

Peer prediction markets to elicit unverifiable information

Aurélien Baillon ¹ Cem Peker ² Sophie van der Zee ³

December 20, 2022

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³Erasmus School of Economics, Erasmus University Rotterdam

Background

Education:

- PhD in Economics (30.03.2023, Tinbergen Institute, Netherlands)
- BSc in Industrial Engineering, Bogazici University

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Publications:

- Peker, C. (2022). Extracting the collective wisdom in probabilistic judgments. *Theory and Decision*. doi: 10.1007/s11238-022-09899-4
- Peker, C. (2022). Incentives for self-extremized expert judgments to alleviate the shared-information problem. *Decision*. doi.org: 10.1037/dec0000198

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Today's paper: Peer prediction markets to elicit unverifiable information (joint with A. Baillon and S. van der Zee)

More info: <https://cempeker.github.io/>

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“Have you stood less than 6 feet apart from another person in a queue yesterday?”

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2. ...report honestly (**incentives to lie?**)

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Incentivize carefully considered and truthful answers?

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Incentivize carefully considered and truthful answers?

Your answer is unverifiable!

Carefully considered and truthful answers

“Have you stood less than 6 feet apart from another person in a queue yesterday?”

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Peer Prediction (Miller et al., 2005):

- “Yes” and “No” types have different beliefs on others’ answers

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Peer Prediction (Miller et al., 2005):

- “Yes” and “No” types have different beliefs on others’ answers
- **Your prediction on others’ answers is verifiable!**

Peer-Prediction Market

Your prediction on others' answers is verifiable!

This paper: **Peer-Prediction Market (PPM)**

- One-shot market, buy/sell a single asset
- Trade \equiv A bet on others' answers

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This paper: **Peer-Prediction Market (PPM)**

- One-shot market, buy/sell a single asset
- Trade \equiv A bet on others' answers
- **Trades reveal carefully considered and truthful answers**
- Theory & evidence from 2 experimental studies

The Formal Framework

The framework

- *Center* asks a binary question $\{ \text{Yes}, \text{No} \}$
- N risk-neutral *agents*

The framework

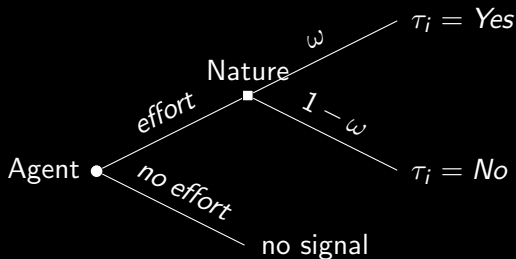
- *Center* asks a binary question $\{\text{Yes}, \text{No}\}$
- N risk-neutral *agents*
- Each agent i **can receive** a costly signal $\tau_i \in \{\text{Yes}, \text{No}\}$.
Signal cost = c_i

The framework

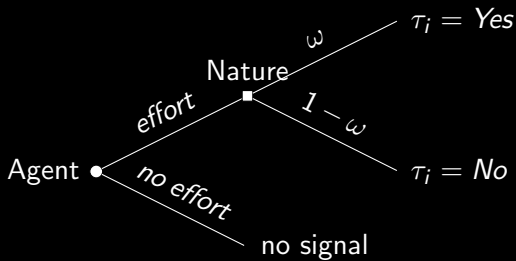
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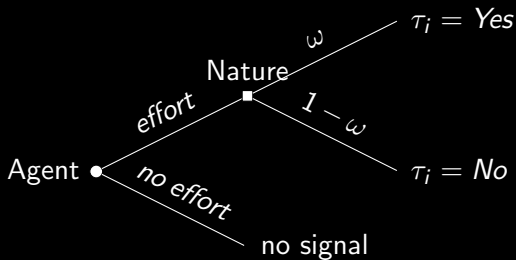
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“Have you stood less than 6 feet apart from another person in a queue yesterday?”

Signal $\tau_i \equiv$ honest answer. Why is τ_i costly?

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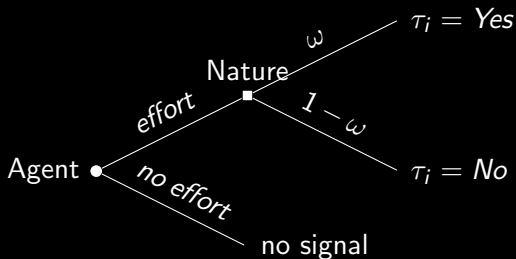


“Have you stood less than 6 feet apart from another person in a queue yesterday?”

Signal $\tau_i \equiv$ honest answer. Why is τ_i costly?

Socially stigmatized behavior → **Unwilling to recall**

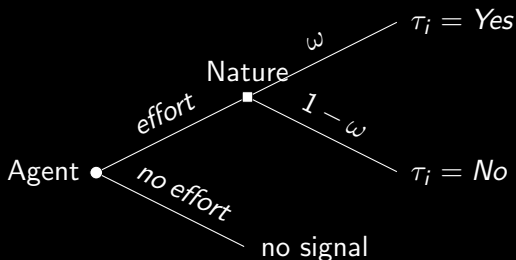
The framework



Assumptions:

- Common prior expectation $E[\omega]$ on ω .
- $E[\omega]$ is public knowledge.
- Agents follow Bayesian updating.

The framework



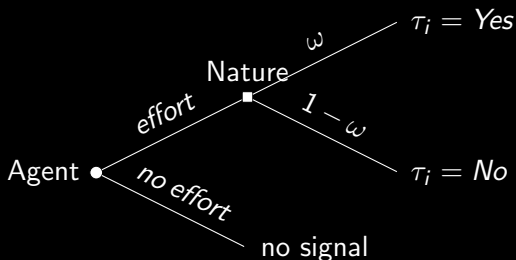
3 groups of agents with posterior expectations:

$$E[\omega | \text{effort and } \tau_i = \text{Yes}]$$

$$E[\omega | \text{effort and } \tau_i = \text{No}]$$

$$E[\omega | \text{no effort}] = \text{Prior} = E[\omega]$$

The framework



Posterior expectations satisfy:

$$E[\omega | \tau_i = \text{Yes}] > E[\omega] > E[\omega | \tau_i = \text{No}]$$

“Yes”-types expect $\omega > E[\omega] = \text{prior}$.

“No”-types expect $\omega < E[\omega] = \text{prior}$.

Peer prediction market

The mechanism

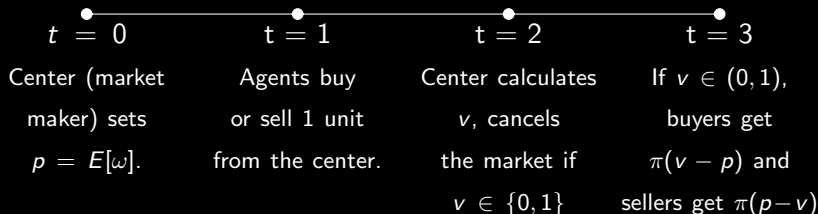
One-shot market

- Single asset
- Asset price = $p = E[\omega]$
- Asset value = v = proportion of agents who buy

The mechanism

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- Single asset
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The mechanism

Numerical example:

- Currency is dollar, $\pi = 10$
- Price: $p = E[\omega] = 0.5$
- 40% of the participants buy, $v = 0.4$
- Buyer's payoff: $10 (0.4 - 0.5) = -\$1$
- Seller's payoff: $10 (0.5 - 0.4) = \$1$

The mechanism

Strategy = Effort or not + probability of buy in various situations

The mechanism

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Agent i 's full strategy profile = $(e_i, R_i, R_i^{no}, R_i^{yes})$

- $e_i \in \{0, 1\}$ effort or no effort
- R_i probability of buy if $e_i = 0$,
- R_i^{no} probability of buy if $e_i = 1$ and $\tau_i = No$,
- R_i^{yes} probability of buy if $e_i = 1$ and $\tau_i = Yes$.

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Center would like: $e_i = 1$, $R_i^{no} = 0$, and $R_i^{yes} = 1$.

The mechanism

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Center would like: $e_i = 1$, $R_i^{no} = 0$, and $R_i^{yes} = 1$.

⇒ **Truthful strategy**: Trades reflect honest answers.

Assumption. The following are **common knowledge**:

- The market mechanism
- Signal technology, beliefs, costs and the strategy space.
- Risk-neutrality and Bayesianism of agents.

Ensures that we have a *Bayesian game* (Osborne and Rubinstein, 1994, Definition 25.1).

For convenience, we let $N \rightarrow \infty$.

Equilibrium analysis

Equilibria

Truthful equilibrium: For $N \rightarrow \infty$, truthful strategy is a Nash equilibrium if the rewards are scaled sufficiently high such that

$$\frac{c_i}{\pi} < E[\omega] (E[\omega | \tau_i = \text{Yes}] - E[\omega]) + (1 - E[\omega]) (E[\omega] - E[\omega | \tau_i = \text{No}])$$

for all $i \in \{1, \dots, N\}$

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for all $i \in \{1, \dots, N\}$

In the truthful equilibrium...

- All agents exert effort
- Yes-types buy, No-types sell
- Truthful answer \equiv Equilibrium trade

Equilibria

Truthful equilibrium: Full effort, Yes-types buy, No-types sell

How?

Equilibria

Truthful equilibrium: Full effort, Yes-types buy, No-types sell

How? Suppose,

- Agent i exerts effort ($e_i = 1$)
- All agents $j \neq i$ are truthful

Equilibria

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Types

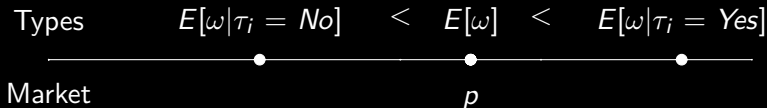
$$E[\omega | \tau_i = \text{No}] < E[\omega] < E[\omega | \tau_i = \text{Yes}]$$


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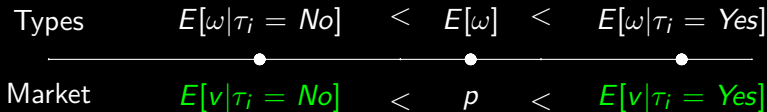


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Truthful equilibrium: Full effort, Yes-types buy, No-types sell

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Asset value (v) \equiv Proportion of buyers \rightarrow Proportion of Yes-type (ω)

Equilibria

Truthful equilibrium: Full effort, Yes-types buy, No-types sell

How? Suppose,

- Agent i exerts effort ($e_i = 1$)
- All agents $j \neq i$ are truthful

Types	$E[\omega \tau_i = No]$	$<$	$E[\omega]$	$<$	$E[\omega \tau_i = Yes]$
Market	$E[v \tau_i = No]$	$<$	p	$<$	$E[v \tau_i = Yes]$

Optimal: Buy if $\tau_i = Yes$, sell if $\tau_i = No$

Incentive to “learn” your type $\rightarrow e_i = 1$

Equilibria

Multiple equilibria

No-effort equilibrium: If $c_i > \pi$ for all $i \in \{1, \dots, N\}$, then Nash equilibria are characterized by $e_i = 0$ and $R_i \in \{0, E[\omega], 1\}$.

Expected payoffs are 0.

→ No effort when costs are too high.

Equilibria

Multiple equilibria

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Expected payoffs are 0.

→ No effort when costs are too high.

Partial effort equilibrium: There are NE in which $K < N$ agents exert no effort and buy with probability $E[\omega]$ while the other agents are truthful.

→ People with low cost exert effort, others do not.

Equilibria

Multiple equilibria

All-buy or all-sell: There exists Nash equilibria such that $e_i = 0$ and $R_i = 0$ or $R_i = 1$ for all i . Expected payoffs are 0.

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Multiple equilibria

All-buy or all-sell: There exists Nash equilibria such that $e_i = 0$ and $R_i = 0$ or $R_i = 1$ for all i . Expected payoffs are 0.

Truthful equilibrium: Strictly higher payoff than no-effort, all-buy and all-sell equilibria

Psychological costs

“Have you stood less than 6 feet apart from another person in a queue yesterday?”

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Reporting “Yes” is shameful → higher cost?

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Reporting “Yes” is shameful \rightarrow higher cost?

- **Asymmetric reporting cost:** Cost $a_i \geq 0$ of reporting “Yes”, no matter (presence of) signal.
- **Deception cost:** The cost $d_i \geq 0$ of reporting “Yes” when $\tau_i = \text{No}$ or “No” when $\tau_i = \text{Yes}$.

Psychological costs

“Have you stood less than 6 feet apart from another person in a queue yesterday?”

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Truthful equilibrium if π is scaled appropriately

Experimental Evidence

Testing PPM

Two experimental studies.

Study 1:

- Closely follows the theoretical model.
- Real effort task.

Study 2:

- Health survey, questions of 6-feet-apart type.
- Psychological costs & practical feasibility

Study 1 - A pair of boxes



100 balls
More than 60 ●



100 balls
More than 40 ●


Total : 120 ● , 80 ●

One of the boxes has been selected (Q=“more yellow” or I=“less yellow”).


Guess which one.



Study 1 - A pair of boxes



100 balls
More than 



100 balls
More than 

Total : 120 , 80 

One of the boxes has been selected (Q=“more yellow” or I=“less yellow”).

Guess which one. **Want to see a ball from the selected box?**

Study 1 - Real effort task

0	0	1	1	0	1
1	0	0	1	0	0
0	0	1	1	1	1
0	0	1	1	0	1

Count the number of 0s and you draw..




OR




Color of your draw \equiv signal


Link with theory



100 balls
More than 60 



100 balls
More than 40 


Total : 120 , 80 

0	0	1	1	0	1
1	0	0	1	0	0
0	0	1	1	1	1
0	0	1	1	0	1


- Let's say a yellow draw is equivalent to $(\tau_i = \text{Yes})$.
- $E[\omega] = 0.6$ (common prior expectation on prop. yellow).



Link with theory



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- c_i = cognitive effort of counting 0s in matrix.



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- c_i = cognitive effort of counting 0s in matrix.
- Picking Box Q \equiv Buying \equiv Reporting yellow ("Yes").

Study 1 - 3 treatments

- **Flat** fee: £3.25 completion fee.
- **Accuracy** incentives: £3.25 \pm 0.20 per prediction task if the pick is correct or not.
- **PPM**: £3.25 + PPM incentives:
Bonus: (% of people who pick the same box) – (prior).

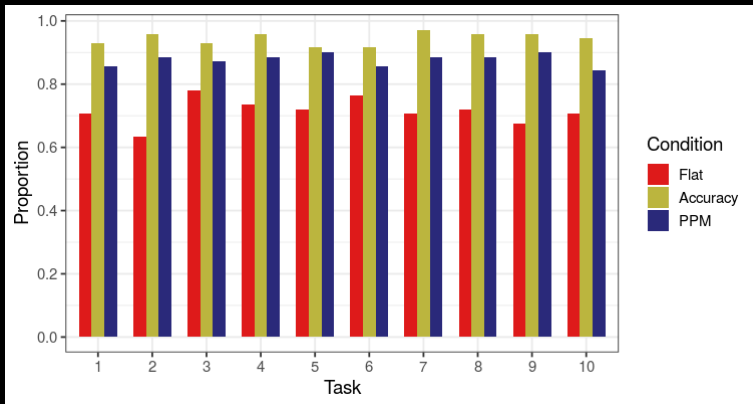
“Accuracy” is a benchmark for verifiable tasks.

Participants

- Online experiment, May 2020
- 210 U.S. citizens, students, recruited on Prolific
- 10 tasks (10 pairs of boxes, 10 matrices).

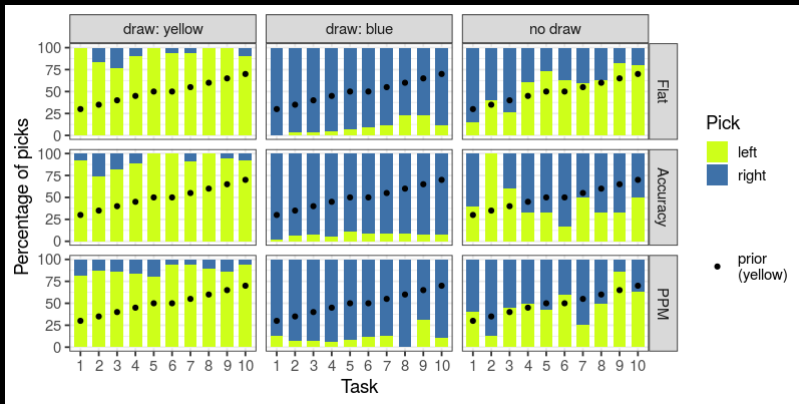
Study 1 - Effort

Proportion of subjects who complete the effort task



Accuracy > *PPM* > *Flat* in effort elicitation

Study 1 - Picks



Picks are as predicted by the truthful equilibrium.

Marginal effects, logistic regression

	<i>Dep. var.: P(effort task completed)</i>			
	<i>(whole sample)</i>		<i>(filtered sample)</i>	
	(1)	(2)	(3)	(4)
PPM	0.10** (0.03)	0.09** (0.03)	0.10** (0.03)	0.08** (0.03)
Accuracy	0.18*** (0.03)	0.18*** (0.03)	0.18*** (0.03)	0.18*** (0.03)
Age		-0.00 (0.00)		-0.00 (0.00)
Female?		0.04 (0.03)		0.04 (0.03)
US resident?		-0.02 (0.06)		-0.02 (0.06)
Num. obs.	2100	2070	2060	2030

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; + $p < 0.1$

PPM can elicit effort when incentives for accuracy are not feasible (unverifiable questions).

Study 2

Study 1: Simple task, carefully controlled setup.

Study 2: Online field experiment

- Health & safety guidelines during the Covid-19 pandemic
- Did people follow them?

Study 2

Study 1: Simple task, carefully controlled setup.

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- Health & safety guidelines during the Covid-19 pandemic
- Did people follow them? **(Difficult to measure)**

Study 2

Study 1: Simple task, carefully controlled setup.

Study 2: Online field experiment

- Health & safety guidelines during the Covid-19 pandemic
- Did people follow them? **(Difficult to measure)**
- Would they self-report their unsafe behavior? **(Unverifiable)**
- A health survey with PPM incentives

Study 2 - Covid Survey

Question 2 of 8 ([show instructions](#))

Please try to remember how many times you were in the following situation:

I was seated less than 2 metres away from someone who is not part of my household in a restaurant/cafe/bar at least once in the last 7 days.

True
(picked by 44% last week)

False
(picked by 56% last week)

Submit

Study 2 - Covid Survey

Question 2 of 8 ([show instructions](#))

Please try to remember how many times you were in the following situation:

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“True” could be underreported.

Would a PPM elicit a higher % of “True” responses?

Study 2 - True/False statements

1.	I have been in an elevator with another person in it at least once in the last 7 days
2.	I may have stood less than 2 metres away from the person in front in a queue at least once in the last 7 days
3.	I was seated less than 2 metres away from someone who is not part of my household in a restaurant/cafe/bar at least once in the last 7 days
4.	I have been in a social gathering with more than 6 people who are not part of my household at least once in the last 7 days
5.	I have been in a busy shop/market with no restrictions on number of customers at least once in the last 7 days
6.	I participated in an indoor activity with more than 6 people who are not part of my household at least once in the last 7 days
7.	I have been in a shop/market where one or more of the staff did not wear a mask at least once in the last 7 days
8.	I had an interaction with someone experiencing high body temperature, persistent cough or loss of taste/smell at least once in the last 7 days

Study 2 - Link with theory

Question 2 of 8 ([show instructions](#))

Please try to remember how many times you were in the following situation:

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If you report True, $\text{bonus} > 0$ if $\% \text{ True this week} > 0.44$

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Question 2 of 8 ([show instructions](#))

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True

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False

(picked by 56% last week)

Submit

If you report True, $\text{bonus} > 0$ if $\% \text{ True this week} > 0.44$

Analogous to PPM:

- $v = \% \text{ True this week}$
- $p = E[\omega] = 0.44$ (common prior on True)

Study 2 - Link with theory

Question 2 of 8 ([show instructions](#))

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- Mental cost of remembering.
- Shame of answering “True” or lying.

Study 2 - Experimental conditions

Weekly survey in the UK, 3 weeks, November 2020

3 Experimental conditions

Control-1 (flat fee)

I may have stood less than 2 metres away from the person in front in a queue at least once in the last 7 days.

True

False

Study 2 - Experimental conditions

Weekly survey in the UK, 3 weeks, November 2020

3 Experimental conditions

Control-1 (flat fee)

I may have stood less than 2 metres away from the person in front in a queue at least once in the last 7 days.

True

False

Treatment (PPM incentives), Control-2 (flat fee)*

True

(picked by 65% last week)

False

(picked by 35% last week)

* tests the effect of just showing the last week's %s.

Study 2 - Marginal effects, Pr(Response = "True")

	(week 2)		(week 3)	
	(1)	(2)	(3)	(4)
(Intercept)				
Control-2	0.05 (0.04)	0.04 (0.04)	-0.01 (0.04)	-0.00 (0.04)
PPM	0.11*** (0.03)	0.10** (0.03)	0.08* (0.04)	0.08* (0.04)
Age		-0.00 (0.00)		-0.00 (0.00)
Female?		0.02 (0.03)		-0.02 (0.03)
UK citizen?		-0.00 (0.03)		0.03 (0.04)
Num. obs.	1259	1259	1279	1279

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; + $p < 0.1$

Higher rate of self-reported unsafe behavior in the PPM treatment.

Contribution

Conclusion

Mechanism design literature: Explored ways to reveal private signals (Cr mer and McLean, 1988).

Peer-prediction markets: Novel solution for eliciting effort & truthful revelation.

Conclusion

Mechanism design literature: Explored ways to reveal private signals (Cr  mer and McLean, 1988).

Peer-prediction markets: Novel solution for eliciting effort & truthful revelation.

Peer prediction method (Miller et al., 2005): similar framework, but

- The complete prior must be known
- Scoring is not transparent

Bayesian truth-serum (Prelec, 2004) and follow-ups:

- Detail-free (implementer needs less), but more demanding from respondents (answer + prediction)

Usually, costly effort to acquire signal not modelled.

Conclusion

Peer prediction markets: Transparent, easy to implement.

Conclusion

Peer prediction markets: Transparent, easy to implement.

Strong assumptions, but same as or weaker than in the literature.

Limitations: Binary questions only, multiple equilibria.

Thank you!

<https://cempeker.github.io/>

References

- Cr mer, J. and McLean, R. P. (1988). Full extraction of the surplus in bayesian and dominant strategy auctions. *Econometrica: Journal of the Econometric Society*, pages 1247–1257.
- Miller, N., Resnick, P., and Zeckhauser, R. (2005). Eliciting informative feedback: The peer-prediction method. *Management Science*, 51(9):1359–1373.
- Osborne, M. J. and Rubinstein, A. (1994). *A course in game theory*. MIT press.
- Prelec, D. (2004). A bayesian truth serum for subjective data. *Science*, 306(5695):462–466.