APPLIED MECHANISM DESIGN FOR SOCIAL GOOD

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Lecture #25 – 04/26/2018

CMSC828M
Tuesdays & Thursdays
9:30am – 10:45am

COMPUTER SCIENCE
UNIVERSITY OF MARYLAND

PREDICTION MARKETS

Thanks to: Yiling Chen (YC), Christian Kroer (CK), Dave Pennock's blog (DP)

ORANGE JUICE FUTURES AND WEATHER

Trades of 15,000 pounds of orange juice solid in March

SAT	SUN	MON
Mostly Sunny	T-storms	Sunny
High: 76°	High: 72°	High: 55°
Low: 52°	Low: 37°	Low: 32°

Orange juice futures price can improve weather forecast! [Roll 1984]

EVENTS OF INTEREST

Will category 3 (or higher) hurricane make landfall in Florida in 2017?

Will Google reinstate its Chinese search engine?

Will Democratic party win the Presidential election?

Will Microsoft stock price exceed $65?

Will there be a cure for cancer by 2020?

Will sales revenue exceed $200k in April?

THE PREDICTION PROBLEM

An uncertain event to be predicted

- Q: Will category 3 (or higher) hurricane make landfall in Florida in 2011?

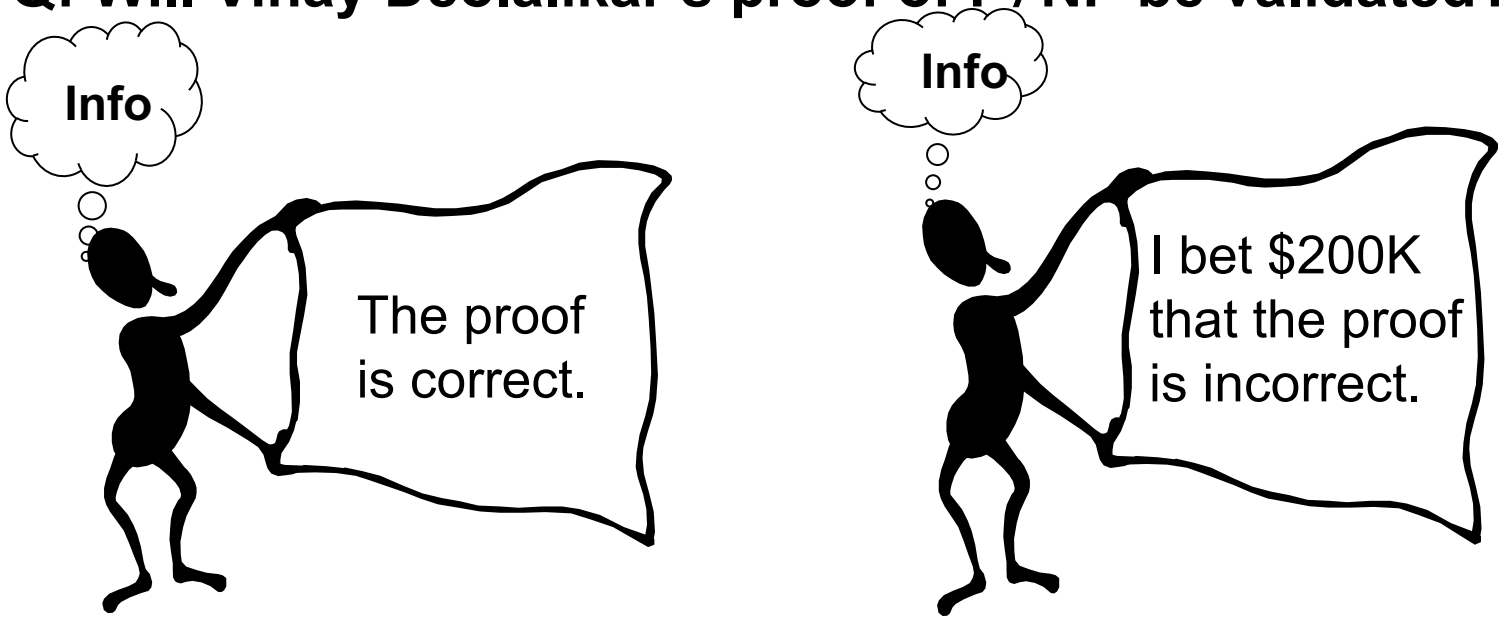
Dispersed information/evidence

- Residents of Florida, meteorologists, ocean scientists…

Goal: Generate a prediction that is based on information from all sources

BET = CREDIBLE OPINION

Q: Will Vinay Deolalikar's proof of P≠NP be validated?



Scott Aaronson: "I have a way of stating my prediction that no reasonable person could hold against me: I've literally bet my house on it."

Betting intermediaries

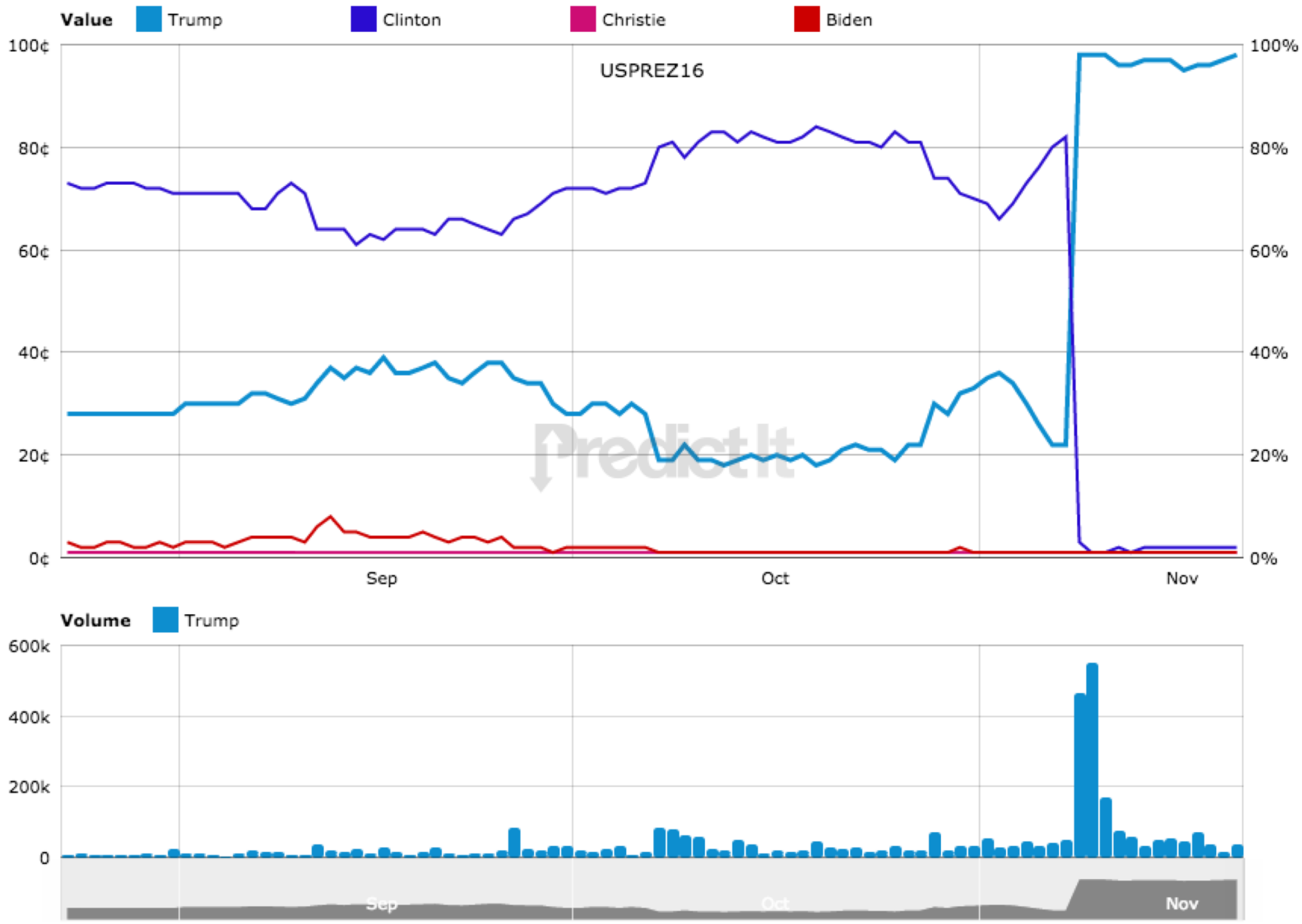
- Las Vegas, Wall Street, IEM, Intrade (in the past), PredictIt, …

PREDICTION MARKETS

A prediction market is a financial market that is designed for information aggregation and prediction.

Payoffs of the traded contract is associated with outcomes of future events.

$1×Percentage of Vote Share That Trump Wins



Source: PredictIt US General Election Market

DOES IT WORK?

Yes, evidence from real markets, laboratory experiments, and theory

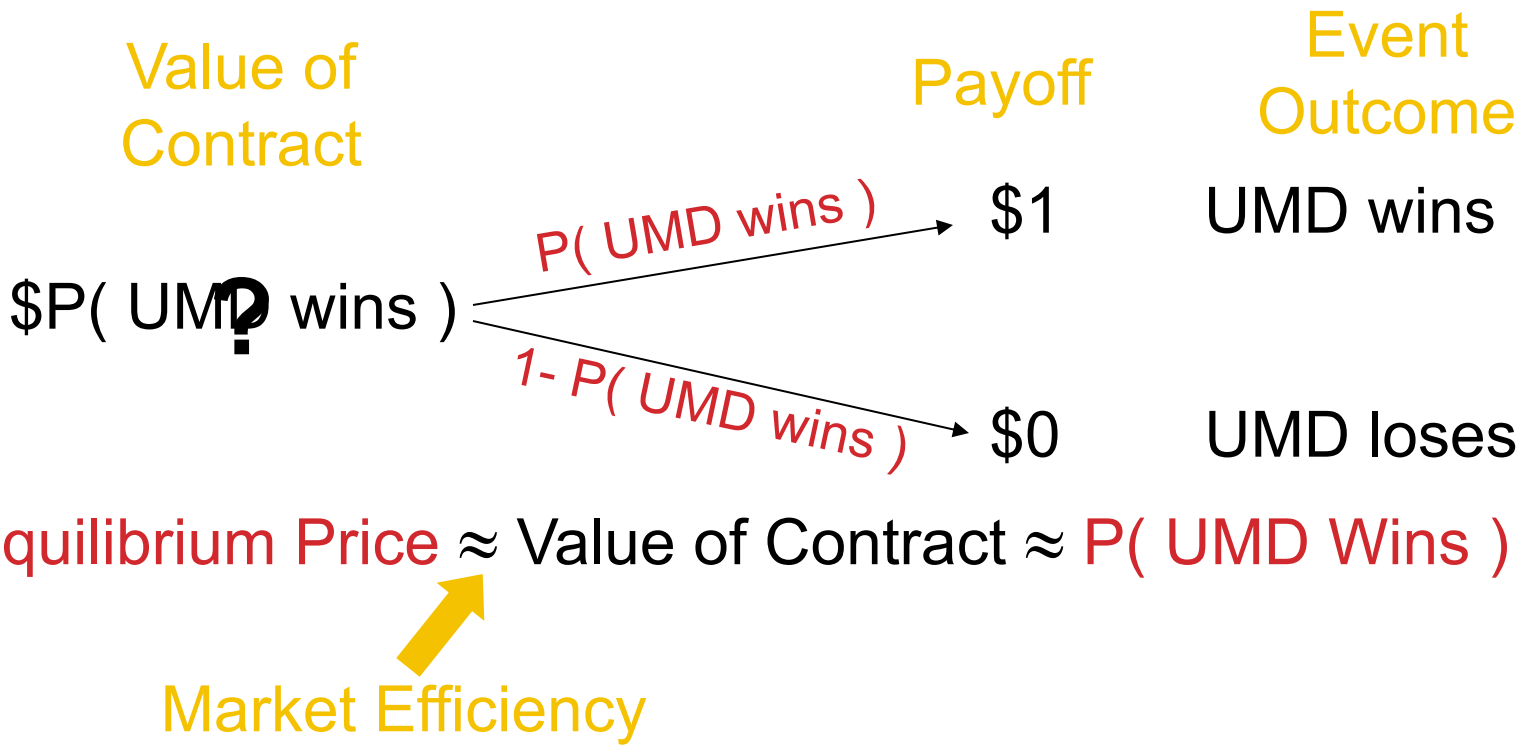
- Racetrack odds beat track experts [Figlewski 1979]
- I.E.M. beat political polls 451/596 [Forsythe 1992, 1999][Oliven 1995][Rietz 1998][Berg 2001][Pennock 2002]
- HP market beat sales forecast 6/8 [Plott 2000]
- Sports betting markets provide accurate forecasts of game outcomes [Gandar 1998][Thaler 1988][Debnath EC'03][Schmidt 2002]
- Market games work [Servan-Schreiber 2004][Pennock 2001]
- Laboratory experiments confirm information aggregation [Plott 1982;1988;1997][Forsythe 1990][Chen, EC'01]
- Theory: "rational expectations" [Grossman 1981][Lucas 1972]
- Prediction markets still beat polls in the 2016 US Election

WHY MARKETS? – GET INFORMATION

Speculation ➔ price discovery

price ≈ expectation of r.v. | all information

$1 if UMD wins, $0 otherwise



NON-MARKET ALTERNATIVES VS. MARKETS

Opinion poll

- Sampling
- No incentive to be truthful
- Equally weighted information
- Hard to be real-time

Ask Experts

- Identifying experts can be hard
- Combining opinions can be difficult

Prediction Markets

- Self-selection
- Monetary incentive and more
- Money-weighted information
- Real-time
- Self-organizing

NON-MARKET ALTERNATIVES VS. MARKETS

Machine learning/Statistics

- Historical data
- Past and future are related
- Hard to incorporate recent new information

Prediction Markets

- No need for data
- No assumption on past and future
- Immediately incorporate new information

Caveat: Markets have their own problems too – manipulation, irrational traders, etc.

PREDICTION MARKET DESIDERATA

Liquidity

- People can find counterparties to trade whenever they want

Bounded budget (loss)

- Total loss of the market institution is bounded

Expressiveness

- There are as few constraints as possible on the form of bets that people can use to express their opinions

Computational tractability

- The process of operating a market should be computationally manageable

CONTINUOUS DOUBLE AUCTION (CDA)

$1 if UMD wins, $0 otherwise

Buy orders		Sell orders
$0.12		**$0.30**
$0.09	Price = $0.14	**$0.17**
$0.15		**$0.13**

WHAT'S WRONG WITH THE CDA?

Thin market problem

- When there are not enough traders, trade may not happen

No trade theorem **[Milgrom & Stokey 1982]**

- Why trade at all? These markets are zero-sum games (negative sum w/ transaction fees)
- For all money earned, there is an equal (greater) amount lost; am I smarter than average?
- Rational risk-neutral traders will never trade
- But trade happens …

AUTOMATED MARKET MAKERS (MM)

An automated market maker is the market institution who sets the prices and is willing to accept orders at the price specified

Why use them ????????????

- Liquidity!

Market makers bear risk. Thus, we desire mechanisms that can bound the loss of market makers.

- That bound has to be a function of the actions of the bidders and prices charged by the MM … what do we do?

LOGARITHMIC MARKET SCORING RULE (LMSR)

[Hanson 03, 06]

Example: one market, two outcomes o_1, o_2

- **Two types of shares:**
  - "Trump wins": pays $1 if Trump wins, else $0
  - "Trump doesn't win": pays $1 if Trump doesn't win, else $0

MM tracks shares outstanding for each outcome

- q_1, q_2 are total quantity purchased for each outcome

MM keeps cost function tracking total money spent by traders so far, $C(q_1, q_2)$

- $C(q_1, q_2) = b * \ln(e^{q1/b} + e^{q2/b})$ (for LMSR, at least)

Must set scalar b – black art [Pennock 2010]

- Higher b: higher (i.e., worse) bound on MM loss ☹
- Higher b: can buy more shares without huge price swing ☺

LOGARITHMIC MARKET SCORING RULE (LMSR)

[Hanson 03, 06]

Trader arrives, wants to buy 13 shares of o_1:

- Price = $C(q_1 + 13, q_2) - C(q_1, q_2)$

Trader arrives, wants to sell 250 shares of o_2:

- Price = $C(q_1, q_2 - 250) - C(q_1, q_2)$

Trader arrives, wants to change shares outstanding to (q_1^*, q_2^*):

- Price = $C(q_1^*, q_2^*) - C(q_1, q_2)$

MM can quote price for changing an outcome o_i:

- "Price" $p_i(q_1,q_2) = e^{qi/b} / (e^{q1/b} + e^{q2/b})$
- Price to move from q_i to $q_i+k = \int_{q_i \text{ to } q_i+k} p(q_1,q_2)dq_i$

LMSR: A CONCRETE 2-OUTCOME EXAMPLE

Set b = 100, start of the market $(q_1,q_2) = (0,0)$

- Prices ??????????
- $p_1 = p_2 = e^{0/100} / (e^{0/100} + e^{0/100}) = ½$

Trader arrives, wants to buy 10 shares of o_1:

- $C(10,0) – C(0,0) = 100*[\ln(e^{10/100} + e^{0}) - \ln(e^{0} + e^{0})] = \$5.12$

… Time passes, $(q_1,q_2) = (50,10)$ …

Trader arrives, wants to sell 10 shares of o_1:

- $C(40,10) – C(50,10) =$
  $100*[\ln(e^{40/100} + e^{10/100}) - \ln(e^{50/100} + e^{10/100})] = -\$5.87$

Trader profited \$5.12 - -\$5.87 = \$0.75!

LOGARITHMIC MARKET SCORING RULE (LMSR)

[Hanson 03, 06]

Standard LMSR-based MM:

Contracts: \$1 iff o_1, \$1 iff o_2, …, \$1 iff o_N

Price functions

Cost function

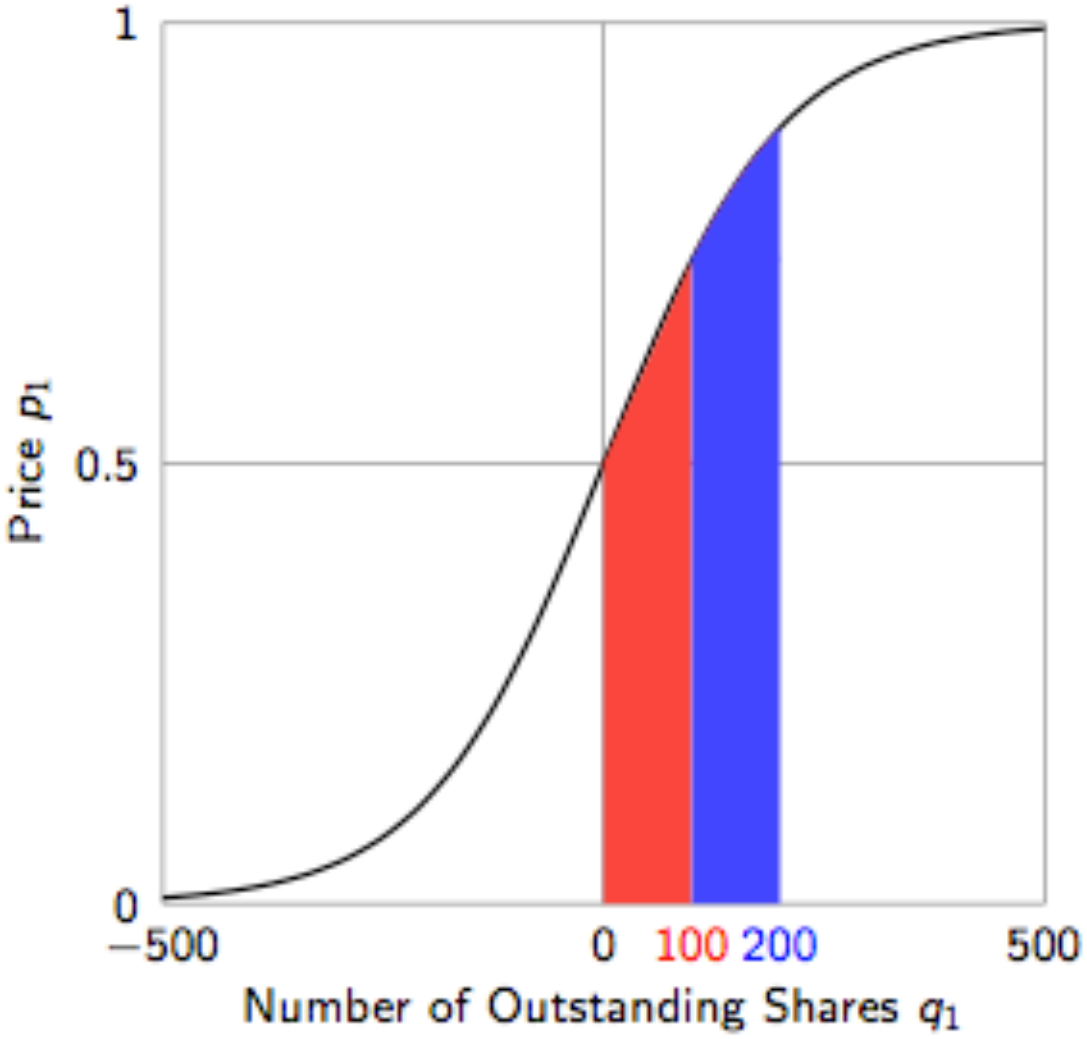
$$p_i(\vec{q}) = \frac{e^{q_i/b}}{\sum_{j=1}^{N} e^{q_j/b}}$$

Payment

$$C(\vec{q}) = b \log \sum_{j=1}^{N} e^{q_j/b}$$

$$\Delta C = C(\vec{q}_{new}) - C(\vec{q}_{old}).$$

LOGARITHMIC MARKET SCORING RULE (LMSR) [Hanson 03, 06]



Worst-case MM loss = $b \log N$

(Setting b is a bit of an art form.)

COMBINATORIAL PREDICTION MARKETS

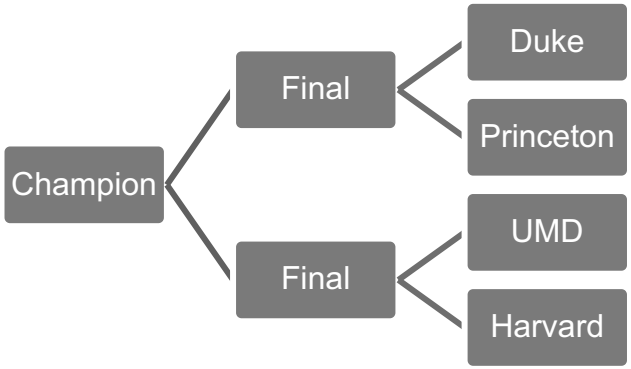
Events of interest often have a large outcome space

Information may be on a combination of outcomes

Expressiveness:

- Expressiveness in getting information
- Expressiveness in processing information (on the MM side)

COMBINATORIAL
PREDICTION MARKETS



Example bets:

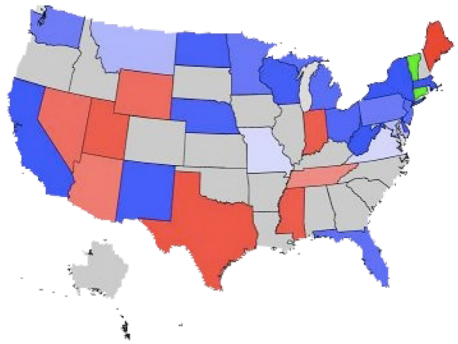
1. Duke wins at least 1 match
2. UMD beats Harvard but doesn't become champion
3. Harvard beats Duke
4. UMD+Princeton wins more matches than Harvard

Price of security should be equal to probability of event

How should purchase of no. 4 affect probability of no. 1?

Microsoft® Research

COMBINATORICS: BOOLEAN LOGIC



***n* Boolean events**

Outcomes: all possible 2^n combinations of the events

Contracts (created on the fly):

$1 iff Boolean Formula

2-clause Boolean betting

- A Democrat wins Florida & not Massachusetts

COMBINATORICS: PERMUTATIONS

***n* competing candidates**

Outcomes: all possible n! rank orderings

Contracts (created on the fly):

$1 iff Property

Subset betting

- Candidate A finishes at position 1, 3, or 5
- Candidate A, B, or C finishes at position 2

Pair betting

- Candidate A beats candidate B

PRICING COMBINATORIAL BETTING WITH LMSR

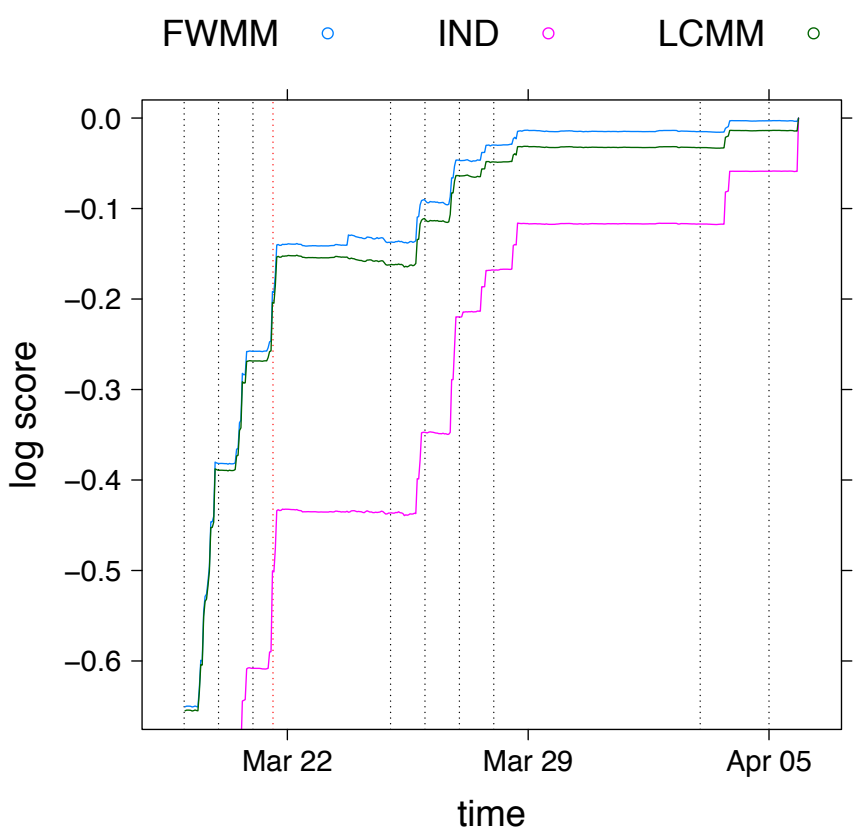
LMSR price function:

$$p_i(\mathbf{q}) = e^{qi/b} / \Sigma_j e^{qj/b}$$

It is #P-hard to price 2-clause Boolean betting, subset betting, and pair betting in LMSR. [Chen et. al. EC-08]

Restricted tournament betting with LMSR can be priced in polynomial time. [Chen, Goel, and Pennock EC-08]

EXPRESSIVENESS MATTERS! [Kroer et al. EC-16]



State of the art:

- General bidding languge in combinatorial prediction market
- Dramatic improvement over running multiple independent markets for each outcome
- Huge (theoretical and experimental) tractability issues

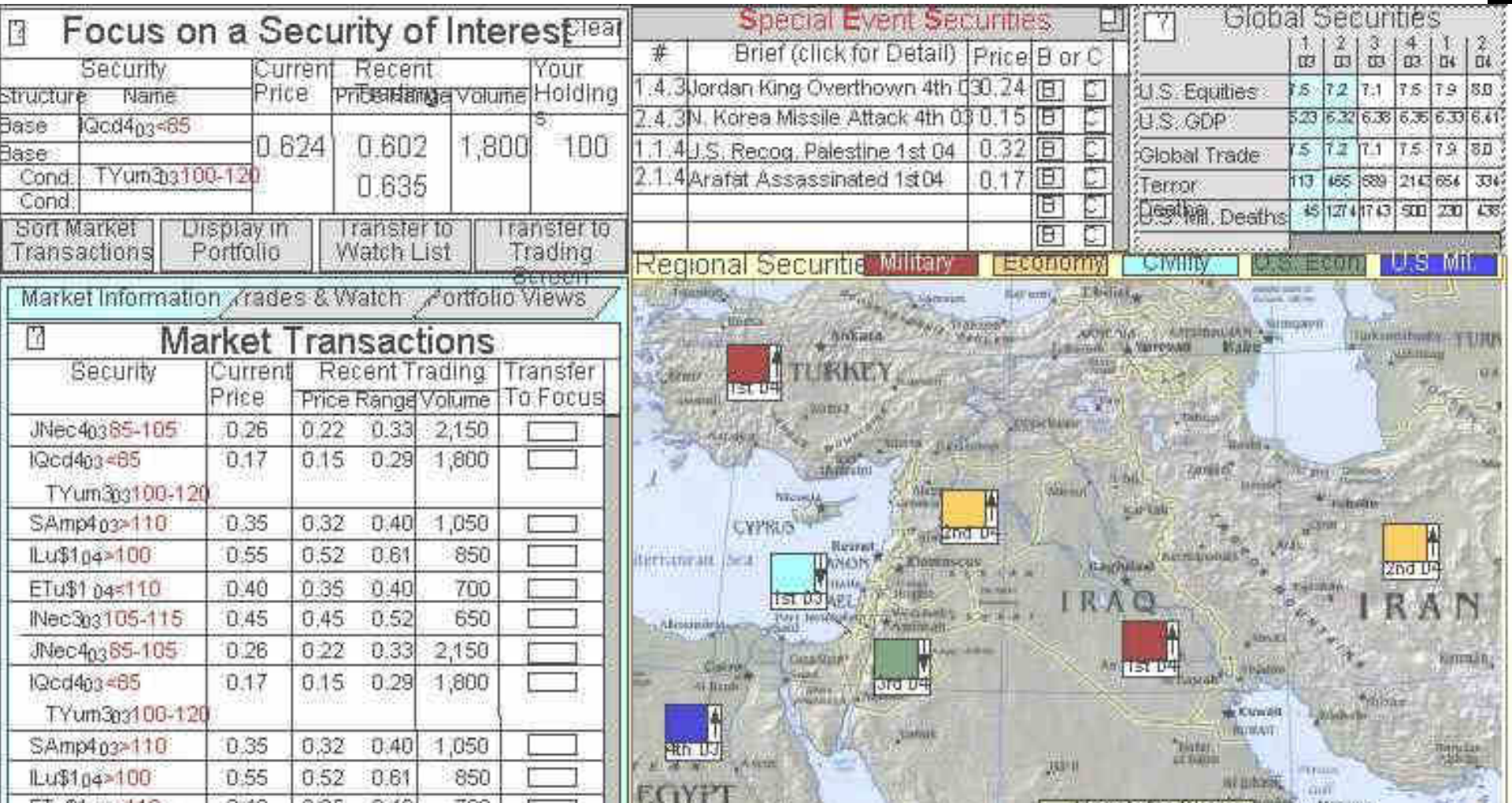
AN ETHICIST'S VIEW ON THE USE OF PREDICTION MARKETS

SPECIFICALLY, POLICY ANALYSIS MARKETS (PAM)

Thanks to: Dan Weijers, Philosophy Prof @ Cal State

PREDICTING TERRORISM

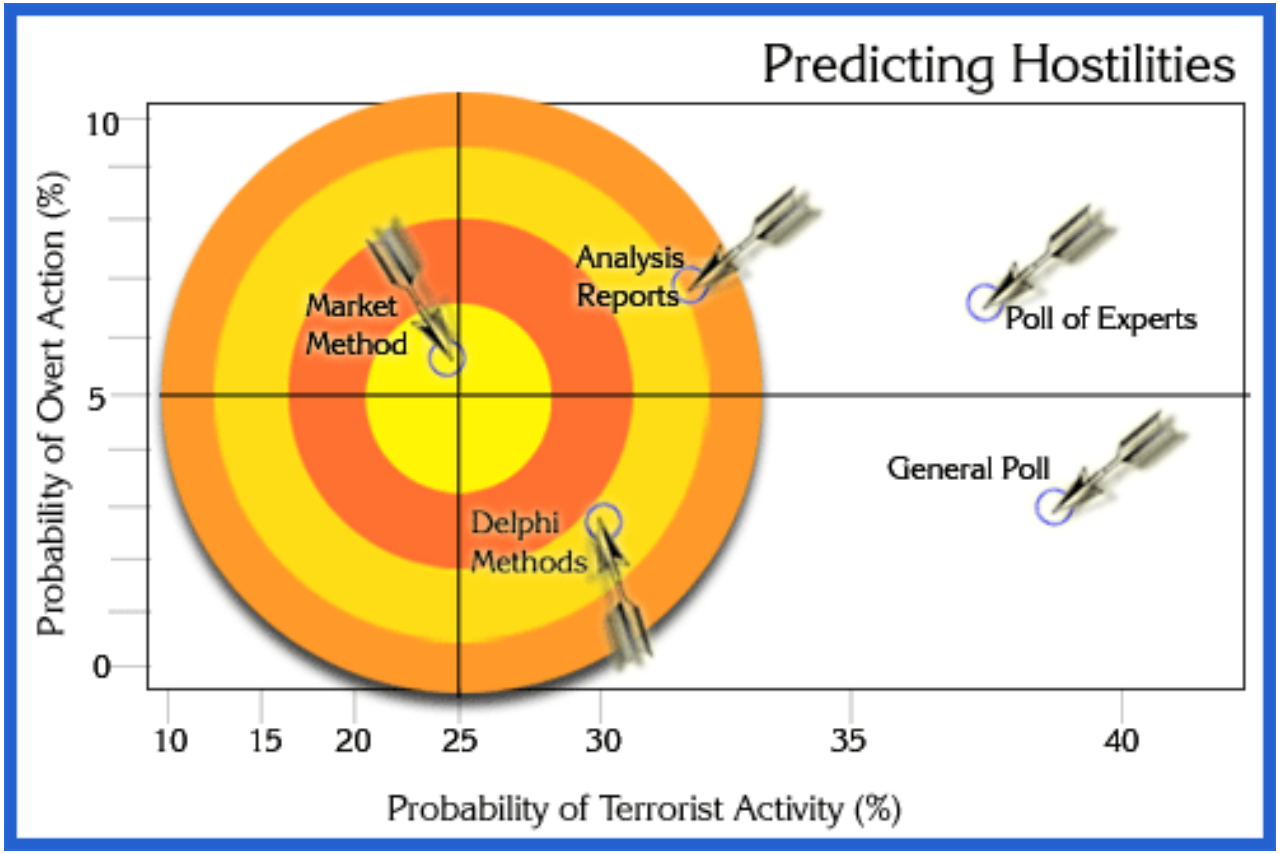
DARPA → funds → FutureMAP → includes sub-project → PAM



THE MAIN METHOD OF PREDICTING TERRORISM?

Supposedly better than:

- Reports
- Delphi
- Experts
- Polls



THE FALLOUT

Less than positive comments:

- “just wrong”
- “ridiculous… grotesque,”
- “defies common sense”
- “absurd… disgusting”
- “loopiest manifestation of … belief… markets [can] solve all problems”
- “a new level of absurdity”
- “unbelievably stupid”

FutureMAP terminated asap

PRIVATE GROUPS TAKE OVER

Future Exchange & Others

- Play money
- Small
- Open to all

Intrade

- Unlimited money, large
- Open to most, but not US
- Closed: “financial irregularities”

iPredict

- $10,000 net limit on money in
- Small/med
- Only available in New Zealand

	BUSHXX	0/100/	0	Bush dies or incapacitated
*	Dark01	0/100/	0	CA 2001 Summer Blackout Days
	ElcTer	0/100/	0	Terror <=2wks before elections
	GBNuke	0/100/	0	US not nuked and Bush remains
	GBTerr	0/100/	0	US Terrorism and Bush remains
	JKNuke	0/100/	0	US not nuked and Bush leaves
	Marbrg	0/100/	0	Marburg kills 1000 within year
	MbrgG7	0/100/	0	G7 Marburg deaths >499 by 8/05
*	NewO	0/100/	0	New Orleans population in 2010
	NukeUS	0/100/	0	US Territory Nuked < 2010
	panflu	0/100/	0	flu-pandemic before 2010
	PkNuke	0/100/	0	Pakistan Detonates Nuke <2000
	QRNTN	0/100/	0	US Quarantine by 2004
	Quak	0/100/	0	Big West Coast Quake by 2010
	sarspd	0/100/	0	>100K SARS case by 2003-06-01
	Smlpox	0/100/	0	Smallpox returns<2010
	suibmb	0/100/	0	US Suicide Bombers< 2005
	TEast	0/100/	0	Terrorism in eastern US
	Terr	0/100/	0	Nuke capable Terrorists
	Terr02	0/100/	0	Another US attack in 2001
	Terr10	0/100/	0	Another US Terrorist < 2010
	TerRP	0/100/	0	USTerr w/2000 GOP Pres.
	Tr10x3	0/100/	0	3 Distinct Terrorists < 2010
	TWAC	0/100/	0	Bomb Blew Up TWA Flt 800
	TWAm	0/100/	0	Missile caused TWA 800 crash
	WarmSU	0/100/	0	Pres Mentions Global Warming
*	WarXNK	0/100/	0	Iraq War Prevents Nuke Attack
	Y2Kdrf	0/100/	0	Y2K-US Federal Draft
	Y2Kdth	0/100/	0	>=200 deaths caused by Y2K bug

INTRADE

WMD TERROR ATTACK

Open price: $1.15 ≈ 11.5%

Life high: $5.99 ≈ 59.9%

Open interest: 709 shares

Life low: $0.50 ≈ 5.0%

Total volume: 1,314 shares

A successful WMD terrorist attack to occur anywhere in the world before midnight ET 31 Dec 2013

Event: Successful terrorist attack using WMD

11.5% CHANCE

Predict

Ayman al-Zawahiri to be captured or killed before midnight ET 31 Dec 2012

Event: Ayman al-Zawahiri

0.6% CHANCE

Predict

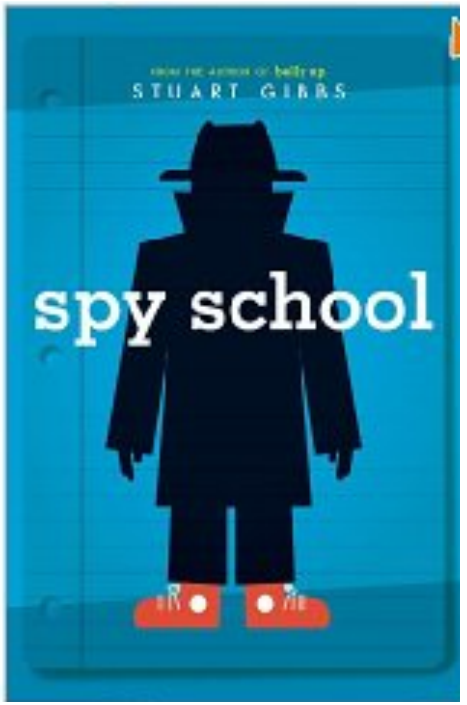
USA and/or Israel to execute an overt Air Strike against Iran before midnight ET 30 Jun 2013

Event: US/Israeli Overt Air Strike against Iran

22.4% CHANCE

Predict

FUNDING THE WRONG THING



“If our intelligence agencies are that incompetent, shouldn’t we be more concerned with improving the intelligence than setting up some goofy-ass online casino?” – Blogger Greg Saunders

Budget for trial of FutureMAP was USD 1-5MM

In terms of total DoD budget: non-issue

ENCOURAGING TERRORISM

“Most traders try to influence their investments” – US Senator Daschle

Could cause people to commit acts of terror to make a quick buck

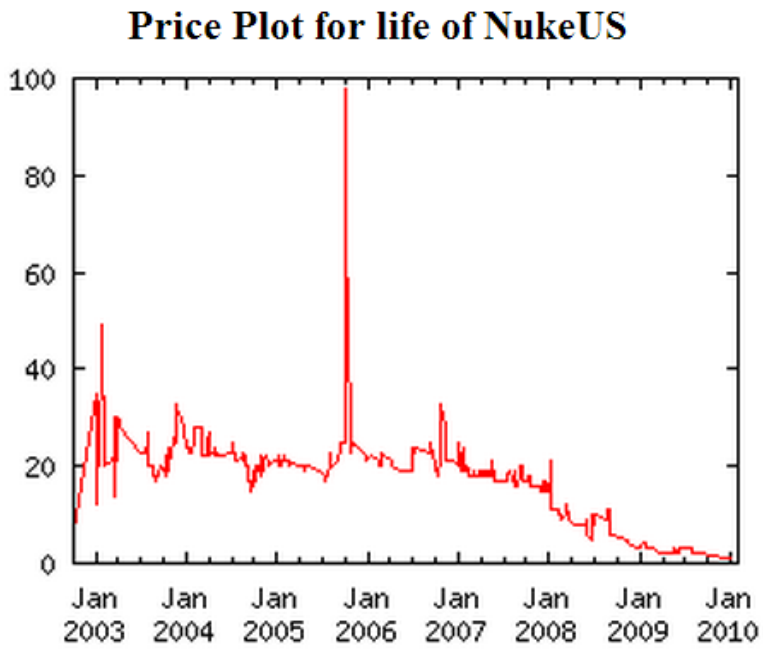
Less risky ways to make money

Could make money from stock market anyway

Non-issue

TERRORISTS WILL USE IT TO TRICK US

"[T]errorists themselves could… make false bets to mislead intelligence authorities." – US Senators Wyden and Dorgan



Prediction markets very resistant to manipulation

- But maybe not for terrorist events
- Different notion of utility …

Potential major issue

- Should be investigated further

FUNDING TERRORISTS

"Would be assassins and terrorists could easily use … clever trading strategies to profit from their planned misdeeds." – Pearlstein (columnist)

Paying bad guys for the greater good

- Paying informants
- Paying ransoms

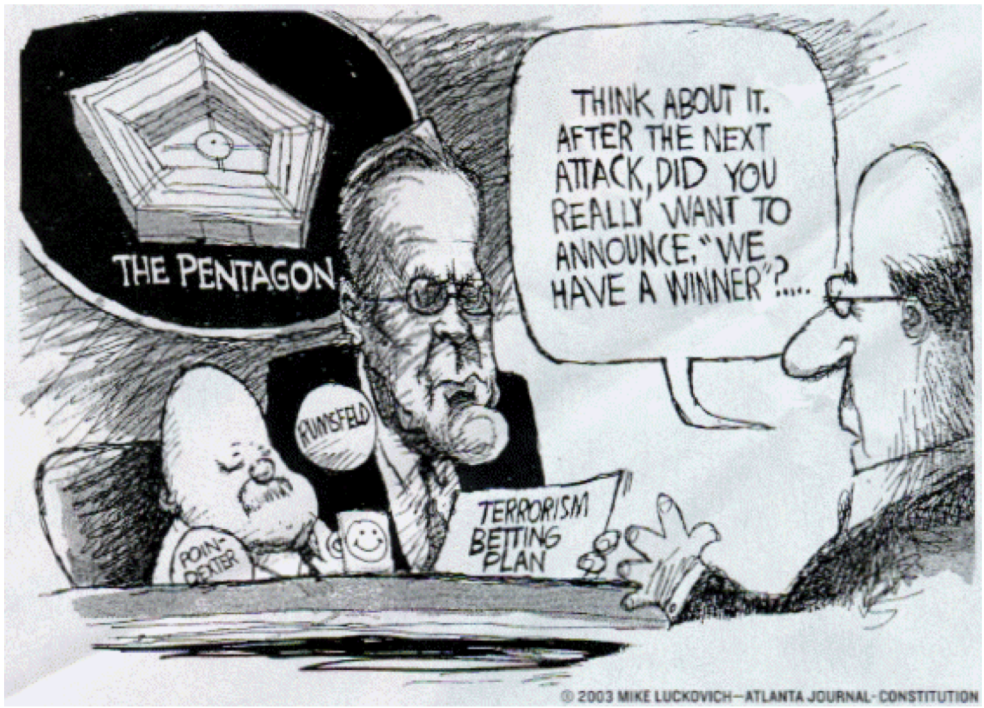
It's a big risk for terrorists

- They make their chances of getting caught higher …

A minor issue

THE REPUGNANCE OF BETTING ON DEATH

"[T]he fact that our government is essentially setting up a terrorist bookmaking operation is despicable." – Blogger Greg Saunders



Betting on death isn't new

Life insurance

Military spending decisions

Non-issue unless…

HOW WOULD YOU LIKE IT?

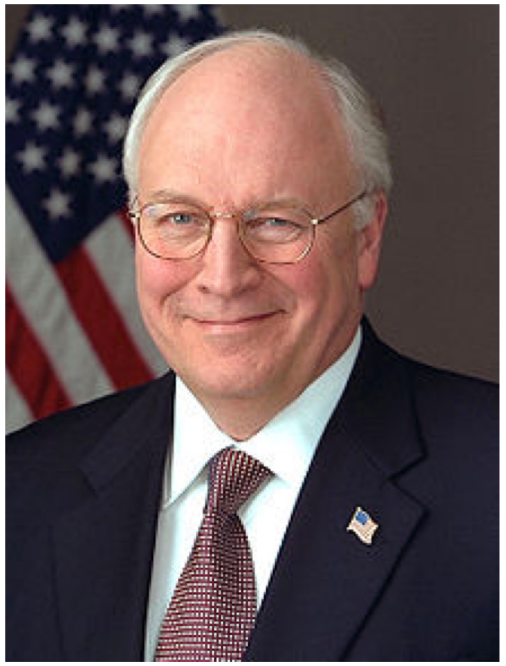
Death pool aka dead pool

Imagine a contract:

- On your death or assassination
- On a WMD attack on your city
- On your PM's assassination?

Depends on if you were already a target

INNOCENTLY PROFITING FROM TERRORISM



Anyone profiting from successful acts of terrorism seems wrong…

But many non-terrorists already accidentally profit from terrorism

- People who specialize in monitoring/preventing terrorism
- Some stocks
- Some businesses

Accidental profiting is a non-issue

PURPOSEFULLY PROFITING FROM TERRORISM

Believing there will be a terrorist attack and deciding to profit from it

- Trying to benefit from an immoral act
- Analogy: Using Nazi medical research?
  - Different motives: help others vs. self?

Seems repugnant when done to benefit self

But what is immoral about it?

- Who or what is harmed?

WISDOM OF REPUGNANCE?

…Or knee-jerk moralizing?

Person-affecting

- Desensitized to terrorism → become terrorist?
- Some people would find it offensive
- Virtue ethics (character-tarnishing)
- Analogy: violent computer games?

Disrespect of an important ideal

- Life, peace, freedom?
- Analogy: blasphemy?

"Shallow are the souls that have forgotten how to shudder." – Leon Kass

MOTIVATIONS & MORAL EFFECTS

Moral effect	Motivations				
	$$	Status	Fun	Manipulative	Informative
Effect on character	Induce greed, callousness, schaden-freude/mild sadism	Induce pride, callousness, schaden-freude/mild sadism	Induce callousness, schaden-freude/mild sadism	Dishonesty, callousness, (morbid curiosity?)	Beneficence
Disrespect of ideals	Life, peace, freedom	Life, peace, freedom	Life, peace, freedom	Life, peace, freedom	*Respect* for life, peace, freedom

"PAM… should prove as engaging as it is informative."—Official PAM website

Beneficence: researchers should explicitly prioritize a research participant's welfare as a goal in any trial

THE HARMS OF PMS ON TERRORISM

So PMs on terrorism could:

- Desensitize people to the point they become terrorists
- Offend some people
- Encourage greed, pride, callousness, schadenfreude/mild sadism, dishonesty, morbid curiosity, and beneficence
- Disrespect the ideals of life, peace, and freedom

… just like computer games?


MutaSan (Swiss)
-unnamed69-
The bomb has been planted!
(RADIO) MutaSan (Swiss): Fire in the hole!
$ 610
31
100
30 | 60
5.56
45

BUT MORE RECENTLY …

HOW SERIOUS ARE THE HARMS?

Desensitize people to the point they become terrorists

- Very serious but very very unlikely = Non-issue

Disrespect the ideals of life, peace, and freedom

- Not very serious (?) but very likely = Minor issue

Encourage greed, pride, callousness, schadenfreude/mild sadism, dishonesty, morbid curiosity, and beneficence

- Not very serious (effects on character will be tiny)
- … but very likely = Minor issue

Offending some people

- Not very serious but very likely = Minor issue

ETHICAL ISSUES SCORECARD

Compared to no PMs	Offensive	Character tarnishing	Ideal disres-pecting	Might fund terrorism	Terrorists manipu-lating us	Likely to produce useful information
Govt. only PM	No	No	No	No	No	Yes ?
PAM	Yes	Yes	Yes	Yes	Maybe	Yes ??
Intrade	Yes	Yes	Yes	Yes	Unlikely	Maybe ??
Net Exchange	Yes	Yes	Yes	No	Unlikely	No ?
	Minor issue	Minor issue	Minor issue	Minor issue	Potential major issue	Major benefit

ETHICAL ASSESSMENT

Compared to no PMs	Issues that should cause repugnance	Terrorists manipulating us	Likely to produce useful information	**Net benefit?**
Govt. only PM	None	No	Yes ?	**Definitely**
PAM	4	Maybe	Yes ??	**Probably**
Intrade	4	Unlikely	Maybe ??	**Unlikely**
Net Exchange	3	Unlikely	No ?	**No**
	Minor issues	Potential major issue	Major benefit	

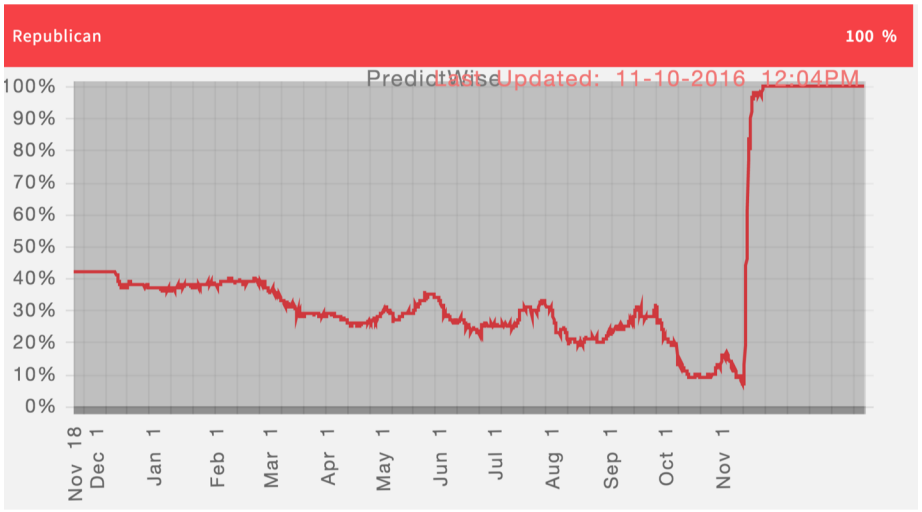
THOUGHTS FROM THE CS SIDE OF THINGS

Economists and philosophers – and CS folks – can be very tone deaf, to the point of ruining what could be good ideas

Price manipulation seems like a huge concern to me

These markets are currently heavily regulated in the US (i.e., generally must use funny money) ...

- **... and maybe that's okay until we figure things out**



NEXT CLASS:
THANKSGIVING = ∅ (THURSDAY)