Economics 219D
Experimental economics
(Spring 2014)

Risk preferences
Lectures III & IV

Preferences

Let X be some set of alternatives (consumption set). Formally, we represent the consumer's preferences by a binary relation $\succsim$ defined on the consumption set X.

For any pair of baskets (or bundles) x and y, if the consumer says that x is at least as good as y, we write $x \succsim y$ and say that x is *weakly preferred* to y.

Bear in mind: economic theory often seeks to convince you with simple examples and then gets you to extrapolate. This simple construction works in wider (and wilder circumstances).

The basic assumptions about preferences

The theory begins with two (not three!) assumptions about preferences

[1] Completeness

$$x \succsim y \text{ or } y \succsim x$$

for any pair of bundles x and y.

[2] Transitivity

$$\text{if } x \succsim y \text{ and } y \succsim z \text{ then } x \succsim z$$

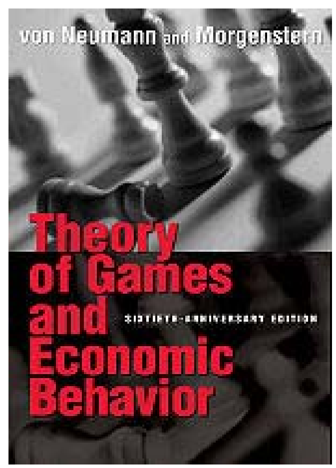
or any three bundles x, y and z.

Together, completeness and transitivity constitute the formal definition of *rationality* as the term is used in economics.

Rational economic agents are ones who [1] have the ability to make choices, and [2] whose choices display a logical consistency.

The preferences of a rational agent can be represented, or summarized, by a *utility function* (more later).

The paternity of decision theory and game theory (1944)



Preferences toward risk

The standard model of decisions under risk (known probabilities) is based on von Neumann and Morgenstern Expected Utility Theory.

Let X be a set of *lotteries*, or gambles, (outcomes and probabilities). A fundamental assumption about preferences toward risk is *independence*:

For any lotteries x, y, z and $0 < \alpha < 1$

$$x \succ y \text{ implies } \alpha x + (1-\alpha)r \succ \alpha y + (1-\alpha)r.$$

Experiments à la Allais

Allais (1953) I

– Choose between the two gambles:

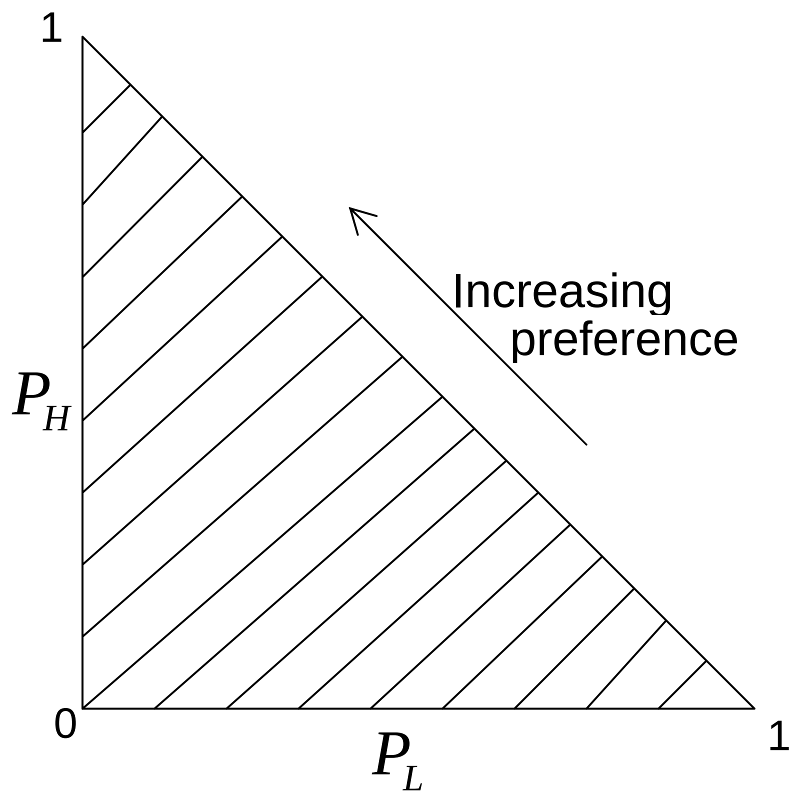
$$A := \begin{cases} \overset{.33}{\nearrow} \ \$25,000 \\ \overset{.66}{\longrightarrow} \ \$24,000 \\ \underset{.01}{\searrow} \ \$0 \end{cases} \qquad B := \overset{1}{\longrightarrow} \ \$24,000$$

Allais (1953) II

– Choose between the two gambles:

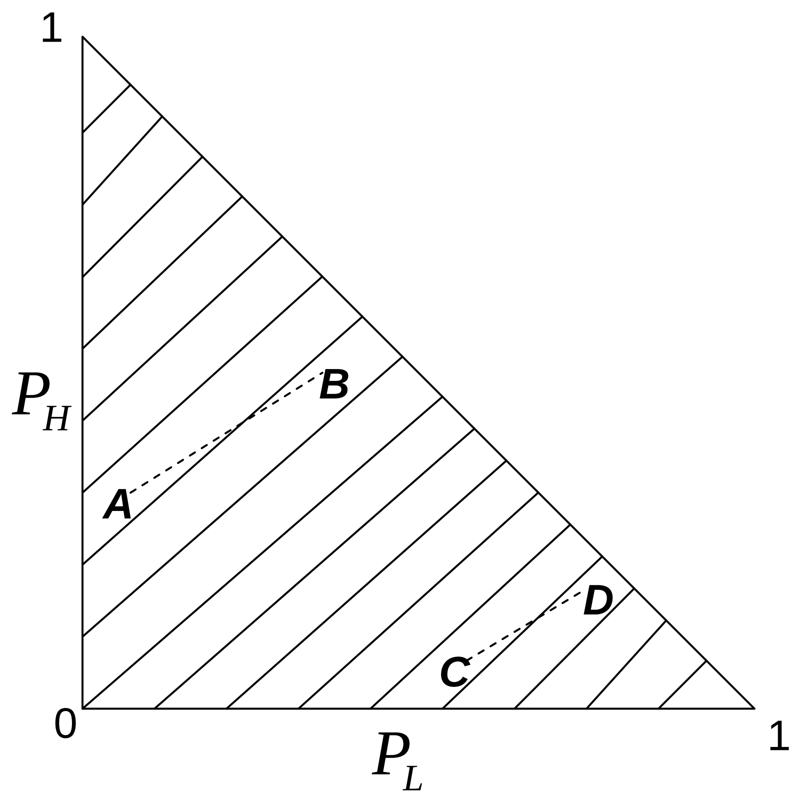
$$C := \begin{cases} \xrightarrow{.33} \$25,000 \\ \xrightarrow{.67} \$0 \end{cases} \qquad D := \begin{cases} \xrightarrow{.34} \$24,000 \\ \xrightarrow{.66} \$0 \end{cases}$$

The Marschak-Machina probability triangle



H, *M*, and *L* are three degenerate gambles with certain outcomes *H*>*M*>*L*

A test of Expected Utility Theory (EUT)



EUT requires that indifference lines are parallel so one must choose either ***A*** and ***C***, or ***B*** and ***D***.

Contributions

Results have generated the most impressive dialogue between observation and theorizing (Camerer, 1995):

- Violations of EUT raise criticisms about the status of the Savage axioms as the touchstone of rationality.
- These criticisms have generated the development of various alternatives to EUT, such as Prospect Theory.

Limitations

Choice scenarios narrowly tailored to reveal "anomalies" limits the usefulness of data for other purposes:

- Subjects face "extreme" rather than "typical" decision problems designed to encourage violations of specific axioms.

- Small data sets force experimenters to pool data and to ignore individual heterogeneity.

Research questions

Consistency

- Is behavior under uncertainty consistent with the utility maximization model?

Structure

- Is behavior consistent with a utility function with some special structural properties?

Recoverability

– Can the underlying utility function be recovered from observed choices?

Extrapolation

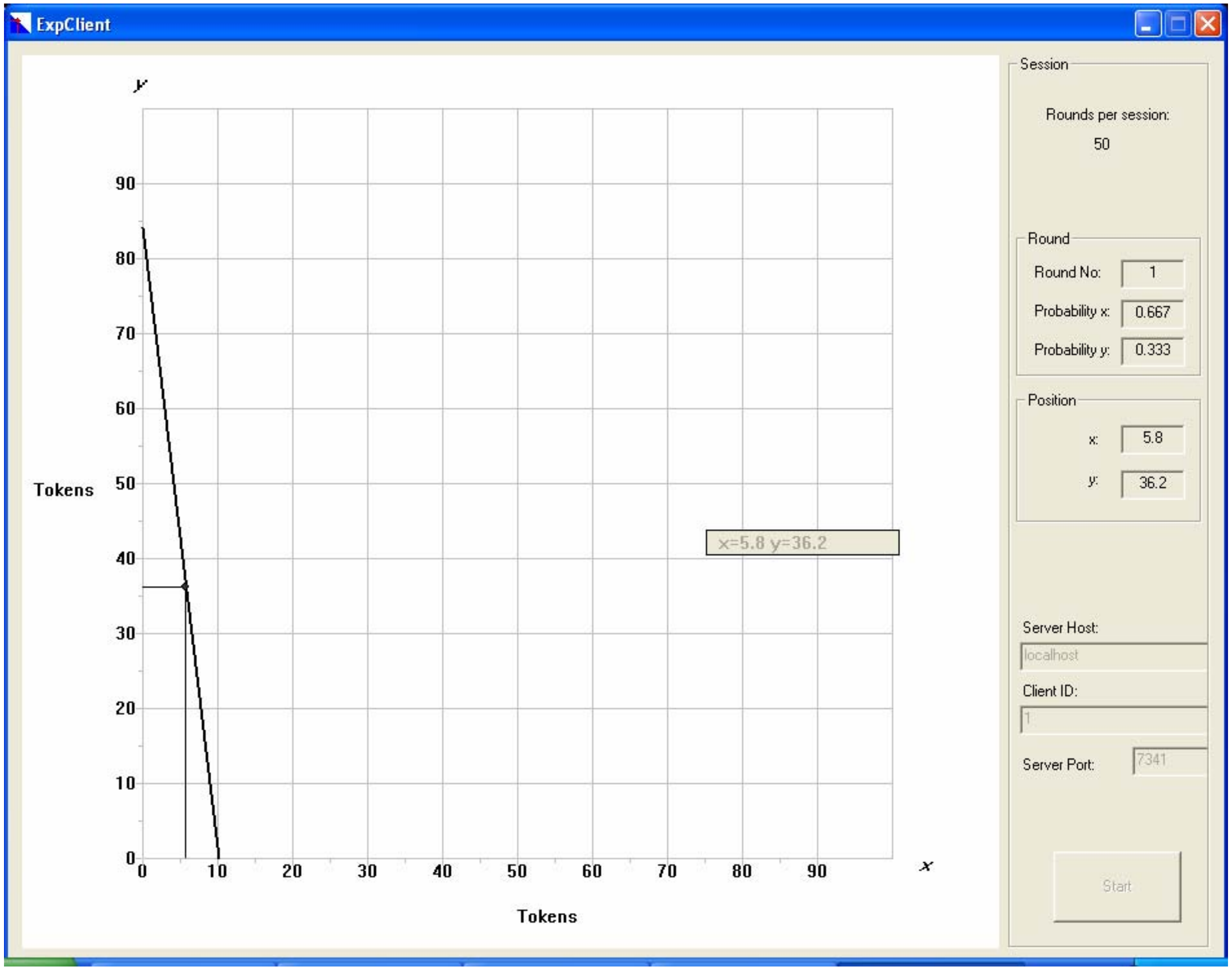
– Given behavior in the laboratory, can we forecast behavior in other environments?

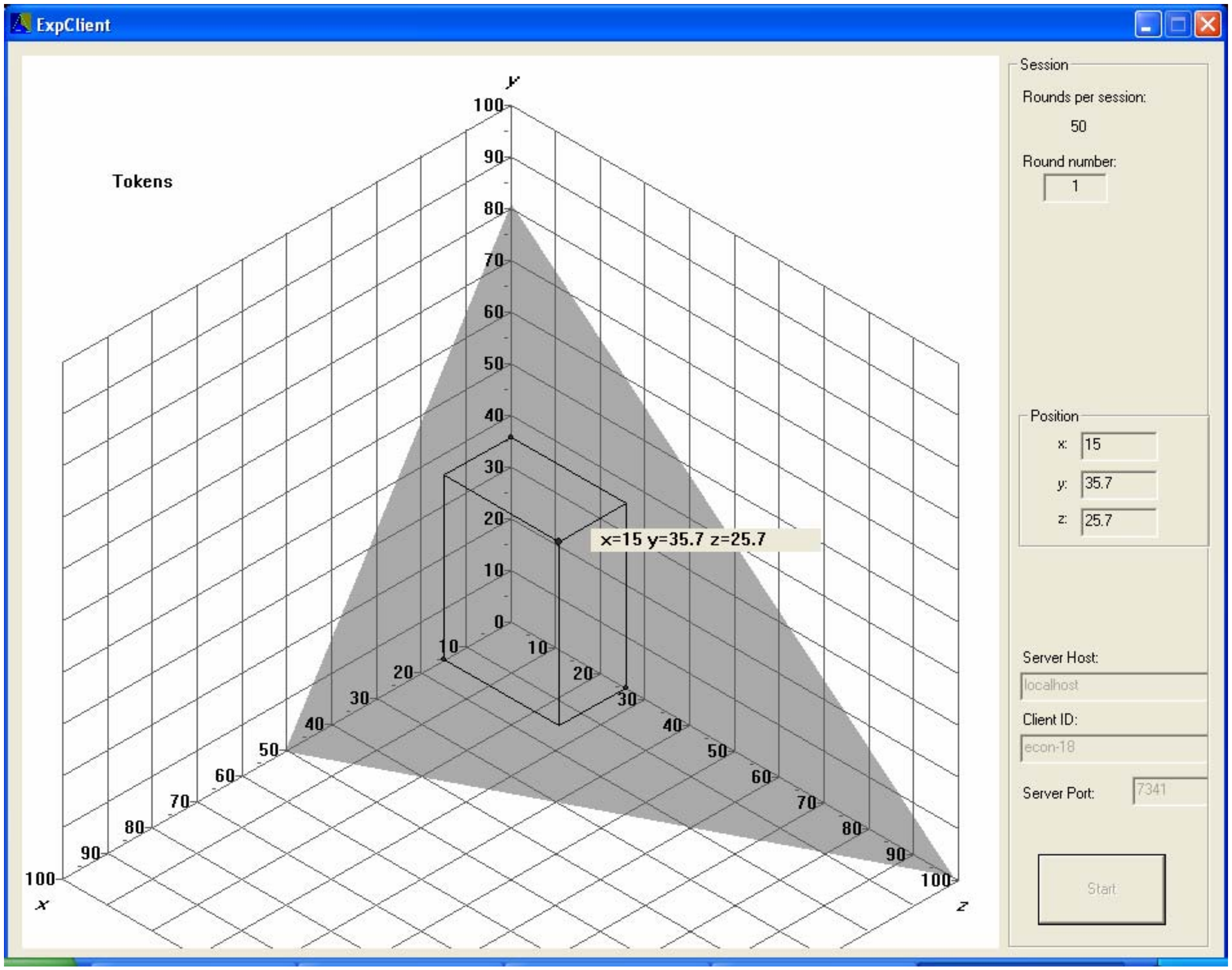
A new experimental design

An experimental design that has a couple of fundamental innovations over previous work:

- A selection of a bundle of contingent commodities from a budget set (a portfolio choice problem).
- A graphical experimental interface that allows for the collection of a rich individual-level data set.

The experimental computer program dialog windows




ExpClient
Tokens
x=15 y=35.7 z=25.7
Session
Rounds per session:
50
Round number:
1
Position
x: 15
y: 35.7
z: 25.7
Server Host:
localhost
Client ID:
econ-18
Server Port:
7341
Start

Rationality

Let $\{(p^i, x^i)\}_{i=1}^{50}$ be some observed individual data (p^i denotes the i-th observation of the price vector and x^i denotes the associated portfolio).

A utility function $u(x)$ *rationalizes* the observed behavior if it achieves the maximum on the budget set at the chosen portfolio

$$u(x^i) \geq u(x) \text{ for all } x \text{ s.t. } p^i \cdot x^i \geq p^i \cdot x.$$

Foundations of Economic Analysis (1947)

Paul A. Samuelson (1915-2009) – the first American Nobel laureate in economics and the foremost (academic) economist of the 20th century (and the uncle of Larry Summers…).

Revealed preference

A portfolio x^i is *directly revealed preferred* to a portfolio x^j if $p^i \cdot x^i \geq p^i \cdot x^j$, and x^i is *strictly directly revealed preferred* to x^j if the inequality is strict.

The relation *indirectly revealed preferred* is the transitive closure of the directly revealed preferred relation.

Generalized Axiom of Revealed Preference (GARP) *If* x^i *is indirectly revealed preferred to* x^j*, then* x^j *is not strictly directly revealed preferred (i.e.* $p^j \cdot x^j \leq p^j \cdot x^i$*) to* x^i*.*

GARP is tied to utility representation through a theorem, which was first proved by Afriat (1967).

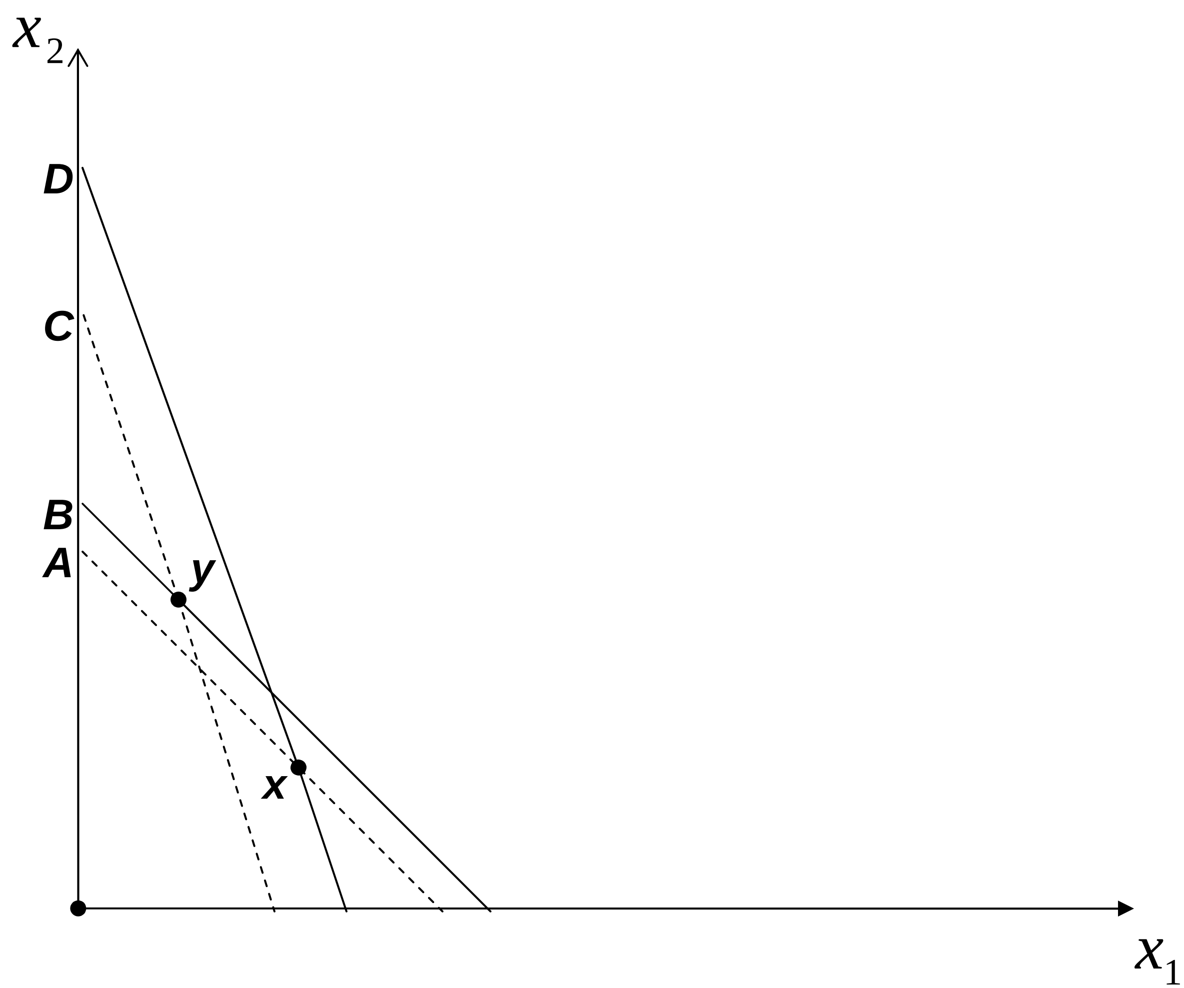
Afriat's Theorem *The following conditions are equivalent:*

- *The data satisfy GARP.*
- *There exists a non-satiated utility function that rationalizes the data.*
- *There exists a concave, monotonic, continuous, non-satiated utility function that rationalizes the data.*

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.*

The CCEI is bounded between zero and one. The closer it is to one, the smaller the perturbation required to remove all violations and thus the closer the data are to satisfying GARP.

The construction of the CCEI for a simple violation of GARP



The agent is 'wasting' as much as *A/B*<*C/D* of his income by making inefficient choices.

A benchmark level of consistency

A random sample of hypothetical subjects who implement the power utility function

$$u(x) = \frac{x^{1-\rho}}{1-\rho},$$

commonly employed in the empirical analysis of choice under uncertainty, with error.

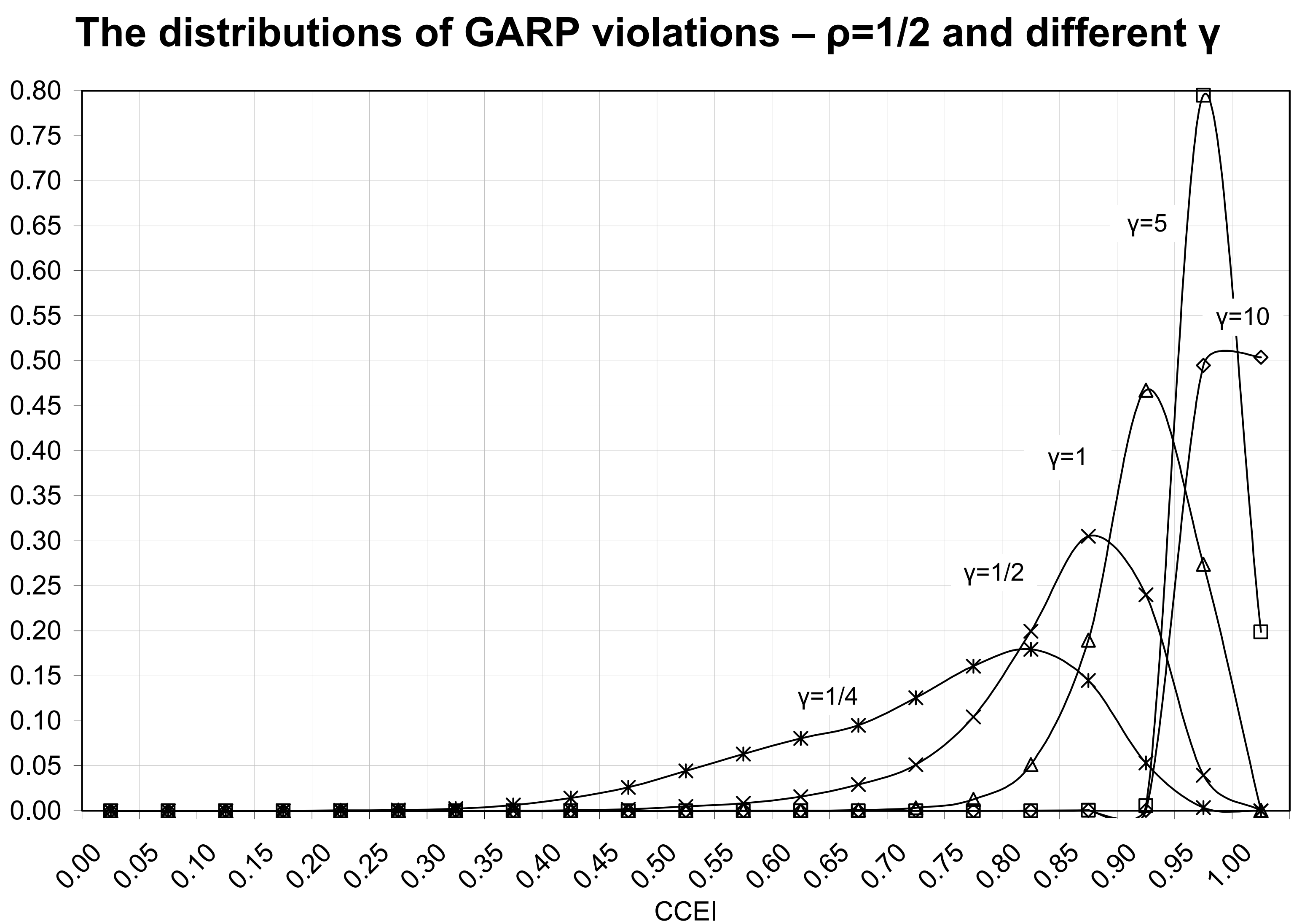
The likelihood of error is assumed to be a decreasing function of the utility cost of an error.

More precisely, we assume an idiosyncratic preference shock that has a logistic distribution

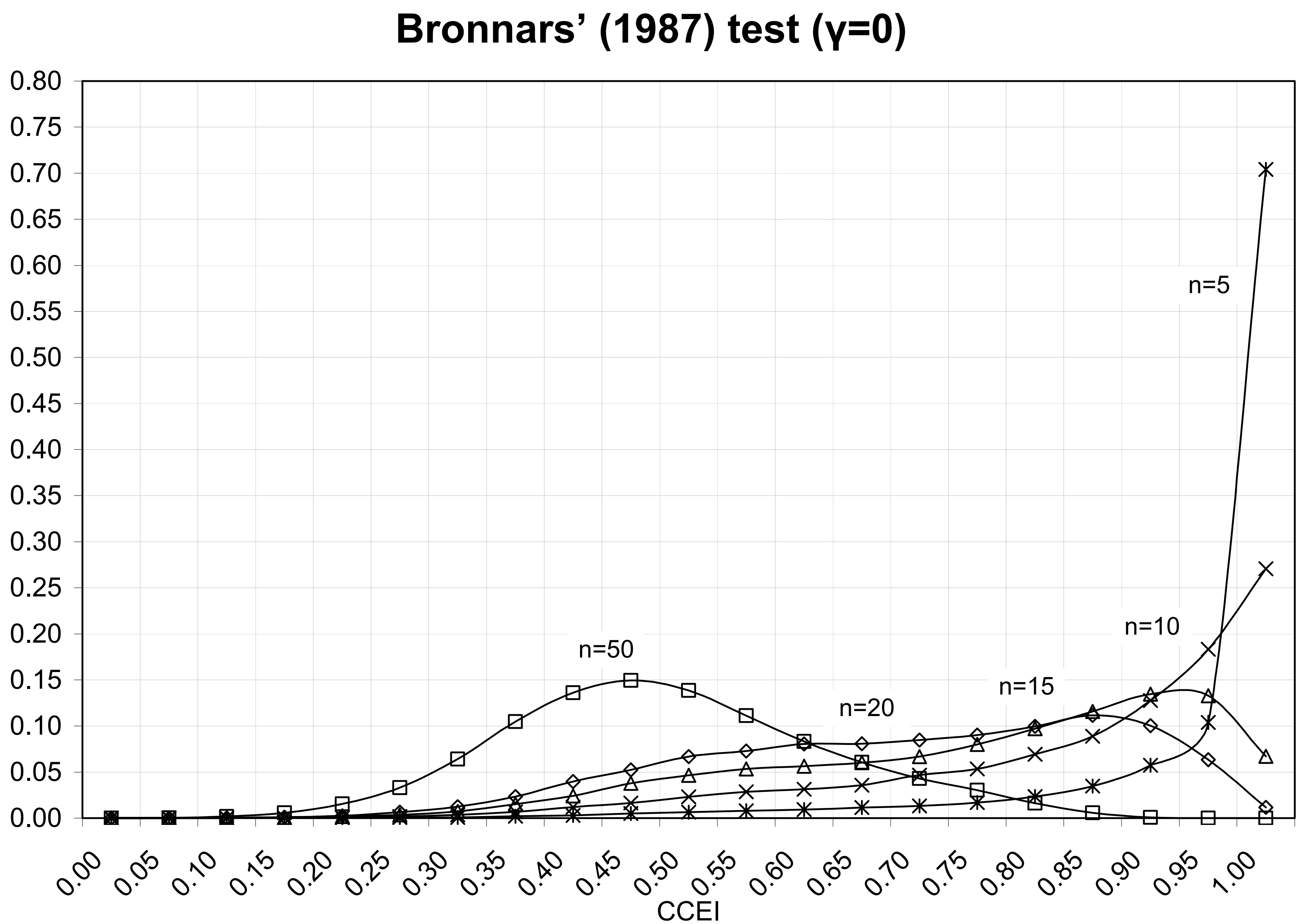
$$\text{Pr}(x^*) = \frac{e^{\gamma \cdot u(x^*)}}{\int\limits_{x:p \cdot x = 1} e^{\gamma \cdot u(x)}},$$

where the precision parameter γ reflects sensitivity to differences in utility.

If utility maximization is not the correct model, is our experiment sufficiently powerful to detect it?



The distributions of GARP violations – ρ=1/2 and different γ
γ=5
γ=10
γ=1
γ=1/2
γ=1/4
0.80
0.75
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50 0.55 0.60 0.65 0.70 0.75 0.80 0.85 0.90 0.95 1.00
CCEI


Bronnars' (1987) test (γ=0)
0.80
0.75
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
n=5
n=10
n=15
n=20
n=50
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50 0.55 0.60 0.65 0.70 0.75 0.80 0.85 0.90 0.95 1.00
CCEI

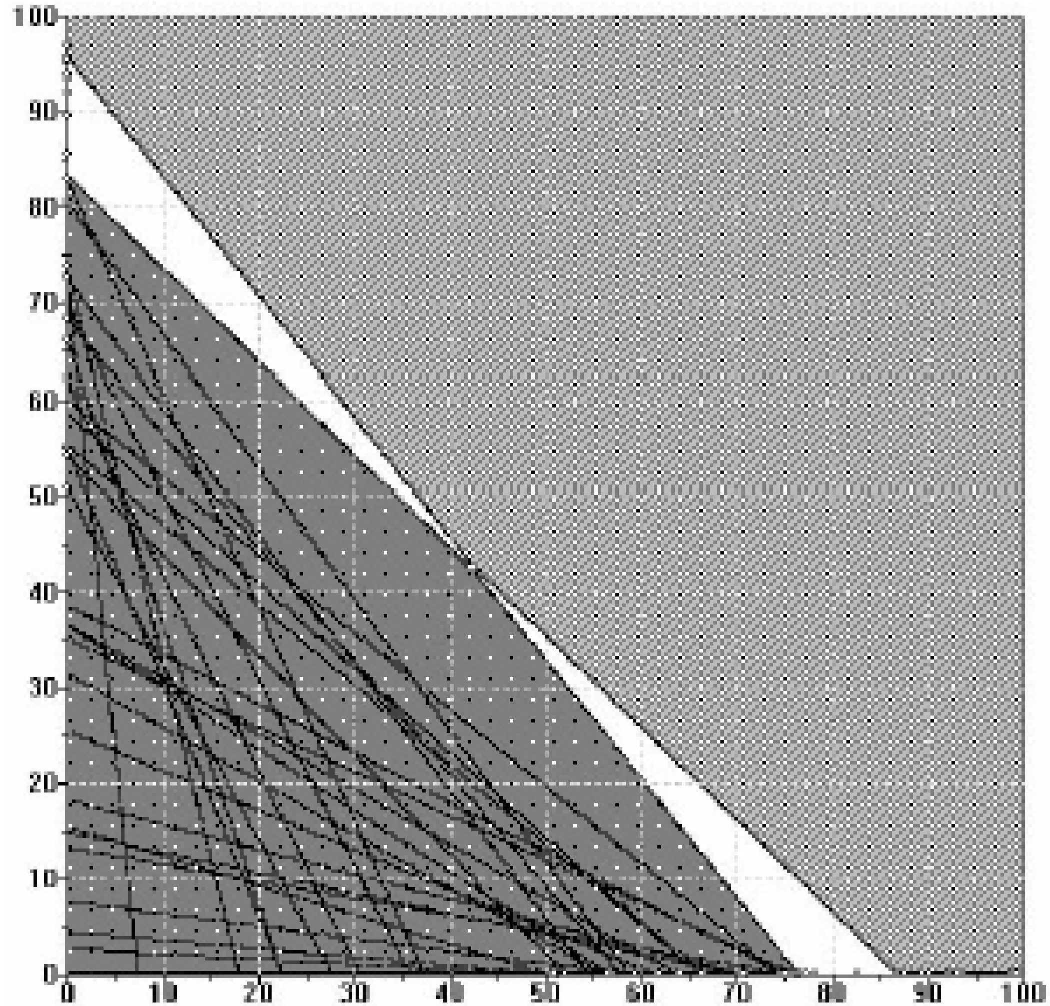
Recoverability

- Revealed preference relations in the data contain the information that is necessary for recovering preferences.

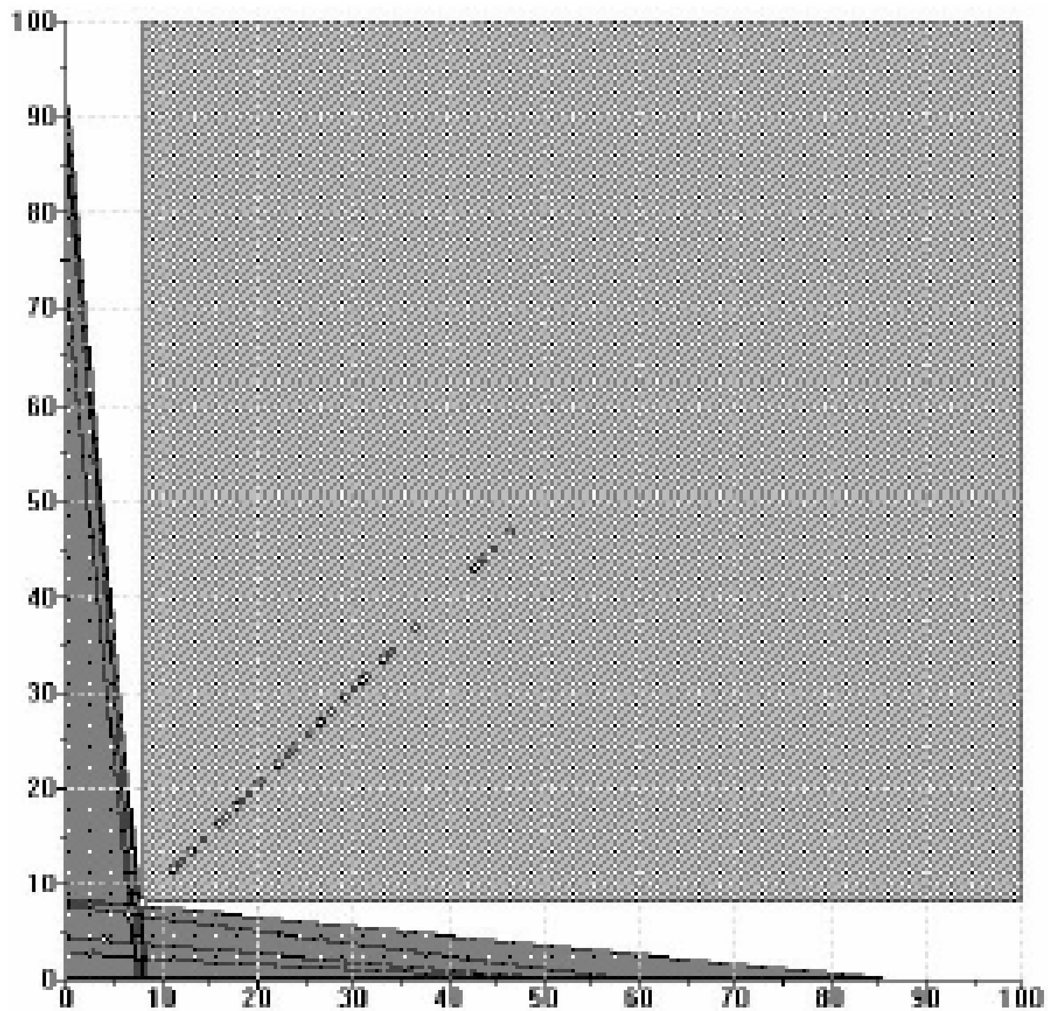
- Varian (*ECMA*, 1982) uses GARP to generate an algorithm that can recover preferences from choices.

- This approach is purely nonparametric making no assumptions about the parametric form of the underlying utility function.

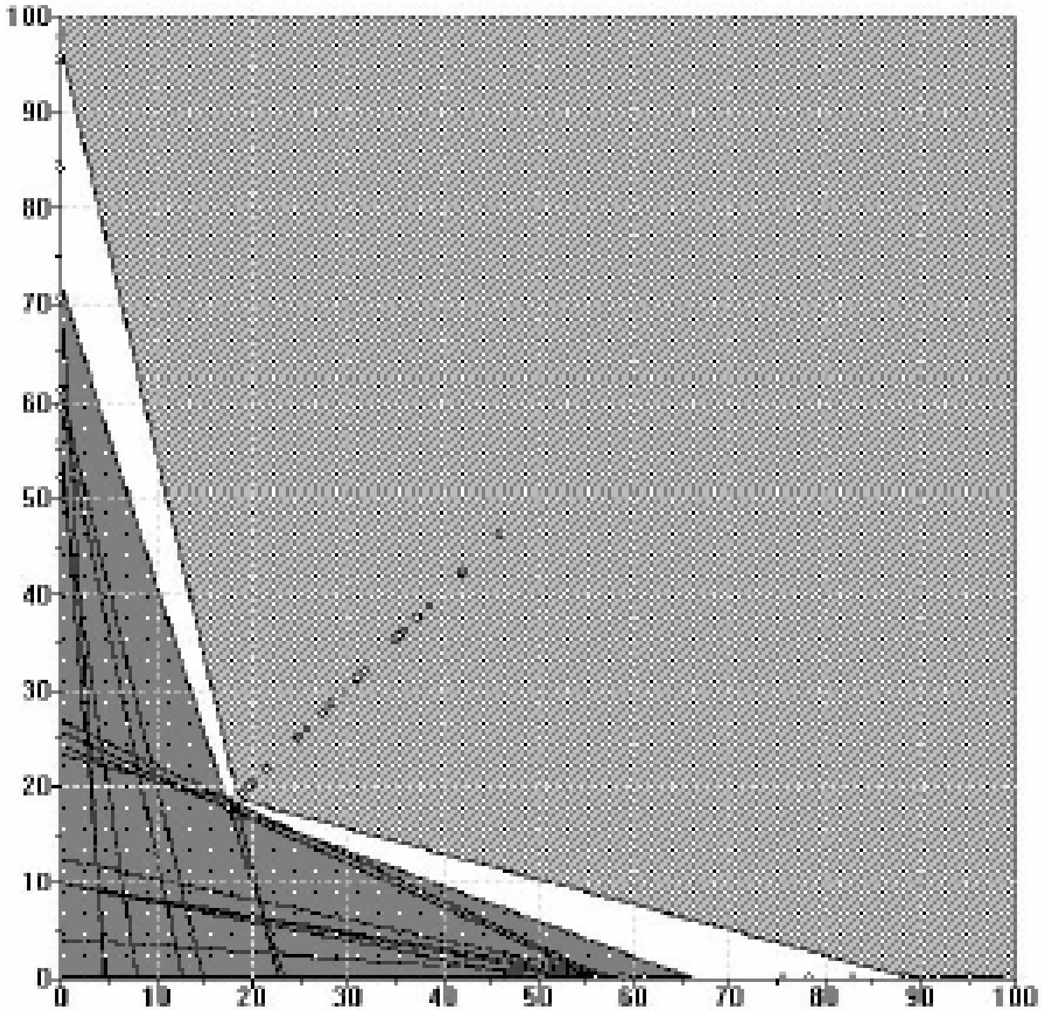
Risk neutrality



Infinite risk aversion



Loss / disappointment aversion



The CentERpanel

- A representative sample of over 2,000 Dutch-speaking households (5,000 individual members) in the Netherlands.

- A wide range of individual socio-demographic and economic information for the panel members.

- The subjects in the experiment were randomly recruited from the entire CentERpanel body.

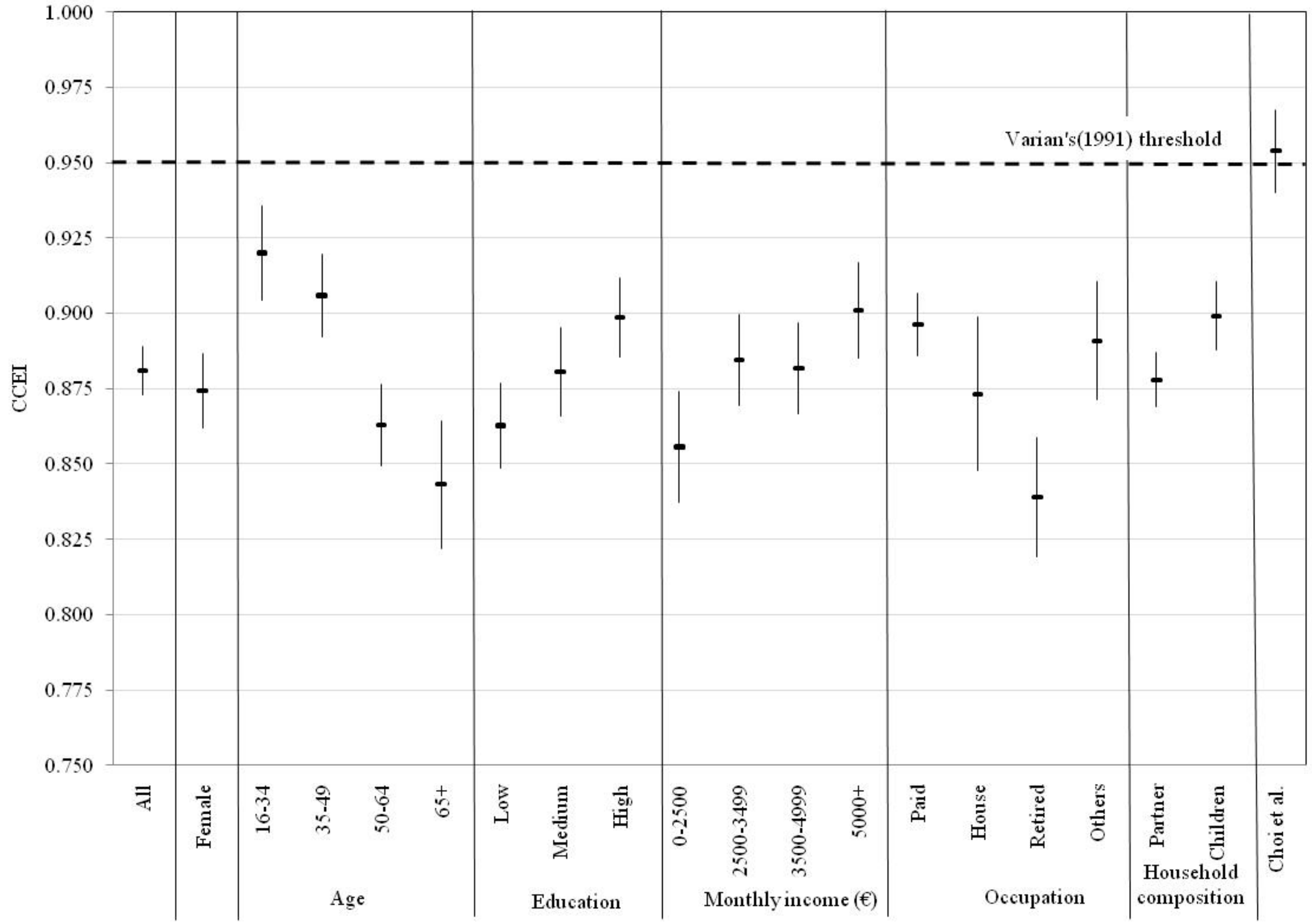
Types of analysis

[1] A descriptive overview of the average quality of decisions (consistency with economic rationality).

[2] The relationship between decision-making quality and demographic and economic characteristics.

[3] The correspondence between wealth accumulation and behavior in the laboratory.

Mean CCEI scores



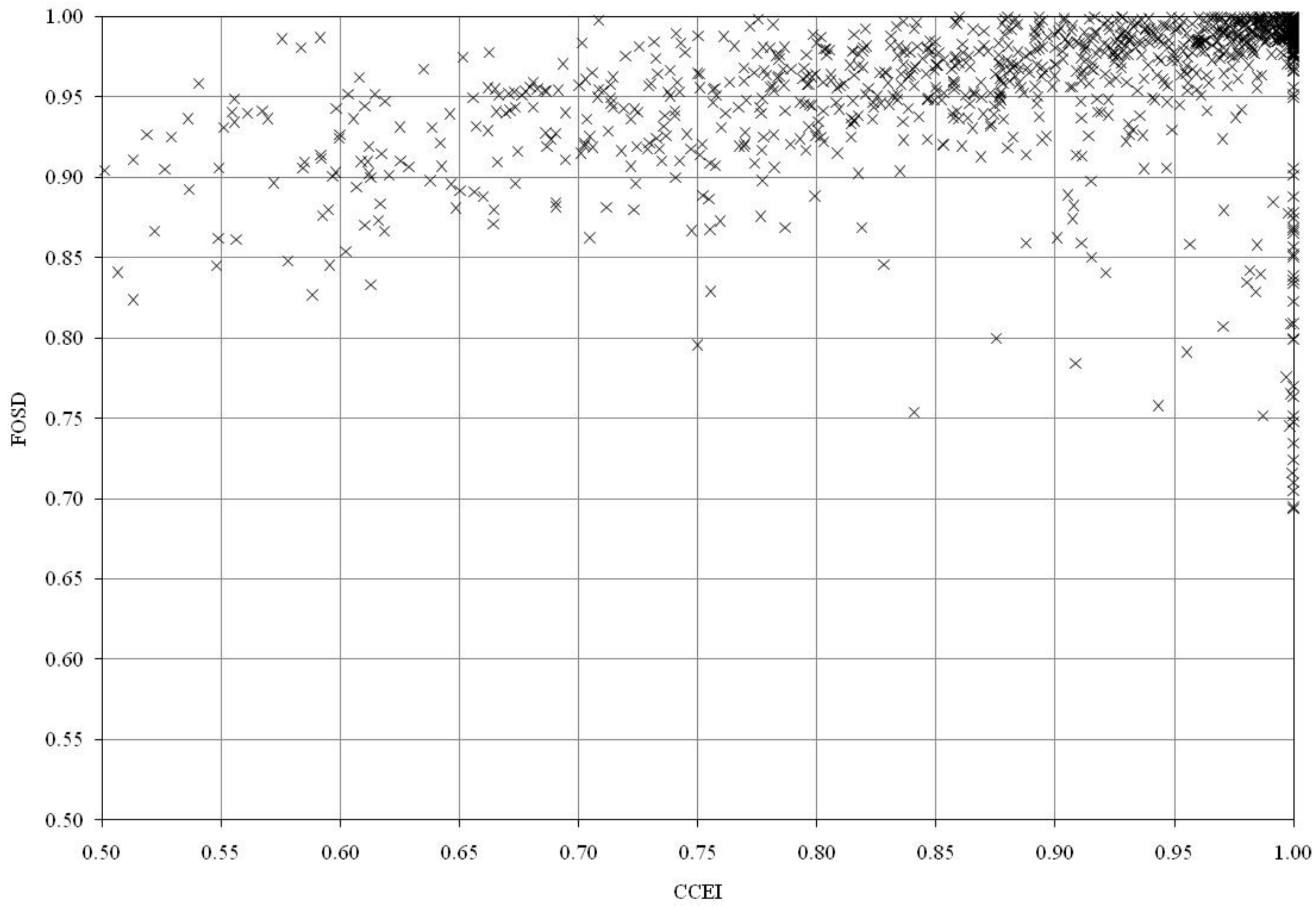
Dominance

- Violations of monotonicity with respect to first-order stochastic dominance (FOSD) are errors, regardless of risk attitudes.

- A decision to allocate *less* tokens to the *cheaper* account violates dominance but need not involve a violation of GARP.

- We use expected payoff calculations (largest upward probabilistic shift) to assess how nearly choice behavior complies with dominance.

A scatterplot of CCEI and FOSD scores



Wealth differentials

$\Longrightarrow$ The heterogeneity in wealth is not well-explained either by standard observables (income, education, family structure) or by standard unobservables (intertemporal substitution, risk tolerance).

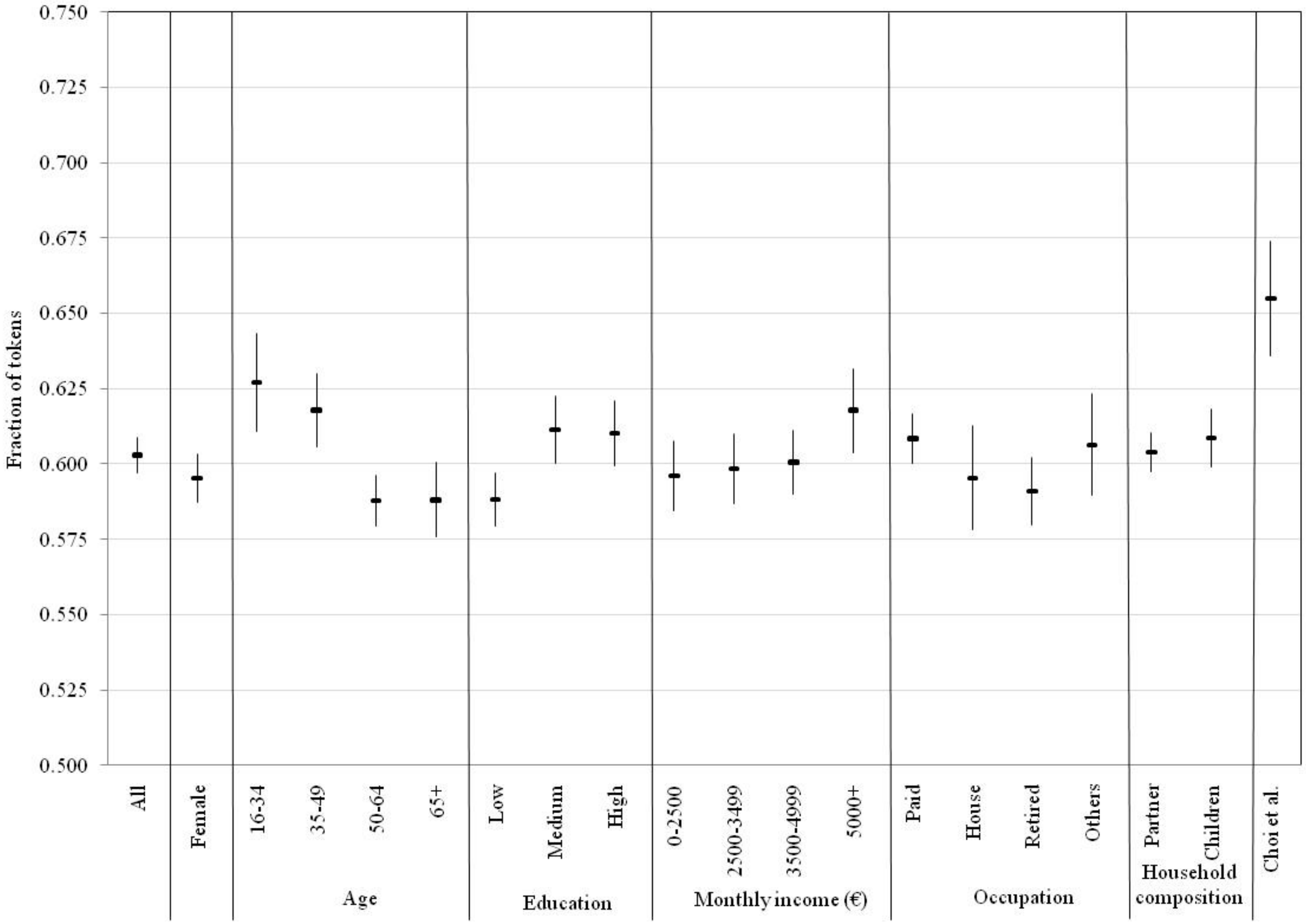
$\Longrightarrow$ If consistency with utility maximization in the experiment were a good proxy for (financial) decision-making quality then the degree to which consistency differ across subjects should help explain wealth differentials.

Wealth regressions

	Ln(hhld wealth)			
CCEI	1.425**	1.348*	1.781**	1.728**
	(0.565)	(0.714)	(0.746)	(0.750)
Combined CCEI		0.078	-0.091	-0.038
		(0.381)	(0.381)	(0.384)
Risk attitude			-1.361	-1.366
			(0.838)	(0.840)
Conscientiousness				0.103
				(0.072)
Ln(hhld income '08)	0.601***	0.602***	0.520***	0.514***
	(0.127)	(0.127)	(0.121)	(0.121)
Female	-0.228	-0.229	-0.299	-0.321
	(0.164)	(0.164)	(0.168)	(0.169)
Age	-0.286	-0.284	-0.310	-0.282
	(0.316)	(0.316)	(0.319)	(0.316)
Age^2	0.006	0.006	0.007	0.006
	(0.005)	(0.005)	(0.005)	(0.005)
Age^3	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Partner	0.682***	0.682***	0.733***	0.714***
	(0.183)	(0.183)	(0.191)	(0.191)
# of children	0.103	0.103	0.095	0.090
	(0.092)	(0.093)	(0.095)	(0.095)
Education controls	Y	Y	Y	Y
Constant	5.932	5.888	7.797	7.371
	(5.862)	(5.879)	(5.880)	(5.841)
R^2	0.1794	0.1778	0.1801	0.1819
# of obs.	517	517	494	494

Risk aversion and loss aversion

Risk aversion – the fraction of tokens allocated to the cheaper asset



Loss/disappointment aversion

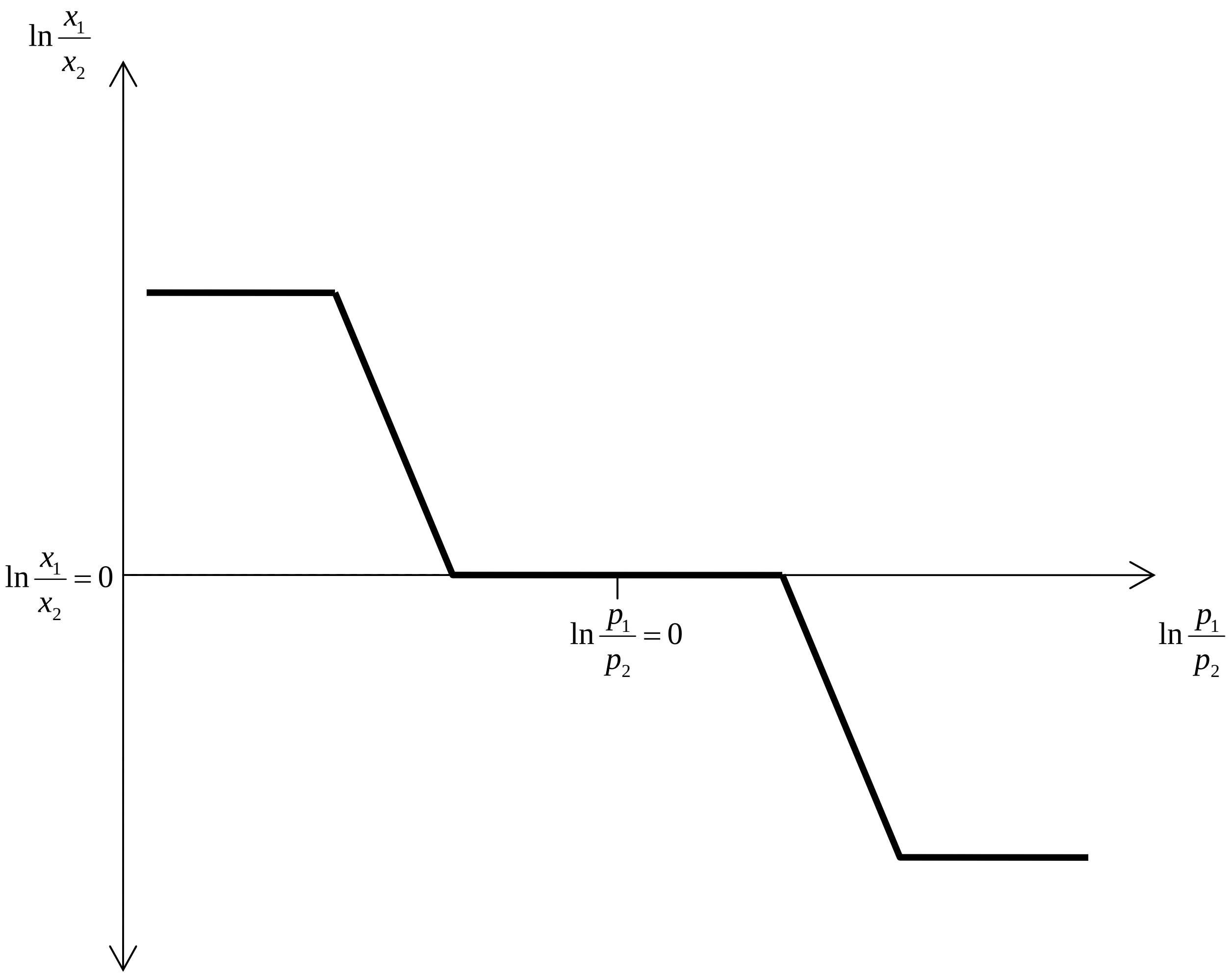
The theory of Gul (1991) implies that the utility function over portfolios takes the form

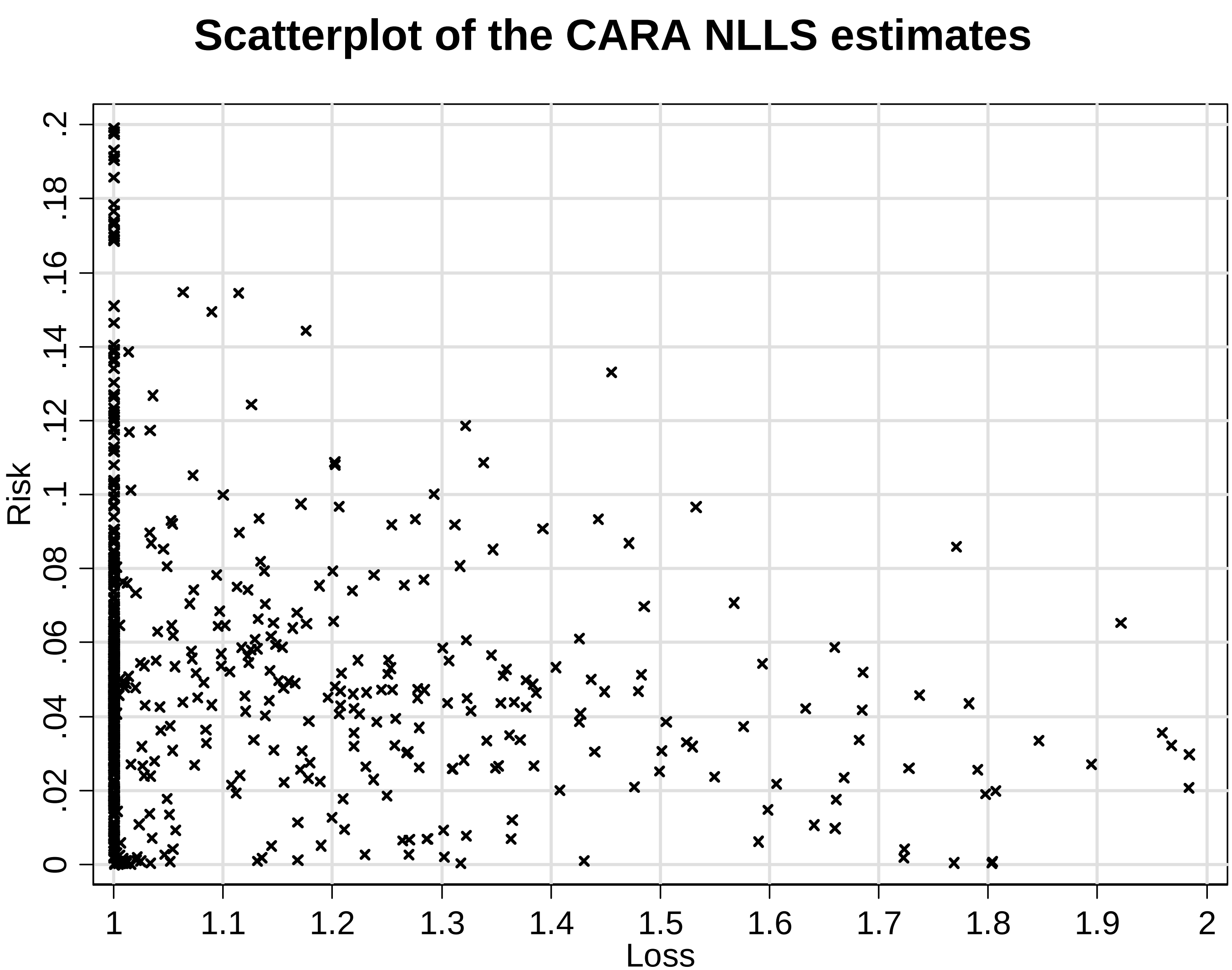
$$\min \left\{ \alpha u\left(x_1\right) + u\left(x_2\right), u\left(x_1\right) + \alpha u\left(x_2\right) \right\},$$

where $\alpha \geq 1$ measures loss/disappointment aversion and $u(\cdot)$ is the utility of consumption in each state.

If $\alpha > 1$ there is a kink at the point where $x_1 = x_2$ and if $\alpha = 1$ we have the standard EUT representation.

An illustration of the derived demand




Scatterplot of the CARA NLLS estimates
Risk
0
.02
.04
.06
.08
.1
.12
.14
.16
.18
.2
1
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2
Loss

Risk aversion (CARA)

	All sample	CCEI ≥ 0.8	CCEI ≥ 0.9
Female	0.060***	0.086***	0.110***
	(0.021)	(0.026)	(0.032)
Age			
35-49	0.020	0.025	0.047
	(0.030)	(0.036)	(0.043)
50-64	-0.007	0.011	0.026
	(0.029)	(0.035)	(0.042)
65+	0.085*	0.148**	0.187***
	(0.045)	(0.058)	(0.071)
Education			
Medium	-0.026	-0.049	-0.069*
	(0.024)	(0.031)	(0.038)
High	0.002	-0.018	-0.053
	(0.024)	(0.030)	(0.038)
Income			
€2500-3499	-0.023	0.004	0.023
	(0.027)	(0.035)	(0.044)
€3500-4999	-0.010	0.009	0.010
	(0.027)	(0.035)	(0.044)
€5000+	0.003	0.022	0.041
	(0.031)	(0.039)	(0.048)
Occupation			
Paid work	0.098***	0.141***	0.146**
	(0.038)	(0.050)	(0.065)
House work	0.046	0.056	0.017
	(0.042)	(0.057)	(0.072)
Others	0.091**	0.133**	0.108
	(0.043)	(0.056)	(0.072)
Household composition			
Partner	-0.033	-0.034	-0.031
	(0.026)	(0.032)	(0.039)
# of children	0.005	0.008	0.005
	(0.010)	(0.013)	(0.015)
Constant	0.125**	0.088	0.113
	(0.054)	(0.068)	(0.088)
R^2	0.022	0.03	0.037
# of obs.	1,182	901	681

Loss aversion (CARA)

	All sample	CCEI ≥ 0.8	CCEI ≥ 0.9
Female	-0.021	0.024	0.151
	(0.166)	(0.203)	(0.247)
Age			
35-49	0.468*	0.543*	0.706**
	(0.241)	(0.280)	(0.333)
50-64	0.013	0.121	0.301
	(0.236)	(0.277)	(0.331)
65+	0.834**	1.230***	1.413**
	(0.363)	(0.455)	(0.560)
Education			
Medium	0.155	0.078	0.116
	(0.192)	(0.239)	(0.296)
High	0.475**	0.523**	0.428
	(0.192)	(0.235)	(0.291)
Income			
€2500-3499	0.396*	0.620**	0.773**
	(0.216)	(0.270)	(0.337)
€3500-4999	-0.118	0.046	-0.098
	(0.217)	(0.272)	(0.339)
€5000+	0.097	0.216	0.192
	(0.244)	(0.299)	(0.369)
Occupation			
Paid work	0.394	0.752*	0.782
	(0.306)	(0.394)	(0.508)
House work	0.293	0.752*	0.524
	(0.340)	(0.447)	(0.561)
Others	0.750**	1.253***	1.283**
	(0.347)	(0.440)	(0.563)
Household composition			
Partner	-0.565***	-0.742***	-0.799***
	(0.207)	(0.249)	(0.305)
# of children	0.180**	0.204**	0.215*
	(0.083)	(0.100)	(0.120)
Constant	1.663***	1.316**	1.432**
	(0.436)	(0.538)	(0.692)
R^2	0.036	0.047	0.051
# of obs.	1,182	901	681

Ambiguity aversion

Ambiguity aversion

- The distinction between settings with risk and ambiguity dates back to at least the work of Knight (1921).

- Ellsberg (1961) countered the reduction of subjective uncertainty to risk with several thought experiments.

- A large theoretical literature (axioms over preferences) has developed models to accommodate this behavior.

Experiments à la Ellsberg

Consider the following four two-color Ellsberg-type urns (Halevy, 2007):

I. 5 red balls and 5 black balls

II. an unknown number of red and black balls

III. a bag containing 11 tickets with the numbers 0-10; the number written on the drawn ticket determines the number of red balls

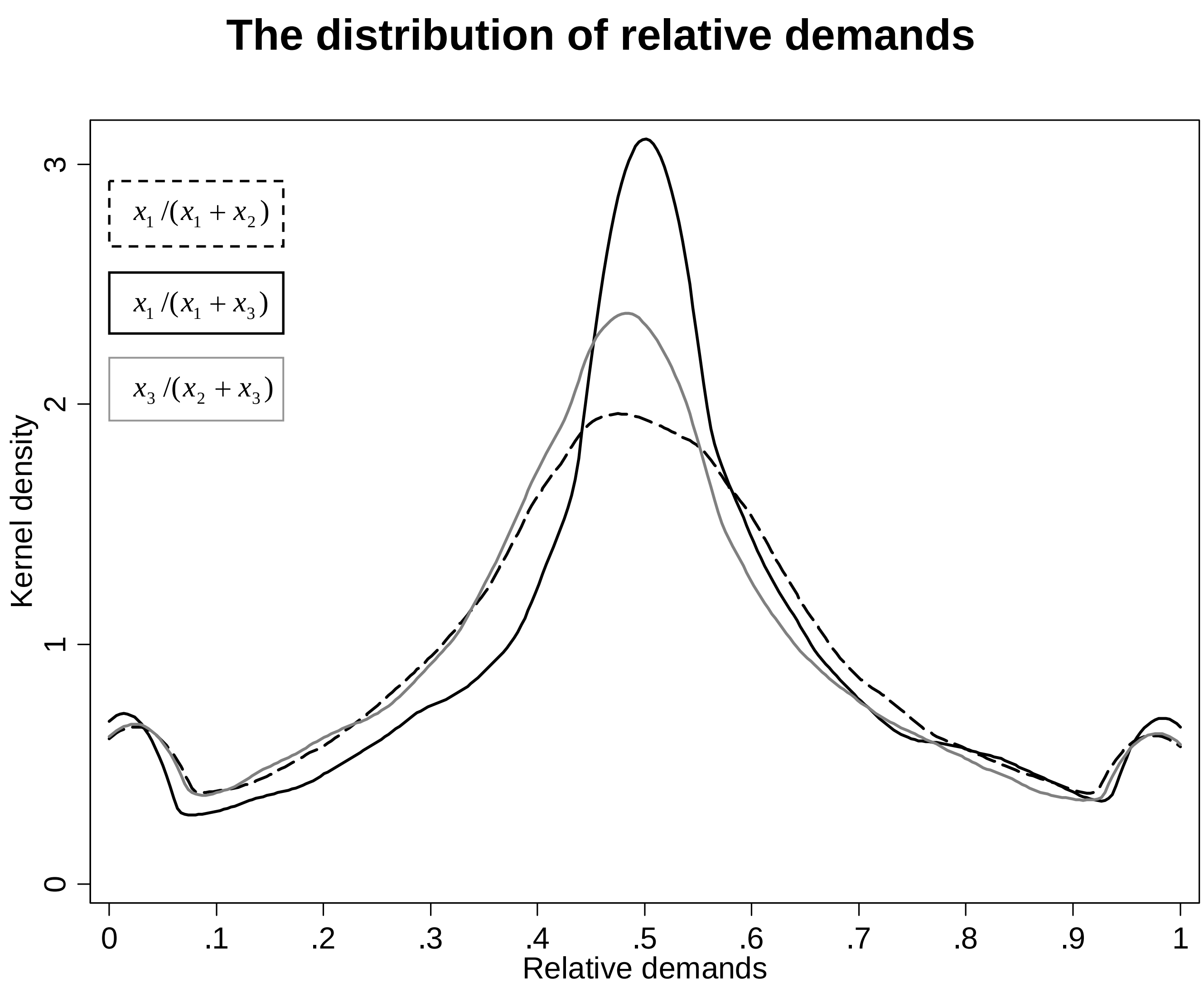
IV. a bag containing 2 tickets with the numbers 0 and 10; the number written on the drawn ticket determines the number of red balls

- A <u>cleverly</u> designed experiment that allows distinguishing between four models of ambiguity aversion — SEU, MEU, REU and RNEU.

- The different models of ambiguity aversion generate different predictions about how the urns will be ordered.

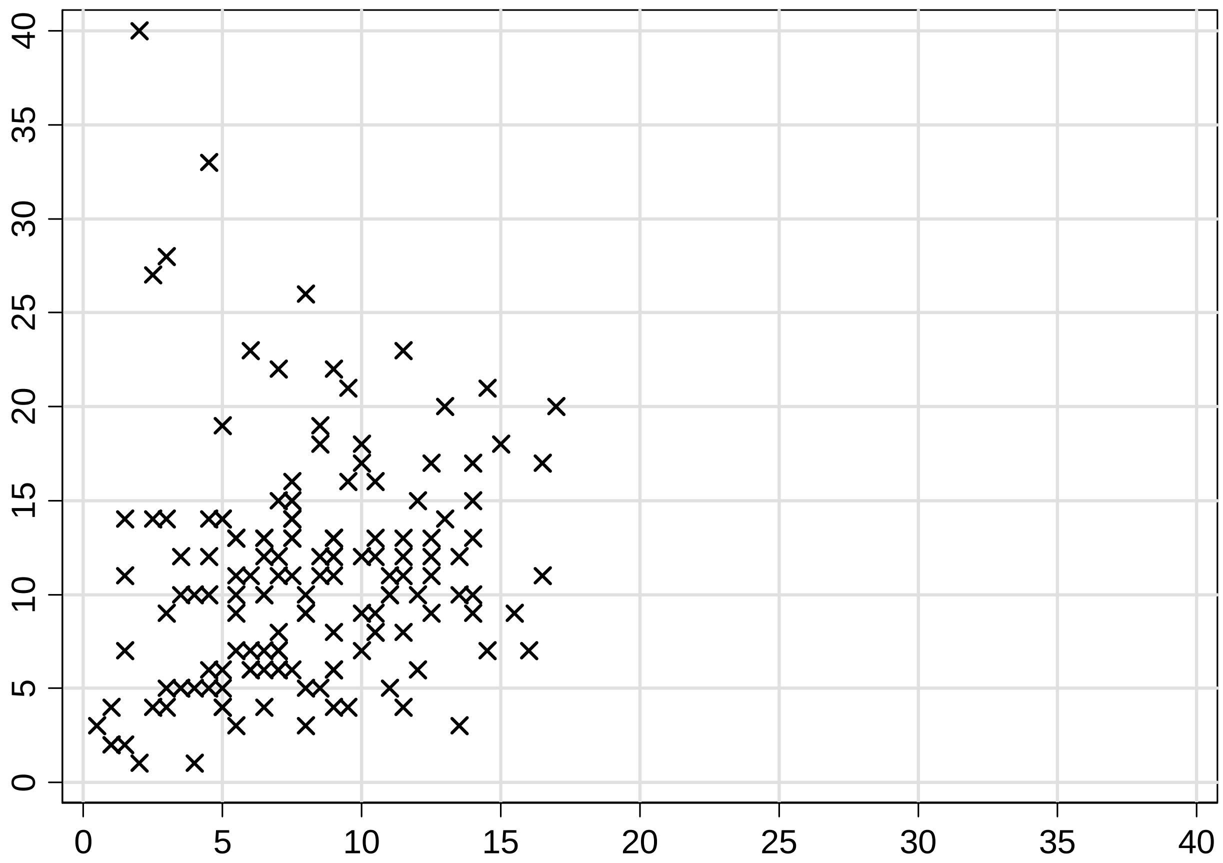
- For each subject, there will be a unique model that predicts (is consistent with) the subject's reservation values.

- No single model predicts all the observed behaviors, and all models are represented in the pool of subjects.



The distribution of relative demands
$x_1/(x_1+x_2)$
$x_1/(x_1+x_3)$
$x_3/(x_2+x_3)$
Kernel density
0
1
2
3
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1
Relative demands

The number of diagonal portfolios by subject
(ambiguity - vertical axis / loss - horizontal axis)



Parametric analysis

There is a variety of theoretical models of attitudes toward risk and ambiguity, but they all give rise to one of two main specifications:

[1] kinked specification rationalized by α-Maxmin Expected Utility (α-MEU), Choquet Expected Utility, or Contraction Expected Utility.

[2] smooth specification, based on the class of Recursive Expected Utility (REU) models.

The kinked specification has the form

$$\alpha\left[\tfrac{2}{3}u(\text{min}\{x_1, x_3\}) + \tfrac{1}{3}u(x_2)\right] \\ + (1-\alpha)\left[\tfrac{2}{3}u(\text{max}\{x_1, x_3\}) + \tfrac{1}{3}u(x_2)\right],$$

where α is the ambiguity parameter.

The indifference curves have a "kink" at all unambiguous portfolios where $x_1 = x_3$.

The general form of the smooth specification is

$$\int_{\mathbf{\Delta} S} \varphi \left(\int_S u(x_s)\, d\pi(s) \right) d\mu(\pi),$$

where $\mu \in \mathbf{\Delta}(\mathbf{\Delta}(S))$ is a (second-order) distribution over possible priors π on S and $\varphi : u(\mathbf{R}_+) \to \mathbf{R}$ is a possibly nonlinear transformation over expected utility levels.

The REU models are based a cardinal utility indicator – the preferences generated are not independent of a change in the scale of utility.

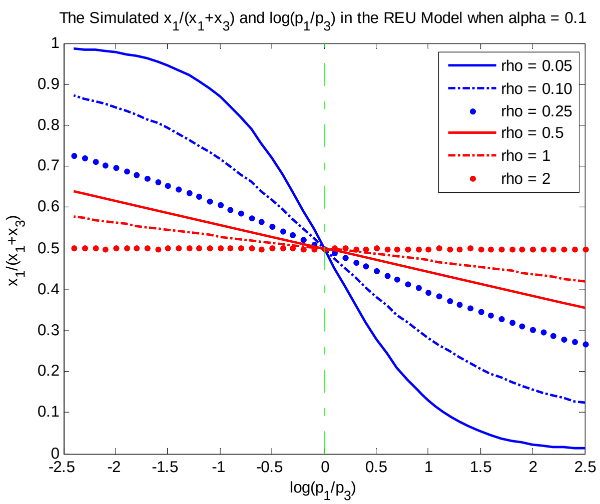
To clarify, suppose risk preferences are represented by a von Neumann-Morgenstern utility function $u(x)$ with constant absolute risk aversion (CARA)

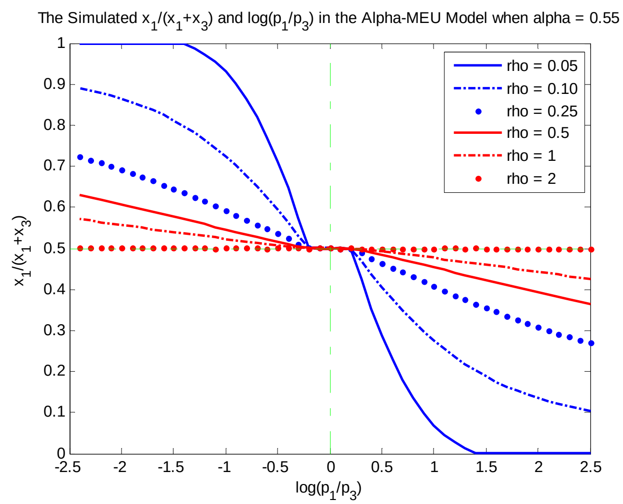
$$u(x) = -Ae^{-\rho x},$$

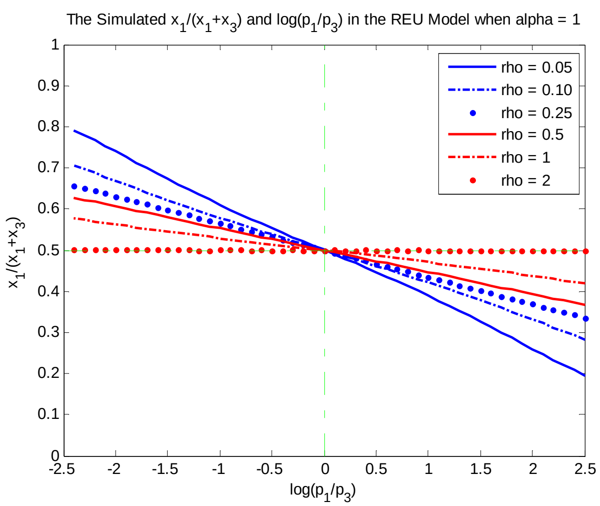
where x is the number of tokens, A a scale parameter, and ρ is the coefficient of absolute risk aversion.

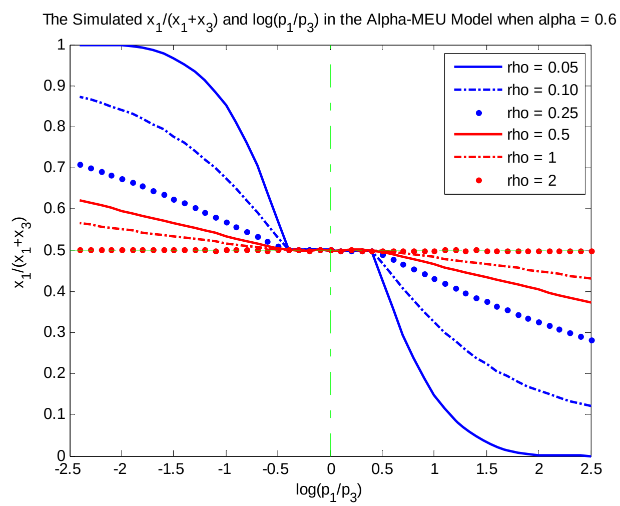
The concavity of the transformation φ implies that the ranking of uncertain prospects will not be invariant to changes in A (cannot identify φ and A separately).

Smooth (left) and kinked (right) specifications









Estimation

→ Our first parametric assumption is that risk preferences are represented by a von Neumann-Morgenstern utility function with CARA,

$$u(x) = -e^{-\rho x}.$$

→ We restrict, WLOG, the parameters so that preferences are always risk and ambiguity averse – $\rho \geq 0$ in both specifications, $1/2 \leq \alpha \leq 1$ in the kinked specification and $0 \leq \alpha$ in the smooth specification.

→ For each subject n and for each specification, we generate estimates of the ambiguity and risk aversion parameters, $\hat{\alpha}_n$ and $\hat{\rho}_n$, using nonlinear least squares (NLLS).

Econometric results

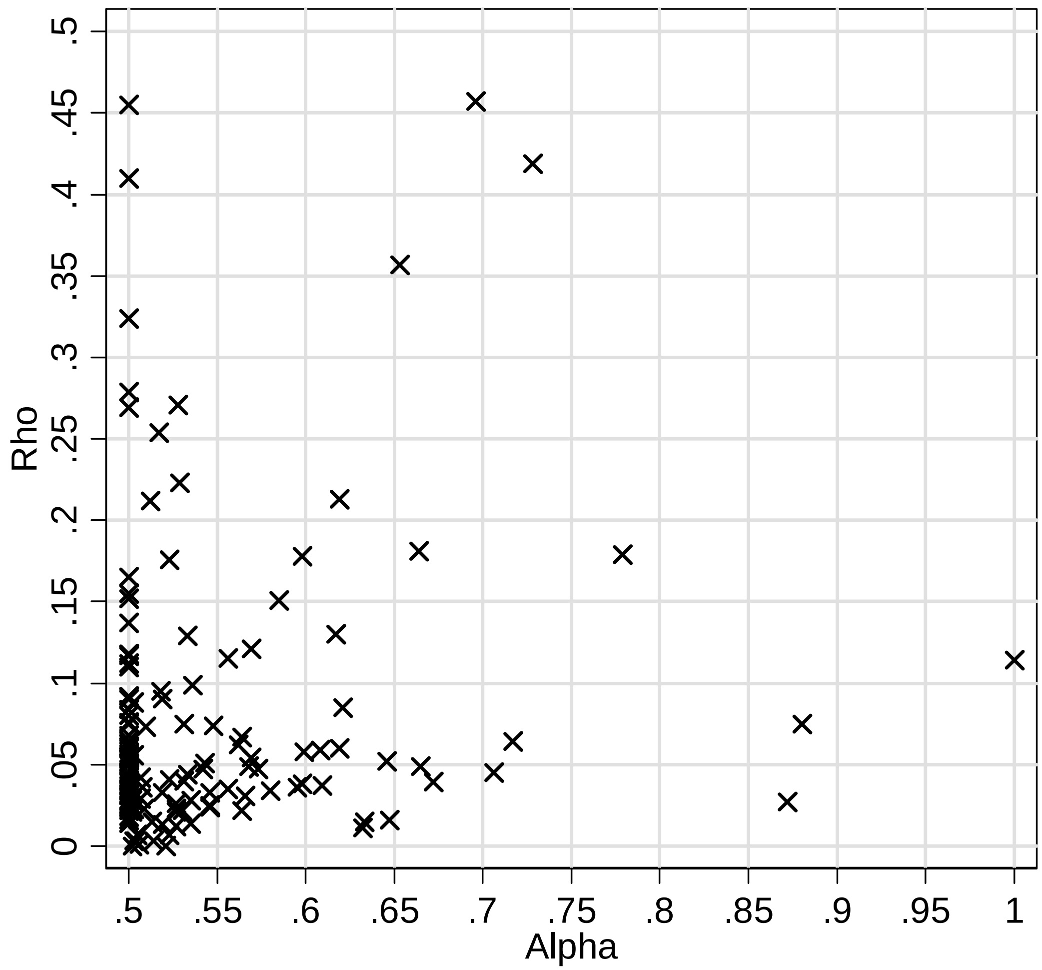
Kinked specification

56 subjects (38.9%) have non-kinky preferences $\hat{\alpha}_n \approx 1/2$. We cannot reject the hypothesis that $\alpha_n = 1/2$ for a total of 109 subjects (75.7%) at the 5% significance level.

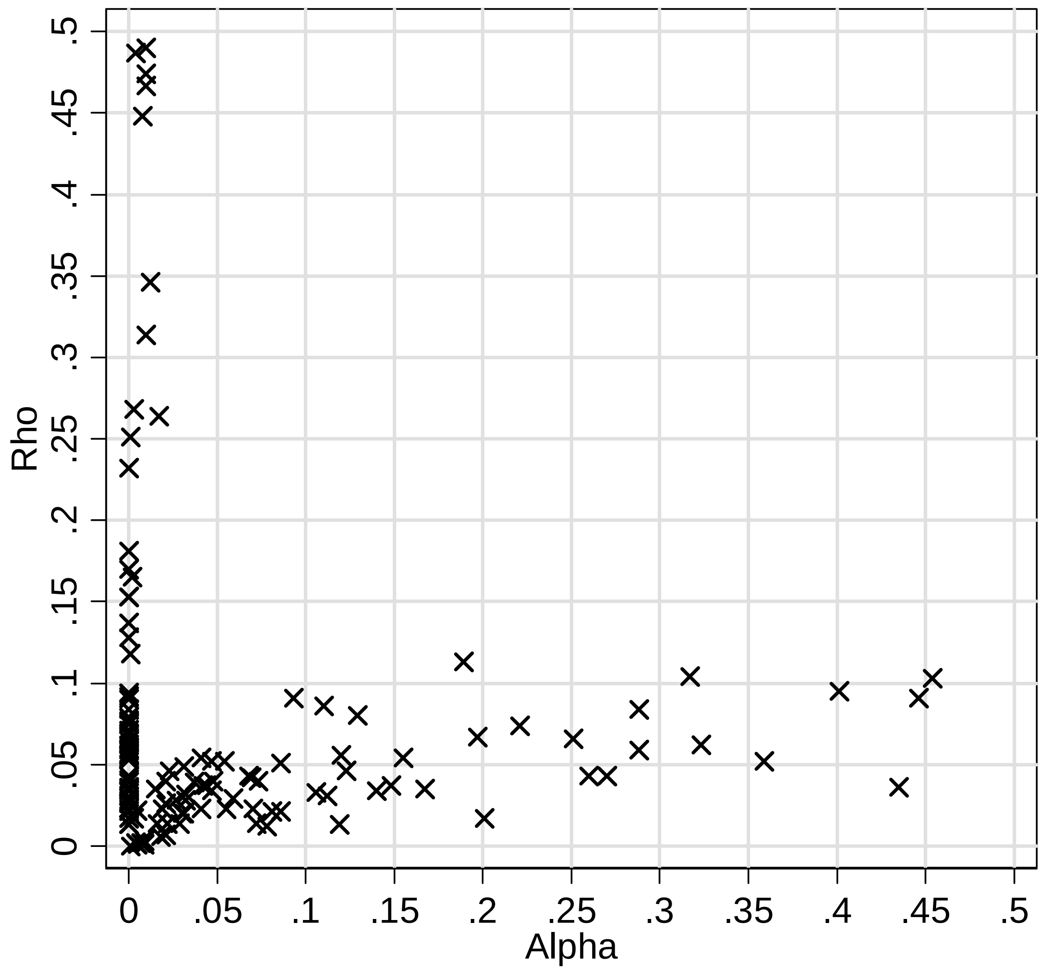
Smooth specification

44 subjects (30.6%) have $\hat{\alpha}_n \approx 0$, indicating ambiguity neutrality. We cannot reject the hypothesis that $\alpha_n = 0$ for a total of 97 subjects (67.4%) at the 5% significance level .

Scatterplot of the estimated parameters – kinked specification



Scatterplot of the estimated parameters – smooth specification



- There is the strong tendency for subjects to equate the demand for the securities that pay off in the ambiguous states, x_1 and x_3.

- This feature of the data is consistent with the kinked specification but not with the smooth specification.

- But the tendency to equate x_1 and x_3 cannot be attributed solely to ambiguity aversion.

- In the first place, there is also strong tendency to equate the demand for the securities that pay off in any pair of states.

A model of ambiguity aversion and loss/disappointment aversion

- If both loss aversion and ambiguity aversion are present in the data, we need a structural model in order to disentangle the two effects.

- In order to allow for kinks at portfolios where $x_s = x_{s'}$ for any $s \neq s'$, we make use of the rank-dependent utility (RDU) model of Quiggin (1982).

- This is a generalization of the SEU model that replaces probabilities with *decision weights* when calculating the value of expected utility.

- In Quiggin (1982), the decision weight of each payout depends only on its (known) probability and its ranking position.

Following α-MEU, we assume that the unknown probabilities π_1 and π_3 are skewed using the weights α and $1 - \alpha$:

$$x_{\text{min}} = \min\{x_1, x_3\}$$

is given a probability weight $\frac{2}{3}\alpha$ and

$$x_{\text{max}} = \max\{x_1, x_3\}$$

is given probability weight $\frac{2}{3}(1 - \alpha)$ where the parameter $\frac{1}{2} \leq \alpha \leq 1$ measures the degree of ambiguity aversion.

The utility of a portfolio $\mathbf{x} = (x_1, x_2, x_3)$ takes the form

I. $x_2 \leq x_{\text{min}}$

$$\beta_1 u(x_2) + \beta_2 u(x_{\text{min}}) + (1 - \beta_1 - \beta_2) u(x_{\text{max}})$$

II. $x_{\text{min}} \leq x_2 \leq x_{\text{max}}$

$$\beta_3 u(x_{\text{min}}) + (\beta_1 + \beta_2 - \beta_3) u(x_2) + (1 - \beta_1 - \beta_2) u(x_{\text{max}})$$

III. $x_{\text{max}} \leq x_2$

$$\beta_3 u(x_{\text{min}}) + \beta_4 u(x_{\text{max}}) + (1 - \beta_3 - \beta_4) u(x_2)$$

where

$$\beta_1 = w\left(\frac{1}{3}\right),$$
$$\beta_2 = w\left(\frac{2}{3}\alpha + \frac{1}{3}\right) - w\left(\frac{1}{3}\right),$$
$$\beta_3 = w\left(\frac{2}{3}\alpha\right),$$
$$\beta_4 = w\left(\frac{2}{3}\right) - w\left(\frac{2}{3}\alpha\right),$$

and the mapping from the four parameters $\beta_1, ..., \beta_4$ to two parameters δ and γ is as follows:

$$\beta_1 = \frac{1}{3} + \gamma,$$
$$\beta_2 = \frac{1}{3} + \delta,$$
$$\beta_3 = \frac{1}{3} + \gamma + \delta,$$
$$\beta_4 = \frac{1}{3} - \delta.$$

The parameter δ measures the degree of ambiguity aversion and the parameter γ measures the degree of loss aversion:

- $\delta \geq 0$ and $\gamma = 0$ – kinked specification

- $\delta = 0$ and $\gamma \geq 0$ – loss/disappointment aversion (Gul, 1991)

- $\delta = 0$ and $\gamma = 0$ – standard SEU representation.

The indifference curves will have kinks where $x_s = x_{s'}$ and agents will choose portfolios that satisfy $x_s = x_{s'}$ for a non-negligible set of prices.

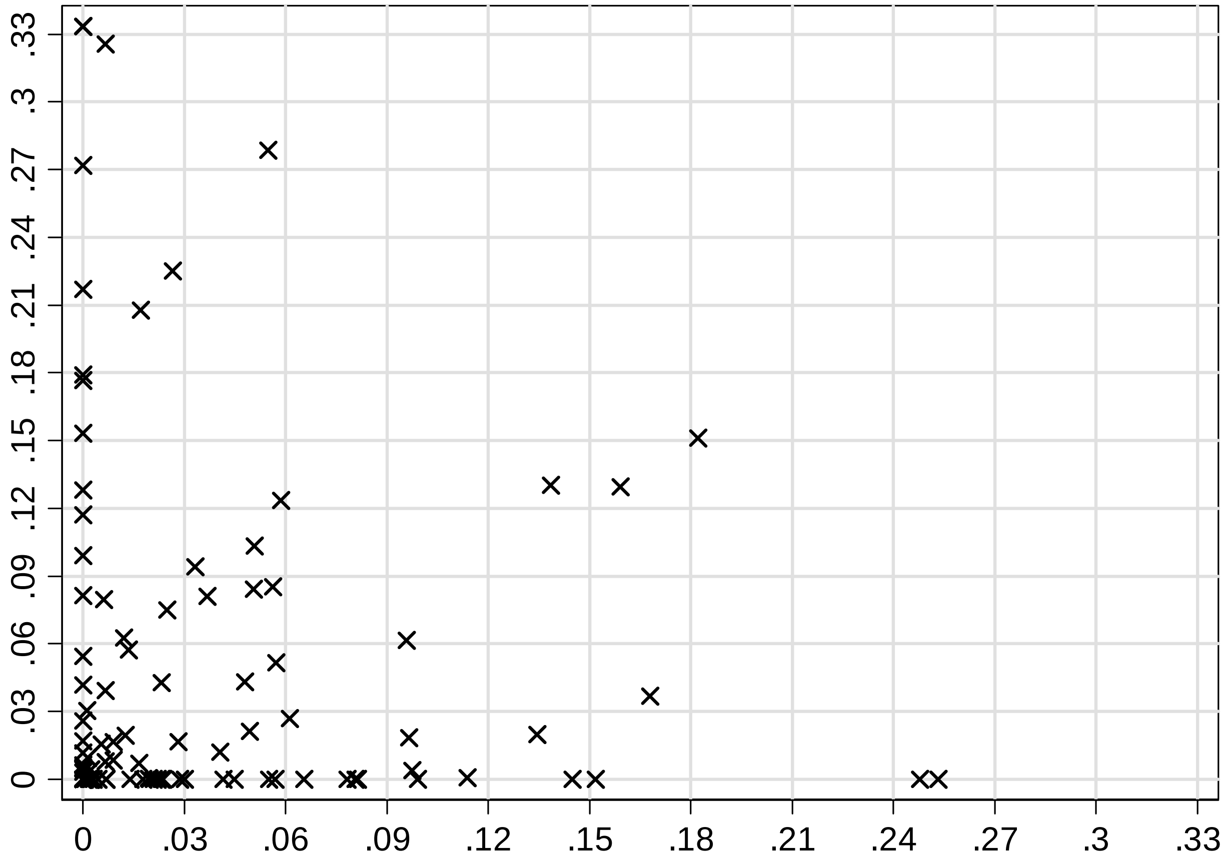
Econometric results

The vast majority of the subjects are well described by the loss- and ambiguity-neutral SEU model. The remainder appear to have a significant degree of loss and/or ambiguity aversion

		Ambiguity		
		Neutral	Averse	Total
Loss	Neutral	60.4	16.7	77.1
	Averse	18.1	4.9	22.9
	Total	78.5	21.5	

There is considerable heterogeneity in both $\hat{\delta}_n$ or $\hat{\gamma}_n$ and that their values are not correlated ($r^2 = 0.029$).

Scatterplot of the estimated parameters – generalized kinked specification (ambiguity - horizontal axis / loss - vertical axis)



Procedural rationality

Procedural rationality

- How subjects come to make decisions that are consistent with an underlying preference ordering?

- Boundedly rational individuals use *heuristics* in their attempt to maximize an underlying preference ordering.

  - There is a distinction between true *underlying* preferences and *revealed* preferences.

  - Preferences have an EU representation, even though revealed preferences appear to be non-EU.

Archetypes and polytypes

- We identify a finite number of stylized behaviors, which collectively pose a challenge to decision theory.

- We call these basic behaviors *archetypes*. We also find mixtures of archetypal behaviors, which we call *polytypes*.

- The archetypes account for a large proportion of the data set and play a role in the behavior of most subjects.

- The combinations of types defy any of the standard models of risk aversion.

Discussion

Suppose there are ℓ states of nature and ℓ associated Arrow securities and that the agent's behavior is represented by the decision problem

$$\begin{array}{ll} \text{max} & u(\mathbf{x}) \\ \text{s.t.} & \mathbf{x} \in \mathbf{B}(\mathbf{p}) \cap \mathcal{A} \end{array}$$

where $\mathbf{B}(\mathbf{p})$ is the budget set and $\mathcal{A}$ is the set of portfolios corresponding to the various archetypes the agent uses to simplify his choice problem.

The only restriction we have to impose is that $\mathcal{A}$ is a pointed cone (closed under multiplication by positive scalars), which is satisfied if $\mathcal{A}$ is composed of any selection of archetypes except the *Centroid*.

We can derive the following properties of the agent's demand:

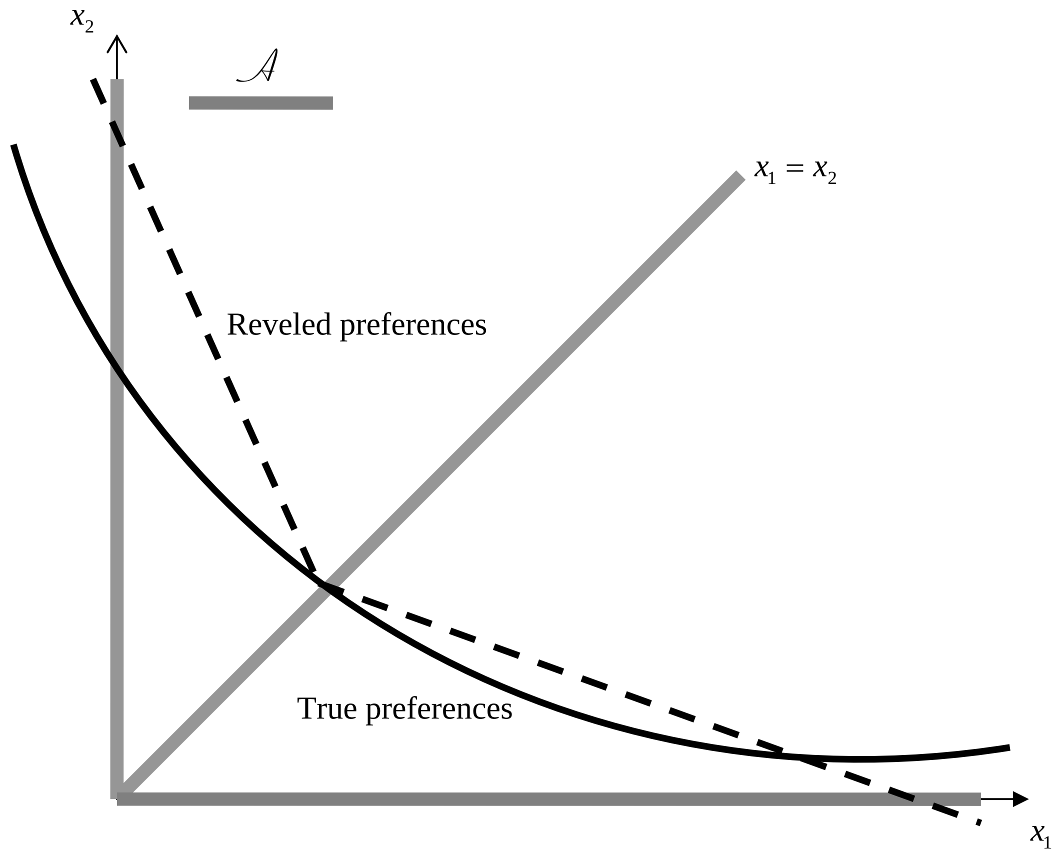
1. Let $\mathbf{p}^k$ denotes the k-th observation of the price vector and

$$\mathbf{x}^k \in \arg\max \left\{ u(\mathbf{x}) : \mathbf{x} \in \mathbf{B}\left(\mathbf{p}^k\right) \cap \mathcal{A} \right\}$$

   denotes the associated portfolio. Then the data $\left\{\mathbf{p}^k, \mathbf{x}^k\right\}$ satisfy GARP.

2. There exists a utility function $u^*(\mathbf{x})$ such that for any price vector $\mathbf{p}$,

$$\mathbf{x}^* \in \arg\max \{u(\mathbf{x}) : \mathbf{x} \in \mathbf{B}(\mathbf{p}) \cap \mathcal{A}\}$$
$$\Leftrightarrow$$
$$\mathbf{x}^* \in \arg\max \{u^*(\mathbf{x}) : \mathbf{x} \in \mathbf{B}(\mathbf{p})\}.$$



x_2
$\mathcal{A}$
$x_1 = x_2$
Reveled preferences
True preferences
x_1

Takeaways

[1] Classical economics assumes that decisions are based on substantive rationality, and has little to say about the procedures by which decisions are reached.

[2] Rather than focusing on the consistency of behavior with non-EUT theories, we study the fine-grained details of individual behaviors in search of clues to procedural rationality.

[3] The “switching” behavior that is evident in the data leads us to prefer an “alternative” approach – one that emphasizes standard preferences and procedural rationality.

Individual-level data

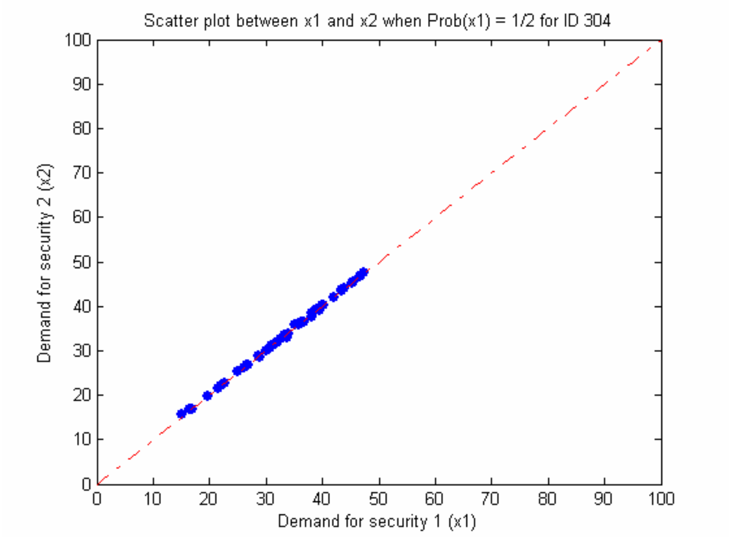
Individual-level data

- A review of the full data set reveals striking regularities *within* and marked heterogeneity *across* subjects.

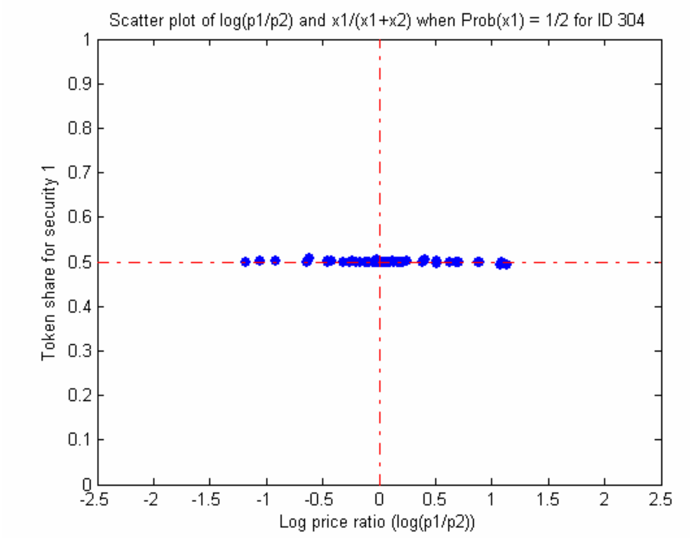
- A quick look at the individual-level data indicates that whatever is going on is not consistent with the standard interpretation of EUT.

- Examples that reveal some of the unexpected features of the data and illustrate the role of heuristics.

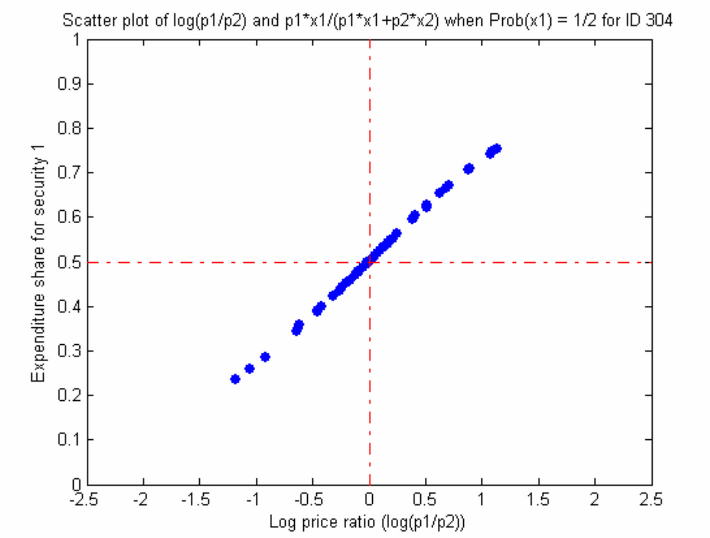
Diagonal



Scatter plot between x1 and x2 when Prob(x1) = 1/2 for ID 304
Demand for security 2 (x2)
Demand for security 1 (x1)

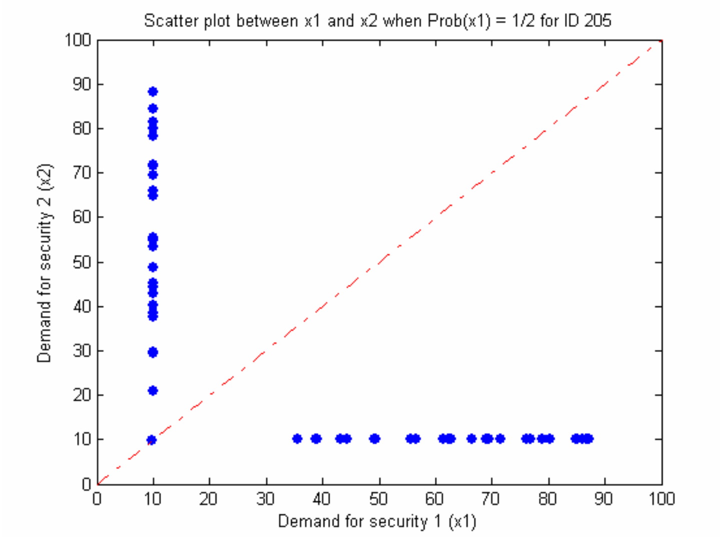


Scatter plot of log(p1/p2) and x1/(x1+x2) when Prob(x1) = 1/2 for ID 304
Token share for security 1
Log price ratio (log(p1/p2))

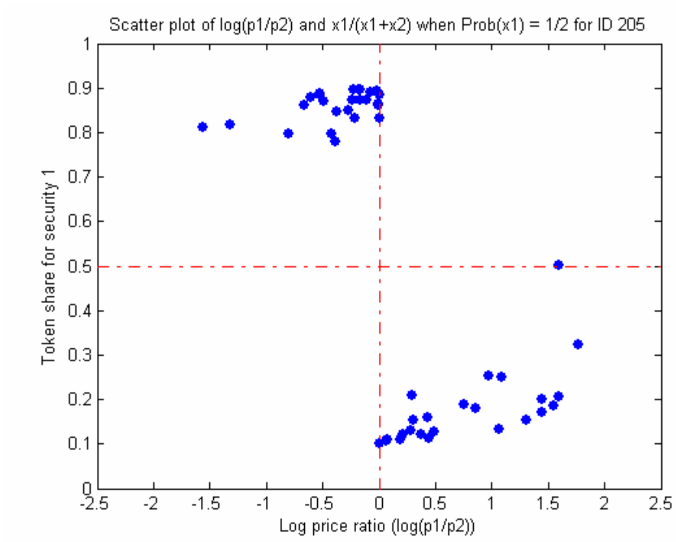


Scatter plot of log(p1/p2) and p1*x1/(p1*x1+p2*x2) when Prob(x1) = 1/2 for ID 304
Expenditure share for security 1
Log price ratio (log(p1/p2))

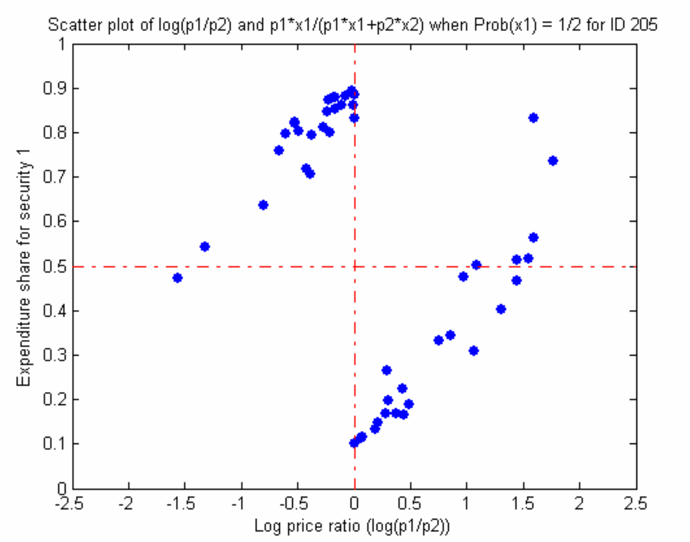
Boundary



Scatter plot between x1 and x2 when Prob(x1) = 1/2 for ID 205
Demand for security 2 (x2)
Demand for security 1 (x1)
0
10
20
30
40
50
60
70
80
90
100

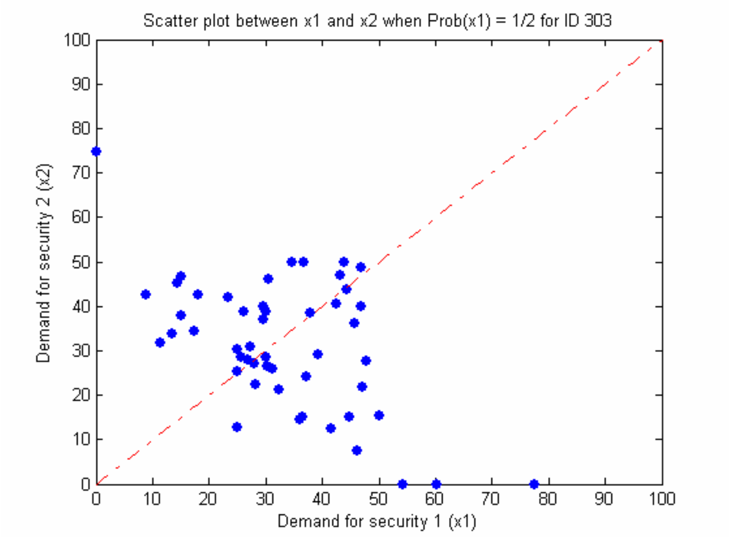


Scatter plot of log(p1/p2) and x1/(x1+x2) when Prob(x1) = 1/2 for ID 205
Token share for security 1
Log price ratio (log(p1/p2))
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5

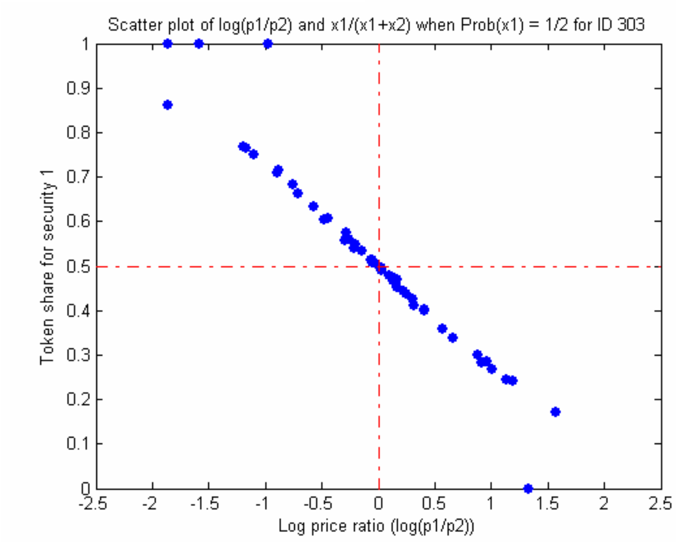


Scatter plot of log(p1/p2) and p1*x1/(p1*x1+p2*x2) when Prob(x1) = 1/2 for ID 205
Expenditure share for security 1
Log price ratio (log(p1/p2))
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5

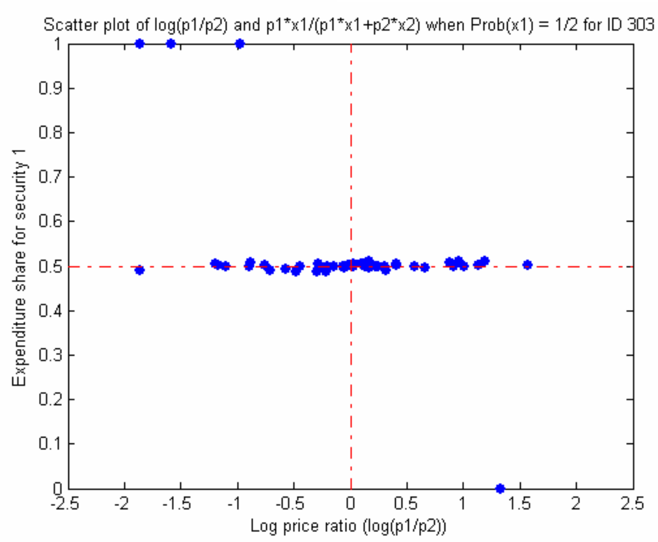
Smooth



Scatter plot between x1 and x2 when Prob(x1) = 1/2 for ID 303
Demand for security 2 (x2)
Demand for security 1 (x1)

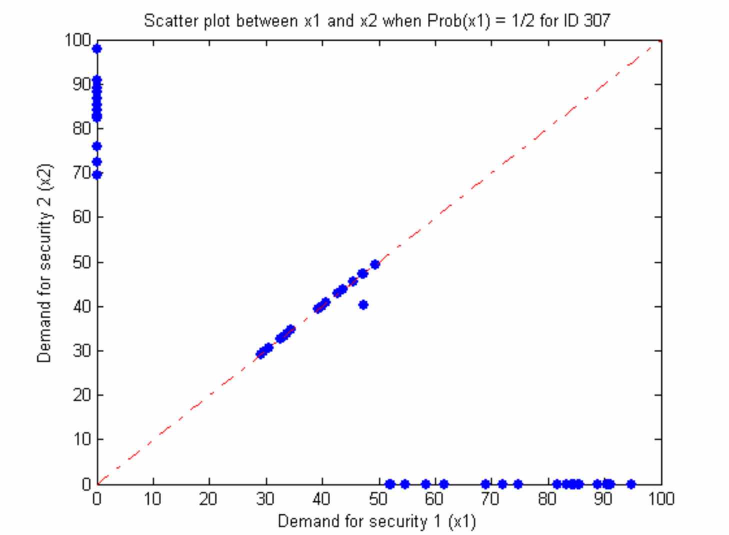


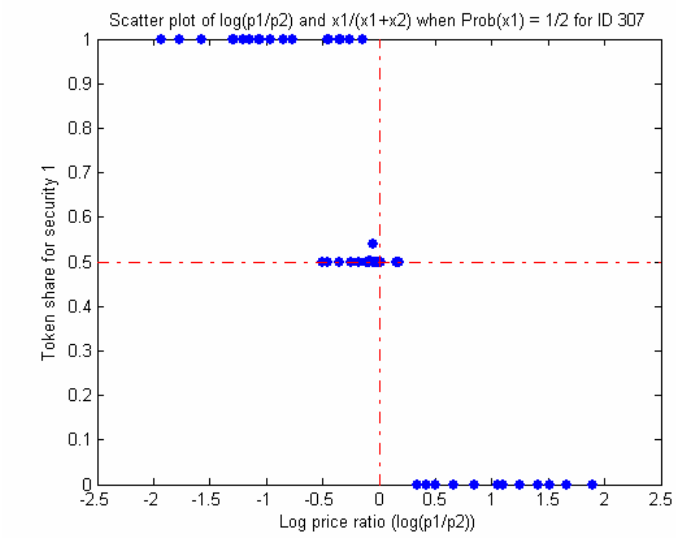
Scatter plot of log(p1/p2) and x1/(x1+x2) when Prob(x1) = 1/2 for ID 303
Token share for security 1
Log price ratio (log(p1/p2))

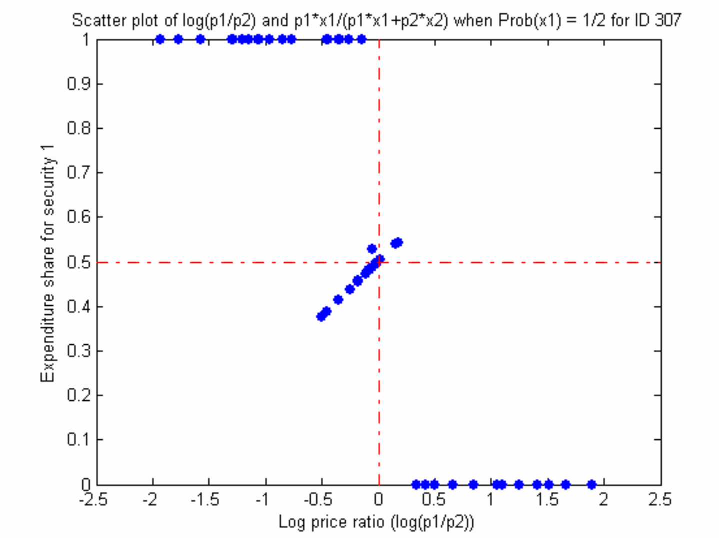


Scatter plot of log(p1/p2) and p1*x1/(p1*x1+p2*x2) when Prob(x1) = 1/2 for ID 303
Expenditure share for security 1
Log price ratio (log(p1/p2))

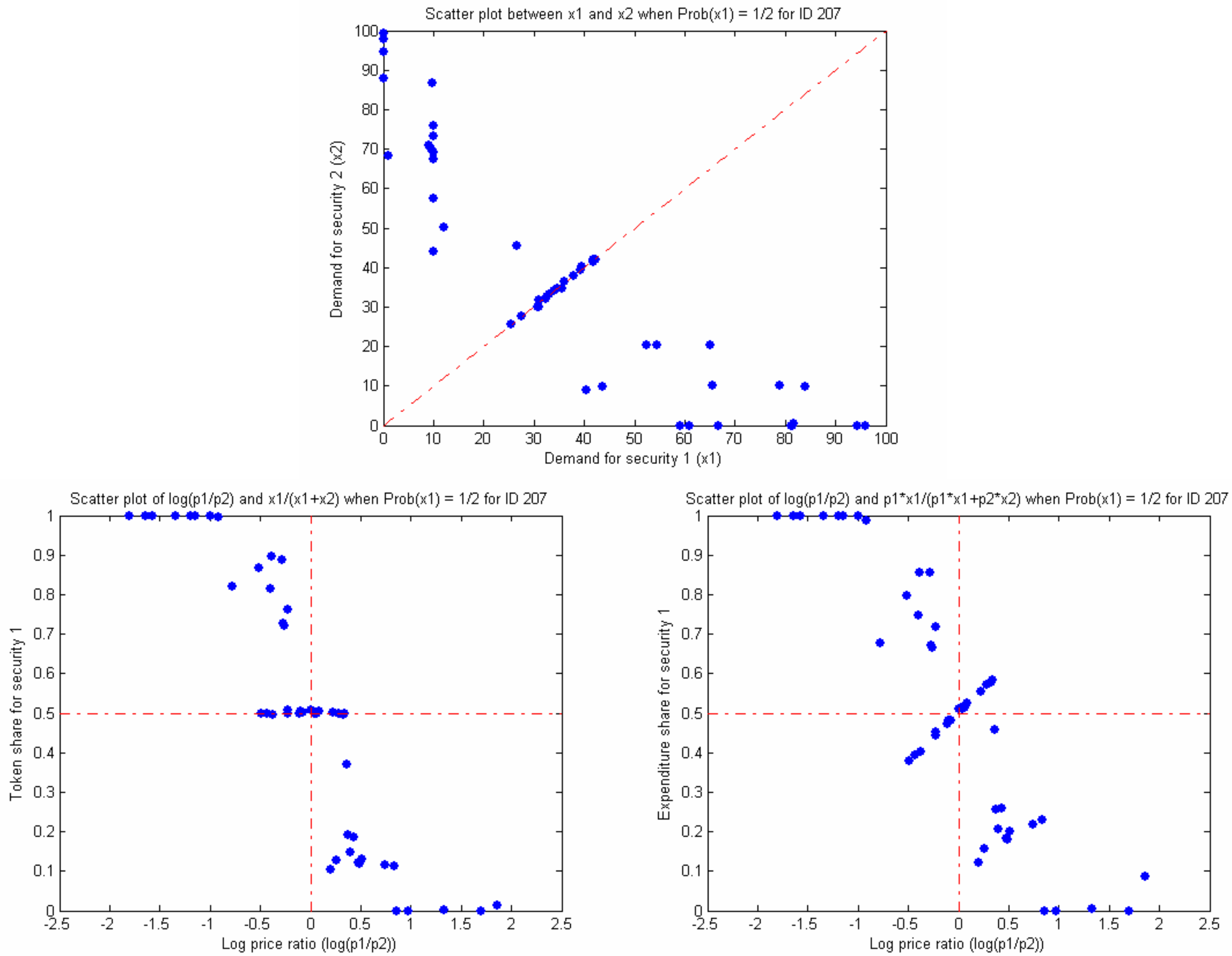
Diagonal and boundary



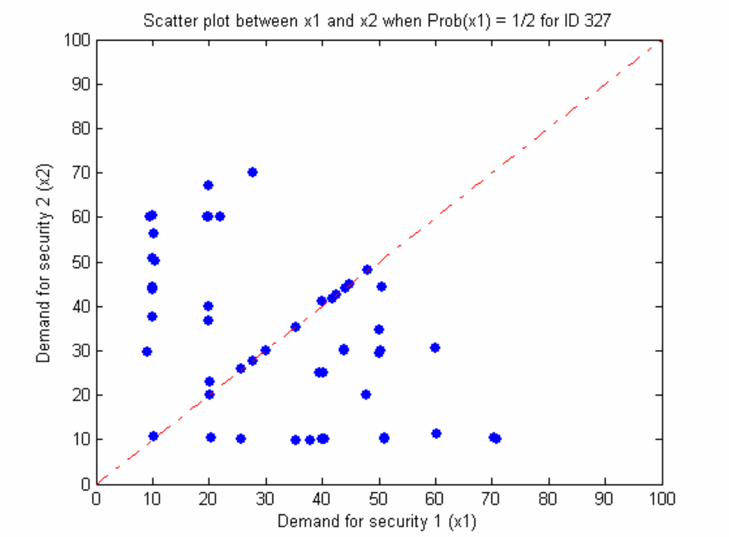


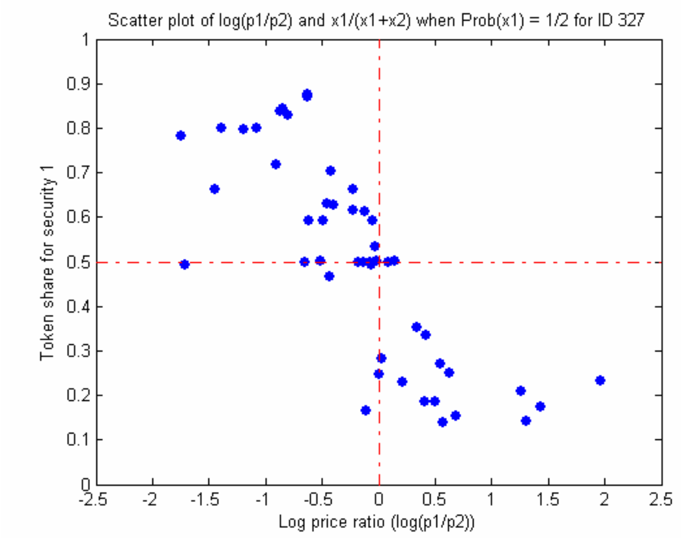


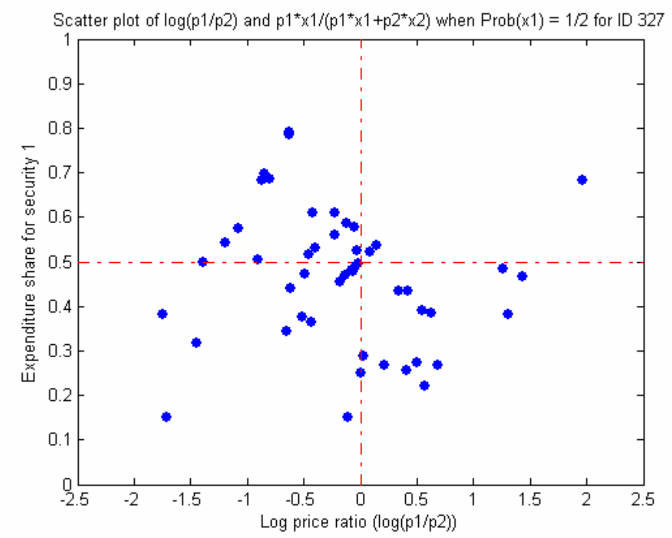
Diagonal, boundary and smooth



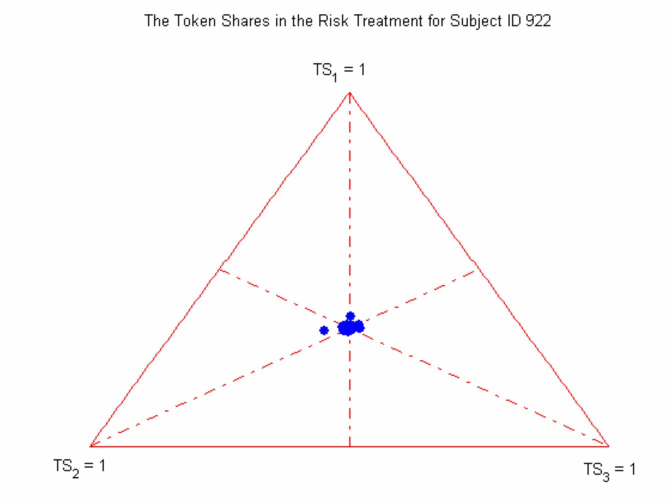
Diagonal, boundary and smooth



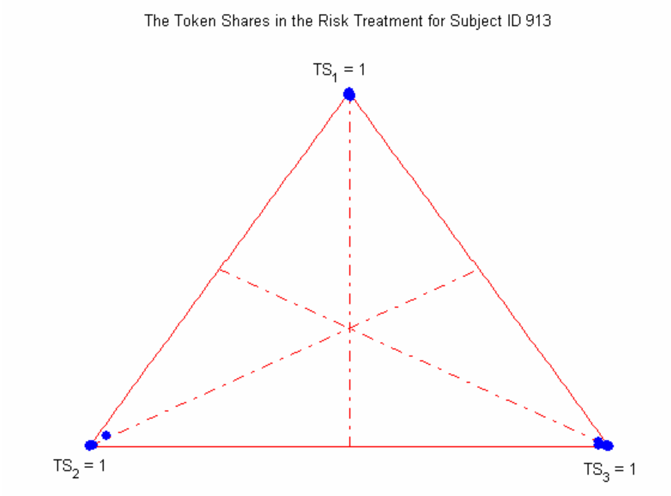




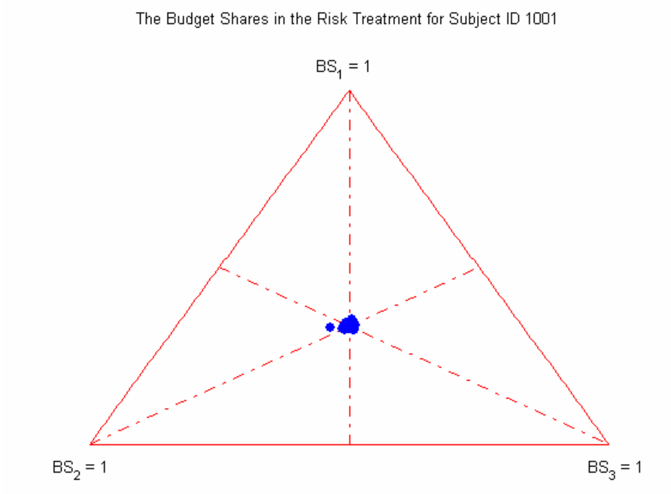
Center



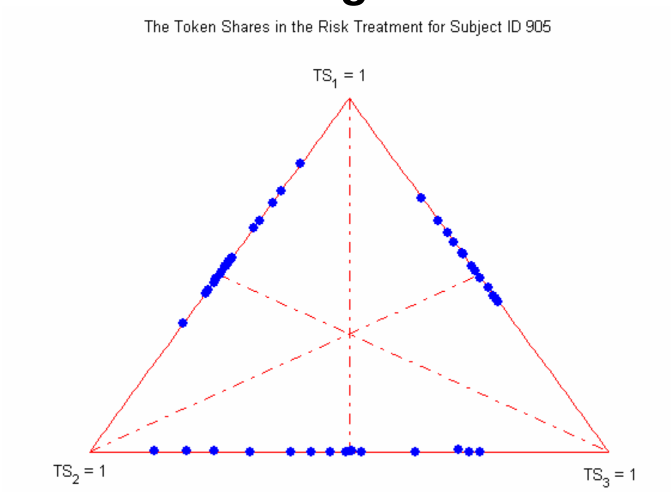
Vertex



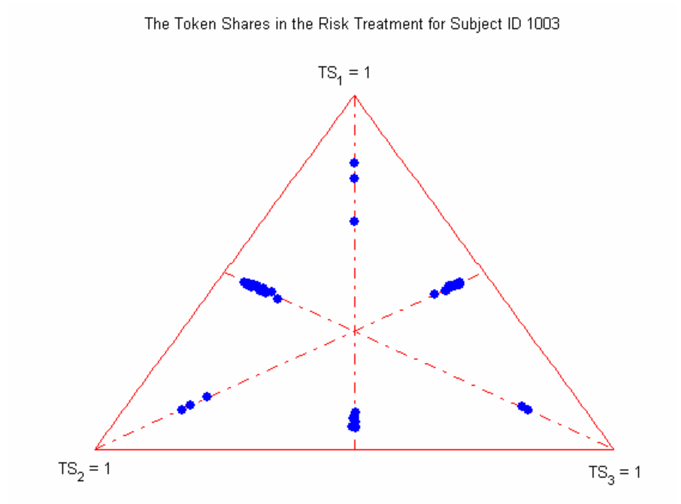
Centroid (budget shares)



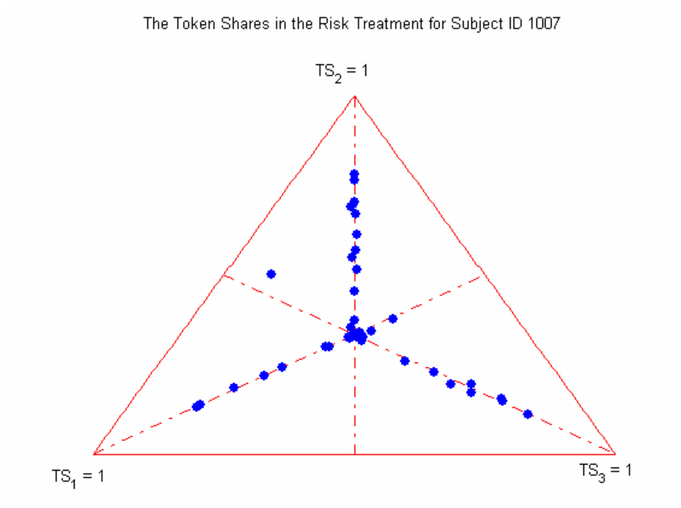
Edge



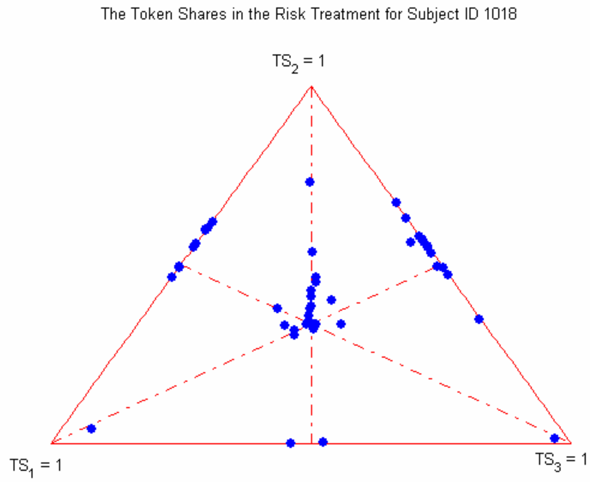
Bisector



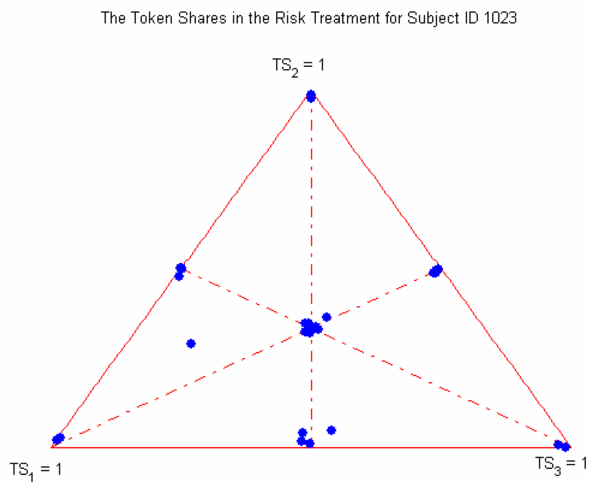
Center and bisector



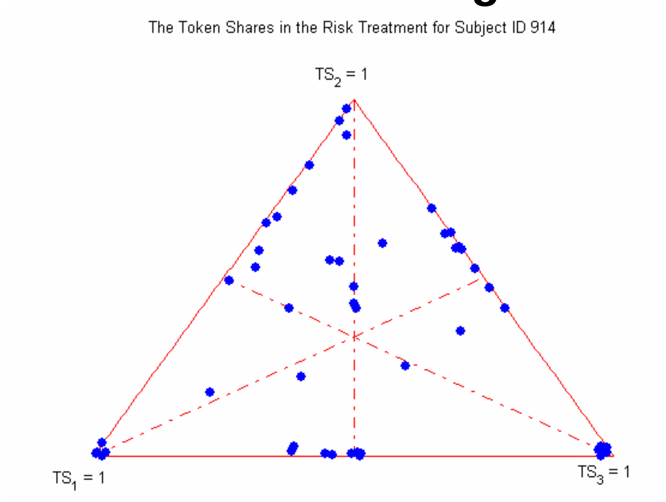
Edge and bisector



Center, vertex, and edge



Vertex and edge



Center and bisector