Prediction Market Alternatives for Complex Environments

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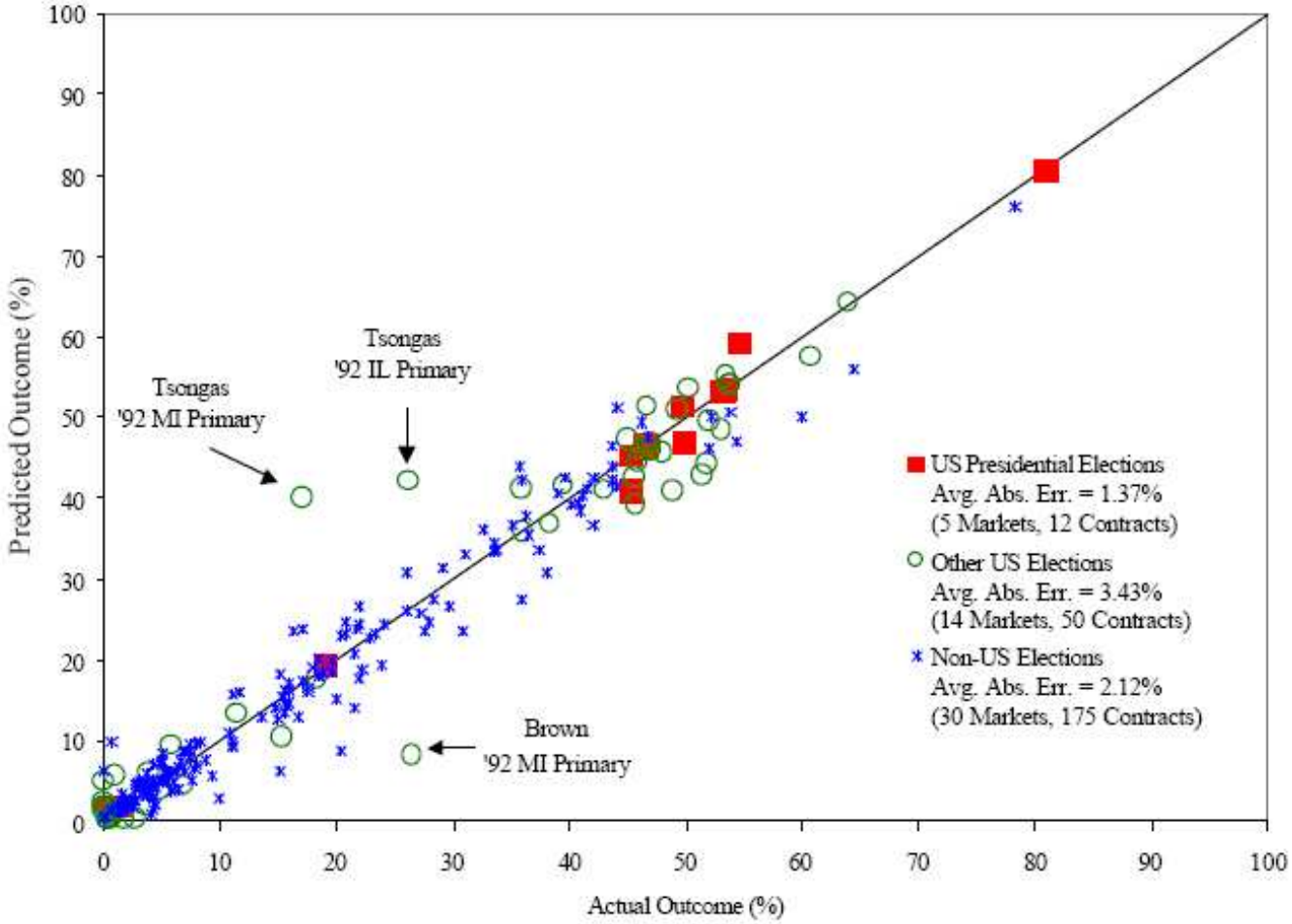
The Success of Prediction Markets

- Wall St. market: 1848–1940 (Rhode & Strumpf 2004)
  - 11/15 correct in mid-October, only 1 very wrong (Wilson 1916)
- Iowa Electronic Markets (Berg et al. 2003)
  - See figure...

The Success of Prediction Markets



Avg. Error: 1.5% vs. 2.1%. Source: Berg,Forsythe, Nelson & Rietz (2003)

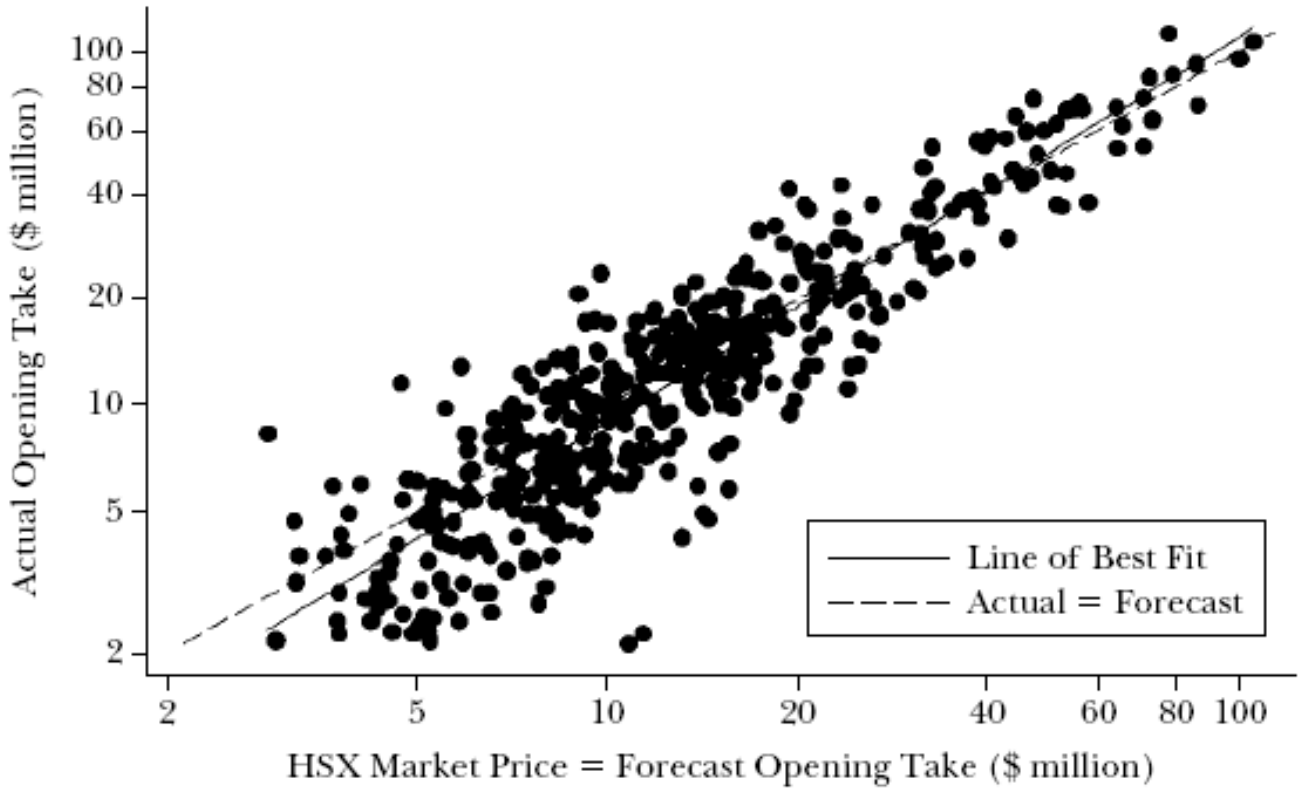
The Success of Prediction Markets

- Wall St. market: 1848–1940 (Rhode & Strumpf 2004)
  - 11/15 correct in mid-October, only 1 wrong (W. Wilson)
- Iowa Electronic Markets (Berg et al. 2003)
  - See figure...
  - But... Erikson & Wlezien use *trends* in polls
- TradeSports (Tetlock, Wolfers, Zitzewitz, others...)
  - Trade volume during Davidson vs. Kansas $\approx$ 7,700 \$10 tickets
- NewsFutures, Hollywood Stock Exchange (Pennock et al. 2001)
  - See figure...

The Success of Prediction Markets

Figure 3

Predicting Movie Success



Source: Data from 489 movies, 2000–2003 (⟨http://www.hsx.com⟩).

Source: Wolfers & Zitzewitz (2004)

Corporate Applications

- Predicting printer sales at Hewlett-Packard (K-Y Chen & Plott 2002)
- Companies claiming to use prediction markets:

Abbot Labs	Arcelor Mittal	Best Buy	Chrysler
Corning	Electronic Arts	Eli Lilly	Frito Lay
General Electric	Google	Hewlett-Packard	Intel
InterContinental Hotels	Masterfoods	Microsoft	Motorola
Nokia	Pfizer	Qualcomm	Siemens
TNT			

- Are they doing it 'right'? Volume? Complexity??

The Policy Analysis Market (PAM)

- 2001–2003 DARPA (DoD) => NetExchange (Ledyard, Polk, Hanson)
- Goal: Predict events the DoD might care about
- NetExchange focus: political instability in Middle East
- A subset of the issues:
  - Correlation blows up the state space
  - Manipulation? (Camerer 98, Strumpf & Rhode 07)
  - Moral Hazard? (Hanson et. al 07)
  - Moral repugnance & P.R. (Roth 07, Hanson 07)
- Aug 03: Shut Down, DARPA audited, Poindexter 'retired'

This Paper

Questions:

1. Can markets actually work when the environment gets 'complicated'?
2. Would other mechanisms do better?

Answers:

Test markets vs. 3 other mechs in complex lab environments

1. Market performs poorly; incentived, iterated polls perform better

Behavioral Mechanism Design

- Methodology of comibining experiments & theory to design better mechanisms for real-world use
- Short run goal: find a better mechanism
  1. Propose alternative mechanisms
     - Existing theory & behavioral data as guides
  2. Testbed proposed mechanisms
     - The control of the laboratory
  3. Tweak if necessary
- Long run goal: improve the design process
  1. Identify general principles while testbedding
  2. Add new constraints, etc., to the design problem

This Paper

Questions:

1. Can markets actually work when the environment gets complicated?
2. Would other mechanisms do better?

Answers:

Test markets vs. 3 other mechs in complex lab environments

1. Market falls apart, simple iterated polls perform better
2. *Why* the poll seems to do better in this environment

Easy vs. Hard Environments

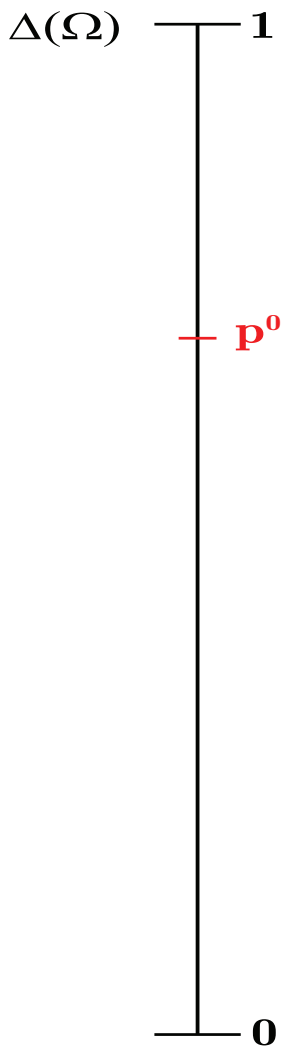
Example similar to our experiment:

1. **Simple:** Will UNC beat Kansas tonight?
   - Two states: {UNC,Kansas}, one security
2. **Hard:** Who will win each of the last 3 games (2 semi's and final)?
   - Three events, not independent
   - Eight states: {UNC,Kansas}×{Memphis,UCLA}×{East,West}
   - "Eastern finalist wins" is correlated with other 2 events
   - Incomplete set of securities is typically used
     - TradeSports offers 6 securities (1+1+4)
   - We will use a complete set of 8

2-State Environment

- Two coins: $\theta \in \Theta = \{X, Y\}$
- Two flip outcomes: $\omega \in \Omega = \{H, T\}$
- State of the world $= (\theta, \omega)$
- θ and ω are correlated, but we care only about ω
  - $p(H|X) = 0.2$
  - $p(H|Y) = 0.4$
- One coin θ is randomly drawn (50/50)
- Each subject sees flips of chosen coin
  - $s_i = (H, T, H, H)$
  - $\#s_i \in \{2, 3, 4\}$
- Observe sample ω's, infer about true θ, predict true ω

Distributions: 2 States



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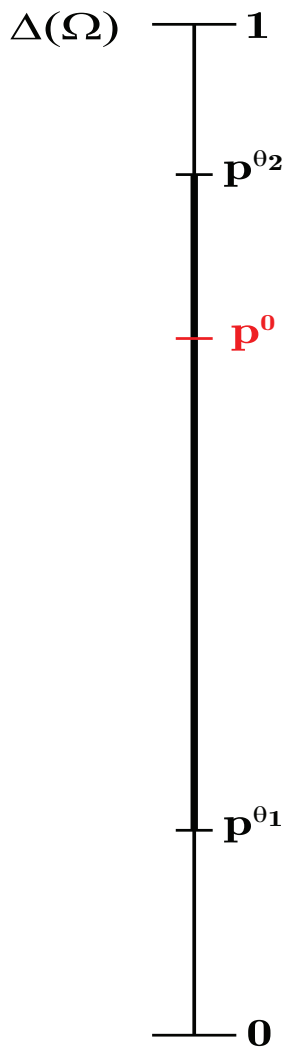

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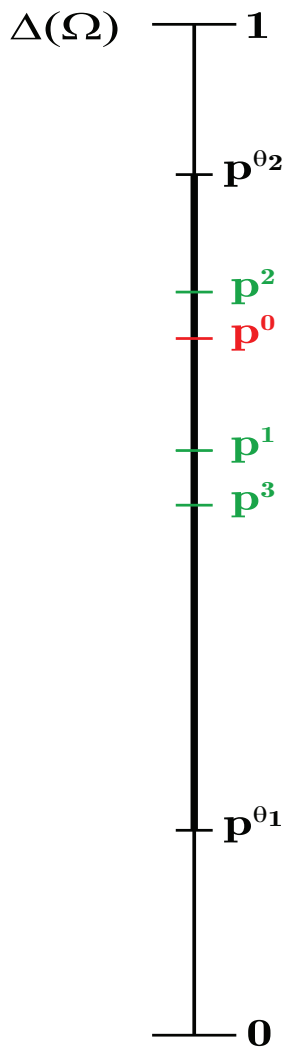

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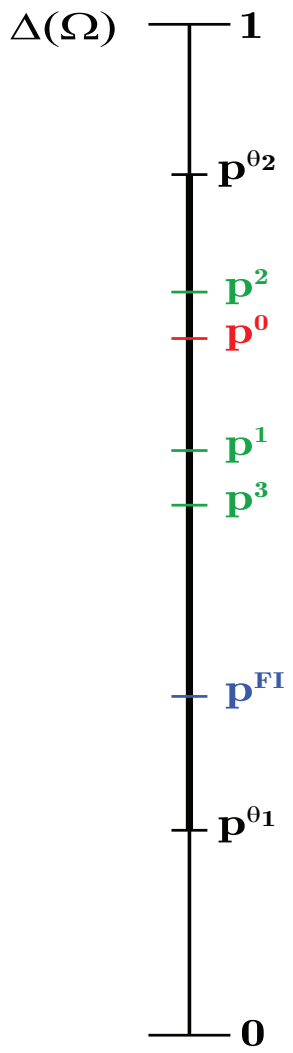

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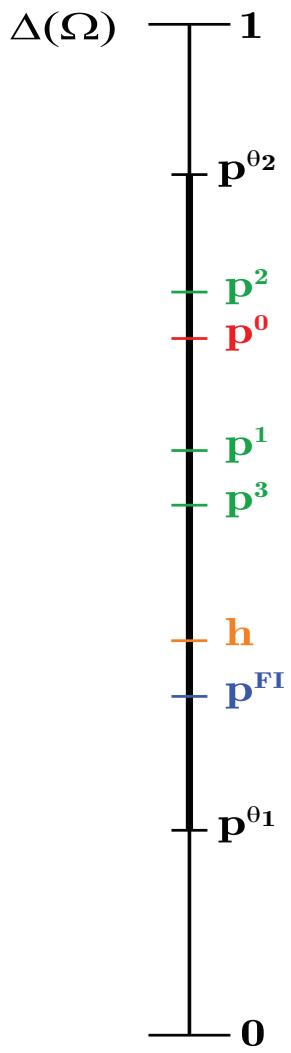

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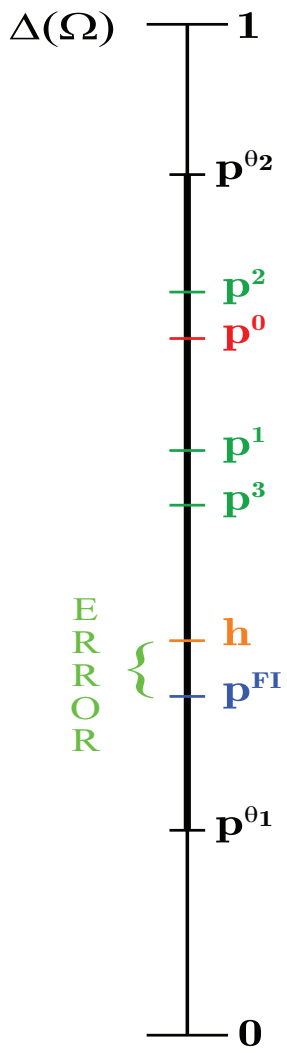
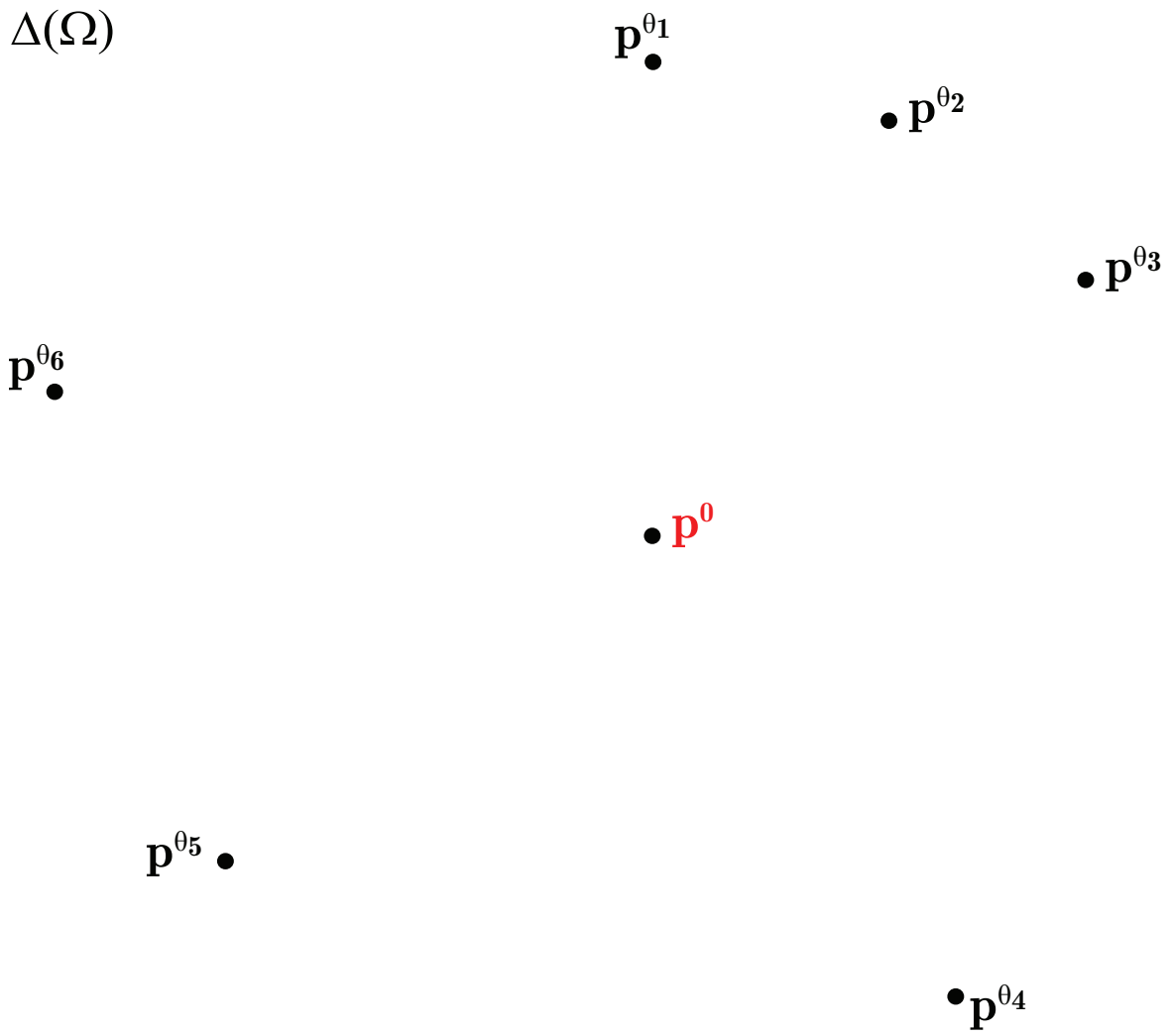


8-State Environment

- Three coins, ordered: $\theta \in \Theta = \{XYZ, XZY, YXZ, YZX, ZXY, ZYX\}$
- Eight flip outcomes:
  $\omega \in \Omega = \{TTT, TTH, THT, THH, HTT, HTH, HHT, HHH\}$
  - $\Pr[X = H] = 0.2$
  - $\Pr[Y = H] = 0.4$
  - $\Pr[Z = H] = 0.4$
  - $\Pr[Y = X] = 2/3$ (correlation distinguishes Y, Z)
- One ordering θ is randomly drawn (uniformly)
- Each subject sees flips from chosen coin ordering
  - $s_i = (THT, THT, HHH, TTT, HTH)$
  - $\#s_i \in \{3, 5, 7\}$

Distributions: 8 States



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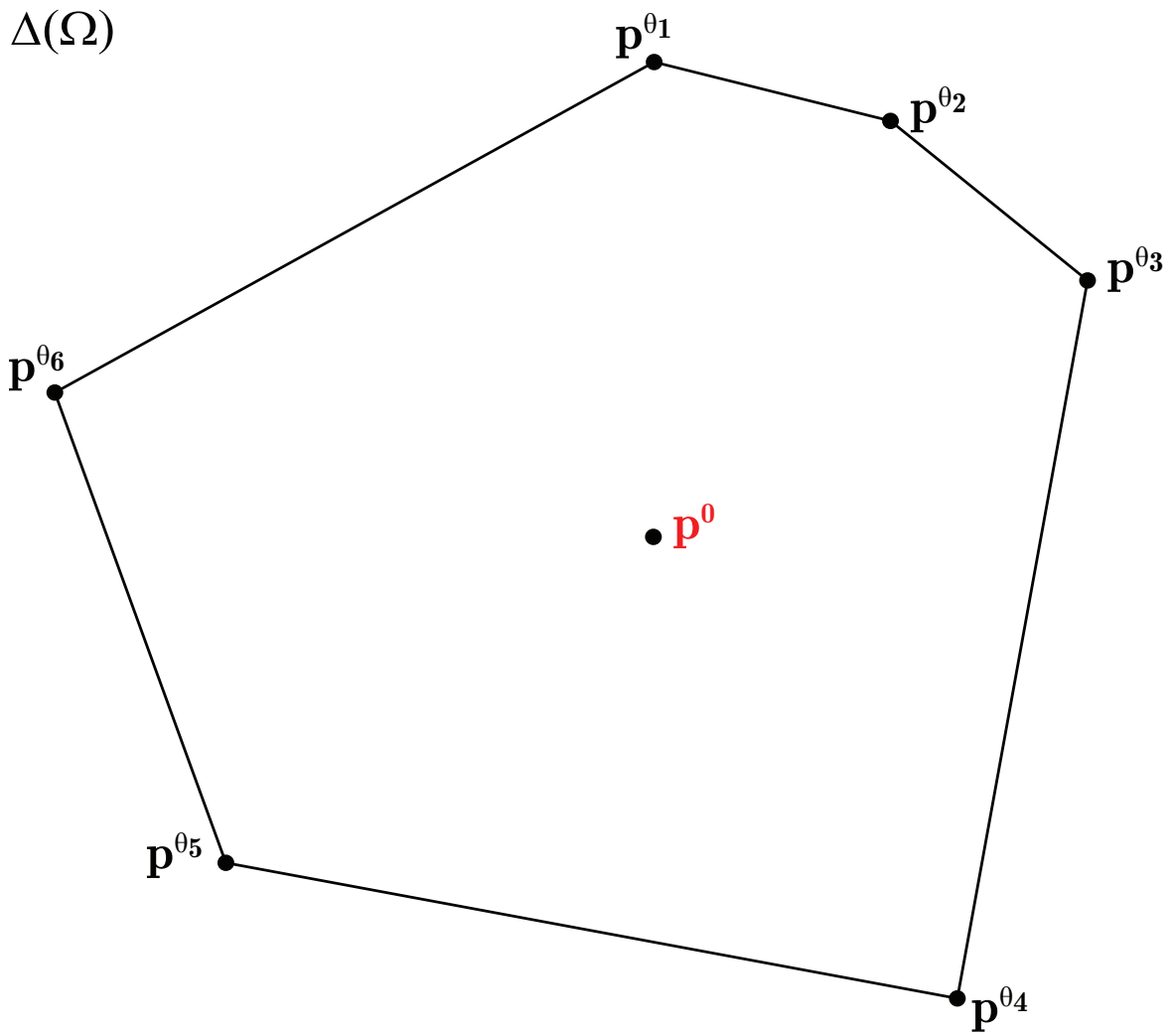

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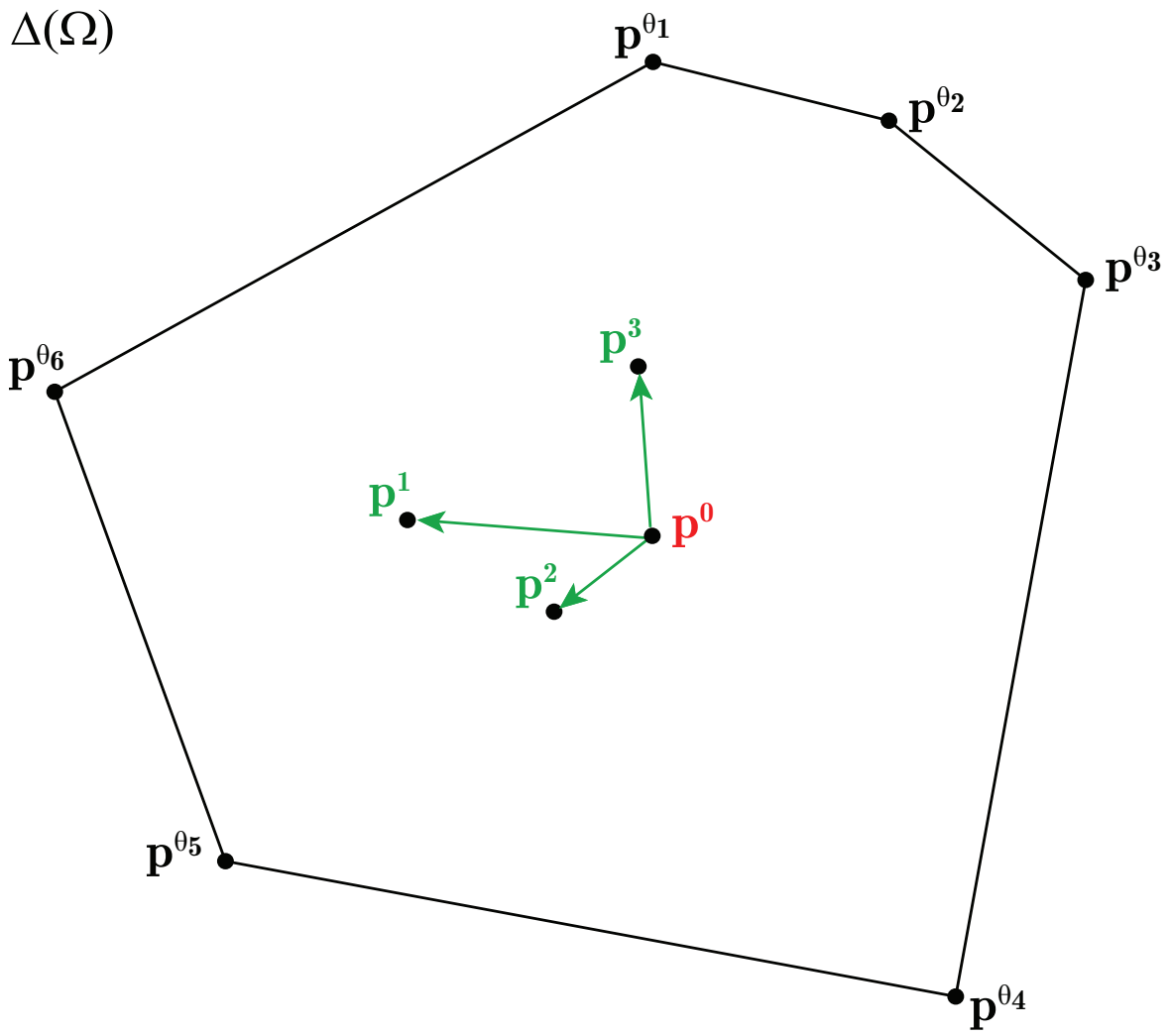

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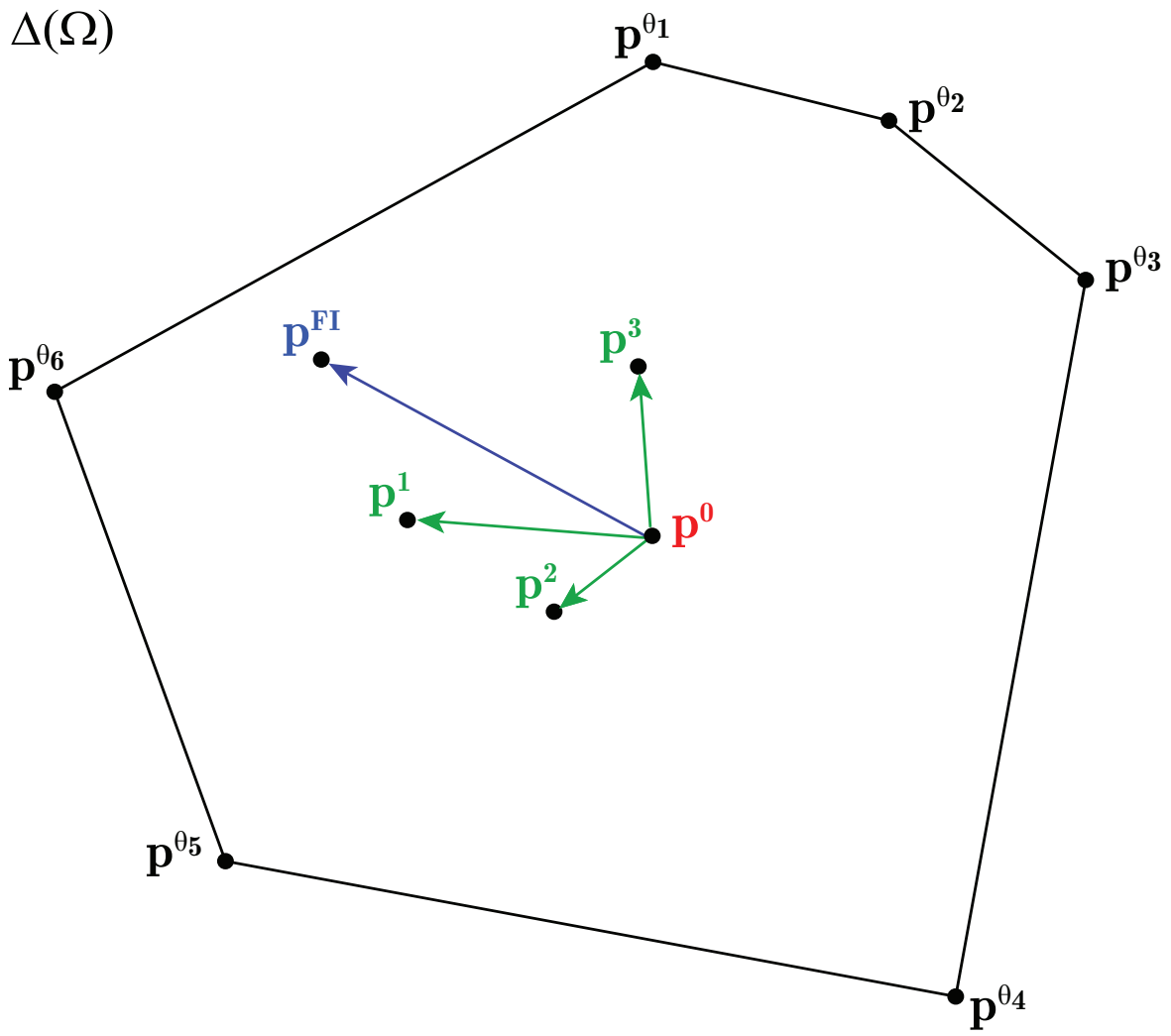

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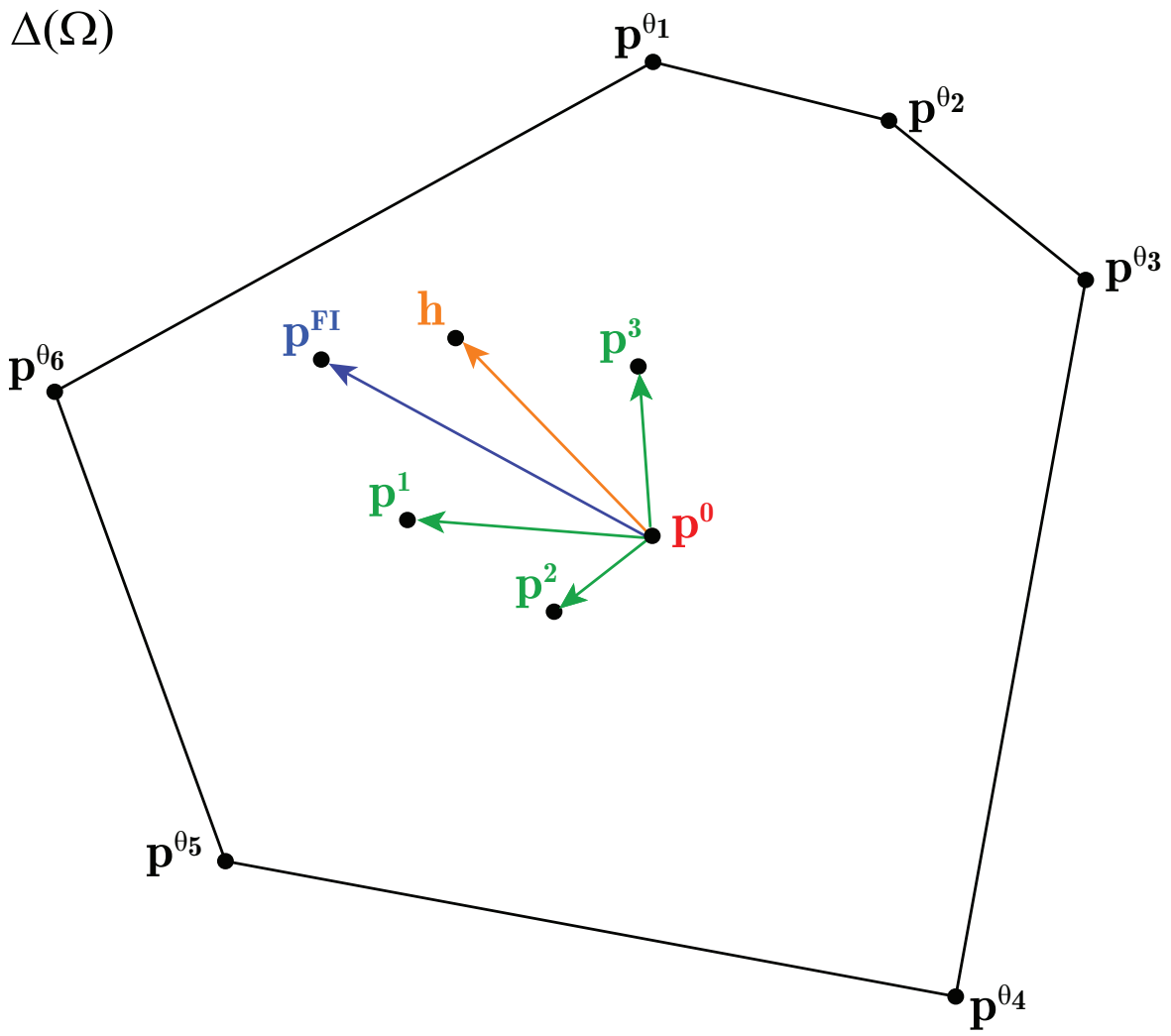

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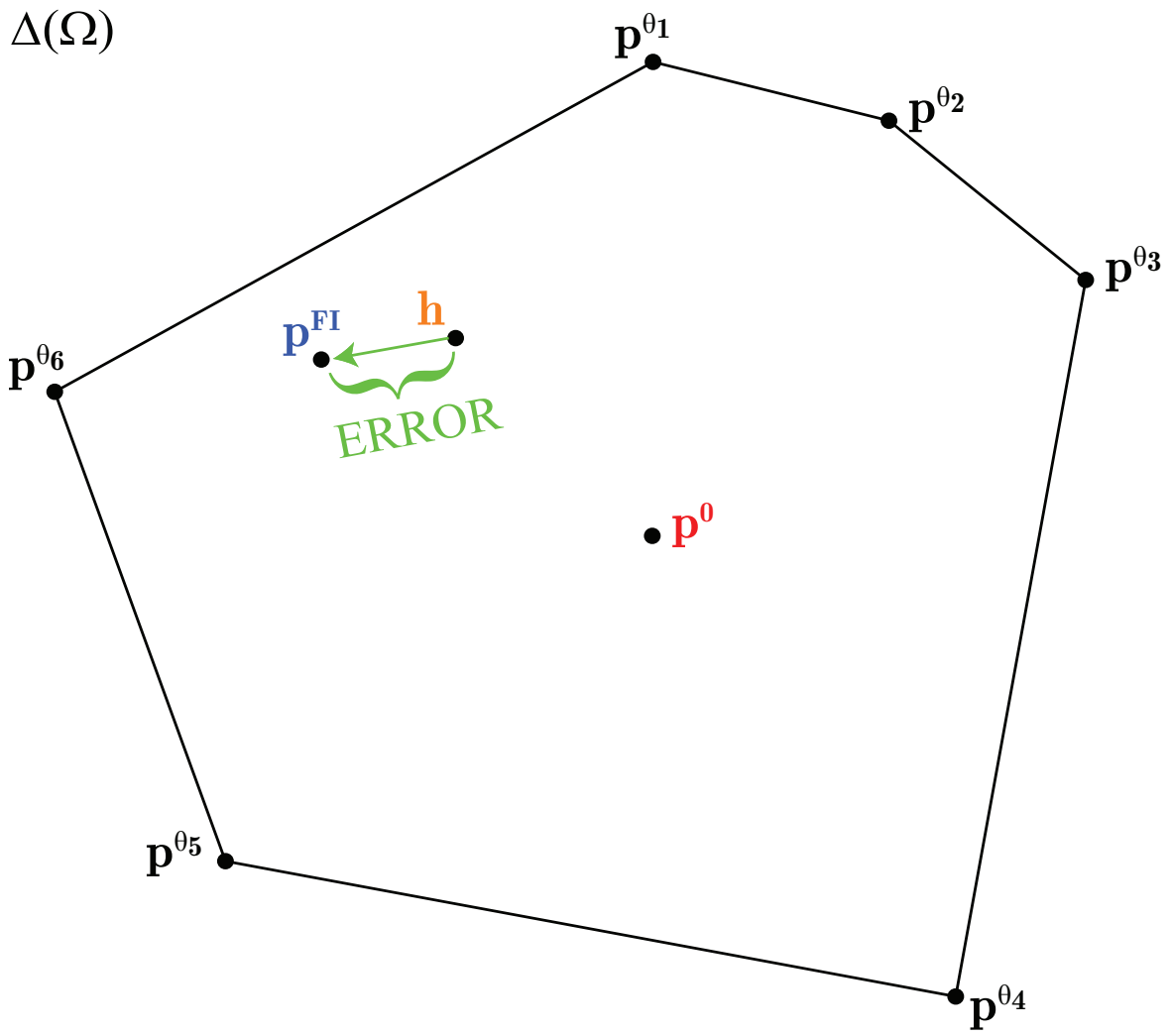


The Mechanisms

1. Double Auction (prediction market)
2. Pari-mutuel (horse track)
3. Iterated Poll ('Delphi method': RAND/USAF)
4. Market Scoring Rule (Hanson 2003)

Alternative Mechanisms: Pari-Mutuel

- Bettors buy tickets on each event
  - $n_j = \#$ of tickets purchased on event j
- Payoff odds of event-j tickets $= \left(n_j / \sum_k n_k\right)^{-1}$

- Still need 2^k securities
- Still have a no-trade theorem

Alternative Mechanisms: Poll

- Players announce a belief distribution P^i over the 8 events
- $\bar{P} = (1/n) \sum_i P^i$ is shown
- Repeat 5 times
- Everone paid based on final average distribution $\bar{P}$
- Incentive compatible scoring rule:
  - Everyone receives $\left(\ln\left[\bar{P}_j\right] - \ln\left[1/8\right]\right)$ event-j securities
  - If event k is true, event-k security pays \$1.

- There exist many seq. equil. with full info aggregation
- There exist babbling seq. equil. with "almost" no aggregation

Alternative Mechanisms: Market Scoring Rule (Hanson)

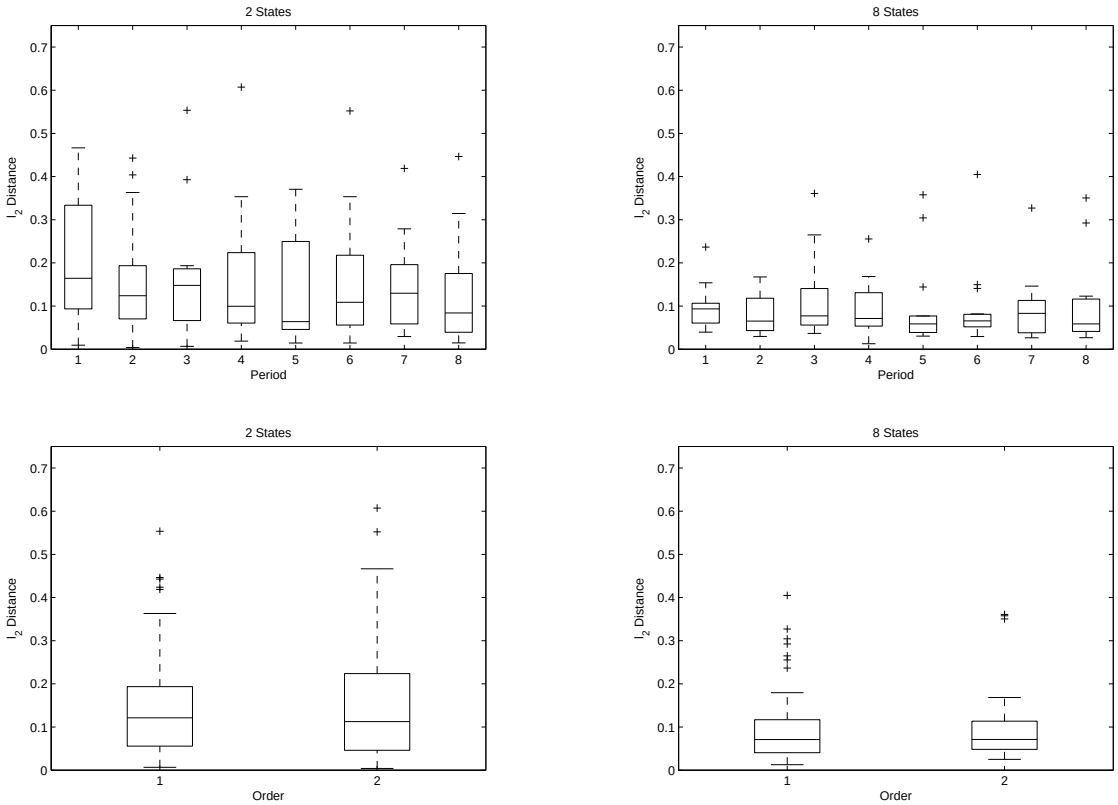
- A public distribution is shown: $(1/8, \ldots, 1/8)$
- Individuals may 'move' the distribution to $\left(P_1^i, \ldots, P_8^i\right)$
- Move from $(Q_1, \ldots, Q_8)$ to $\left(P_1^i, \ldots, P_8^i\right) \implies$
  - Receive $\left(\ln\left[P_j^i\right] - \ln\left[Q_j^i\right]\right)$ event-j securities for each j
  - Moving P_j up means buying, down means selling
  - If event k is true, event-k security pays \$1
  - Incentive compatible: you should move to your best guess

- Subsidized $\implies$ avoids no-trade theorem
- Incentive compatible $\implies$ myopic players reveal truthfully
- Incentive to misrepresent? Depends on move timing...

Methodology

- Run experiments using Caltech undergrads paid $\approx$ \$35
- No experience
- Crossover design: DA-Poll, Poll-DA, MSR-Pari, Pari-MSR
- 3 subjects per group
- 8 periods with each mechanism
- No rematching

Period & Order Effects



No significant period or order effects (good!)

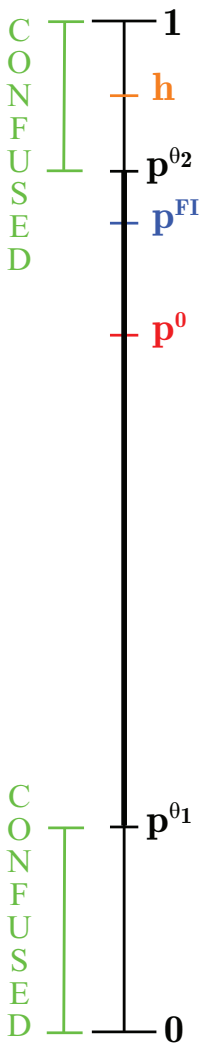
2 States: Error

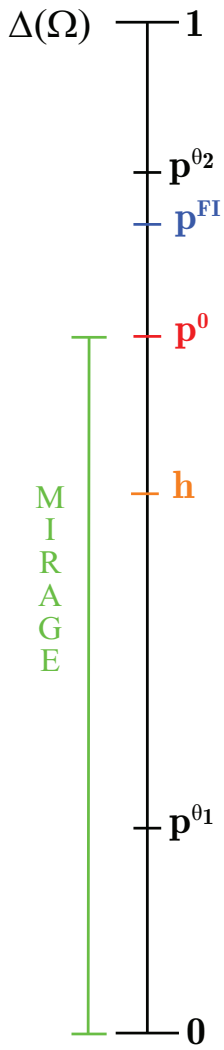
Comparison of l_2 distances with 2 states:

	Avg Dist.	Wilcoxon p-values DblAuctn	MSR	Parimutuel	Poll
Avg Dist.	–	0.262	0.419	0.295	0.266
DblAuctn	0.262	–	**0.092**	0.646	0.663
MSR	0.419	–	–	0.225	**0.098**
Parimutuel	0.295	–	–	–	0.519
Poll	0.266	–	–	–	–

$$\text{MSR} \geq \text{Parimutuel} \geq \text{Poll} \geq \text{DblAuctn}$$
$$\text{MSR} > \text{Poll} \geq \text{DblAuctn}$$

2 States: Confusion & Mirages





2 States: Catastrophes

Periods with catastrophes:

(32 pers. total)	DblAuc	MSR	Pari	Poll
No Trade	0	1	**4**	0
Confusion	5	7	6	**11**
Mirage	13	**14**	10	12
Confused Mirage	0	1	1	**3**
None	**14**	12	13	12

2 States: Summary of Results

	2 States				8 States			
Mech	Err	NoTrd	Mirg	Conf	Err	NoTrd	Mirg	Conf
DblAuc	✓	✓	✓	✓				
MSR	×	✓	×	✓				
Pari	✓	×	✓	✓				
Poll	✓	✓	✓	×				

8 States: Error

Comparison of l_2 distances with 8 states:

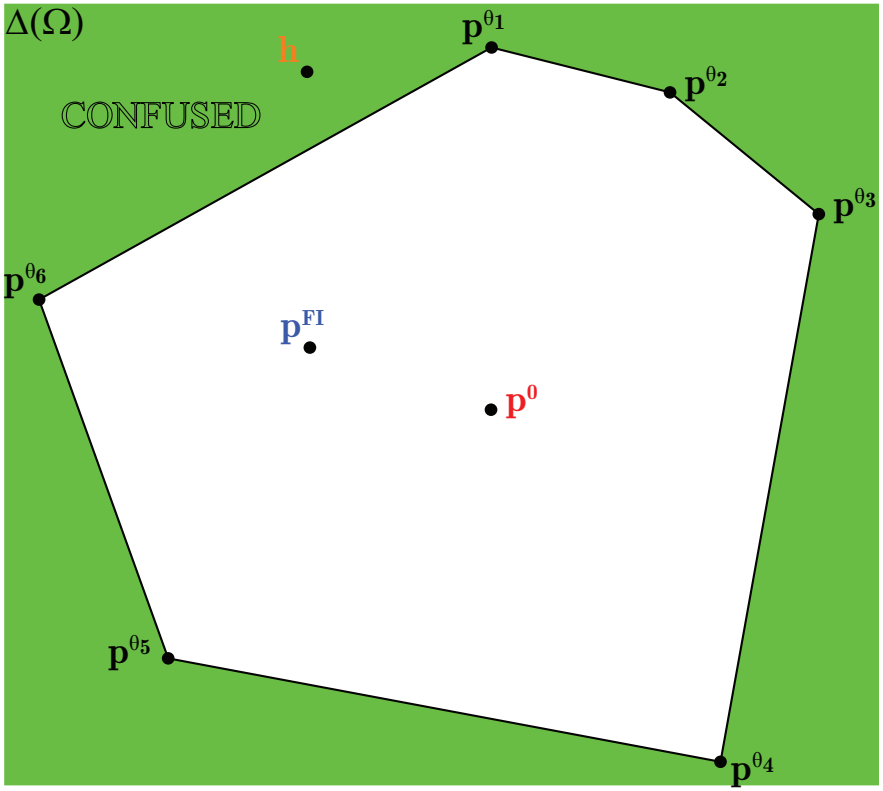
	Avg l_2 Dist.	Wilcoxon p-values			
		DblAuc	MSR	Parimutuel	Poll
Avg l_2 Dist.	–	0.696	0.527	0.605	0.418
DblAuc	0.696	–	**0.002**	**0.093**	$<$ **0.001**
MSR	0.527	–	–	**0.083**	0.324
Parimutuel	0.605	–	–	–	**0.001**
Poll	0.418	–	–	–	–

$$\text{DblAuc} > \text{Parimutuel} > \text{MSR} \geq \text{Poll}$$

8 States: Catastrophes: No Trade

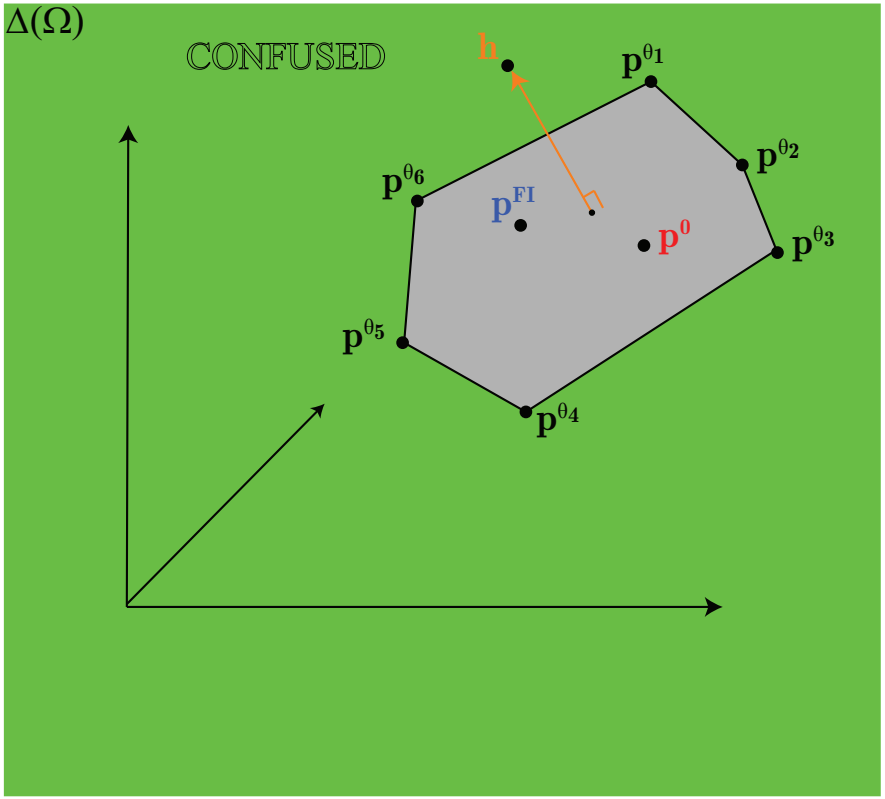
	DblAuc	MSR	Parimutuel	Poll
Periods w/ No Trade	0	0	9/32	0

8 States: Confusion



$$\Pr(TTT|\theta) = 24/75 \;\&\; \Pr(HHH|\theta) = 4/75 \;\forall\theta$$

8 States: Confusion



Confusion occurs in *every* period of *every* mechanism

8 States: Catastrophes: Confusion

l_2 distance to convex hull, conditional on trade occurring:

	Avg Dist.	DblAuc	MSR	Pari.	Poll
Avg. Dist.		0.447	0.362	0.398	0.312
# Trade Pers.		32	32	23	32
DblAuc	0.447	–	**0.001**	0.107	$<$ **0.001**
MSR	0.362		–	0.180	0.257
Pari	0.398			–	**0.008**
Poll	0.312				–

$$\text{DblAuc} \geq \text{Pari} \geq \text{MSR} \geq \text{Poll}$$
$$\text{DblAuc} > \text{MSR} \geq \text{Poll}$$
$$\text{DlbAuc} \geq \text{Pari} > \text{Poll}$$

8 States: Catastrophes: Mirages

Frequency of Mirages:

	Pers. w/ Trade	No. of Mirages	Frequency
DblAuc	32	13	0.406
MSR	32	7	0.219
Pari.	23	7	0.304
Poll	32	3	0.094

$$\text{DblAuc} > \text{MSR} > \text{Poll}$$
$$\text{Pari} > \text{Poll}$$

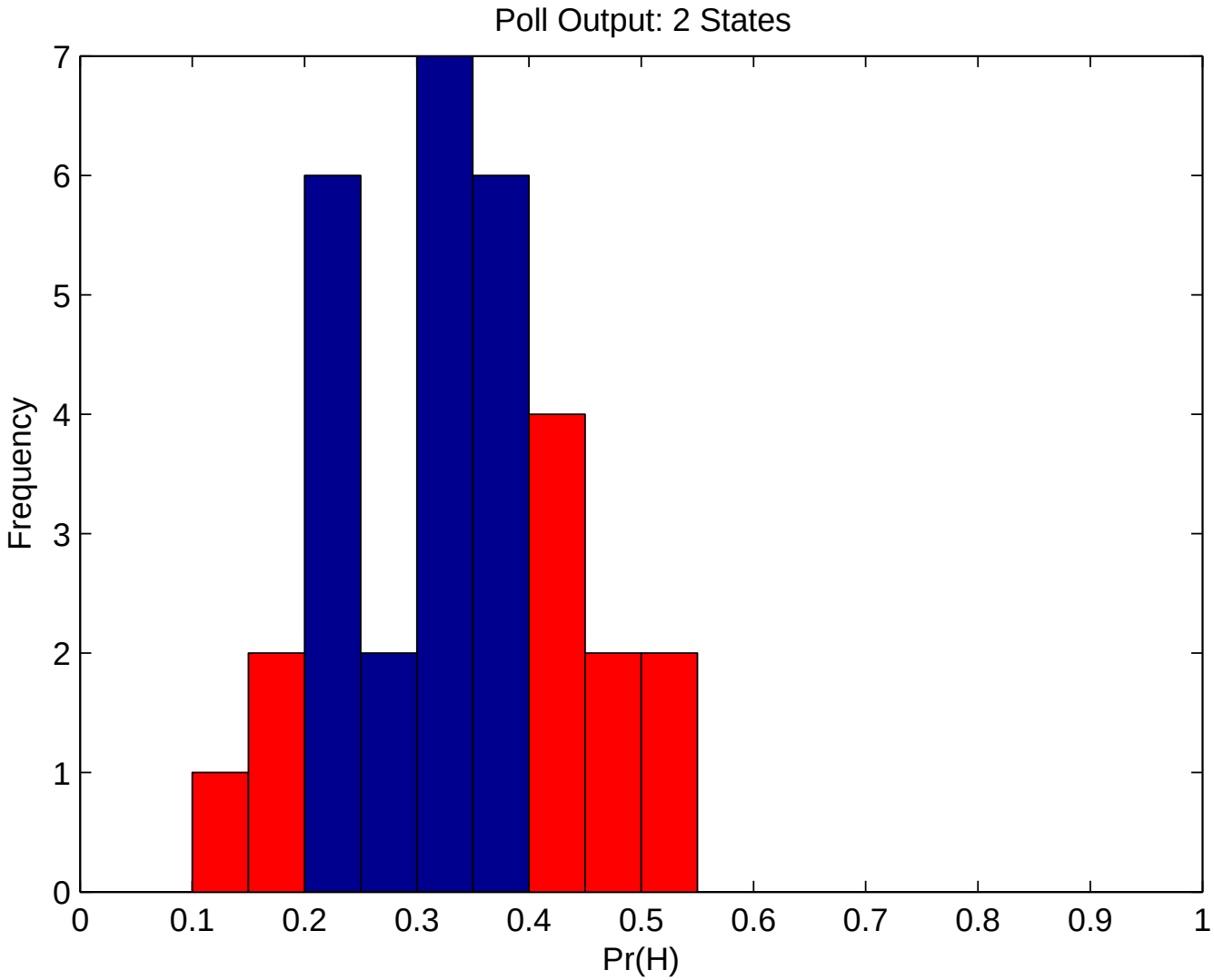
8 States: Summary

	2 States				8 States			
Mech	Err	NoTrd	Mirg	Conf	Err	NoTrd	Mirg	Conf
DblAuc	✓	✓	✓	✓	×	✓	×	×
MSR	×	✓	×	✓	✓	✓	✓	✓
Pari	✓	×	✓	✓	×	×	✓	×
Poll	✓	✓	✓	×	✓	✓	✓	✓

Increased complexity: Double auction fails, MSR & Poll work

Declaring a Winner?

Poll's only failing: confusion in 2-states. How bad is it?



Beating the Prior

Percentage of periods where mechanism outperformed the "informed" prior:

	2 States	8 States
DblAuc	0.375	0.000
MSR	0.355	0.250
Pari	0.393	0.044
Poll	**0.406**	**0.313**

Poll looks good (relatively)...

Observations

- *Why* does the poll out-perform the market?
- **Observation 1:** Preferences are aligned in the poll, so traders have no incentive to misrepresent
- 'Misrepresentor': Move away from full info, then move toward
- Number of misrepresentors per mechanism:

DblAuc	MSR	Pari	Poll
14	5	12	3

Observations

- **Observation 2:** Traders have an incentive to participate in the poll
- No-trade theorem in DblAuc and Parimutuel
- MSR and poll are subsidized
  - 25.9 cents/trader/period in 2-state
  - 35.0 cents/trader/period in 8-state
- Pari-mutuel no trade: 4/32 and 9/32 pers.
- DblAuc: 1 inactive trader in 4/64 periods
- MSR: 1 period of no trade (1st period confusion?)

Observations

- **Observation 3:** Attention is 'spread thin' in the DblAuc

States	Txns/Min.	Vol./Min.
2	5.00	6.48
8	2.60	14.47

- % of txns on 2 most active securities: 46%
- % of txns on 2 least active securities: 8%
- Low-hanging fruit is missed:
  - $p(TTT) = 24/75$ and $p(HHH) = 4/75$ regardless of pvt info
  - Avg $|p(TTT) - 24/75|$ and Avg $|p(HHH) - 4/75|$ are greater than any other mechanism
  - Significantly greater than MSR and Poll

Observations

- **Observation 4:** Poll averages traders' announcements, mitigating effects of a single aberrant trader
- Frequency of worse-than-average final reports & predictions

	2 States		8 States	
Mech	Last Report	Prediction	Last Report	Prediction
DblAuc	11	11	24	24
MSR	18	18	9	9
Pari-mutuel	11	11	9	9
Poll	**28**	**8**	**21**	**8**

Summary

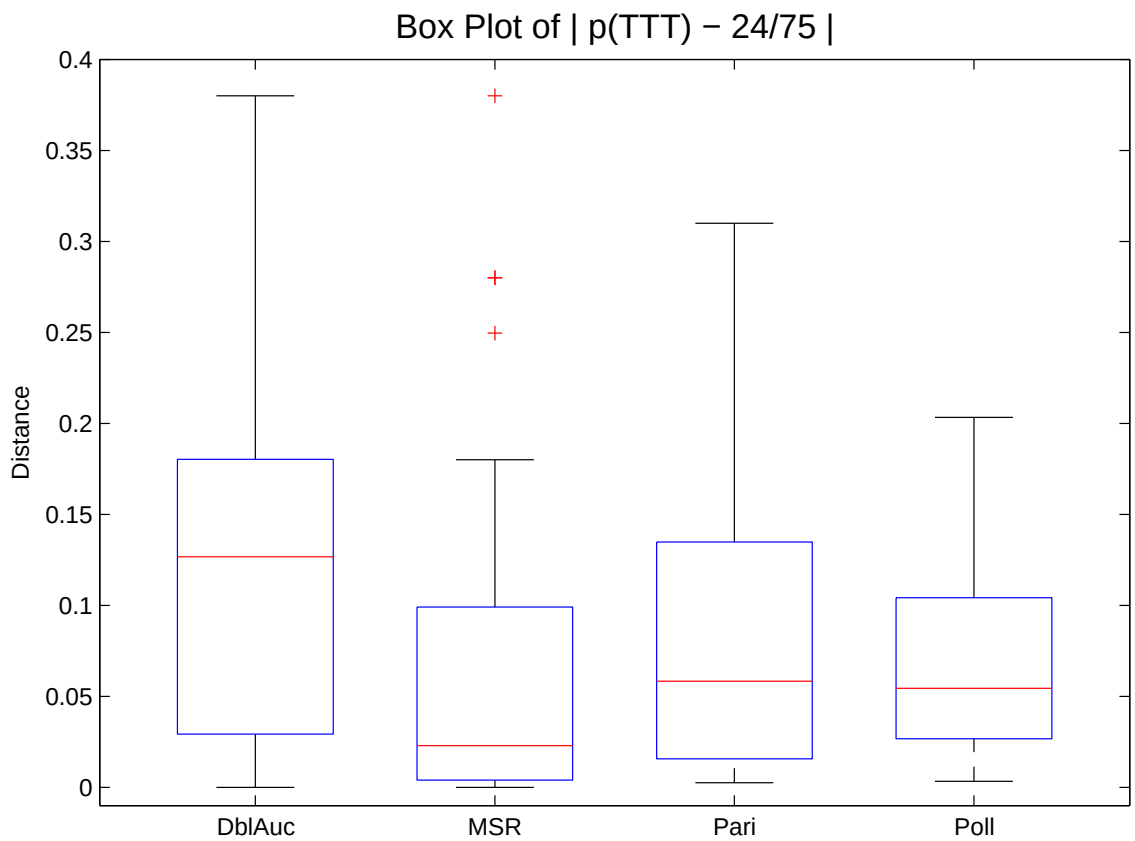
- Double auction works fine with 2 states, not 8
  - Observation: think markets problem (focus on 2 securities)
  - Note: not market power problem
- Pari-mutuel hurt by delay and no trade
- MSR helps 'unfocus' attention, but prone to bad outcomes
  - Single 'bad' player can damage performance
- Poll performs best
  - Aligned incentives, participation incentives, averaging smooths behavior, completely 'unfocused'

The End

The End

p(TTT) and p(HHH)

Recall that $p(TTT) = 24/75$ and $p(HHH) = 4/75$ regardless of signals



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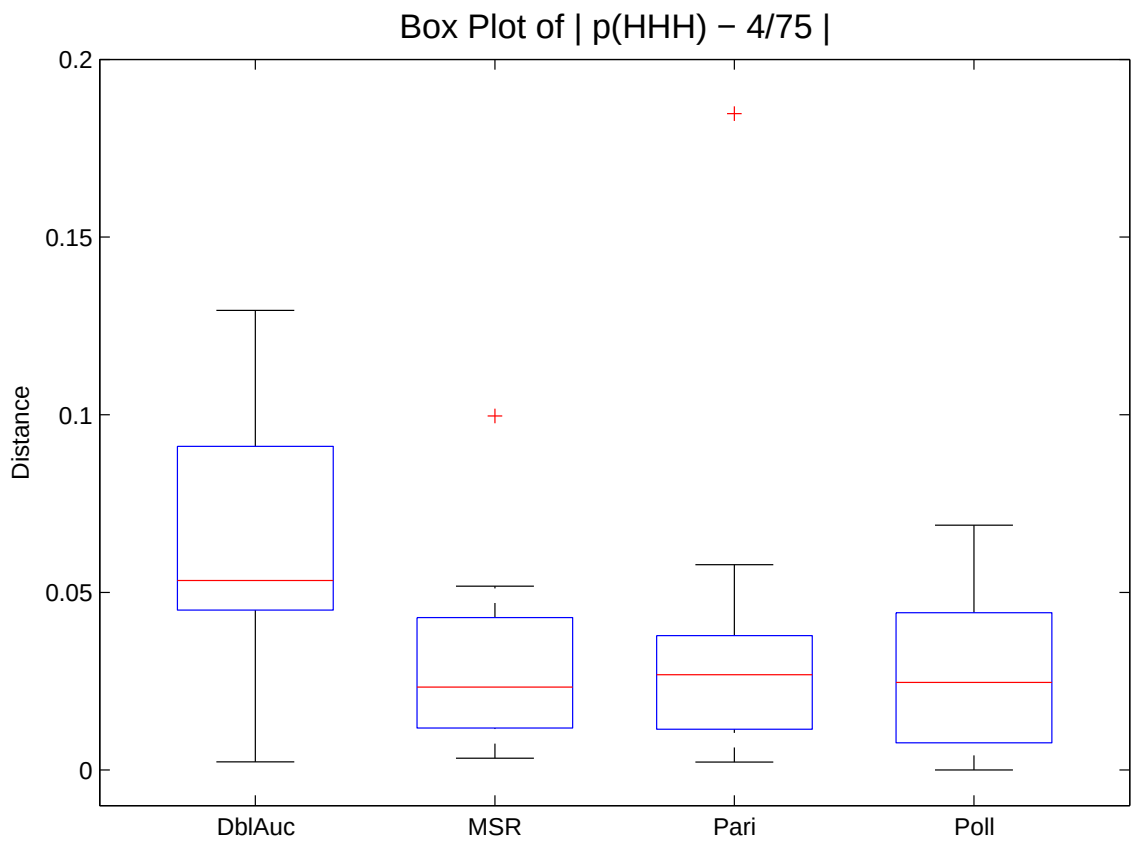

Double Auction: Market Thinness

- 8 states vs. 2 states:

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  - *Fewer* transactions per minute (2.60 vs. 5.00), despite more markets!

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Double Auction: Market Thinness

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  - *Fewer* transactions per minute (2.60 vs. 5.00), despite more markets!
  - *More* total volume per minute (14.47 units vs. 6.48 units)
- Fraction of trades in each market:

Session	TTT	TTH	THT	THH	HTT	HTH	HHT	HHH
1	0.18	0.13	0.15	**0.04**	**0.01**	0.15	0.12	0.23
2	0.25	0.17	0.07	**0.03**	0.15	0.05	0.14	0.12
3	0.34	**0.04**	0.26	0.07	0.14	**0.02**	**0.02**	0.11
4	0.16	0.07	0.23	0.12	0.17	0.09	0.07	0.09
All	0.27	0.11	0.16	0.05	0.14	0.05	0.09	0.12

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4	0.16	0.07	0.23	0.12	0.17	0.09	0.07	0.09
All	0.27	0.11	0.16	0.05	0.14	0.05	0.09	0.12

- 'FOCUS' = standard deviation of these distributions

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Session	TTT	TTH	THT	THH	HTT	HTH	HHT	HHH
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2	0.25	0.17	0.07	**0.03**	0.15	0.05	0.14	0.12
3	0.34	**0.04**	0.26	0.07	0.14	**0.02**	**0.02**	0.11
4	0.16	0.07	0.23	0.12	0.17	0.09	0.07	0.09
All	0.27	0.11	0.16	0.05	0.14	0.05	0.09	0.12

- 'FOCUS' = standard deviation of these distributions
- Focus, # transactions, and trading volume don't predict accuracy well.

MSR: Market Thinness

- Is MSR 'trading' focused on a small number of securities?

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1	0.23	0.12	0.11	0.09	0.17	0.12	0.09	0.07
2	0.36	0.14	0.17	**0.02**	0.14	0.06	**0.02**	0.08
3	0.22	0.16	0.13	0.08	0.10	**0.03**	0.07	0.21
4	0.20	0.13	0.06	0.10	0.16	0.10	0.10	0.16
All	0.24	0.13	0.11	0.08	0.14	0.08	0.08	0.14

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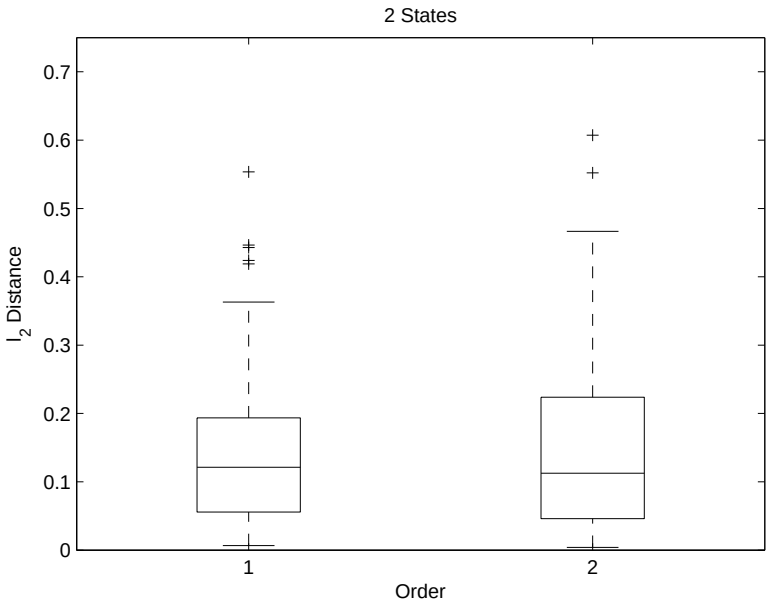
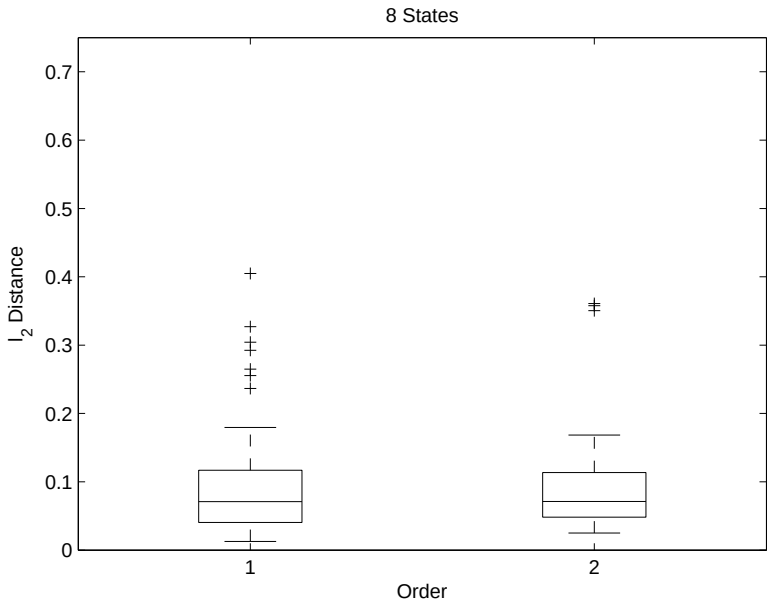
- Step 5: Run the mechanism, which generates $h(\omega)$ over Ω.

Order Effects





- Pairwise Wilcoxon tests: $p = 0.82$ or 0.93
- By mechanism: $p \geq 0.39$ or ≥ 0.07 (Pari. worse)

2 States: Catastrophes: Confusion

Average l_2 distance to convex hull, conditional on confusion:

DblAuc	0.0011
MSR	0.0340
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- Is slight confusion any better than bad confusion??

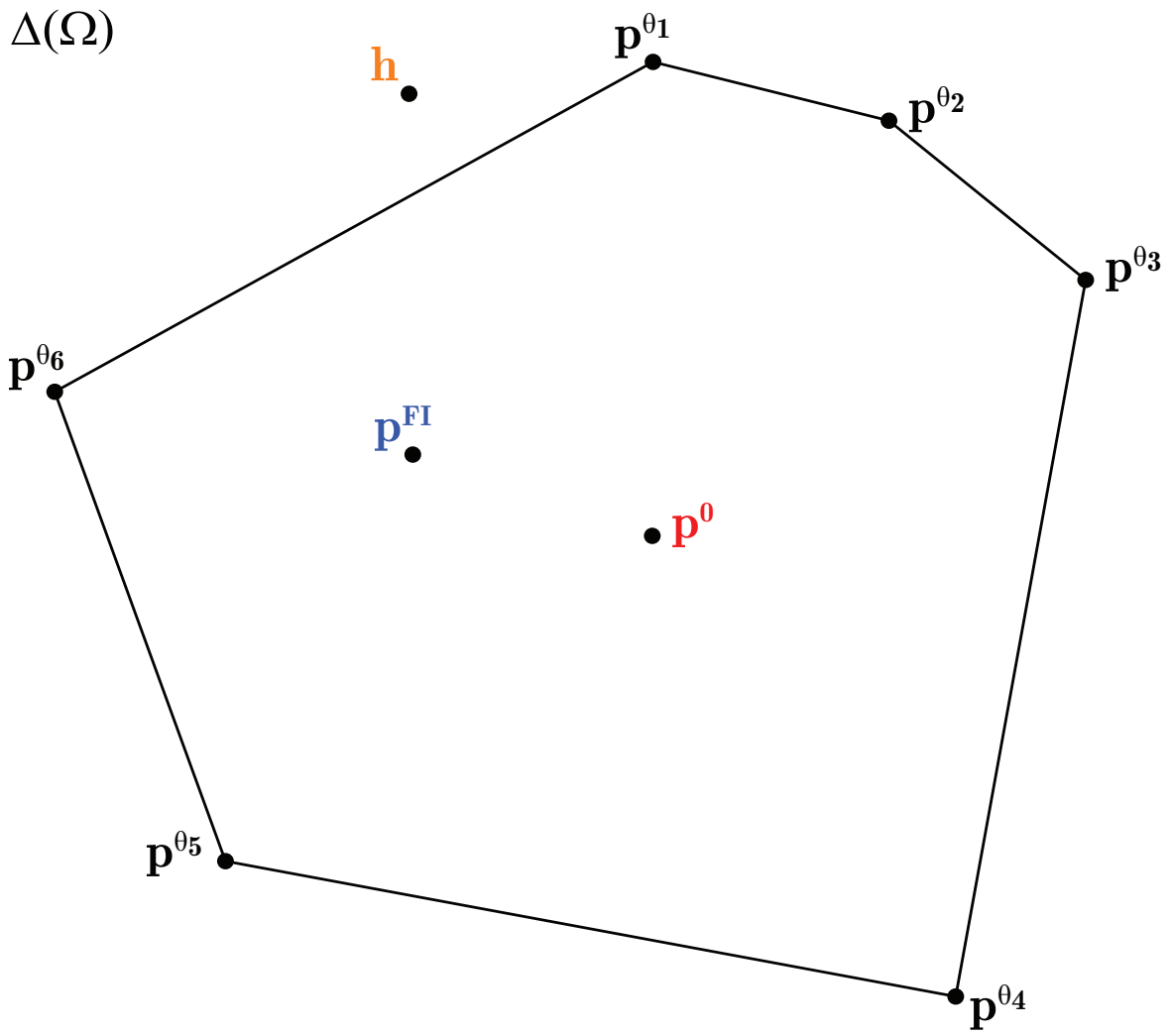
2 States: Mechanism Error Without Confusion

Average mechanism error, conditional on NO confusion:

	No Confusion	All Periods
DblAuc	0.128	0.131
MSR	0.136	0.210
Pari	0.110	0.148
Poll	0.093	0.133

No significant differences in pairwise tests

8 States: Catastrophes: Confusion



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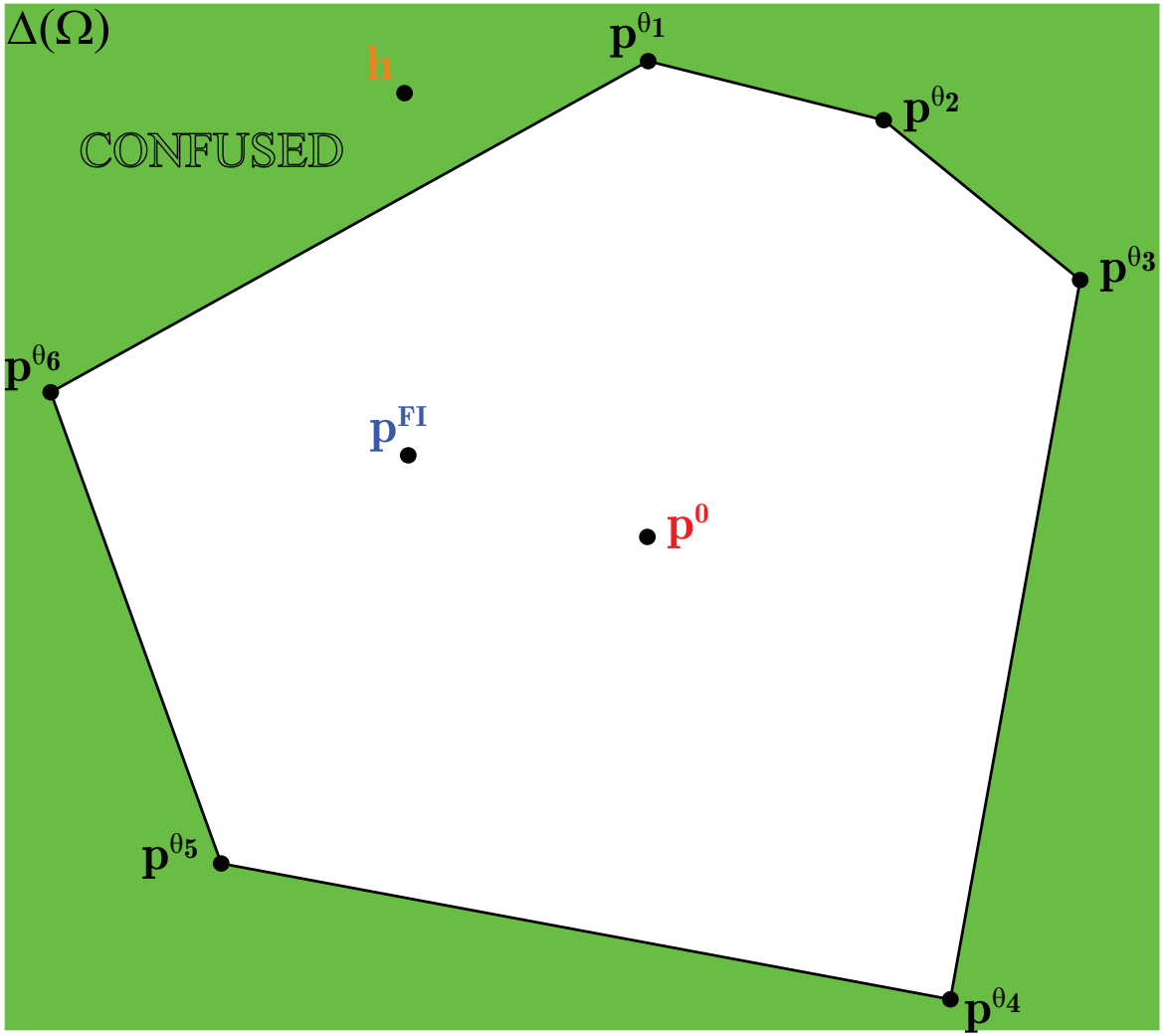

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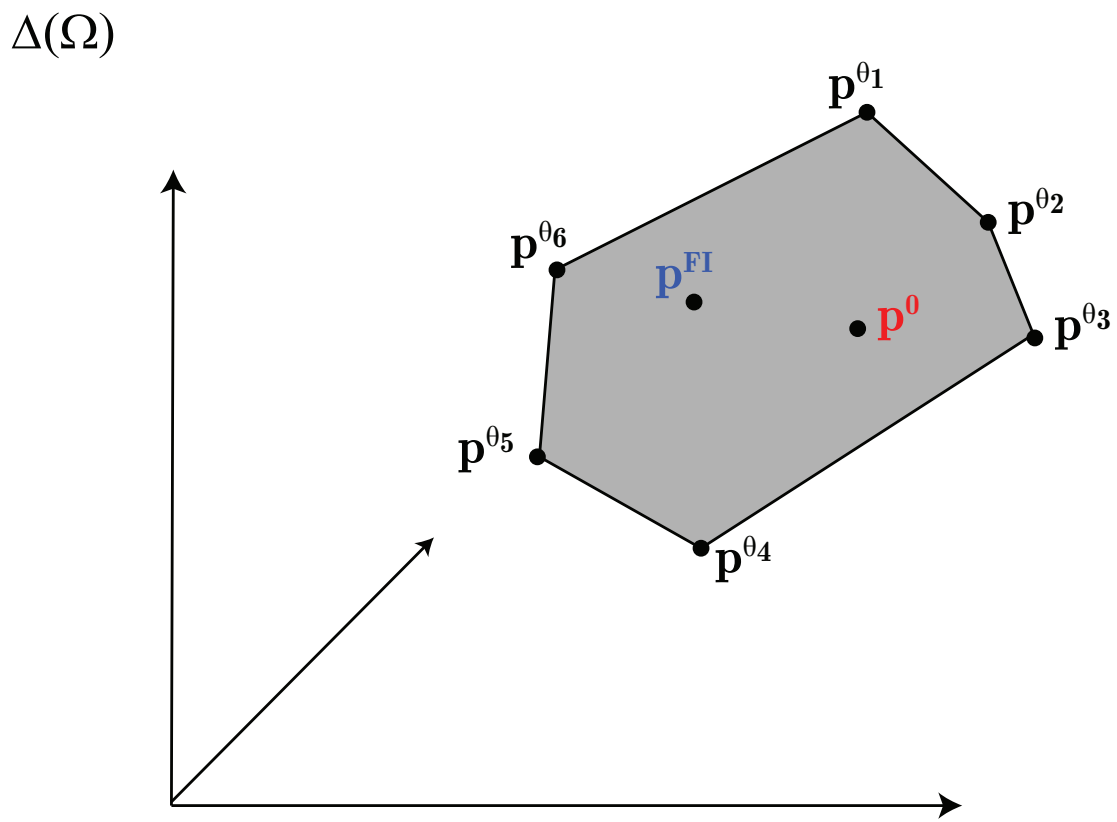

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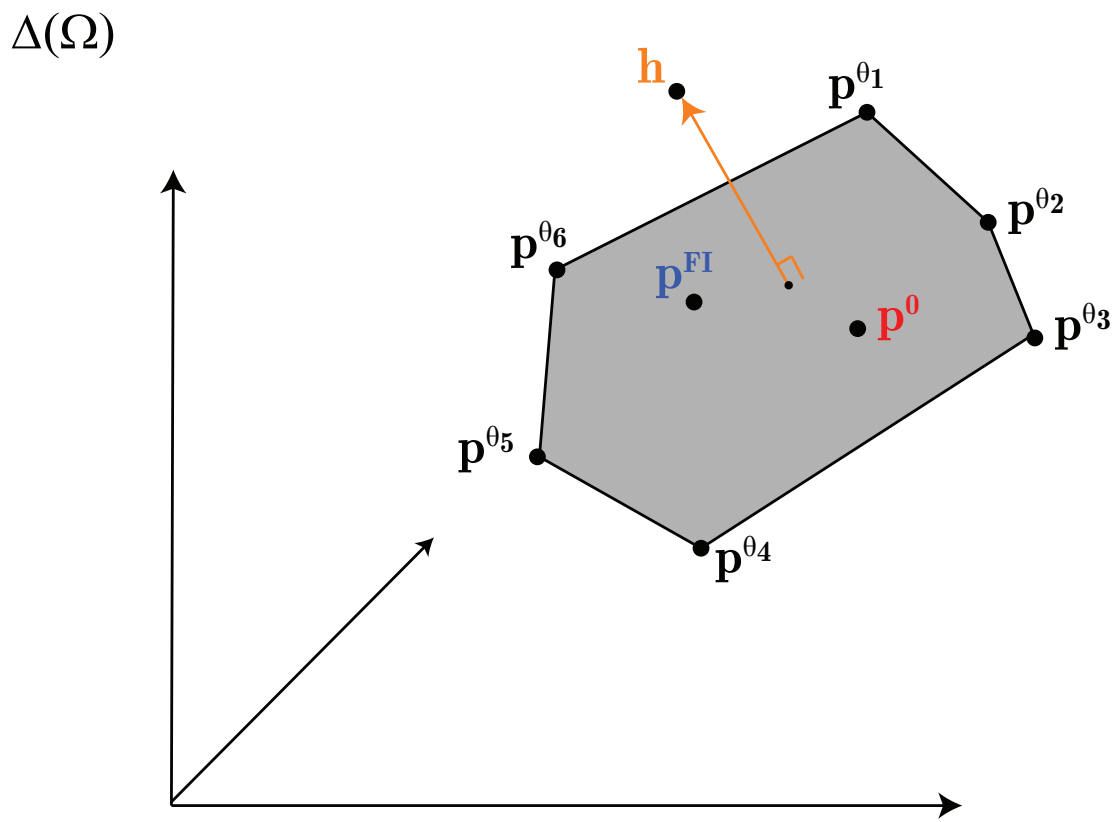

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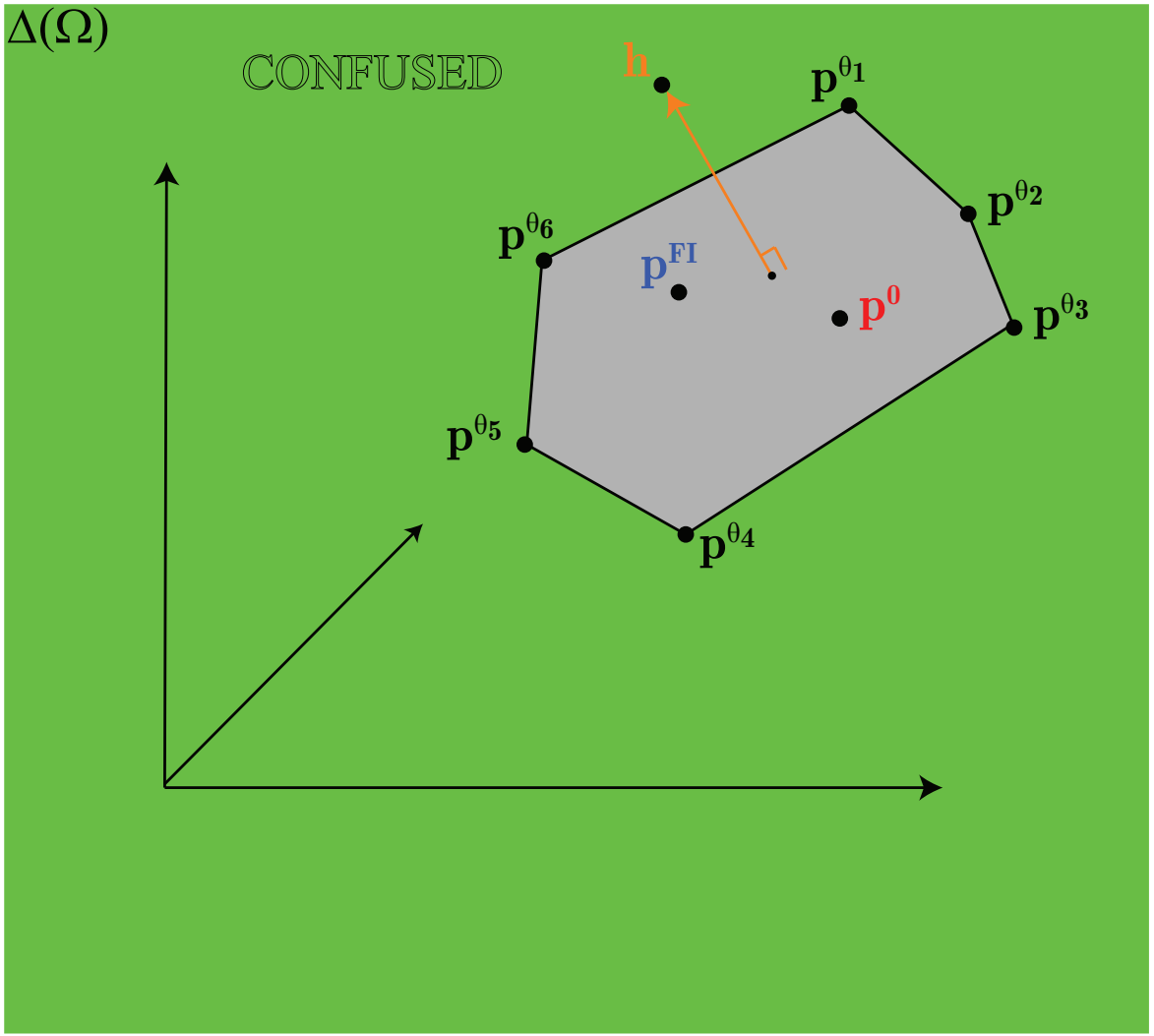

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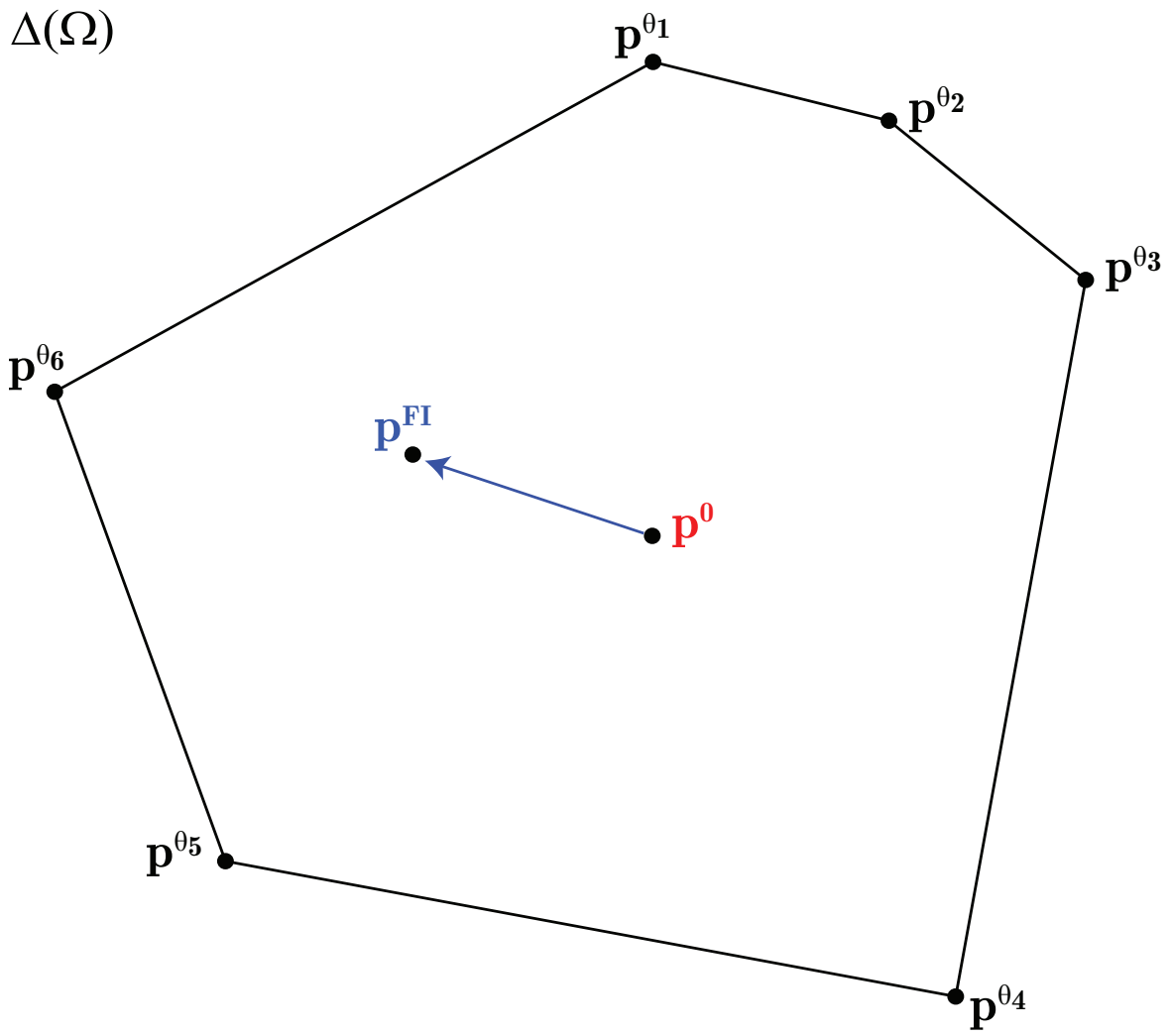

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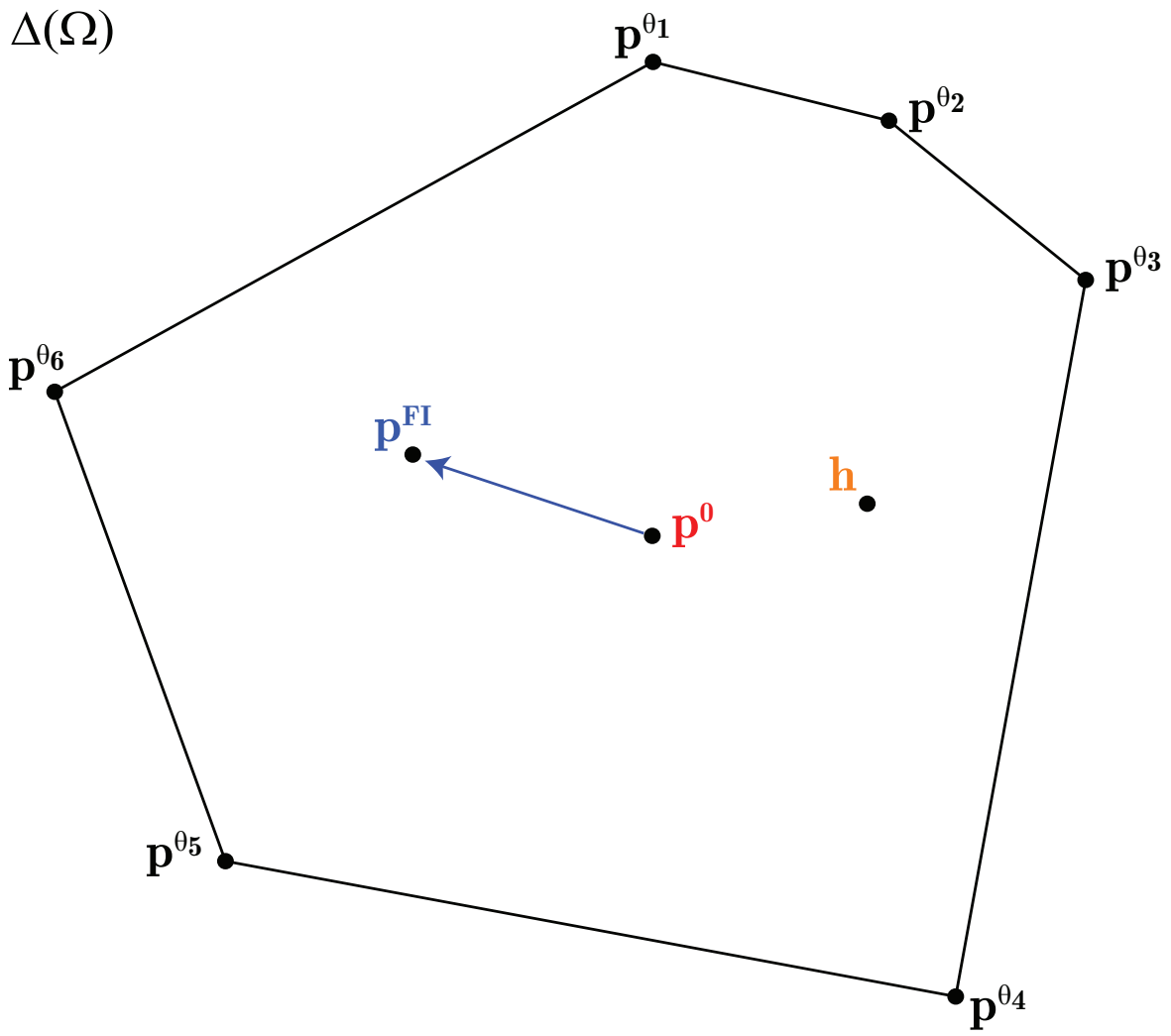

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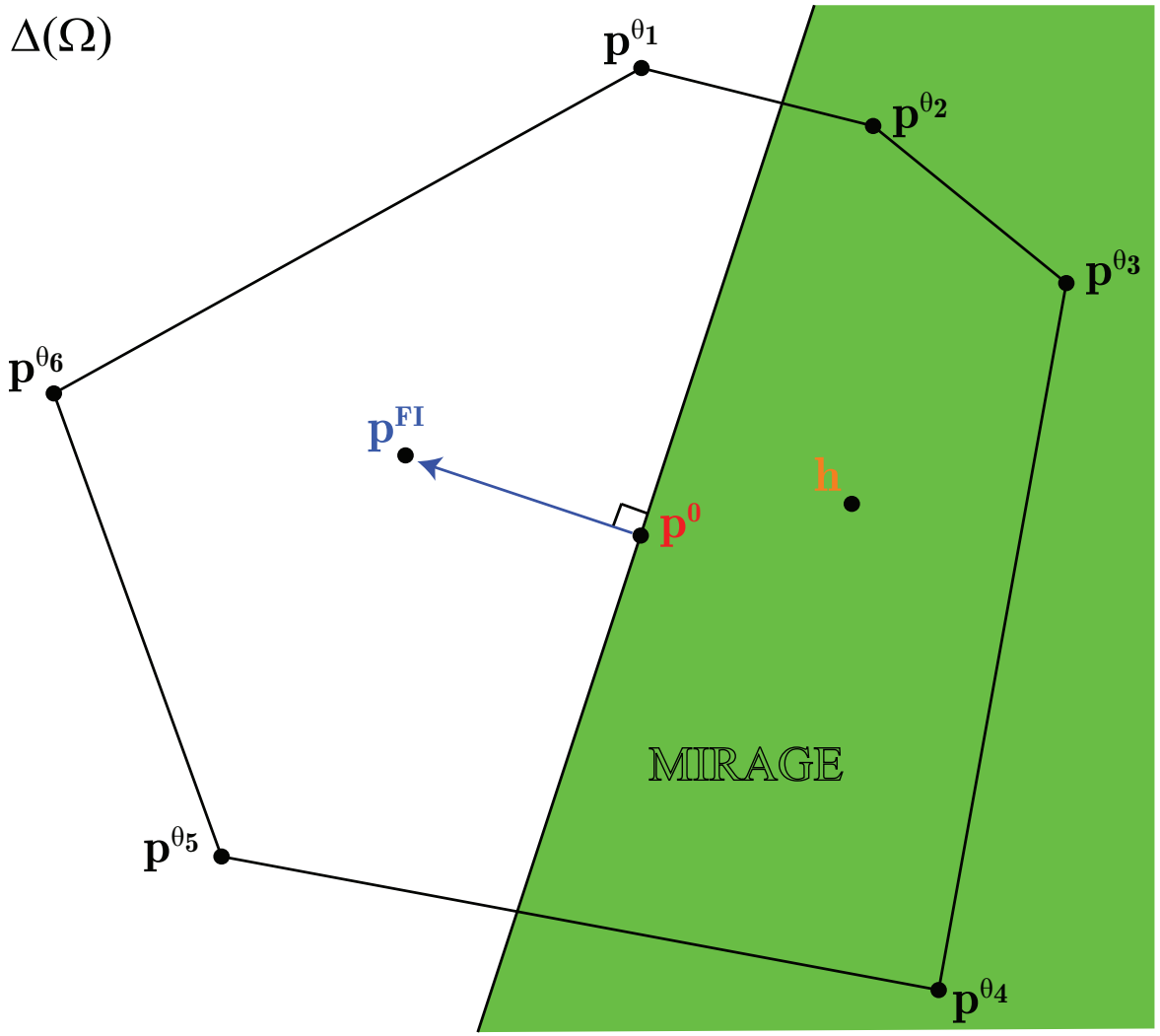

8 States: Catastrophes: Mirages

- An alternative definition:
  - Of the 8 probabilities, 6 should move from p^0
  - How many (out of 6) move the right way?

	Mean	MSR	Pari	Poll
DblAuc	3.03	**0.049**	**0.046**	**0.034**
MSR	3.69		0.798	0.239
Pari	3.70			0.467
Poll	3.97			

Wilcoxon p-values

8 States: Mirages

Wilcoxon test on 'angles' between $\left(h - p^0\right)$ and $\left(p^{FI} - p^0\right)$:

	MSR	Pari	Poll
DblAuc	**0.025**	0.490	0.290
MSR		0.180	0.773
Pari			0.286
Poll			

Wilcoxon test p-values

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- Is # of txns predictive of price accuracy?
  - $ERROR_{t,\omega} = 0.941 - 0.011 \times NUMTXNS_{t,\omega}$, p-value $= 0.367$