Dynamic Inconsistencies: A Revealed Preference Approach

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Three Questions on Intertemporal Choice

1. Consistency
   - Is behavior consistent with a model of utility maximization?
2. Structure of preferences
   - What are the structural properties of the underlying utility function?
3. Parsimony
   - Is a simple rational model well-specified for observed choices?

In This Talk

- Revealed preference analysis for (in-)consistency of intertemporal choices

- A novel experimental design allowing us to explore this at the individual level

- Nonparametric analysis of both consistency with utility maximization and time consistency (or more precisely, stationarity)

Decision in the Experiment

- Subjects choose any non-negative allocation $x = (x_t, x_{t+k})$ such that

$$x_t + \frac{x_{t+k}}{1+r} = m$$

- Subjects make choices in a wide range of budget lines w.r.t. r and m.

- Each subject faces two time frames – **near** and **distant** – by varying the sooner payment date, $t < t'$. Time horizon k are held constant.

- The same set of budget lines are presented in the two frames (randomly ordered).

Further Detail of the Experiment

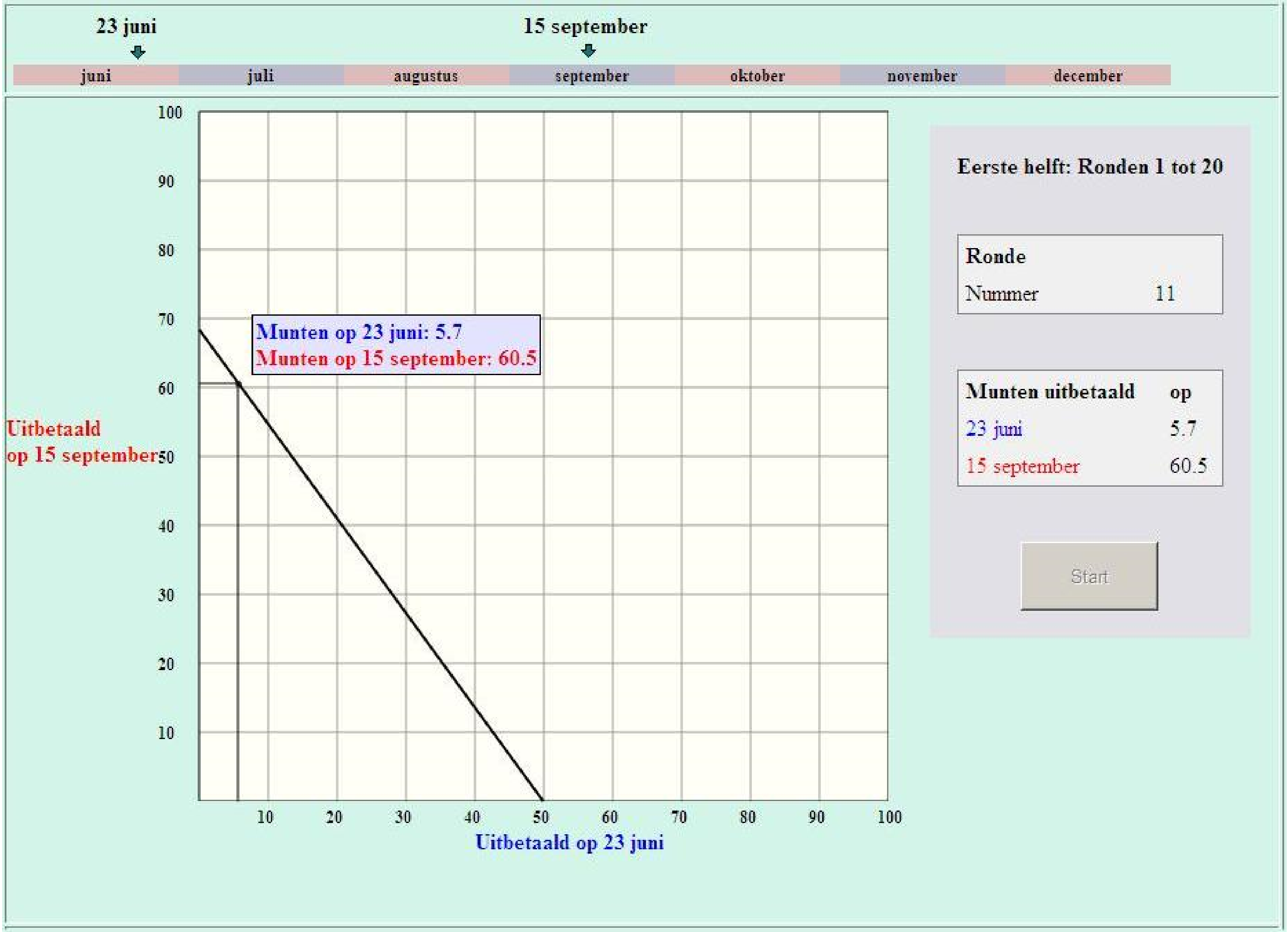
- Environments
  - 1,425 subjects from the CentERpanel
  - 211 subjects from Xlab at UC Berkeley

- Dates and horizon
  - At the Xlab, t (tomorrow), k (28 days), t' (a month later)
  - At the CentERpanel, t (a week later), k (12 weeks), t' (13 weeks later)

- Number of choices in a time frame
  - 20 choices at the CentERpanel and 50 choices at the Xlab

- At the end of the experiment, one decision problem was randomly chosen for payment.

Sample Screen



Revealed Preferences within Time Frame

- Let $\{(p^i, x^i)\}$, for $i = 1, \ldots, N$, denote observed individual data within time frame.

- **Generalized Axiom of Revealed Preferences (GARP)**

$$\left.\begin{array}{c} p^1 \cdot x^1 \geq p^1 \cdot x^2 \\ p^2 \cdot x^2 \geq p^2 \cdot x^3 \\ \cdots \\ p^{n-1} \cdot x^{n-1} \geq p^{n-1} \cdot x^n \end{array}\right\} \Longrightarrow p^n \cdot x^n \leq p^n \cdot x^1$$

- **Afriat's Theorem** *If the data satifies GARP, then there exists a utility function that rationlizes the observed choices.*

- GARP offers an exact test: either the data satisfy GARP or not.

Quantifying GARP violations: CCEI

- **Afriat's critical cost efficiency index (CCEI)** *The amount by which each budget constraint must be relaxed in order to remove all violations of GARP.*

- CCEI is the largest number $e \in [0, 1]$ such that

$$\left.\begin{array}{c} e(p^1 \cdot x^1) \geq p^1 \cdot x^2 \\ e(p^2 \cdot x^2) \geq p^2 \cdot x^3 \\ \cdots \\ e(p^{n-1} \cdot x^{n-1}) \geq p^{n-1} \cdot x^n \end{array}\right\} \Longrightarrow e(p^n \cdot x^n) \leq p^n \cdot x^1$$

- CCEI measures the extent of GARP violations in terms of monetary costs.

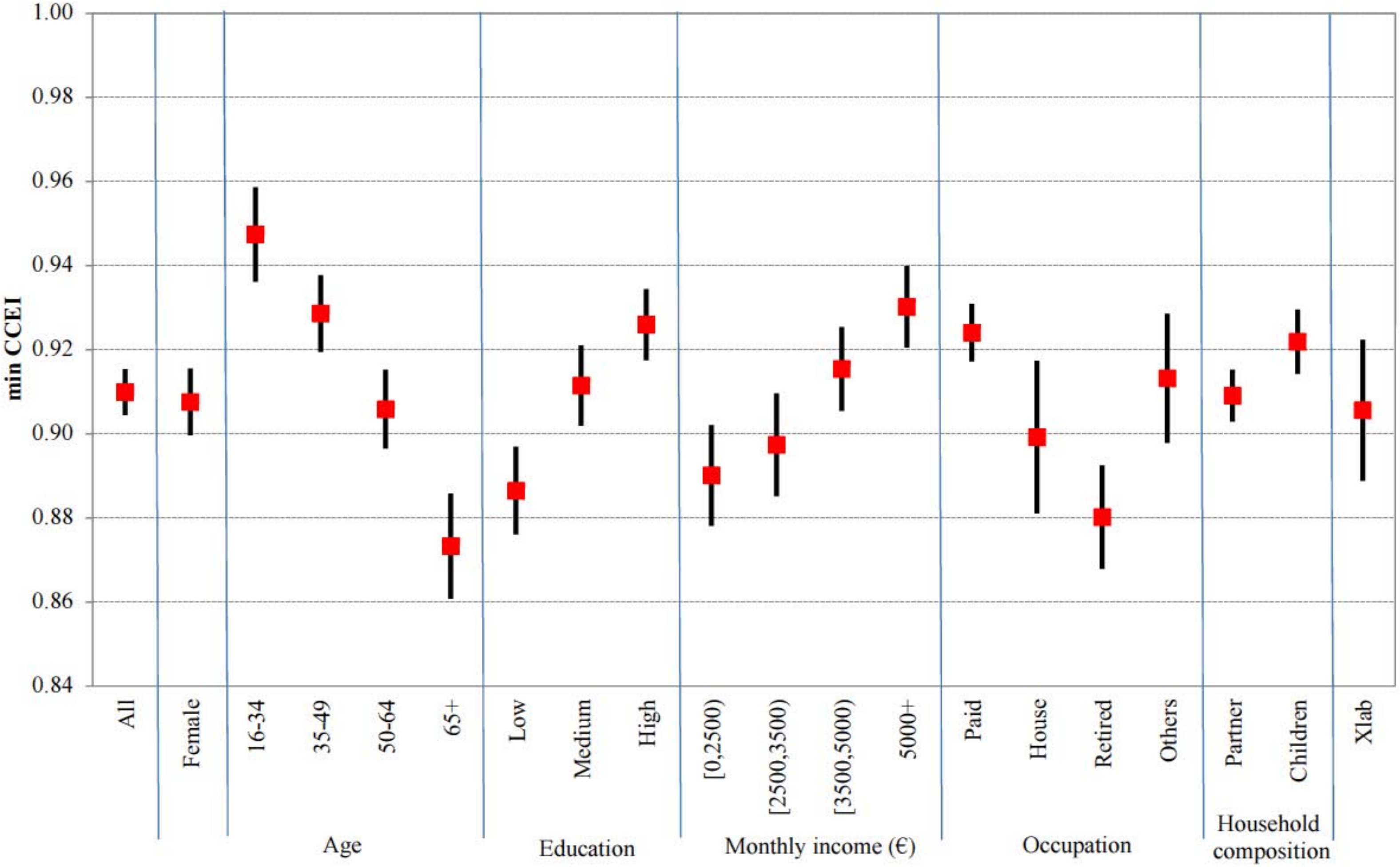
Consistency within Time Frame

- We use the minimum of CCEIs of the near and distant time frames as an overall summary of consistency with utility maximization (within time frame).

- Who is more rational? We correlate heterogeneity in CCEI and sociodemographic information of subjects in the CentERpanel experiment.

- Findings in the domain of intertemporal decision making corroborate those in an earlier work in the domain of decision making under uncertainty, Choi et al. (2014).

Minimum of CCEI Scores of Two Time Frames
(sample means and 95% CIs)



A GARP Test of Stationarity

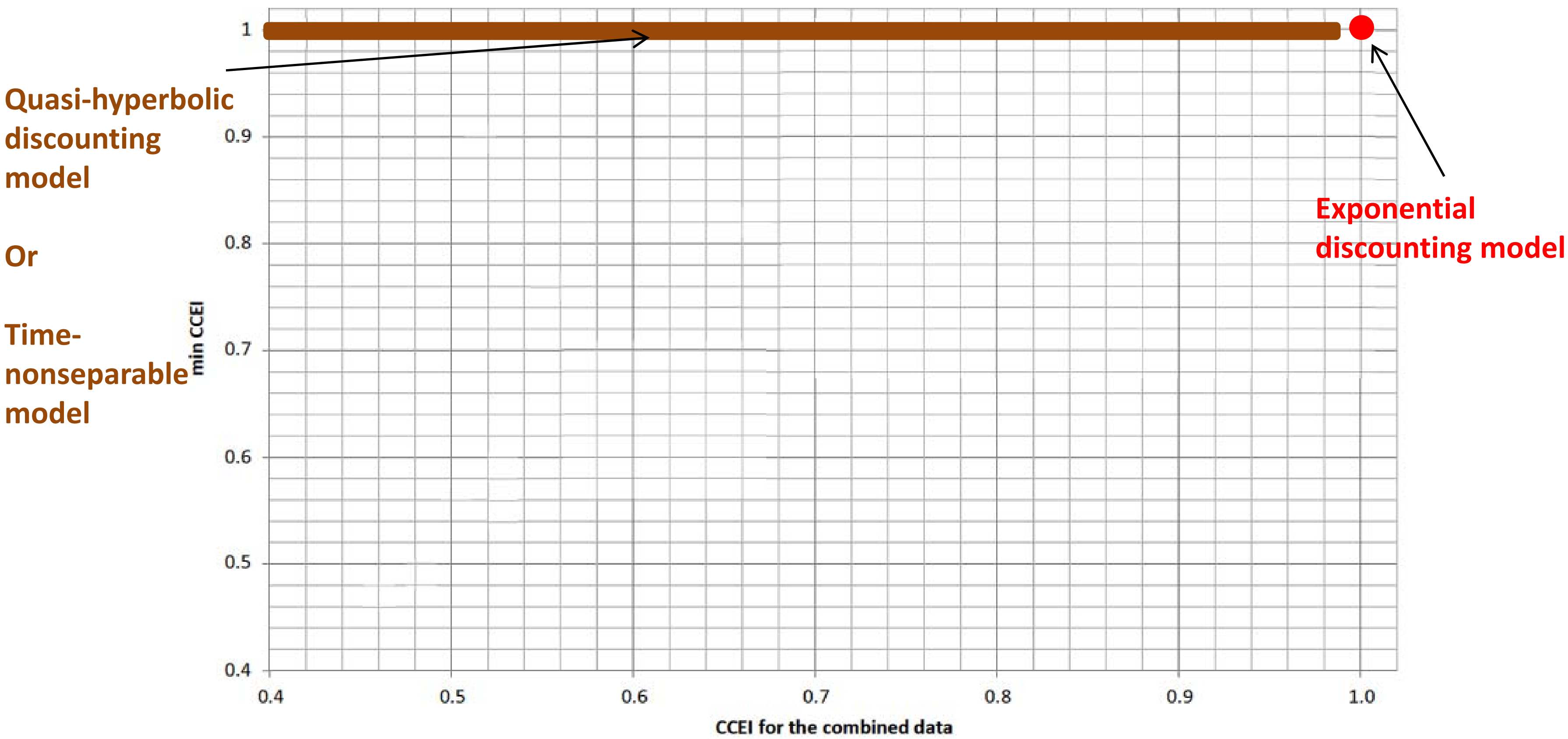
- In order to examine patterns of consistency **between** time frames, we first compute the CCEI of the combined data of the two time frames.

- We relate this with the minimum of CCEIs of the near and distant time frames.

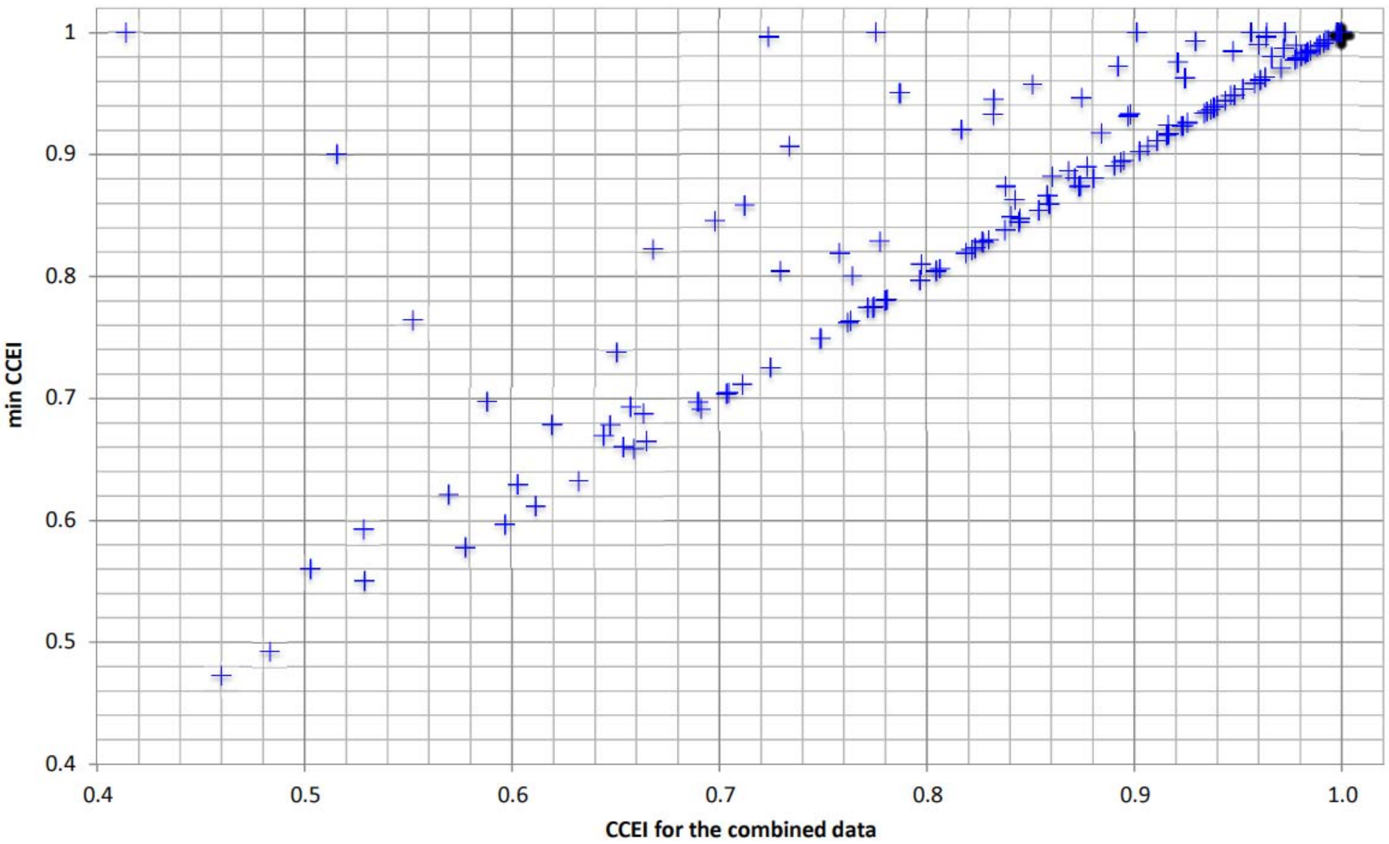
- By definition, the CCEI of the combined data cannot be higher than the minimum of CCEIs.

- Different models of time preferences predict different relationships between these two variables.

Predicted Relation between min CCEI and CCEI of the combined data

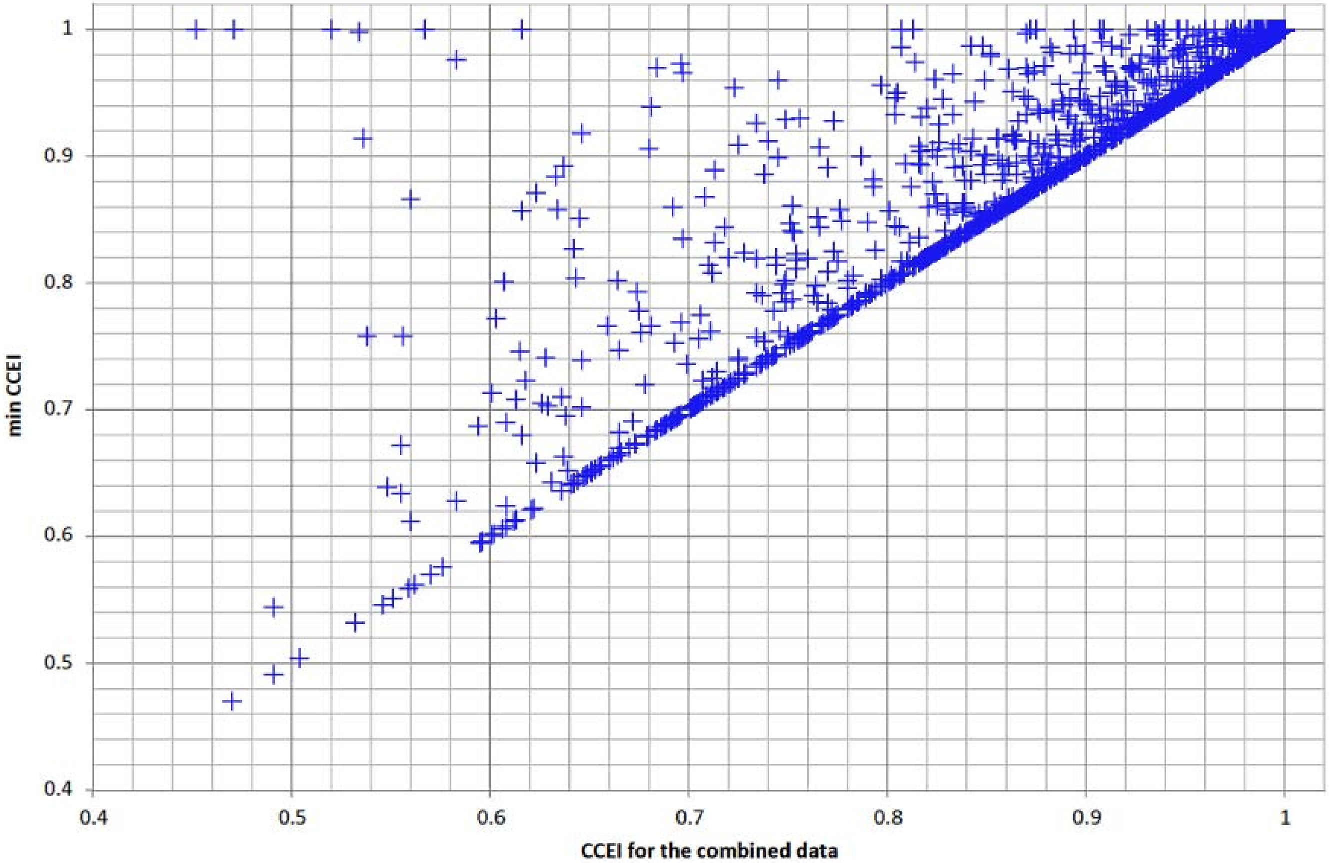


Relation between min CCEI and CCEI of the combined data: Xlab data



- 52% of subjects: (CCEI for the combined data) ≤ 0.95
- 62% of them: (CCEI for the cobmined data) = (min CCEIs)
- Only around 6% of them: (min CCEIs) ≈ 1

Relation between min CCEI and CCEI of the combined data: CentERpanel data



- 57% of subjects: (CCEI for the combined data) ≤ 0.95
- 64% of them: (CCEI for the combined data) = (min CCEIs)
- Only around 5% of them: min CCEIs ≈ 1

A Statistical (Permutation) Test of Stationarity

- To obtain a distribution for the test statistic under the null hypothesis of stationarity,

  1) Rearrange (permute) the choice data by randomly reassigning the choices from the two time frames for each budget line;

  2) Compute the consistency score for each permutation and construct the joint probability distribution of the min and max scores;

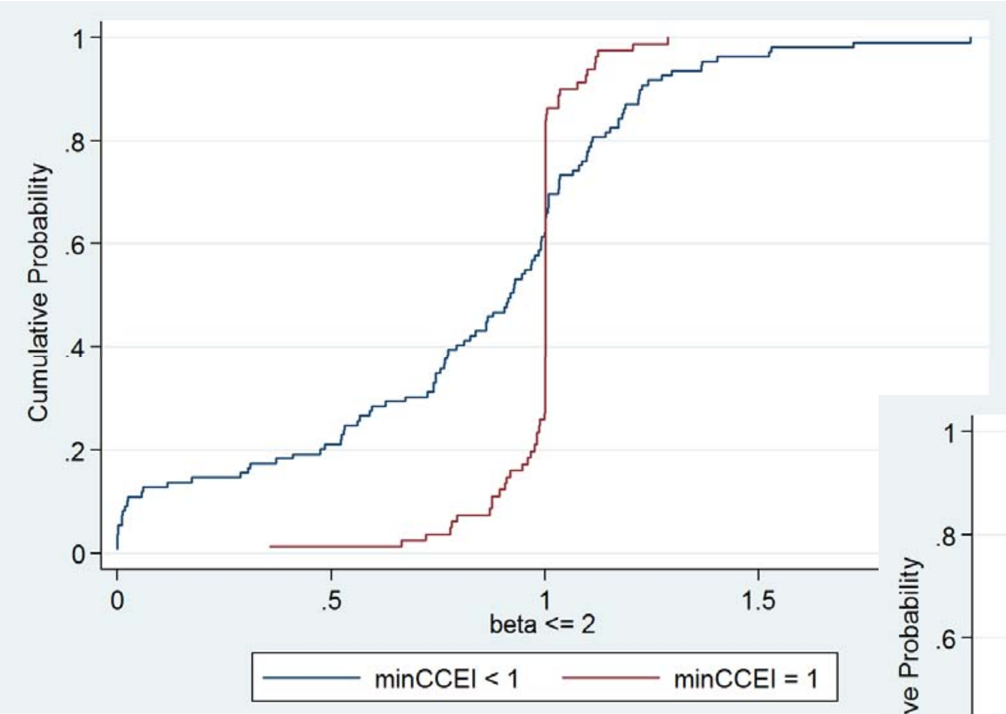
  3) Compare the actual min and max scores with their permutation distribution.

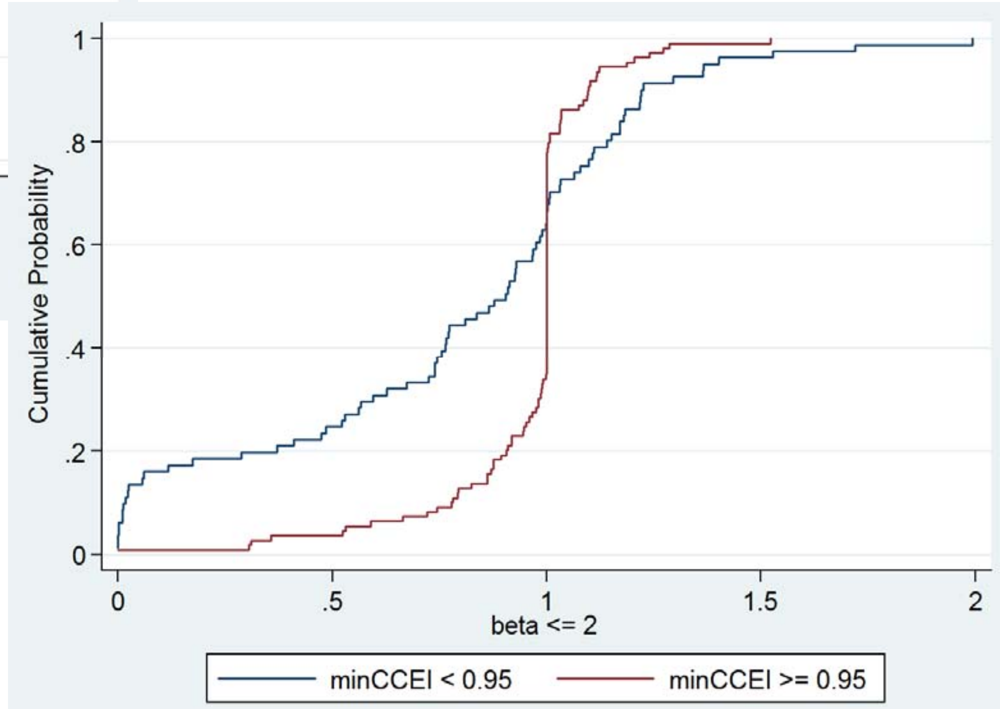
Relation b/w Permutation Test and (β, δ) Model

- Compare the permutation test with standard (β, δ) model (with power utility function).

	Permutation test	
	Stationary	Nonstationary
$\hat{\beta} < 1$ (50)	54% (27)	46% (23)
$\hat{\beta} = 1$ (131)	**84% (110)**	16% (21)
$\hat{\beta} > 1$ (30)	67% (20)	33% (10)
Total (211)	74% (157)	26% (54)

Relation b/w minCCEI and (β, δ) Model





Summary

- There is a high level of heterogeneity in (within-frame) consistency, which is strongly correlated with socioeconomic information.

- A GARP test of stationarity is largely driven by inconsistency within frame.

- The estimation of standard (β, δ) model tends to reject stationarity too frequently due to inconsistency.