Asset Demand Tests of Risk Preferences with Probability Dependent NM Indices

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⇒ Asset demands are functions of *probabilities*, prices, and income.

⇒ Asset demands can be generated by 'EU' preferences, where the von Neumann-Morgenstern (NM) index depends on probabilities.

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  - Revealed preference (Polisson, Quah, and Renou, 2017),
  - Experimental design (Choi *et al.* 2007).
- We compare the empirical performances of EU, probability dependent NM, and rank dependent utility (RDU).

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(a) EU over all slices with the *same* NM index,

(b) EU on each slice but with different NM indices corresponding to the different distributions defining each slice,

(c) RDU over all slices with the *same* value function and probability weighting function.

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With $S \geqslant 2$, a consumption plan is given by $x = (x_1, x_2, \ldots, x_S) \in \mathbb{R}^S_+$ and $\Delta(S) = \{\pi \in \mathbb{R}^S_{++} : \sum_s \pi_s = 1\}$.

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(TC) Tradeoff Consistency: For any given $\pi \in \Delta(S)$,

$$x_{-s}(a) \sim_\pi x'_{-s}(b), \;\; x_{-s}(c) \sim_\pi x'_{-s}(d), \;\; x''_{-s'}(a) \sim_\pi x'''_{-s'}(b)$$

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TC is critical for existence of an EU representation on a single slice.

Furthermore, TC can be *modified*/strengthened to hold *across* slices, which is critical for existence of an EU representation on a *set* of slices and with the same NM index on each slice.

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Consider the utility function given by

$$U(x;\pi) = -\sum_{s=1}^{3} \pi_s(\exp(-\pi_1 x_s) + \exp(-\pi_2 x_s) + \exp(-\pi_3 x_s))$$
$$= \sum_{s=1}^{3} \pi_s u_\pi(x_s),$$

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If, instead, $\pi = \bar{\pi} = (\bar{\pi}_1, \bar{\pi}_2, \bar{\pi}_3)$ is fixed, then

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Let $\mathcal{O} = \{(p^t, x^t)\}_{t=1}^{T}$ be a finite set of prices $p^t = (p_1^t, p_2^t, \ldots, p_\ell^t) \gg 0$ and demands $x^t = (x_1^t, x_2^t, \ldots, x_\ell^t) \geqslant 0$ drawn on a consumer.

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Definition: A utility function $U : \mathbb{R}_+^\ell \to \mathbb{R}$ is said to rationalize the data set $\mathcal{O} = \{(p^t, x^t)\}_{t=1}^T$ if, at every observation $t = 1, 2, \ldots, T$,

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(4) $\mathcal{O}$ is rationalizable by a utility function U, which is increasing, concave, and continuous.

Contingent Consumption and Rationalizability

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Now suppose that an agent is choosing contingent consumption, i.e.,

$$p^t = (p_1^t, p_2^t, \ldots, p_S^t),$$

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are vectors of state prices and contingent consumption, respectively.

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How might one conduct revealed preference tests analogous to Afriat's for different tailor-made models of decision making under risk?

E.g., if we know the probability of state s to be $\pi_s > 0$, how do we test for rationalizability by EU, i.e., that there is an *increasing* and *continuous* function $u : \mathbb{R}_+ \to \mathbb{R}$ such that, at every $t = 1, 2, \ldots, T$,

$$\sum_{s=1}^{S} \pi_s u(x_s^t) \geqslant \sum_{s=1}^{S} \pi_s u(x_s) \text{ for any } x \in B^t,$$

where $B^t = \{x \in \mathbb{R}_+^S : p^t \cdot x \leqslant p^t \cdot x^t\}$?

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Given $\mathcal{O}$, define the set $\mathcal{X} = \{x_s^t : (s,t) \in \{1,\ldots,S\} \times \{1,\ldots,T\}\} \cup 0$, and then the finite lattice $\mathcal{L} = \mathcal{X}^S$.

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Then, $\mathcal{X} = \{0,1,2,3,4,5,6\}$, and $\mathcal{L} = \mathcal{X} \times \mathcal{X}$.

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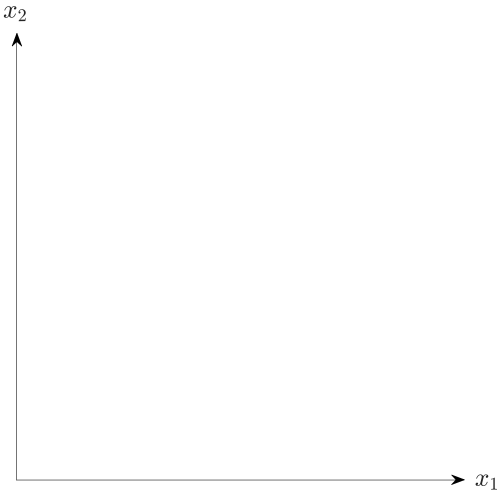

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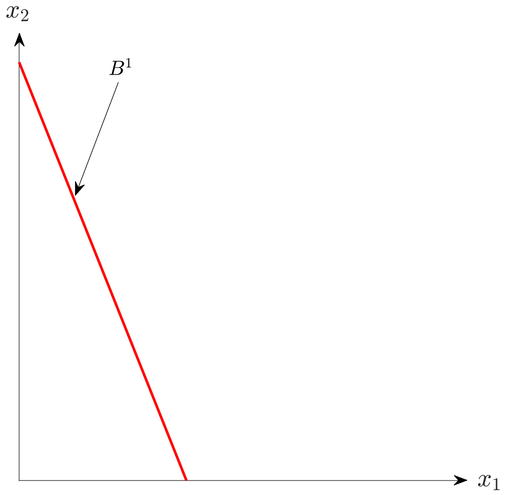

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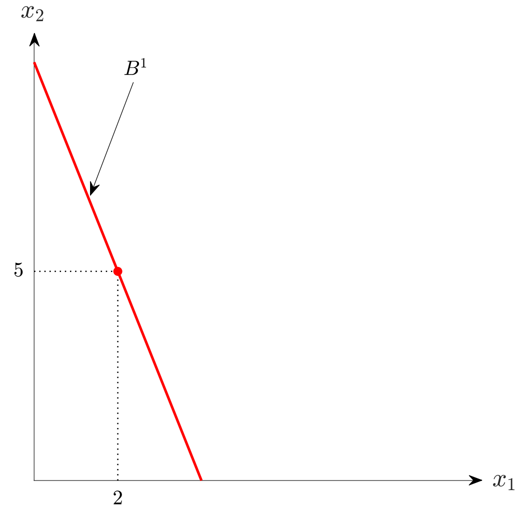

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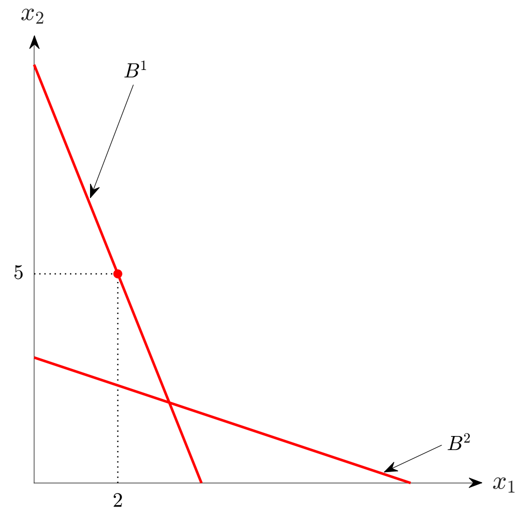

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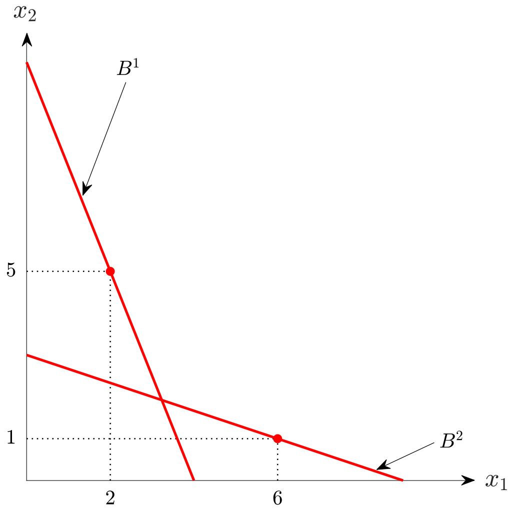

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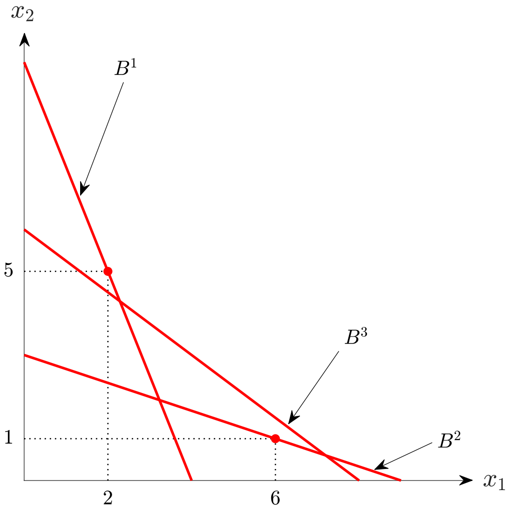

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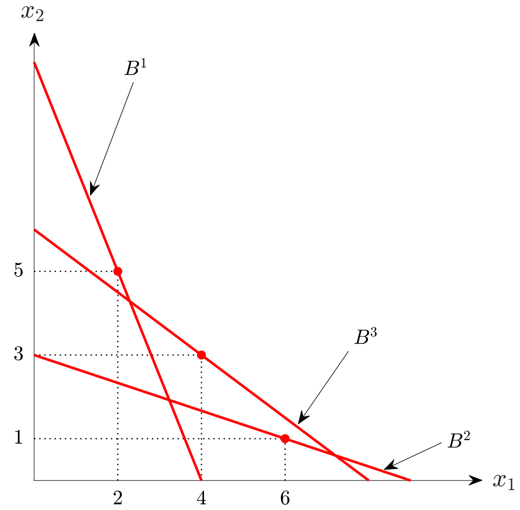

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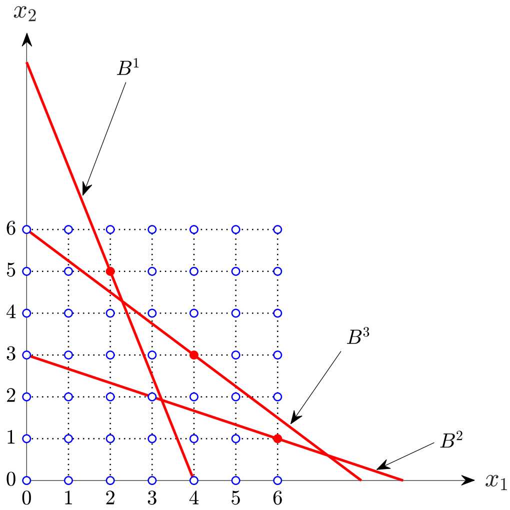

$$\mathcal{X} = \{0, 1, 2, 3, 4, 5, 6\}, \quad \mathcal{L} = \mathcal{X} \times \mathcal{X}$$

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Given $\mathcal{O}$, define the set $\mathcal{X} = \{x_s^t : (s,t) \in \{1,\ldots,S\} \times \{1,\ldots,T\}\} \cup 0$, and then the finite lattice $\mathcal{L} = \mathcal{X}^S$.

E.g., suppose that we observe $x^1 = (2,5),\ p^1 = (5,2),\ x^2 = (6,1),$ $p^2 = (1,3),\ x^3 = (4,3),\ p^3 = (3,4),\ \pi = (1/2,1/2)$.

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For EU-rationalizability, it is clearly *necessary* that there are real numbers $\bar{u}(0) < \bar{u}(1) < \cdots < \bar{u}(6)$, such that, at every $t \in \{1,2,3\}$,

$$\frac{1}{2}\bar{u}(x_1^t) + \frac{1}{2}\bar{u}(x_2^t) \geqslant \frac{1}{2}\bar{u}(x_1) + \frac{1}{2}\bar{u}(x_2) \text{ for any } x \in B^t \cap \mathcal{L},$$

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E.g., suppose that we observe $x^1 = (2,5),\ p^1 = (5,2),\ x^2 = (6,1)$, $p^2 = (1,3),\ x^3 = (4,3),\ p^3 = (3,4),\ \pi = (1/2,1/2)$.

Then, $\mathcal{X} = \{0,1,2,3,4,5,6\}$, and $\mathcal{L} = \mathcal{X} \times \mathcal{X}$.

For EU-rationalizability, it is clearly *necessary* that there are real numbers $\bar{u}(0) < \bar{u}(1) < \cdots < \bar{u}(6)$, such that, at every $t \in \{1,2,3\}$,

$$\frac{1}{2}\bar{u}(x_1^t) + \frac{1}{2}\bar{u}(x_2^t) \geqslant \frac{1}{2}\bar{u}(x_1) + \frac{1}{2}\bar{u}(x_2) \text{ for any } x \in B^t \cap \mathcal{L},$$

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It is also *sufficient* to guarantee EU-rationalizability by an increasing and continuous function $u : \mathbb{R}_+ \to \mathbb{R}$ that extends $\bar{u} : \mathcal{X} \to \mathbb{R}$.

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So we only need to check for EU-rationalizability on a finite lattice, which is a straightforward linear test.

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Theorem: The data set $\mathcal{O} = \{(p^t, x^t)\}_{t=1}^T$ is EU-rationalizable with $\pi = \{\pi_s\}_{s=1}^S$ if there is an increasing utility function $\bar{u} : \mathcal{X} \to \mathbb{R}$ such that, at every observation $t = 1, 2, \ldots, T$,

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Intuition: First we replace $\bar{u}$ with the step function $\hat{u} : \mathbb{R}_+ \to \mathbb{R}$ such that $\hat{u}(y) = \bar{u}(y)$ for all $y \in \mathcal{X}$ and $\hat{u}$ is constant between values of $\mathcal{X}$. Clearly, $\hat{u}$ rationalizes the data in the sense that

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The only problem is that $\hat{u}$ is neither increasing nor continuous. But it is possible to find another utility function u, arbitrarily close to $\hat{u}$, that is increasing and continuous which also rationalizes the data.

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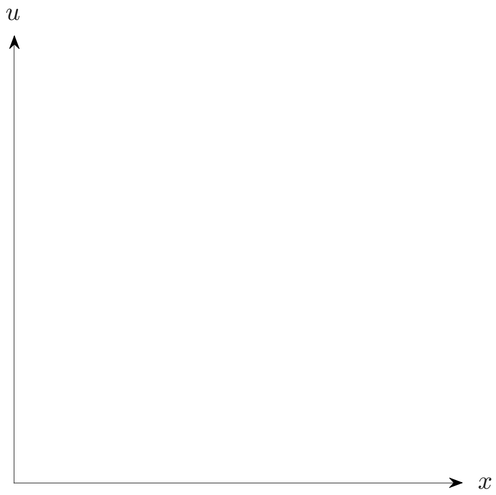

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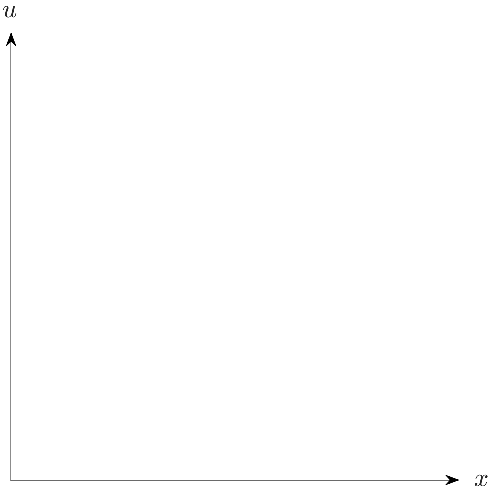

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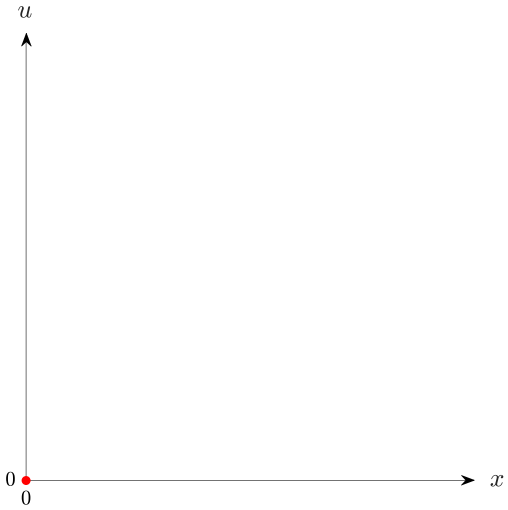

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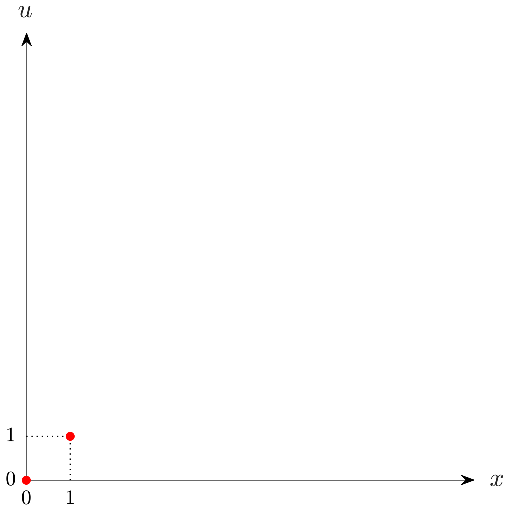

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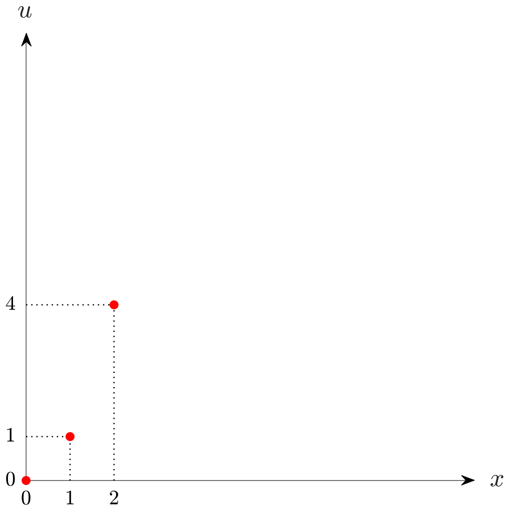

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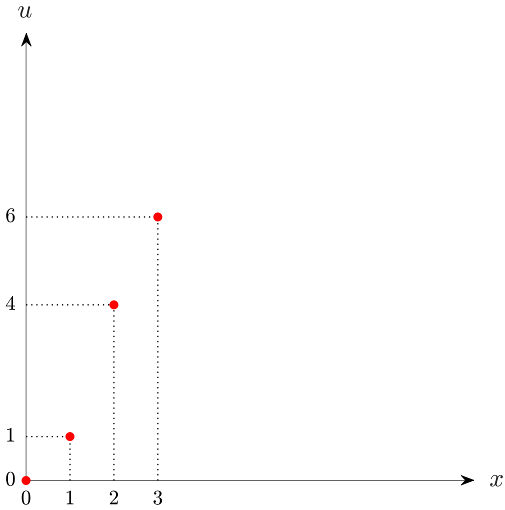

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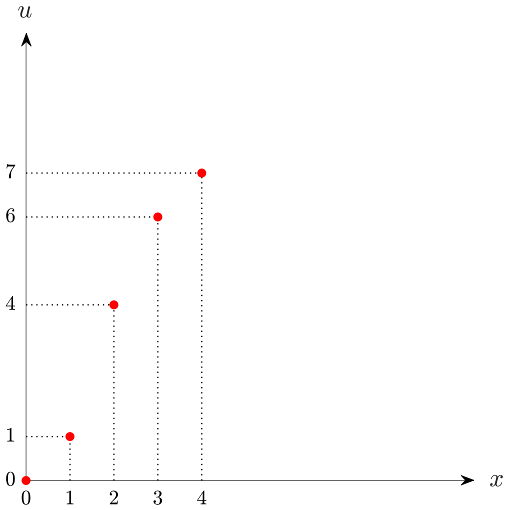

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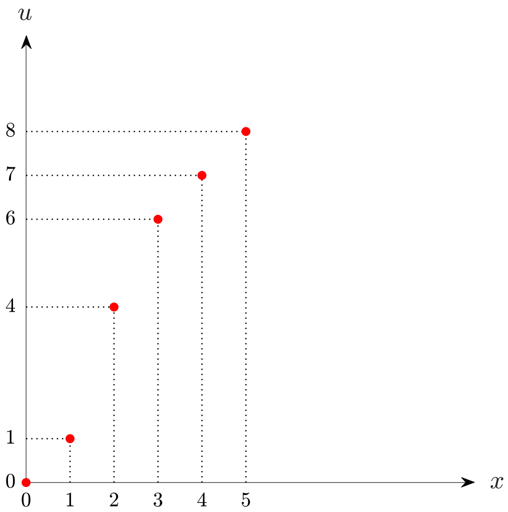

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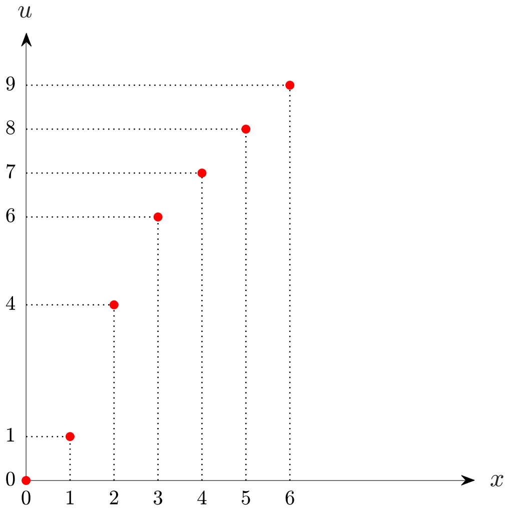

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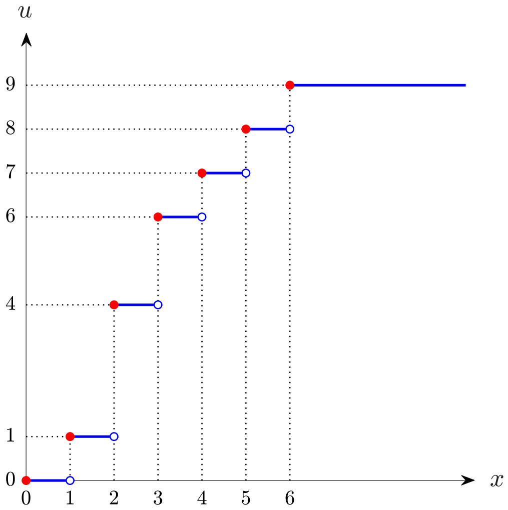

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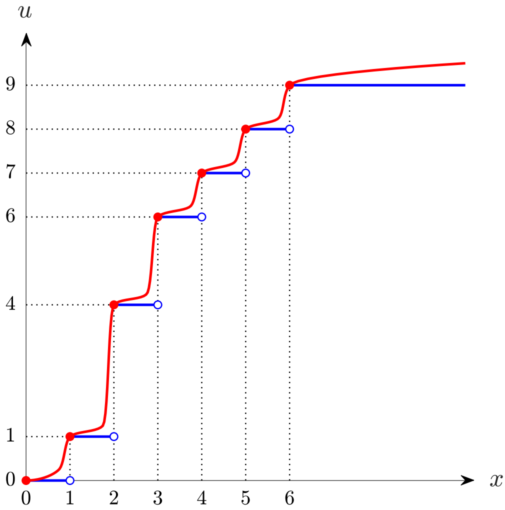

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where $u : \mathbb{R}_+ \to \mathbb{R}$ is again an increasing and continuous function, and where $\phi : \mathbb{R}^S \to \mathbb{R}$ is an increasing and continuous function that is drawn from the family Φ, which is specific to the model.

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E.g., objective and subjective expected utility, rank dependent utility, disappointment aversion, choice acclimating personal equilibrium, maxmin expected utility, and variational preferences.

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- The largest e at which a data set passes the test is known as the critical cost efficiency index (CCEI).

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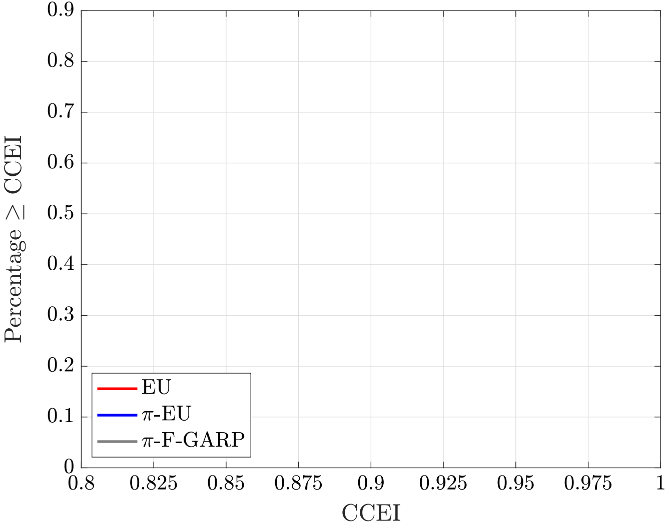

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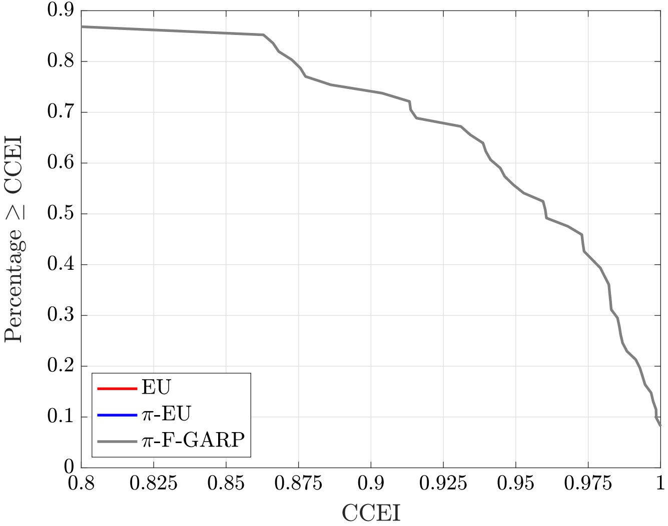

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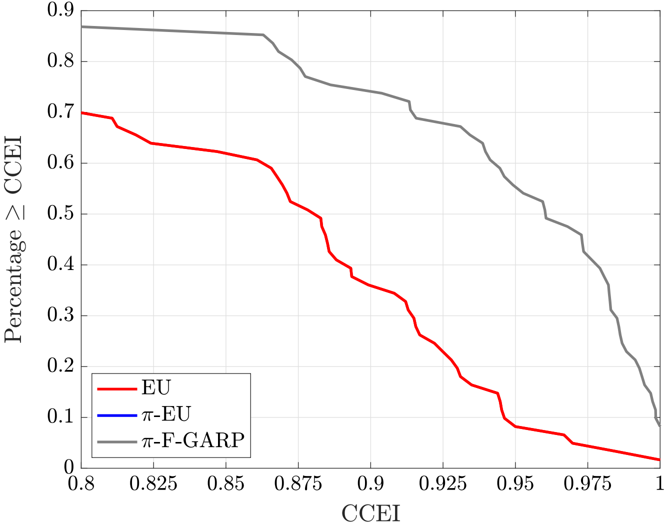

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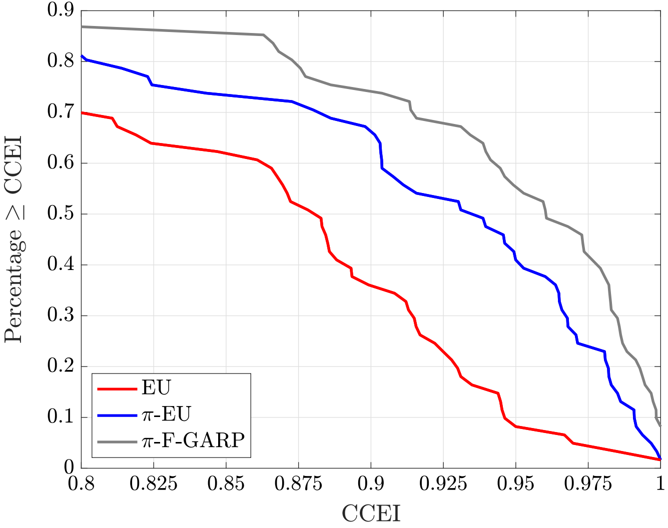

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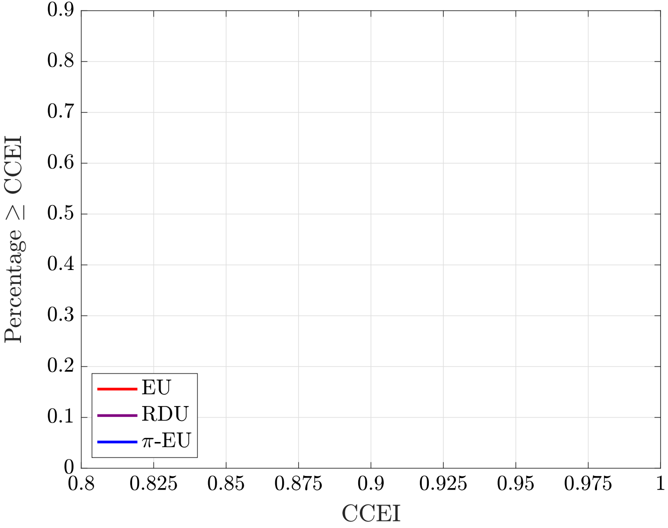

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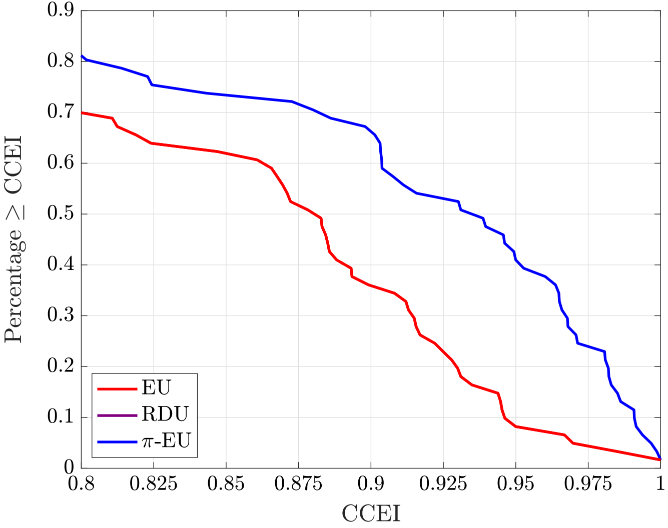

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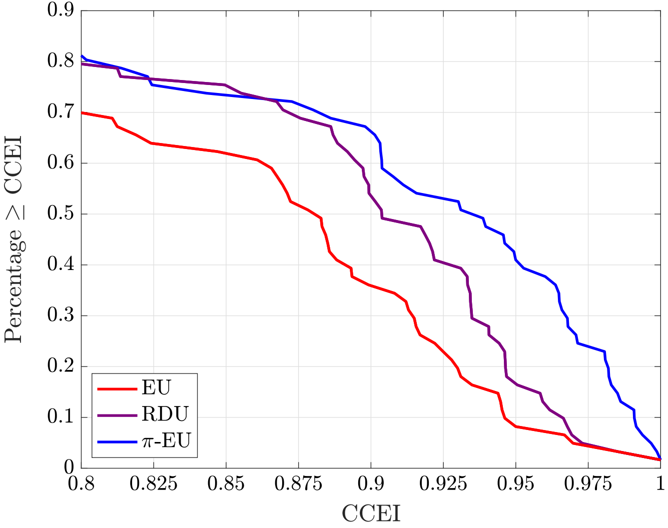

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