How sellers decide on dynamic mechanisms: Information matters

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Nov 2024

Optimal Dynamic Mechanism Design

- To maximize the revenues (payoff), the seller (principle) sets rules of allocations and prices over multi-period as the buyer (agent) receives private information over time.

  - **Repeated selling of perishable goods**
  - Long-term principal-agent relationship

- Dynamic mechanism improves revenues and the efficiency (Baron & Besanko, 1984).

- How do <u>human sellers</u> choose a dynamic mechanism?

Two Simple Dynamic Mechanisms

- ▶ Non-Clairvoyant: not using future information ⇒ general form.

(RS) Repeated Static Mechanism (Myerson, 1981)

- ▶ 100% optimal static revenue (intra-period)
- ▶ 0% optimal dynamic revenue (inter-period)

(NC) Non-Clairvoyant Dynamic Mechanism (Mirrokni et al., 2020)

- ▶ 50% optimal static revenue (intra-period)
- ▶ 50% optimal dynamic revenue (inter-period)

NC Cannot Always Outperform RS

- ▶ Relative size of inter-period revenue matters (Gui and Houser, 2024).

Research Question

How do Sellers Decide on Dynamic Mechanisms?

▶ How do Sellers choose between NC and RS?

▶ Can Sellers make good decisions and improve revenues?

What Information Sellers Use in Deciding on Mechanism?

▶ **Relative Simplicity**: NC is harder: set more prices.

▶ **Demand Knowledge**: NC outperforms RS in some scenarios.

▶ **Feedback**: NC gets less revenue as buyers might quit the later period.

Experimental Procedure

Settings

- **Clairvoyant environment**: F_1, F_2 known for Sellers at the beginning.
- 10 Rounds + 2 Practice Rounds, feedback on each round, each period.
- Fixed role, re-match for each round.
- Risk task and ambiguity task (random ordered) at the end.

Choosing from Two Mechanisms in each Round

- Non-Clairvoyant Dynamic Mechanism (NC)
- Repeated Static Mechanism (RS)

Experimental Task in each Round

Period 1

1. Seller chooses mechanism, **M** (=NC or RS), buyer is informed
2. Seller sets reserve price r_1^M for Period 1, Buyer makes a bid $b_1(v_1)$.
   - in RS: buyer pays r_1^M if $b_1 \geq r^{M_1}$
   - in NC: buyer has 50% chance to get free item

Choose Mechanism for two Periods
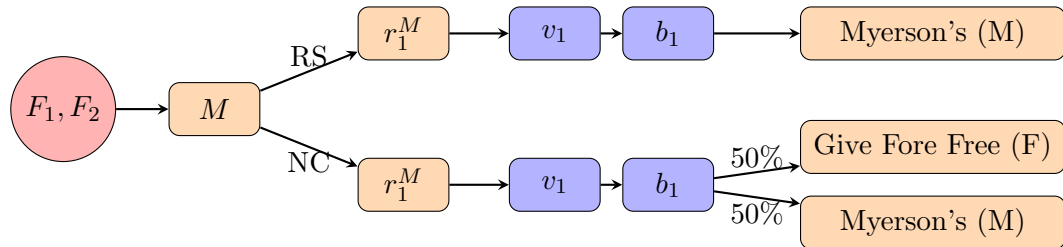
Experimental Task in each Round
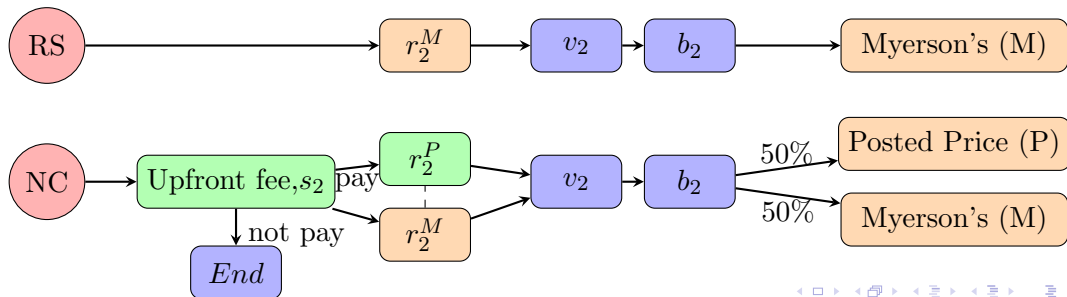
Period 2

1. Seller sets reserve price r_2^M for Period 2
   Treatment Set 2: s_2, r_2^P will be set by the Computer optimally
   Treatment Set 4: s_2, r_2^P will be set by the Seller

2. Buyer chooses to pay the upfront fee s_2 or not
   Buyer makes a bid $b_2(v_2)$ in RS or in NC if entering in the market

Experimental Design: Different Information

Relative Simplicity - Two Treatments (Between-subject)

- ▶ Treatment Set 2: Automated Posted Price Auction (green area)
- ▶ Treatment Set 4: Sellers set 4 prices in NC and 2 prices in RS.

Scenario-specific Demand - Twelve Scenarios (3 Categories) (Within-subject)

- ▶ 4 NC Better: $Rev^{NC} > Rev^{RS}$
- ▶ 4 RS Better: $Rev^{NC} < Rev^{RS}$
- ▶ 4 Same: $Rev^{NC} = Rev^{RS}$
- ▶ For each Session: 2 Same in Practice Stage + 2 in Tail Stage
  Early Stage (4 rounds): 2 NC Better + 2 RS Better
  Later Stage (4 rounds): 2 NC Better + 2 RS Better

Feedback - Revenue of each Round

NC Better ($Rev^{NC} > Rev^{RS}$)

Period 2 is Profitable

- ▶ Inter-period dynamic revenue is more important in NC
- ▶ ∃ "target buyers" (high valuation but low probability) in Period 2

$REV^{RS} = 4$, $REV^{NC} = 4.5$ ↑ 12.5%

$$F_A = \{v, p(v)\} = \{(2, \tfrac{1}{2}), (4, \tfrac{1}{4}), (8, \tfrac{1}{8}), (16, \tfrac{1}{16}), (32, \tfrac{1}{16})\}, \quad \mathbb{E}_A = 6.$$

1. $F_1 = \{v, p(v)\} = \{(2, \tfrac{1}{2}), (4, \tfrac{1}{2})\}, \quad F_2 = F_A$
2. $F_1 = \{v, p(v)\} = \{(2, \tfrac{1}{2}), (4, \tfrac{1}{4}), (8, \tfrac{1}{4})\}, \quad F_2 = F_A$
3. $F_1 = \{v, p(v)\} = \{(2, \tfrac{1}{2}), (4, \tfrac{1}{4}), (8, \tfrac{1}{8}), (16, \tfrac{1}{8})\}, \quad F_2 = F_A$
4. $F_1 = \{v, p(v)\} = \{(2, \tfrac{1}{2}), (4, \tfrac{1}{4}), (8, \tfrac{1}{8}), (16, \tfrac{1}{16}), (32, \tfrac{1}{16})\}, \quad F_2 = F_A$

RS Better ($Rev^{NC} < Rev^{RS}$)

Period 2 is not Profitable

- ▶ Intra-period revenue is more important in NC
- ▶ *e.g.*, Constant valuation, $v_2 = 0$ in Period 2.

$REV^{RS} = 4$, $REV^{NC} = 3.5 \downarrow 12.5\%$

$$F_B = \{v, p(v)\} = \{(2, \tfrac{1}{2}), (4, \tfrac{1}{2}), \}, \quad \mathbb{E}_B = 3.$$

1. $F_1 = \{v, p(v)\} = \{(2, \tfrac{1}{2}), (4, \tfrac{1}{2})\}, \quad F_2 = F_B$
2. $F_1 = \{v, p(v)\} = \{(2, \tfrac{1}{2}), (4, \tfrac{1}{4}), (8, \tfrac{1}{4})\}, \quad F_2 = F_B$
3. $F_1 = \{v, p(v)\} = \{(2, \tfrac{1}{2}), (4, \tfrac{1}{4}), (8, \tfrac{1}{8}), (16, \tfrac{1}{8})\}, \quad F_2 = F_B$
4. $F_1 = \{v, p(v)\} = \{(2, \tfrac{1}{2}), (4, \tfrac{1}{4}), (8, \tfrac{1}{8}), (16, \tfrac{1}{16}), (32, \tfrac{1}{16})\}, \quad F_2 = F_B$

Same ($Rev^{NC} = Rev^{RS}$)

Inter- is as important as Intra- revenue

- $\iff Rev^P = Rev^{M_1} + Rev^{M_2}$
- *e.g.*, Constant valuation, $v_1 = c_1 = 0$ in Period 1, $v_2 = c_2 \geq 0$ in Period 2.

$REV^{RS} = REV^{NC} = 4$

$F_C = \{v, p(v)\} = \{(2, \frac{1}{2}), (4, \frac{1}{4}), (8, \frac{1}{4})\}, \quad \mathbb{E}_C = 4.$

1. $F_1 = \{v, p(v)\} = \{(2, \frac{1}{2}), (4, \frac{1}{2})\}, \quad F_2 = F_C$
2. $F_1 = \{v, p(v)\} = \{(2, \frac{1}{2}), (4, \frac{1}{4}), (8, \frac{1}{4})\}, \quad F_2 = F_C$
3. $F_1 = \{v, p(v)\} = \{(2, \frac{1}{2}), (4, \frac{1}{4}), (8, \frac{1}{8}), (16, \frac{1}{8})\}, \quad F_2 = F_C$
4. $F_1 = \{v, p(v)\} = \{(2, \frac{1}{2}), (4, \frac{1}{4}), (8, \frac{1}{8}), (16, \frac{1}{16}), (32, \frac{1}{16})\}, \quad F_2 = F_C$
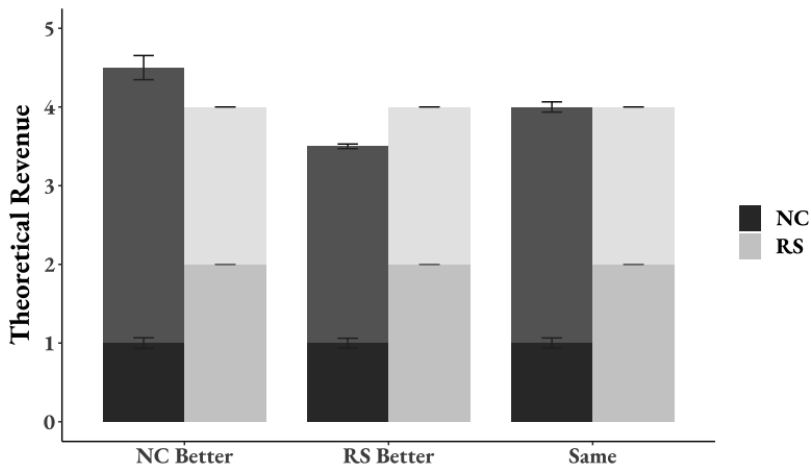
Summary of Theoretical Revenue (Total)

Figure 1: Theoretical Revenue (Total)

Hypotheses

Relative Simplicity

- ▶ H1: Sellers choose more NC in the treatment Set 2.

Demand Knowledge

- ▶ H2: Sellers Choose NC more (less) in NC Better (B) in the Later Stage.
- ▶ ⇒ Sellers choose correct mechanism more in Later stage.

Feedback on Revenues

- ▶ H3: Sellers choose NC more (less) when past revenue from NC is high (low).

* Buyers' Behaviors

- ▶ H4: Buyers participate Period 2 more in the treatment Set 2.

Experiments

- 256 George Mason Students. October to November 2022.

Table 1: Summary Statistic

| Treatment | Set 2 | | Set 4 | |
Role	**Sellers**	**Buyers**	**Sellers**	**Buyers**
Age	22.6	22.2	21.2	22.5
Gender (Male=1)	0.59	0.62	0.52	0.50
Risk aversion	3.14	3.95	3.90	3.70
Ambiguity	3.30	3.02	3.67	3.32
Observation	64	64	64	64

Result 1. Relative Simplicity does not Matter

R1. Sellers do not choose NC more in the treatment Set 2. H1 is not supported.

► Early Stage: no difference from 50% in neither Treatment.

► Later Stage: Significant less than 50% in the treatment Set 2 ($p < 0.01$).

► No treatment difference in either stage.

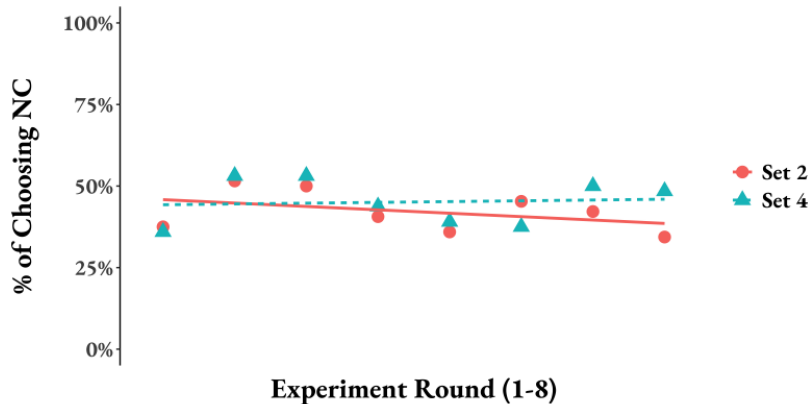# Sellers do not Choose NC More in General

Figure 2: % of Choosing NC

Result 2. Demand Knowledge Matters

R2. Sellers choose NC less in RS Better in Later Stage. H2 is supported.

- ▶ NC Better: No difference from 50%
- ▶ RS Better: Significant less than 50% ($p < 0.01$ in Set 2, $p < 0.01$ in Set 4).
- ▶ More correct mechanisms in the Later stage ($p = 0.01$, in Set 2, $p < 0.01$ in Set 4)
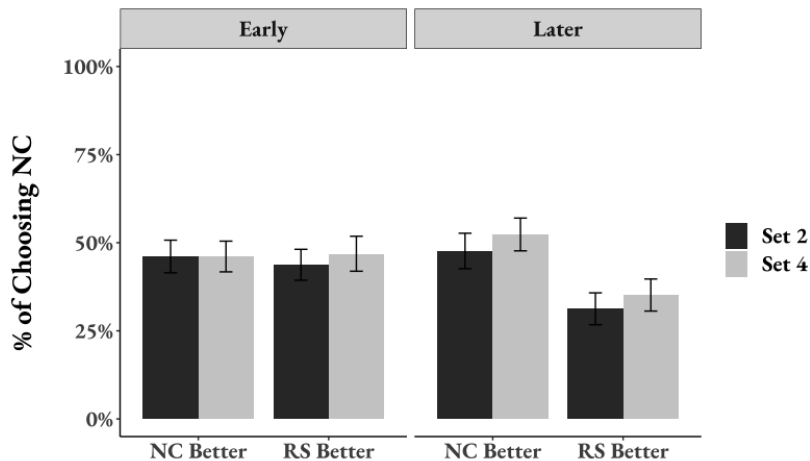
R2. Sellers Choose NC Less in RS Better

Figure 3: % of Choosing NC by Group of Scenario
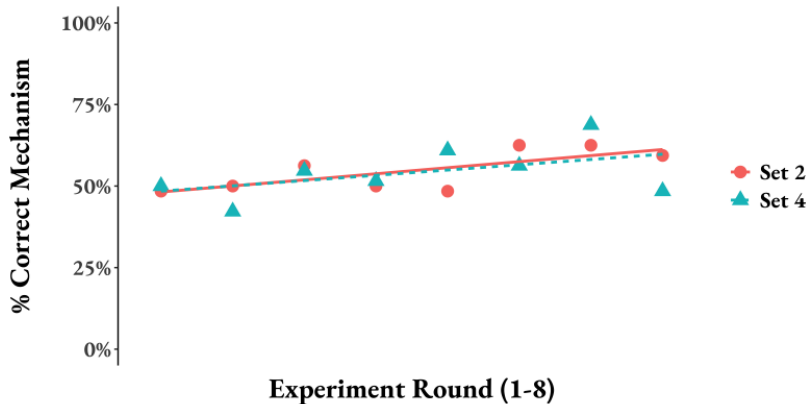
% of Choosing Correct Mechanism ↑

Figure 4: % of Choosing correct Mechanism

Result 3. Feedback on Revenue Matters

R3. Sellers choose NC less if past revenue from NC is low. H3 is supported.

▶ Persist NC more in Later rounds.
▶ Less likely to choose NC if last round NC got less than 3 points.

Reaction to Negative Feedback

Table 2: Regression of Choosing NC

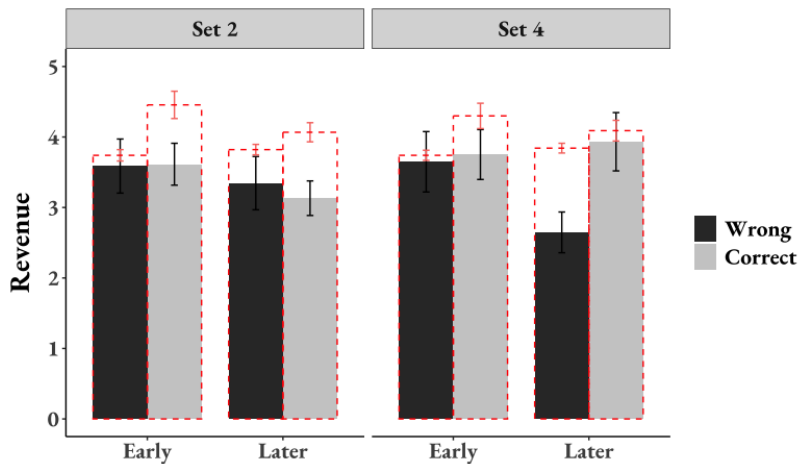|	DV: Choosing NC	
	(1)	(2)
β_1: Last (payoff<Ave, NC)	-0.21^{***}	-0.21^{***}
	(0.07)	(0.07)
β_2: Later * Treatment Set 4	0.01	-0.00
	(0.04)	(0.04)
β_3: Later * RS Better Scenarios	-0.18^{***}	-0.18^{***}
	(0.06)	(0.06)
β_4: Later * Last (NC)	0.16^{*}	0.17^{*}
	(0.09)	(0.09)
β_5: Later * Last (Correct = NC)	0.02	0.01
	(0.10)	(0.10)
Constant	0.46^{***}	0.31^{**}
	(0.04)	(0.13)
Controls	No	Yes
R^2	0.05	0.05
Num. obs.	1024	1024

Revenue Improvement by choosing Correct Mechanism

Figure 5: Experimental Revenue

Result 4. Buyers Reacting to high entry fee.

R4. Buyers participate less in the treatment Set 4. H4 is supported.

- ▶ Explained by higher entry fee set by Sellers in the treatment Set 4.

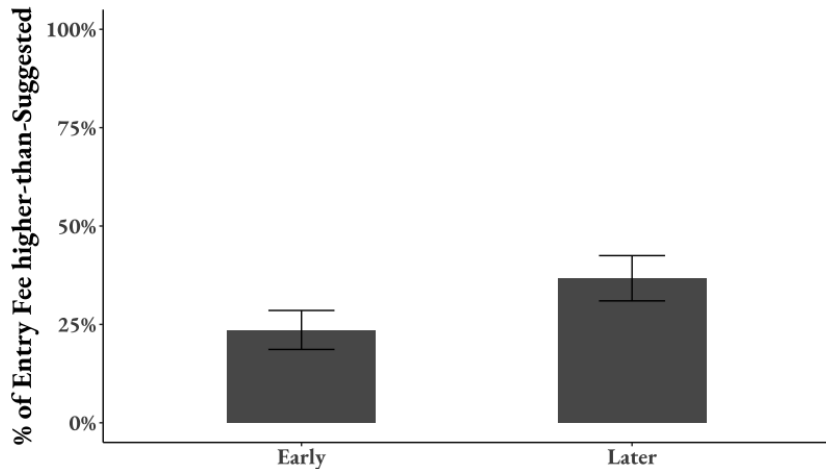# Sellers set higher than suggested entry fee

Figure 6: % of Setting Entry Fee Higher than Suggested

Sellers Set higher Prices

In Period 1

- ▶ "Go big or go home".
- ▶ Aimed high, looking for a heavy bid
- ▶ You'd be surprised when I say - I based it off the charts.
- ▶ Random.

In Period 2

- ▶ Again, attempted high roll, but failed greedily.
- ▶ Higher price didn't work so I went lower.
- ▶ buyer bid for 1?? which makes no sense so I wanted to get some out of him and set the price to 6 as possible values could have been pretty high. Then set price to 4 as I would get it 50% of the time
- ▶ Set a low price, however, buyer decided not to purchase.
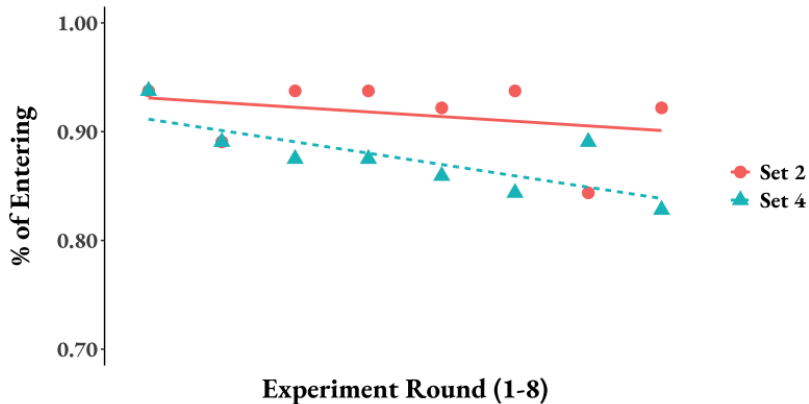
Buyers participated less in the treatment Set 4

Figure 7: % of Entering Period 2

High Entry Fee Deters Entering

Table 3: Probit Regression of Enter in Period 2

	DV: Enter in Period 2	
	(1)	(2)
β_1: Entry Fee	-0.24^{***}	-0.22^{***}
	(0.04)	(0.04)
β_2: Set 4	-0.12	-0.19
	(0.20)	(0.21)
β_3: Set 4 * Later	-0.07	-0.18
	(0.23)	(0.24)
β_4: Later	-0.36^{**}	-0.35^{**}
	(0.16)	(0.17)
Constant	2.04^{***}	2.34^{***}
	(0.23)	(0.69)
Controls	No	Yes
Num. obs.	447	447

Table 4: Probit Regression of Enter in Period 2

Conclusion

Distributional knowledge and Feedback matter in Choosing Mechanism

► Sellers can find the optimal mechanism after gaining trading experience.

► Sellers abandon the mechanism with low revenue.

► Selling strategy evolves as selling condition or expectation changes.

Discussion

► Decision Support Pool: appropriate expectation on Buyers behaviors.

► Experts: advice setting (lower) prices.

Thank you!