

Combinatorial Information Market Design

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Wanted: $E[\text{Outcome}|\text{Decision}]$

Outcomes

- Stock price
- Product sales
- Unemployment
- Economic growth
- Crime rate

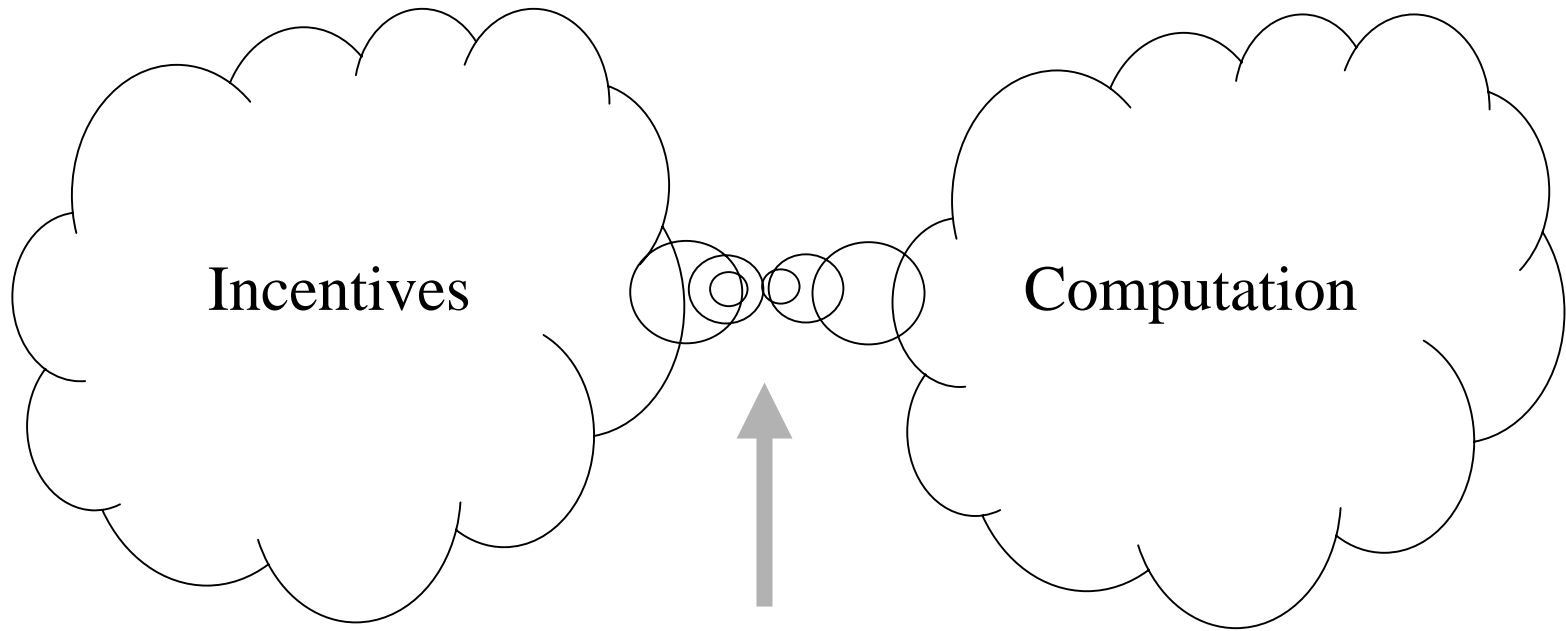
Decisions

- Dump CEO
- Which ad campaign
- Who elected president
- Fed raise/lower rates
- More gun control

Info Tech \neq Bit Tech!

- E.g., $E[US \text{ terror deaths} \mid \text{invade Iraq}]$
- Bit tech = move/map bits (telecom/computer)
 - Now much easier to find what people say, but ...
- Info tech ideal: $p(E)$ for all events E
 - Full joint probability distribution over events
 - Combines all anyone knows or could learn
 - Key: *incentives* to learn, reveal, combine

Economics & Computer Science



Seek tractable interface

Old Tech: Proper Scoring Rules

- Assume: ex post verifiable vars, give states i
- When report \mathbf{r} , state is i , reward is $s_i(\mathbf{r})$
- $\mathbf{p} = \operatorname{argmax}_{\mathbf{r}} \sum_i p_i s_i(\mathbf{r}), \quad \sum_i p_i s_i(\mathbf{p}) \geq 0$
- E.g., log rule (Good 1952) $s_i = \alpha \log(r_i)$
- Long used in weather/business forecasting, student test scoring, economics experiments

Old Tech Issues

Problems

- Incentives
- Number shy
- Non risk-neutral
- State-varying utility
- Cognitive bias
- Combo explosion
- Disagreements

Solutions

- Proper scoring rules
- Prob wheel, word menu
- Lottery payoffs
- Lottery insurance game
- Corrections
- Dependence network
- Dictator per Q, ??

} centralized

New Tech: Information Markets

- Most markets aggregate info as side effect
- Info markets beat competing institutions
 - OJ futures improve weather forecast (Roll 1984)
 - HP market beat sales forecast 6/8 (Plott 2000)
 - I.E.M. beat president polls 451/596 (Berg et al 2001)

$$\boxed{\$1 \text{ if } A} \leftrightarrow p(A) \boxed{\$1} \quad \boxed{\$ x} \leftrightarrow E_p[x] \boxed{\$1}$$

$$\boxed{\$ x \text{ if } A} \leftrightarrow E_p[x|A] \boxed{\$1 \text{ if } A}$$

Coming Soon ...

E[US terror deaths / invade Iraq] for real!

- DARPA, Net Exchange, Caltech, GMU
- Two year field test, starts spring 2003
- Open to public, real money markets
- ~20 nations, 8 quarters, ~5 variables each:
 - Economic, political, military, US actions
- Want many combos ($> 2^{500}$ states!)

New Tech Issues

Problems

- Incentives
- Shy, complex utility
- Who expert on what
- Cognitive bias
- Disagreements
- Thin markets
- Combo explosion

Solutions

- Bet? irrational, subsidy
- Same solutions
- Self-select
- Arbitrageurs
- Equilibrate, risk
- Market scoring rules
- Structure dictator, ??

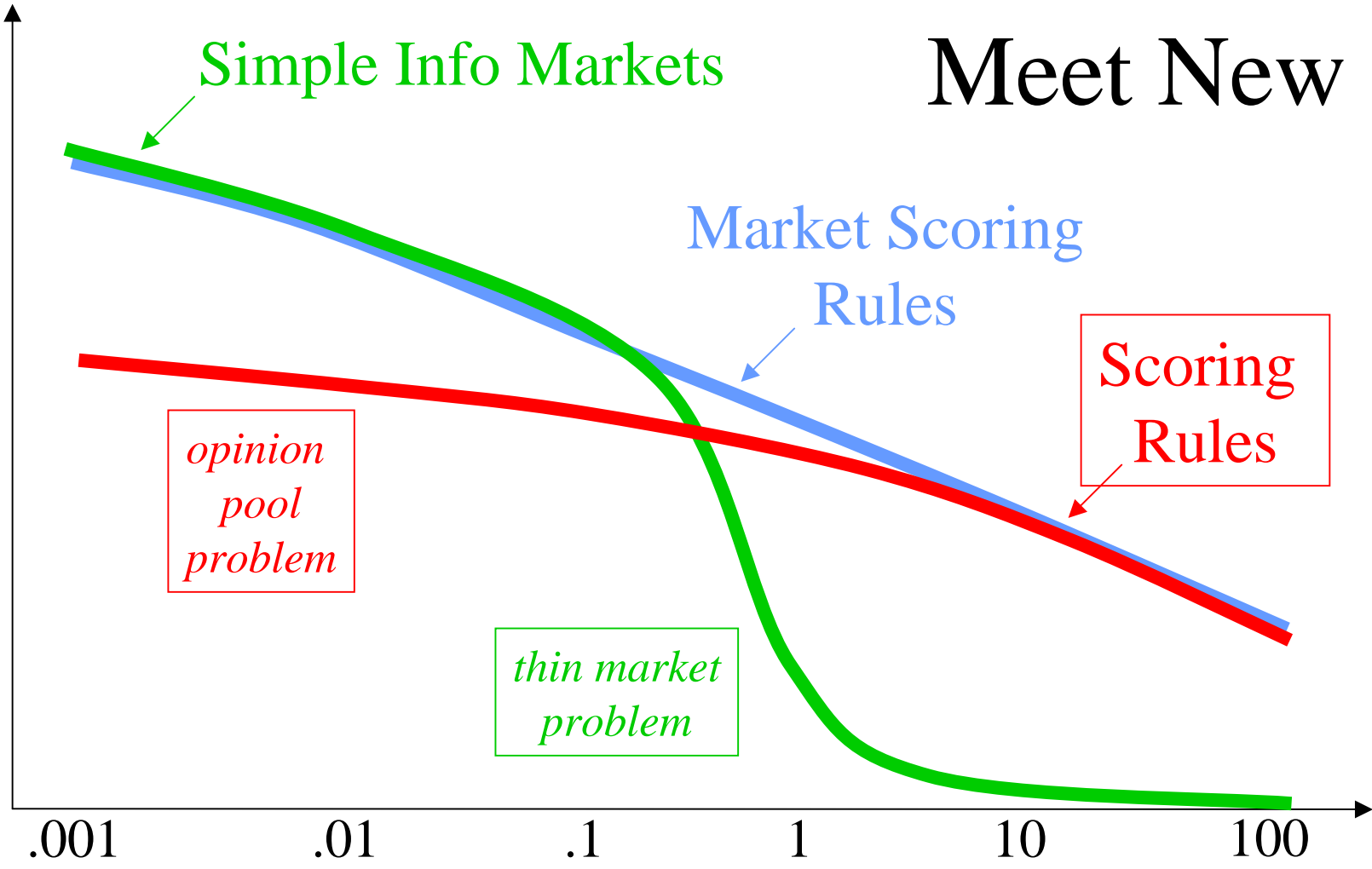
decentralized

Thin Market Problem

- Trade requires *coordinate* in *Assets* and
 - *Time*: waiting offers suffer adverse selection
 - Call markets, combo match, can help some, but
- Most possible info markets do not exist
 - Most are illegal, and for most of the rest
 - Expect few traders, so don't make offer
- *If known that only one person has opinion on a topic, simple price not reveal it!*

Old Tech Meet New

Accuracy



Estimates per trader

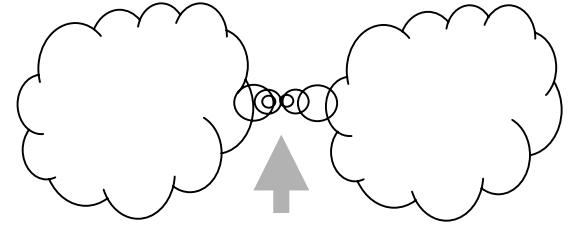
Market Scoring Rules

- MSR combines scoring rules, info markets
- User t faces \$ rule: $\Delta s_i = s_i(\mathbf{p}^t) - s_i(\mathbf{p}^{t-1})$
“Anyone can use scoring rule if pay off last user”
- Is auto market maker, price from net sales \mathbf{s}
 - Tiny sale $\$ \epsilon_i$ if i fee: $\cong p_i(\mathbf{s}) \epsilon_i$ ($s_i \rightarrow s_i + \epsilon_i$)
 - Big sale $\$ \mathbf{s}(1) - \mathbf{s}(0)$ fee: $\int_0^1 \sum_i p_i(\mathbf{s}(t)) s_i'(t) dt$
 - Log MSR is: $p_i(\mathbf{s}) = \exp(\lambda s_i) / \sum_k \exp(\lambda s_k)$

Log MSR Cost & Modularity

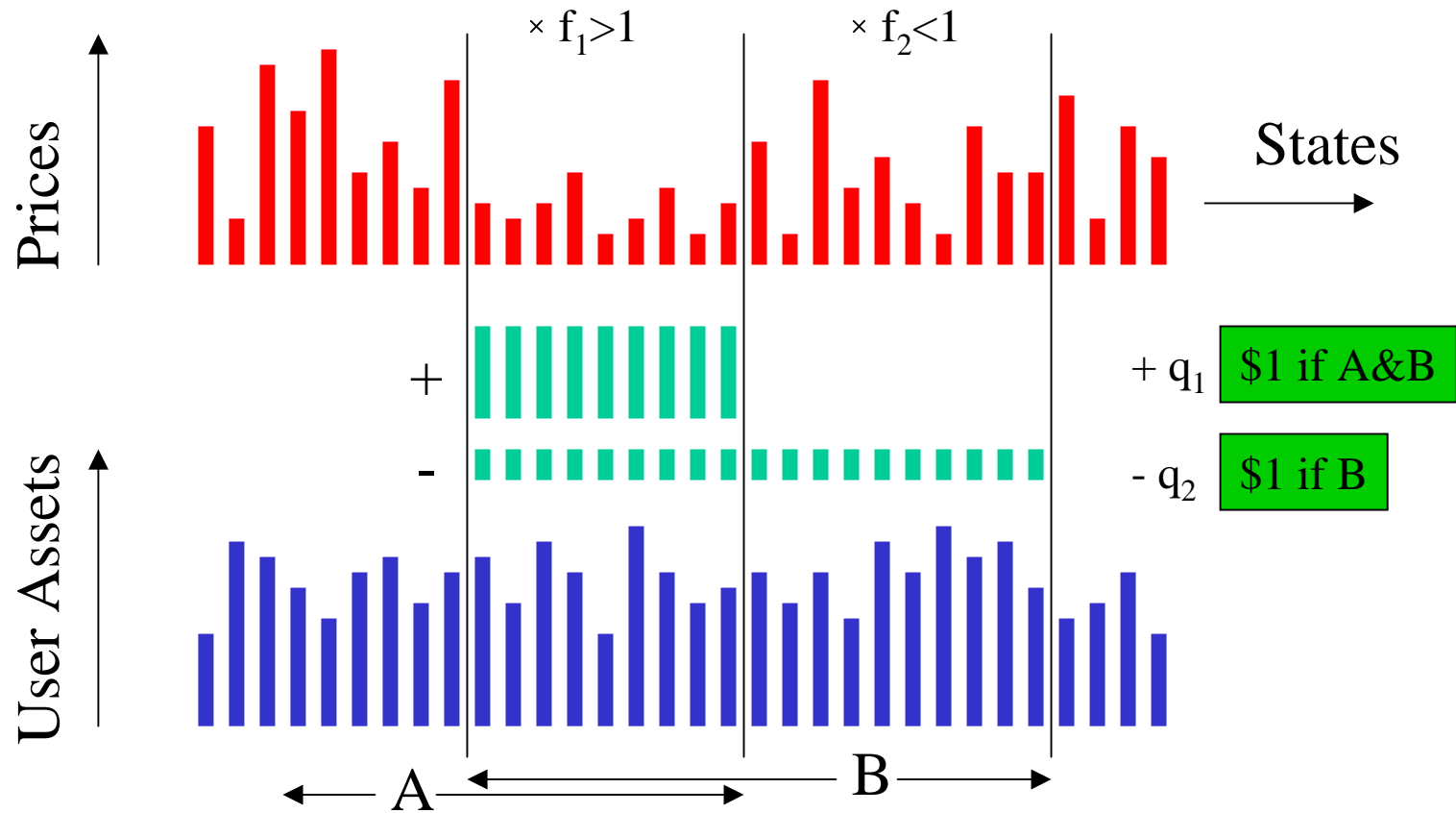
- Cost = $s_{\text{true}}(\mathbf{p}^{\text{end}}) - s_{\text{true}}(\mathbf{p}^{\text{start}})$
 - Expected cost: $E_{\pi}[C] \leq \sum_i \pi_i (s_i(\mathbf{1}_i) - s_i(\boldsymbol{\pi}))$
 - Log cost bound \propto entropy: $S(\boldsymbol{\pi}) = - \sum_i \pi_i \log(\pi_i)$
 - $S(\boldsymbol{\pi}_{\text{all}}) \leq \sum_{\text{var}} S(\boldsymbol{\pi}_{\text{var}})$, so all combos \leq rule per var!
- Log is modular
 - $\boxed{\$1 \text{ if } A\&B} \leftrightarrow p(A|B) \boxed{\$1 \text{ if } B}$
 - Changes $p(A|B)$, but not $p(B)$, $p(C|A\&B)$, $p(C|\neg A\&B)$, $p(C|\neg B)$, $I(\mathcal{A}, \mathcal{B}, \mathcal{C})$, $I(\mathcal{B}, \mathcal{A}, \mathcal{C})$

MSR Compute Tasks

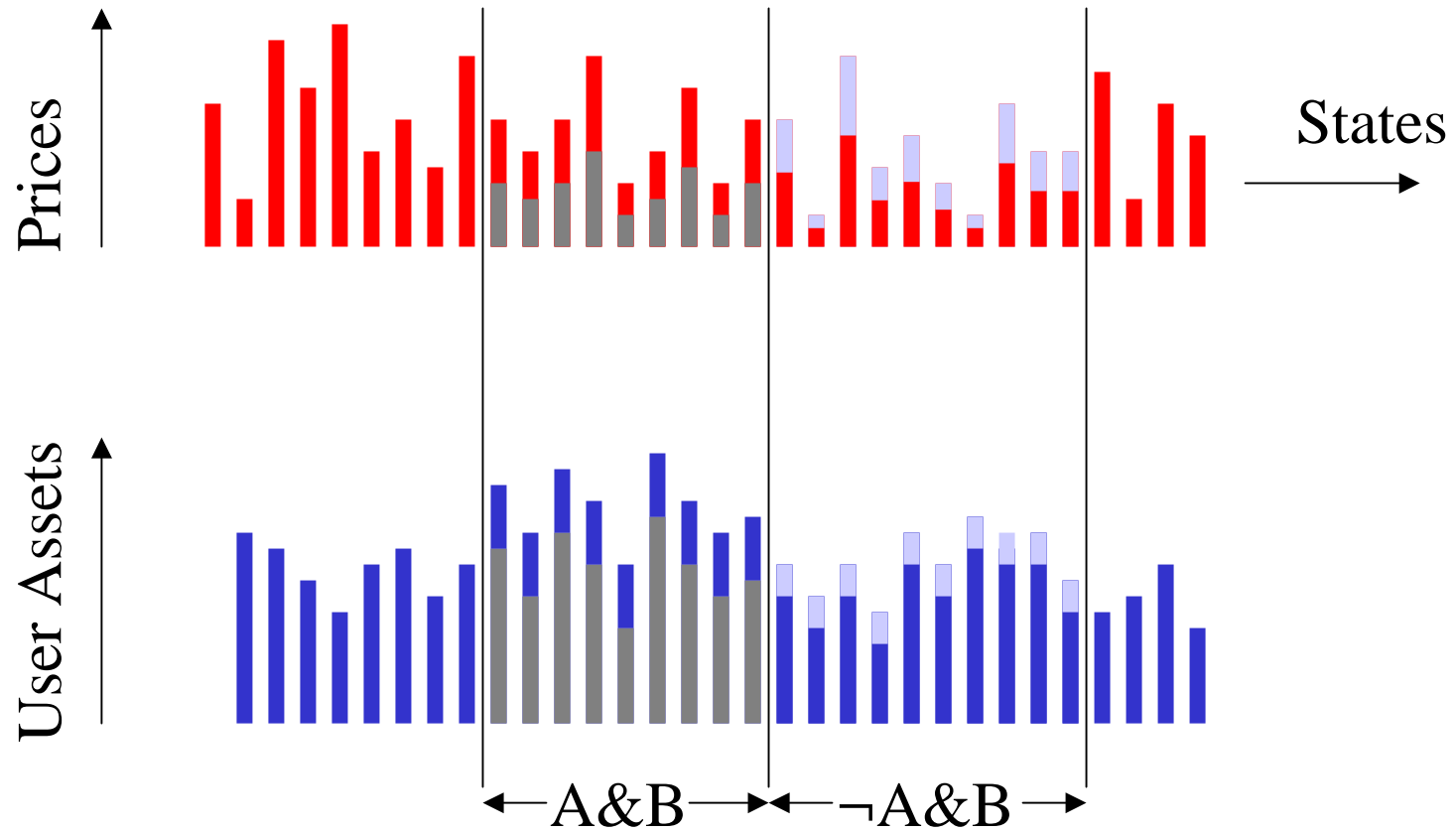


- Trade - change $P(A|B)$ from p to p'
 - Update user asset holdings $+ q_1$ \$1 if A&B $- q_2$ \$1 if B
 - Update all prices (avoid being money pump)
- Prepare for trade
 - Show prices (browse B scenario, seeking an A)
 - Collect/identify assets can support certain trade
 - Browse assets, see if now long/short on $P(A|B)$
- Misc: add var, decide value, abstractions

A Simple Implementation

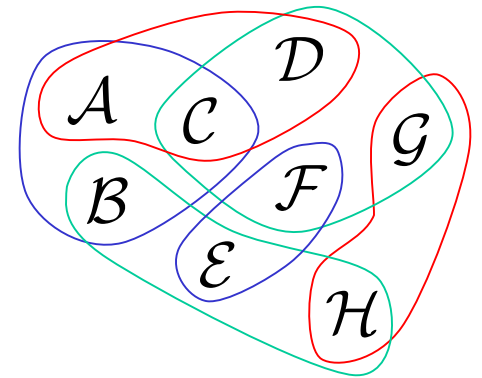


A Simple Implementation

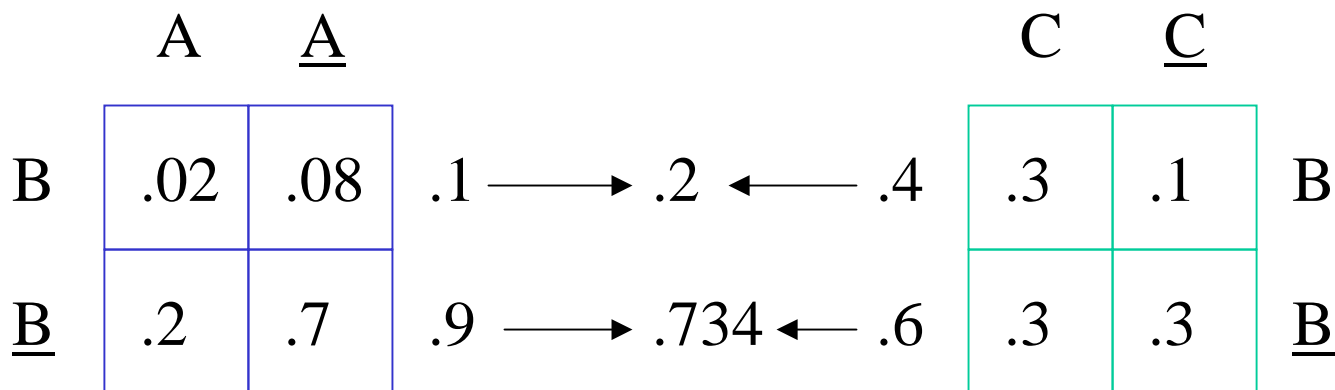
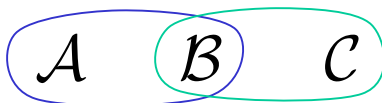


A Scalable Implementation

- Overlapping variable patches
- A simple MSR for each patch
- Arbitrage neighbor patches
 - Limits profits to users who find inconsistencies
- Only allow trade if all vars in same patch?
- User assets per patch, move via overlap
- Regroup patches from request activity?



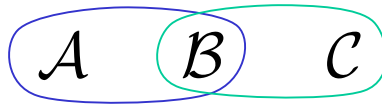
Arbitraging Patches



.065

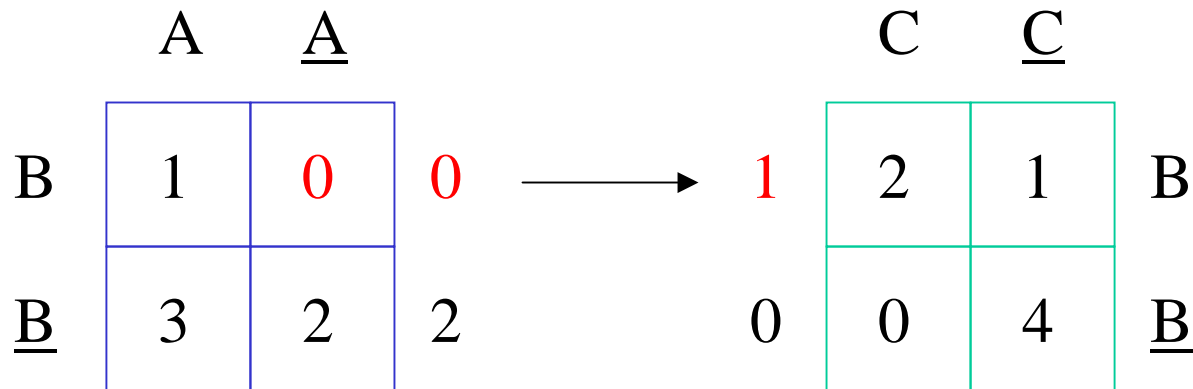
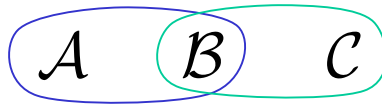
1.000
Cash extracted

Arbitraging Patches

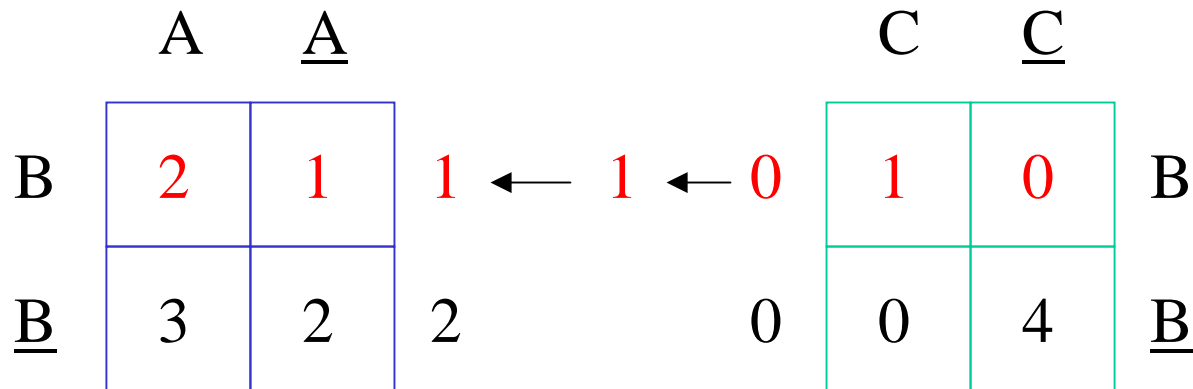
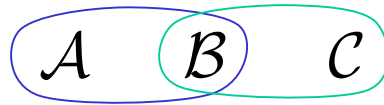


	<u>A</u>	<u>A</u>		<u>C</u>	<u>C</u>			
<u>B</u>	.043	.171	.214 ←	.214 →	.160	.053	.214	<u>B</u>
<u>B</u>	.175	.611	.786 ←	.786 →	.393	.393	.786	<u>B</u>

Moving Assets Between Patches

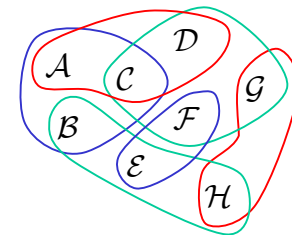
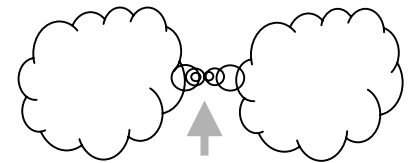


Moving Assets Between Patches



Summary

- Want info tech, not just bit tech: $E[x/A]$
 - DARPA field test soon
- Combine scoring rules, info markets: MSR
 - Solves: opinion pool, thin market, subsidy
 - Decentralized: fix bias, who expert
- Defines computational problem
 - Exists one scaleable approach
 - Can we do better?



Opinion Pool “Impossible”

- Task: pool prob. $T(A)$ from opinions $p^n(A)$
- Any 2 of IPP, MP, EB \Rightarrow dictator ($T = p^d$) !
 - IPP = if A,B indep. in all p^n , are indep. in T
 - MP = commutes: pool, coarsen states (σ -field)
 - EB = commutes: pool, update on info
- MP $\Rightarrow T = \sum_{n=0} w_n p^n$, with w_n indep. of A