Behavioral Mechanism Design

Lecture 2/2

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Outline

Application I:
Designing Stable Mechanisms

Healy (2006)

Mathevet (2008)

Healy & Mathevet

Implementing Lindahl Equilibria

1. Yan Chen's work (1996-2002)
2. Healy (2006)
3. Healy & Mathevet

Previous Experiments

- Chen & Plott 96
  - GL100 ($\gamma = 100$) $>$ GL1 ($\gamma = 1$)
  - High $\gamma \Rightarrow$ better convergence
- Chen & Tang 98
  - GL100 $>$ GL1 $\gamma >$ Walker
  - Claims that supermodularity is sufficient for convergence
- Arifovic & Ledyard 03
  - GL50 $>$ GL100 $>$ GL150
  - GL50 is not supermodular, still converges

The Public Goods Environment

- n agents
- 1 private good x, 1 public good y
- Endowed with private good only (ω_i)
- Preferences: $u_i(x_i,y)=v_i(y)+x_i$
- Linear technology (κ)
- Mechanisms: $m_i \in M_i$

$$y(m) = y(m_1, m_2, \ldots, m_n)$$

$$t_i(m) = t_i(m_1, \ldots m_n)$$

$$x_i = \omega_i - t_i(m)$$

Five Mechanisms

- "Efficient" => $g \circ \mu(e) \in PO(e)$
- Inefficient Mechanisms
    - Voluntary Contribution Mech. (VCM)
    - Proportional Tax Mech.
- (Outcome-) Efficient Mechanisms
  - Dominant Strategy Equilibrium
    - Vickrey, Clarke, Groves (VCG) (1961, 71, 73)
  - Nash Equilibrium
    - Groves-Ledyard (1977)
    - Walker (1981)

VCG Mechanism: Theory

$$M_i = \Theta_i \quad m_i = \hat{\theta}_i = \left(\hat{a}_i, \hat{b}_i\right)$$

$$y(\hat{\theta}) = \arg\max_{y \geq 0} \left[\sum_j v_j \left(y \mid \hat{\theta}_j\right) - \kappa y \right]$$

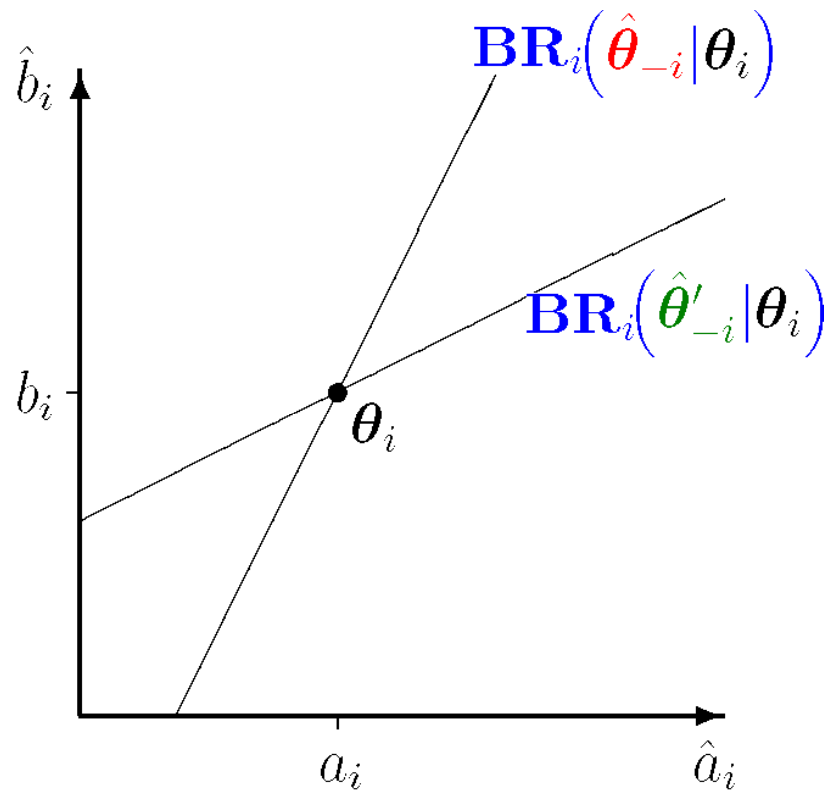
$$t_i(\hat{\theta}) = \frac{\kappa y(\hat{\theta})}{n} - \left(\sum_{j \neq i} v_j \left(y(\hat{\theta}) \mid \hat{\theta}_j\right) - \frac{n-1}{n} \kappa y(\hat{\theta}) \right) + \max_{y \geq 0} \left(\sum_{j \neq i} v_j \left(y \mid \hat{\theta}_j\right) - \frac{n-1}{n} \kappa y \right)$$

- Truth-telling is a dominant strategy
- Pareto optimal public good level
- Not budget balanced
- Not always individually rational

VCG Mechanism: Best Responses

- Truth-telling ($\hat{\theta}_i = \theta_i$) is a *weak* dominant strategy
- There is always a continuum of best responses:

$$BR_i(\hat{\theta}_{-i}) = \left\{ \hat{\theta}_i : y\left(\hat{\theta}_i, \hat{\theta}_{-i}\right) = y\left(\theta_i, \hat{\theta}_{-i}\right) \right\}$$



VCG Mechanism: Previous Experiments

- Attiyeh, Franciosi & Isaac ’00
  - Binary public good: weak dominant strategy
  - Value revelation around 15%, no convergence

- Cason, Saijo, Sjostrom & Yamato ’03
  - Binary public good:
    - 50% revelation
    - Many pairings play dominated Nash equilibria
  - Continuous public good with single-peaked preferences (strict dominant strategy):
    - 81% revelation

VCG Experiment Results

- Demand revelation: 50 – 60%
  – NEVER observe the dominant strategy equilibrium
- 10/20 subjects fully reveal in 9/10 final periods
  – “Fully reveal” = both parameters
- 6/20 subjects fully reveal < 10% of time
- Outcomes very close to Pareto optimal
  – Announcements may be near non-revealing best responses

Summary of Experimental Results

- **VCM:** convergence to dominant strategies
- **Prop Tax:** non-equil., but near best response
- **Groves-Ledyard:** convergence to stable equil.
- **Walker:** no convergence to unstable equilibrium
- **VCG:** low revelation, but high efficiency

Goal: A simple model of behavior to explain/predict which mechanisms converge to equilibrium

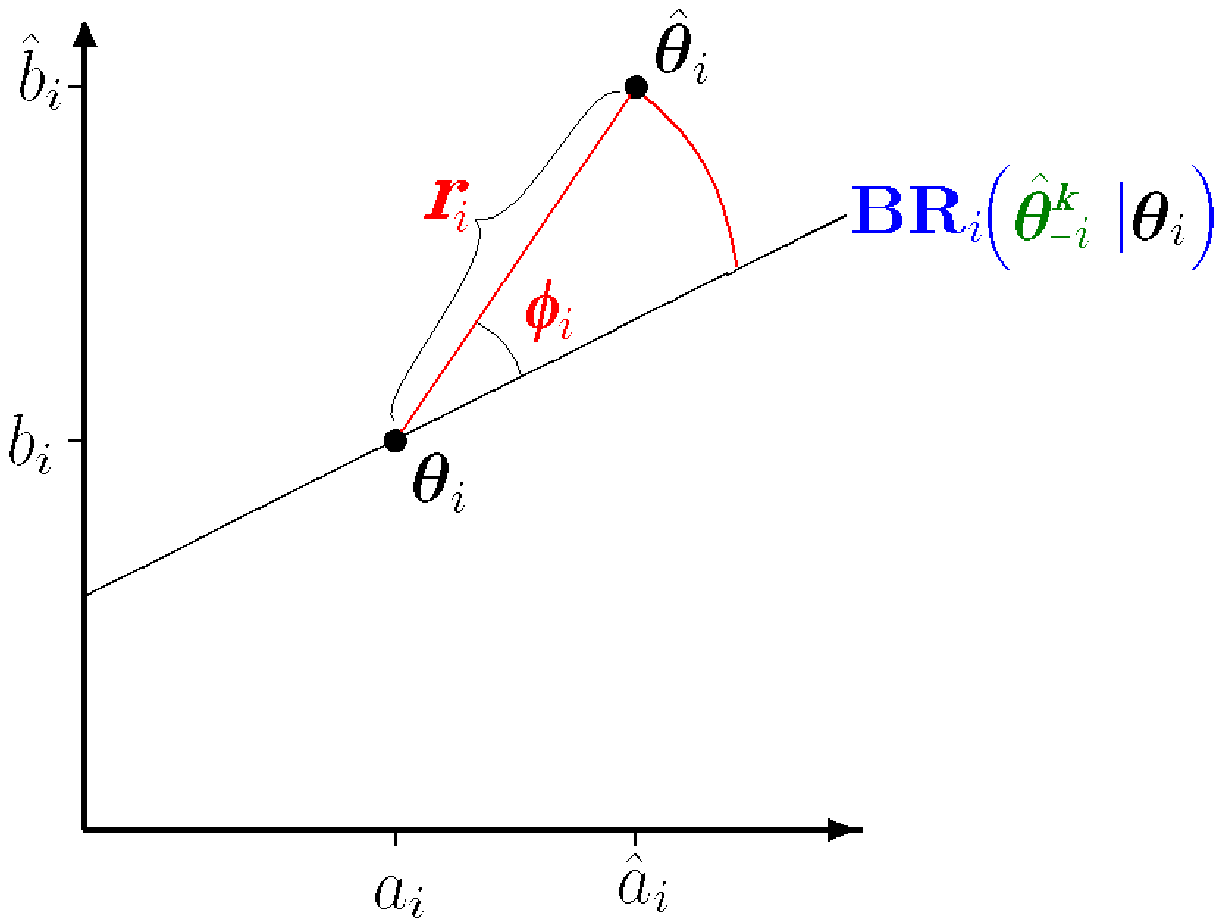
Observation: Results are qualitatively similar to best response predictions

5-period B.R. vs. Nash Equilibrium

- Voluntary Contribution (strict dom. strats): $EQ_i^t \approx BR_i^t$
- Groves-Ledyard (stable Nash equil): $EQ_i^t \approx BR_i^t$
- Walker (unstable Nash equil): 73/81 tests reject H_0
  - No apparent pattern of results across time
- Proportional Tax: 16/19 tests reject H_0
- 5-period model beats *any* static prediction

Best Response in the VCG Mechanism

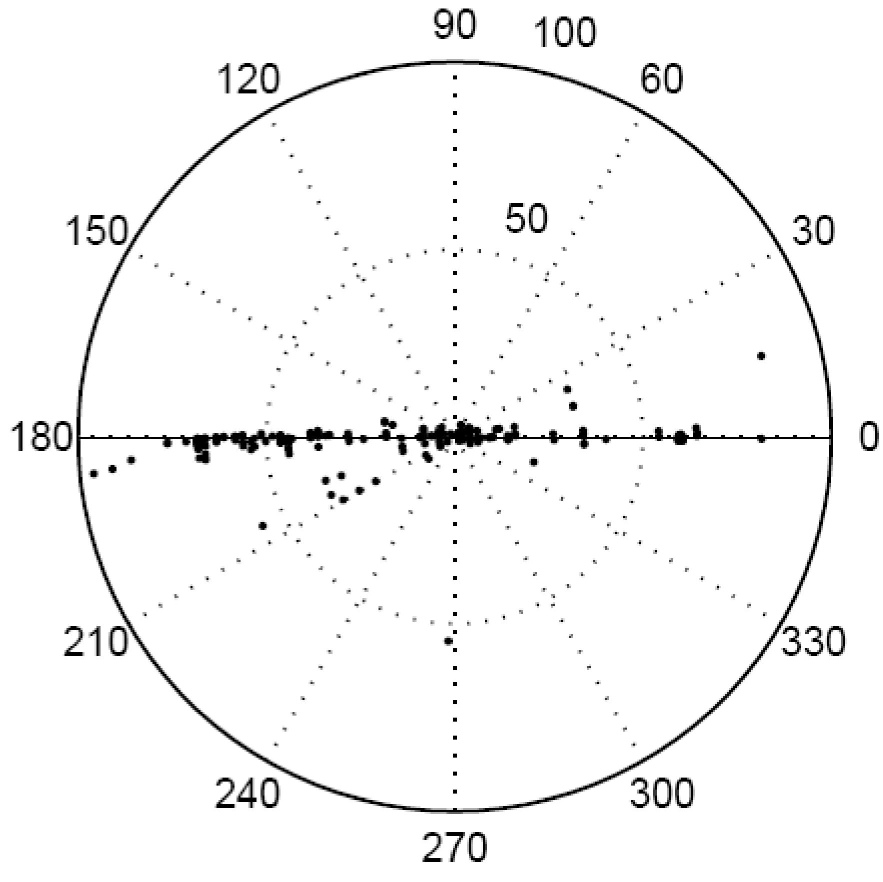
- Convert data to polar coordinates:



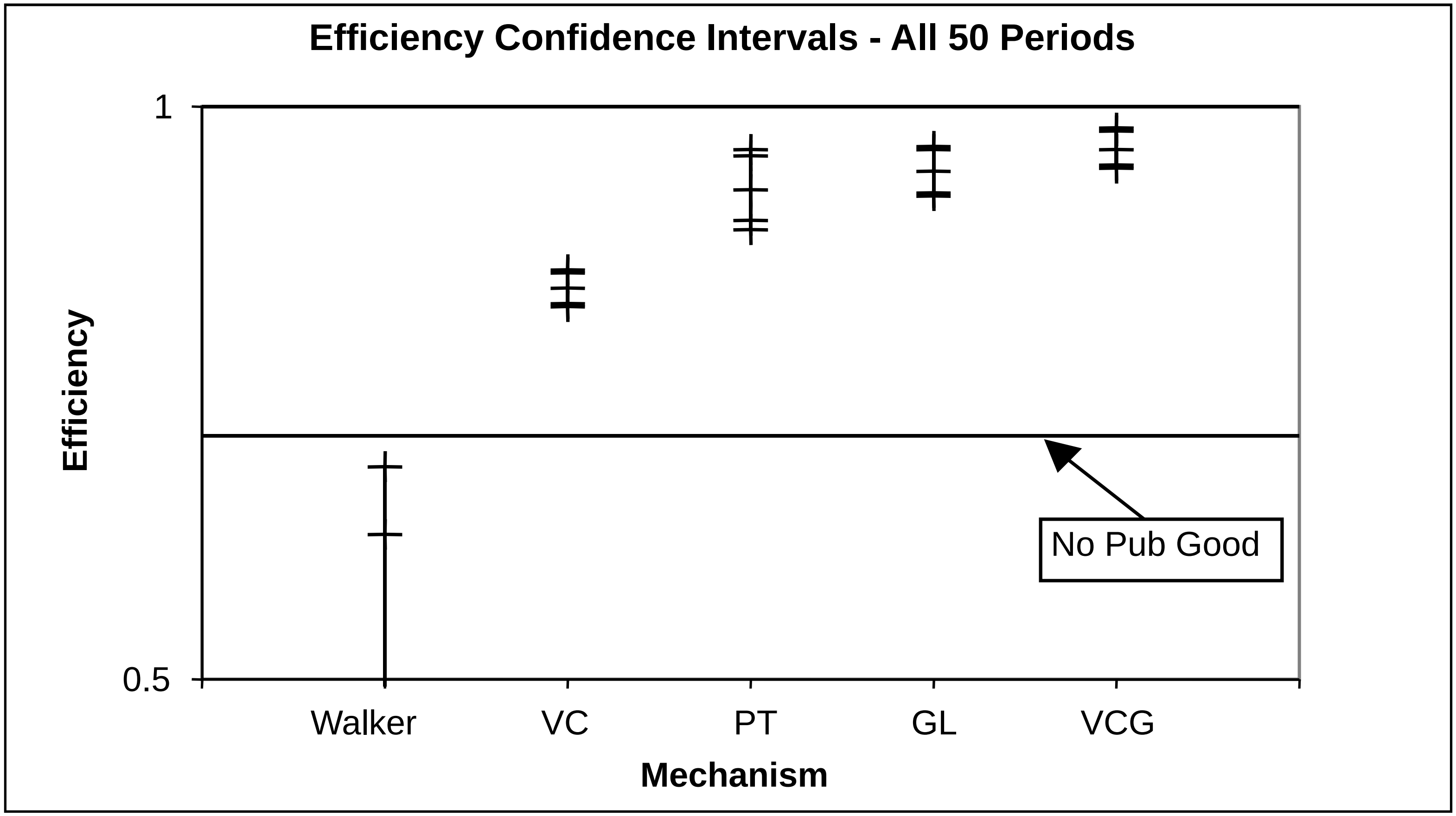
Best Response in the cVCG Mechanism

Origin = Truth-telling dominant strategy

0-degree Line = Best response to 5-period average



Efficiency



Efficiency Confidence Intervals - All 50 Periods
1
0.5
Efficiency
No Pub Good
Walker
VC
PT
GL
VCG
Mechanism

Conclusions

- Importance of **dynamics** & **stability**
  - Dynamic models outperform static models
- Strict vs. weak dominant strategies
- Applications for “real world” implementation
- Directions for theoretical work:
  - Developing stable mechanisms
- Open experimental questions:
  - Efficiency/equilibrium tension in VCG
  - Effect of the “What-If Scenario Analyzer”
- *Better* learning models

Mathevet 2008

- Take any Bayesian mechanism
- Add ‘penalty term’ to make the game supermodular
- Penalty terms wash out (like d’AGV’s mechanism)
- This trick doesn’t work in general complete info settings

Healy & Mathevet

- Known mechanisms for public goods are eerily similar...
  Theorem 1: Green-Laffont-type characterization
- Experimental results say 'stability (supermodularity?) matters'
  Theorem 2: With one-dimensional strategy space, can't guarantee supermodularity
  Theorem 3: Show how to get stability by adding 2^{nd} dim.

Mechanisms

Real-message mechanisms:

- Strategy space: $\mathcal{M}_i = \mathbb{R}^k \ \forall i$
- Outcome function: $(y(m), t_1(m), \ldots, t_n(m))$

Trivial Observation:

Every mechanism's tax functions can be written as

$$t_i(m) = \underbrace{q_i(m_{-i})}_{\text{'Price'}} y(m) + \underbrace{g_i(m)}_{\text{'Penalty'}} .$$

Note: 'Price-taking' assumption

Existing Mechanisms

- Groves-Ledyard 1977
- Hurwicz 1979
- Walker 1981
- Kim 1993
- Chen 2002
- Others...

Eerie Similarities

Conjecture

For any continuous mechanism implementing Lindahl allocations...

1. if $\mathcal{M}_i = \mathbb{R}^1$ then $g_i \equiv 0$, and
2. if $\mathcal{M}_i = \mathbb{R}^k$ for $k > 1$ then let $\mathcal{M}_i = \mathcal{S}_i \times \mathcal{Z}_i$ s.t. $y(m) \equiv y(s)$, then $g_i(m^*) \equiv 0$ whenever m^* is in equilibrium.

Interpretation: $t_i(m) = q_i(m_{-i})y(m) + \cancel{g_i(m)}$

1. Agents solve Lindahl's program (as price takers) given z^*
2. Additional dimensions can be used to provide desirable off-equilibrium properties

Proving The Conjecture: Assumptions

A1: Rich Domain

$$\{-\alpha y^2 + \beta y + x_i : \alpha \in \mathbb{R}_+, \beta \in \mathbb{R}\} \subseteq \{u_i(\cdot|\theta_i) : \theta_i \in \Theta_i\}$$

$$(\{-\alpha\,|y - \beta| + x_i : \alpha \in \mathbb{R}_+, \beta \in \mathbb{R}\} \subseteq \{u_i(\cdot|\theta_i) : \theta_i \in \Theta_i\}).$$

A2: Differentiable Mechanisms

$y(m)$, $t_i(m)$ are all twice continuously differentiable and $\partial y(m)/\partial m_i$ is bounded away from zero $\forall i$.

Proving The Conjecture: Non-NE

Consider the 1-dimensional case:

- If m is a NE for some environment $\phi(m) \in \Theta$ then we can derive restrictions from $t_i(m) = p_i(\phi_i(m))y(m)\forall m$.
- No restrictions on $t_i(m)$ for m that are never NE

Lemma

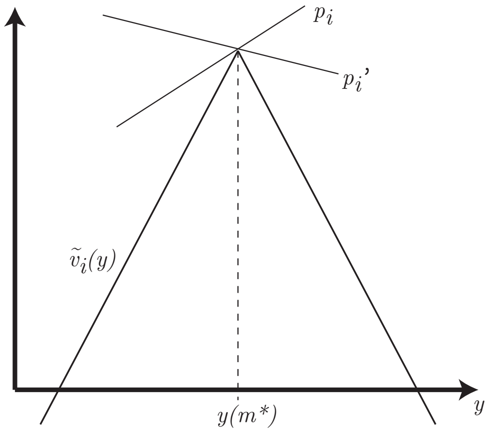
With a rich domain, m^* is a Nash equilibrium for <u>some</u> environment if $\forall i, m\ \exists \gamma_i$ s.t. $\forall m_i'$

$$\left| t_i(m^*) - t_i(m_i', m_{-i}^*) \right| \leq \gamma_i \left| y(m^*) - y(m_i', m_{-i}^*) \right| . \qquad (1)$$

A3: All $m \in \mathcal{M}$ are NE

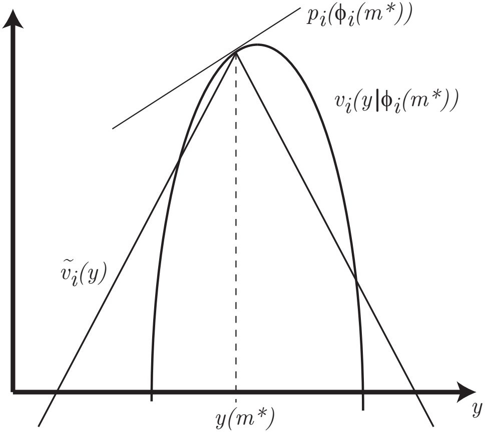
$$(\mathcal{M}, (y(m), t(m))) \text{ satisfies condition 1 a.e.}$$

Proving the Conjecture: Multiple Prices



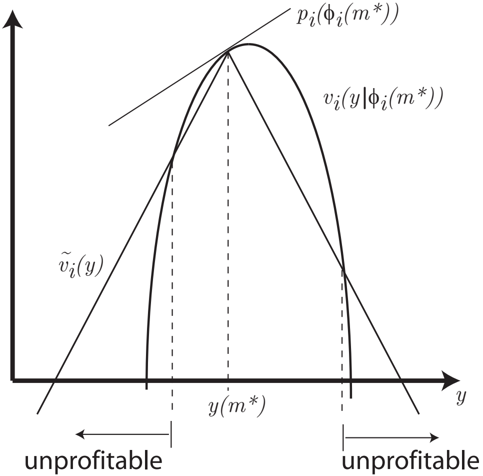
Non-unique Lindahl price ⇒ no useful restrictions on transfers.

Proving the Conjecture: Quadratic Prefs



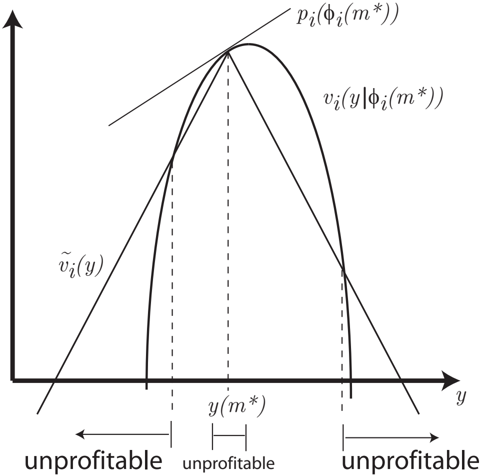
Choose parameters to satisfy FOC, local SOC at $y(m^*)$.

Proving the Conjecture: Check Deviations



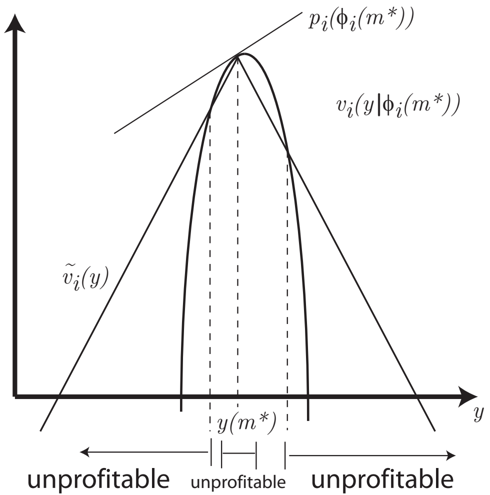
Large changes in y are not profitable.

Proving the Conjecture: Check Deviations



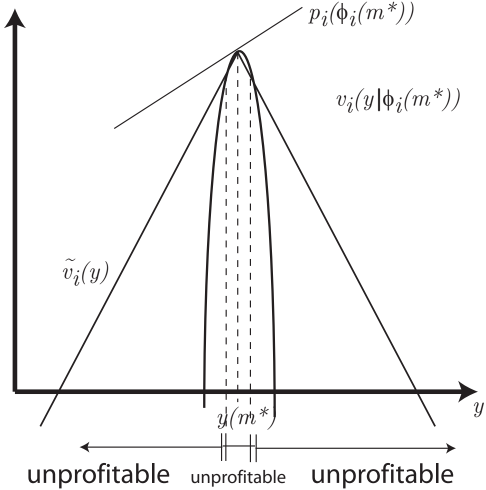
Tiny changes in y are not profitable.

Proving the Conjecture: ↑ Concavity



Increase concavity of v_i, keep FOC & local SOC.

Proving the Conjecture: No Deviations



Eventually all deviations are unprofitable; m^* is a NE.

Proving the Conjecture: Restriction #1

All m are NE and all NE give Lindahl allocations $\Rightarrow$

$$t_i(m) = q_i(m_{-i})y(m) + g_i(m) = p_i(\phi(m))y(m),$$

so

$$g_i(m) = [p_i(\phi(m)) - q_i(m_{-i})]y(m).$$

Differentiating gives

$$\begin{aligned} \frac{\partial g_i(m)}{\partial m_i} &= \frac{\partial[p_i(\phi(m)) - q_i(m_{-i})]}{\partial m_i} y(m) \\ &\quad + [p_i(\phi(m)) - q_i(m_{-i})]\frac{\partial y(m)}{\partial m_i} \end{aligned} \qquad (2)$$

Proving the Conjecture: Restriction #2

All m are NE implies FOC w.r.t. m_i holds at all m:

$$\begin{aligned}\frac{\partial v_i(y(m)|\phi_i(m))}{\partial y}\frac{y(m)}{\partial m_i} &= \frac{\partial t_i(m)}{\partial m_i} \\ &= q_i(m_{-i})\frac{\partial y(m)}{\partial m_i} + \frac{\partial g_i(m)}{\partial m_i}.\end{aligned}$$

Lindahl pricing implies $\partial v_i / \partial y = p_i$, so

$$p_i(\phi(m))\frac{y(m)}{\partial m_i} = q_i(m_{-i})\frac{\partial y(m)}{\partial m_i} + \frac{\partial g_i(m)}{\partial m_i}$$

or

$$\frac{\partial g_i(m)}{\partial m_i} = [p_i(\phi(m)) - q_i(m_{-i})]\frac{\partial y(m)}{\partial m_i} \tag{3}$$

Proving the Conjecture: Conclusion

We have

$$\frac{\partial g_i(m)}{\partial m_i} = \frac{\partial[p_i(\phi(m)) - q_i(m_{-i})]}{\partial m_i} y(m) + [p_i(\phi(m)) - q_i(m_{-i})] \frac{\partial y(m)}{\partial m_i}$$

$$\frac{\partial g_i(m)}{\partial m_i} = [p_i(\phi(m)) - q_i(m_{-i})] \frac{\partial y(m)}{\partial m_i}.$$

Thus, $p_i(\phi(m))$ doesn't depend on m_i.

$$g_i(m) = \underbrace{[p_i(\phi(m)) - q_i(m_{-i})]}_{h_i(m_{-i})} y(m)$$

$$\begin{aligned} t_i(m) &= q_i(m_{-i}) y(m) + h_i(m_{-i}) y(m) \\ &= \tilde{q}_i(m_{-i}) y(m) \\ &= p_i(\phi(m)) y(m) \end{aligned}$$

Theorem 1

Theorem

Assume all quasilinear-quadratic preferences are admissible. If a mechanism $(\mathbb{R}^n, (y, t))$ Nash implements the Lindahl allocations and on some open set $\mathcal{M}^* \subseteq \mathcal{M}$ the mechanism is twice continuously differentiable, has $\partial y / \partial m_i$ bounded away from zero, and satisfies the relative Lipschitz condition, then the transfers must be of the form

$$t_i(m) = q_i(m_{-i}) y(m)$$

for all $m \in \mathcal{M}^*$.

- See Brock 1980 (and G-L 1987)
- Sufficiency

Two Dimensions

Let $m_i = (s_i, z_i)$ but $y(m) = y(s)$.

- $\tilde{z}_i(s_i, m_{-i})$: transfer-minimizing z_i ($\exists$?)
- Not all m may be NE - only characterize on NE set
- Relative Lipschitz condition:

$$\begin{aligned}|t_i(s_i, \tilde{z}_i(s_i, m_{-i}), m_{-i}) - t_i(s_i', \tilde{z}_i(s_i', m_{-i}, m_{-i})| \\ \leq \gamma_i |y(s) - y(s_i', s_{-i})|\end{aligned}$$

- In FOC: $\frac{\partial g_i}{\partial z_i}\frac{\partial \tilde{z}_i}{\partial s_i} = 0$, so same proof
- Thus, $g_i = 0$ in equilibrium

Walrasian Equilibria

- Proof is nearly identical
- Characterization result extends

Supermodular Games: Definition

A game $\mathcal{G} = (N, \{(S_i \times Z_i)\}, u)$ with twice-differentiable u_i is supermodular if for all i,

- Each u_i is supermodular in m_i:

$$\frac{\partial^2 u_i}{\partial s_i \partial z_i} \geq 0$$

- Each u_i has increasing differences in (m_i, m_{-i}): $\forall j$

$$\frac{\partial^2 u_i}{\partial s_i \partial s_j} \geq 0 \qquad \frac{\partial^2 u_i}{\partial s_i \partial z_j} \geq 0$$
$$\frac{\partial^2 u_i}{\partial z_i \partial s_j} \geq 0 \qquad \frac{\partial^2 u_i}{\partial z_i \partial z_j} \geq 0$$

- u_i is upper-semicontinuous in m_i and continuous in m_{-i}.
- Each $S_i \times Z_i$ is compact

Supermodular Implementation: Definition

- Definition: The mechanism Γ supermodularly Nash implements the Lindahl allocations if for all θ,

  1. Equilibrium outcomes $=$ Lindahl allocations
  2. The game induced by Γ is supermodular for all θ.

- If there exists such a Γ then the Lindahl (social choice) correspondence is said to be (Nash) supermodular implementable.

Theorem 2

- Definition: The outcome function y is symmetric if $y(m_i, m_j, m_{-ij}) = y(m_j, m_i, m_{-ij})$ for all m, i, j.

Theorem

Under the above assumptions, there can be no one-dimensional mechanism with a symmetric outcome function that supermodularly implements the Lindahl correspondence.

- Explains why existing supermodular mechanisms are not one-dimensional: Ex. Chen 2003 and Kim 1996.

Theorem 3

- Impossibility result points to more dimensions.

A4: Q-L with bounded concavity

$u_i(x_i, y|\theta_i) = v_i(y|\theta_i) + x_i$ and $\partial^2 v_i / \partial y^2$ is negative & bounded.

Theorem

Under Assumptions 1–4, any one-dimensional mechanism $\Gamma = (M, (y, t))$ that implements Lindahl allocations can be converted into a supermodular two-dimensional mechanism that implements Lindahl allocations.

Intuition for the Result

- Add a function $g_i(s, z)$ to the transfers
    - $t_i^{SM} = t_i(m) + \rho_i g_i(z_i, m)$

  such that
    - g_i does not alter the m component of NE
    - $g_i = 0$ at any equilibrium (same tax)
    - Cross-partials of g_i are bounded above zero, ρ_i ramps up cross-partials
- Exactly how Chen's 2002 mechanism is constructed
- Similar in spirit to Mathevet 2007: Add complementarities that vanish in equilibrium.

Summary

- Experimental results suggest stability matters
- Characterization theorem answers an open question
- For Lindahl implementation, supermodularity can be added
- Requires slightly larger strategy space
- Ultimate goal: practical mechanism design

Application II:
Prediction Markets

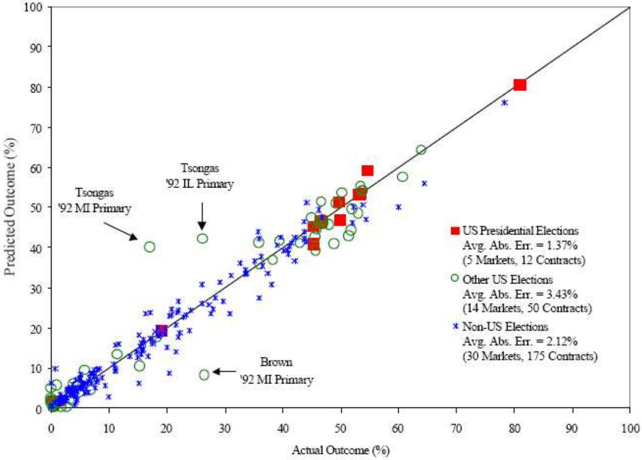
"Prediction Market Alternatives for Complex Environments"

Healy, Ledyard, Linardi & Lowery (2008)

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



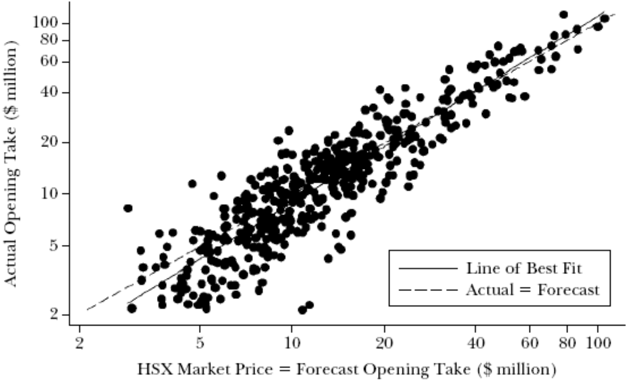
Avg. Error: 1.5% vs. 2.1%. Source: Berg,Forsythe, Nelson & Rietz (2003)

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 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 Rays beat Red Sox?
   - Two states: {Rays,Red Sox}, one security
2. **Hard:** Who will win each of the last 3 series (2 pennants and World Series)?
   - Three events, not independent
   - Eight states: {Rays,Red Sox}$\times${Phillies,Dodgers}$\times${AL,NL}
   - "AL Champion 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

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 $\left(\ln\left[\bar{P}_j\right] - \ln[1/8]\right)$ 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)

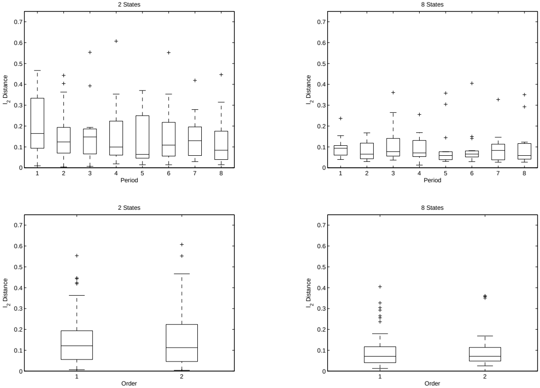
- A public distribution is shown: $(1/8, \ldots, 1/8)$
- Individuals may 'move' the distribution to $\left(P_1^i, \ldots, P_8^i\right)$
- Move from $(Q_1, \ldots, Q_8)$ to $\left(P_1^i, \ldots, P_8^i\right) \implies$
  - Receive $\left(\ln\left[P_j^i\right] - \ln\left[Q_j^i\right]\right)$ event-j securities 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	–	–	–	–

MSR $\geq$ Parimutuel $\geq$ Poll $\geq$ DblAuctn
MSR $>$ Poll $\geq$ DblAuctn

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

Mech	2 States Err	NoTrd	Mirg	Conf	8 States 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	–	–	–	–

DblAuc $>$ Parimutuel $>$ MSR $\geq$ Poll

8 States: Catastrophes: No Trade

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

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				–

DblAuc $\geq$ Pari $\geq$ MSR $\geq$ Poll
DblAuc $>$ MSR $\geq$ Poll
DlbAuc $\geq$ Pari $>$ 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

DblAuc > MSR > Poll
Pari > Poll

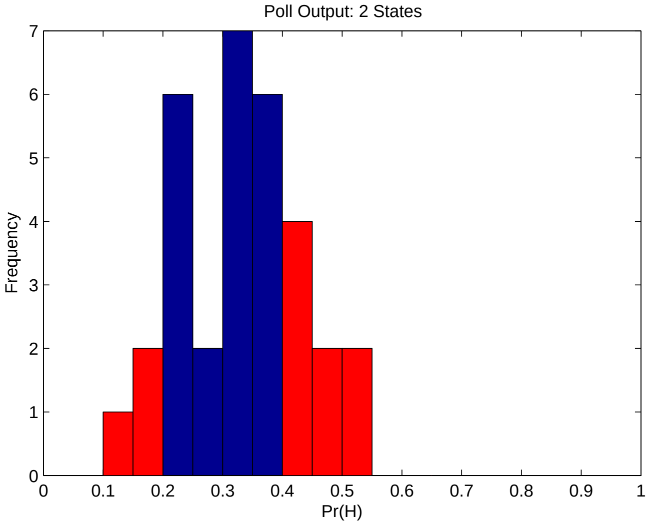
8 States: Summary

	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

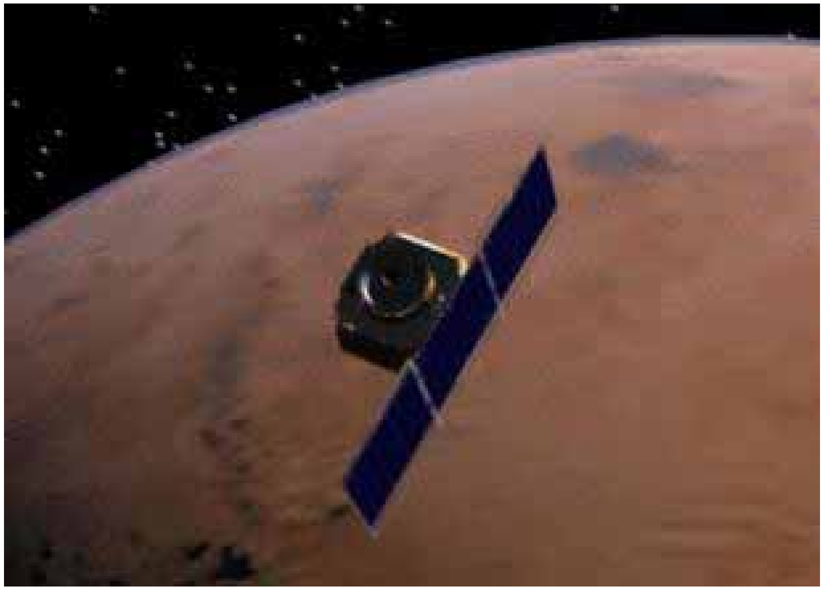
	2 States		8 States	
Mech	Last Report	Prediction	Last Report	Prediction
DblAuc	11	11	24	24
MSR	18	18	9	9
Pari-mutuel	11	11	9	9
Poll	**28**	**8**	**21**	**8**

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’

Application III:
Optimal Contracting within NASA

Healy, Ledyard, Noussair,
Thronson, Ulrich & Varsi



Mars Climate Orbiter

- Launched: 12/11/98
- Lost: 9/23/99 (orbit entry)
- English-to-Metric problem

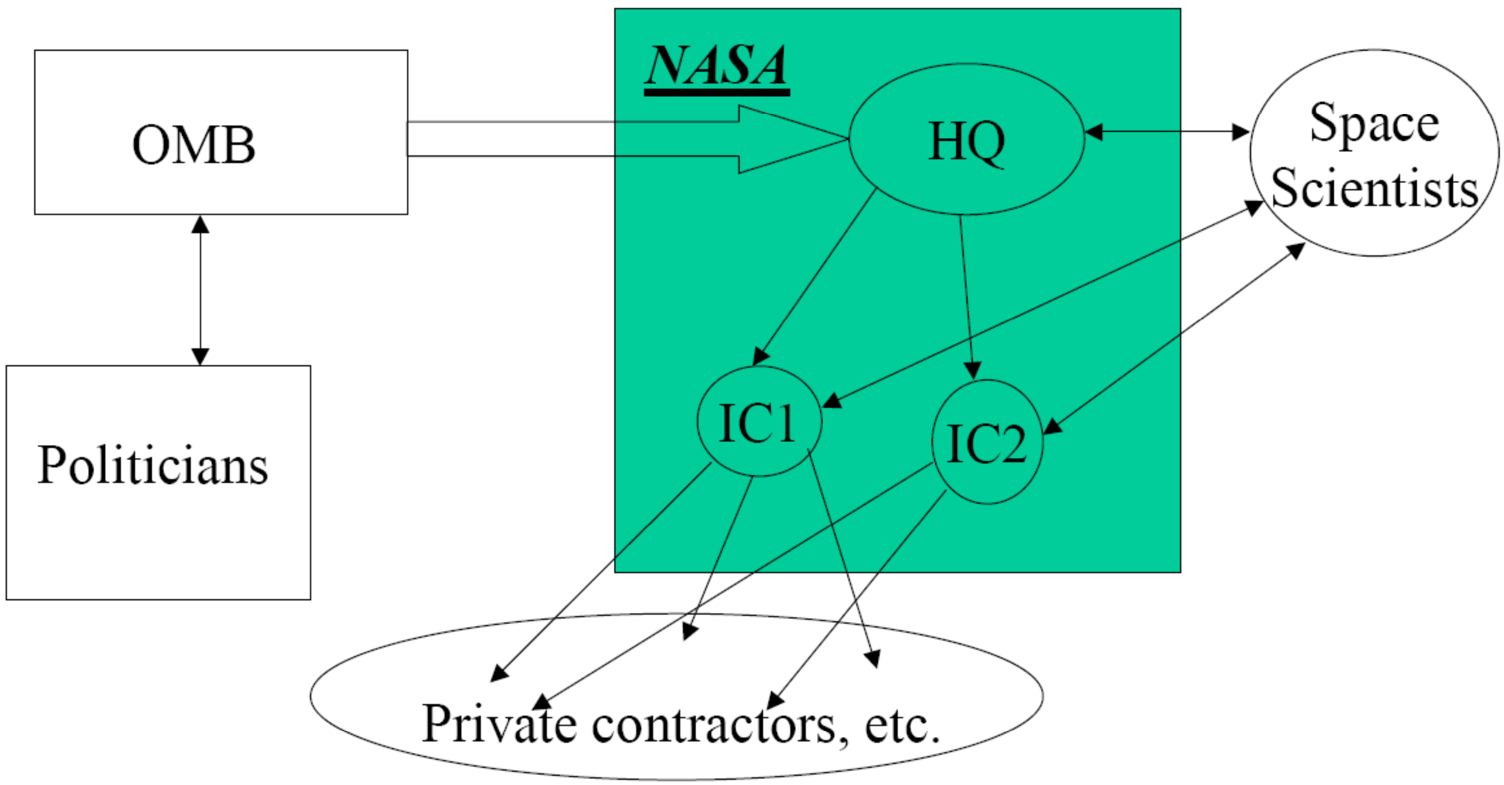
Mars Polar Lander

- Launched: 1/3/99
- Lost: 12/3/99 (landing)
- Landing software glitch?

Total Cost: $327 Million

Deeper issue: Cost overruns

NASA Mission Acquisition



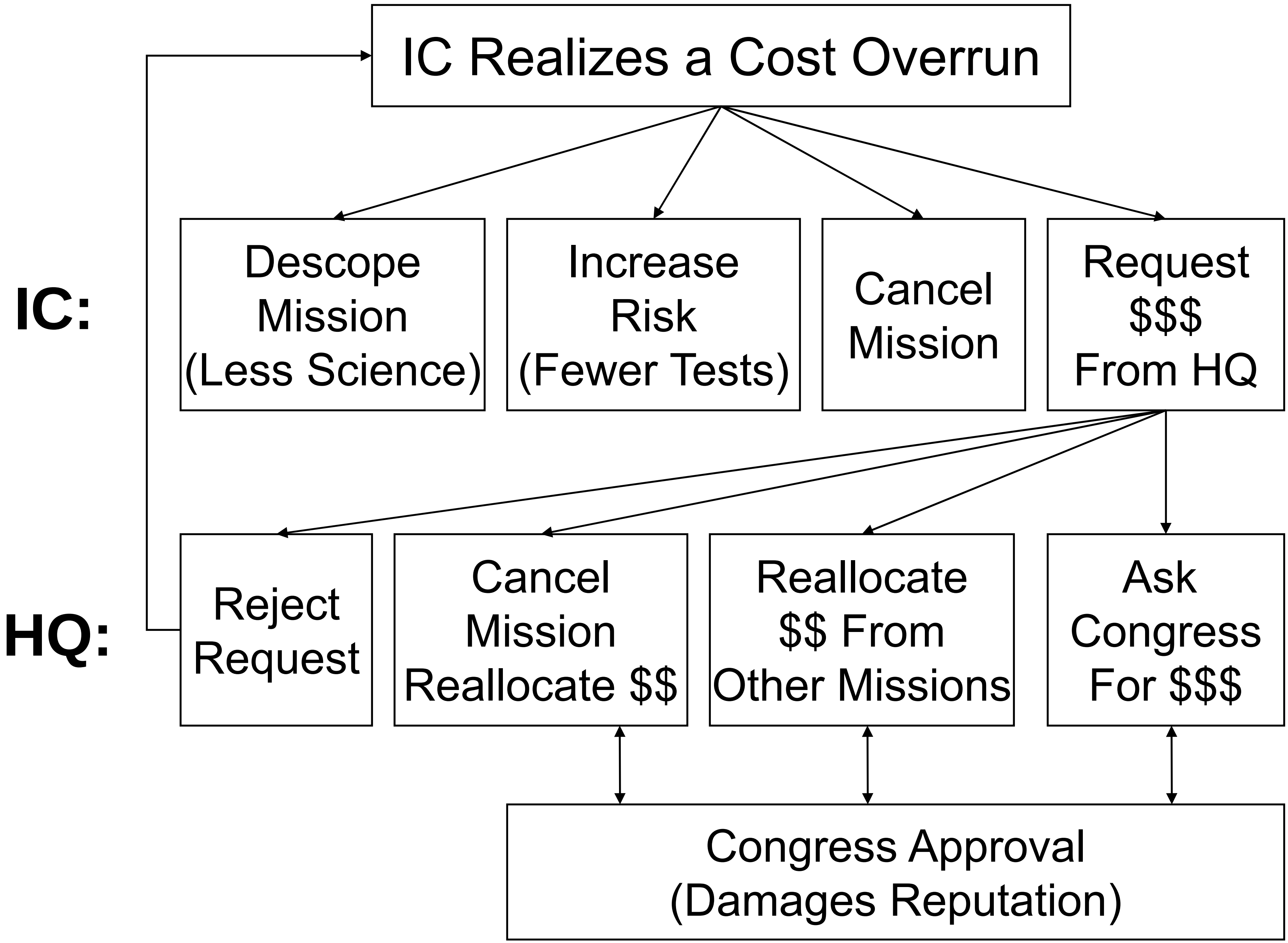
HQ = Principal

ICs = Agents

Budget Allocation: Cost Caps

1. HQ: Menu of missions for near future
2. ICs: Review menu, provide cost estimates*
3. HQ: Assigns missions to ICs*
4. ICs: Refine cost estimates
5. HQ: Assign cost caps for each mission
6. ICs: Build mission**
7. HQ: Fund mission up to cost cap**

*Adverse Selection   **Moral Hazard


IC Realizes a Cost Overrun
IC:
Descope Mission (Less Science)
Increase Risk (Fewer Tests)
Cancel Mission
Request $$$ From HQ
HQ:
Reject Request
Cancel Mission Reallocate $$
Reallocate $$ From Other Missions
Ask Congress For $$$
Congress Approval (Damages Reputation)

Mars Orbiter & Lander

- **Review Board:**

  "Program was under-funded by 30%."

  JPL requested additional $19 million: rejected.

- **Ed Weiler:**

  "[Poor] engineering decisions were made because people were trying to emphasize keeping within the cost cap."

  HQ should have a reserve of money for overruns.

- **Dan Goldin:**

  "The Lockheed Martin team was overly aggressive, because their focus was on winning [the contract]."

Theory: A Fixed Project

- Agent

  Luck: L Effort: e

  Cost: $C(e) = L – e$ Disutility: $f(e)$ ($f' > 0$, $f'' > 0$)

  Payment from Principal: T

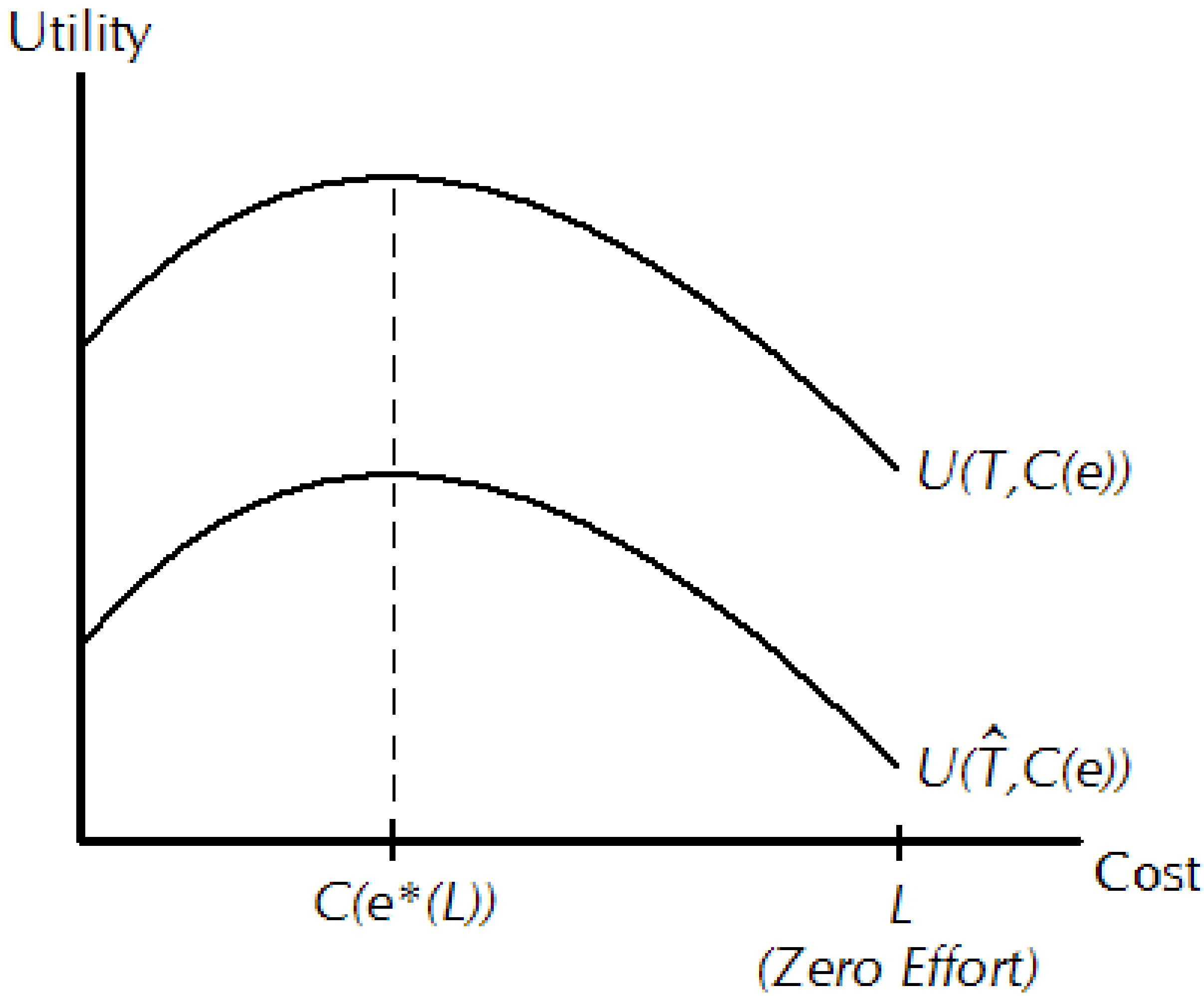
  Payoff: $U(T,e) = T – C(e) - f(e)$

- Principal

  Observes C, not L or e.   Payment to agent: T

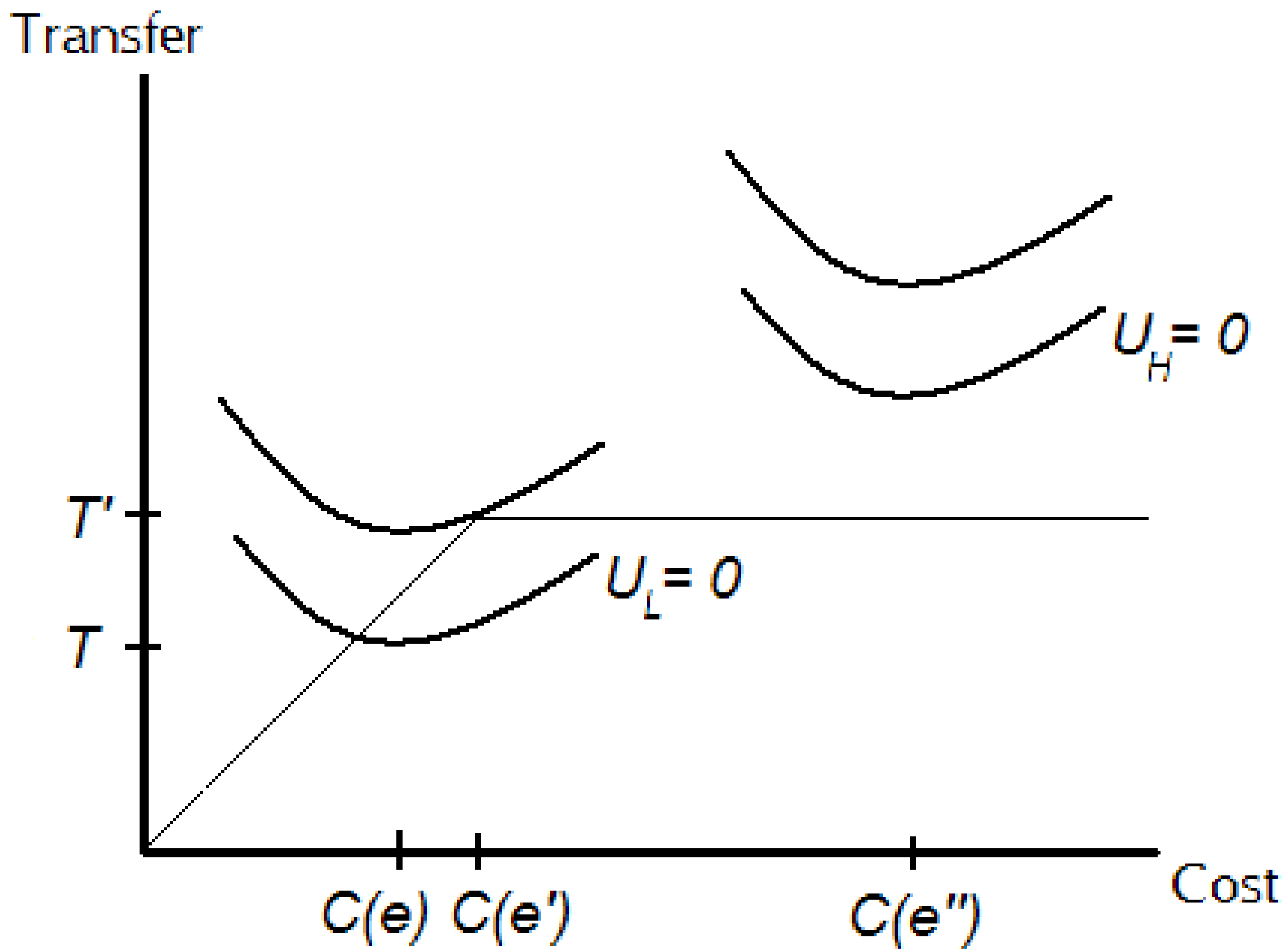
  Benefit of project: S Cost of capital: λ

  Payoff: $V(T,e) = S + U(T,e) – (1+ \lambda)T$



Mechanism Design Problem:

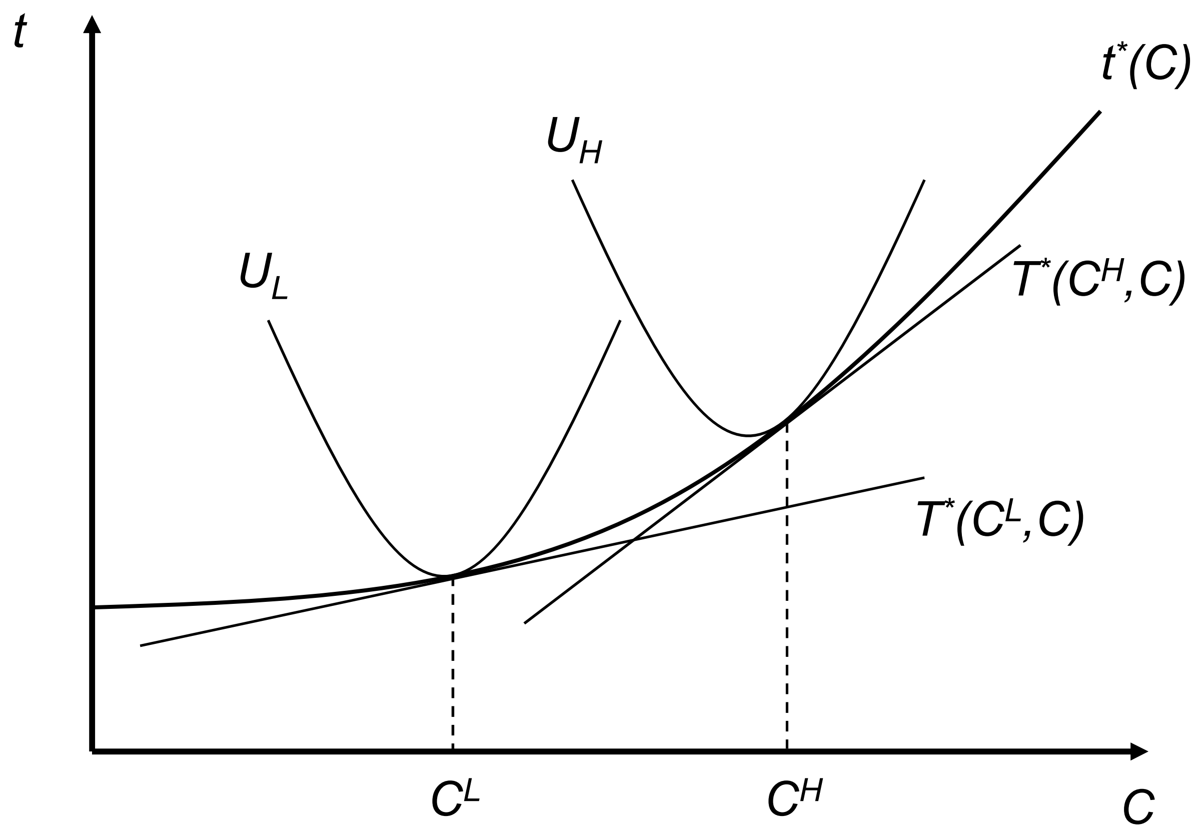
What’s the right *T* when *L* is unknown?



Cost Cap: Low type reduces effort, gets higher transfer

High type earns <0 if he participates

Menu of Optimal Linear Contracts



Agent: Announce C^E **Principal**: Pay $T = T^*(C^E,C)$

Cost caps are *backwards!*

Optimal Contract Features

- High cost types get enough money
- Low cost types don't misrepresent

  (Strong cost saving incentives)

- Multiple agents:

  Use cost estimates as bids

  Solves adverse selection problem

- Second best: some distortion occurs

Theory vs. Reality

- IC's cost estimates sharpen in time
  - Luck + innovation while building
- Project size, complexity can vary *(S not fixed)*
- IC also cares about outcome *(S)*
- Project is a lottery
- Failure is worse than cancellation
- Interaction is repeated
- *f(e)* and *C(e)* are not known, not observable
- Common knowledge priors, utility maximizing…

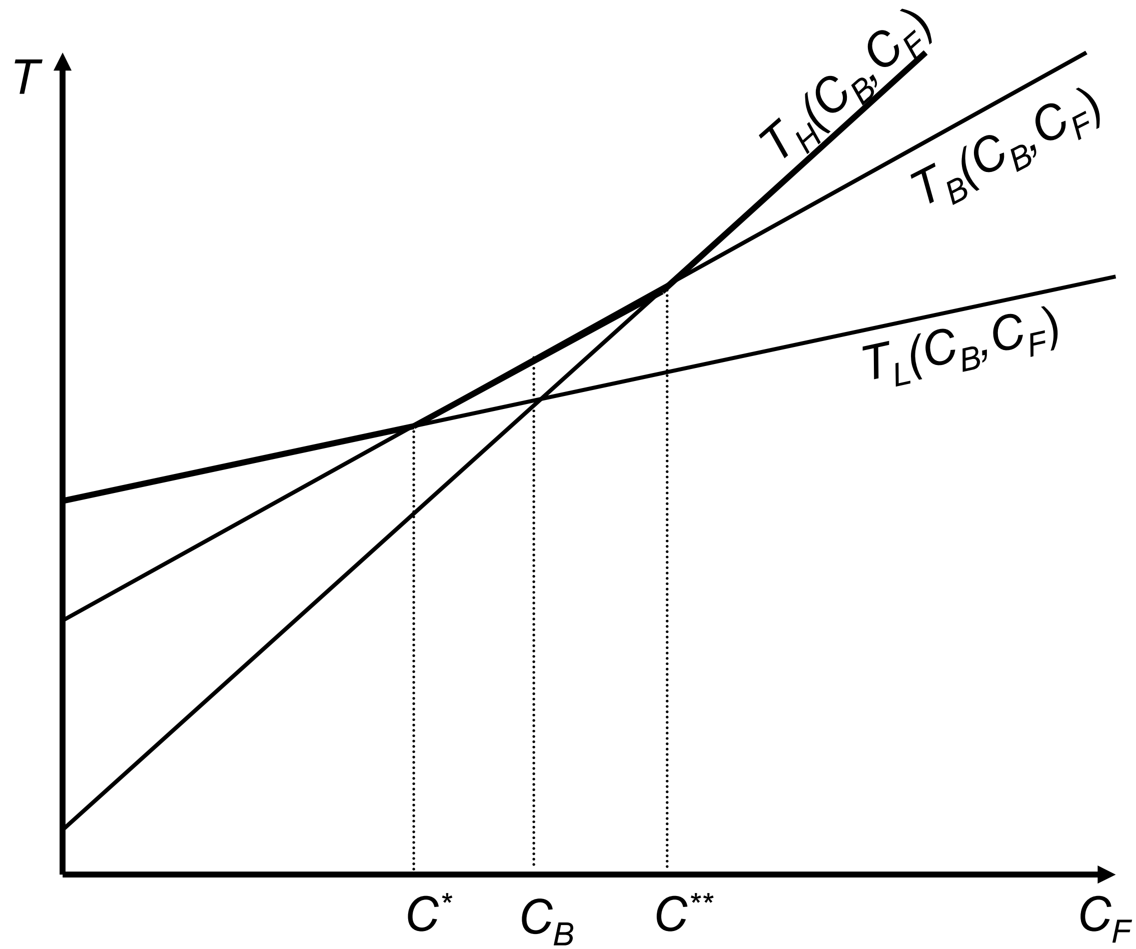
Proposal: MCCS

1. IC & HQ negotiate cost “baseline” C_B
2. *3* linear contracts: *Hi, Base, Low*

   (Each is a function of C_B)
3. IC begins building, innovating

   (Costs change, partly due to luck)
4. IC picks a contract
5. HQ pays IC based on contract, cost
6. IC & HQ can keep savings for future

Proposal: MCCS



Hypothesis

- MCCS outperforms cost caps

  ↑ payoffs ↓ delays ↑ innovations

- Why?
  - Low types have cost-saving incentive
  - High types get enough money
  - Risk sharing → more innovation → lower cost
  - Intertemporal budgets → insurance

Experiment

- 1HQ + {1 or 2} ICs
- Static menu of 2 missions, 3 levels each
- HQ has annual budget of 1500 francs
- HQ allocates budget via {Cost Cap or MCCS}
  - Money earmarked for IC *and* mission *and* level
- IC Innovation
  - Spend more → higher prob. of big cost reductions
- IC Building
  - Chooses Science (*S*) and Reliability (*R*)
  - Mission crashes with probability *1-R*
  - Payout: *S* if succeeds, *-F* if fails, *0* if cancelled
  - Don’t care about money: unspent funds are wasted

Timing

1. HQ/IC negotiate cost caps/baselines
2. ICs attempt 1st innovation
3. Renegotiation (cost caps only)
4. 2nd Innovation attempt
5. IC Builds: Science (S) + Reliability (R)

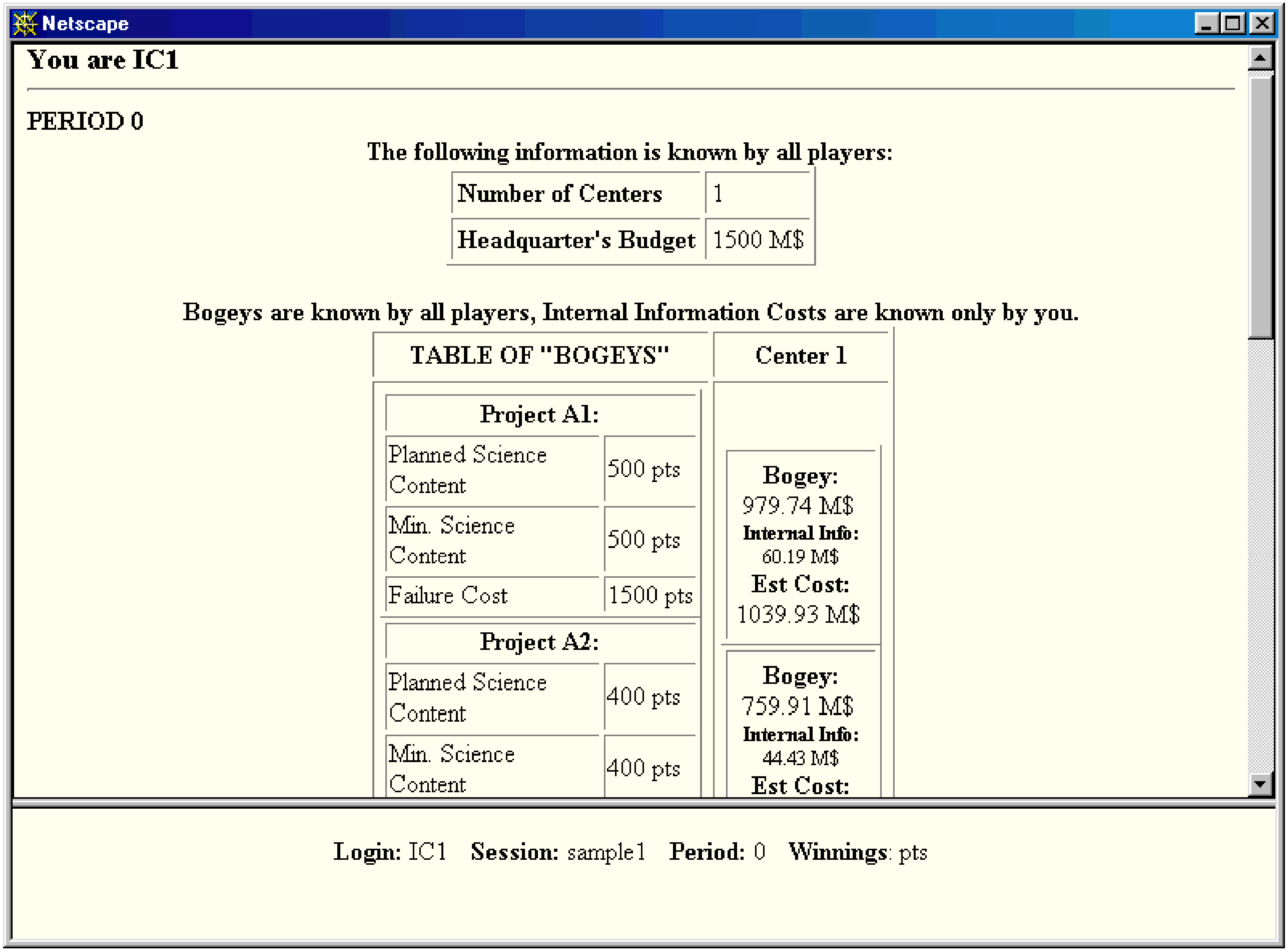
   (Receive transfer, pay *C(S,R)*)
6. Project launched: success/fail

HQ Expected Payoff: R*S - (1-R)*F

Luck + Bonus

- IC's cost is changed by 3 luck "shocks"
  - 1st: Before negotiation
  - 2nd: During innovation
  - 3rd: Pre-build

- IC gets a bonus if a "level 1" mission flies
  - Only difference between IC and HQ.


Netscape
You are IC1
PERIOD 0
The following information is known by all players:
Number of Centers
1
Headquarter's Budget
1500 M$
Bogeys are known by all players, Internal Information Costs are known only by you.
TABLE OF "BOGEYS"
Center 1
Project A1:
Planned Science Content
500 pts
Min. Science Content
500 pts
Failure Cost
1500 pts
Bogey:
979.74 M$
Internal Info:
60.19 M$
Est Cost:
1039.93 M$
Project A2:
Planned Science Content
400 pts
Min. Science Content
400 pts
Bogey:
759.91 M$
Internal Info:
44.43 M$
Est Cost:
Login: IC1 Session: sample1 Period: 0 Winnings: pts

Netscape

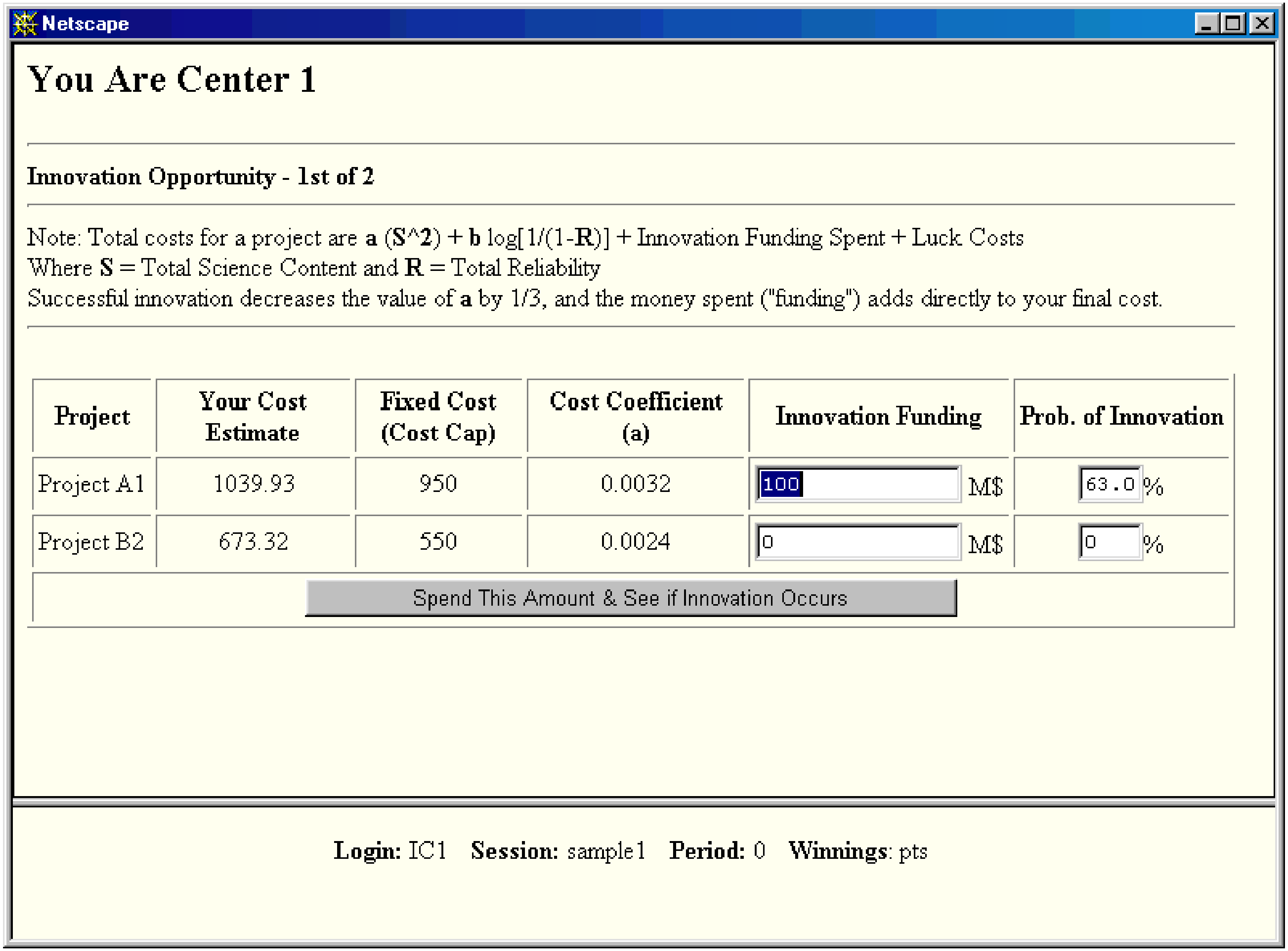
Negotiating Fixed Costs (Cost Caps) - Round 1 of 3

Allocating a Fixed Cost (Cost Cap) of $0 indicates that a Center is not assigned a mission

Project	Center	Bogey	Requested Fixed Cost (Cost Cap)	Your Response
A1	Center1	979.74 mf	1000	0
A2	Center1	759.91 mf	0	0
A3	Center1	539.87 mf	0	0
B1	Center1	1579.74 mf	0	0
B2	Center1	659.91 mf	678	0
B3	Center1	389.87 mf	0	0
Total Requested:			**1678**	
Total Planned Response:				0
Total Budget:			**1500**	

Send New Fixed Costs (Cost Caps) Back to Centers

Login: HQ **Session:** sample1 **Period:** 0 **Winnings**: pts


Netscape
You Are Center 1
Innovation Opportunity - 1st of 2
Note: Total costs for a project are a (S^2) + b log[1/(1-R)] + Innovation Funding Spent + Luck Costs
Where S = Total Science Content and R = Total Reliability
Successful innovation decreases the value of a by 1/3, and the money spent ("funding") adds directly to your final cost.
Project
Your Cost Estimate
Fixed Cost (Cost Cap)
Cost Coefficient (a)
Innovation Funding
Prob. of Innovation
Project A1
1039.93
950
0.0032
100
M$
63.0
%
Project B2
673.32
550
0.0024
0
M$
0
%
Spend This Amount & See if Innovation Occurs
Login: IC1 Session: sample1 Period: 0 Winnings: pts

Netscape

ou Are Center 1

ilding - Phase D only

oose the amount of Science Content and Reliability to build in Phase D only.

tal Science Content = Science Content from Phase A-C + Science Content from Phase D
tal Reliability = Reliability from Phase A-C + Reliability from Phase D

roject	DON'T DELIVER THIS PROJECT	Science Content from Phase A-C	Science Content for Phase D	Total Science Content	Min. Science Content for All Phases	Reliability for Phase A-C	Reliability for Phase D	Final Reliability for All Phases	Total Innovation Funding Spent	Cost from Phase A-C	Second Luck Cost	Final Total Cost	Total Fixed Cost (Cost Cap)
roject A1	☐	260 (52% of Min.)	260 52 % of Min.	520 104 % of Min.	500	46%	46 %	92 %	200 M$	318.63	71.52	844.7	850
roject B2	☐	225 (45% of Min.)	284 56.8 % of Min.	509 101. % of Min.	500	44%	47.5 %	91.5 %	150 M$	138.96	29.73	649.42	650

Build and Launch This Project

Login: IC1 **Session:** sample1 **Period:** 0 **Winnings**: pts

Treatments & No. of Periods

Number of Centers	Variance of Cost Shocks	Cost Caps		MCCS	
		Inexper.	Exper.	Inexper.	Exper.
1	Low	5	10	30	5
	High	30	15	20	15
2	Low	20	5	25	5
	High	20	10	20	5
Total		75	40	95	30

Results: Total Earnings

	# of Centers	Cost Variance	Cost Caps Inexper.	Cost Caps Exper.	Cost Caps N.C.B.	MCCS Inexper.	MCCS Exper.	MCCS C.B.
Average HQ Payoff	1	Low	748	768	672	802	863	860
		High	730	778	672	800	874	860
	2	Low	746	524	672	805	883	860
		High	767	777	672	962	1000	860
	Average		745	744	672	836	894	860
Average IC Payoff	1	Low	1111	950	1160	1134	1297	1255
		High	1021	963	1160	1133	1345	1255
	2	Low	908	777	1160	1106	1398	1255
		High	997	1007	1160	1383	1569	1255
	Average		991	948	1160	1179	1383	1255

- HQ + IC earn more under MCCS
- MCCS with experienced subjects > benchmarks
- (MCCS – Cost Cap) > (C.B. – N.C.B)

Results Cont'd

- MCCS vs. Cost Cap:
  - More innovation
  - Lower final costs
  - Fewer missions cancelled
  - Experience increases payouts
- Issues with MCCS:
  - Overinvest in innovation effort
  - Overinvest in science
  - "Fair" distribution of missions

Summary

- NASA Project: Ongoing
  - Single contract cost sharing
  - Different parameters, functional forms

- Bending theory to fit the problem
- Lab as a “Testbed”
- Results/Design feedback loop