Efficiency and Property Rights in Land Assembly: Mechanism Design and Experiments

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The Assembly Problem

Many projects require assembly of rights or properties

- Urban redevelopment, public infrastructure projects
- Licensing patents for new smartphone/drug; copyrights
- Buying up shares for corporate take-over; debt restructuring

Market failure: holdout owners delay or block efficient assemblies, require information rents

Also known as the holdout/anti-commons/complements problem

Assembly Mechanism Design

Can we design institutions for assembling complementary goods that improve upon *status quo*?

- Incentive-compatible, self-financing direct mechanisms can identify efficient transfers
- We propose: Strong Pareto (SP) mechanism—fully protects right of property owners (IR)
- Second-best theorem: SP is least inefficient IR mechanism
- Can't achieve both *ex post* efficiency and individual rationality

So yes, but we must trade off efficiency and property rights

Experiments Evaluating the Tradeoff

For a family of mechanisms that generalizes SP, we ask:

- How much efficiency do we gain as we let go of adequate compensation (IR)?
  - Efficiency: fraction of potential gains-from-trade realized?
  - Property rights/Individual rationality: frequency and severity of under-compensation; would people participate voluntarily?
- Incentive compatibility: truthful revelation of private values; actual versus predicted performance?

Relaxing IR "solves" holdout problem, but cost is non-trivial

Overview

The Assembly Problem

Assembly Mechanism Design

- The SP and Plurality Mechanisms
- Second-Best Theorem

Evaluating The Tradeoff

- Performance
- Incentive Compatibility

Ways to conceptualize the assembly problem

- Multilateral trade w/ perf. complementary goods
- Collaboration (Cournot)
- Fragmented property rights/ownership of resource (Land assembly, anticommons literatures)
- Yes/no decision– all must agree, determine cost sharing, e.g. approve construction of polluting factory (Mailath & Postlewaite, 1990)

What to do when bargaining fails?

In land assembly, status quo institution is *eminent domain*

- State has legal power to expropriate land for the public good
- Without market test can't properly judge efficiency
- Fair market value is *lower bound* for private value $\Rightarrow$ undercompensation, completion of inefficient projects
- Does not account for externalities
- Justification for ED despite property rights violations reveals perceived inefficiency

Can we do better with a direct mechanism that implements truth-telling?

Formalizing the mechanism design problem

- n sellers endowed with one good, valuation (cost) v_i^*
- m buyers, value for assembled package w_j^*, else zero
- An *assembly mechanism* (X, Y) is a direct mechanism
  - Outcome function $Y : \mathbf{R}^{m+n} \to \{0, 1, \ldots, m\}$ with $Y(v, w) = 0 \Longrightarrow$ no sale.
  - Transfer function $X : \mathbf{R}^{m+n} \to \mathbf{R}^{m+n}$ with X^s and X^b transfers to sellers, buyers, resp.

Desirable Properties of a Mechanism

IC Truth-telling is dominant strategy

- Clarifies what is 'just' compensation
- Allows determination of efficiency

SF Self-financing: $\sum X_i^s + \sum X_j^b \leq 0$ (no subsidies required)

FRP Full respect for property rights (or *ex post* IR): rational participants never made worse-off

- $Y(v, w) = 0 \Longrightarrow X(v, w) \geq 0$
- $X_i^s - v_i^* \geq 0$ for all sellers i, if sale
- Successful buyer j pays no more than w_j^* and unsuccessful buyers pay nothing

EF *Ex post* efficient: sale to j iff $\sum v_i^* \leq w_j^*$ and w_j^* is maximal

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PK No structure is imposed on participants' beliefs about (v^*, w^*), except that each knows own valuation and that individual valuations are independent.

Our Approach

- Can't satisfy *all* properties
- IC, SF, FRP required of an *acceptable* mechanism
- Objective: EF; Constraint: FRP
- Admission: Some efficiency-improving undercompensation may be permissible

Overview

Introduction to the SP and PL Mechanisms

- Sellers assigned fixed, exhaustive shares α_i
- Announce valuations v_i, w_j
- Second-price auction for buyers,
  $B = \text{Winning buyer's offer} = \text{2nd price}$
- If sale, sellers paid $\alpha_i B$, else retain v_i^*
- Individual agrees to sale if: $\alpha_i B \geq v_i$ (reserve $r_i = \frac{v_i}{\alpha_i}$)
- SP requires unanimity for sale approval ($r = \max\{r_i\}$)
- X-PL(urality) requires fraction X to agree

Properties of the SP Mechanism

- Incentive Compatible (for sellers):
  - Exogenous $\alpha_i \Rightarrow$ stated v_i does not influence own payoff (conditional on sale)
  - Overstating v_i^* only can lower probability of profitable sale
- Balanced-budget (better than SF)
- Fully preserves property rights: unanimous voting mechanism
- No informational requirements
- Efficiency is necessary for sale: $\sum v_i^* \leq r \leq B$
- But not sufficient:
  - Second-price may be too low: $B < r \leq w_j^*$ ($m \uparrow \Rightarrow E[\mathrm{EF}] \uparrow$)
  - Auction reserve may be too high: $\sum v_i^* \leq B < r$ ($n \uparrow \Rightarrow E[\mathrm{EF}] \downarrow$)

Examples: What makes the SP reserve too high?

- Suppose $n = 2$, $\sum v_i^* = 10$, $B = 12$
- Sale is efficient. Does it succeed?

v_1^*	v_2^*	α_1	α_2	r_1	r_2	r	Sale
5	5	1/2	1/2	10	10	10	Y
5	5	4/5	1/5	6.25	25	25	N
8	2	1/2	1/2	16	4	16	N
8	2	4/5	1/5	10	10	10	Y

- Assignment of shares is crucial: more in proportion to actual share of value, $\frac{v_i^*}{\sum v_i^*} \Longrightarrow$ more efficient
- Some information, e.g. knowledge of distributions or signals about valuations could be used to improve efficiency

Overview

Separable Mechanisms

- A mechanism is *separable* if
  - Buyer transfers and the winning buyer depend only on w (hold auction to determine winner)
  - Given net transfers from buyers, seller transfers and whether or not sale is approved depend only v
- Can separately consider buyer mechanism (auction) and seller mechanism ($\sim$ dichotomous public goods mechanism)
- Claim: in pursuit of efficiency among acceptable mechanism, it is sufficient to consider only *separable* mechanisms
- Idea of proof: Given any non-separable mech., construct new, separable mechanism without efficiency loss

Optimal Buyer Mechanism

- FRP implies only winner pays (no all-pay)
- IC implies kth price auction, $k > 1$
- Reserve determined by seller mechanism
- Second-price ($k = 2$) maximizes chance of exceeding reserve

Optimal Seller Mechanism

Outcome function: $Y^s(v, B)$

- FRP and SF imply that only efficient sales are approved ($\sum v_i \leq B$)
- Cutoff value for acceptable B (the auction reserve), otherwise could improve efficiency

Transfer function: $X^s(v, B)$

- IC implies $X_i^s(v, B)$ is independent of v_i
- So can write $X_i^s(v, B) = \alpha_i(v_{-i}, B)B$, where $\alpha_i > 0$
- SF requires $\sum \alpha_i \leq 1$ (shares)

Optimal Seller Mechanism

Mechanism using exhaustive, non-manipulable shares to determine auction reserve is minimally inefficient

- IR $\Rightarrow \alpha_i(v_{-i}, B)B \geq v_i$, so need $B \geq \frac{v_i}{\alpha_i(v_{-i},B)}$ for all i
- In other words, $r(v) \geq \max_i\{\frac{v_i}{\alpha_i(v_{-i},B)}\}$
- But efficiency requires
  - $r(v) = \max_i\{\frac{v_i}{\alpha_i(v_{-i},B)}\}$
  - $\sum \alpha_i = 1$ (shares are exhaustive, i.e. balanced budget)
- This yields generalized SP family, with $\alpha_i(v_{-i}, B)$ non-manipulable, but not nec. constant
- However, without placing structure on beliefs
  - Require constant α_i to maintain IC
  - Cannot make efficiency judgments within SP family

We Must Trade Off Efficiency and Property Rights

Several families of IC, self-financing mechanisms proposed:

- SP mechanism (GPS,2010): protects property rights at the expense of efficiency
- Plurality (PL) mechanisms (KW,2010): tradeoff continuous in required plurality, SP is simply limiting case
- Concordance (KW,2010), self-assessment (PT,2010) mechanisms: efficient, but inadequate compensation

How to assess this tradeoff? What is the recommended mapping from environments $\times$ preferences $\longrightarrow$ mechanisms?

Little is known about these tradeoffs—theoretically or empirically

Overview

Performance Measures: Efficiency and Under-compensation

Ideal mechanism would capture all gains-from-trade, with no under-compensation

- Potential gains-from-trade for an assembly problem:

$$f^* = \max\{0, B - \sum v_i^*\}$$

- Realized gains-from-trade (single outcome):

$$f = 1_{\text{sale}}[B - \sum v_i^*]$$

- Efficiency index (average outcome, normalized): $F = \frac{\bar{f}}{\bar{f}^*}$
- Under-compensation: $u = 1_{\text{sale}} \sum_i \max\{0, v_i^* - \alpha_i B\}$
- Compensation index: $C = \frac{\bar{f}^* - \bar{u}}{\bar{f}^*}$
- Welfare: $W = F + \beta C$; $\beta = MRS$ between efficiency and compensation

Experimentally Induced Assembly Problems

Challenge: how to realistically (and cost-effectively) implement a *high-stakes*, *one-shot* decision in the lab?

Key design features

- 18 people/session: 2 groups w/ $n = 9$
- Values, shares and bids drawn from triangular distribution:
  - $v_i \sim T[0, 10, 20]$
  - $\alpha_i \sim T[0, .5, 1]$, then normalized
  - Robot bidder: $B \sim T[0, 180, 360]$, $E[B] = 180$
- 15 practice, 10 paid rounds; 1 selected
- Feeling: weighty decision with opportunity to consult, learn, reflect

Data from 7 conditions

For each: 2 sessions, 40 assembly problems, 360 observations (with exceptions noted)

- SP: 9/9 required for sale (3 ses., 42 prob., 378 obs)
- H(igh)PL: 8/9 required (4 ses., 80 prob., 720 obs)
- PL: 5/9 required for sale (28 prob., 252 obs)
- TIOLI Bargaining: sale iff $B \geq \sum v_i$, sellers paid $v_i + \frac{1}{n}(B - \sum v_i)$ if sale
- TIOLI Barg. with full info.: B, v_i^* common knowledge
- SP & PL with opt-in: sellers learn v_i^*, choose whether or not to participate, no sale unless *all* opt in

Total: 820 assembly problems (7380 obs); 310 of which (2790 obs) are paid

Benchmark: Average Potential Gains From Trade

Ideal mechanism would capture all, with no under-compensation

	$\bar{B}$	$\overline{\sum v_i^*}$	$B \geq \sum v_i^*$?	$\bar{f}^*$
10k simulations	179.73	90.03	.88	93.28
SP	185.53	90.88	0.86	98.23
HPL	190.82	90.35	0.96	101.78
PL	167.04	91.55	0.86	79.77
Barg	185.52	89.39	0.95	97.87
Barg FI	174.32	90.50	0.88	86.22
SP opt in	188.69	91.55	0.95	98.94
PL opt in	191.68	90.14	0.88	97.35

We normalize efficiency and compensation indices by the condition-specific average potential gains

Comparing Performance Across Mechanisms

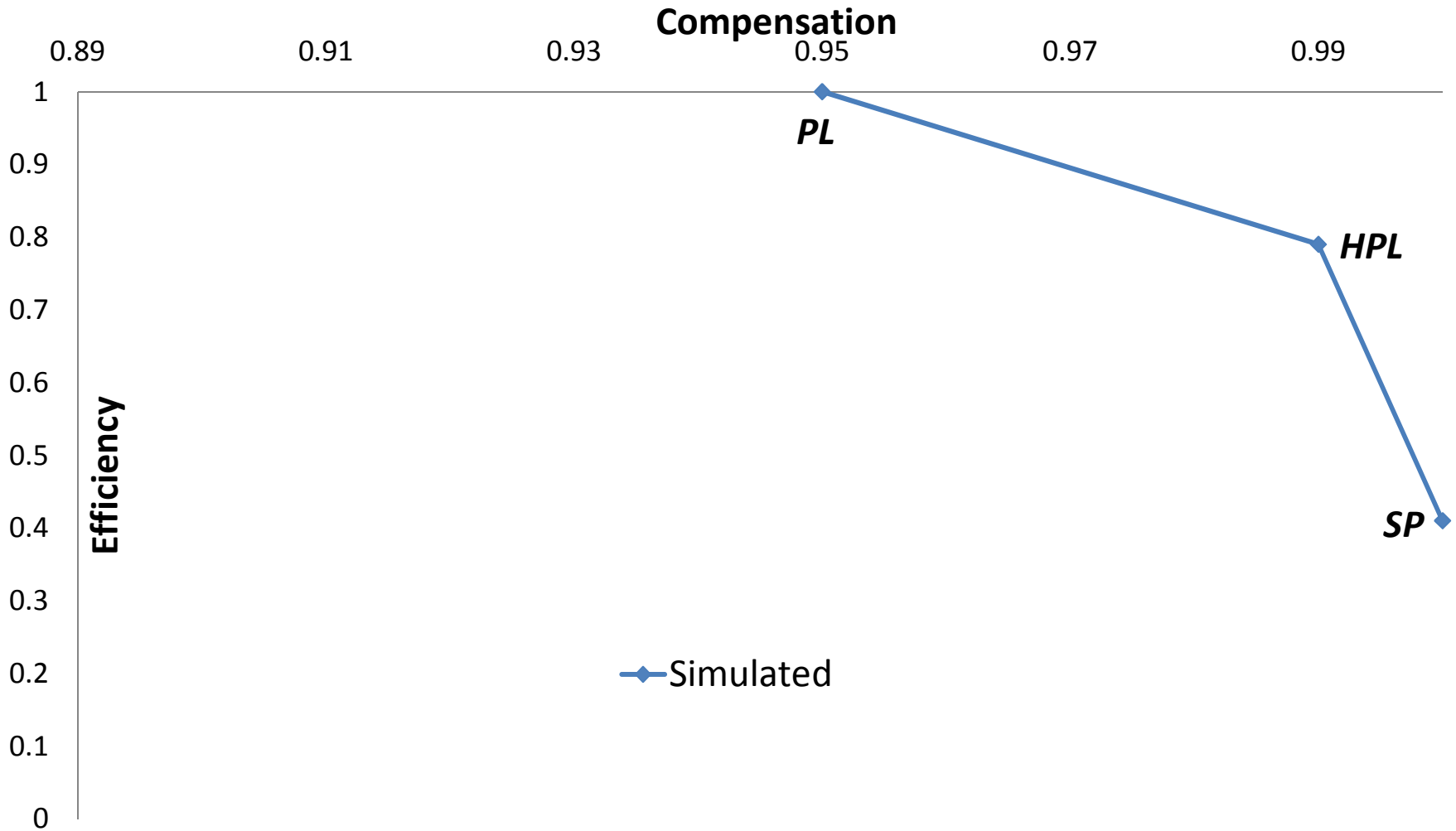
What are the costs, benefits of relaxing IR?

	Predicted						Actual		
	Simulations			Drawn values					
	C	F	β^*	C	F	β^*	C	F	β^*
SP	1.00	0.41		1.00	0.38		1.00	0.45	
HPL	0.99	0.79	**38**	1.00	0.33	$-\infty$	1.00	0.15	**161**
PL	0.95	1.00	**12**	0.90	1.00	**7**	0.93	0.98	**8**
Barg							0.98	0.80	**18**
Barg FI				1.00	1.00		0.97	0.79	**13**
SP opt in				1.00	0.43		1.00	0.08	**181**
PL opt in				0.95	1.00	**13**	0.99	0.42	**−2**

$\beta^* = -\frac{F_{PL}-F_{SP}}{C_{PL}-C_{SP}}$ is defined by $W(SP|\beta^*) = W(PL|\beta^*)$, answers: how much must you penalize under-compensation before SP is preferred to PL?

Comparing Performance Across Mechanisms

Actual vs. Predicted performance



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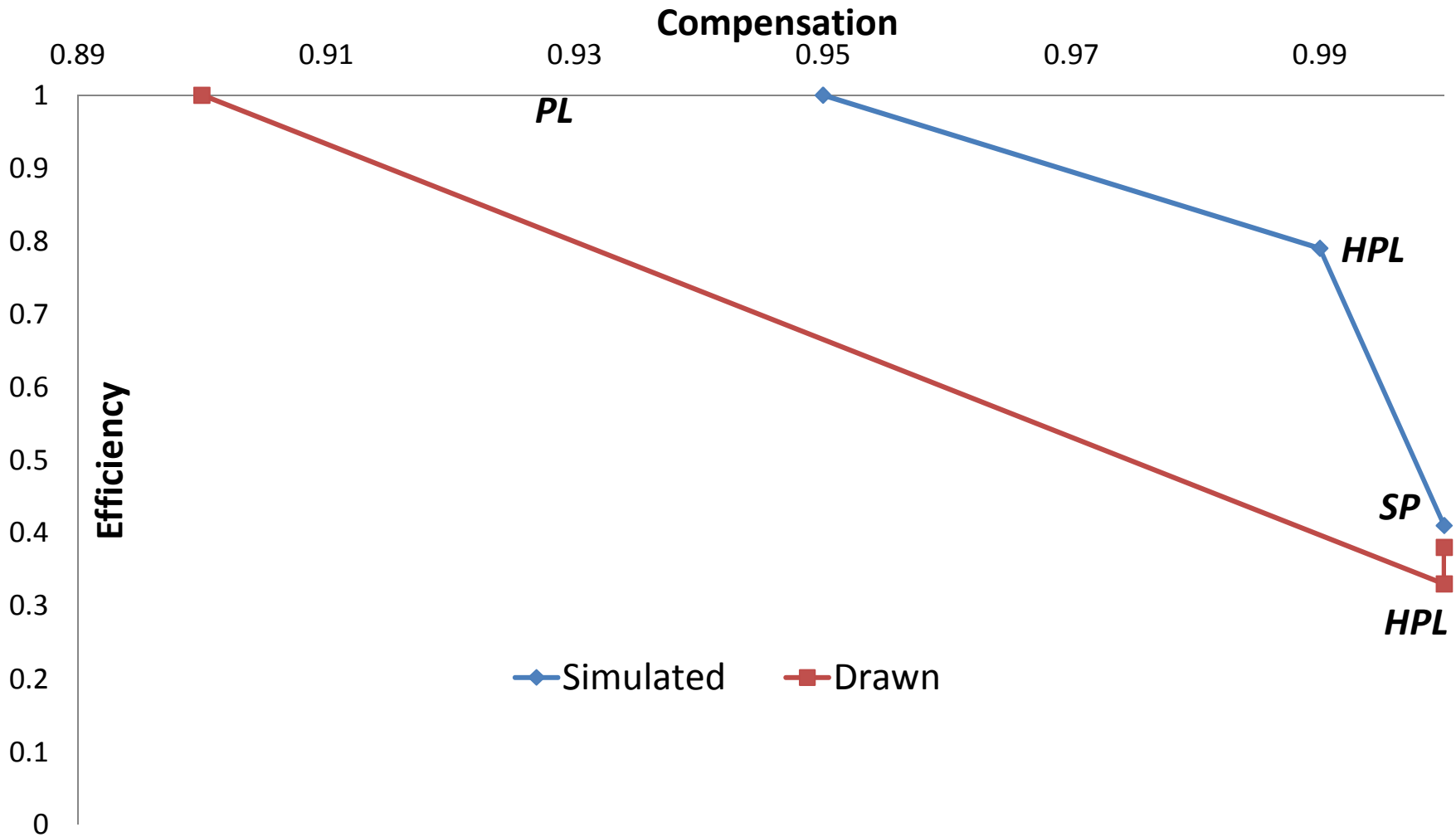

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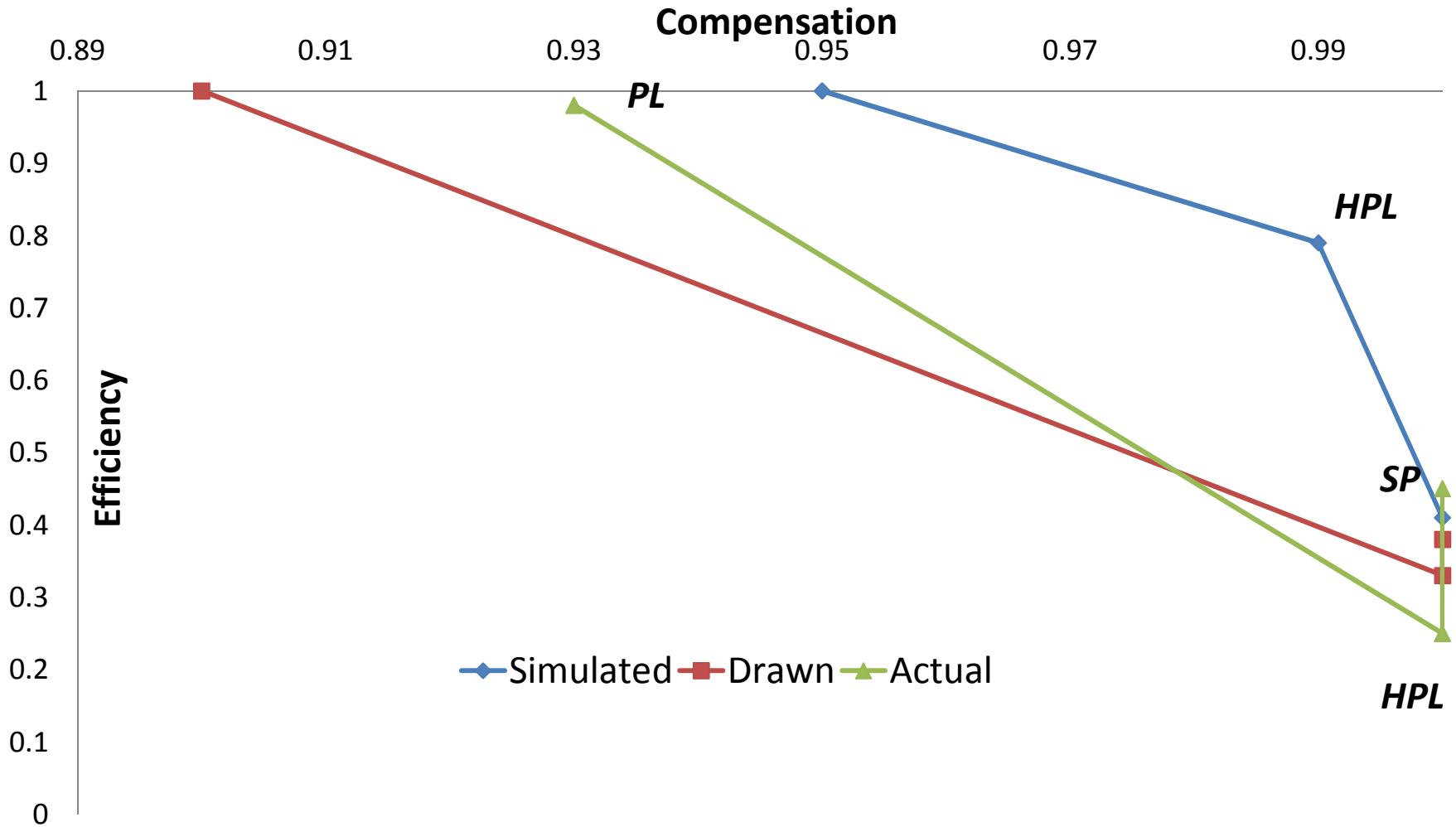


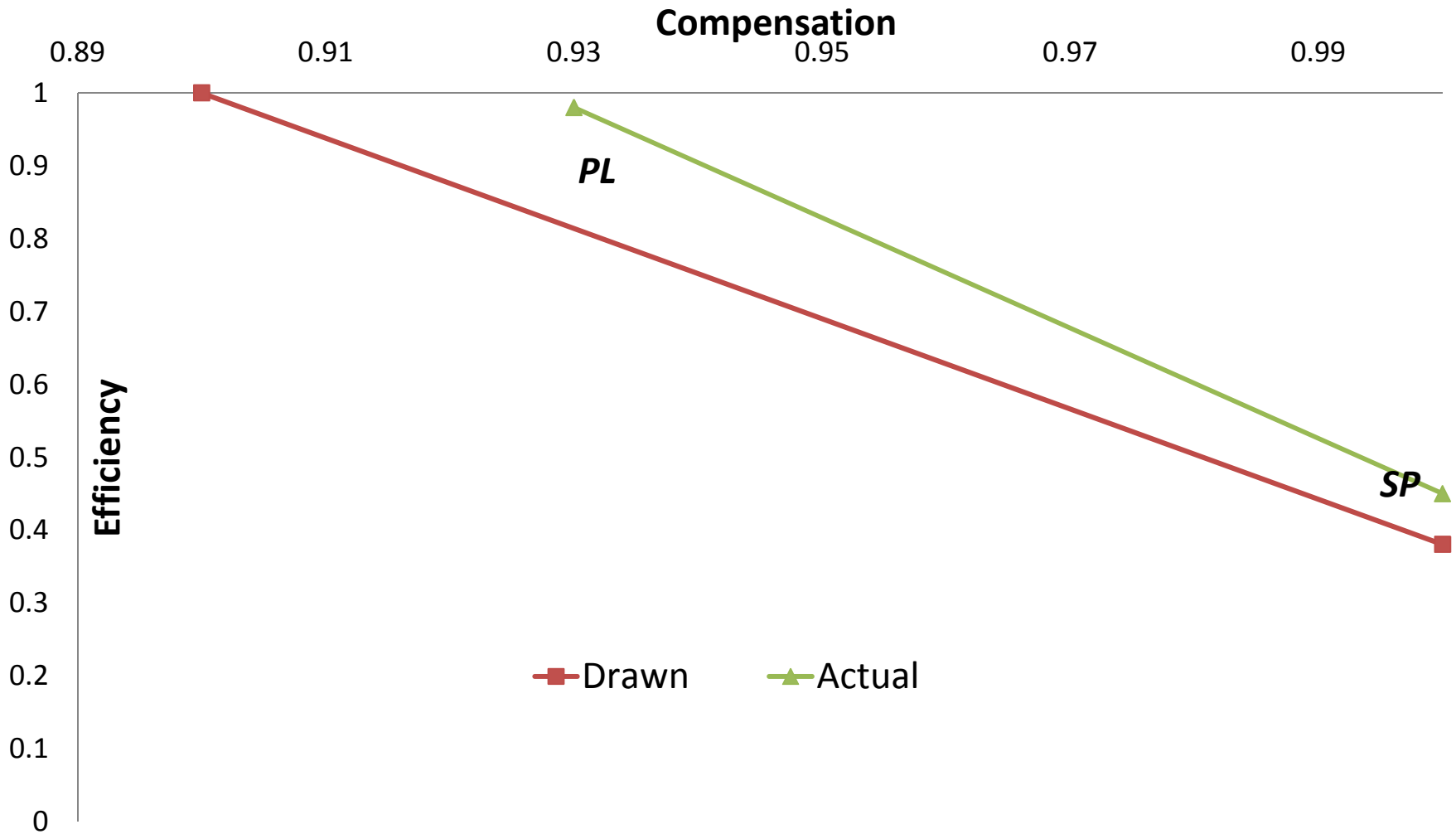
Comparing Performance Across Mechanisms

What are the costs, benefits of relaxing IR?

- PL "solves" holdout problem, but cost is non-trivial
- SP, PL both slightly more attractive than predicted
- Simulated HPL quite attractive, experimental draws appear non-representative (80 assembly problems vs. 10k)

Comparing Mechanisms to Benchmarks

Actual vs. Predicted performance



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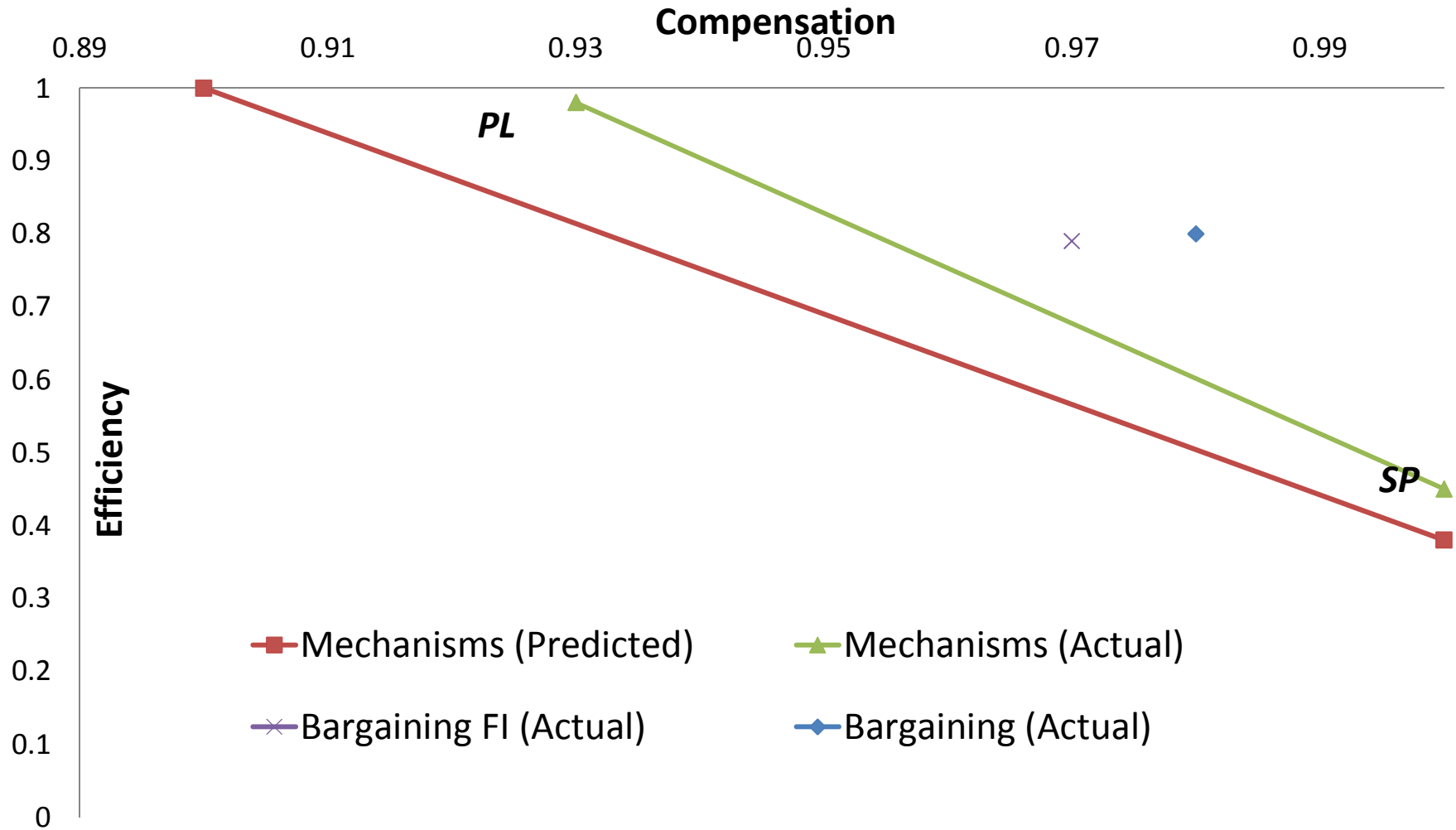

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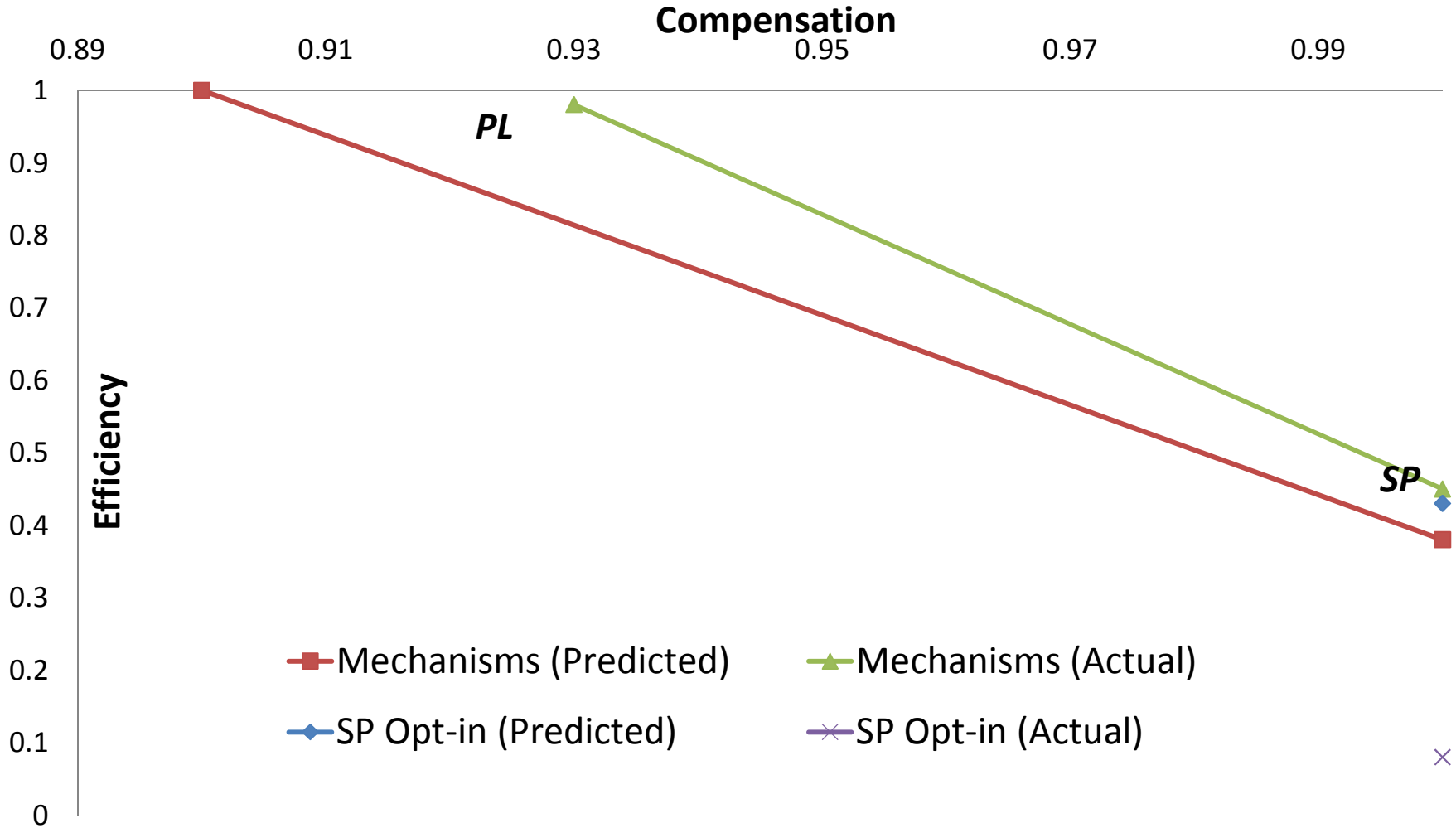

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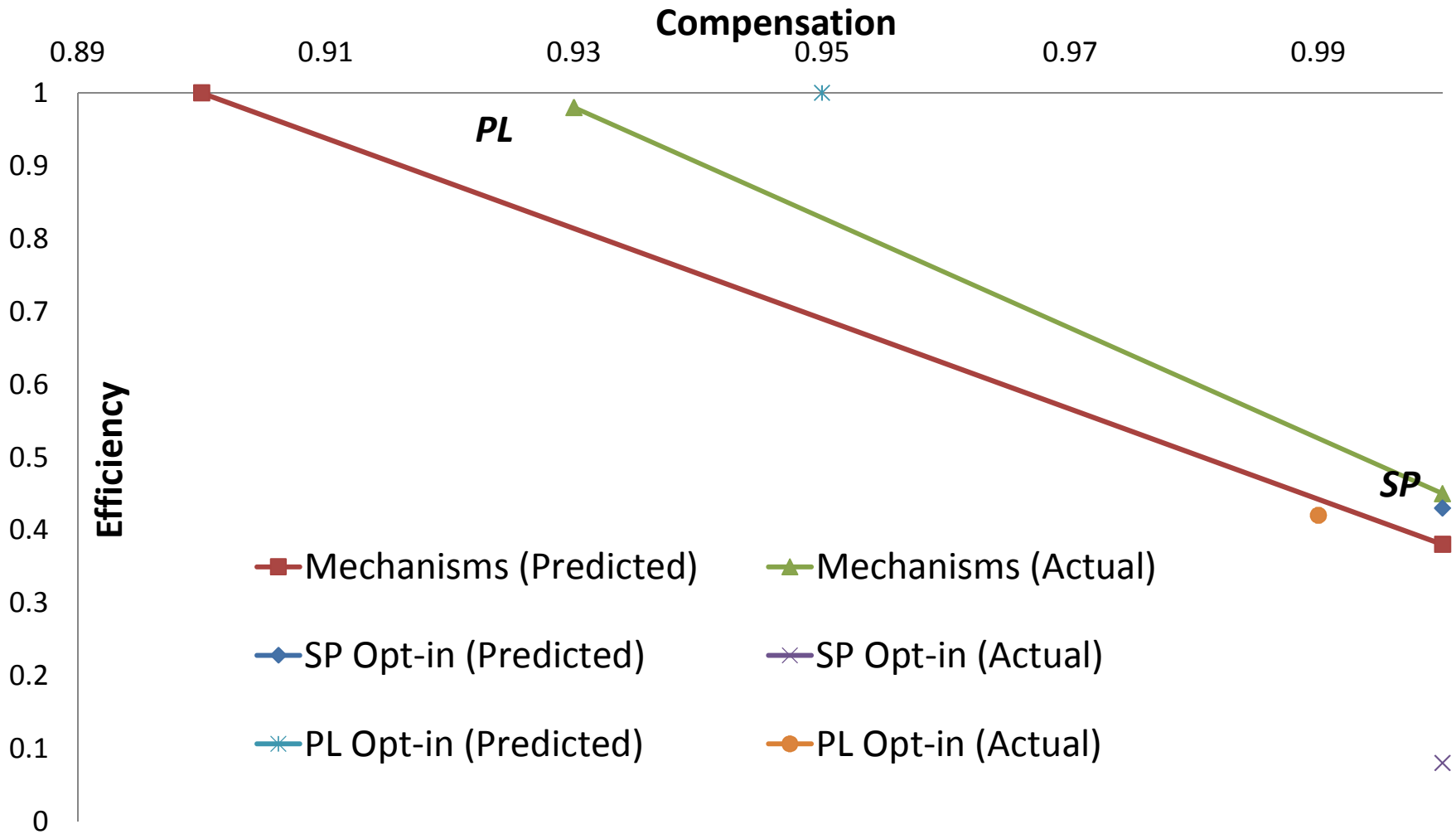

Comparing Mechanisms to Benchmarks

Bargaining and Opt-in

- SP less efficient than bargaining
- Bargaining failure not just due to incomplete info
- Opt-in significantly reduces efficiency, even when IR is supposed to hold, implies problem with voluntary participation

Incentive Compatibility

What fraction of announcements are close to the truth?

	Practice	Paid
Exact (w/in .01)	0.16	0.21
Within in 1	0.39	0.46

Observe learning

Many (about half) of the announcements are close to the truth, but far from all

Incentive Compatibility

Do people overbid? Underbid?

	Practice	Paid
Underbid	0.19	0.24
Within 1	0.39	0.46
Overbid	0.42	0.30

Both. Why?

Understanding behavior will allow us to do more behaviorally appropriate simulations

Incentive Compatibility

Extreme announcements

	Practice	Paid
$v_i^* \geq 19$	0.01	0.00
$v_i > 20$	0.09	0.07
$v_i > 360$	0.01	0.01
$v_i^* \leq 1$	0.00	0.01
v_i	0.09	0.11

Deliberately blocking/seeking sale (why?) or confused about incentives?

Incentive Compatibility

Incentive Compatibility

What determines announced price?

	(1)	(2)
Value	0.841***	0.833***
	(0.0610)	(0.0555)
SP	-0.458	
	(0.796)	
HPL	0.0374	
	(0.991)	
Bargaining	8.026***	
	(0.882)	
Period	0.110*	0.148**
	(0.0381)	(0.0344)
Constant	1.626	4.276***
	(1.025)	(0.627)
Observations	2018	2018

(2) includes session fixed effects

Std. err. in parentheses; clustered by session

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Incentive Compatibility

Individual Analysis

- Classify each person
  - Blocker: always announces > 19
  - Accepter: always announces < 1
  - Truther: always within 1 of value
  - Shader: always $>$ value $+ 1$, but not a blocker
  - Birther: ???
- Largest group: Truthers $= 10 - 25\%$, more in SP, PL than Barg.
- Very few blockers, only 2, who happen to be in HPL
- 1/6 blockers in bargaining, no accepters
- About 5% shaders outside of bargaining, mostly in pl; MANY 58% shaders in bargaining
- Robust to relaxing classification standard
- Most people are unclassified, require more sophisticated way to predict behavior, e.g. QRE

Conclusions & Extensions

- Potential for huge welfare gains through use of institutions designed to resolve holdout and protect property rights
- We face efficiency/property rights tradeoffs, but don't know their exact nature
- Simulations and experiments allows us to understand
  - Costs and benefits of relaxing various constraints
  - How actual behavior deviates from predicted behavior
  - What incentives/schemes are easy to use
  - What environmental variables/institutions facilitate welfare, e.g. experience, feedback, advice, tools
- These theoretical, empirical, and behavioral insights allow us better select and design institutions
- How does relative performance change with info quality?
- Other mechanisms: concordance, self-assessment, VCG

Design and evaluation of assembly mechanisms: a fecund area of research with the potential to significantly impact policy/welfare.