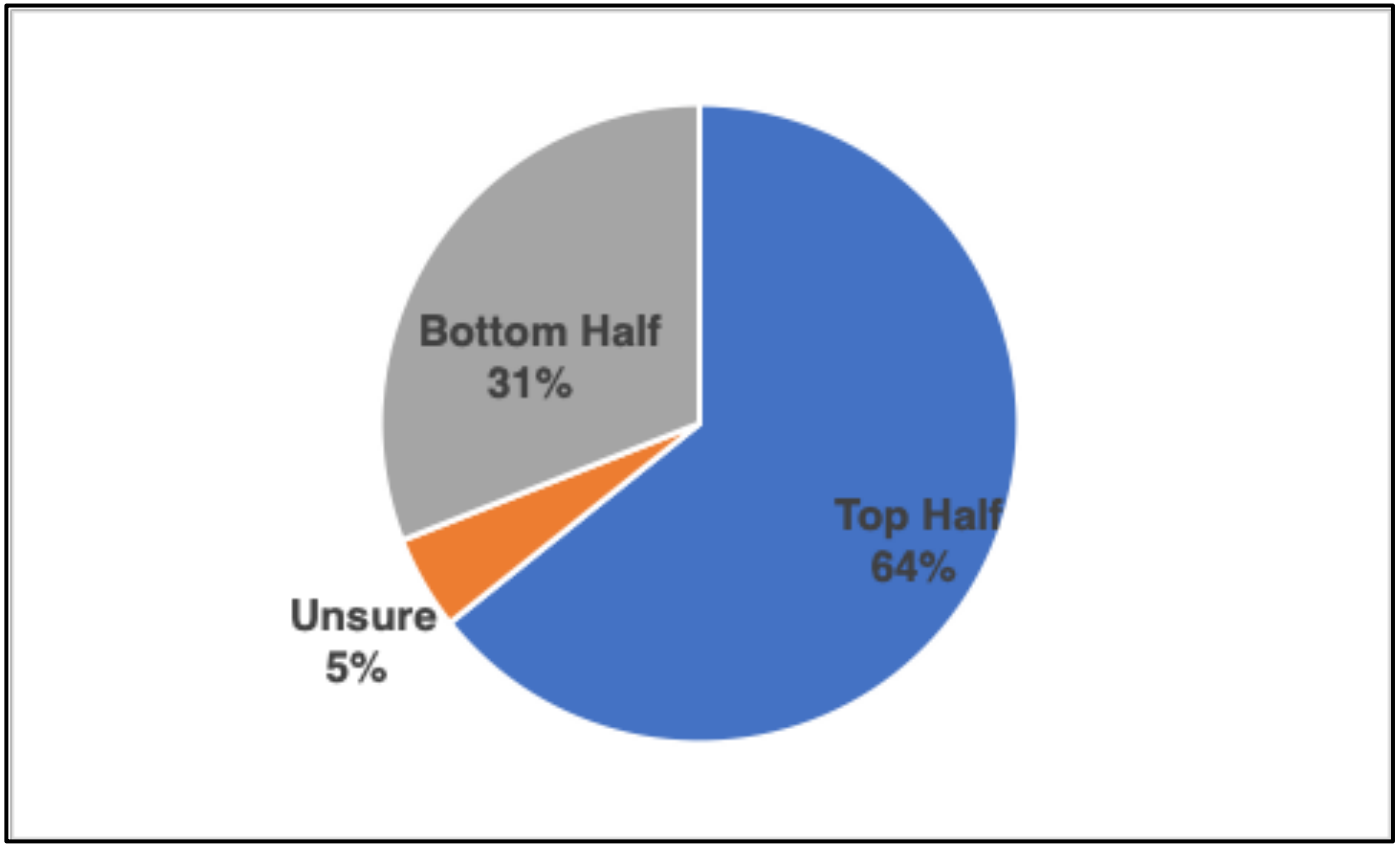
Optimism

- People have been reliably shown to be overly rosy in their beliefs of the abilities and prospects.
- Typically, over 90% have shown to believe they are above average in their driving ability, sense of humor and ability to get along with people. Surveys of CFO/CEOs show them to be systematically optimistic their own companies relative to all other companies.
- They also show a systematic planning fallacy: they predict that tasks (such as writing a paper, or completing a case (hint hint!)) will take much less time than it actually does.
- Evidence shows that the closer one is to the situation (“inside view”), the more optimistic one tends to be. The further one is removed from the situation (“outside view”) the less optimistic one tends to be. Examples might be what group of engineers who are tasked with building a database estimate it will take versus the estimate of their peers; or the CFO/CEO from above.
- This is one of the most pervasive and strongest biases. Only one group has been shown to have systematically accurate (non-optimistic) estimates. Can you guess who it is?

  The clinically depressed

Psychological Behavior

MIT Students: View of Own Prospects In This Class



Psychological Behavior

Overconfidence

- Extensive evidence has shown that people are overconfident in their judgements.

  Note: Optimism is about your estimate of the mean; overconfidence about the standard errors (surety) of your estimate.

  - People give far too small confidence intervals to estimates of quantities – say, their estimates of the S&P 500, one year from now. Generally, their 98% confidence intervals assume the true quantity only about 50%-60% of the time.

  - People are poorly calibrated when estimating probabilities.

    - Events they deem 100% certain to occur happen usually only 80% of the time.

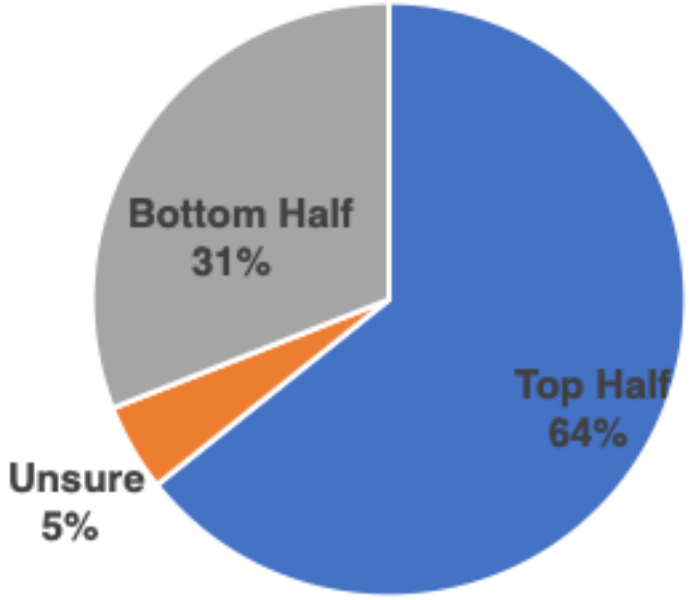
    - Events they deem 100% impossible to occur happen about 20% of the time.

- Does it matter if you are an expert in the subject matter?

  - No. Experts have been shown to be every bit as overconfident in their subject matter as lay-people on events.

  - Stocks analysts on earnings estimates; Geotechnical Engineers on foundation failures; Nuclear engineers on nuclear reactor safety; Airplane designers on technological failures ….

Where might you see participants in the stock market exhibit such a bias?



Your Prospects In This Class?

they fell into

- 12% were 100% sure which group they belonged to
- 35% were >90% sure which group they belong to
- 30% gave their estimate as 50% “sure” or “coin flip”

Not sure how to handle the two people who said they were 25% sure they were in the top half

Psychological Behavior

Representativeness Heuristic

- When people try to estimate that the Data Set A was generated by Model B OR that Object A belongs to Class B, people put too much weight on the probability that A represents some essential characteristic of B.
- This can cause several severe biases and bad outcomes.
- *Base Rate Fallacy*:

$$\mathrm{P(Statement\ B\ |Description\ )}=\frac{P(Description|Statement\ B)x\ P(Statement\ B)}{P(Description)}$$

People too much weight on $P(Description|Statement\ B)$ and too little weight on $P(Statement\ B)$, or the base rate.

Let's give an example!

Psychological Behavior

Kevin works at hedge fund in New York City. He went to Harvard Business School where he won accolades for his strong speaking and debating skills – so much so that his classmates and professors elected him a Baker Scholar for his contributions to the classroom. Before attending Harvard, Kevin went to Duke University where he studied government and public policy, was the president of his fraternity house, and captained the soccer team that made it to the NCAA national semi-finals. In his spare time, Kevin likes to play with his 3 children, sail his yacht on the Long Island Sound, and take vacations in the wine regions of California, Italy and France. His closest friends from HBS work in Silicon Valley in the private equity field or venture capital.

Which of the statement about Kevin is more likely?

A. Kevin is quantitative researcher building large statistical and machine learning models using cutting mathematical techniques, numerical estimation methods.

B. Kevin was drawn to the quantitative finance field because it gives the lifestyle flexibility to coach his children's soccer team and do his programming at odds in the night and so he became a quantitative researcher building large statistical and machine learning models using cutting mathematical techniques.

Kevin background sounds like a discretionary trader and his interests are stereotypically ***not*** those of quantitative researcher. Not many hard core Quant Researchers go to HBS!

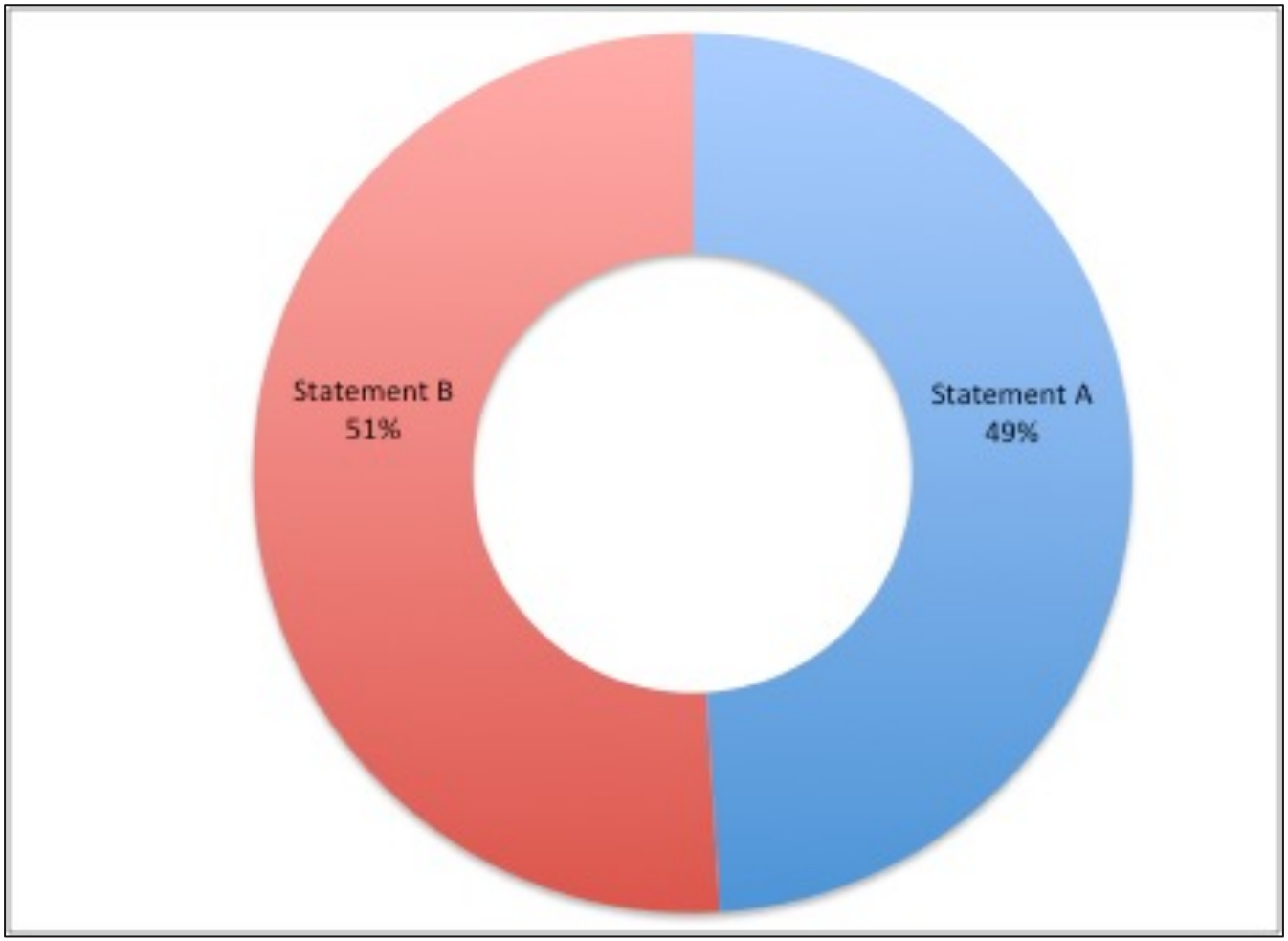
His interest are not representative of Quant Researcher, so we look for another reason to understand why Kevin mght have ended up as quant.

But it is impossible for B to more likely than A! P(A) >= P(A and B)

Psychological Behavior

MIT Students:

Kevin, the HBS Student, Yacht Racing, Lacrosse Playing, Quant



Psychological Behavior

Representativeness Heuristic

- *Small Sample Size Neglect*:
- When judging the likelihood that a data set was generated by a particular model, people often fail to take the sample size into account.
- This means when people *do not know* the data generating process, they infer too quickly from too few data points
- Examples:
  - Case A: Six tosses of a coin, giving 3 Heads and 3 Tails.
    Case B: 1000 tosses of a coin, giving 500 Heads and 500 Tails.
    Representativeness means that people will judge both to be equally likely of representing a fair coin when Case B is much more informative.
  - A manager who has outperformed the S&P 500 on a risk-adjusted basis for 3 years is a talented manager because 3 consecutive years of success is representative of a good manager not a poor or mediocre manager.
  - The “hot hand” phenomenon is sports: a player who has made 5 shots in a row is on a “hot streak” and will likely score again. There is no evidence of this and considerable evidence against it.

  This is also often called the “law of small numbers”

Psychological Behavior

Representativeness Heuristic

- *Small Sample Size Neglect*:
- When judging the likelihood that a data set was generated by a particular model, people often fail to take the sample size into account.
- This means when people *do know* the data generating process in advance, the law of small numbers leads to the gamblers fallacy.
- Examples:
  - I have flipped a coin 5 times, and it has come up heads all 5 times.
    Tails is due!

    Since even a small sample is representative of a large sample, there have to be more tails now to balance out the heads.

  - Joe: Please put my money on red 21on the roulette wheel.
    Dealer: Are you sure you want to do that? Red 21 just came up on the last spin.
    Joe: I didn't know! Thank you. Please put it on Black 15, instead. I can't believe I almost made that mistake!

  - Eric: For my lottery numbers I chose 6, 14, 22, 31, 38, 56. What did you choose?
    Peter: I chose 1, 2, 3, 4, 5, 6.
    Eric: You idiot! Those numbers will never come up.

Psychological Behavior

The city of Dullsville has two hospitals: Westside and Eastside. In Westside Hospital about 45 babies are born each day and in Eastside Hospital about 15 babies are born each day. About 50% of the babies born in the U.S. are boys but the exact percentage varies each day.

During 2015, each hospital recorded the number of days when the more than 60% of the babies born were boys.

Which hospital do you think recorded more such days?

A. Eastside

B. Westside

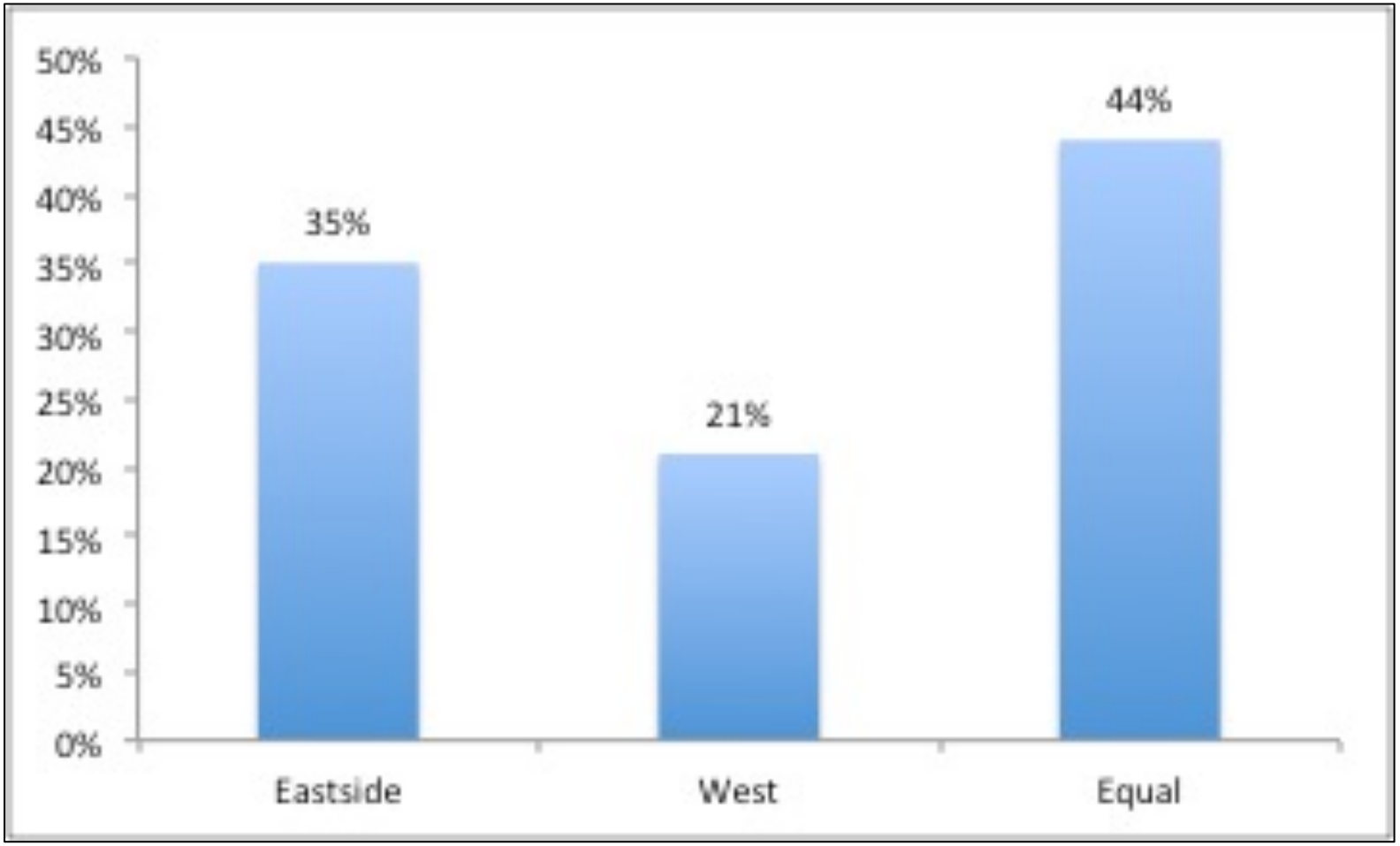
C. More or less equal (within 5% of each other)

Eastside is a much smaller sample than Westside.

So it is much more likely that Eastside will have a much greater number of days that differ from the true "data generating" process – will less representative of the true population mean.

Psychological Behavior

MIT Students: Eastside vs Westside Hospital



Psychological Behavior

Representativeness Heuristic

- *Mean Reversion*:

- Related to the concept of representativeness and the law of small numbers is a failure to understand "mean reversion" – the tendency over the long-run of process to revert to their long-term mean.

- Failure to understand this convergence to the mean is wide-spread and leads to a number of distortions in markets, social sciences, as well as even child-rearing.

- Examples:

  Israeli Air Force instructors, practicing landings on Air Force carrier ships in the Mediterranean Sea, adopted a policy of never praising pilots after a good landing and berating them, by screaming into the headsets, after bad landings.
  They did this because they found it effective at correcting those pilots with poor landings. In contrast, when they praised pilots with unusually good landings, they found they had poorer landings in the future.

  A baseball player who has had an unusually good first half of the year will often command a premium when being traded to another team. They often have a disappointing second-half of the season.
  This has largely led teams to believe that the importance of "team chemistry" is not to be overlooked nor the importance of being in training camp at the beginning of the year and "learning the system".

  Can you think of a stock market example?

Psychological Behavior

Anchoring

- When forming estimates, people start with some initial value (often arbitrary) and then adjust away from it. Experimental evidence has shown that people adjust too little. This is called anchoring – they "anchor" to their initial value.
- Anchoring also leads to "extrapolation". People perform just a few steps of computation and estimate the rest by product of extrapolation or adjustment. But the adjustment or extrapolation is often insufficient.

Examples:

One group of students was given 5seconds to multiply the numbers:

1 x 2 x 3 x 4 x 5 x 6 x 7 x 8

Another group of students was given 5 second to multiply the numbers:

8 x 7 x 6 x 5 x 4 x 3 x 2 x 1

The median estimate for the first group was 512

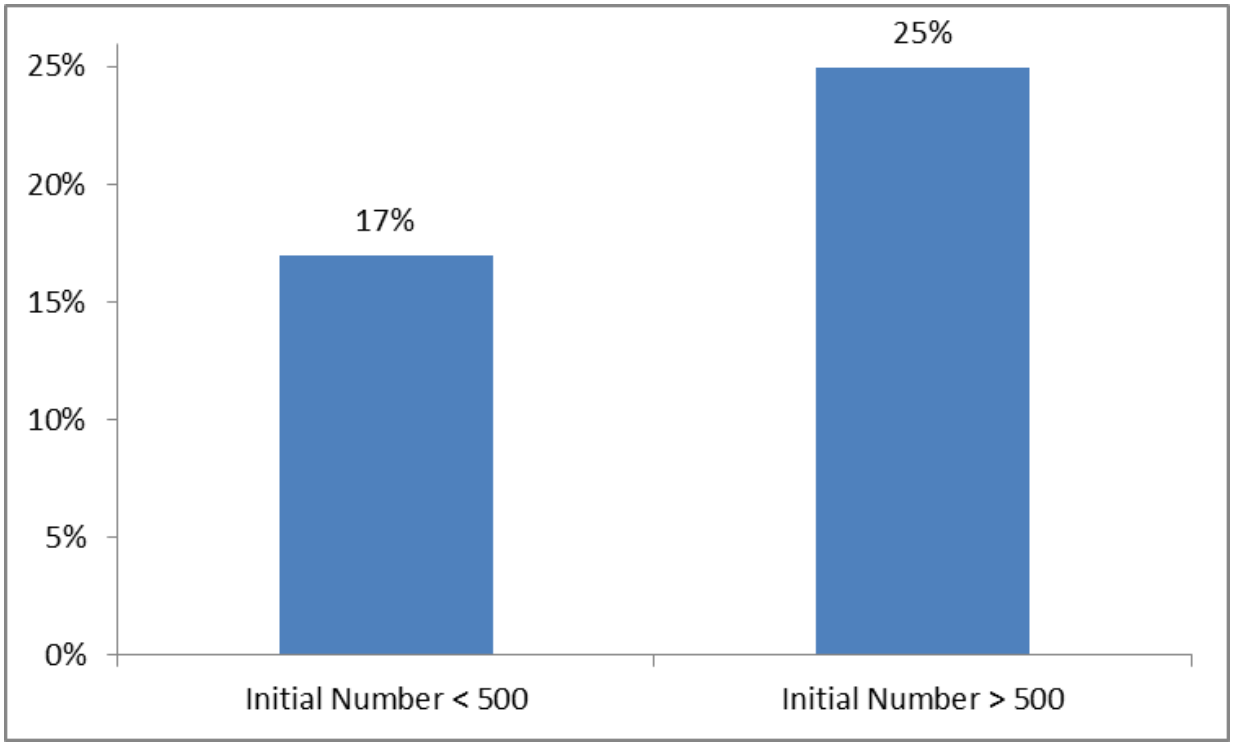
The median estimate for the second group was 2,250

The correct answer is 40,320

Where might you see this behavior in the market? Among financial analysts?

Psychological Behavior

MIT Students: United Nations Guess (mean)



Psychological Behavior

Availability Biases

- When asked to assess the frequency of a situation (“class”) or the probability of an event, people often do so by the ease with which the instances or occurrences can be brought to mind. This is called availability.
- This is a useful rule of thumb (or “heuristic device”) because generally more frequent or probable events are recalled better than less frequent events.
- However, availability is affected by other factors than just frequency and probability. This leads to predictable biases.

- <u>Retrievability Issues:</u>
  - Familiarity (“famousness”) makes something more retrievable.
  - Salience (“impact”) makes something more retrievable.
  - Media mentions makes something more retrievable.
  - General exposure / cultural background can make events have different degrees of retrievability.

Psychological Behavior

Availability Biases

- Effectiveness of the Search Set:
  - People recall things often by how easy is to “search their minds” for that “class” as opposed to how frequent that “class” actually is.

Examples:

- People are asked to imagine all the sets of three-letter (or more) words in English. Is it more likely that a word starts with the letter *r* or that the letter *r* is in the third position?

  People can much more easily search their minds for words that begin with the letter *r* than search for words with r in the third position. This true even though r actually appears more often in the later case.

- People are asked to imagine the frequency of abstract words – love, thought, freedom – and the frequency of concrete words – door, car, television.

  It is easier to imagine the contexts which abstract words appear than concrete words appear. People judge abstract words to occur much more frequently than concrete words, even though this isn’t necessarily the case.

Psychological Behavior

Availability Biases

- Imaginability:
  - The assessment of probabilities is often associated with how easy it is to imagine bad or good outcomes occurring or of their conceivability.
  - If people are prompted with notions and examples of possible outcomes, they have a far easier time imagining a wider and fuller range of outcomes or being biased into seeing one side of the outcomes.

Examples:

- People are asked to estimate the risk involved in an adventurous expedition, by imagining the contingencies with which the expedition is not equipped to cope.

  The expedition can be made to look exceedingly dangerous, if many such difficulties are vividly described, even, though, the ease of which with this disasters can occur has nothing to do with their probability.

  Conversely, the risk of the expedition can be grossly underestimated if some of the possible dangers are either difficult to conceive of (or are not brought to mind).

What are some examples where this might be applicable to markets and companies?

Psychological Behavior

How many people killed in all terrorist attacks on U.S. soil since the 9/11/2001 until today?

Answer: 339
Median: 3,941 with [15,55,00].
But 81% of responses did not have the answer within the confidence interval
Min: 5 and Max: 696,000

How many people have killed by lightening in the U.S. over the same period?

Answer: 447
Median: 1,129 with [150,250].
95% of responses did not have the answer within the confidence interval
Max guess was 502,500

Psychological Behavior

How many people have killed by shark attacks in the U.S. over the same period?

Answer: 19
Median: 1,209 with [5, 6,600]
81% of responses did not have the answer within the confidence interval

How many people have killed by falling televisions in the U.S. over the same period?

Answer: 542
Median: 1871 with [542, 88,000]
93% of responses did not have the answer within the confidence interval

Some people guessed [15,25] [0,20] [17,23] [2, 50] and then [80, 1.5mln]

Psychological Behavior

How many people in Africa are killed by hippopotamuses each year?

Answer: 2,900
Median: 500 with [113,287]
93% of responses did not have the answer within the confidence interval

Hippos are the most deadly mammal in Africa.

Snakes kill over 435,000 people per year in sub-Saharan Africa

Mosquitoes kill over 215 million people per year in Africa through the transmission of malaria.

Note: I threw out confidence internals where the 95th percentile was lower than the 5th percentile

Psychological Behavior

Preferences

- Prospect Theory:
  - Due to Amos Tversky and Daniel Kahneman (1979). Most cited article in all of social sciences.
  - People measure outcomes not according to wealth but relative to a “reference point”
  - They are risk-adverse over gains but are risk loving over losses. This is often referred to loss aversion.
  - They generally feel the pain of losses twice as acutely as the feel the pleasure of gains
  - They overweight the probability of small outcomes. This is called the certainty effect.

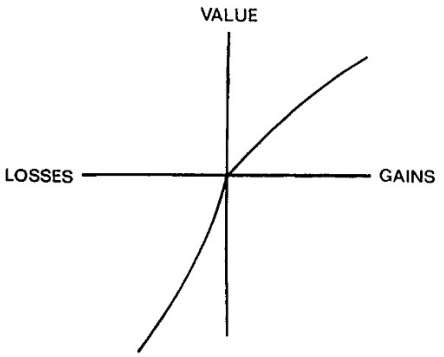
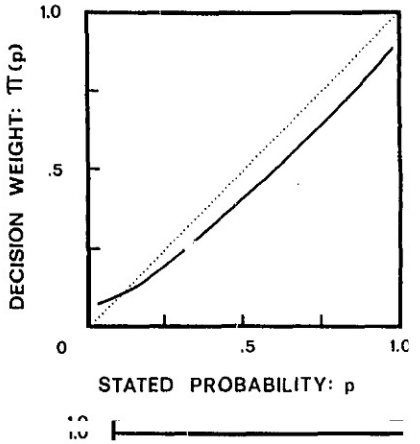


FIGURE 3.—A hypothetical value function



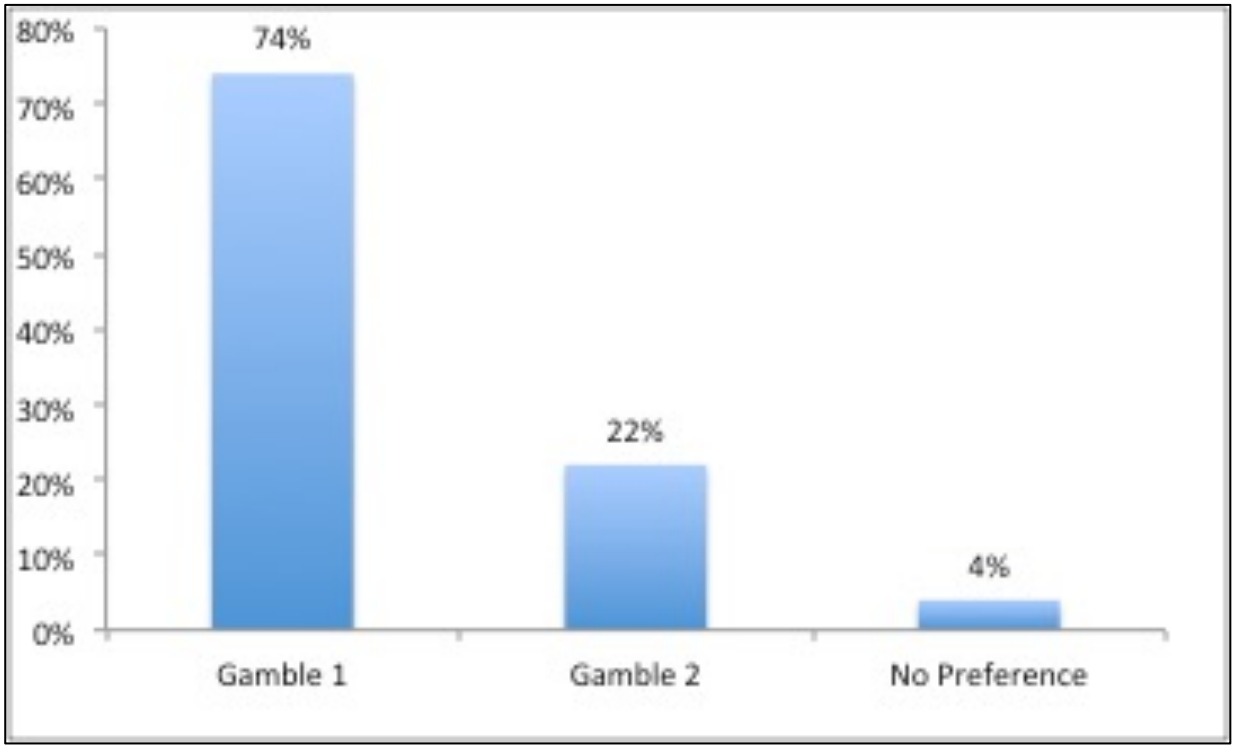
Psychological Behavior

Which do you prefer?

1. A 100% chance of winning $250

OR

2. A 25% chance of winning $1,000 and a 75% chance to win nothing



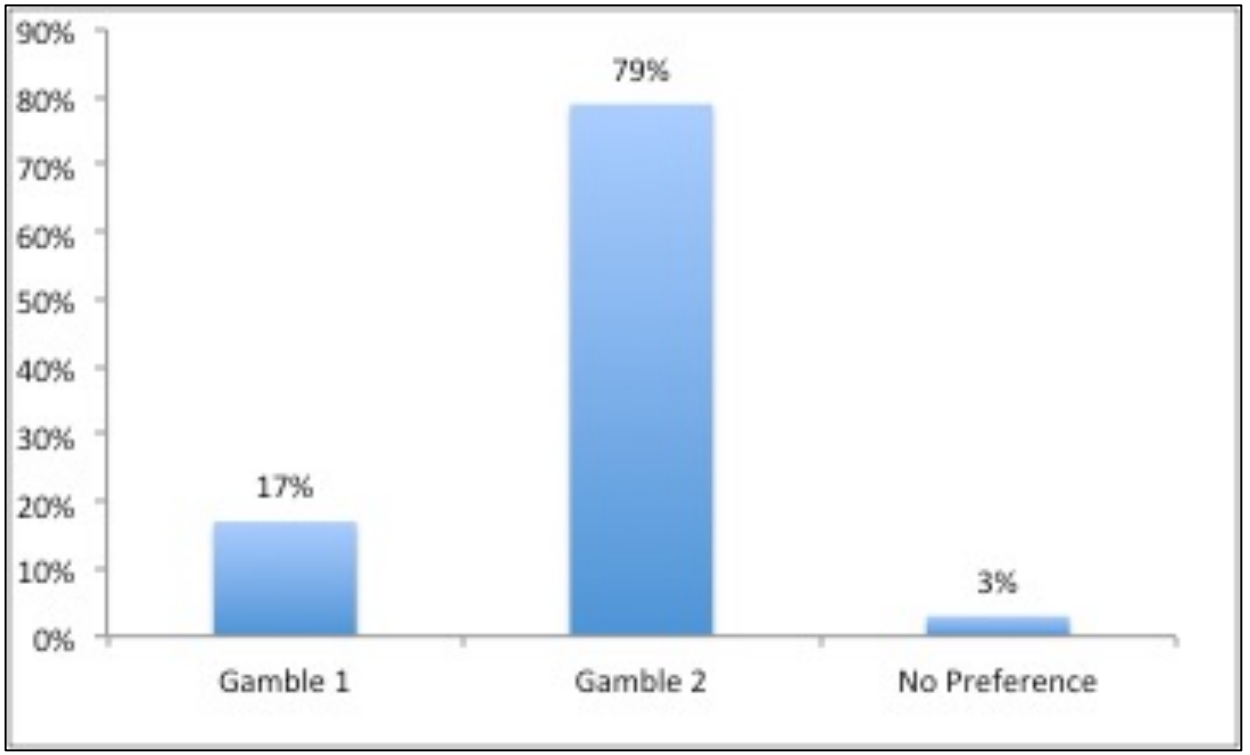
Psychological Behavior

Which do you prefer?

1. A 100% chance of losing $750

OR

2. A 75% chance of losing $1,000 and a 25% chance to lose nothing



We Are Not Super Computers or Fully Rational

Even MIT graduate students have a hard time computing conditional probabilities!

What hope is there for anyone else?

You heard a report on television about a rare disease, PSC, that is becoming more widespread and believe that you should be tested for it. The testing methods for this disease are correct 99.9% of the time – in other words, if you have the disease, it shows you do have it with 99.9% probability and if you don't have the disease, it shows you have don't have it with a 99.9% probability.

Now this disease is fairly rare, occurring randomly in the general population in only 1 out of every 10,000 people.

Your test results come back positive!

What is the probability that you actually have the disease?

(a) 99.9% (b) 99% (c) 10% (d) 1% (e) 0.1% (f) 1 out of 10,000

We Are Not Super Computers or Fully Rational

Remember Bayes Theorem:

$$P(A|B) = P(A \text{ and } B)\ P(A)\ /\ P(B)$$

Or

$$P(A|B) = P(B|A)\ P(A)\ /\ (\ P(B|A)P(A) + P(B \mid \text{not } A)\ P(\text{not } A)$$

Let A = You have the disease
Let B = Test Positive

What probability does the problem give you?

"if you have the disease, [then the test] shows you do have with 99.9% probability and if you don't have the disease, [then the test] shows you have don't have it with a 99.9% probability."

This is P(B|A)

What are you asked for?

"Your test results come back positive! What is the probability that you actually have the disease?"

This is P(A|B)

We Are Not Super Computers or Fully Rational

Remember Bayes Theorem:

$$P(A|B) = \frac{P(B|A)P(A)}{P(B|A)P(A) + P(B|\text{not } A)P(\text{not } A)}$$

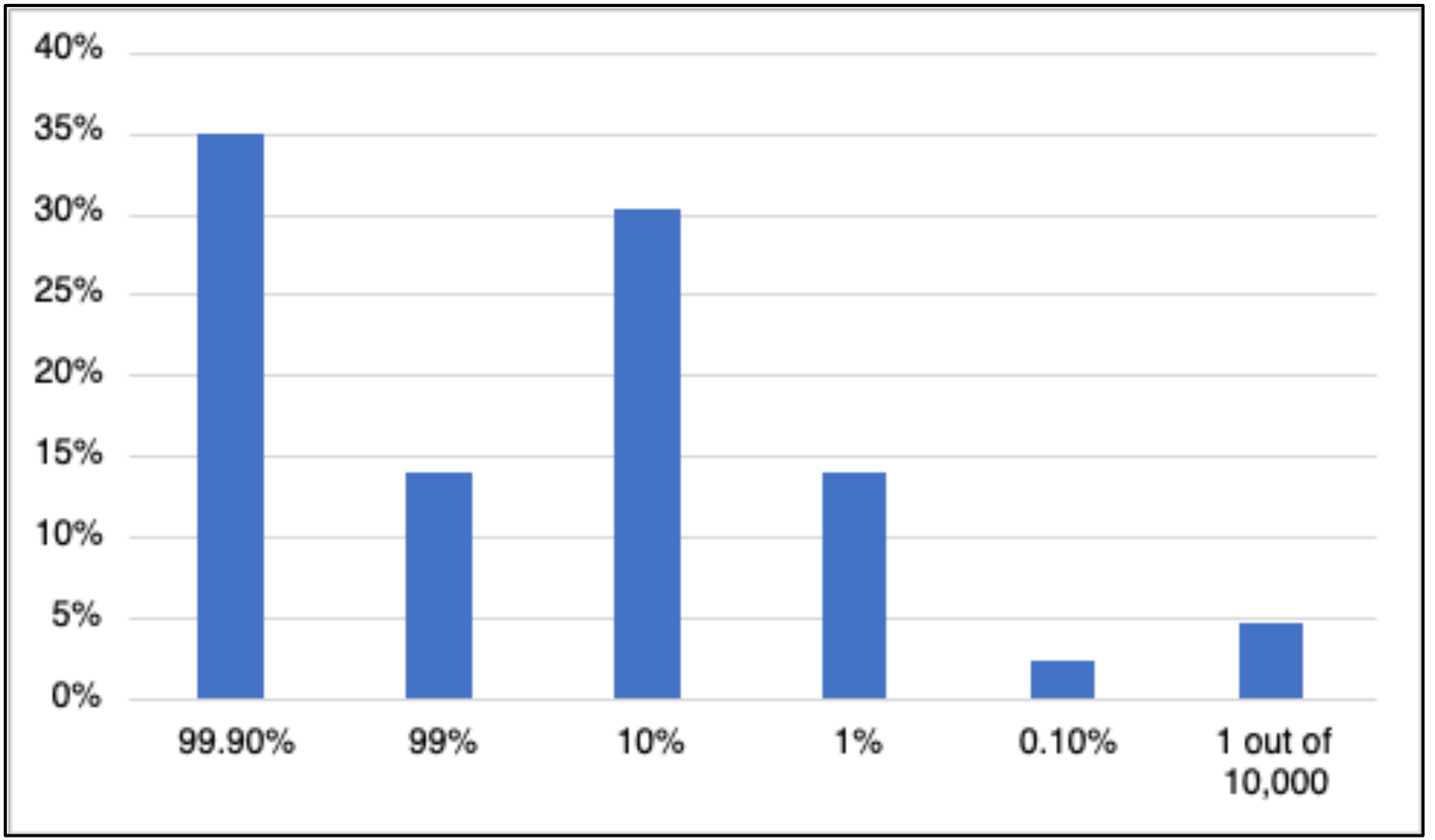
P(A|B) = P(B|A) P(A) / (P(B|A)P(A) + P(B | not A) P(not A))

Let A = You have the disease
Let B = Test Positive

$$P(A\,|B) = \frac{(99.9\%)(0.01\%)}{(99.9\%)(0.01\%) + (0.1\%)(99.99\%)}$$

$$P(A\,|B) = 9.1\% \quad \text{or Answer C}$$

We Are Not Super Computers or Fully Rational



We Are Not Super Computers or Fully Rational

Are we fully rational? And how rational do we believe everyone else in our class?

And if we think they are fully rational, does that make us irrational?

> Guess a number between 0 – 100.
>
> The guess closest to 2/3rd of the average guess of the class will win a prize. Note: ties will be broken randomly.
>
> Please write down your guess.

What is an irrational guess?

Any guess over 66.6!

We give this a rationality level of zero

A rationality level 1 guess would be 33 or (50 x 2/3)

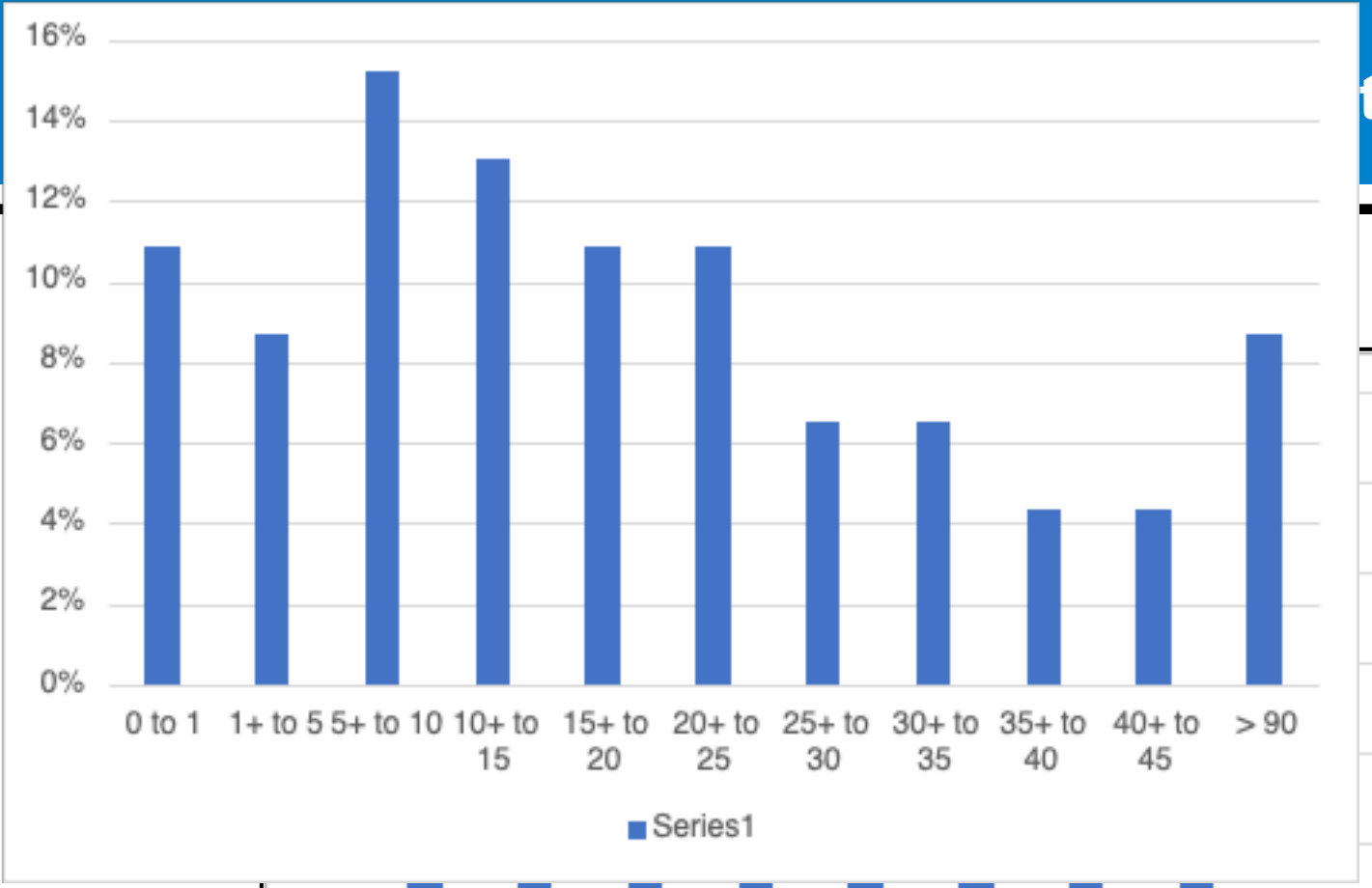
A rationality level 2 guess would be (33 x 2/3) or 22.2

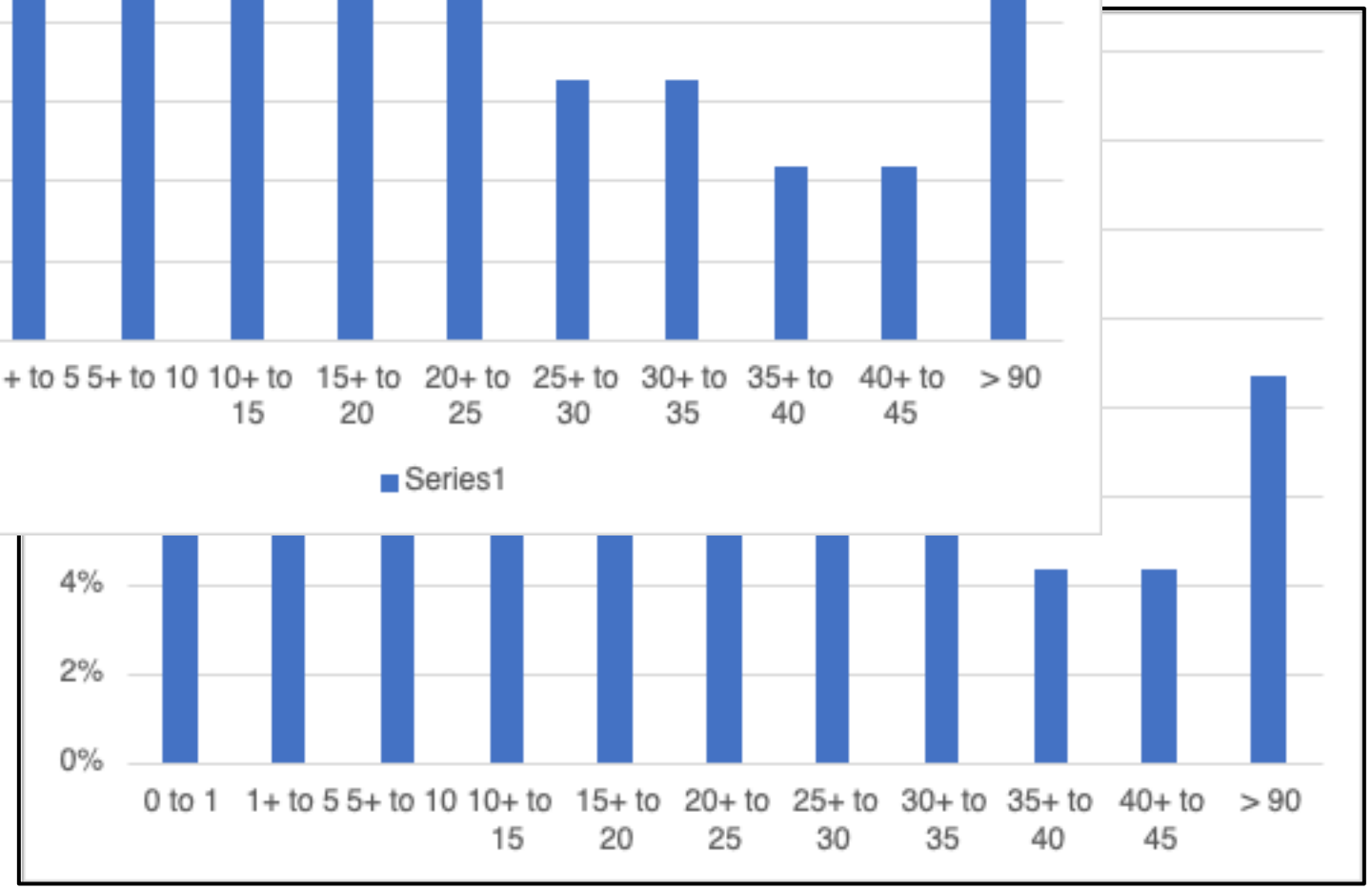
A rationality level 3 guess would be (22.2 x 2/3) or 14.8

A rationality level 4 guess would be (14.8 x 2/3) or 9.9

And so on …..

tional

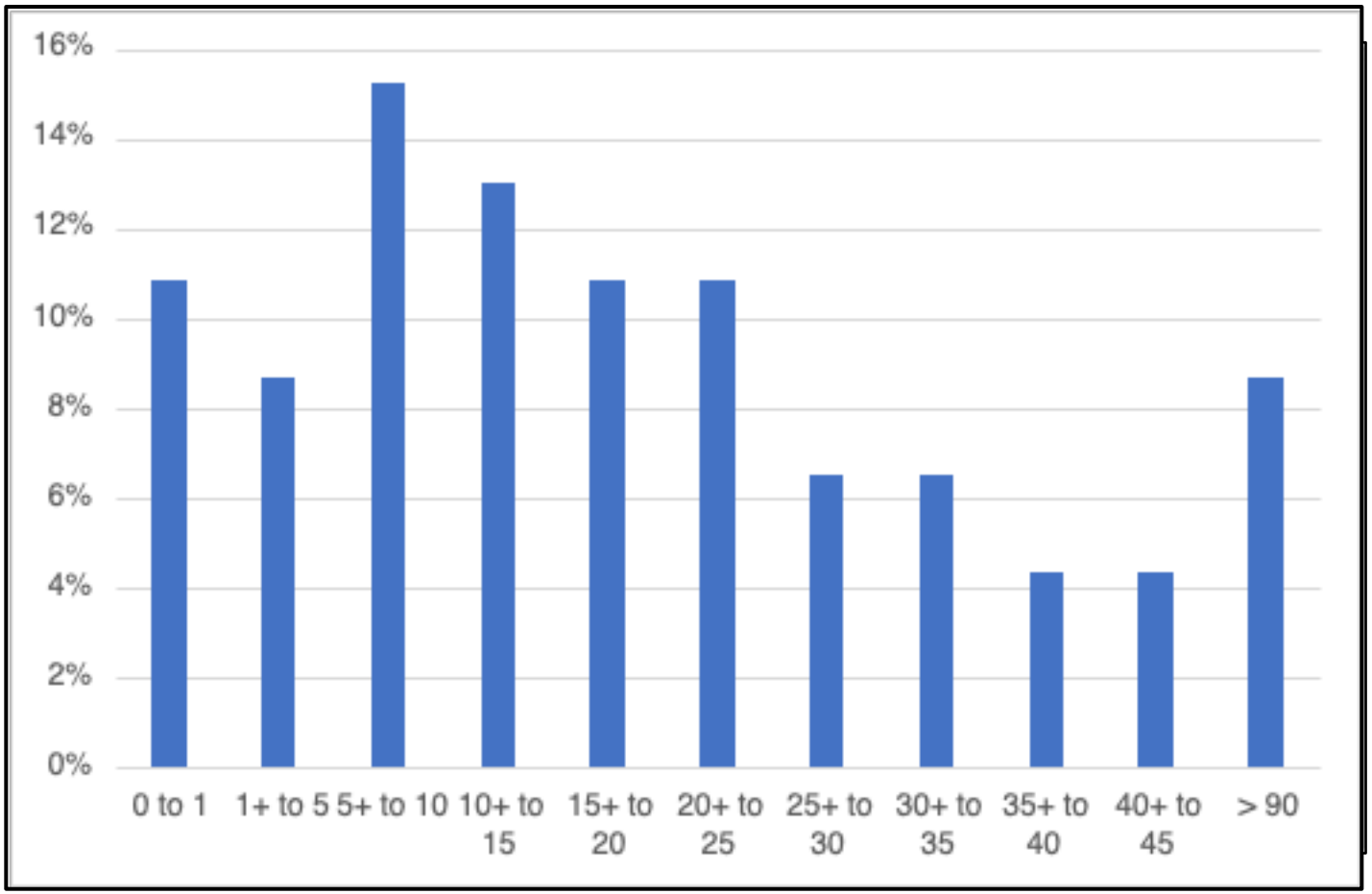




The average guess was 22.6. Two thirds is 15.1
Closest guess was by Rachel Duan.

We Are Not Super Computers or Fully Rational

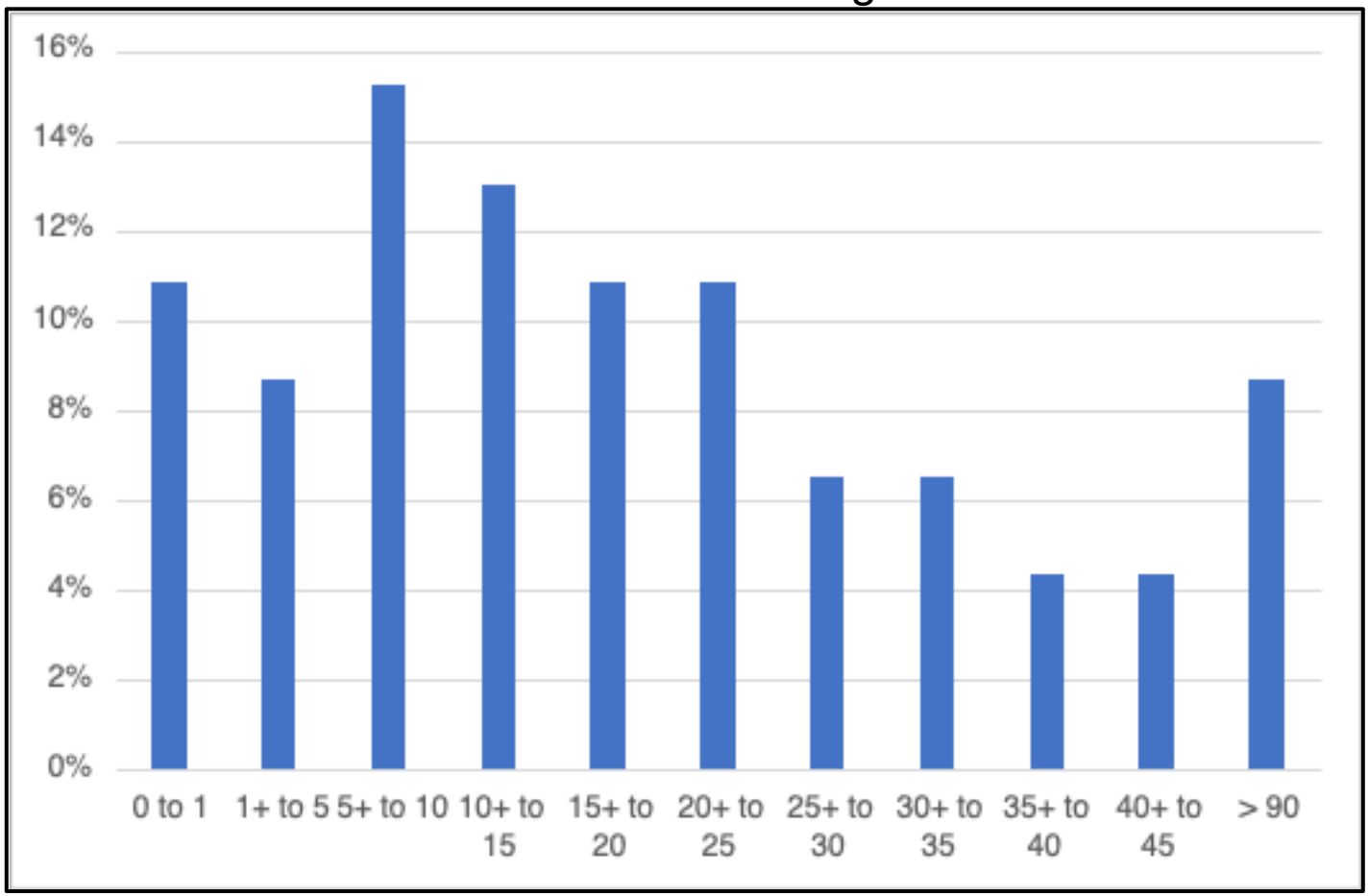
What is the distribution of guesses?



Of the people who guessed over 90, 3 of the 4 people thought they were in the top half of the class

We Are Not Super Computers or Fully Rational

What is the distribution of guesses?



Of the people who guessed between 0 to 5, 8 of the 9 people thought they were in the top half of the class…. Are these 8 people good “investors”? Remember Keynes Baby Beauty Contest!

Why Might Biases Impact Markets

Why Might Biases Impact Markets?

Why don't people learn their way out of biases? If we repeated these examples over again, wouldn't most of the biases disappear?

- Learning is hard and needs to be very specific.
- The world is non-stationary.
- The problems change.
- How much do you believe in other's rationality now? More or less?
- Are you less loss averse now that you are aware of it?
- Are you better at estimating at how many people in the U.S. are killed by deer each year because you know how many people were killed by hippos?
- Are you better at recalling how many times the letter "s" appears in the third position?
- Anyone want to try another example of Bayes Theorem?
- Anyone want to try 20 factorial?

Why Might Biases Impact Markets?

We have seen that these biases aren't "white noise". They are not random errors but systematic biases that people make and can't "learn" their way out of.

So is quantitative investing the answer? Maybe.

Or to ask it another way:

If people are making systematic mistakes that are leading prices to be incorrect, why can't some super smart really rich investor (sophisticated hedge fund) come in, take advantage of these inefficiencies, make lots of money and then arbitrage them away (e.g. make prices correct)?

Limits of Arbitrage

Why Might Biases Impact Markets? Limits of Arbitrage

Imagine the following situation:

- You are really smart manager, managing money for some set of investors.
- You have figured out that some stock, XYZ, is really worth $50. The stock is currently selling in the market for $100. So you go short the stock today.
- At the end of the next quarter, the stock is trading at $150. You have tripled checked your analysis (quadruple checked it) and you know you are right.
- How do you think your investors are reacting now?
- You are so sure of your thesis, and the misvaluation has become even bigger – in other words the inefficiency has grown worse – so you short even more of the stock.
- At the end of the next quarter, the stock is now trading at $200.
- How are you investors reacting now?

Why Might Biases Impact Markets? Limits of Arbitrage

Imagine the following situation:

- You still are convinced of your thesis and go short even more of the stock. Again, it is an even bigger opportunity for you and your investors to make money.
- At the end of the next quarter, the stock is now trading at $300!
- What do you think your investors are going to start doing?
- The longer this goes on, the more and more pressure there will be for you to "give up" and close out your position!
- In other words, the greater the inefficiency becomes the harder it is for you to actually bet against it! The harder it is for you to correct it.
- Again, the larger the inefficiency grows and the longer it persists the harder it is for as a money manager to bet against it.
- This goes against the theory of markets being efficient because "smart money" drives out (wipes out) the dumb money.

Why Might Biases Impact Markets? Limits of Arbitrage

This is known as the Limits of Arbitrage.

What makes this problem? What do you need for it to exist?

1. You are managing other people's money.
2. They can't tell for sure if you are really smart (and right) or you are wrong. *There is some probability that you are wrong and that probability grows as the market moves against you.*
3. You don't have unlimited capital. Such a thing really doesn't exist. At some point, the markets can stay irrational longer than you can stay solvent.

Condition (1) makes the situation obvious but not necessary if you are an introspective, risk averse investor – in other words, you too think you might be wrong.

But admittedly this is a bigger problem in "delegated money management".

Why Might Biases Impact Markets?

Lessons

- Arbitrage is limited because of delegated investing. It is really a Limits of Learning problem.
- Ironically, the worse the irrationality and the longer it persists, the worse the problem gets.
- Extreme cycles of irrationality won't lead to more people to rush in but will lead to the extinction of arbitrageurs.
- The greater the arbitrage opportunity, the potentially fewer people there are to take advantage of it.
- To a professional arbitrageur, you need markets to be "just the right amount" inefficient. If they are too inefficient you have a problem. If they are too efficient then there are no opportunities. Goldilocks inefficient.
- Remember Cliff Assness's conversation with his wife!
- Remember the market can remain inefficient longer than you can stay solvent
- Remember the Keynes Baby Beauty contest story.

Why Might Biases Impact Markets?

Where Might The Limits of Arbitrage Be Important

- Where learning is hard!
  - Examples:
    - Non-stationarity;
    - New “asset classes”;
    - “Games” which are not-repeated (or low repetition);
    - Where there is no incentive to “experiment”;
    - Where the signal to noise ratio is low; where the rewards to learning are low
- Where the wrong answer can persist for a while!
  - Examples:
    - Where learning is hard;
    - Where it is hard to correct the mispricing due to a lack of appropriate assets, costs of shorting, or other institutional constraints

Why Might Biases Impact Markets?

Institutional Constraints:

The regulations and constraints that institutions operate under may lead to inefficiencies developing that are very hard to arbitrage away.

Examples:

- Short sale constraints
- ERISA / Prudent Man guidelines
- Leverage Aversion
- Benchmarking: Sharpe Ratio vs Information Ratio

Summary

Summary

- Questions:
  - Where might the “law of small numbers” and representatives lead to issues in how analyst’s analyze companies or investors pick mutual funds? Or mean-reversion?
  - Where might issues of optimism be present in how CEOs behave? What type of actions might this lead them to do or not do? How might these be different than those driven by overconfidence?
  - How might the availability heuristic impact companies and markets? If you were a regulator (e.g. the SEC) are there any actions you might want to take to help alleviate issues that could rise here?
  - What is Prospect Theory? Is it just standard utility with a “kink” in the utility curve? Or is it something more? Do you think you “Prospect Theory” describes your behavior? And if so, now that you know about it, what concrete action are you going to do to become more “rational”?
  - How might the fact that our brains are not super computers specifically impact the efficiency of markets? Discuss with specific examples from today’s class.
  - Why do biases continue to exist? What kind of biases might we learn our way out of? What kind might persist for a long period of time?
  - People are horrible at assessing risks (as we have seen today). If you were a regulator (Commissioner of the SEC) what actions might you undertake to help people better understand the real risks associated with an investment? Which of the biases do you think are most holding people back here?

Summary

- Questions:
  - Why do some efficiencies get arbitraged away and why might others persist for long periods of time?
  - How might the Limits of Arbitrage story explain the Dot Com bubble? Or the Housing Market bubble in the mid 2000s?
  - Do you think Limits of Arbitrage stories are more powerful when it involves something new and different (e.g. Bitcoin, the Dot Com bubble) than when it involves something more standard (e.g. housing prices)? If so, or not, why? What makes the logic of the Limits of Arbitrage work or not work that way?
  - As an investor, is your job to actually understand the true fundamental value of an asset? Or is to predict what other people think the true fundamental value of an asset is? What are the risks of engaging in either of these approaches? Which is ultimately "more risky" in your mind?
  - What is your favorite example of a "behavioral anomaly" that you believe is most likely to impact asset prices?
  - What is the strongest evidence that you can think of that markets are actually efficient?
  - Why can't professional arbitrageurs with even perfect foresight of the future make essentially unlimited profits? What are the constraints working against that happening?