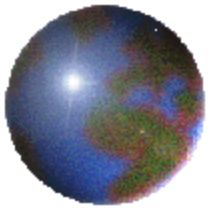
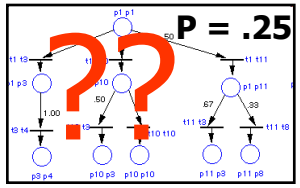


Combinatorial Prediction Markets

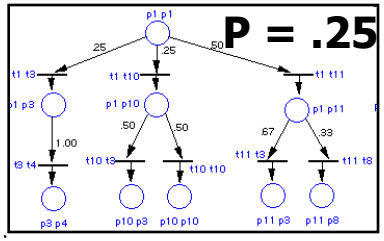
Robin Hanson

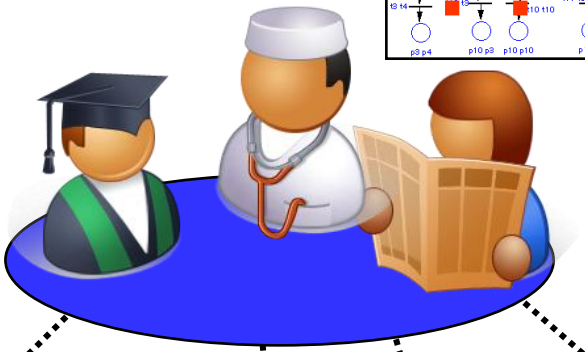
Associate Professor of Economics, GMU

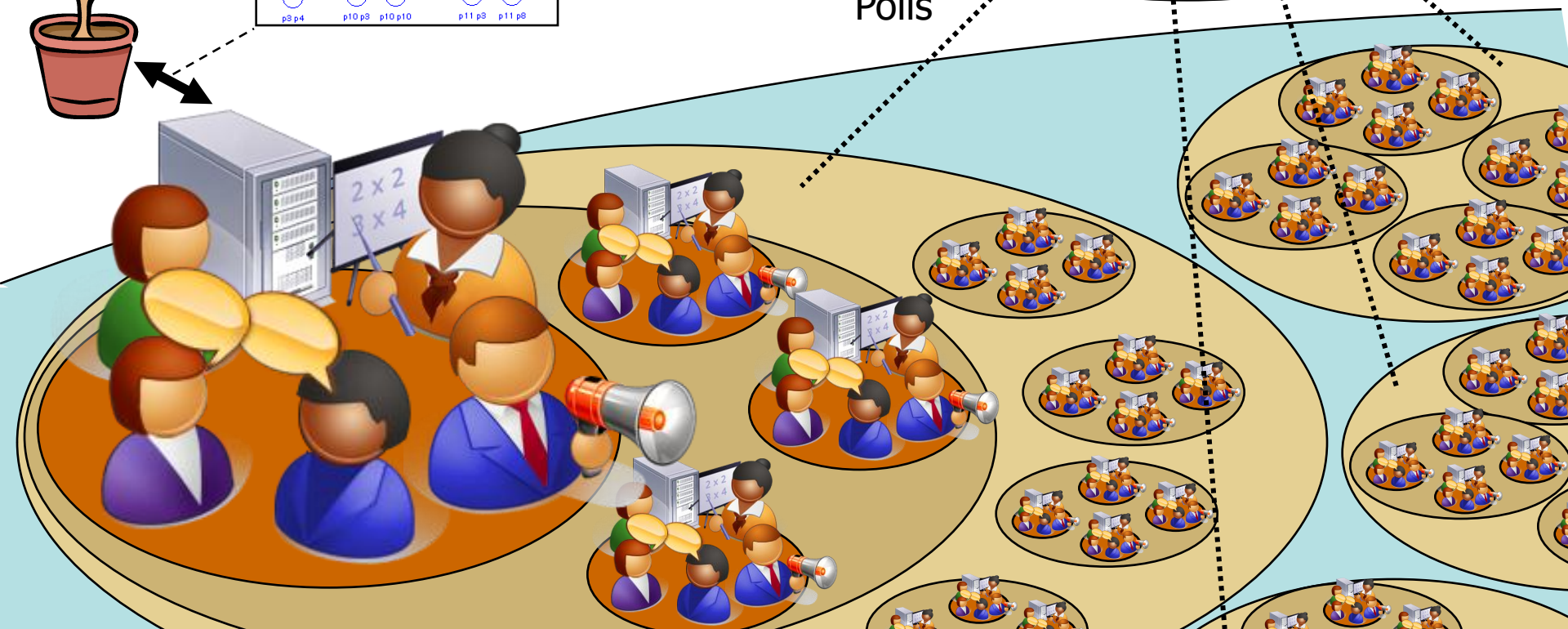
What do "we" believe?



Professions
Academia
Bet Odds
Media
Polls







Buy Low, Sell High

"Pays $1 if Obama wins"

Will price rise or fall?

price

sell

buy

sell

buy

E[price change | ??]

Lots of ?? get tried, price includes all!

(All are "gambling" "prediction" "info")

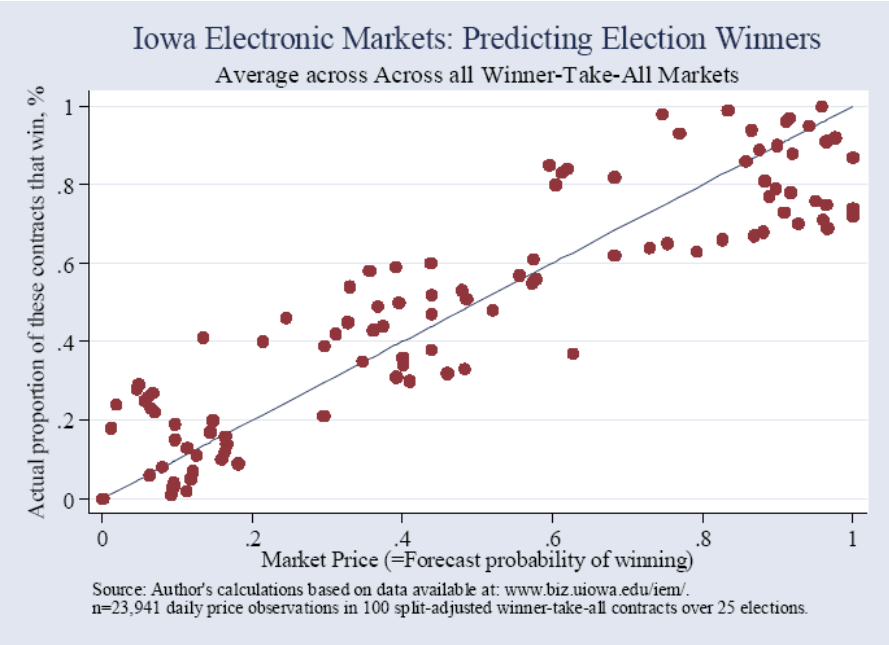
Today's Current Event Prices

65% Obama next US president
15-22% Bird Flu confirmed in US by 2009
6-10% 9.0 Richter Earthquake by 2009
40-60% Yahoo CEO Yang resigns by 2009
3-15% US war act on N. Korea by 4/2009
20-21% Bin Laden caught by 4/2009
40-46% US or Israel air strike on Iran by 4/2009
28-30% US max tax rate > 40% in 2010
21-40% Any nation drop Euro by 2011
20-28% China war act on Taiwan by 2011
19-29% Google Lunar Prize won by 2013

Beats Alternatives

- Vs. Public Opinion
  - I.E.M. beat presidential election polls 451/596 (Berg et al '01)
  - Re NFL, beat ave., rank 7 vs. 39 of 1947 (Pennock et al '04)
- Vs. Public Experts
  - Racetrack odds beat weighed track experts (Figlewski '79)
    - If anything, track odds weigh experts too much!
  - OJ futures improve weather forecast (Roll '84)
  - Stocks beat Challenger panel (Maloney & Mulherin '03)
  - Gas demand markets beat experts (Spencer '04)
  - Econ stat markets beat experts 2/3 (Wolfers & Zitzewitz '04)
- Vs. Private Experts
  - HP market beat official forecast 6/8 (Plott '00)
  - Eli Lily markets beat official 6/9 (Servan-Schreiber '05)
  - Microsoft project markets beat managers (Proebsting '05)
  - XPree beat corp error, 3.5 vs 6.6%

IEM | Iowa Electronic Markets



Item	1988	1992	1996	2000	2004	All
# big polls	59	151	157	229	368	964
Poll "wins"	25	43	21	56	110	255
Market "wins"	34	108	136	173	258	709
% Market	58%	72%	87%	76%	70%	74%
P-value	0.148	0.000	0.000	0.000	0.000	0.000

"Prediction Market Accuracy in the Long Run"
Joyce Berg, Forrest Nelson and Thomas Rietz, Jan. 2008.

Policy Analysis Market

Every nation*quarter:

-Political stability

-Military activity

-Economic growth

-US $ aid

-US military activity

& global, special

& all combinations

DARPA

Economist Intelligence Unit

Net Exchange

EXPANDING THE VALUE OF COMMERCE

The Fuss:

Analysts often use prices from various markets as indicators of potential events. The use of petroleum futures contract prices by analysts of the Middle East is a classic example. The Policy Analysis Market (PAM) refines this approach by trading futures contracts that deal with underlying fundamentals of relevance to the Middle East. **Initially, PAM will focus on the economic, civil, and military futures of Egypt, Jordan, Iran, Iraq, Israel, Saudi Arabia, Syria, and Turkey and the impact of U.S. involvement with each.**

[Click here for a summary of PAM futures contracts]

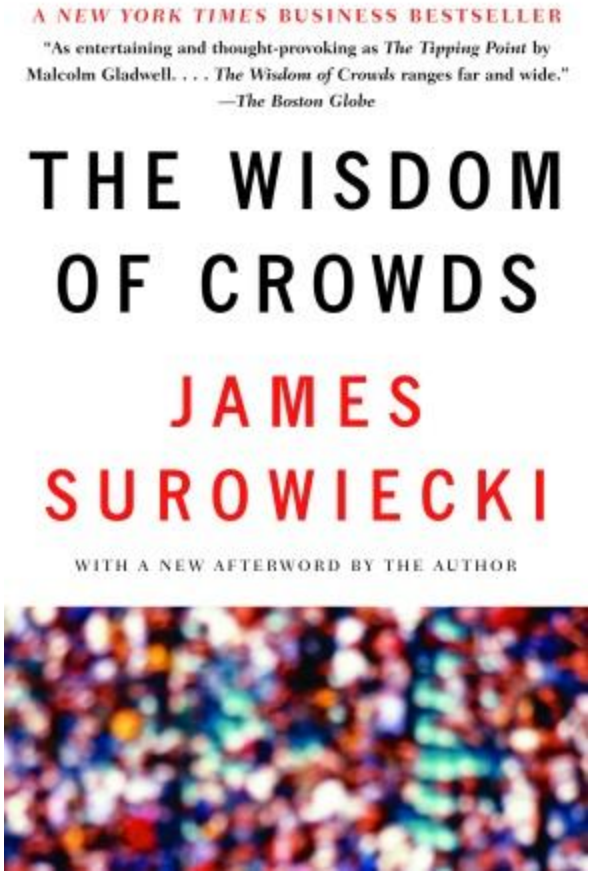
The contracts traded on PAM will be based on objective data and observable events. These contracts will be valuable because traders who are registered with PAM will use their money to acquire contracts. A PAM trader who believes that the price of a specific futures contract under-predicts the future status of the issue on which it is based can attempt to profit from his belief by buying the contract. The converse holds for a trader who believes the price is an over-prediction – she can be a seller of the contract. This price discovery process, with the prospect of profit and at pain of loss, is

The issues represented by PAM contrac
affect civil stability in the country and th
country's military. The trading process a
contracts. Such combinations represent
thus may be able to make money on thr
substantial refinement in predictive pow

[Click here for an example of PAM futur

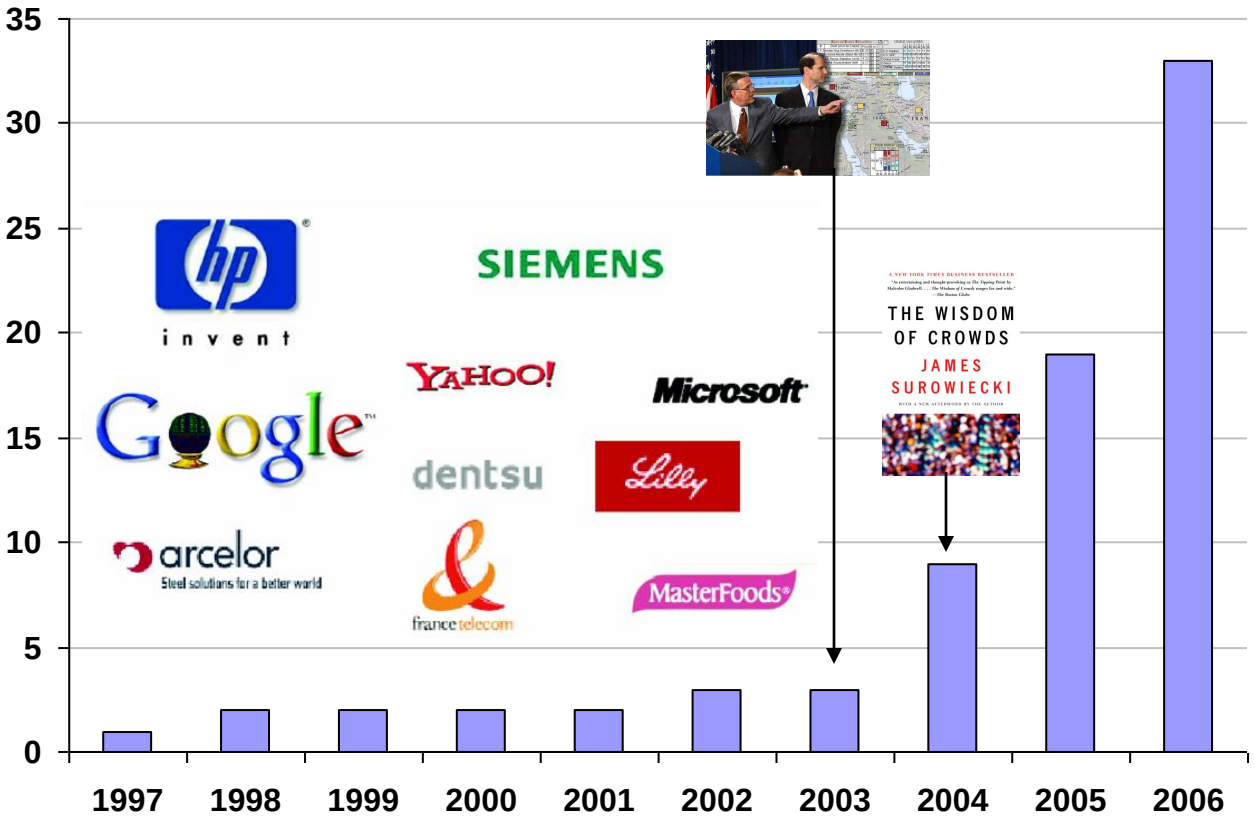
The PAM trading interface presents *A M*
context of the region using a trading lan
be active and accessible 24/7 and shou

Became:



Cummulative number of companies that have implemented an internal prediction market

(lower bound estimate)

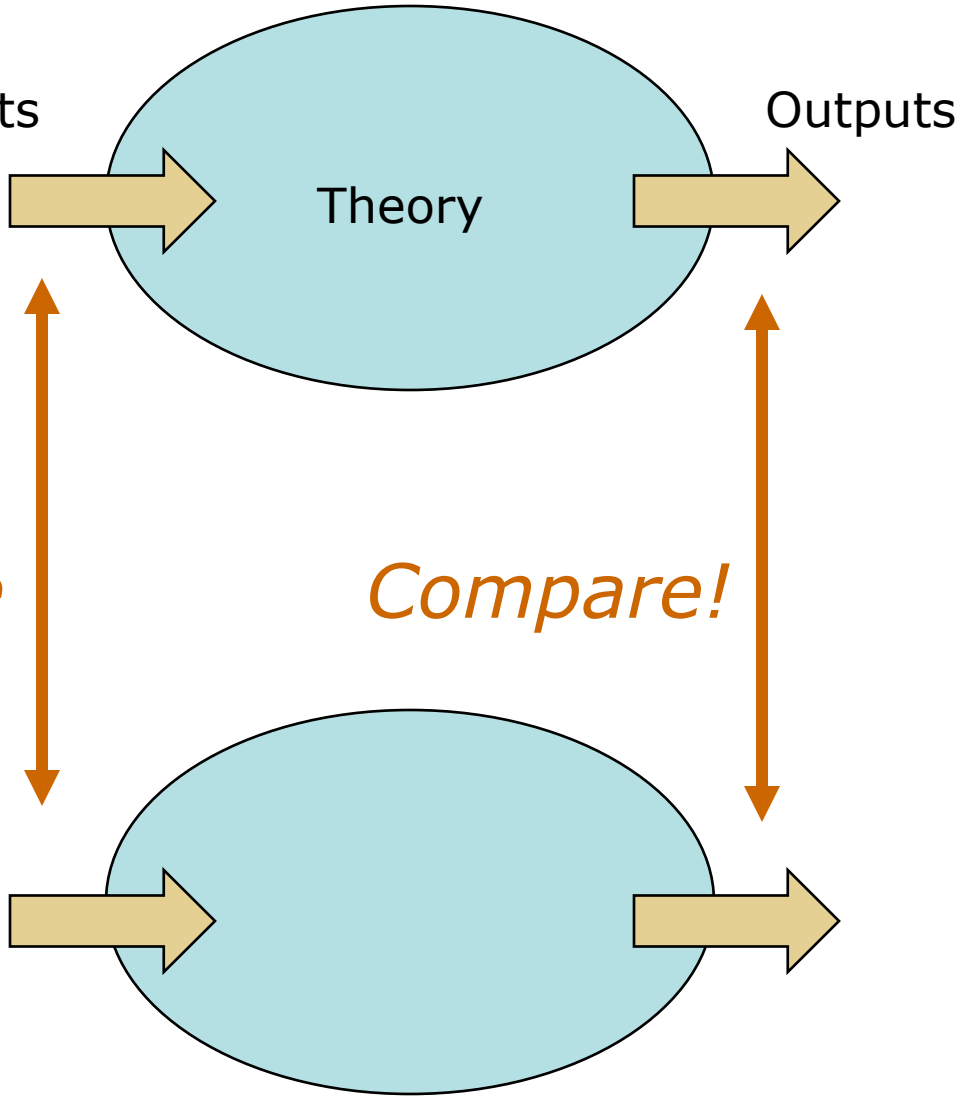


Source: newsfutures PREDICTION MARKETS

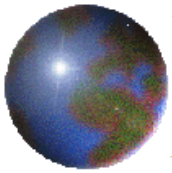
Internal Applications

- **Sales** - HP, Google, Nokia, XPree, O'Reilly, Best Buy
- **Deadlines** - Siemens, Microsoft, Misys
- **Pick Project** - Qualcomm, GE, Lily, Pfizer, Intercontinental Hotels
- **Unknown** - Novartis, GSK, Motorola, ArcelorMittal, Corning, Dentsu, Masterfoods, Thomson, Yahoo, Abbott, Chrysler, Edmunds, InfoWorld, FritoLay, Erickson, IHG, NBC, HVG, RAND, SAIC, SCA, TNT, Cisco, General Mills, Swisscom

Prediction Markets

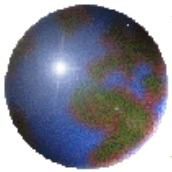


Status Quo Institution



Not *Experts vs. Self-chosen Amateurs*

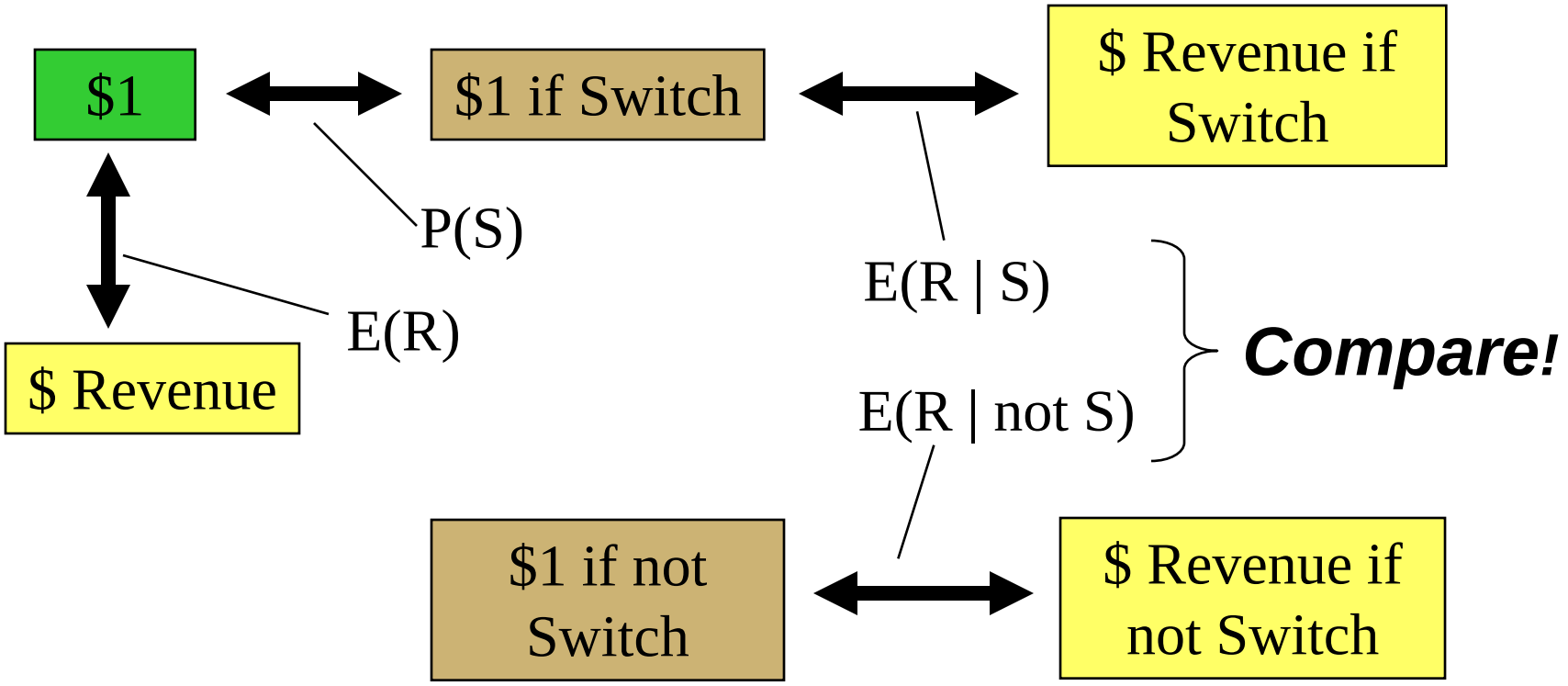
- Forecasting Institution Goal:
  - Given same participants, resources, topic
  - Want most accurate institution forecasts
- Separate question: who let participate?
  - Can limit who can trade in market
- Markets have low penalty for add fools
  - Hope: get more info from amateurs?

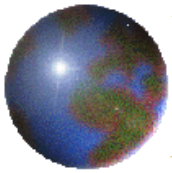


Advantages

- Numerically precise
- Consistent across many issues
- Frequently updated
- Hard to manipulate
- Need not say who how expert when
- At least as accurate as alternatives

Ad Agency Decision Markets





Corporate Applications

E[Revenue | Switch ad agency?]

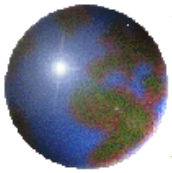
E[Revenue | Raise price 10%?]

E[Project done date | Drop feature?]

E[Project done date | Add personnel?]

E[Stock price | Fire CEO?]

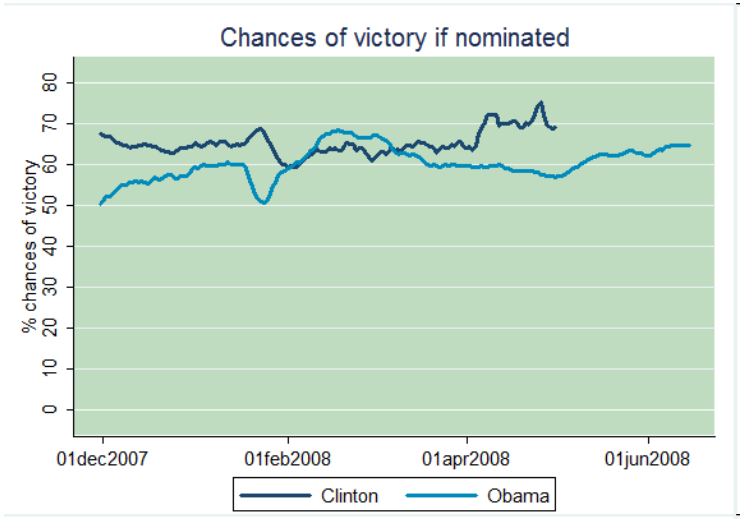
E[Stock price | Acquire firm X?]

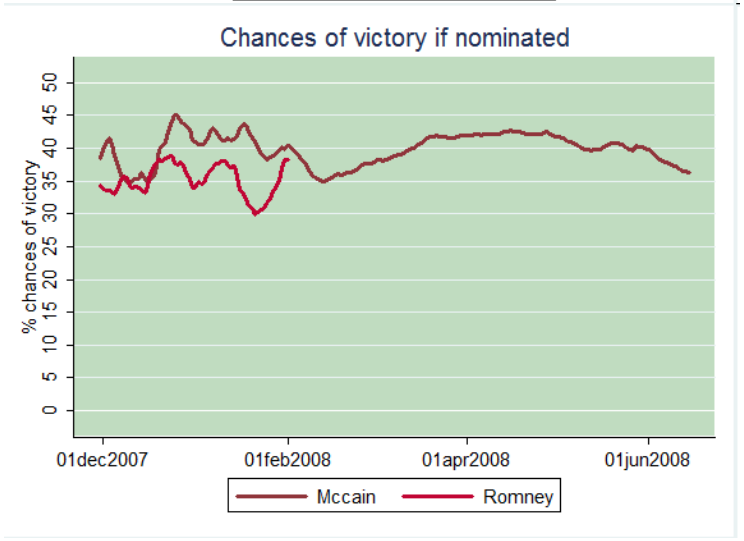


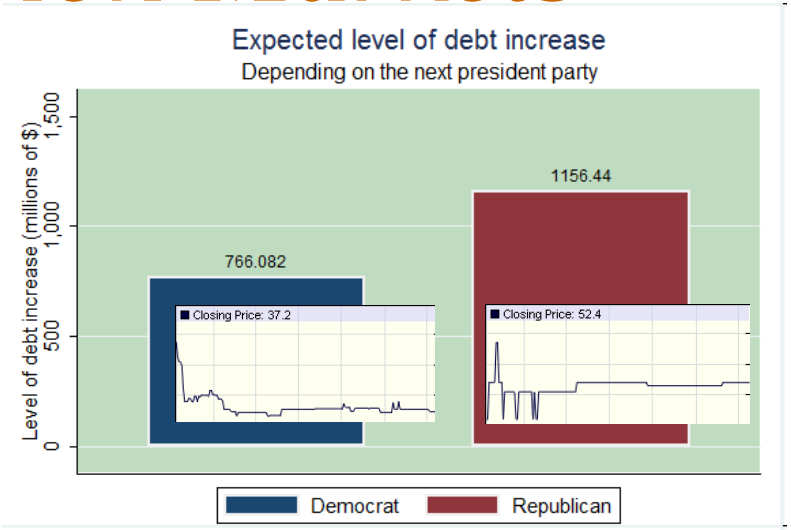
Decision Market Requirements

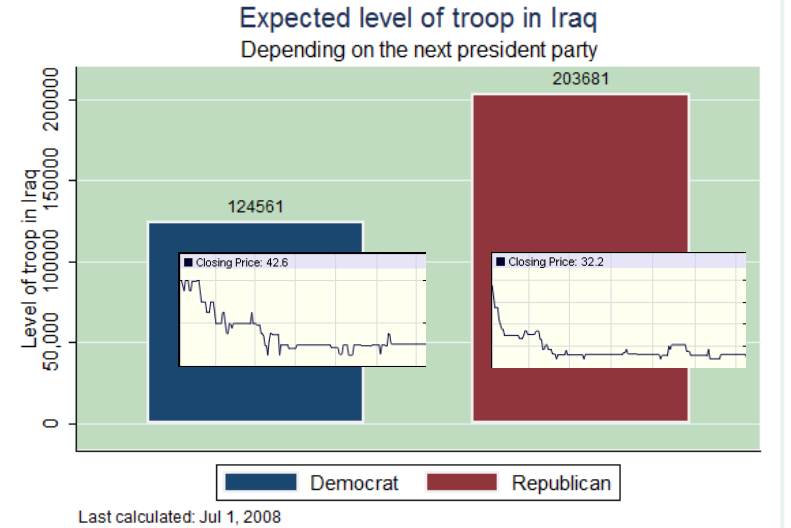
- Legal permission
- Outcome
  - Measured
  - Aggregate-enough
  - Linear-enough
  - Conditional-enough
- Decision
  - Distinct options
  - Important enough
  - Enough influence
- Public credibility
- Traders
  - Enough informed
  - Decision-insiders
  - Enough incentives
  - Anonymity
- Prices
  - Intermediate-enough
  - Can show enough

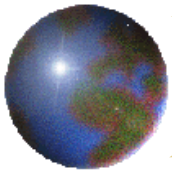
US President Decision Markets









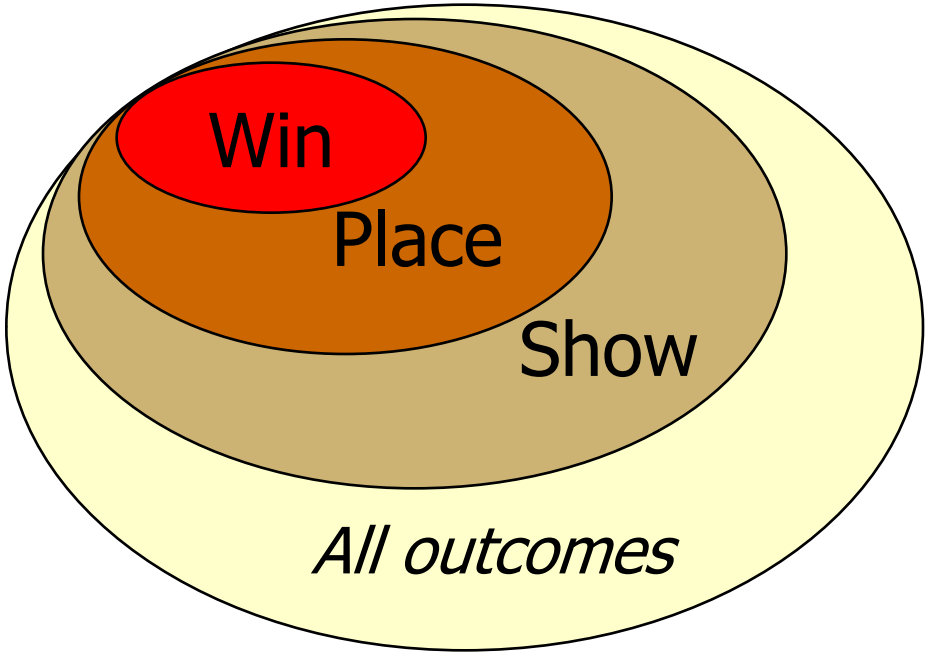


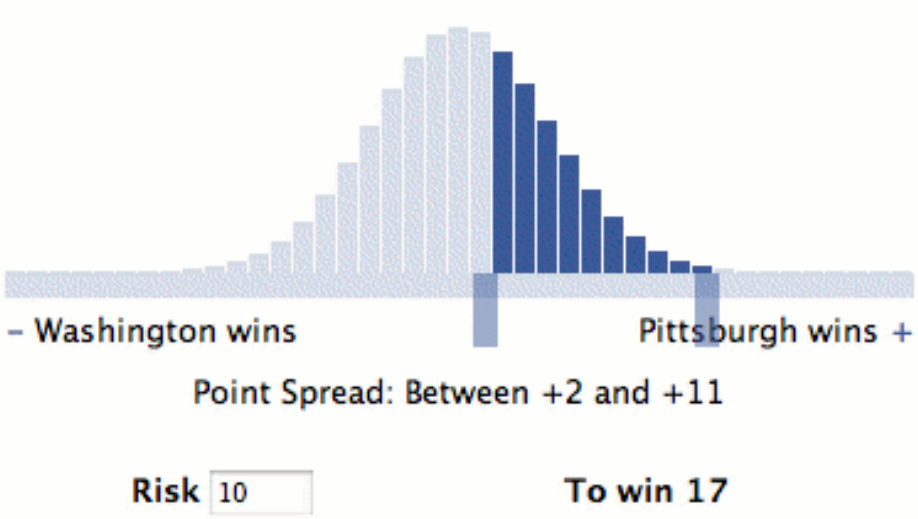
Remake CEO Oversight For $1M!!

- E[stock|fire CEO?] for all Fortune 500
- Subsidize cash trading, where legal
- Expect tons business press, CEOs look at
  - Manipulating CEOs add liquidity
- Track firms follow advice, vs. not
  - Statistically signif. diff. in few years
- Sue boards that ignore advice w/o reason
  - Shy boards then defer to market advice!!

Combo Betting

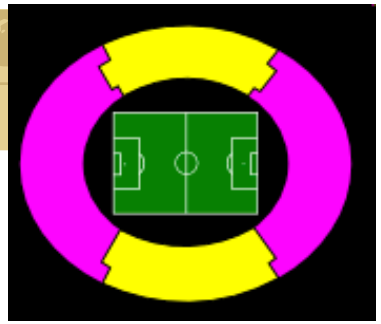
Win	Place	Show
~~Not~~	Not	Not





Yoopick Facebook Application

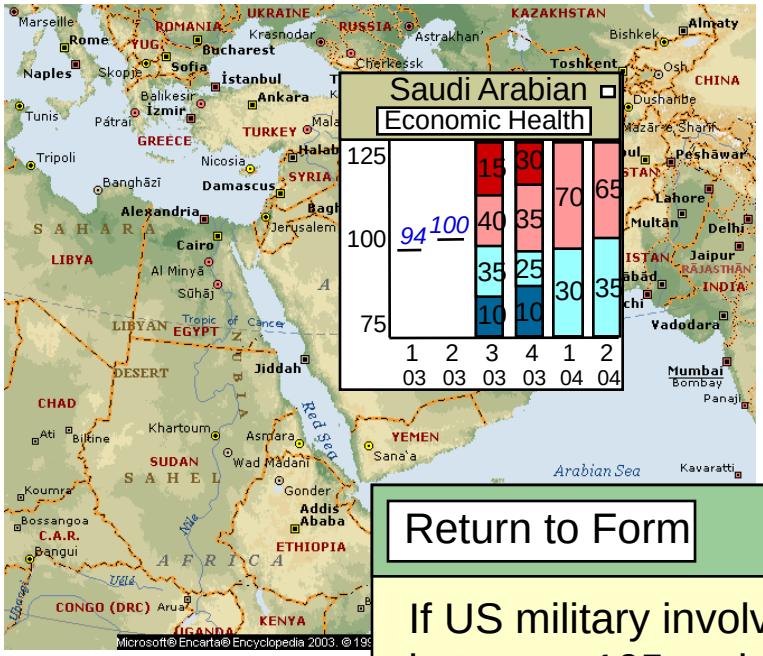
yoonew
THE FUTURES IN TICKETS



Sport Finals Tickets

UEFA EURO 2008	Austria	Croatia	Czech	Germany	Poland	Portugal	Switzerl.	Turkey
France								
Greece		*Greece v. Croatia*	*Ticket if Greece in Finals*					
Italy								
Netherl.								
Romania								
Russia								
Spain				*Actual Game*				
Sweden								

PAM Scenario



Return to Focus

Trade

Update ?

Select	New Price	Payoffs: If $SAum3_{03}$ 105-125 & $IQcs4_{03}$ <85	$IQcs4_{03}$ >85	Ave. pay <85 65%
Buy ☐ Max Up	95.13%	+$34.74	-$85.18	-$19.72
Buy ☐ 10% Up	68.72%	+$2.74	-$3.28	-$1.07
☐ You Pick	65 %	+1.43	-2.04	+0.34
No Trade	62.47%	$0.00	$0.00	$0.00
Sell ☐ 10% Dn	56.79%	-$2.61	+$2.74	-$1.12
Sell ☐ Exit Issue	48.54%	-$15.34	+$26.02	-$6.31
Sell ☐ Max Dn	22.98%	-$120.74	+$96.61	-$22.22

Return to Form

Execute a Trade

?

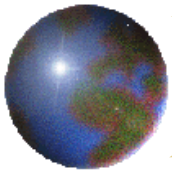
If US military involvement in Saudi Arabia in 3rd Quarter 2003 is not between 105 and 125, this trade is null and void. Otherwise, if Iraq civil stability in 4th Quarter 2003 is below 85, then I will receive $1.43, but if it is not below 85, I will pay $2.04.

Abort trade if price has changed ☐

Execute

Some Consensus Mechanisms

- Competitive Forecasting – like survey
  - Formulas define consensus & score
- Continuous Double Auction
  - make or take offers to buy or sell
- Call Auction – match accumulated offers
- Market maker – always small spread

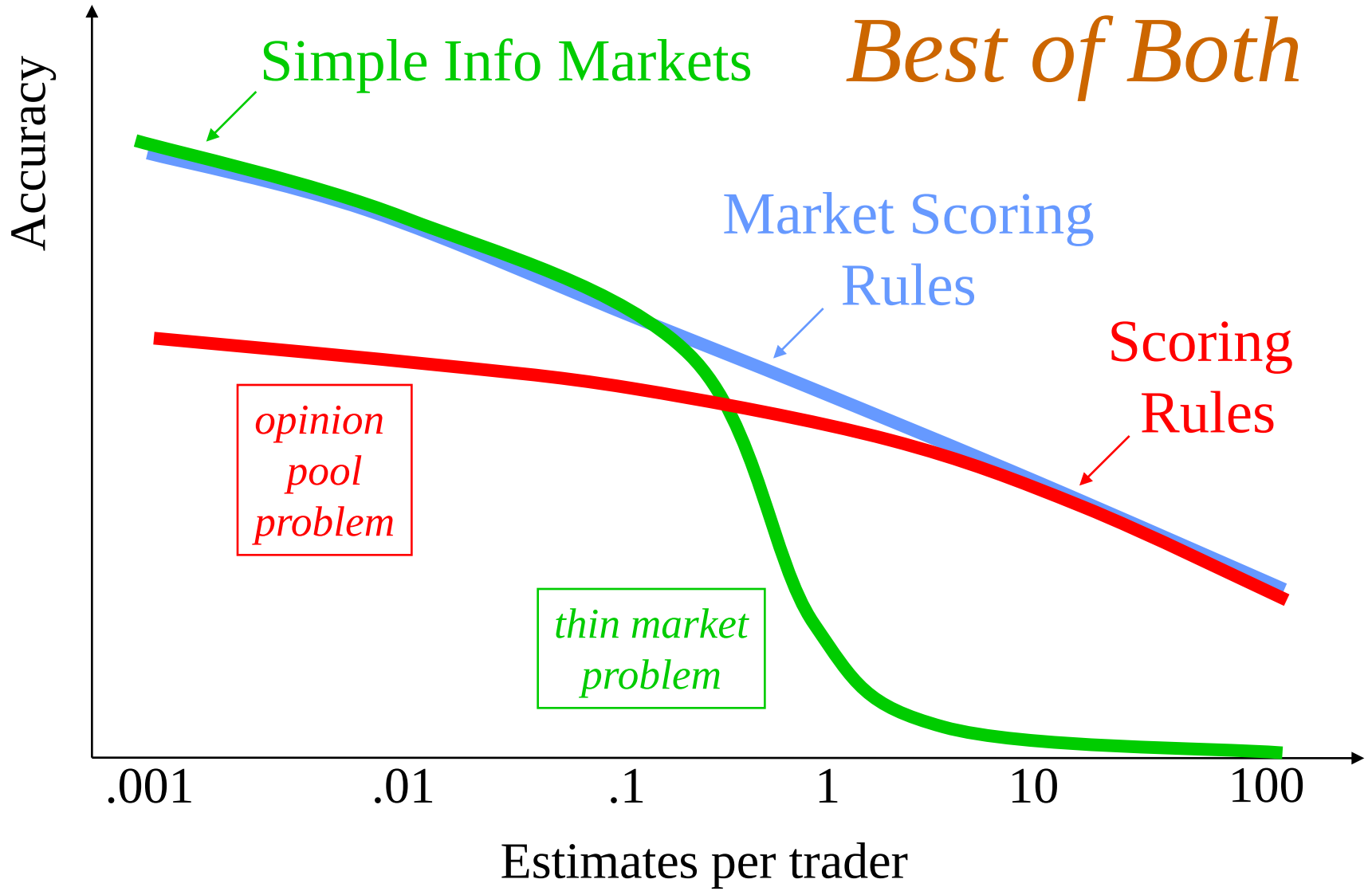


Old Tech Meets New

- To gain info, elicit probs $\mathbf{p} = \{p_i\}_i$, $E_{\mathbf{p}}[x \mid A]$
  (Verify state i later, N/Q = people/questions)
- Old tech (~1950+): *Proper Scoring Rules*
  N/Q ⑥ 1: works well, N/Q ⑦ 1: hard to combine
- New tech (~1990+): *Info/Predict Markets*
  N/Q ⑦ 1: works well, N/Q ⑥ 1: thin markets
- The best of both: *Market Scoring Rules*
  - modular, lab tests, compute issues, …

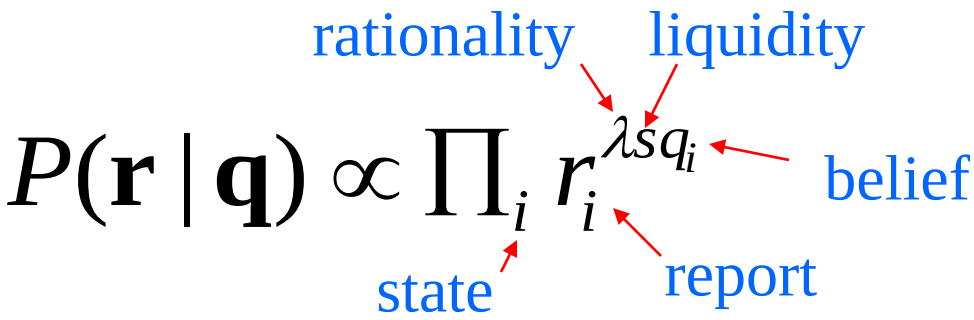
Opinion Pool "Impossibile"

- Task: pool T(A) from opinions $p^1(A)$, $p^2(A)$, …
- Any 2 of IPP, MP, EB ⇒ dictator ($T = p^d$) !
  - IPP = if A,B indep. in all p^n , are indep. in T
  - EB = commutes: pool, update on info
  - MP = commutes: pool, coarsen states (☎♦📠field)
    - (MP ⇒ $T = \sum_{n=0} w_n p^n$, with w_n indep. of A)
- Really want pool via belief origin theory
  - General solution: let traders figure it out?


Best of Both
Simple Info Markets
Market Scoring Rules
Scoring Rules
opinion pool problem
thin market problem
Accuracy
.001
.01
.1
1
10
100
Estimates per trader

Quantal Response Modularity

- Noisy choice: prob(act) ✪ exp(λ*payoff)
- When apply to a log MSR, get user reports (= new prices) independent of the last price:



- Simplifies inferences about beliefs from acts
- Ignores that harder to make complex changes

Laboratory Tests

- Joint work with John Ledyard (Caltech), Takashi Ishida (Net Exchange)
- Trained in 3var session, return for 8var
- Metric: *Kulback-Leibler* $\Sigma_i\, q_i \log(p_i / q_i)$ distance from market prices to Bayesian beliefs given all group info

Environments: Goals, Training

- ***Want in Environment:***
  - Many variables, few directly related
  - Few people, each not see all variables
  - Can compute rational group estimates
  - Explainable, fast, neutral
- ***Training Environment:***
  - 3 binary variables X,Y,Z, $2^3 = 8$ combos
  - P(X=0) = .3, P(X=Y) = .2, P(Z=1)= .5
  - 3 people, see 10 cases of: AB, BC, AC
  - Random map XYZ to ABC

(Actually: X Z Y)

Case	A	B	C
1	1	-	1
2	1	-	0
3	1	-	0
4	1	-	0
5	1	-	0
6	1	-	1
7	1	-	1
8	1	-	0
9	1	-	0
10	0	-	0
Sum:	9	-	3

Same	A	B	C
A	--	--	4
B	--	--	--
C	--	--	--

Experiment Environment

- 8 binary vars: STUVWXYZ
- $2^8 = 256$ combinations
- 20% = P(S=0) = P(S=T) = P(T=U) = P(U=V) = … = P(X=Y) = P(Y=Z)
- 6 people, each see 10 cases: ABCD, EFGH, ABEF, CDGH, ACEG, BDFH
- random map STUVWXYZ to ABCDEFGH

(*Really:* *W* *V* *X* *S* *U* *Z* *Y* *T*)

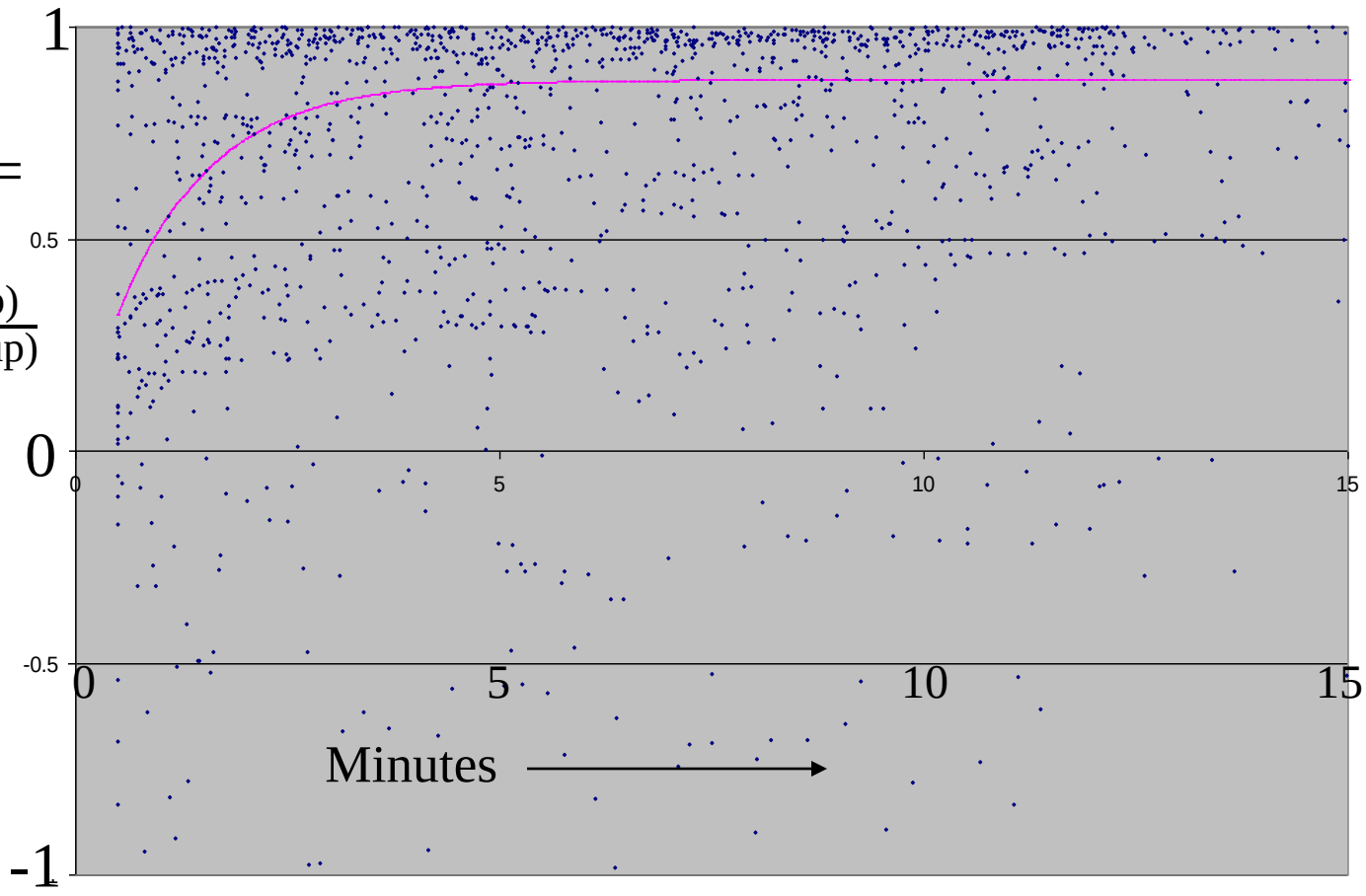
Case	A	B	C	D	E	F	G	H
1	0	1	0	1	-	-	-	-
2	1	0	0	1	-	-	-	-
3	0	0	1	1	-	-	-	-
4	1	0	1	1	-	-	-	-
5	0	1	1	1	-	-	-	-
6	1	0	0	1	-	-	-	-
7	0	1	1	1	-	-	-	-
8	1	0	0	1	-	-	-	-
9	1	0	0	1	-	-	-	-
10	1	0	0	1	-	-	-	-
Sum	6	3	4	10	-	-	-	-

Same	A	B	C	D	E	F	G	H
A	--	1	2	6	--	--	--	--
B	--	--	7	3	--	--	--	--
C	--	--	--	4	--	--	--	--
D	--	--	--	--	--	--	--	--
…								

MSR Info vs. Time – 3 Variables

% Info Agg. =

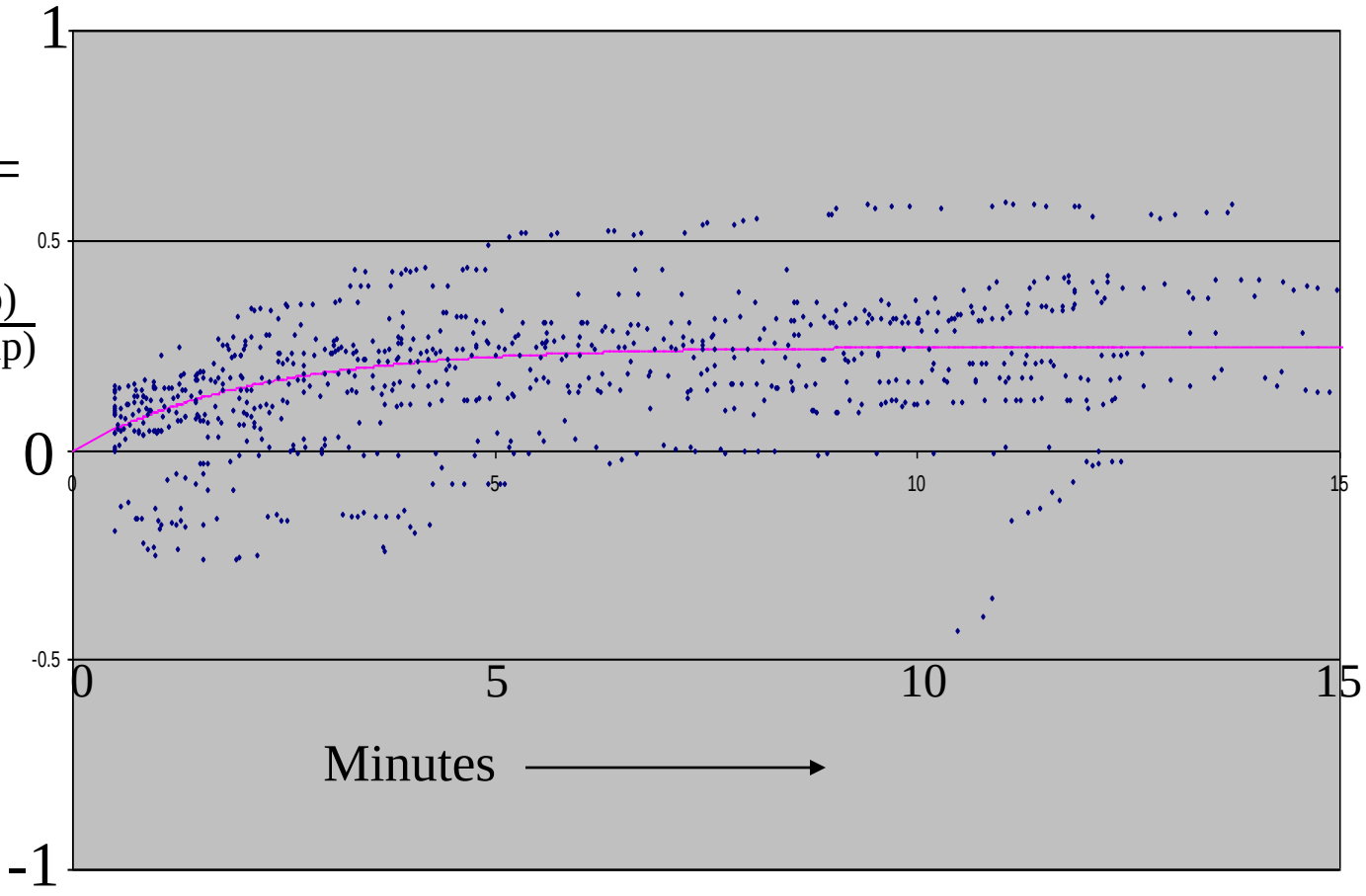
$$1-\frac{KL(prices,group)}{KL(uniform,group)}$$



MSR Info vs. Time – 255 prices

% Info Agg. =

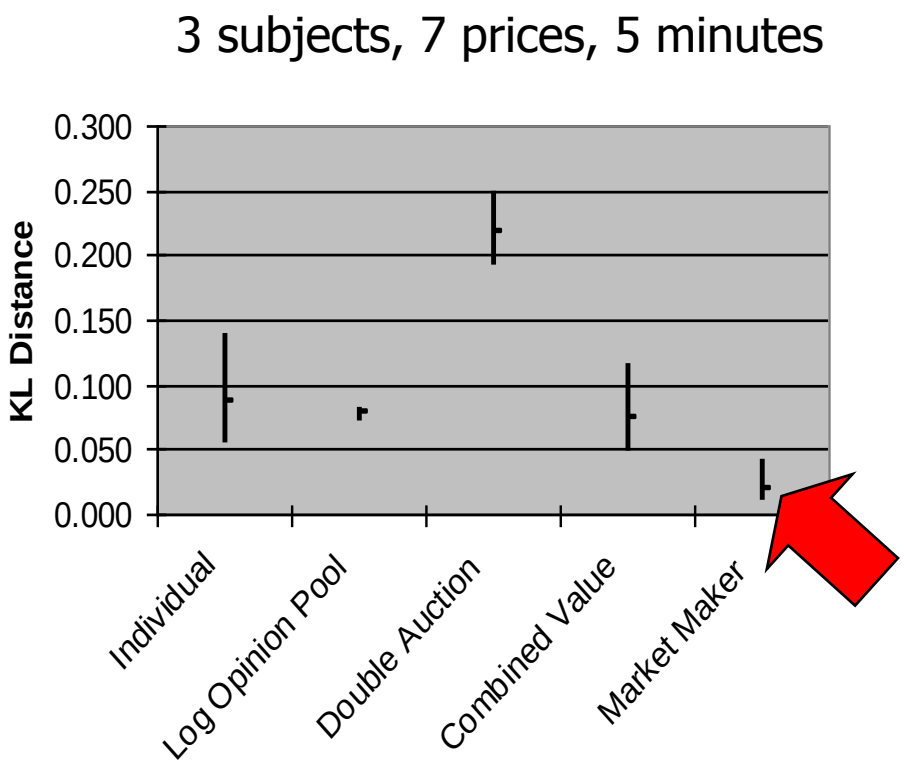
$$1-\frac{KL(prices,group)}{KL(uniform,group)}$$

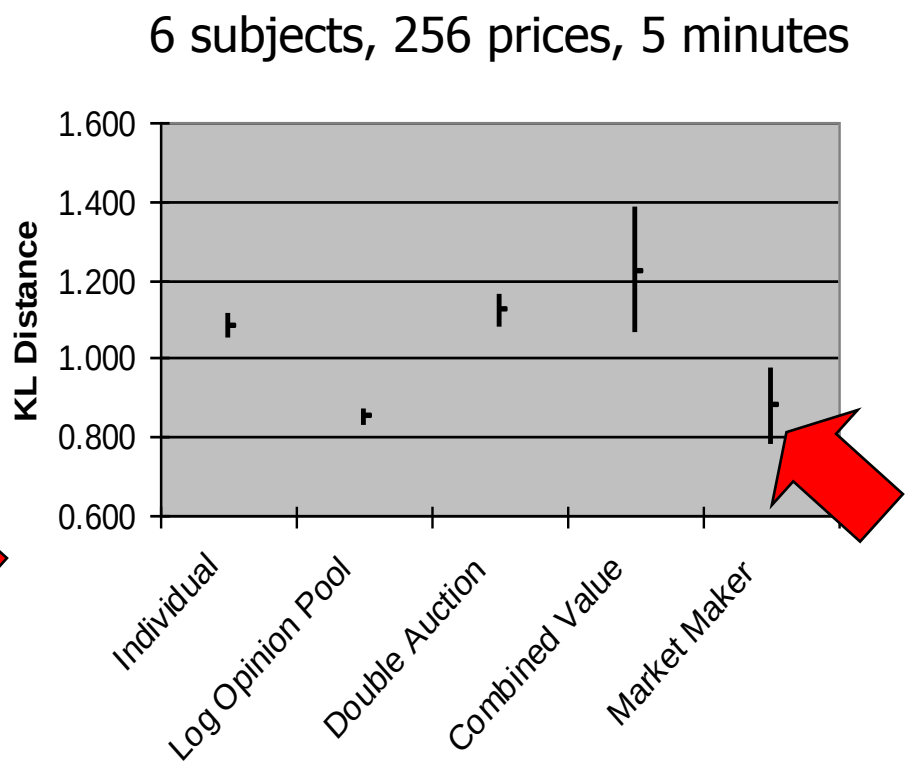


Combinatorial Lab Experiments

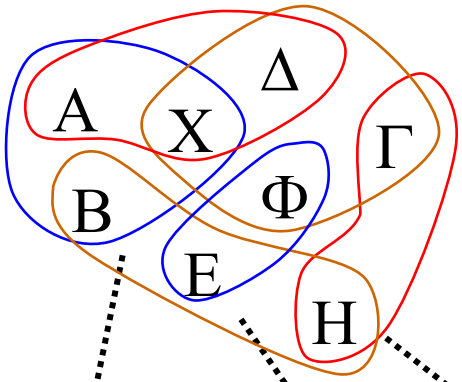
- 7 indep. prices from 3 folks in 4 min.
  - Simple Double Auction < Scoring Rule ~ Opinion Pool ~ Combinatorial Call < Market Scoring Rule
- 255 indep. prices from 6 folks in 4 min.
  - Combinatorial Call ~ Simple Double Auction ~ Scoring Rule < Opinion Pool ~ Market Scoring Rule

Combo Market Maker Best of 5 Mechs

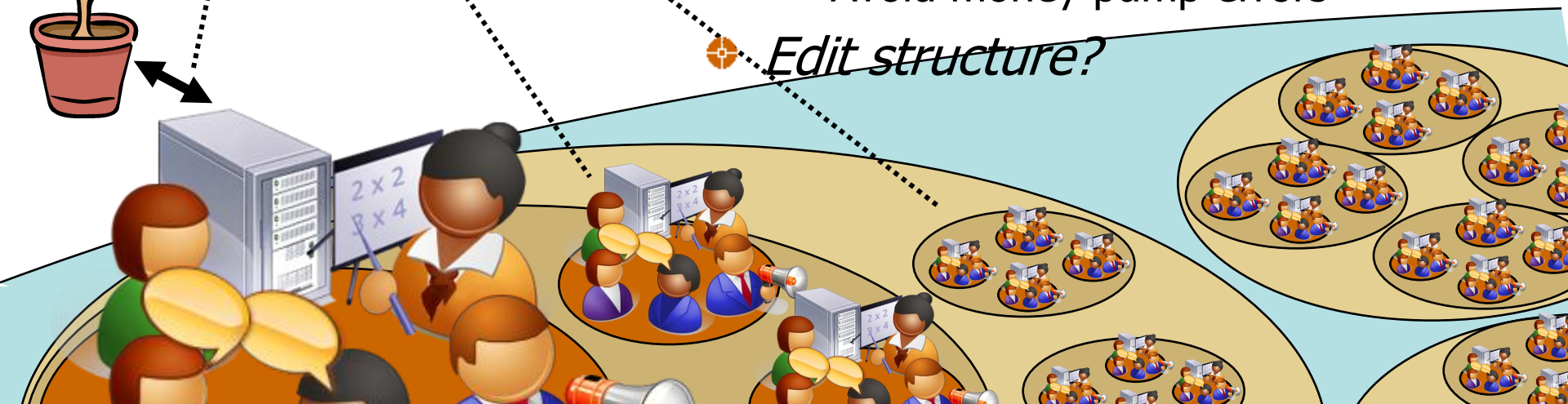




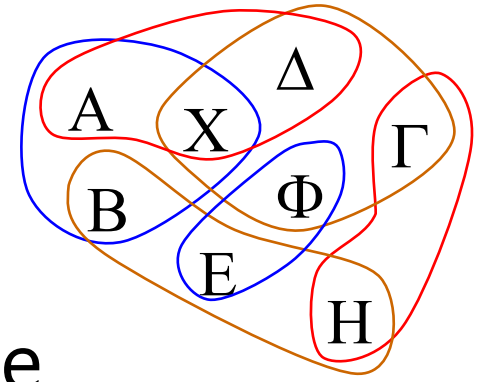
Compute Tasks



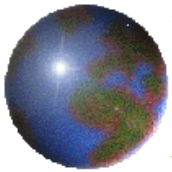
- Represent p(s), $(s,i)
- Add/settle var, Add/take $
- Browse E[x|A] & E[$|A]
  - & history of changes
- For each E[x|A], show max/min/indifferent $ edits
- Allow edit of many E[x|A]
  - Update 👎$(s,i) = b*👎 log(p(s))
  - Avoid money pump errors
- *Edit structure?*



How Close Markov Nets?

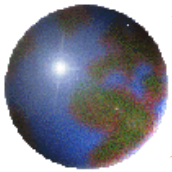


- ✓ Have no forseen error 👎p alg.
  - ❖ But can distribute computation?
- ✓ Ways to browse E[x|A]
- ✓ Can allow edit if vars in same clique
  - ❖ How support other edits?
- Need good $(s) repr. to support:
  - For i take $, max edit, must find $\min_s$ (s,i)
  - Update 👎$ alg without forseen min $ error
- How efficiently store histories?
- How allow structure changes?



Typical Problems In Field Now

- Laws on gambling, insider trading
- "Moral" & "Culture" concerns
- Not really want to know
- Hard to find precise related events
- Little participation for cheap
- Not enough events to validate, learn
- Awkward interfaces



Concerns

- Self-defeating prophecies
- Decision selection bias
- Price manipulation
- Inform enemies
- Share less info
- Combinatorics
- Moral hazard
- Alarm public
- Embezzle
- Bozos
- Lies
- Rich more “votes”
- Risk distortion
- Bubbles

Kyle Style Market Microstructure Game Theory

Simple Manipulation Model

Market maker

$$P = E[v \mid u + x + z]$$

Manipulator

$$\max_z E[z(v - P) + wP]$$

Informed trader

$$\max_{x,\sigma_\varepsilon^2} E[x(v - P) \mid v + \varepsilon, w + \delta] - c(\sigma_\varepsilon^2)$$

Noise trader

$$v \sim N(\bar{v}, \sigma_v^2) \quad w \sim N(\bar{w}, \sigma_w^2) \quad u \sim N(\bar{u}, \sigma_u^2)$$

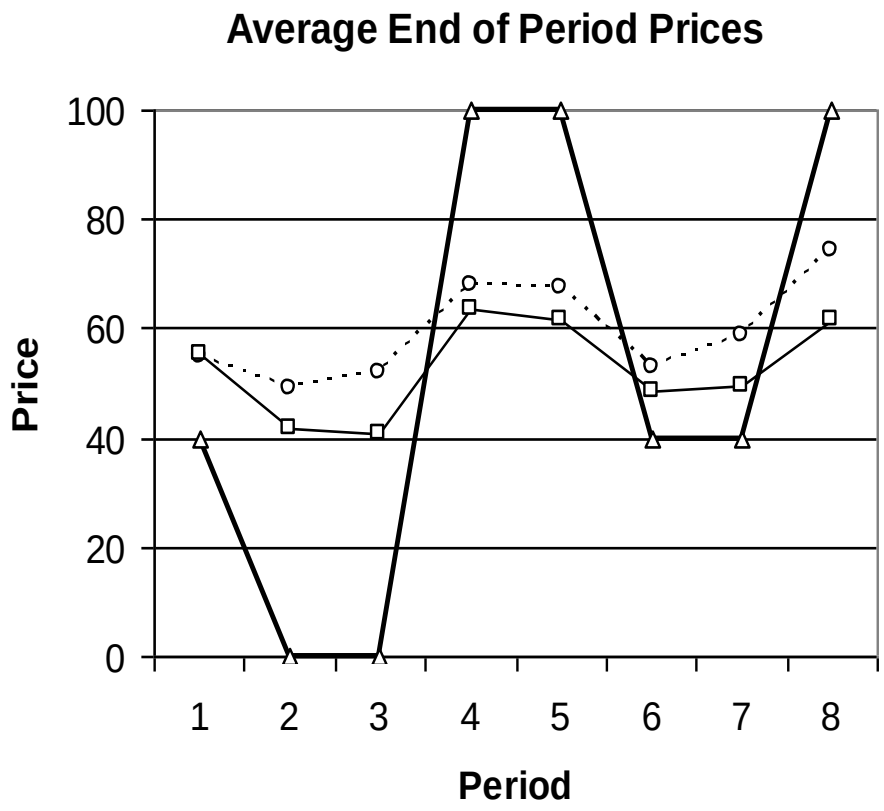
$$\varepsilon \sim N(\bar{\varepsilon}, \sigma_\varepsilon^2) \quad \delta \sim N(\bar{\delta}, \sigma_\delta^2) \quad c' < 0, \; c'' > 0$$

Equilibrium

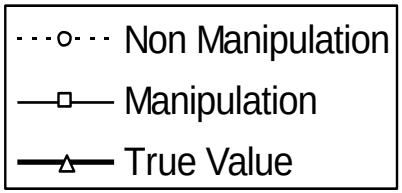
$$E[(v - P)^2] = \frac{\sigma_v^2}{2} \frac{\sigma_v^2 + 2\sigma_\varepsilon^2}{\sigma_v^2 + \sigma_\varepsilon^2}$$

$$\frac{\partial E[(v - P)^2]}{\partial [\sigma_w^2 \text{ or } \sigma_u^2]} < 0$$

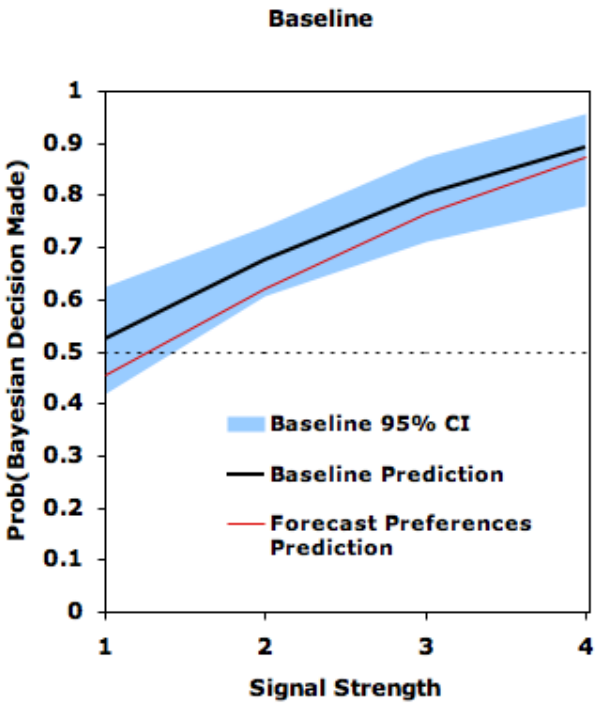
Lab Data

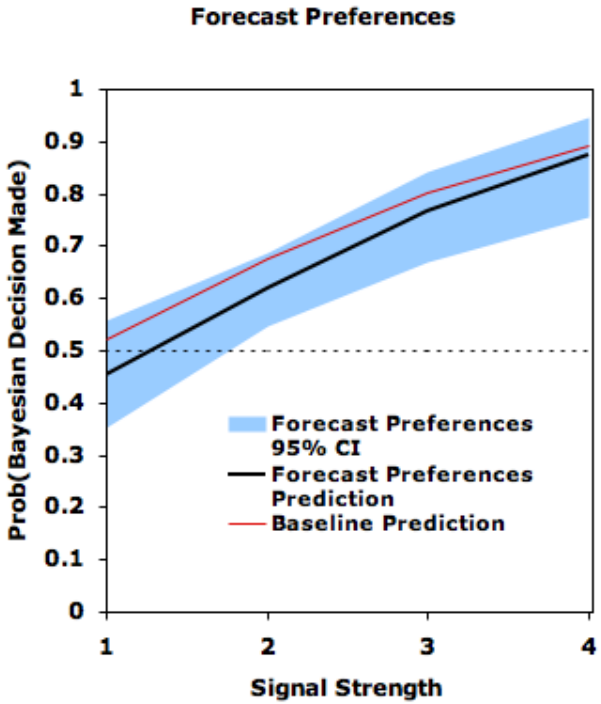


Hanson, Oprea, Porter *JEBO*, 2005



- 12 subjects, value = 0,40,100
- Each clue like "Not 100".
- 6 manipulators, get bonus for higher price
- *Manipulators bid higher*
- *Others accept lower*
- *Prices no less accurate*



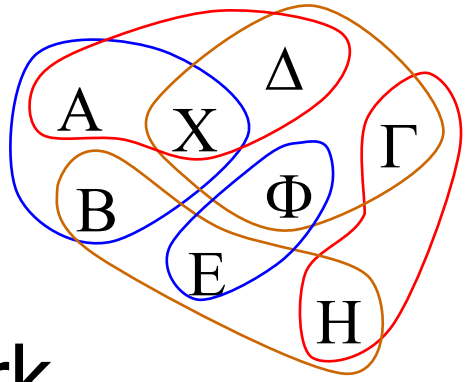


- 8 traders, Value = 0,100
- Each Prob(Clue=V) = 2/3
- 4 manipulators, bonus for price to hidden target 0,100

- 5 judges see prices, predict
- Manipulators bid toward target
- Prices and judges predictions no less accurate

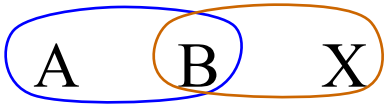
R. Oprea, D. Porter, C. Hibbert, R. Hanson, D.Tila 2006

A Scaleable Implementation



- Overlapping variable patches
- A simple MSR per patch
- If consistent, is Markov network
  - Var independent of rest given neighbors
- Allow trade if all vars in same patch
- Arbitrage overlapping patches
  - Sure to eventually agree, robust to gaming

Arbitraging Patches



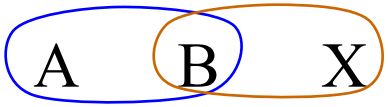
	A	A				C	C	
B	.02	.08	.1	→	.2	.3	.1	B
B	.2	.7	.9	→	.734	.3	.3	B
				←	.2			
				←	.4			
				←	.6			

.065

1.000

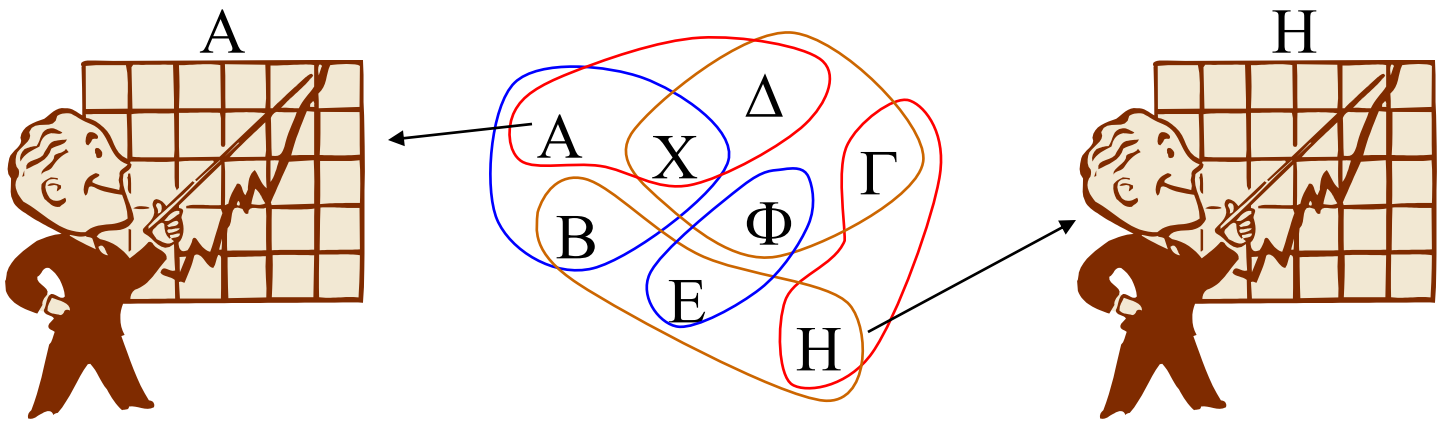
Cash extracted

Arbitraging Patches Continued



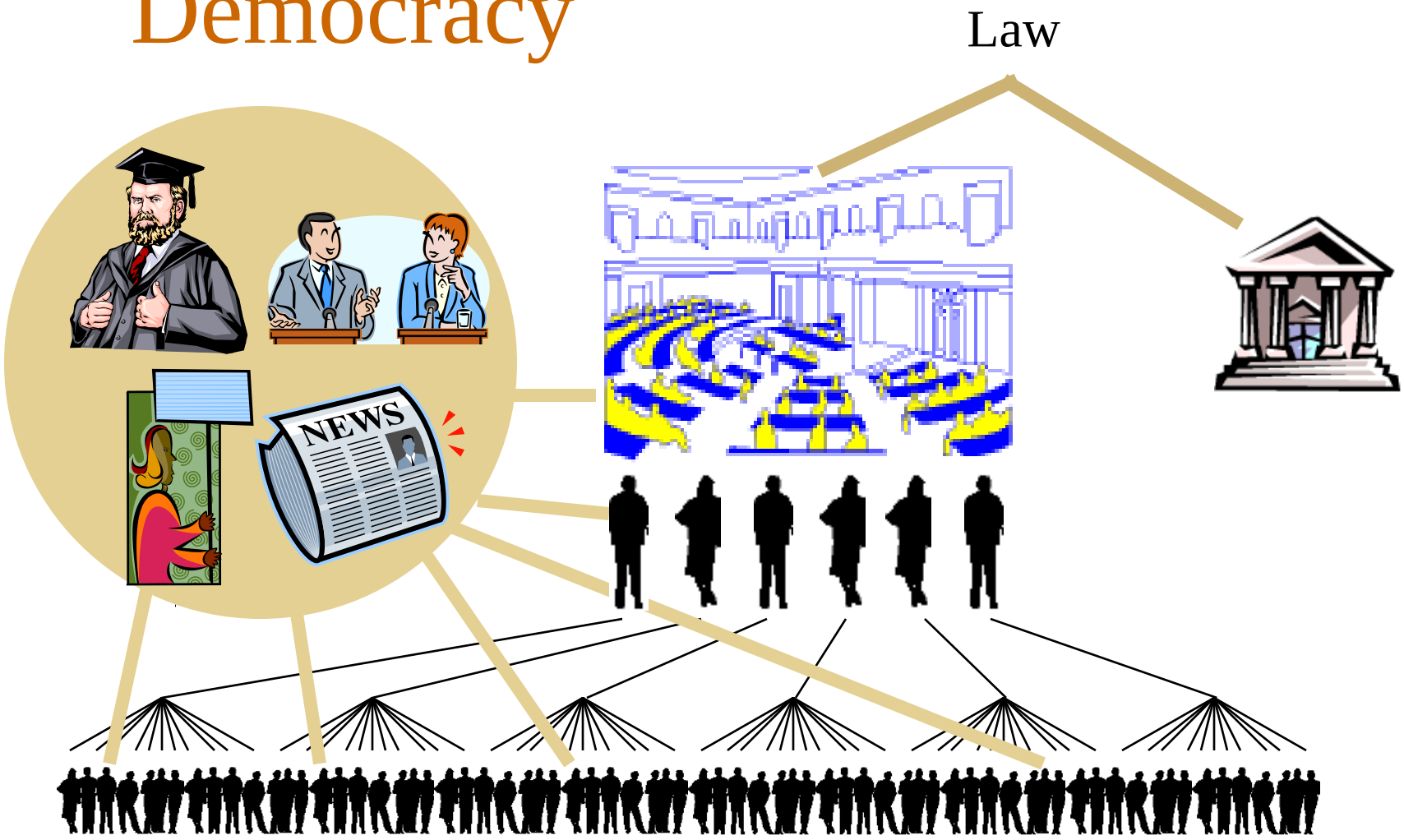
	A	A				C	C	
B	.043	.171	.214 ⟵	.214	⟶ .214	.160	.053	B
B	.175	.611	.786 ⟵	.786	⟶ .786	.393	.393	B

But Arbitrage Is Not Modular

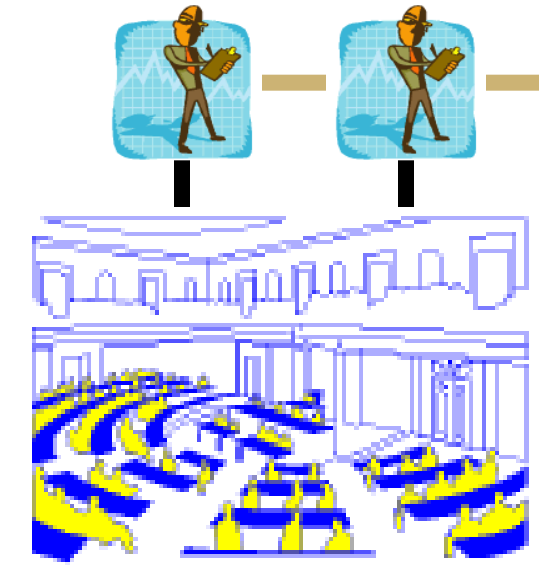


1. Everyone agrees on prices
2. Expert on A gets new info, trades
3. Arbitrage updates all prices
4. Expert on H has no new info, but must trade to restore old info!

Democracy



Vote On Values *But* Bet On Beliefs



E[National Welfare | Alternative] >?
E[National Welfare | Status Quo]