

# Three Essays on Dynamic Mechanism Design

Proposer: Shan Gui

Advisor: Daniel Houser

Committee: Cesar Martinelli, Johanna Mollerstrom, Thomas Stratmann

George Mason University

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# Outline

## Ch1. Non-clairvoyant Dynamic Mechanism Design: Experimental Evidence

- ▶ We compare the performance of two non-clairvoyant mechanisms.
- ▶ We find that non-clairvoyant mechanisms work as theory predicts.

## Ch2. How Sellers Choose Dynamic Mechanism: Information Matters

- ▶ We study whether human sellers can choose the correct dynamic mechanism.
- ▶ We find that human sellers can find intuition when they gain experience.

## Ch3. Using (Merit-Based) Default to Reduce Gender Gaps in Contribution of Ideas: Evidence from an Online Experiment

- ▶ We explore how default options affect the gender gap of idea contribution.
- ▶ We find that random defaults are as effective as merit defaults.

# Chapter 1

## Non-clairvoyant Dynamic Mechanism Design: Experimental Evidence

Shan Gui and Daniel Houser

# 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).

# A “Simple” Example

## Scenario U

- ▶ two-period, single-buyer
- ▶ the seller sells one item in each period; zero production cost
- ▶ Distribution of Buyer's value:  $F_1 = U[0, 1] = F_2$ , independent draws

What are the best rules of allocation and price?

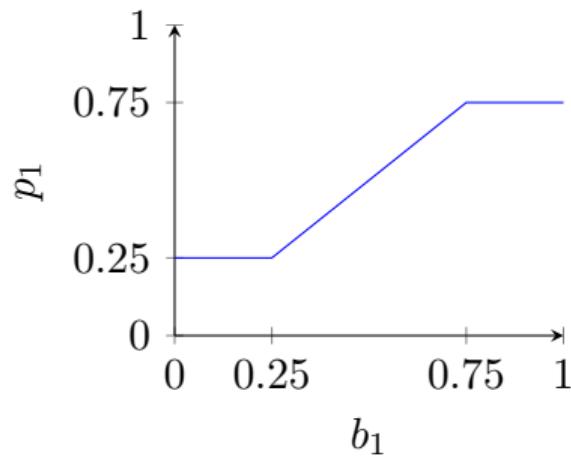
- ▶ Dynamic IC: the buyer reports the true price
- ▶ Ex-post IR: the buyer gain non-negative payoff after the realization of values

## A complicated Answer

Buyer knows the clairvoyant bundle:

$$p_2 = 1 - \sqrt{2p_1 - 0.5}$$

- ▶ Buyer makes a bid in Period 1 (or quit), pays  $p_1$  if  $b_1 \geq p_1$
- ▶  $p_1$  is a function of  $b_1$



Clairvoyant mechanism is hard to solve, understand, and implement

## Clairvoyant Mechanisms

- ▶ Full information design  $\Rightarrow$  Future demand ( $F_2$ ) is used to design the structure

## Why not clairvoyant mechanism in real-life?

- ▶ Difficult to compute
- ▶ Non-intuitive
- ▶ Need to share a common belief
- ▶ Lack of a general form
- ▶ Real revenue is not as expected

# Non-Clairvoyance Environment: more practical

Future demand is not accessible at the beginning.

- ▶ No needs to share unbiased belief.
- ▶ General Form.



$F_2$  is unknown in Day 1



$v_1 \sim F_1$



$v_2 \sim F_2 ?$

## Non-Clairvoyant Mechanisms: general form

RS: Repeated Static optimal mechanism (Myerson, 1981)

- ▶ Rules in two days are independent of each other

Maximize **intra-period revenue** for each period separately.

$\Rightarrow \frac{Rev^{RS*}}{Rev^*}$  could be arbitrarily small (Papadimitriou et al., 2016)

NC: Non-Clairvoyant optimal dynamic mechanism (Mirrokni et al., 2020)

- ▶ Rules in Day 2 depends on bid in day 1

Best Revenue Guarantee:  $\Rightarrow \frac{Rev^{NC*}}{Rev^*} \geq \frac{1}{a}$

Achieve at least  $\frac{1}{2}$  revenue produced by optimal clairvoyant mechanism under all scenarios in **two-period single-buyer** case.

# Constructing Dynamic Mechanisms

Three Basic Dynamic Mechanism satisfies IC and IR

- ▶ F: Free item
- ▶ M: get the item if  $b \geq r$ , pay  $r$
- ▶ P: pay upfront fee  $s = \min[v_{-1}, \mathbb{E}(v)]$ ,  
get the item if  $b \geq r$ , such that  $\mathbb{E}[v - r | v \geq r] = s$

NC, RS in a two-period case

- ▶ RS: M in Period 1 and Period 2;
- ▶ NC: 50% chance of  $F$  and 50% chance of  $M$  in Period 1;  
ask an upfront fee  
50% chance of  $P$  and 50% chance of  $M$  in Period 2

# When can NC do better than RS?

Relative size of optimal intra- and inter-period revenues is the key.

- ▶ Scenario A: Optimal inter - period revenue is larger  $\Rightarrow$  NC outperforms.

$$F_1 = F_A = \{v, p(v)\} = \{(2, \frac{1}{2}), (4, \frac{1}{2})\}, \quad \mathbb{E}_A = 3.$$

$$F_2 = F_B = \{v, p(v)\} = \{(2, \frac{1}{2}), (4, \frac{1}{4}), (8, \frac{1}{8}), (16, \frac{1}{16}), (32, \frac{1}{16})\}, \quad \mathbb{E}_B = 6.$$

$$REV^{RS} = 4, \quad REV^{NC} = 4.5 \uparrow 12.5\%$$

- ▶ Scenario B: Optimal intra - period revenue is larger  $\Rightarrow$  RS outperforms.

$$F_1 = F_B, F_2 = F_A$$

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

# Experimental Design $2 * 2$

## Two Mechanisms \* Two Scenarios

- ▶ Non-Clairvoyant Dynamic Mechanism (NC)
- ▶ Repeated Static Mechanism (RS)
- ▶ Scenario A ( $S_A$ )
- ▶ Scenario B ( $S_B$ )

## Non-Clairvoyant Environment

- ▶ Participants as the **Buyer** trading with **Robot Seller**,  $c = 0$ ,
- ▶ **Two periods:** The buyer can buy one item in each period from the seller
- ▶ **Non-clairvoyance :** The distribution of buyer's value ( $F_t$ ) is common knowledge only in that period
- ▶ **Incomplete Information:** Only buyer knows his value for the item in each period,  $v_t$ , independent draw.
- ▶ **Endowment = 50**

# Mechanism - Repeated Static (RS)

## Period 1

- ▶ Seller sets a reserve price  $r_1$  based on the distributional knowledge  $F_1$ .
- ▶ Buyer learns his value ( $v_1$ ), makes a bid :  $b_1$
- ▶ Buyer can get the item only when  $b_1 \geq r_1$  and pay  $p_1 = r_1$ .

## Period 2

- ▶  $F_2 \Rightarrow r_2, v_2 \Rightarrow b_2$ , pays  $p_2 = r_2$  if  $b_2 \geq r_2$

## Myerson's Auction

monopoly price:  $r_1 = r_2 = 2$

$$r_A = 2 \in \{\arg \max_r r \cdot P(v_A > r)\}, \quad r_B = 2 \in \{\arg \max_r r \cdot P(v_B > r)\}$$

# Mechanism - Non-Clairvoyant Dynamic (NC)

How the dynamic mechanism work?



Half chance of free item in period 1

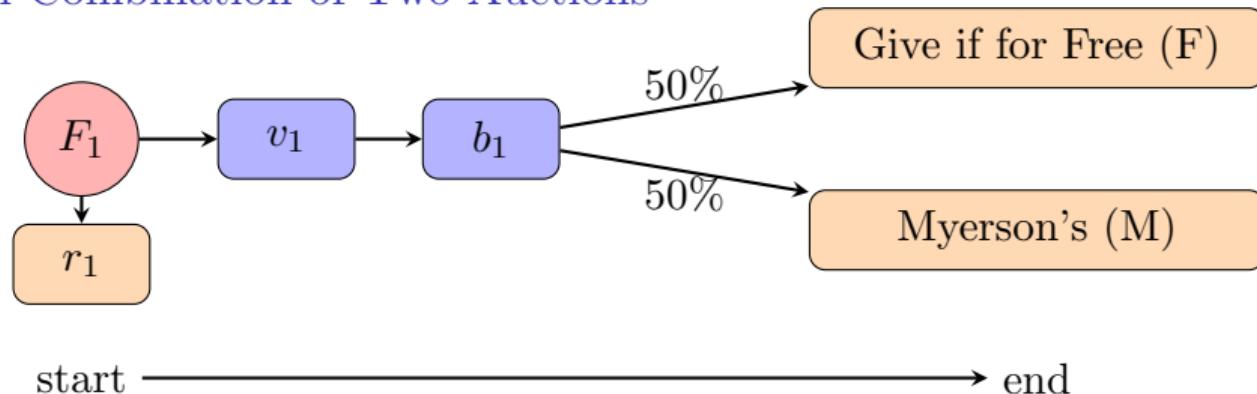


Half chance of upfront fee in period 2

## Non-Clairvoyant Mechanism in Period 1

- ▶ Seller sets a fixed reserve price  $r_1$  based on the distribution  $F_1$ .
- ▶ Buyer learns his value ( $v_1$ ), makes a bid :  $b_1$
- ▶ Buyer has 50% chance to get the item for free:  $p_1 = 0$ ;  
Otherwise, buyer can get the item only when  $b_1 \geq r_1$  and pay  $p_1 = r_1$ .

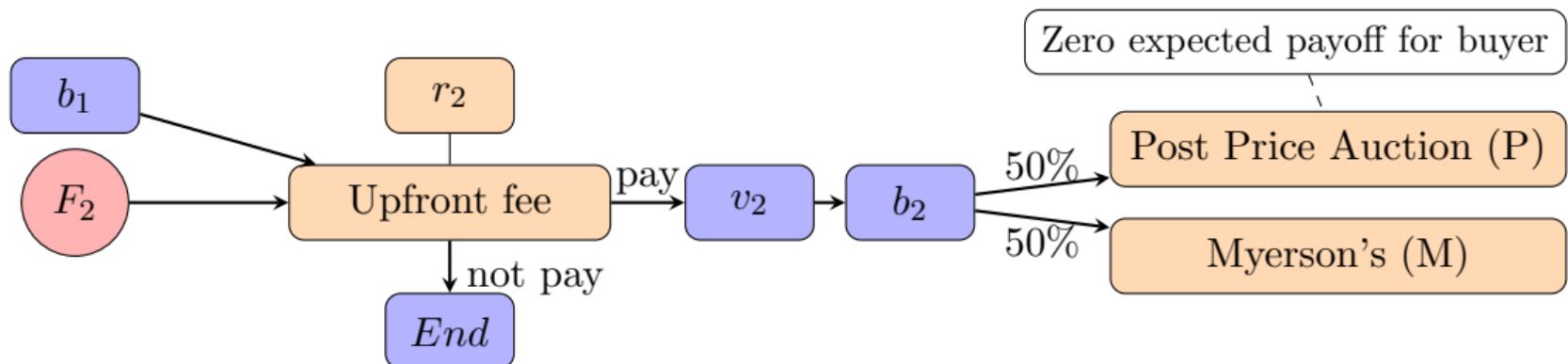
### Uniform Combination of Two Auctions



## Non-Clairvoyant Mechanism in Period 2

- ▶ Seller sets an upfront fee  $s_2 = \min(b_1, E(v_2))$ .
- ▶ Buyer decides pay or leave. If buyer leave ( $enter = 0$ ), game over.
- ▶ If buyer pays, ( $enter = 1$ ),
  - ▶ Buyer learns his value,  $v_2$ , and makes a bid:  $b_2$
  - ▶ Buyer has 50% chance to get refund on the upfront fee ( $luck = 1$ ).
  - ▶ Seller sets two reserve prices ( $r_2$ ) based on the  $F_2, luck$  for each given  $m_2$ ,  
Buyer can get the item only when  $b_2 \geq r_2$  and pay  $p_2 = r_2$

## Uniform Combination of Two Auctions



# Hypotheses

## Hypothesis 1 - On Revenue Comparison

- ▶ In Scenario A ( $S_A$ ), the non-clairvoyant mechanism (NC) generates greater revenue than the repeated static mechanism (RS);
- ▶ In  $S_B$ , NC generates less revenue than RS.

## Hypothesis 2 - On Individual Rationality

- ▶ Some buyers choose not to pay the upfront fee, such that the experimental revenue of the non-clairvoyant mechanism is less than its theoretical prediction.

## Hypothesis 3 - On Incentive Compatibility

- ▶ Participants' bids are closer to true value under NC than RS.

## Experiments

- ▶ 256 George Mason Students. September to November 2021.

Treatment	Non-Clairvoyant	Scenario A		Scenario B	
		Repeated	Static	NC	RS
Age	21.6		22.3	21.9	22.7
Gender (Male=1)	0.48		0.44	0.52	0.47
Risk aversion	4.46		4.90	4.55	4.63
Observation	64		64	64	64

Table 1: Summary Statistic

# Results

## Result 1.

Experimental observations match theoretical predictions.

- ▶ In  $S_A$ , the non-clairvoyant dynamic mechanism gains more revenue than the repeated static mechanism.
- ▶ In  $S_B$ , the non-clairvoyant dynamic mechanism gains less revenue than the repeated static mechanism.

# Experimental Revenue Comparison - Period 1

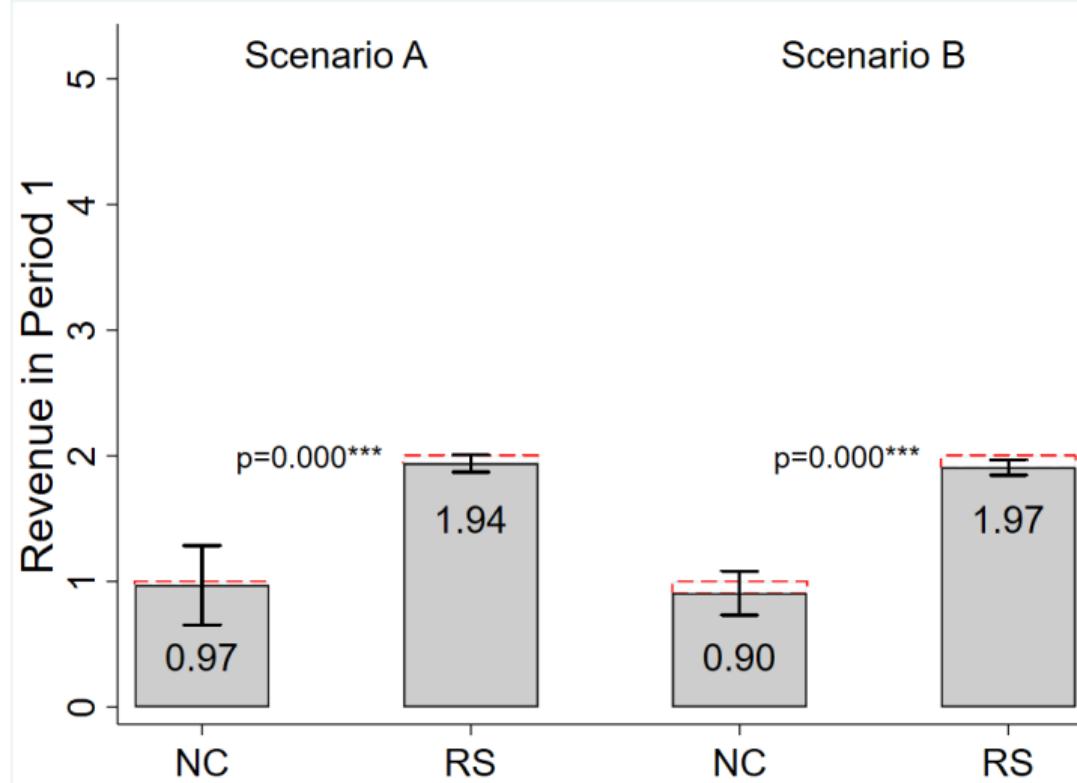


Figure 3: Revenues of Period 1 in each Treatment

# Experimental Revenue Comparison - Period 1 & Period 2

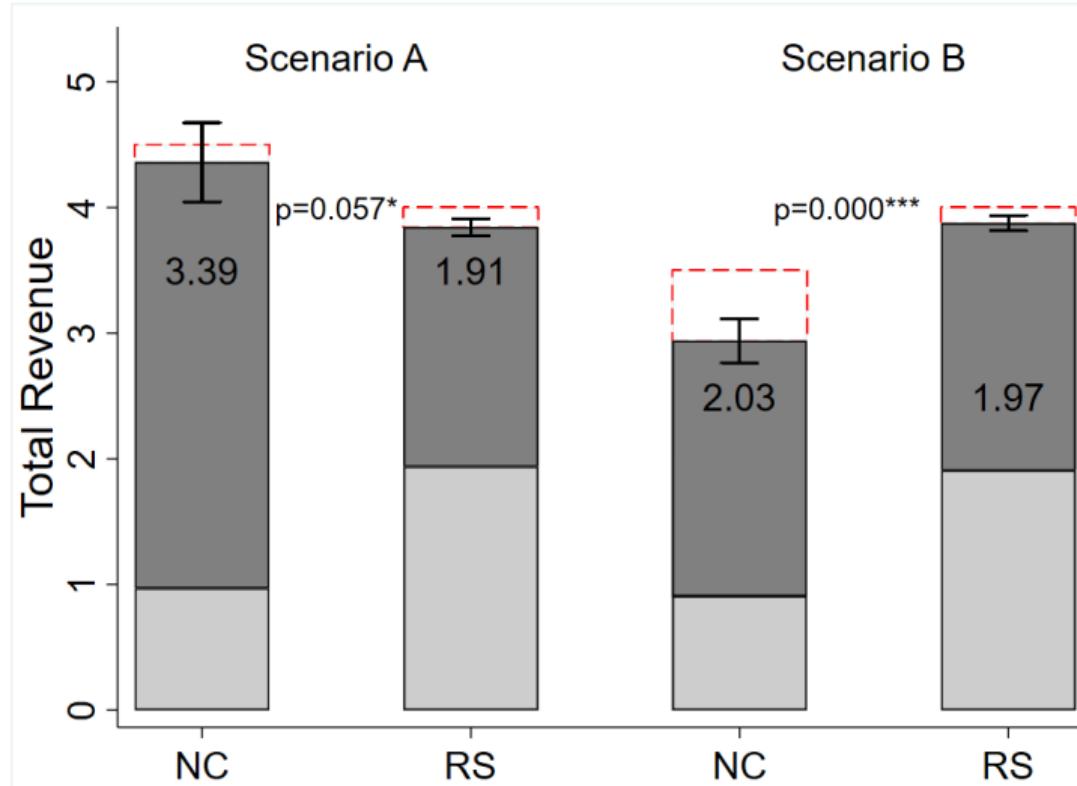


Figure 4: Revenues in each Treatment

# Results

## Result 2.

Risk aversion deters buyers from participating in the second period in NC.

- ▶ In  $S_A$ , 4 buyers quit the second period, and the number doubles in  $S_B$ .
- ▶ Revenue from NC being less than theoretically predicted.

## Revenue Loss Decomposition

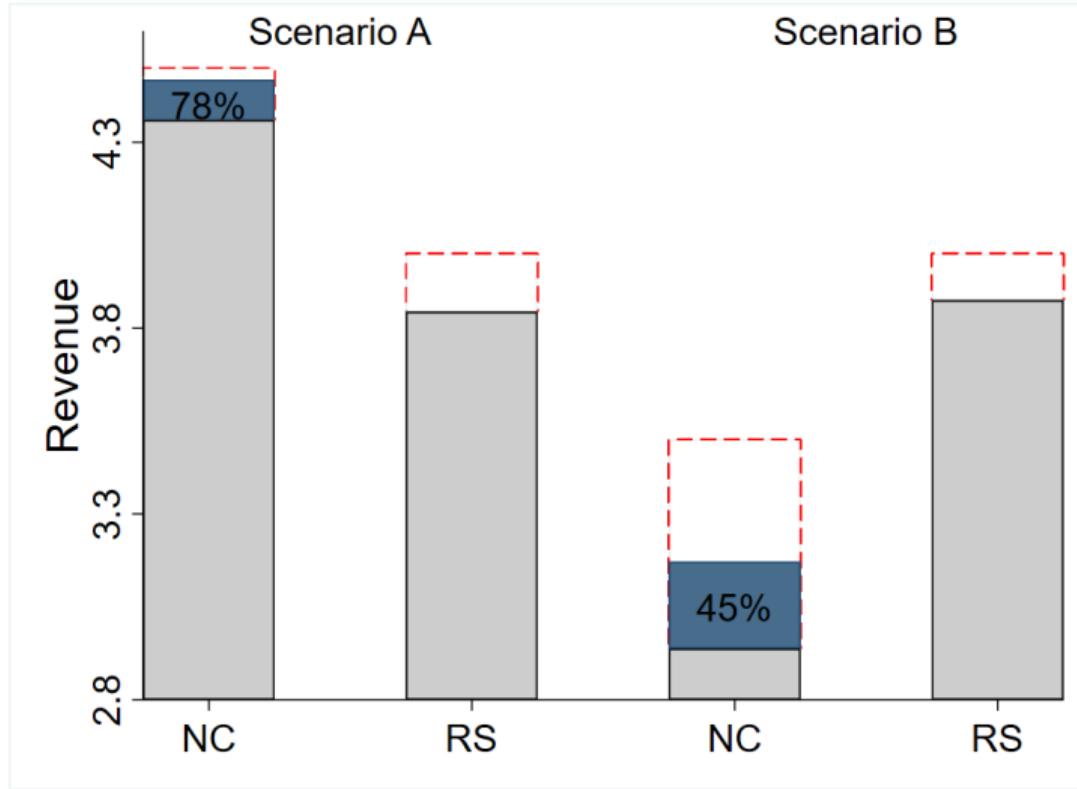


Figure 5: Revenues Increase if all Buyers enter in Period 2.

## Why not Pay the Upfront Fee (membership fee)

- ▶ “Since I got a profit the first time I didn’t want to go again with my luck”
- ▶ “Risk vs Reward..... I got lucky and did not have to pay.”
- ▶ “Based on the membership fee. ”
- ▶ “didn’t want to take any big risks so I just lowballed my offers and refused to take the membership”
- ▶ “i read the instructions carefully. i think the second period isn’t worth losing the points - i had to pay membership fee and could only get the item by bidding higher than the price set by the seller..... honestly, i haven’t been feeling lucky so i’d rather not take my chances. so i tried not to lose money in the first period and just left it as is.”

## Risk Aversion Affects Second-period Participation Indirectly

	DV: Enter in Period 2 (=1)	
	(1)	(2)
Scenario A (=1)	0.17** (0.08)	0.25* (0.13)
<i>notfree</i> <sub>1</sub> (= 1)	0.07 (0.07)	0.08 (0.11)
Scenario A * <i>notfree</i> <sub>1</sub>	-0.18* (0.10)	-0.14 (0.17)
risk aversion	-0.01 (0.01)	-0.03 (0.02)
<i>payoff</i> <sub>1</sub>	0.00 (0.01)	0.00 (0.01)
<i>upfront</i> <sub>2</sub>	-0.01 (0.03)	-0.03 (0.05)
Controls		✓

Standard errors in parentheses. \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ .

Table 2: Regression of Participation Choice on Risk attitude.

# Results

## Result 3.

- ▶ Generally overbid.
- ▶ Buyers overbid less under Non-Clairvoyant mechanism when the distribution of their valuation has low variance.

## Bid-Value Ratio Comparison

Bid/value	Non-Clairvoyant Dynamic	Repeated Static	(p-value) <sup>1</sup>
$F_A$ (Low variance)	1.264 (0.04)	1.379 (0.04)	<b>0.060*</b>
$F_B$ (High variance)	1.194 (0.05)	1.251 (0.04)	0.392
(p-value)	0.116		<b>0.008***</b>

Table 3: Bid-Value Ratio Comparison

<sup>1</sup>We report two-sided p-value under t-test.

# Conclusions

- ▶ We find the experimental observations are consistent with theoretical predictions: the optimal Non-Clairvoyant dynamic mechanism outperforms the optimal Repeated Static mechanism when it is predicted to do so.
- ▶ Buyers' risk attitudes matter in the success of Non-Clairvoyant mechanism.
- ▶ Randomization in non-clairvoyant mechanism leads buyers to overbid less.

# Discussion

- ▶ How do human sellers choose dynamic mechanisms?  $\Rightarrow Ch2$
- ▶ How do clairvoyant mechanisms perform in the lab?  $\Rightarrow$  new treatment OC
- ▶ Another implementation form of NC?  $\Rightarrow$  to be finished

# The Optimal Clairvoyant Mechanism in $S_A$

Clairvoyant menu :

$$\{(p_1, p_2)\} = \{(2, 8), (4, 2)\}$$

⇒ Cannot discriminate in Period 2:

$$REV_2^{OC} = 2$$

⇒ Extract the whole expected value in Period 1:

$$REV_1^{OC} = 3$$

Check IC and IR  $u(b_1)$

- ▶ if  $v_1 = 2$ :  $u(2) = 0 + 4 - 4 * \frac{1}{4} * 8 = 2, u(4) = -2 + 4 = 2$
- ▶ if  $v_1 = 4$ :  $u(2) = 2 + 2 = 4, u(4) = 0 + 4 = 4$

# Implementations of the Optimal Clairvoyant Mechanism in $S_A$

## Free item in Period 1 (Give it for Free)

- ▶ Buyer makes a bid in Period 1 (or quit), pays  $p_1$  if  $b_1 \geq p_1$
- ▶  $p_1 = 0$ , give it for free in Period 1

## Upfront fee in Period 2 (Posted Price Auction)

- ▶ Upfront fee equals to past bid:  $s_2 = b_1$ , buyer pays or quit
- ▶ Buyer makes a bid in Period 2 if enter pays  $p_2$  if  $b_2 \geq p_2$

# The Optimal Clairvoyant Mechanism in $S_B$

Clairvoyant menu:

$$\{(p_1, p_2)\} = \{(2, 4), (4, 1)\}$$

- ▶ Buyer makes a bid in Period 1 (or quit), pays  $p_1$  if  $b_1 \geq p_1$
- ▶  $p_1 = 2$  or  $p_1 = 4$  with equal chance

⇒ Cannot discriminate in Period 2:

$$REV_2^{OC} = 2$$

⇒ Cannot discriminate among  $v_1 \geq 4$ :

$$REV_1^{OC} = \frac{1}{2}(2 + 3) = 2.5$$

Check IC and IR  $u(b_1)$

- ▶ if  $v_1 = 2$ :  $u(2) = 0 + 0 = 0, u(4) = -2 + 2 = 0$
- ▶ if  $v_1 = 4$ :  $u(2) = 2 + 0 = 2, u(4) = 0 + 2 = 2$

## OC does not do better than NC

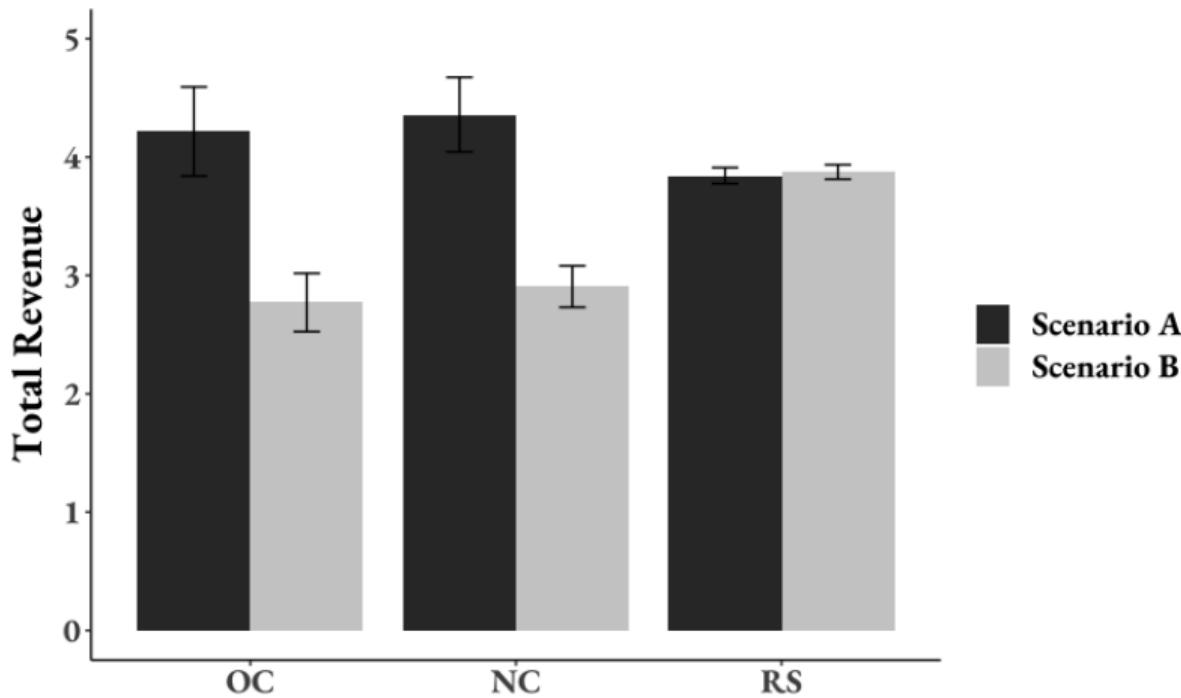
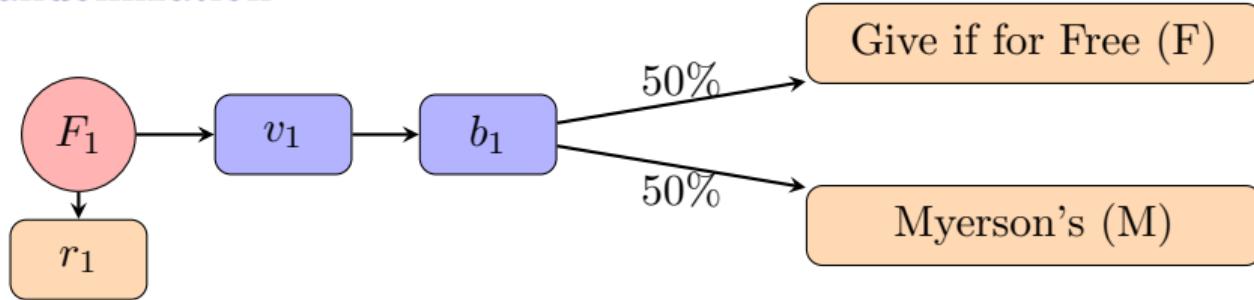


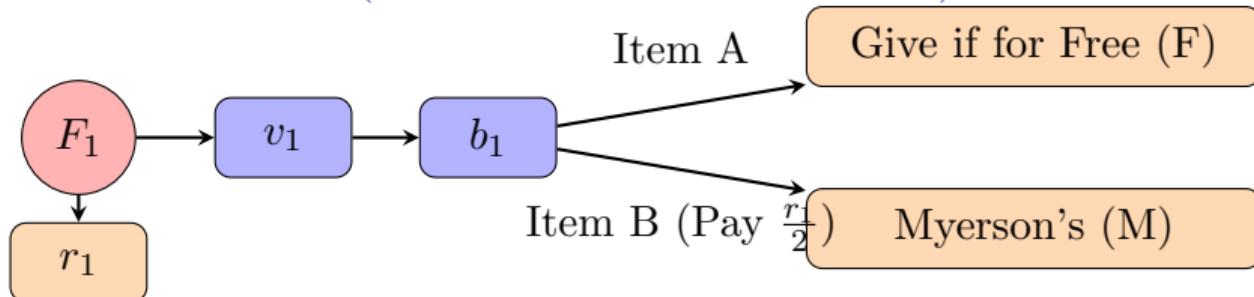
Figure 6: Revenue Comparison

# With and without Randomization in Period 1

With Randomization



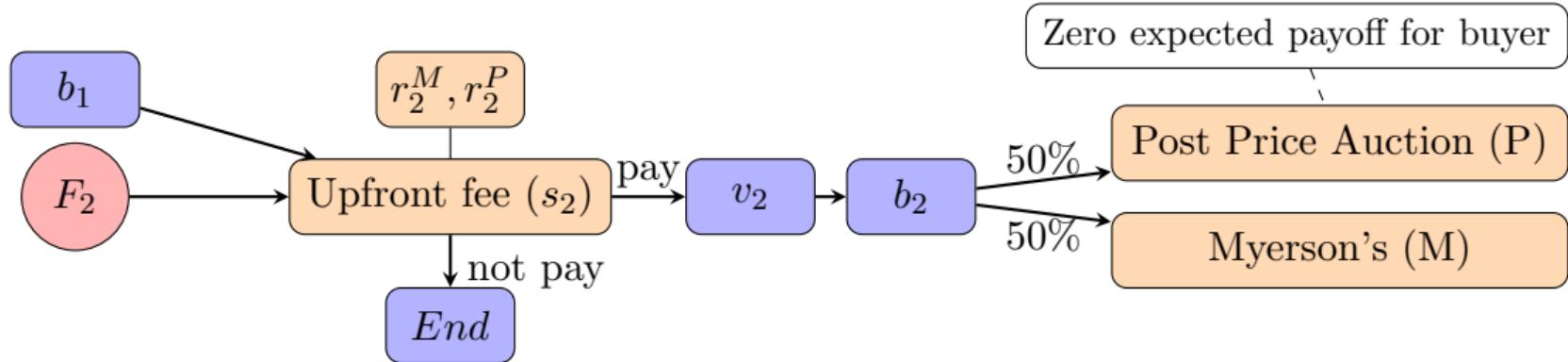
Without Randomization (two small items in Period 1)



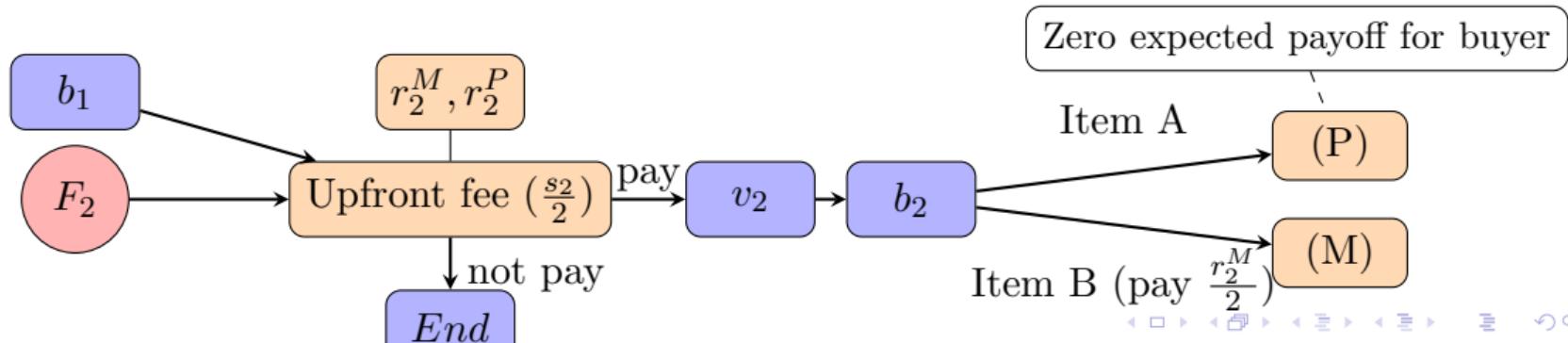
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# With or without Randomization in Period 2

With Randomization



Without Randomization (two small items in Period 2)



## Chapter 2

# How Sellers Choose Dynamic Mechanism: Information Matters

Shan Gui and Daniel Houser

# Research Question

## How do Sellers Decide on Dynamic Mechanisms?

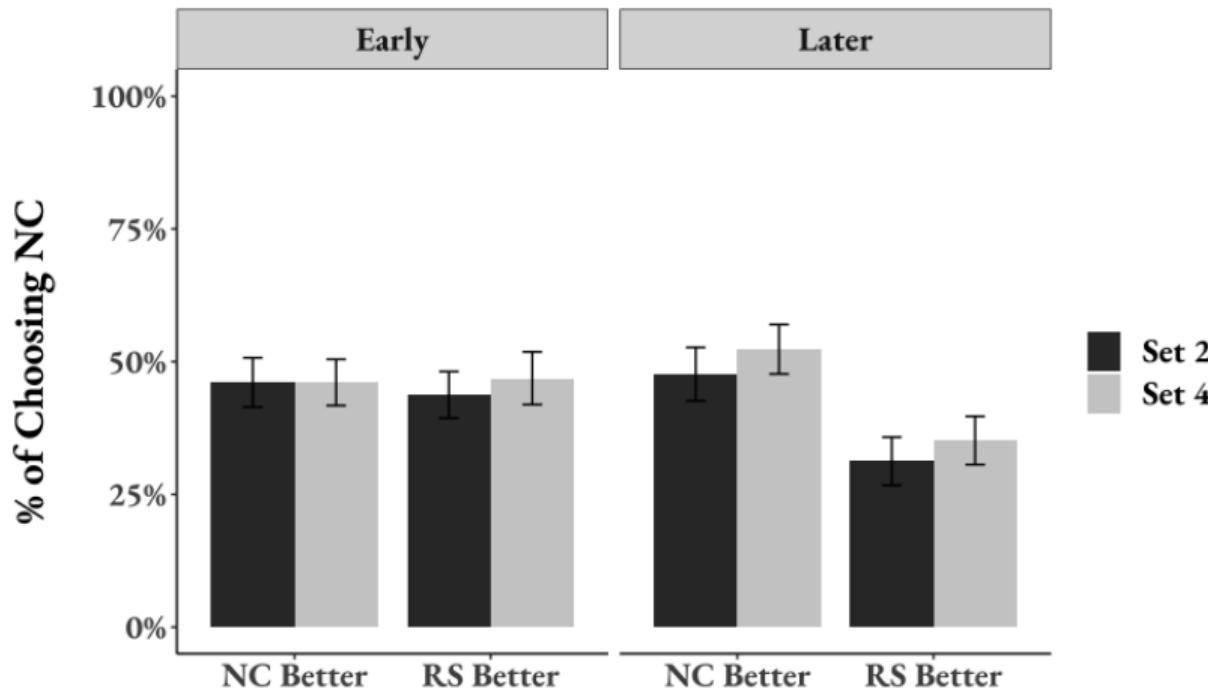
- ▶ How do Sellers choose between NC and RS?
- ▶ Can Sellers make good decision and improve revenues?

## What Information Sellers Use in Deciding on Mechanism?

- ▶ **Relative Simplicity:** NC is harder: set more prices.
- ▶ **Distributional Knowledge:** NC is optimal for some conditions.
- ▶ **Feedback:** NC gets less revenue as Buyers might quit the second period.

# Main Result: Sellers choose more correct mechanism in Later stage

Sellers Choose NC Less in RS Better



# Chapter 3

## Using (Merit-Based) Default to Reduce Gender Gaps in Contribution of Ideas: Evidence from an Online Experiment

Jingnan Chen, Shan Gui, Daniel Houser, and Erte Xiao

## Background

Women are under-represented in many domains.

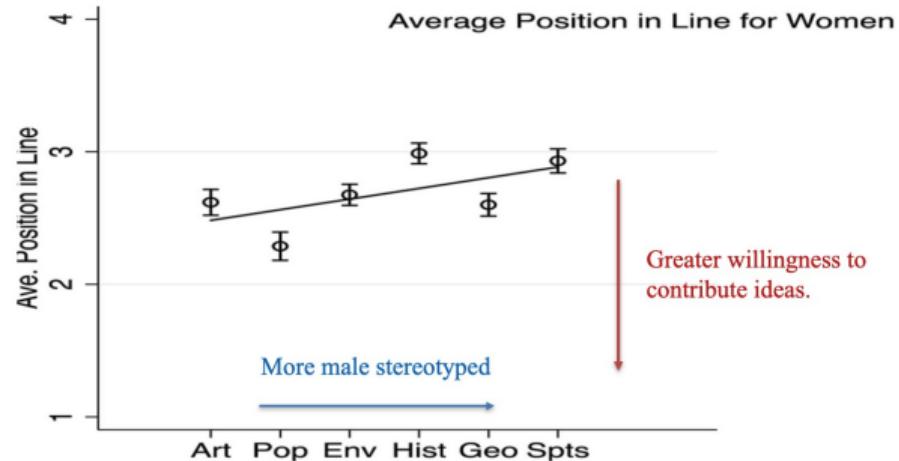
- ▶ 44.3% of labor force in S&P 500 companies are women, only 25.1% executive/senior-level managers are female.
  - ▶ The gender divide is more dramatic in male-stereotyped industries (STEM).

Greater Gender Pay Gap if Women are Under-represented.

# Willingness to Contribute and Stereotype

- Gender gap in willingness to contribute ideas is an important factor in explaining the under representation of qualified women. (Babcock and Laschever, 2007; Coffman 2014).

- Stereotype affects women's willingness to contribute. (Coffman 2014; Chen and Houser 2019)



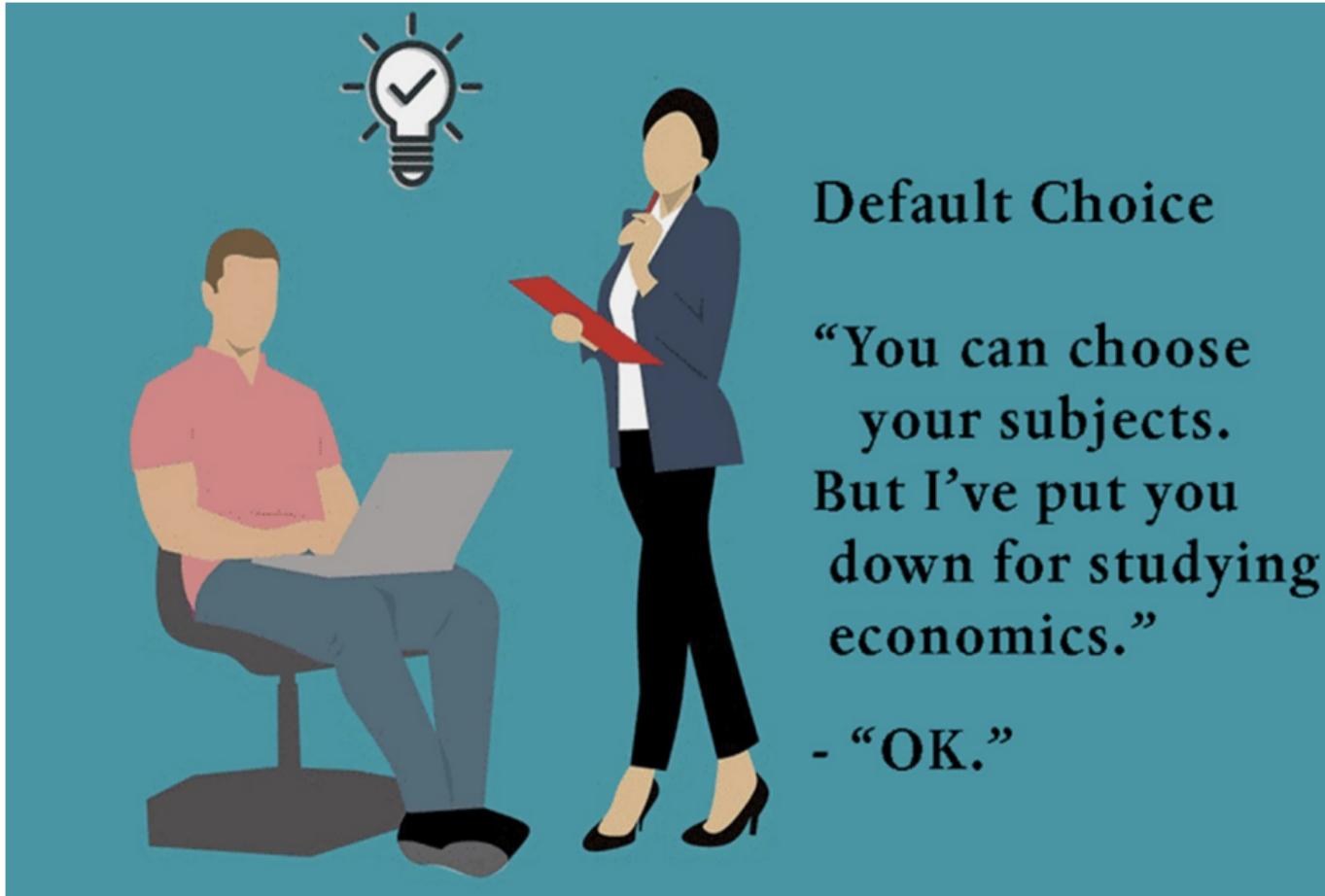
# Motivation

How to reduce the gender gap in contribution of ideas?

- ▶ Increasing pressure to adopt diversity programs – Lack of evidence
- ▶ Training programs – Limited effect
- ▶ Instructive mechanisms such as quotas – Questionable in their effectiveness



What else can we try to encourage women to contribute more to a group?



## Default Choice

“You can choose  
your subjects.  
But I’ve put you  
down for studying  
economics.”

- “OK.”

## Default Effect

- ▶ People generally **stay with** the pre-selected choice significantly more frequently.
- ▶ Widely used technique in environment, consumer, and healthrelated domains.
- ▶ Erkal et al. (2022): opt-out mechanism mitigates the gender gap in participating leadership selection.

## Merit-based or Random-assigned?

- ▶ Individuals react differently toward merit and luck.
- ▶ More willingness to redistribute, steal, lie, and bargain in luck-based mechanisms. (Cappelen et al., 2007; Gravert, 2013; Kajackaite, 2018 ;Cherry et al., 2002)

# Merit Defaults on Contributing Ideas

Only high-qualified individuals are defaulted to contribute.



## Enhancing the default effect

- ▶ Stay with pre-selected options more when deserving the positions.

## Building confidences

- ▶ Being defaulted indicates high ability ⇒ mitigates stereotype effect.

## Promoting the right leader

- ▶ Defaults matched with performances.

## Research Questions

- ▶ Can default options promote greater willingness to contribute ideas?
  - ▶ Whether merit-default is more effective? What is the mechanism behind it?
  - ▶ Can the default option mitigate the stereotype effect on the contribution of ideas?

# Experimental Task

Three parts with a questionnaire (Coffman (2014) and Chen and Houser (2019))

- ▶ Part A – 30 MCQs from 6 categories with varying gender stereotype.  
Individual task.
- ▶ Part B – New 30 MCQs with willingness to contribute elicitation. Group task in pairs.
- ▶ Part C – Confidence elicitation for questions answered in Part B. Individual task.

# Experimental Task - Part A

## Part A - Question 1 of 30

DIS: Finish the lyrics from Aladdin: "I'm like a shooting star, I've \_\_\_\_" My answer is:

- Come to shine
- Come so far
- Danced across the sky
- Got a whole new world
- Lived the night sky

Next

# Experimental Task - Part A

## Part A - Question 1 of 30

DIS: Finish the lyrics from Aladdin: "I'm like a shooting star, I've \_\_\_\_" My answer is:

- Come to shine
- Come so far
- Danced across the sky
- Got a whole new world
- Lived the night sky

Next

## Experimental Task - Part B

### Part B - Question 10 of 30

SPORTS&GAMES: Which of these NHL teams is from New Jersey? My guess is:

- Ducks
- Flames
- Devils
- Jets
- Rangers

My position in line is:

- 1
- 2
- 3
- 4

Next

# Experimental Task - Part B

## Part B - Question 10 of 30

SPORTS&GAMES: Which of these NHL teams is from New Jersey? My guess is:

- Ducks
- Flames
-   Devils
- Jets
- Rangers

My position in line is:

- 1
- 2
- 3
- 4

Next

# Experimental Task - Part C

## Part C - Question 25 of 30

KARD: Who has Khloe Kardashian been married to? My guess was:

- Lamar Odom
- French Montana
- Jonathan Cheban
- Kanye West
- Kobe Bryant

I think the chance of my answer being right is \_\_\_\_ %. The randomly-drawn robot should answer for me if its accuracy is greater than that.

I think the chance of my other group member's answer being right is \_\_\_\_ %. The randomly-drawn robot should answer for me if its accuracy is greater than that.

Next

# Experimental Task - Part C

## Part B - Question 10 of 30

SPORTS&GAMES: Which of these NHL teams is from New Jersey? My guess is:

- Ducks
- Flames
-   Devils
- Jets
- Rangers

My position in line is:

- 1
- 2
- 3
- 4

Next

# Four Treatments

Treatment differs only in Part B

- ▶ Control – No default or feedback
- ▶ Merit default

Default to 1 for all five questions if performs better in that category

Default to 4 otherwise

- ▶ Random default (No feedback)
- ▶ Random default (Feedback)

# Treatments with Defaults

## Part B - Question 4 of 30

KARD: What is the name of the Kardashian's clothing store? My guess is:

- Kardashian
- KimKloKourt
- Kar Clothes
- KUWTK
- Dash

My position in line is:

- 1
- 2
- 3
- 4

Next

# Treatments with Feedback

## Part A Performance Feedback

Category	Best Performer
Art & Literature	Your group member
Cars	Your group member
Disney movies	You
Kardashians	Your group member
Sports	Your group member
Videogames	Your group member

# Experimental Procedure

- ▶ Online experiment, July – Aug, 2023.
- ▶ Carried out on Prolific.
- ▶ 804 subjects. 52% female, average age 35.
- ▶ One-to-one matching. The first wave (402 subjects) experienced no defaults or feedback (pooled into Control in data analysis).

## Result 1. Pure Default Effect (Control VS. RD\_NF)

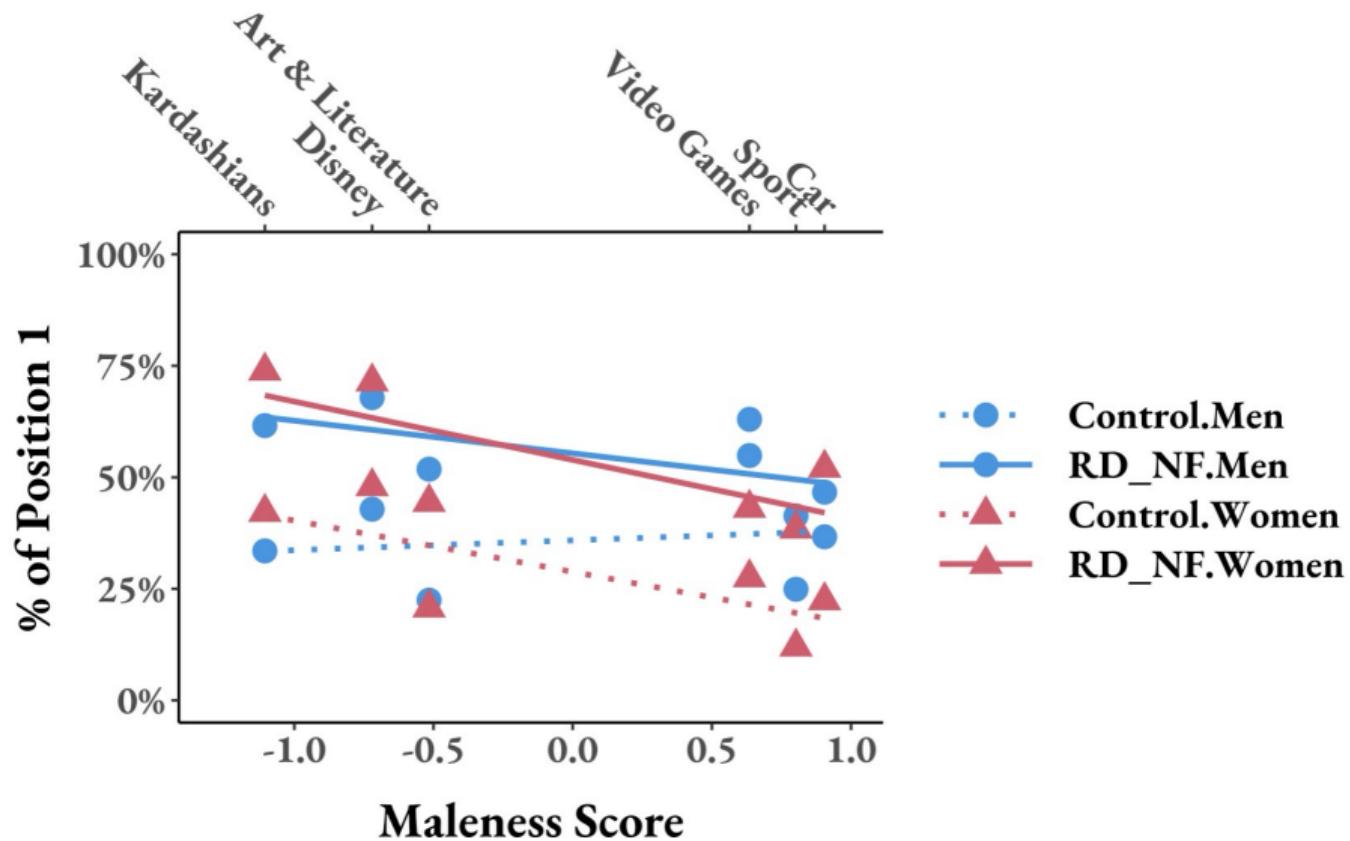
R0. Gender gap and gender stereotypes exist in Control.

- ▶ Gender gap: women are less willing to choose position 1 compared with men.
- ▶ Stereotype effect: women are less willing to choose position 1 in women-dominated categories.

R1. (Random-) Default option mitigates the gender gap.

- ▶ Default Effect: Both men and women choose position 1 more in RD\_NF than in Control.
  - ⇒ No Gender gap: In RD\_NF, women are less willing to choose position 1 as compared with men.
  - ⇒ Stereotype effect exists: In RD\_NF, women are still less willing to choose position 1 in women-dominated categories.

## Result 1. Pure Default Effect



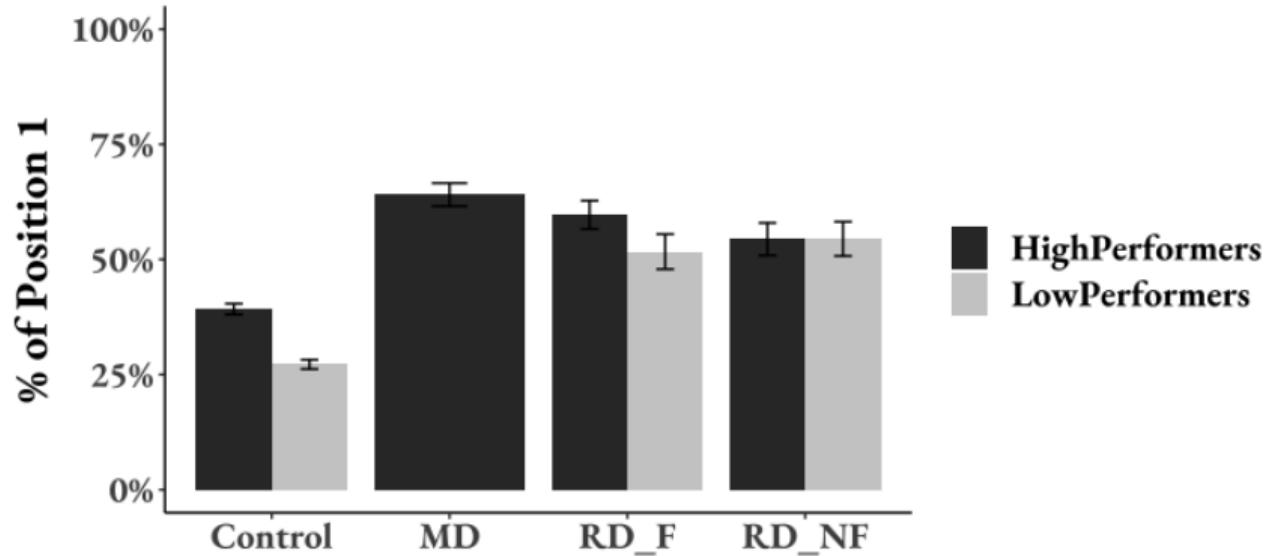
## Result 2. No Merit Effect (Merit vs. RD\_F, RD\_NF)

### R2. The merit default does not enhance the default effect

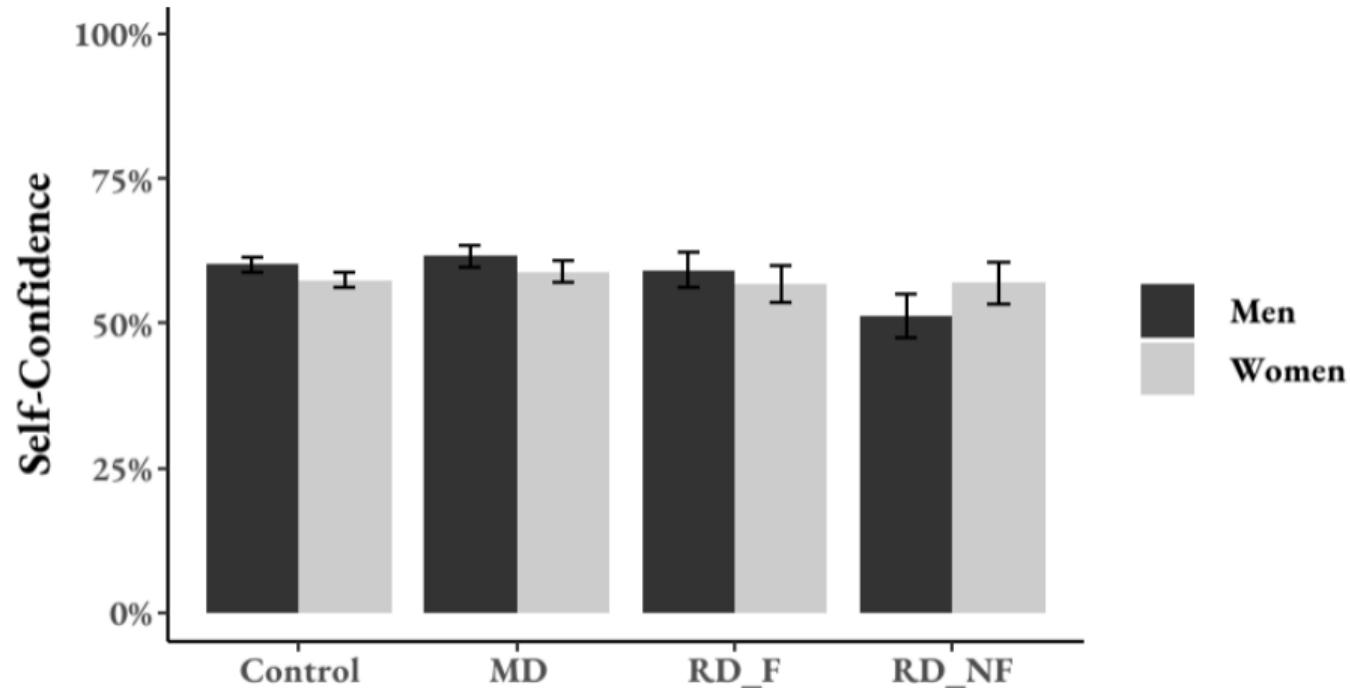
High performers: subjects in wave 2 who answer questions correctly in Part A more than or equal to their partner.

- ▶ No Merit-information effect: High performers in MD and RD\_F are not more willing to contribute ideas, as compared with RD\_NF.
- ▶ No Merit-legitimacy effect: High performers in MD are not more willing to contribute ideas, as compared with RD\_F.

## Result 2. No Merit Effect



### R3. Defaults do not affect self-confidence



## Conclusion and Discussion

Default option is effective in changing people's willingness to contribute.

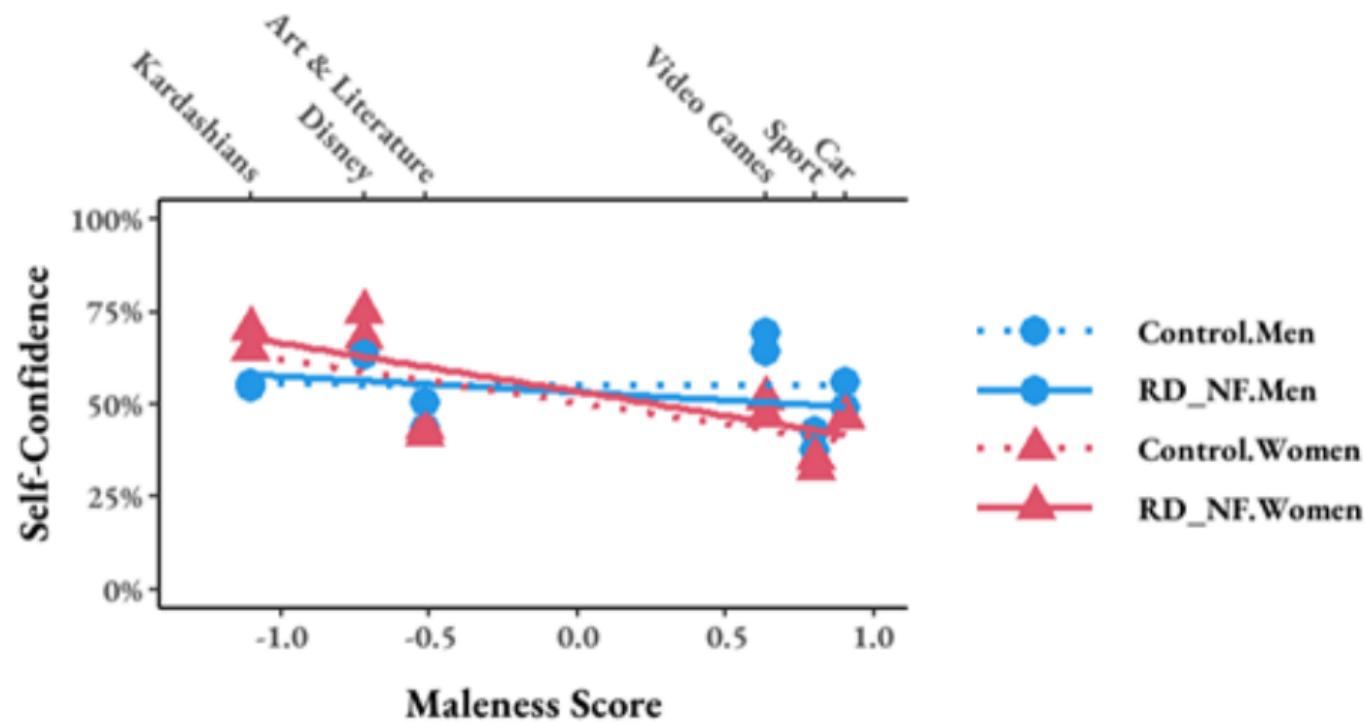
- ▶ Both random default and merit default mitigates the gender gap.
- ▶ However, the default option is ineffective in correcting the stereotype bias in the willingness to contribute.

How to mitigate the stereotype effect?

- ▶ If gender stereotype is a norm such that women should not play an active role in contributing ideas in a group, then default effects might show up in the long run.

*Thank you!*

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