Cognitive Uncertainty:
Measurement and Economic Consequences

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(with Thomas Graeber and other co-authors)

Cognitive uncertainty

- Standard models: people maximize and have no doubt about ex-ante optimality of their decisions
- Vast majority of behavioral models: people may make mistakes but are never nervous about screwing up
- Introspecting:
  - When you take a decision, do you really know what your utility-maximizing action is?
  - People often have meta-cognition that they may not be able to maximize
- **Cognitive uncertainty**: subjective uncertainty about which decision maximizes DEU

Examples of cognitive uncertainty

- Ex 1: given your preferences and beliefs, which equity share maximizes your expected utility? Are you sure?
- Ex 2: given your intrinsic patience, how many hours of exercise this week maximize your discounted utility? Are you sure?
- Ex 3: What is your certainty equivalent for a 70% chance of getting $25? $15? Really?
- Ex 4: Your prior is it rains with prob 10%, now you read a weather forecast that predicts rain; forecast is correct 80% of the time; what's the correct posterior belief? 65%? Or maybe 57%?

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Why does this matter for economics?

Why meta-cognition matters for econ

1. **Understanding and predicting biases / anomalies in individual DM**
   - Predicts systematic judgment and decision errors
   - Ties together behavioral anomalies that are typically viewed as distinct
   - Can be deployed to test formal economic models
   - Intuition: When clueless, we tend towards “intermediate” options

Why meta-cognition matters for econ

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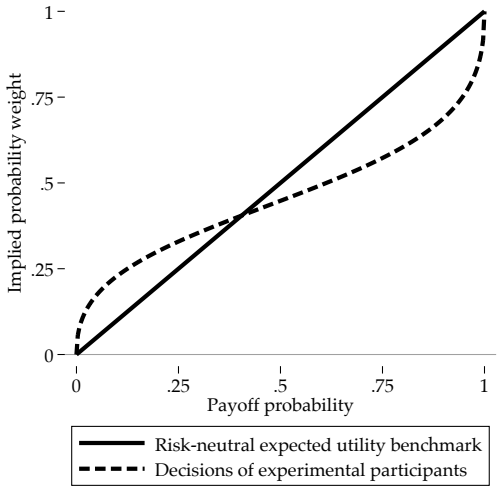
2. **Understanding whether biases matter for aggregate economic outcomes**
   - Determines whether people are likely to “select out” of economic interactions, e.g., don’t bet aggressively in markets
   - Such self-selection can filter the effect of individual biases on aggregate outcomes

References

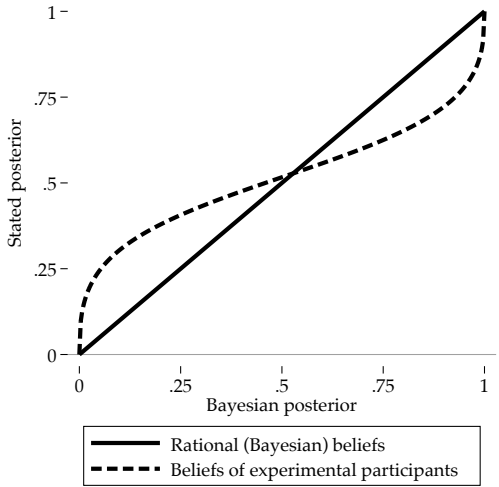
- Enke and Graeber: Cognitive Uncertainty (2019)
- Enke and Graeber: Cognitive Uncertainty in Intertemporal Choice (2021)
- Enke, Graeber and Oprea: Confidence, Self-Selection and Bias in the Aggregate (2021)

Cognitive Uncertainty: Predicting and Tying Together Anomalies

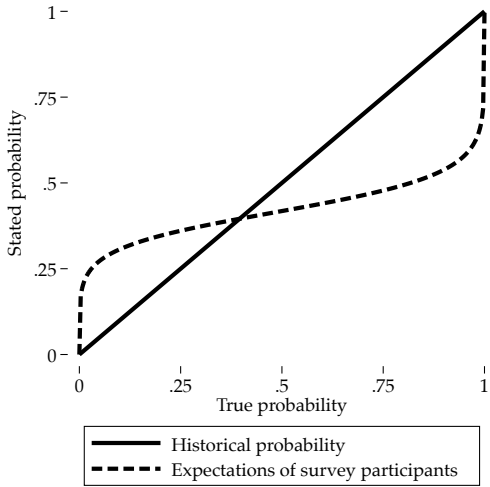
How much chance of $100 is worth to people



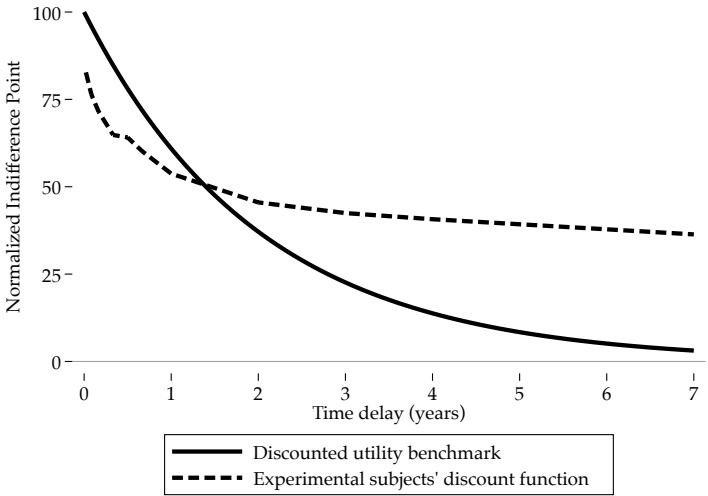
How people update beliefs from information



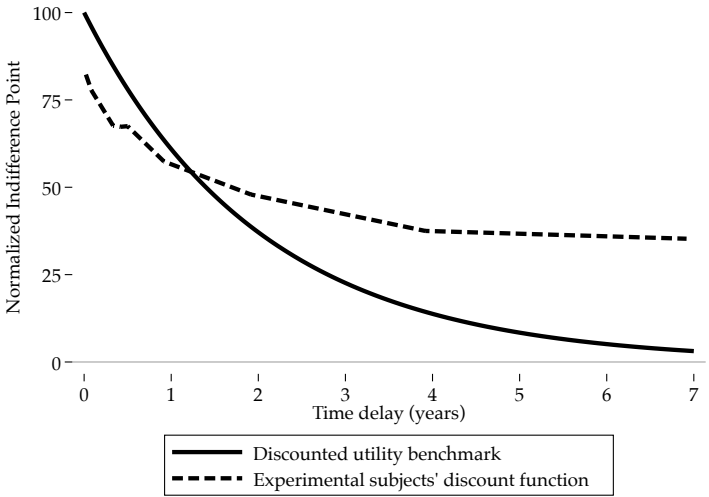
How people forecast economic events



How much $100 in future is worth to people today



Tradeoffs between two future dates



What is going on?

- One view in the literature: **domain-specific preferences or biases**
  - “Probability-dependent risk preferences”
  - “Extreme-belief aversion” / conservatism
  - Base rate insensitivity
  - Regression in economic forecasts
  - Hyperbolic discounting
- Another view: **common mechanism: complexity and cognitive noise**
  - Measurable product of cognitive noise: cognitive uncertainty

Why should cognitive uncertainty predict anomalies? I

Consider two extreme benchmarks for behavior:

1. **No cognitive constraints / endless deliberation:** agent picks utility-maximizing decision $a^*(p)$ that depends on some problem parameter p

2. **Prior to any deliberation:** agent picks "cognitive default decision" d
   - Default = **initial reaction to decision problem**, no deliberation
   - Key feature: independent of specific problem features

Why should cognitive uncertainty predict anomalies? II

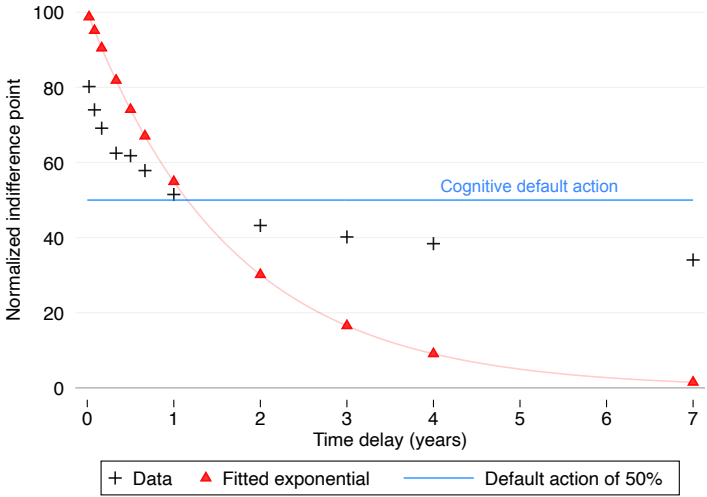
- Observed decision: $a^o = \lambda s(a^*(p)) + (1 - \lambda)d$
  - where $s(\cdot)$ is noisy cognitive signal about optimal decision
  - $\lambda \in [0, 1]$ reflects magnitude of cognitive noise, proxied by cognitive uncertainty
- Interpretation of decision process:
  1. Loosely: **Anchoring-and-adjustment** as in Kahneman-Tversky
  2. Bayesian noisy cognition models / drift-diffusion models: **agent holds prior and adjusts after mentally simulating his optimal action**

Why should cognitive uncertainty predict anomalies? III

- Average observed decision: $E[a^o] = \lambda a^*(p) + (1 - \lambda)d$
- Main implication: **compression effect**: decisions look like they treat different values of parameter p to some degree alike
- "**Cognitive attenuation**"
  - Like attenuation bias in econometrics, except happens inside people's minds

Illustration of role of cognitive uncertainty

(Never mind specific location of default)



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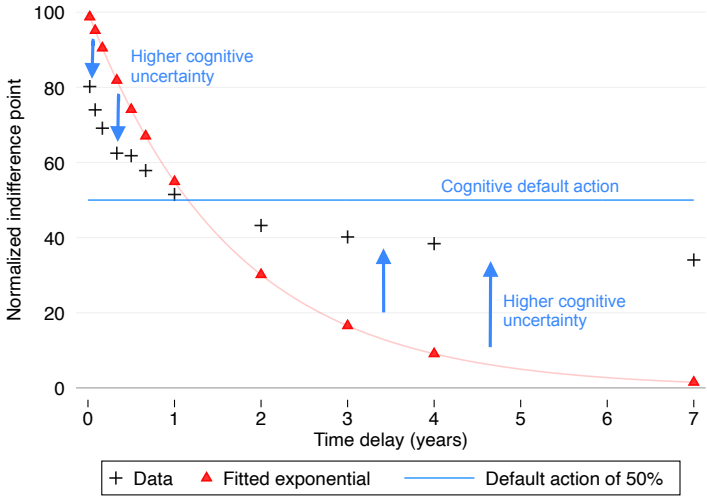

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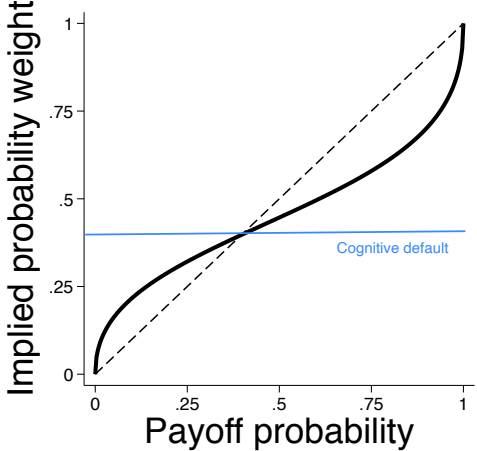

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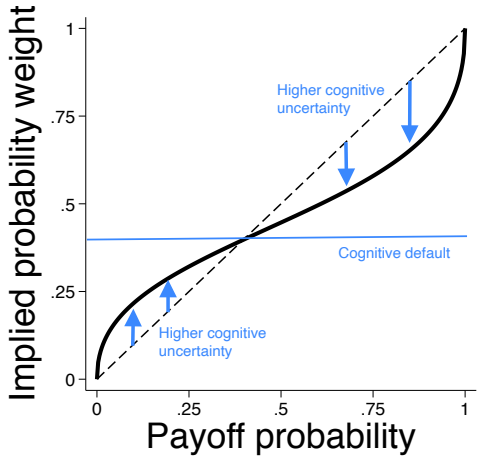

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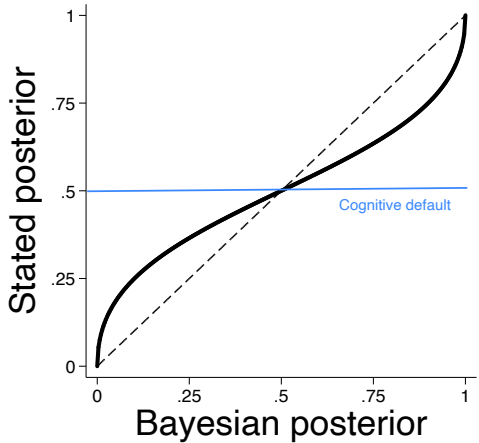

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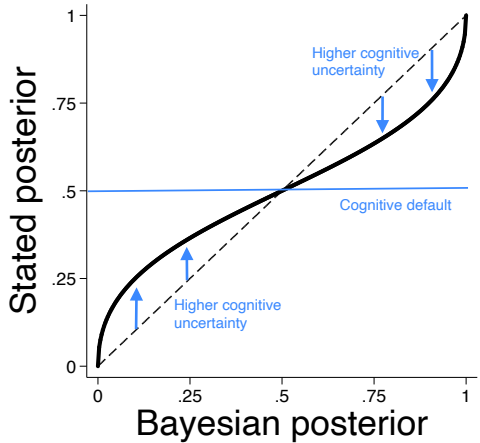


Getting to work:
Measuring cognitive uncertainty

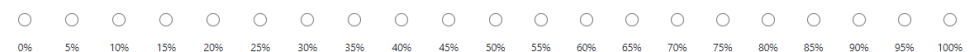
Intertemporal choice behavior

Voucher A		Voucher B
Valid in 1 year: $40 Voucher	◉ ○	Valid today: $2 Voucher
	◉ ○	Valid today: $4 Voucher
	◉ ○	Valid today: $6 Voucher
	◉ ○	Valid today: $8 Voucher
	◉ ○	Valid today: $10 Voucher
	◉ ○	Valid today: $12 Voucher
	◉ ○	Valid today: $14 Voucher
	◉ ○	Valid today: $16 Voucher
	◉ ○	Valid today: $18 Voucher
	◉ ○	Valid today: $20 Voucher
	◉ ○	Valid today: $22 Voucher
	○ ◉	Valid today: $24 Voucher
	○ ◉	Valid today: $26 Voucher
	○ ◉	Valid today: $28 Voucher
	○ ◉	Valid today: $30 Voucher
	○ ◉	Valid today: $32 Voucher
	○ ◉	Valid today: $34 Voucher
	○ ◉	Valid today: $36 Voucher
	○ ◉	Valid today: $38 Voucher
	○ ◉	Valid today: $40 Voucher

Elicitation of cognitive uncertainty

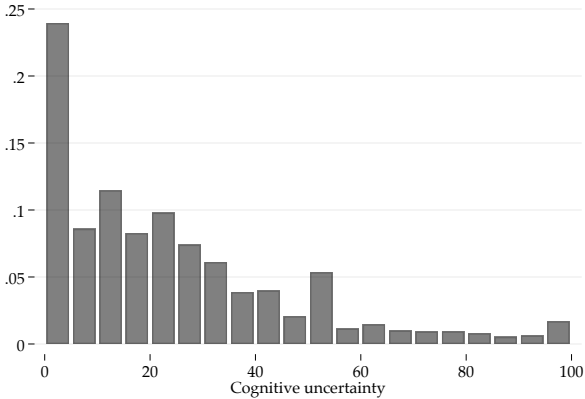
Your choices on the previous screen indicate that you value a $40 voucher that is valid **in 1 year** somewhere between a $22 and a $24 voucher that is valid **today**.

How certain are you that you actually value a $40 voucher that is valid **in 1 year** somewhere between a $22 and a $24 voucher that is valid **today**?



very uncertain **completely certain**

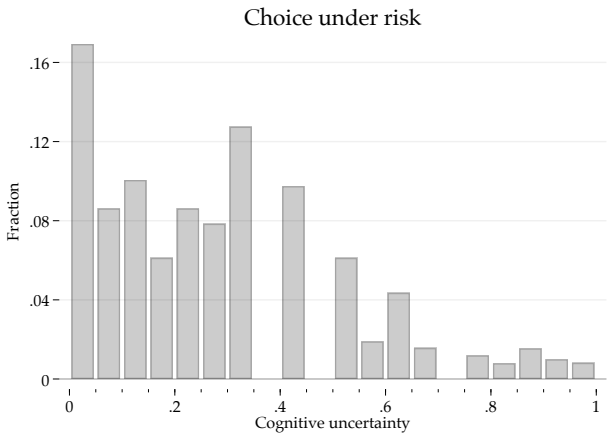
Heterogeneity in CU in intertemporal decisions



Clear evidence for cognitive uncertainty "types":

1. Large fraction of variation (50%) explained by subject fixed effects
2. CU highly correlated within subject across decision domains / tasks

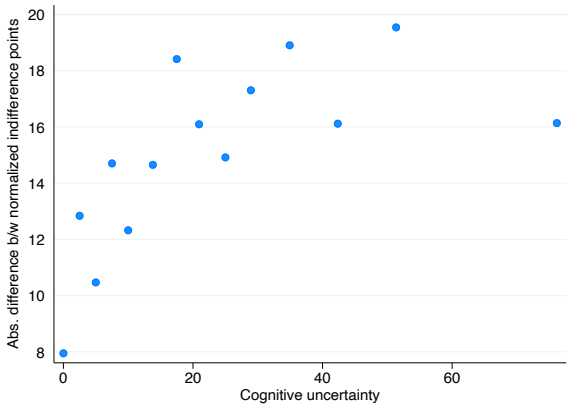
Heterogeneity in CU in lottery choices



Discussion of cognitive uncertainty measure

- **Composite measure of uncertainty**; could have many different origins:
  - Struggle with combining utils and probabilities
  - Don't know your own preferences
  - Don't know Bayes rule
  - Imperfect perception
  - Etc
- Very simple and costless to elicit
- Can easily be tweaked to be applicable to large set of experiments and surveys
- No incentives, BUT **validation with across-trial choice variability / inconsistencies**

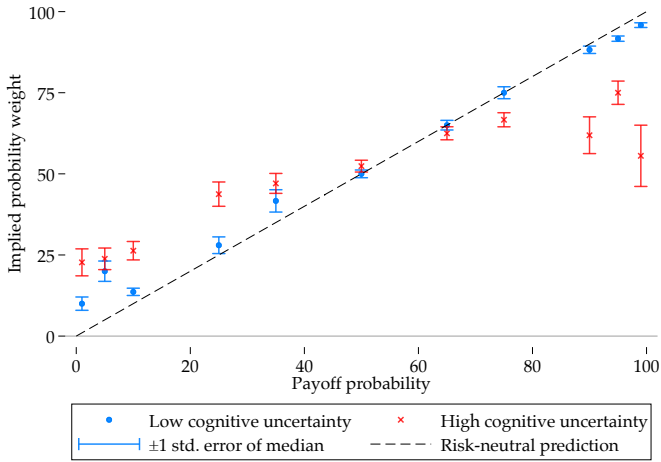
Validation: Across-trial inconsistency and CU



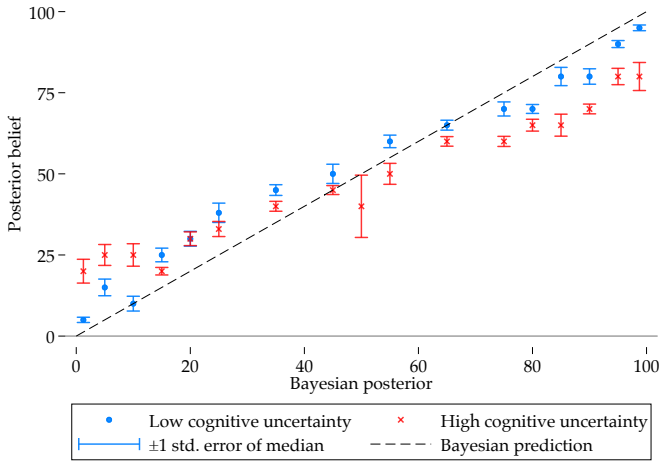
Correlation very similar in lottery choice, intertemporal choice and belief updating ($\rho \approx 0.3$)

Linking cognitive uncertainty to behaviors and beliefs

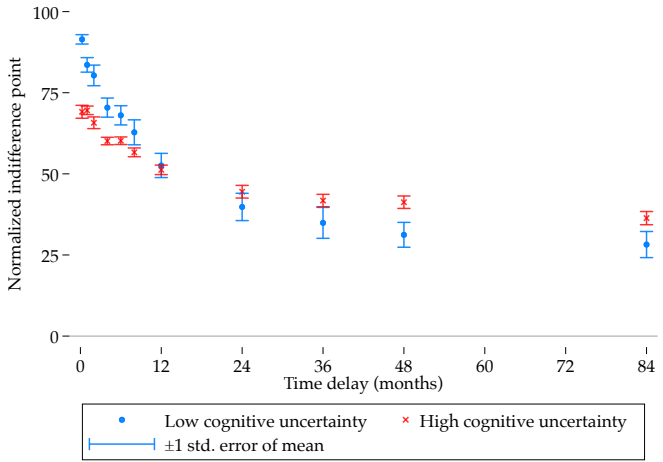
Probability weighting and cognitive uncertainty



Beliefs and cognitive uncertainty



Intertemporal choice and cognitive uncertainty



Experimentally manipulating cognitive noise

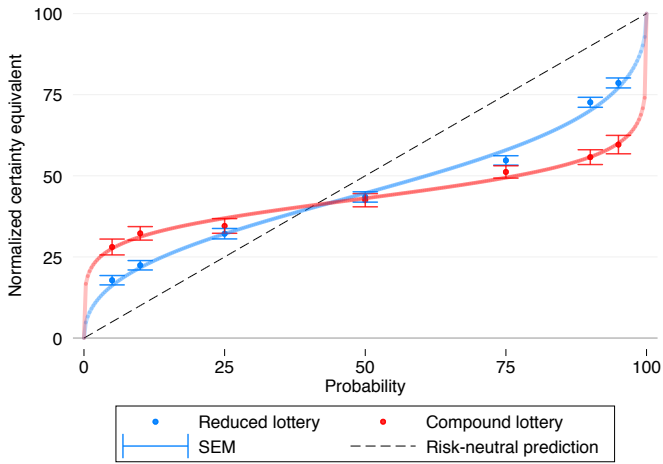
Experimental manipulations

Two broad classes of approaches:

1. **Manipulate cognitive resources** that are available for mental simulation of decision
   - Cognitive load
   - Time pressure
2. **Manipulate complexity** of decision problem
   - Math manipulation: Leverage normative equivalence between (i) 40% chance of \$50 (ii) $22 \times 3/6 + 29\%$ chance of \$50
   - Compound manipulation: Leverage normative equivalence between (i) 40% chance of \$50 (ii) $p \sim U[30, 50]\%$ chance of \$50

$\Rightarrow$ **Hypothesis is always that behavior becomes more "compressed"**

Illustration: compound manipulation in choice under risk



Cognitive uncertainty increases by 30%

Wrap: Cognitive Uncertainty and Behavioral Anomalies

- Cognitive uncertainty **helps to understand empirical regularities that seem unrelated at first**
- Key insight: in presence of cognitive uncertainty, **decisions look like treat different values of problem parameter alike**
- Contributes to "**cognitive turn in behavioral economics**": many decision anomalies that were previously thought of as due to non-standard preferences now attributed to fundamentals such as attention, memory, cognitive noise, complexity

Meta-Cognition and Bias in the Aggregate

Individual errors and aggregate outcomes

- We've uncovered numerous **individual-level biases**, in both lab and field
- Yet: much of econ concerned with **outcomes from interactions** in markets and orgs
- Success of behavioral research partly rests on idea that **irrationalities affect aggregate**: matter for prices, distort allocative efficiency, or have redistributive effects
  - → Many "classical" objections: arbitrage, wealth dynamics, learning...

Does behavioral econ itself provide potential limit to the role of individual errors for economic quantities?

Self-selection and biases in the aggregate

- Experimenters typically **force** people into difficult tasks
- In reality: people often have freedom to **self-select into or out of** decisions:
  - Bet conservatively in **financial markets** competition that exploits fallibility
  - Avoid bidding aggressively in **auctions** for objects you don't fully understand
  - Hold back opinion from discussion in **organizations** / **committees** when unsure
- Gary Becker: "[self-selection] strongly attenuates if not eliminates any effect of bounded rationality"

When does self-selection filter out errors?

- It depends on **who** selects in / out, which will partly depend on...
- **Meta-cognition:** to what degree are people aware of their own biases?
  1. Error-prone people LESS confident $\Rightarrow$ more cautious $\Rightarrow$ Institutions attenuate errors
  2. Error-prone people MORE confident $\Rightarrow$ more aggressive $\Rightarrow$ Institutions amplify errors
- Theoretically, **correlation between objective performance and confidence** more important than average overconfidence

Experimental setup: Institutional filtering

- Subjects do 15 widely-studied tasks organized around Econ101 core principles
- **Part 1**: Provide answer to cognitive task (e.g., CRT, corr neglect, base rate neglect)
- **Part 2**: Participate in one of three institutions (between-subjects)
  1. **Betting market**: Bet on whether Part 1 decision is correct
  2. **Committee voting**: Vote for Part 1 decision to be adopted by cohort
  3. **Auction**: Bid for right to earn a bonus that pays iff own Part 1 decision correct

$\Rightarrow$ Part 2 decision reflects **how aggressively people "self-select"** in institution

Part 2: Institutions

1. **Betting markets**: Well-informed bidders in speculative markets are incentivized to bid more aggressively, producing prices that aggregate information
   - **Parimutuel betting** on accuracy of own Part 1 decision
   - **Aggregate Outcome**: price of Arrow security linked to optimal decision

2. **Allocative markets**: People who highly value products or factor inputs will bid more for them, causing markets to direct resources to "their most highly valued use"
   - **Discriminatory Auction** where highest bidders pay bid and get bonus iff Part 1 is correct
   - **Aggregate Outcome**: optimality rate of auction winners.

3. **Committees**: Organizations aggregate opinions through discussion or voting
   - **Utilitarian voting**: subjects can submit votes for own Part 1 solution
   - **Aggregate Outcome**: vote share on optimal decision

Compare bias in Aggregate Outcome to raw Part 1 optimality rate!

Example

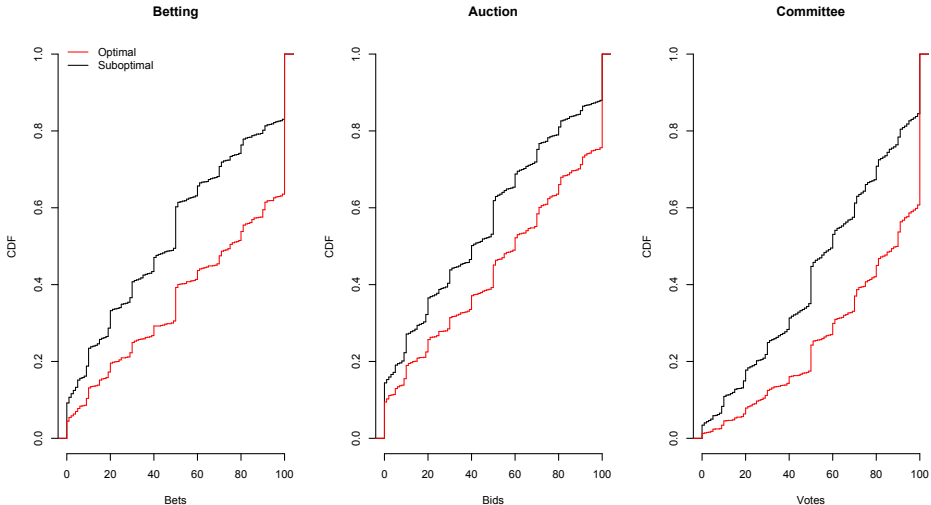
Part 1: Subjects answer Kahneman-Tversky base rate neglect question.

Part 2: Subjects assigned to group of 10 (all of whom solved same Part 1 question)

- Each can submit up to 100 votes for decision to be “adopted by group”.
- Everyone makes same profit that depends on fraction of votes for correct answer

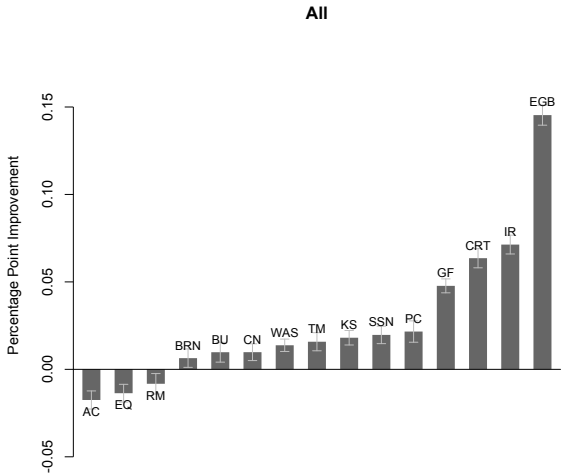
Question: Is the group decision (i.e. vote share on optimal choice) better than average individual decisions? For which tasks?

Do subjects with correct decisions vote / bet / bid more?



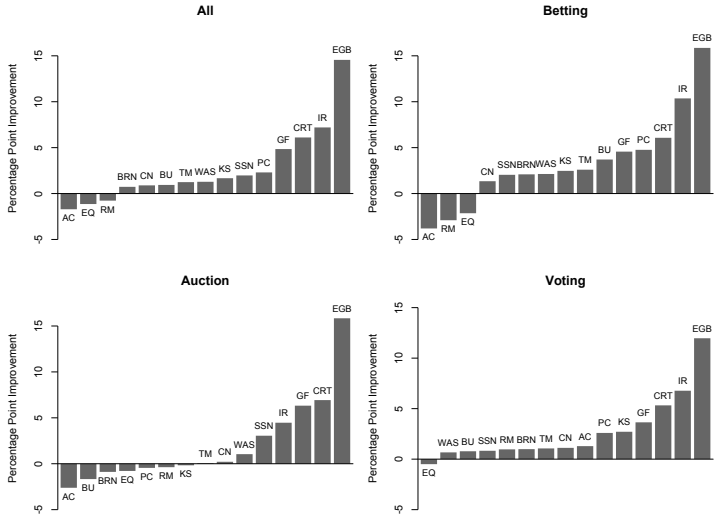
- **Similar differences** across institutions: 30% in Voting, 37% in Betting, 29% in Auction

Which errors do institutions reduce?



AC=Acquiring-a-company; BRN=Base rate neglect; BU=Balls-and-urns belief updating; CN=Correlation neglect; CRT=Cognitive reflection test; EGB=Exponential growth calc.; EQ=Predict others' play; GF: Predict sequence of draws; IR=Backwards induction; KS=Knapsack; PC=Portfolio choice; RM=Attribution; SSN=Account for sample size; TM=Thinking at the margin; WAS=Wason.

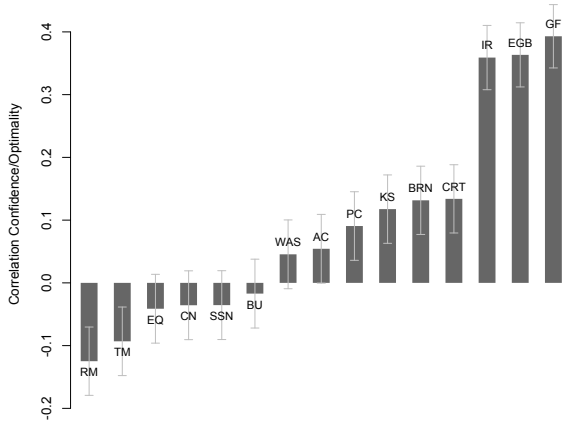
Varies little across institutions



Institutions help on average but...

- Average effect of self-selection is positive but modest.
- **Massive variation across tasks**. For some, institutions don't help or hurt.
- **Why?**
- Pre-registered hypothesis: **variation in relative confidence calibration** across tasks generates heterogeneity in institutional filtering

How strongly are performance and confidence correlated?



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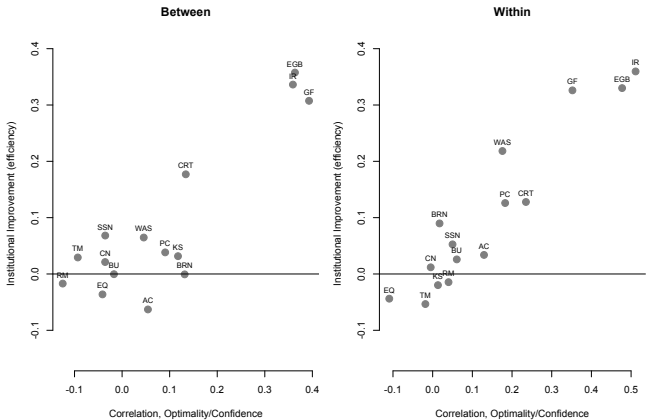
Putting the pieces together: Does calibration of confidence predict institutional filtering?



Calibration predicts improvement: $\rho = 0.76$ (between), $\rho = 0.91$ (within)

Summary: Meta-cognition and bias in the aggregate

- Relative confidence calibration crucial for understanding whether individual-level irrationalities actually matter for aggregate quantities
- Massive variation in quality of meta-cognition across different cognitive biases
- Highlights need to study distribution and determinants of meta-cognition more systematically
  - For social science, meta-cognition as relevant as biases and preferences themselves.
  - Why is confidence well-calibrated in some tasks but not others?

Discussion: Moving Forward with Research on Meta-Cognition and Cognitive Uncertainty

Discussion I

- Meta-cognition **massively understudied** in economics
- We now know it matters for understanding:
  - What people do when they find a problem complex
  - How different seemingly-unrelated behavioral anomalies can be tied together through logic of cognitive noise / cognitive uncertainty
  - Whether individual-level irrationalities affect outcomes of interactions in markets and orgs

Discussion II

- Many open questions:
- What about other pull-to-center anomalies in economics?
  - Famous newsvendor game (OR, econ, business)
  - Well-known pull-to-center effect in performance evaluations in businesses
- What determines whether meta-cognition is good or bad in a given task?
- Learning about quality of confidence calibration in richer institutions?
- Field evidence?
- ...