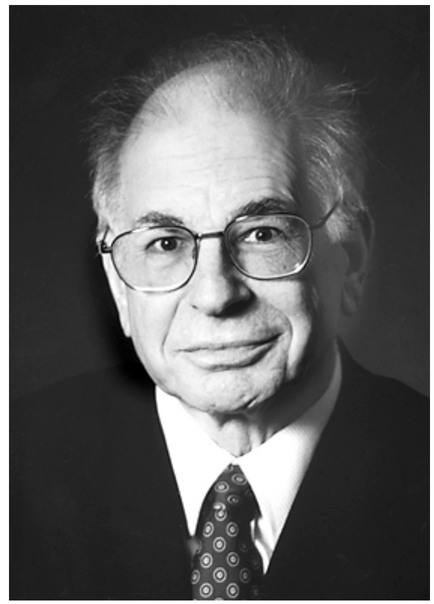
Reichman University
Tiomkin School of Economics
Advanced Microeconomics
Spring 2024

Confronting Theory with Experimental Data and vice versa
Lectures 1 & 2: Risk and Time Preferences

Shachar Kariv
University of California—Berkeley

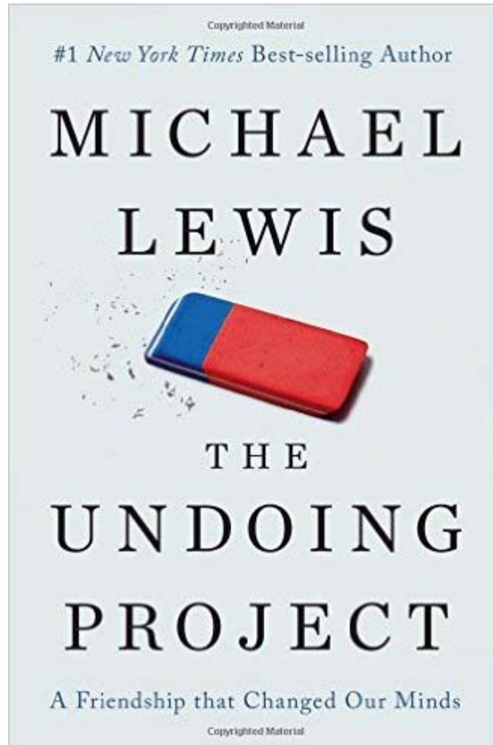
The Mecca of behavioral economics

George A. Akerlof (2001) and Daniel Kahneman (2002)



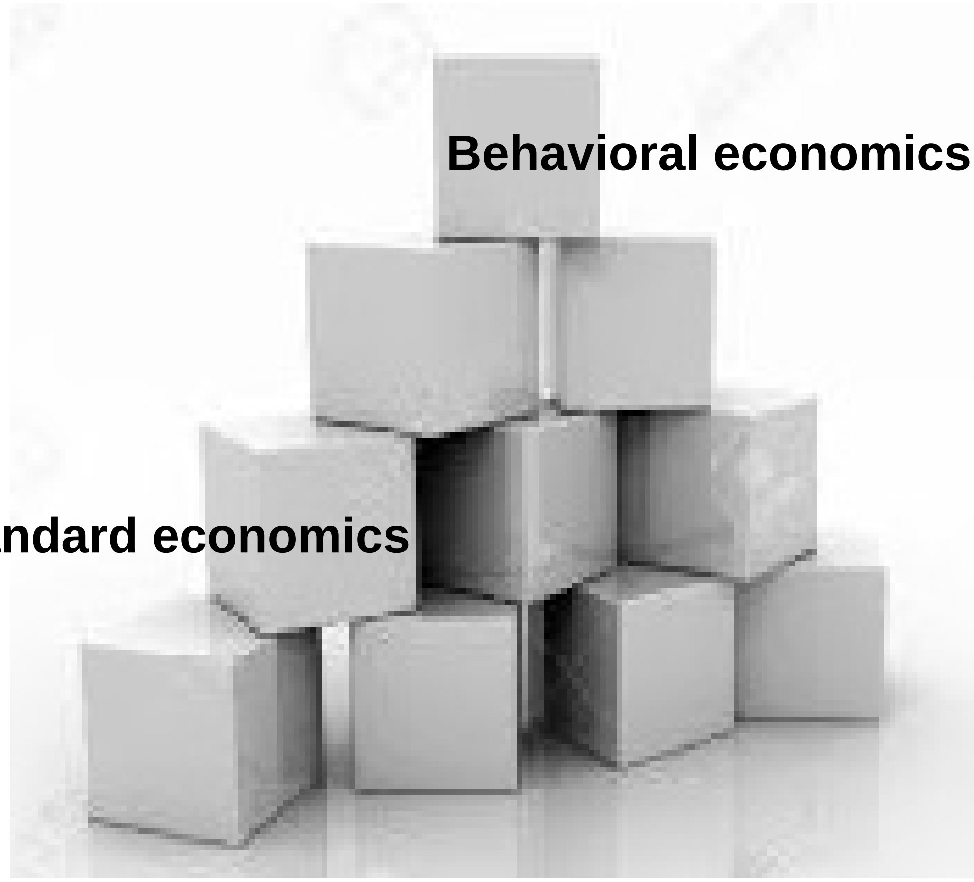
Integration of economic analysis with fundamental insights from cognitive psychology, in particular regarding behavior under uncertainty, thereby laying the foundation for a new field of research.

Michael Lewis' "The Undoing Project: A Friendship That Changed Our Minds"



Behavioral economics

Standard economics



Prologue

Many people think that economists view people as being super-rational and find the material to be highly theoretical and not very "realistic".

... theories do not have to be realistic to be useful...

Even though the assumptions are pretty unrealistic, the theory predicts behavior well and is quite useful.

A theory can be *useful* in three ways:

A. descriptive (how people actually choose)

B. prescriptive (as a practical aid to choice)

C. normative (how people ought to choose)

The fundamental tradeoffs in life

People's attitudes towards risk, time and other people enter every realm of (financial) decision-making:

$$\begin{aligned} \text{risk} &\Longleftrightarrow \text{return} \\ \text{today} &\Longleftrightarrow \text{tomorrow} \\ \text{self} &\Longleftrightarrow \text{others} \end{aligned}$$

Risk, time and social preferences are thus important inputs into any broader measure of welfare and enter virtually every field of economics.

Four types questions concerning preferences

I Consistency

– Is behavior consistent with a model of utility maximization?

II Structure

– What are the structural properties of the underlying utility function?

III Recoverability

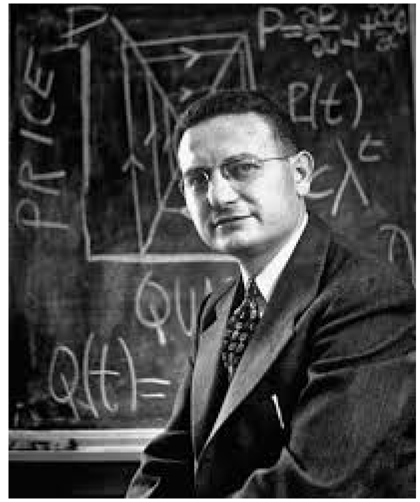
– Can underlying preferences be recovered from observed choices?

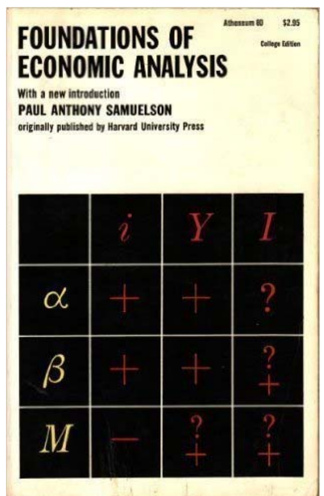
IV Linkages

– What are the linkages between preferences in various environments?

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…).




Atheneum 80
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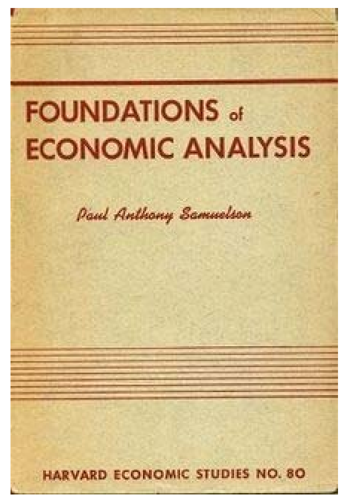
FOUNDATIONS OF
ECONOMIC ANALYSIS
College Edition
With a new introduction
PAUL ANTHONY SAMUELSON
originally published by Harvard University Press


FOUNDATIONS of
ECONOMIC ANALYSIS
Paul Anthony Samuelson
HARVARD ECONOMIC STUDIES NO. 80

Formally, we represent the consumer's preferences by a binary relation $\succsim$ defined on the set of consumption bundles.

For any pair of 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).

From the weak preference relation $\succsim$ we derive two other relations on the set of alternatives:

– Strict performance relation

$$x \succ y \ \text{ if and only if } x \succsim y \text{ and not } y \succsim x.$$

The phrase $x \succ y$ is read x is *strictly preferred* to y.

– Indifference relation

$$x \sim y \ \text{ if and only if } x \succsim y \text{ and } y \succsim x.$$

The phrase $x \sim y$ is read x is *indifferent* to y.

The basic assumptions about preferences

The theory begins with three assumptions about preferences. These assumptions are so fundamental that we can refer to them as "axioms" of decision theory.

[1] Completeness

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

for any pair of bundles x and y.

[2] Transitivity

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

for 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

> have the ability to make choices [1], and whose choices display a logical consistency [2].

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

The third axiom about consumer's preferences for one bundle versus another is that "more is better" (goods are desirable).

[3] Monotonicity

$$\text{if } x_1 \geq y_1 \text{ and } x_2 \geq y_2 \text{ then } x \succsim y$$

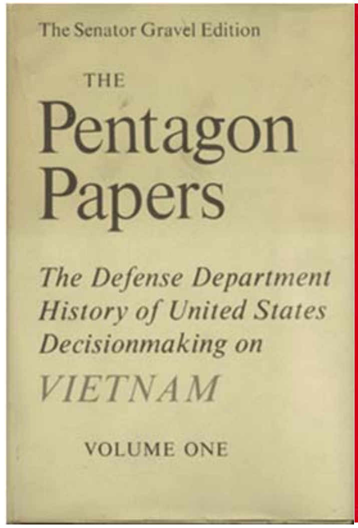
for any pair of bundles x and y.

Decision making under uncertainty

- Uncertainty is a fact of life so people's attitudes towards risk enter every realm of economic decision-making.

- We *must* study individual behavior with respect to choice involving uncertainty.

- Models of decision making under uncertainty play a key role in every field of economics.


The Senator Gravel Edition
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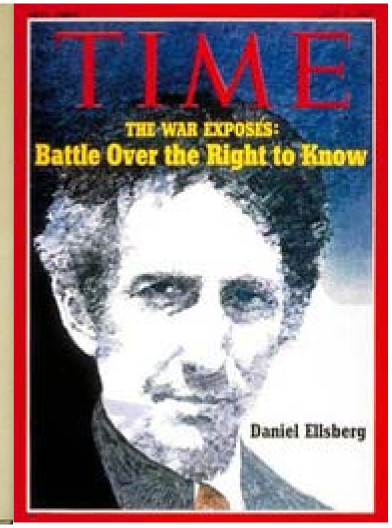
History of United States
Decisionmaking on
VIETNAM
VOLUME ONE


TIME
THE WAR EXPOSES:
Battle Over the Right to Know
Daniel Ellsberg


The Washington Post
FINAL
Documents Reveal U.S. Effort
In '54 to Delay Viet Election
Times Lists
But Retains
Viet Papers
Times' Stand Wins
Wide Hill Support
FBI Seeking
Ex-Pentagon
Aide in Leak
Prosecutor Links Bobby Baker
To Ring Accused in NW Thefts

- I have an urn with 1000 balls in it. Some of the balls are red and some are blue. All the balls are the same size and weight, and they are not distinguishable in any way except in color.

- I will let you reach into this urn without looking and drew out one of these balls. I want to know your preferences between investments (gambles) based on the outcome of this random event.

[1] There are precisely 500 red balls in the urn. Would you rather (fill the blank)

(a) get $_____ for sure
(b) get $100,000 if the ball drawn from the urn is red and $0 if it is blue.

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(a) get $_____ for sure
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[2] There are precisely 500 red balls in the urn. Would you rather (fill the blank)

(a) lose $_____ for sure
(b) lose $100,000 if the ball drawn from the urn is red and $0 if it is blue.

[1] There are precisely 500 red balls in the urn. Would you rather (fill the blank)

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[2] There are precisely 500 red balls in the urn. Would you rather (fill the blank)

(a) lose $____ for sure
(b) lose $100,000 if the ball drawn from the urn is red and $0 if it is blue.

[3] The number of red balls in the urn is unknown. Would you rather (fill the blank)

(a) get $____ for sure
(b) get $100,000 if the ball drawn from the urn is red and $0 if it is blue.

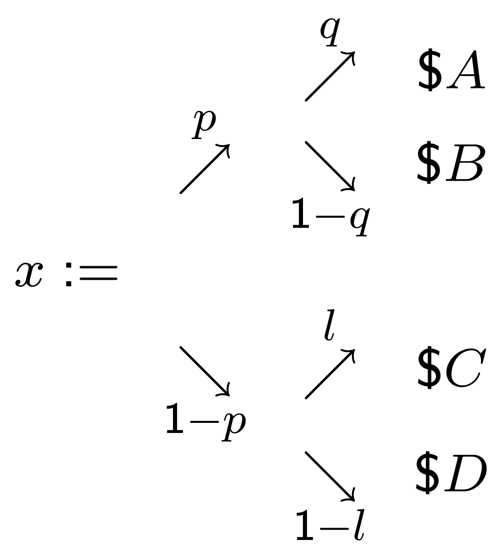
Life is full of lotteries :-(

$$x := \begin{array}{l} \overset{p}{\nearrow} \quad \$A \\ \\ \underset{1-p}{\searrow} \quad \$B \end{array} \qquad\qquad y := \begin{array}{l} \overset{p}{\nearrow} \quad \$A \\ \xrightarrow{q} \quad \$B \\ \underset{1-p-q}{\searrow} \quad \$C \end{array}$$

A risky lottery (left) and an ambiguous lottery (right)

$$x := \begin{array}{c} 1/2 \\ \nearrow \\ \\ \searrow \\ 1/2 \end{array} \begin{array}{c} \$A \\ \\ \\ \$B \end{array} \qquad\qquad y := \begin{array}{c} ? \\ \nearrow \\ \\ \searrow \\ 1-? \end{array} \begin{array}{c} \$A \\ \\ \\ \$B \end{array}$$

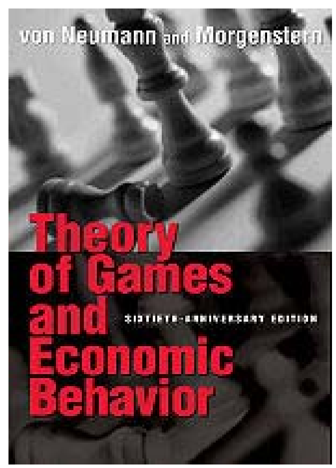
A compounded lottery

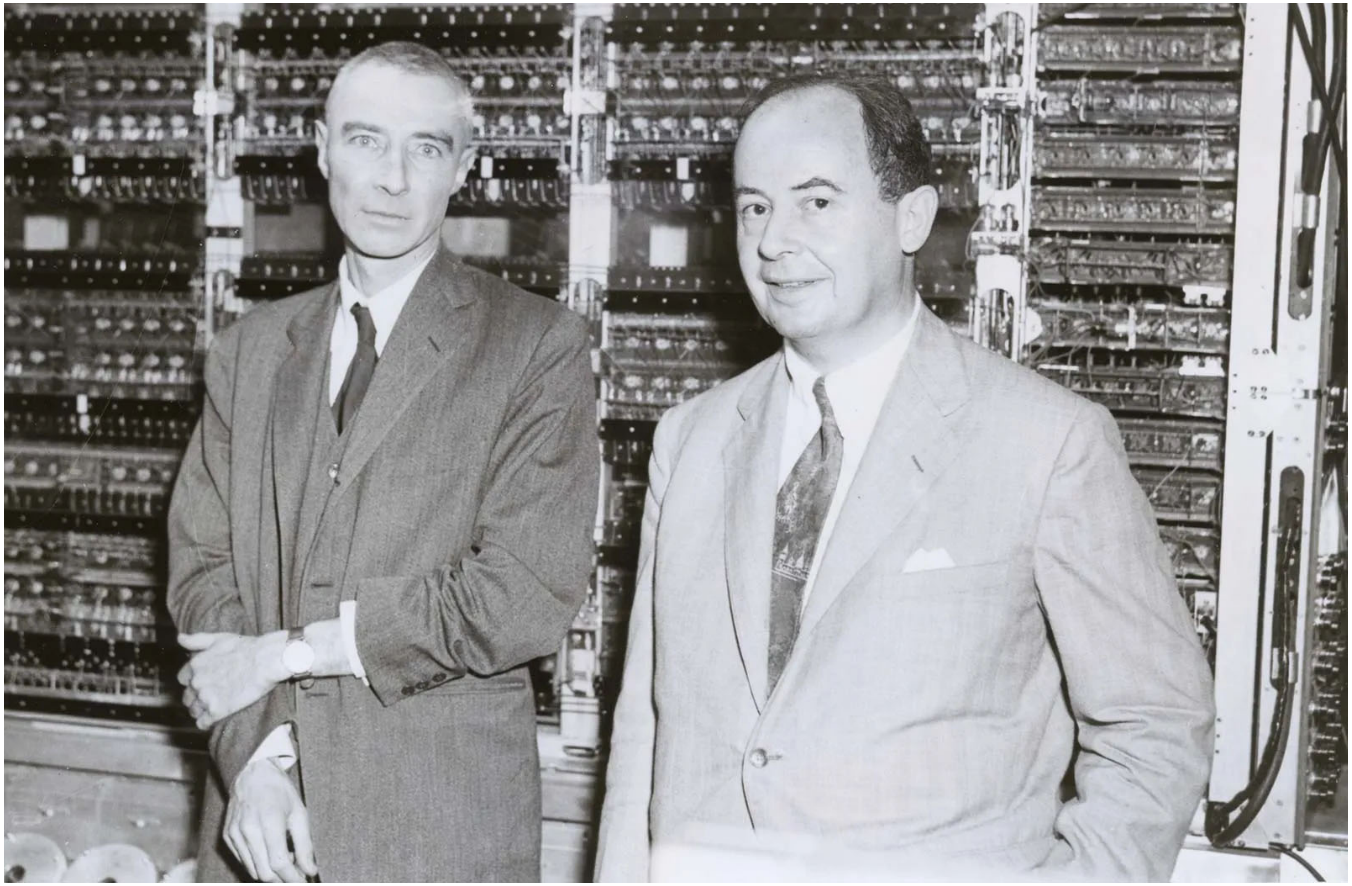


The reduction of a compounded lottery

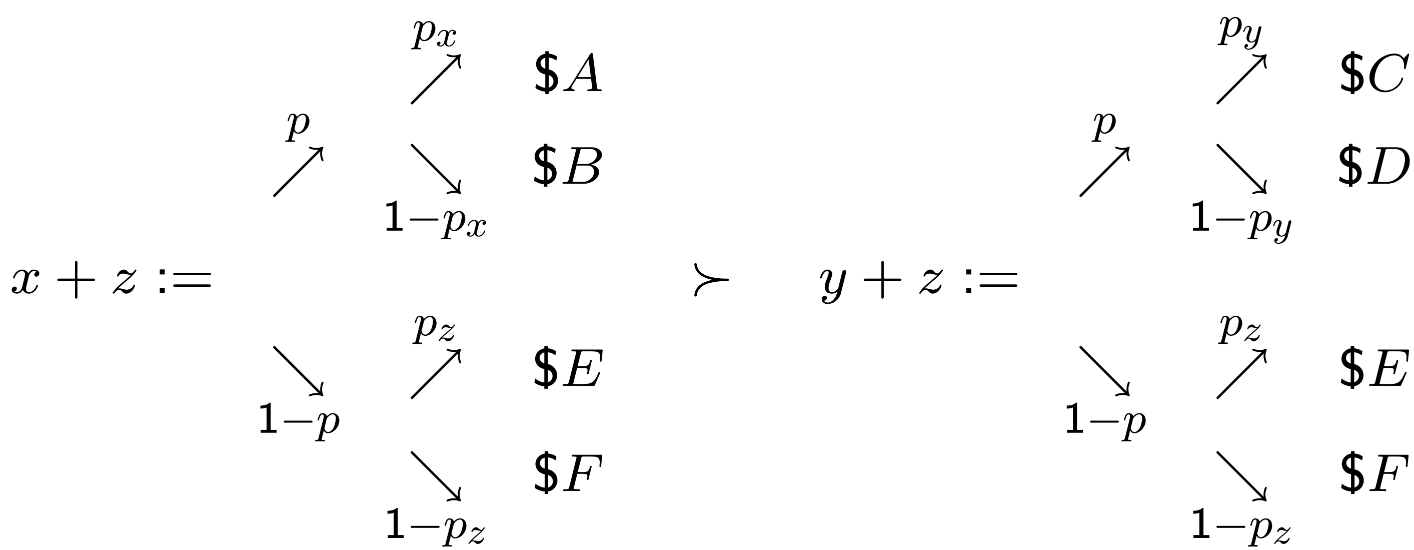
$$
x := \begin{array}{ccccc}
 & & \overset{q}{\nearrow} & \$A & \mid \; pq \\
 & \overset{p}{\nearrow} & & & \\
 & & \underset{1-q}{\searrow} & \$B & \mid \; p(1-q) \\
 & & & & \mid \\
 & & \overset{l}{\nearrow} & \$C & \mid \; (1-p)l \\
 & \underset{1-p}{\searrow} & & & \\
 & & \underset{1-l}{\searrow} & \$D & \mid \; (1-p)(1-l)
\end{array}
$$

The paternity of decision theory and game theory (1944)





$$x := \begin{array}{l} \overset{p_x}{\nearrow} \quad \$A \\ \\ \underset{1-p_x}{\searrow} \quad \$B \end{array} \quad \succ \quad y := \begin{array}{l} \overset{p_y}{\nearrow} \quad \$C \\ \\ \underset{1-p_y}{\searrow} \quad \$D \end{array}$$


$x + z :=$
p
$1-p$
p_x
$1-p_x$
p_z
$1-p_z$
$\$A$
$\$B$
$\$E$
$\$F$
$\succ$
$y + z :=$
p
$1-p$
p_y
$1-p_y$
p_z
$1-p_z$
$\$C$
$\$D$
$\$E$
$\$F$

von Neumann and Morgenstern Expected Utility Theory (EUT)

Allais (1953) I

– Choose between the two gambles:

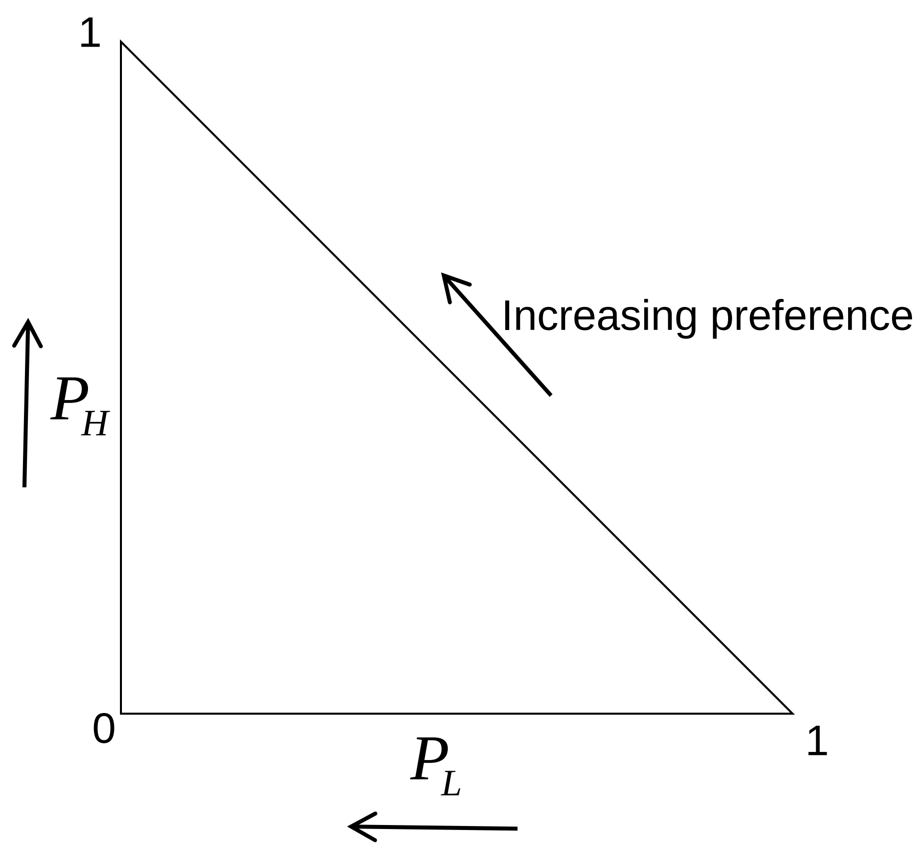
$$x := \begin{array}{l} \overset{.33}{\nearrow} \ \$25,000 \\ \xrightarrow{.66} \ \$24,000 \\ \underset{.01}{\searrow} \ \$0 \end{array} \qquad y := \xrightarrow{1} \ \$24,000$$

Allais (1953) II

- Choose between the two gambles:

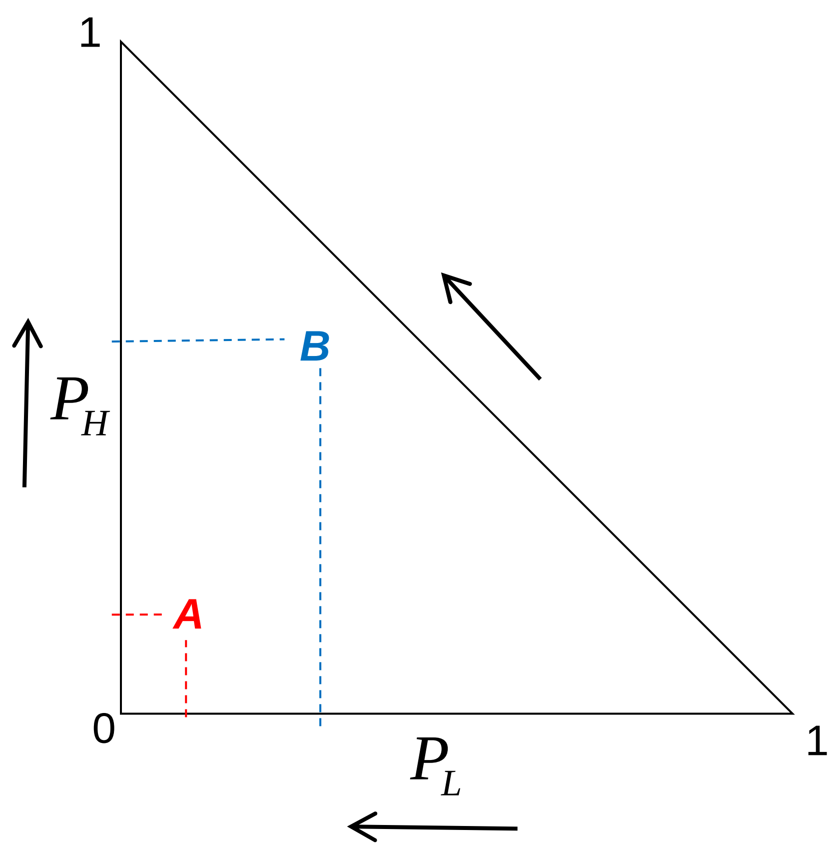
$$z := \begin{array}{ll} \overset{.33}{\nearrow} & \$25,000 \\ \underset{.67}{\searrow} & \$0 \end{array} \qquad w := \begin{array}{ll} \overset{.34}{\nearrow} & \$24,000 \\ \underset{.66}{\searrow} & \$0 \end{array}$$

The (Marschak-Machina) probability triangle



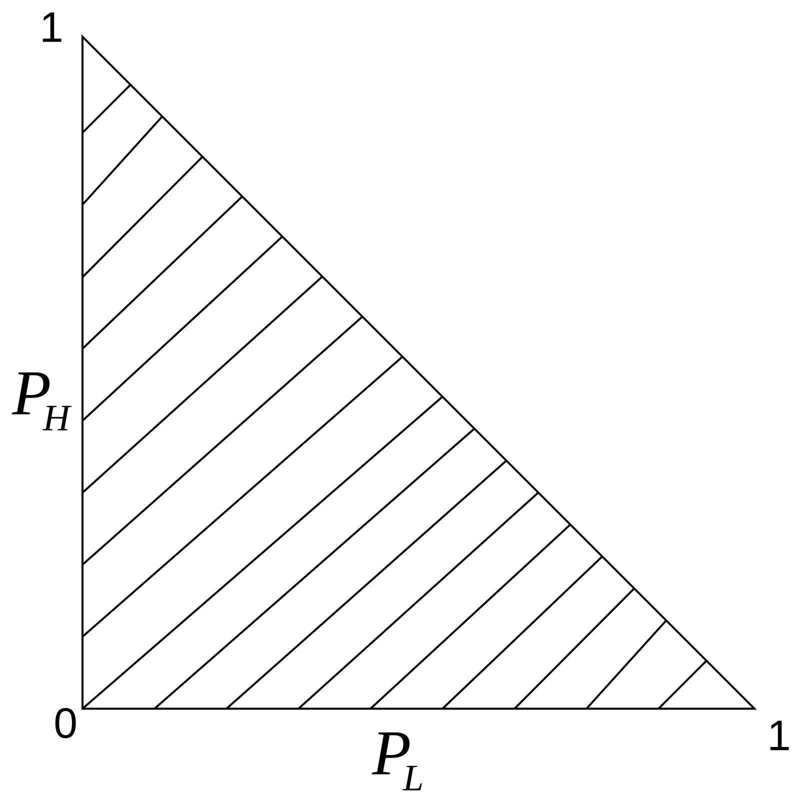
Consider three monetary payouts H, *M*, and *L* where *H>M>L*

Risk profiling



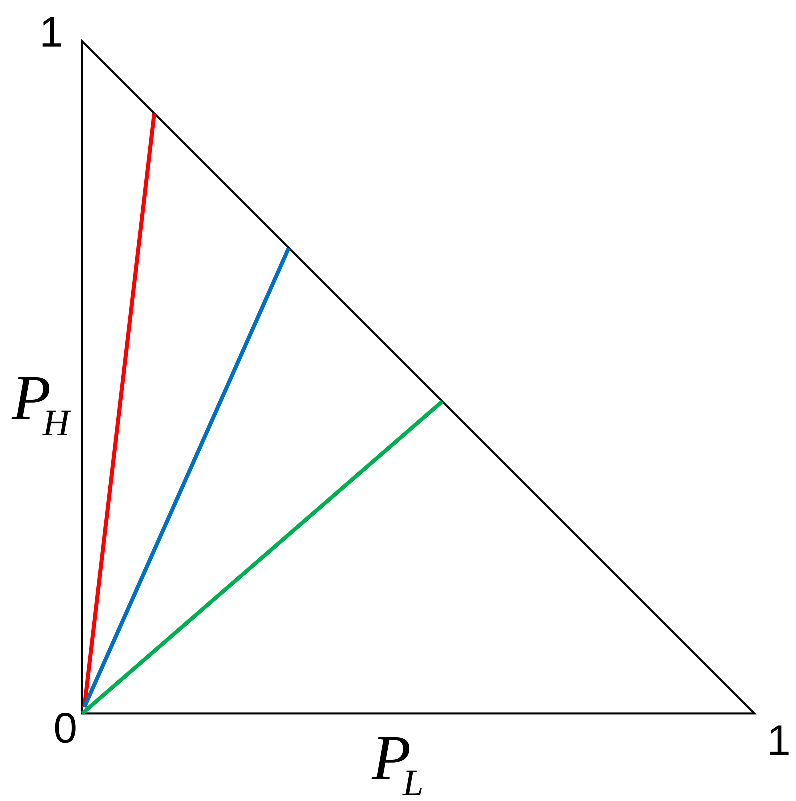
A “complete” risk profiling requires knowing all possible comparisons like between *A* and *B*.

An indifference map of a loss-neutral (expected utility) individual



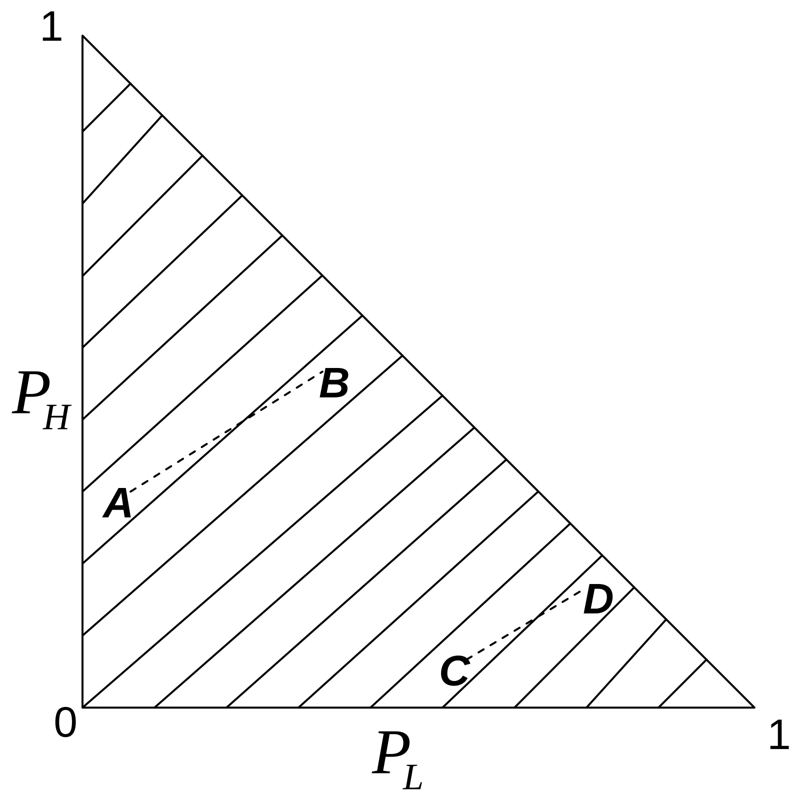
Expected Utility Theory (EUT) requires that indifference lines are parallel

Loss neutral and more risk tolerant



Mr. Green is more risk tolerant than Mr. Blue who is more risk tolerant than Mr. Red. The gentlemen are loss neutral.

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***.

What have we learned from à la Allais experiments (Camerer, 1995)?

– *...EU violations are much smaller (though still statistically significant) when subjects choose between gambles that all lie inside the triangle...*

– *...due to nonlinear weighting of the probabilities near zero (as the rank dependent weighting theories and prospect theory predict)...*

– *...the only theories that can explain the evidence of mixed fanning, violation of betweeness, and approximate EU maximization inside the triangle...*

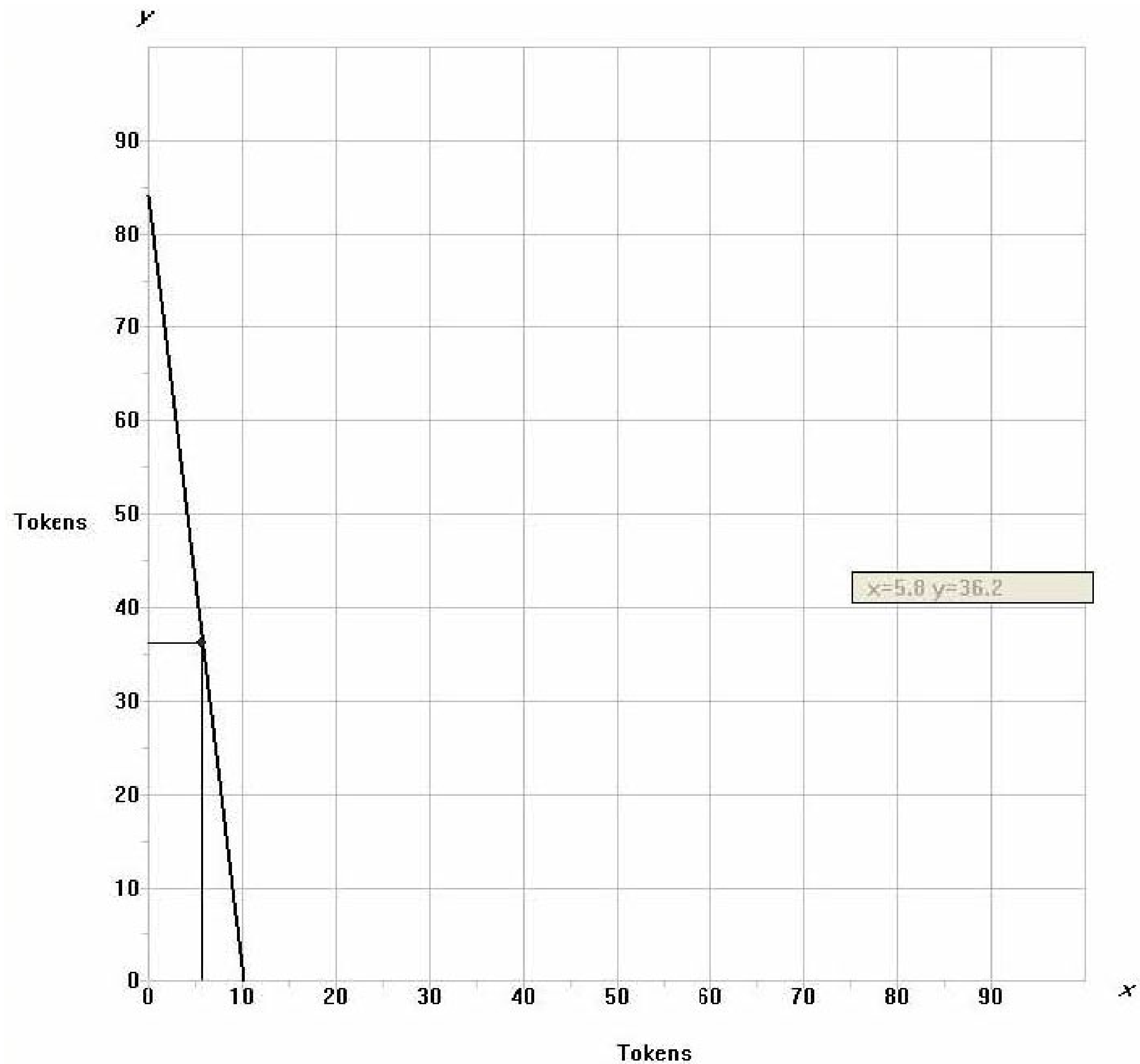
A not-so-new experimental design

An experimental design that has a couple of innovations:

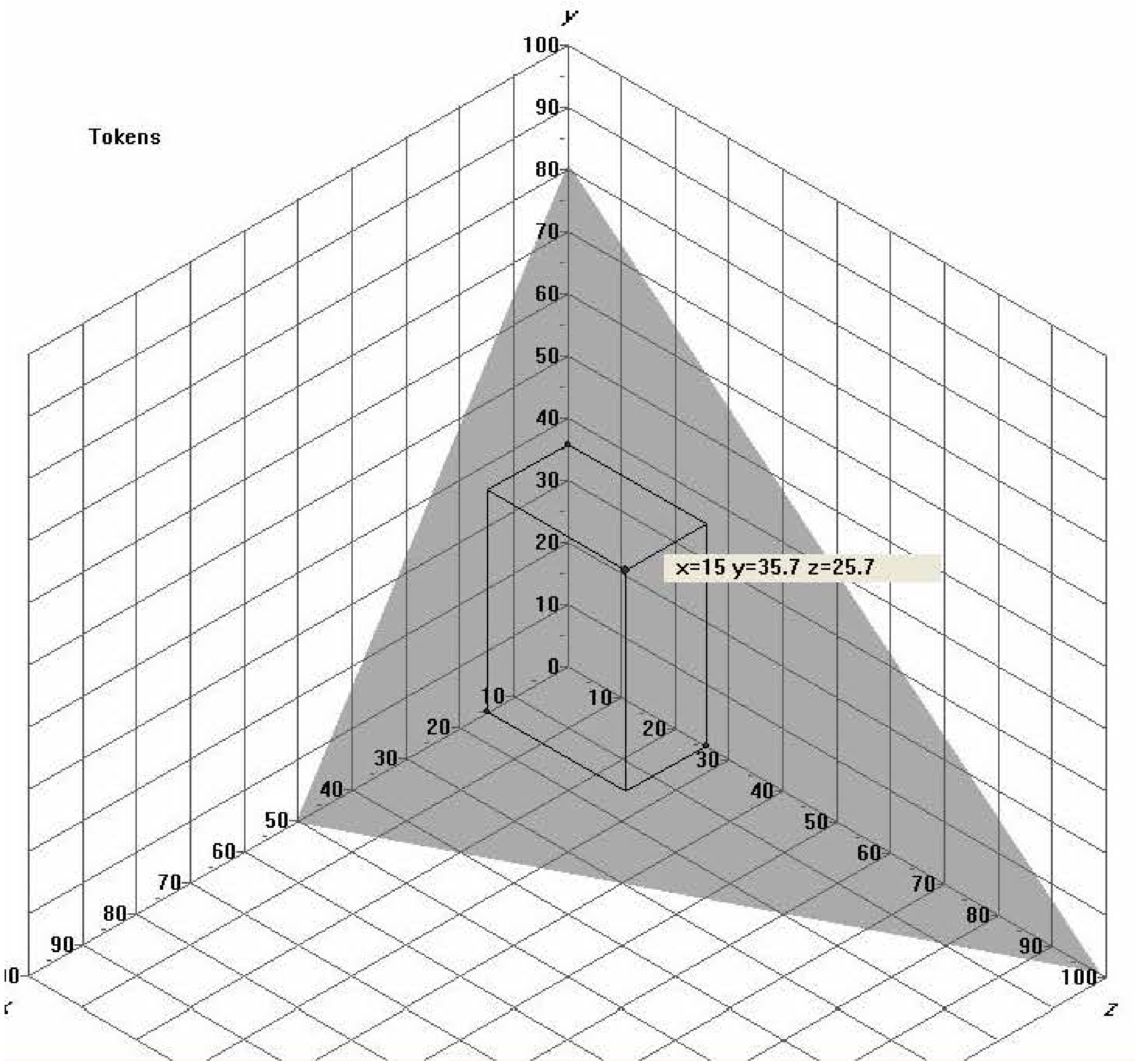
- A selection of a bundle of contingent commodities from a budget set (a portfolio choice problem).
- A large menu of decision problems that are representative, in the statistical sense and in the economic sense.
- A graphical experimental interface that allows for the collection of a rich individual-level data set.

$\Rightarrow$ Build on Nishimura, Ok and Quah (2017), and Polisson, Quah and Renou (2020) and (1) allow subjects to make choices over three-dimensional budget sets, and (2) study choice under ambiguity.

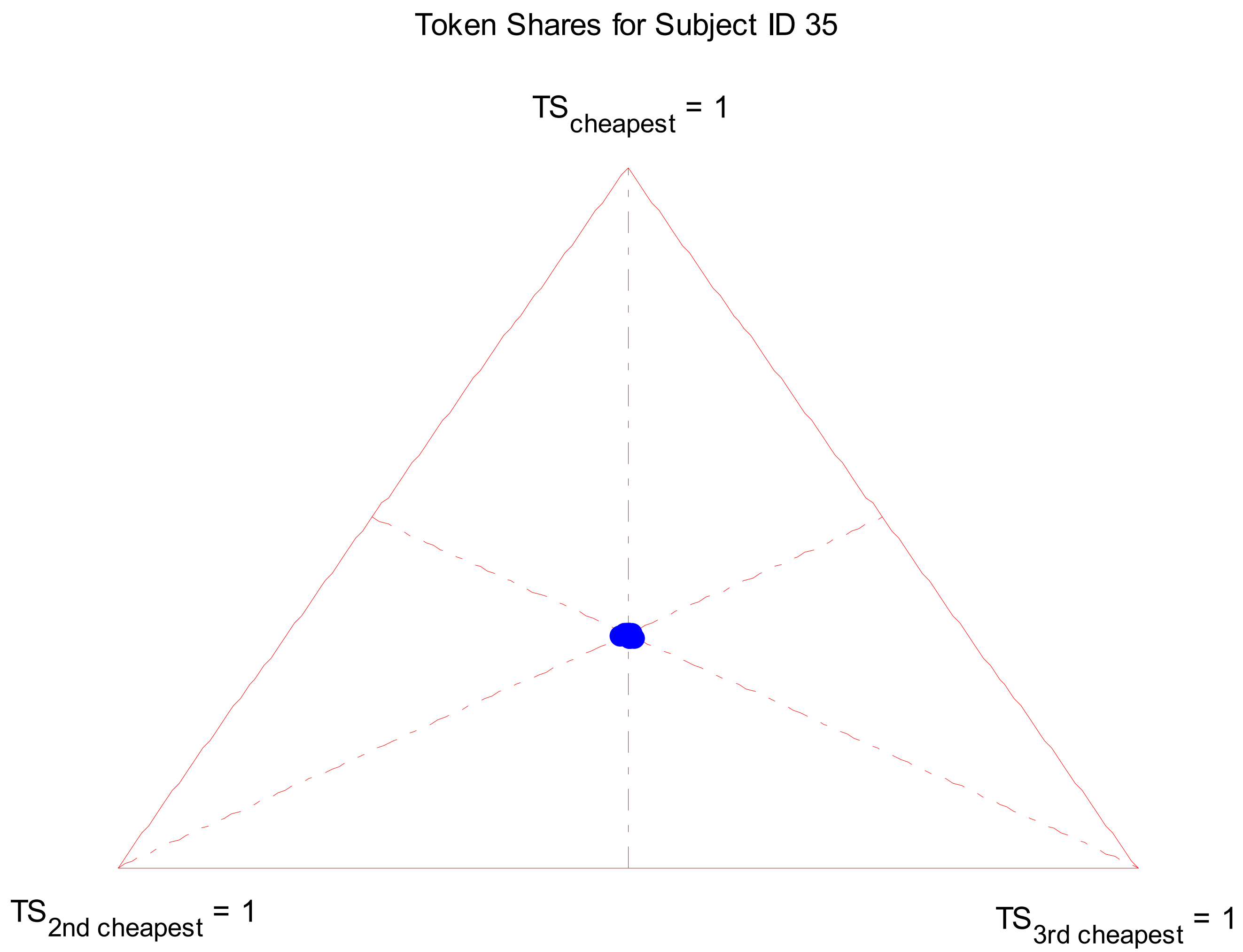
2D experimental interface



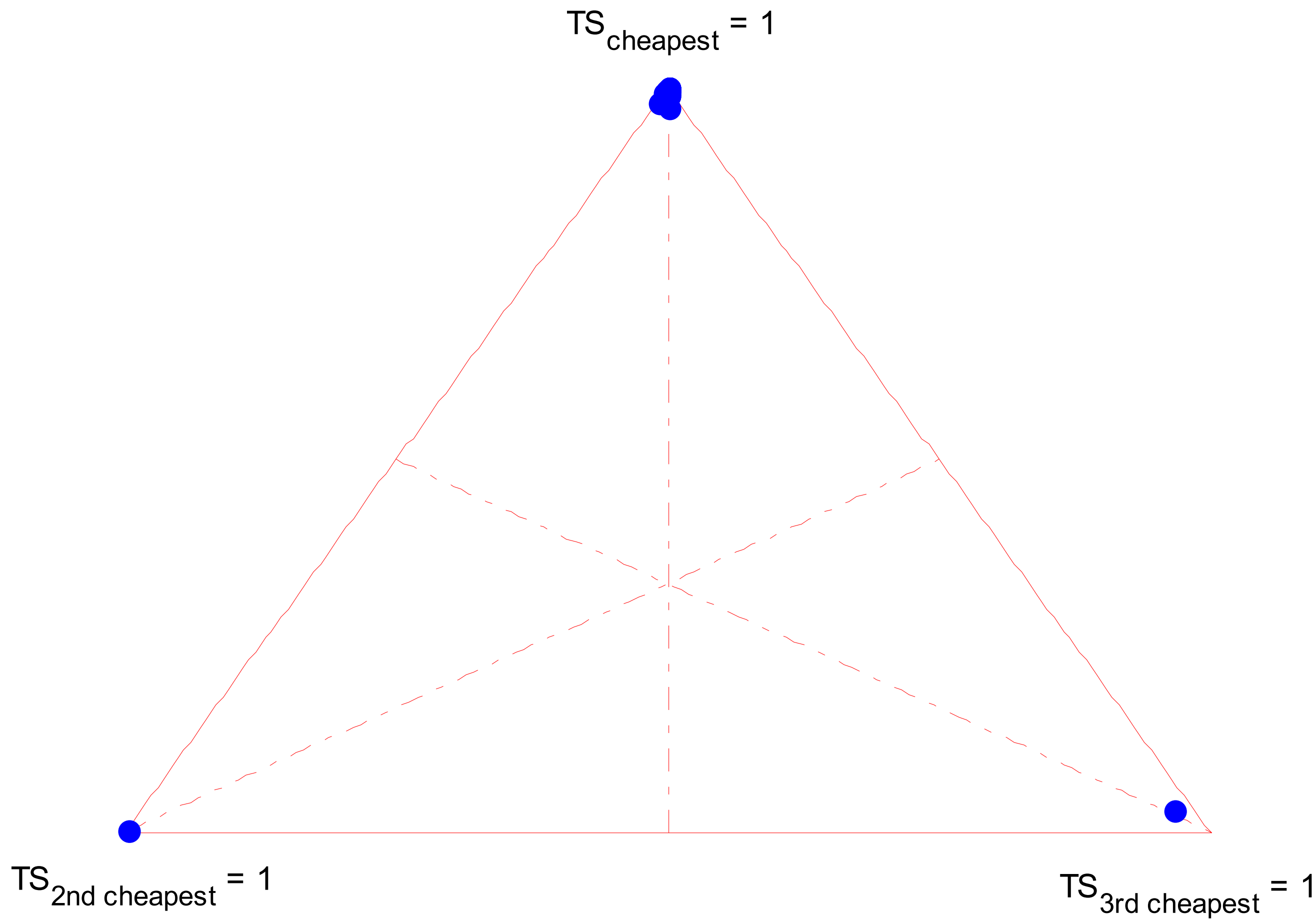
3D experimental interface

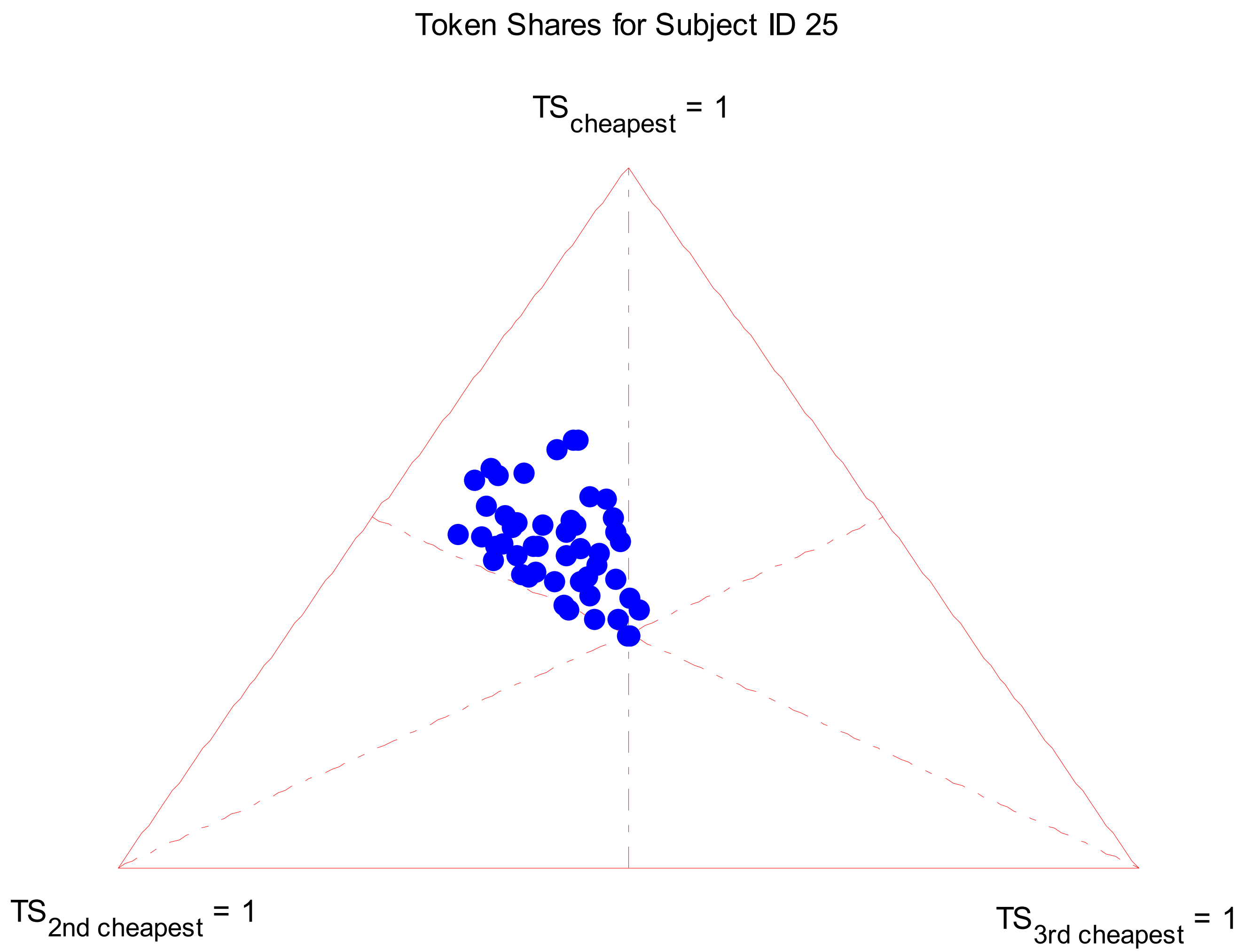


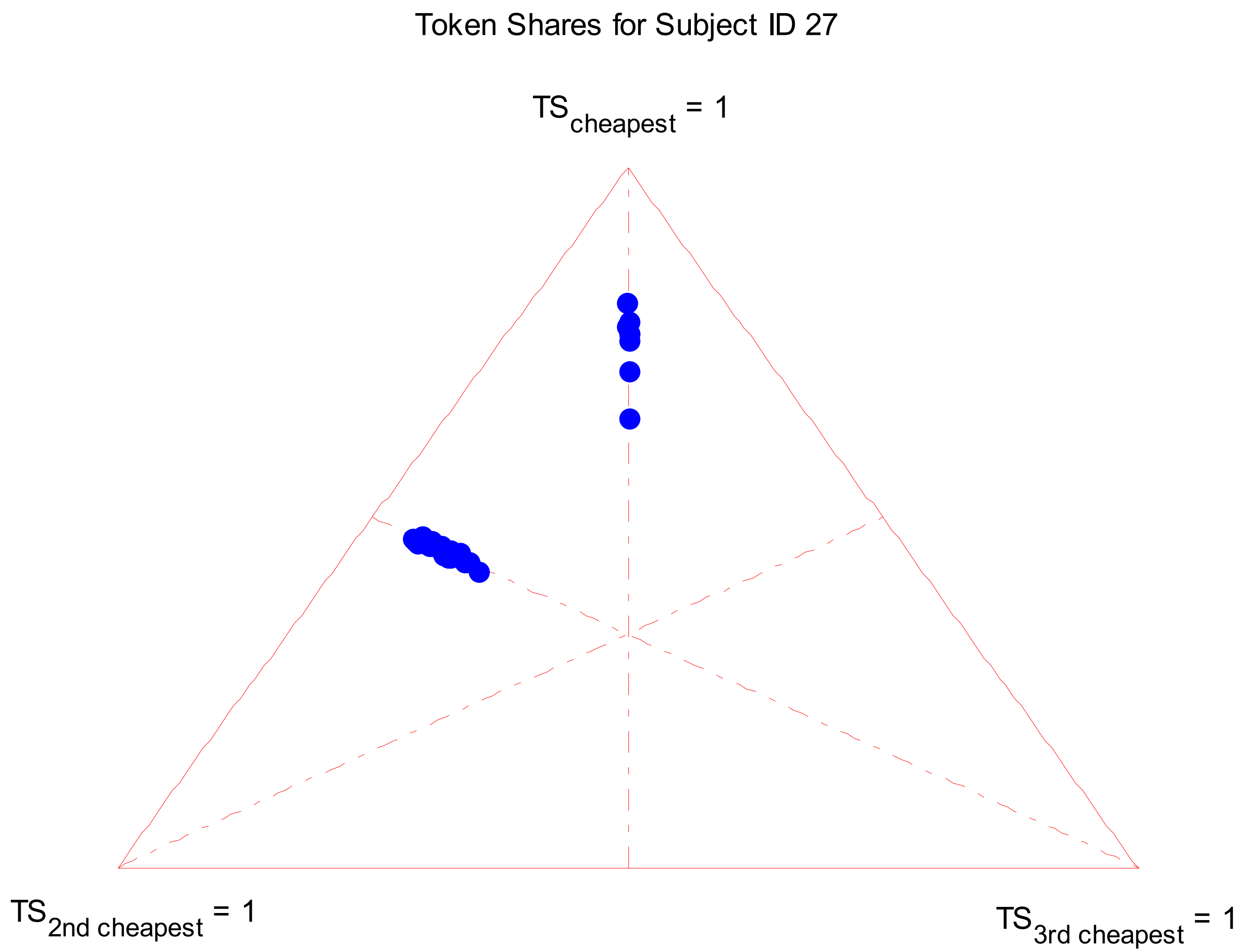
Individual behaviors



Token Shares for Subject ID 13

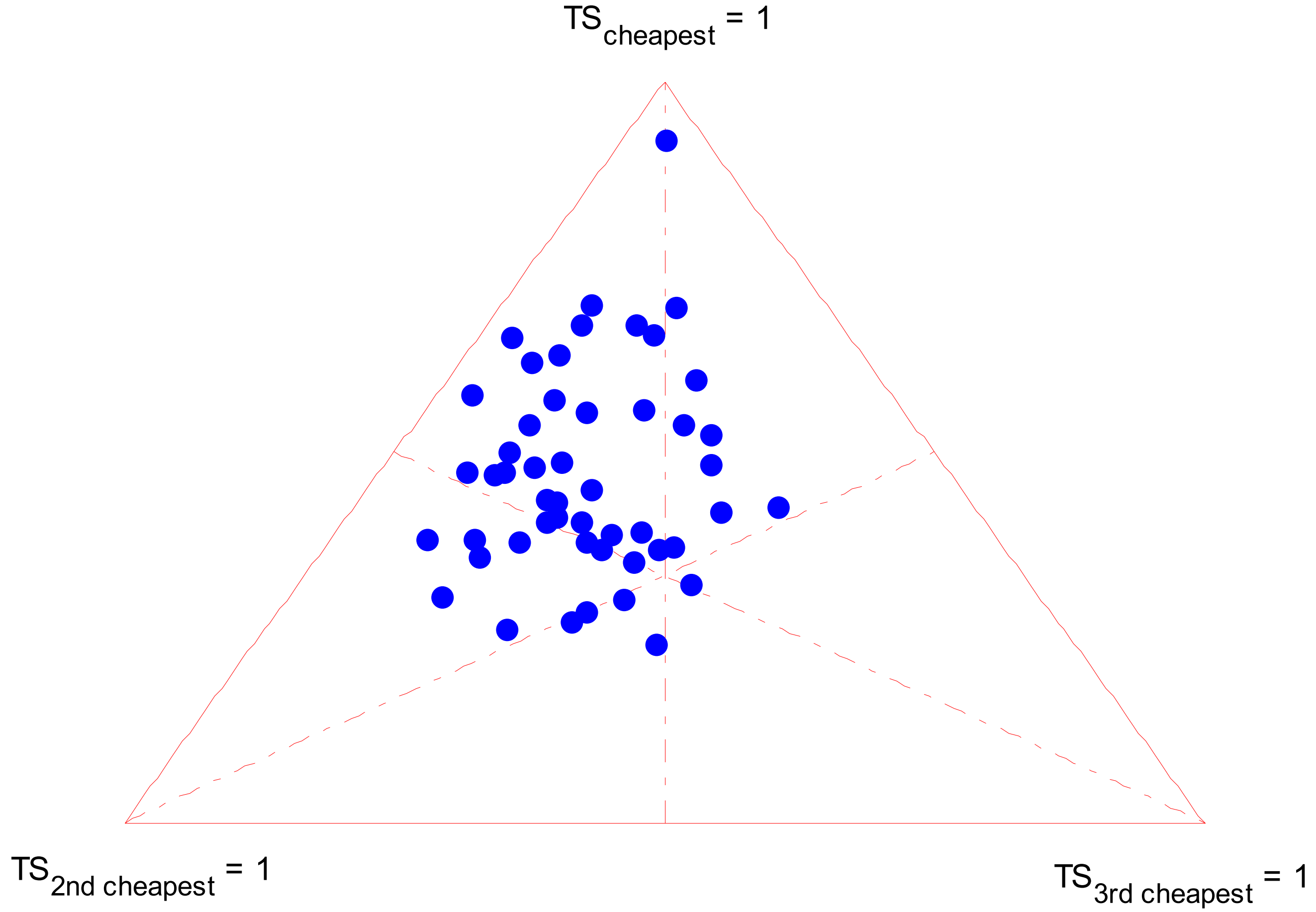



Token Shares for Subject ID 25
TS cheapest = 1
TS 2nd cheapest = 1
TS 3rd cheapest = 1



Token Shares for Subject ID 27
$TS_{cheapest} = 1$
$TS_{2nd\ cheapest} = 1$
$TS_{3rd\ cheapest} = 1$

Token Shares for Subject ID 52



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

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

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).

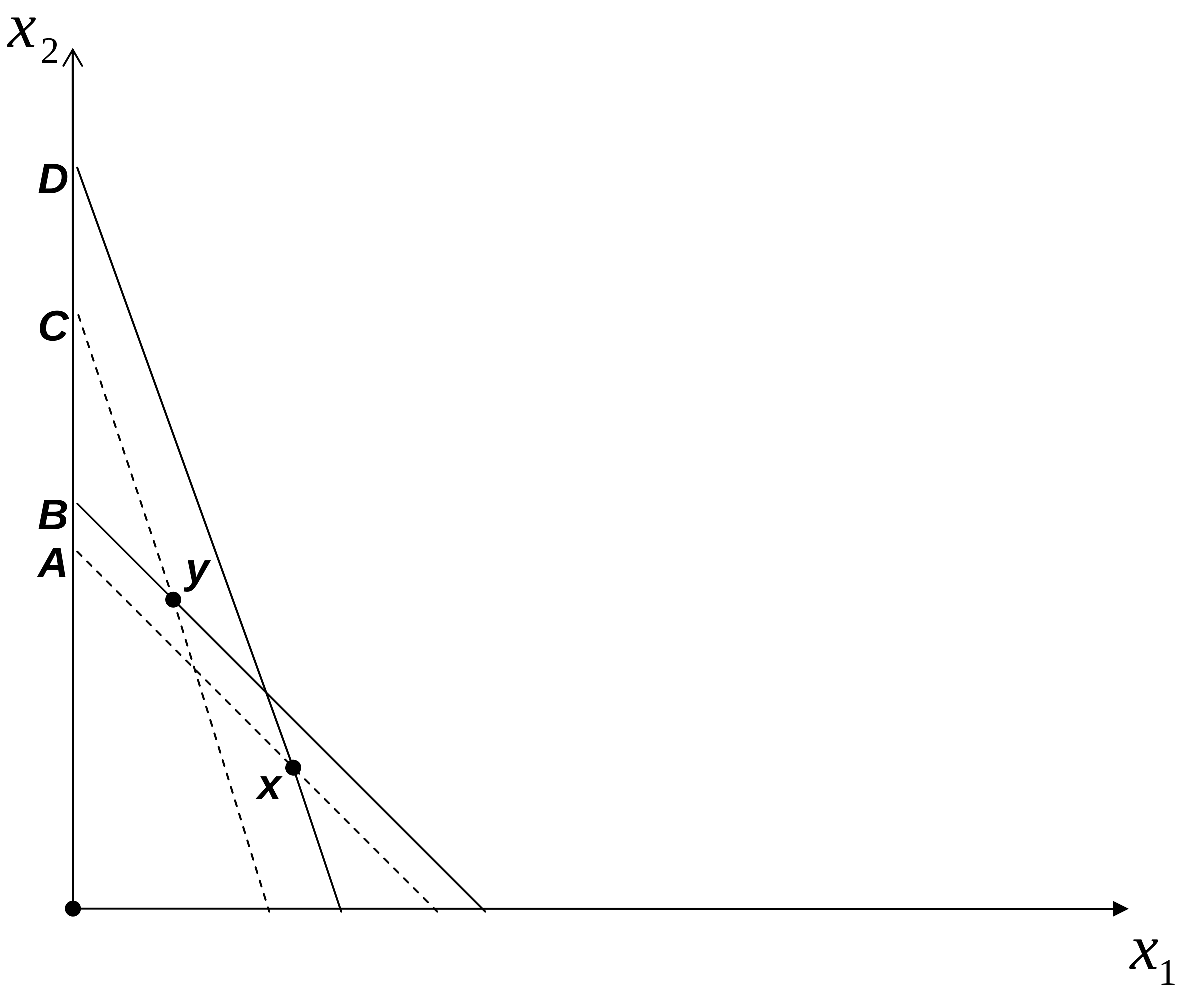
Afriat's Theorem *The following conditions are equivalent:*

- *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.*

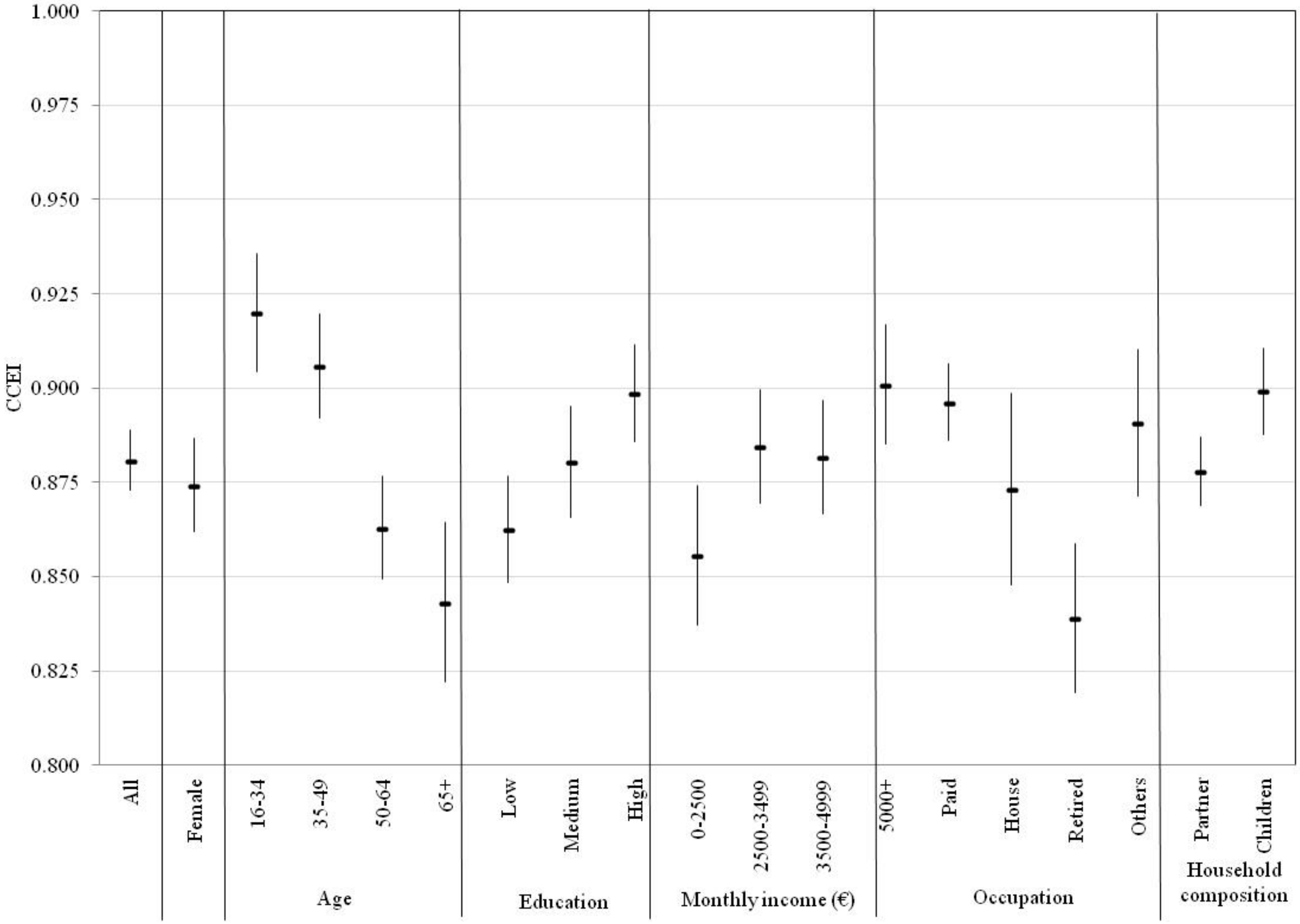
The CCEI is bounded between zero and one. The closer it is to one, the smaller the perturbation required to remove all violations and thus the closer the data are to satisfying GARP.

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.

<u>Homo Economicus</u>: equiprobable lotteries



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 is a good proxy for (financial) DMQ then the degree to which consistency differ across subjects should help explain wealth differentials.

The relationship between CCEI scores and wealth

	(1)	(2)	(3)
CCEI	1.351**	1.109**	101888.0*
	(0.566)	(0.534)	(52691.9)
Log 2008 household income	0.584***	0.606***	
	(0.132)	(0.126)	
2008 household income			1.776***
			(0.4)
Female	-0.313*	-0.356**	-32484.3*
	(0.177)	(0.164)	(17523.9)
Partnered	0.652***	0.595***	46201.9***
	(0.181)	(0.171)	(17173.7)
# of children	0.090	0.109	14078.6*
	(0.093)	(0.086)	(8351.5)
Age	Y	Y	Y
Education	Y	Y	Y
Occupation	Y	Y	Y
Constant	6.292	0.469	76214.4
	(6.419)	(3.598)	(559677.5)
R^2	0.179	0.217	0.188
# of obs.	517	566	568

The robustness of the correlation -- controls for constraints

	(1)	(2)	(3)	(4)	(5)
CCEI	1.322**	1.318**	1.925***	1.888***	1.441**
	(0.570)	(0.574)	(0.672)	(0.652)	(0.578)
Log household income					
2008	19.770	1.000	0.544***	0.285*	0.616***
	(14.629)	.	(0.137)	(0.165)	(0.128)
2008^2	-2.194				
	(1.533)				
2008^3	0.082				
	(0.053)				
2006				0.232	
				(0.231)	
2004				0.215	
				(0.174)	
Female	-0.291	-0.201	-0.337*	-0.296	-0.321*
	(0.181)	(0.173)	(0.185)	(0.186)	(0.176)
Partnered	0.598***	0.561***	0.734***	0.707***	0.641***
	(0.181)	(0.178)	(0.192)	(0.193)	(0.179)
# of children	0.091	0.101	0.018	0.031	0.088
	(0.092)	(0.096)	(0.099)	(0.095)	(0.093)
Age	Y	Y	Y	Y	Y
Education	Y	Y	Y	Y	N
Occupation	Y	Y	Y	Y	Y
Constant	-47.059	0.864	5.354	3.016	6.398
	(46.275)	(6.545)	(6.93)	(7.109)	(6.484)
R^2	0.187		0.205	0.217	0.177
# of obs.	517	517	449	449	517

The robustness of the correlation -- controls for preferences and beliefs

	(1)	(2)	(3)	(4)	(5)
CCEI	1.379**	1.396**	1.404**	1.214*	1.237**
	(0.568)	(0.568)	(0.569)	(0.625)	(0.623)
Risk tolerance					
Quantitative (experiment)	-0.768	-0.808	-0.766		
	(0.714)	(0.711)	(0.718)		
Qualitative (survey)		0.017	0.023		
		(0.074)	(0.076)		
Qualitative (survey) missing		-0.190	-0.162		
		(0.335)	(0.482)		
Conscientiousness			0.089		
			(0.072)		
Conscientiousness missing			-0.040		
			(0.668)		
Longevity expectations					-0.034
					(0.040)
Log 2008 household income	0.589***	0.578***	0.572***	0.443***	0.434***
	(0.132)	(0.131)	(0.133)	(0.123)	(0.123)
Female	-0.316*	-0.310*	-0.323*	-0.415**	-0.417**
	(0.177)	(0.181)	(0.181)	(0.186)	(0.186)
Partnered	0.655***	0.658***	0.642***	0.686***	0.687***
	(0.181)	(0.181)	(0.182)	(0.204)	(0.205)
# of children	0.086	0.087	0.083	0.075	0.083
	(0.093)	(0.093)	(0.093)	(0.102)	(0.102)
Age	Y	Y	Y	Y	Y
Education	Y	Y	Y	Y	Y
Occupation	Y	Y	Y	Y	Y
Constant	6.840	6.883	6.496	3.777	4.411
	(6.361)	(6.357)	(6.395)	(15.258)	(15.256)
R^2	0.179	0.176	0.176	0.163	0.163
# of obs.	517	517	517	414	414

Evaluating alternative measures of *DMQ*

	(1)	(2)	(3)	(4)
CCEI	1.253*	1.401*	1.269*	1.177**
	(0.712)	(0.729)	(0.729)	(0.583)
CCEI (combined dataset)	0.099			
	-0.38			
von Gaudecker et al. (2011)			0.927*	
			(0.485)	
Cognitive Reflection Test (CRT)				0.120*
				(0.071)
CRT missing				-0.203
				(0.237)
Log 2008 household income	0.586***	0.388*	0.383*	0.577***
	(0.132)	(0.155)	(0.154)	(0.132)
Female	-0.314*	-0.218	-0.207	-0.292*
	(0.177)	(0.212)	(0.211)	(0.176)
Partnered	0.653***	0.907***	0.926***	0.690***
	(0.181)	(0.230)	(0.228)	(0.181)
# of children	0.089	0.105	0.096	0.091
	(0.093)	(0.114)	(0.113)	(0.092)
Age	Y	Y	Y	Y
Education	Y	Y	Y	Y
Occupation	Y	Y	Y	Y
Constant	6.237	10.056	8.355	6.855
	(6.424)	(6.976)	(6.990)	(6.464)
R^2	0.177	0.225	0.232	0.181
# of obs.	517	326	326	517

The sources of the relationship

	(1)	(2)	(3)	(4)
	Have checking	Fraction in checking	Have saving	Fraction in saving
CCEI	0.03	-0.098*	-0.047	-0.162*
	(0.032)	(0.057)	(0.053)	(0.097)
Log 2008 household income	0.001	-0.029**	0.003	-0.068***
	(0.002)	(0.013)	(0.010)	(0.021)
Female	0.007	0.023	0.014	0.038
	(0.005)	(0.020)	(0.019)	(0.033)
Partnered	-0.005	-0.031	0.017	-0.054
	(0.004)	(0.020)	(0.022)	(0.033)
# of children	0.000	-0.004	-0.025*	-0.043***
	(0.001)	(0.010)	(0.014)	(0.013)
Age	Y	Y	Y	Y
Education	Y	Y	Y	Y
Occupation	Y	Y	Y	Y
Constant	0.998***	0.106	1.126	1.448
	(0.172)	(0.822)	(0.848)	(1.288)
R^2	-0.007	0.021	-0.011	0.083
# of obs.	512	512	502	502

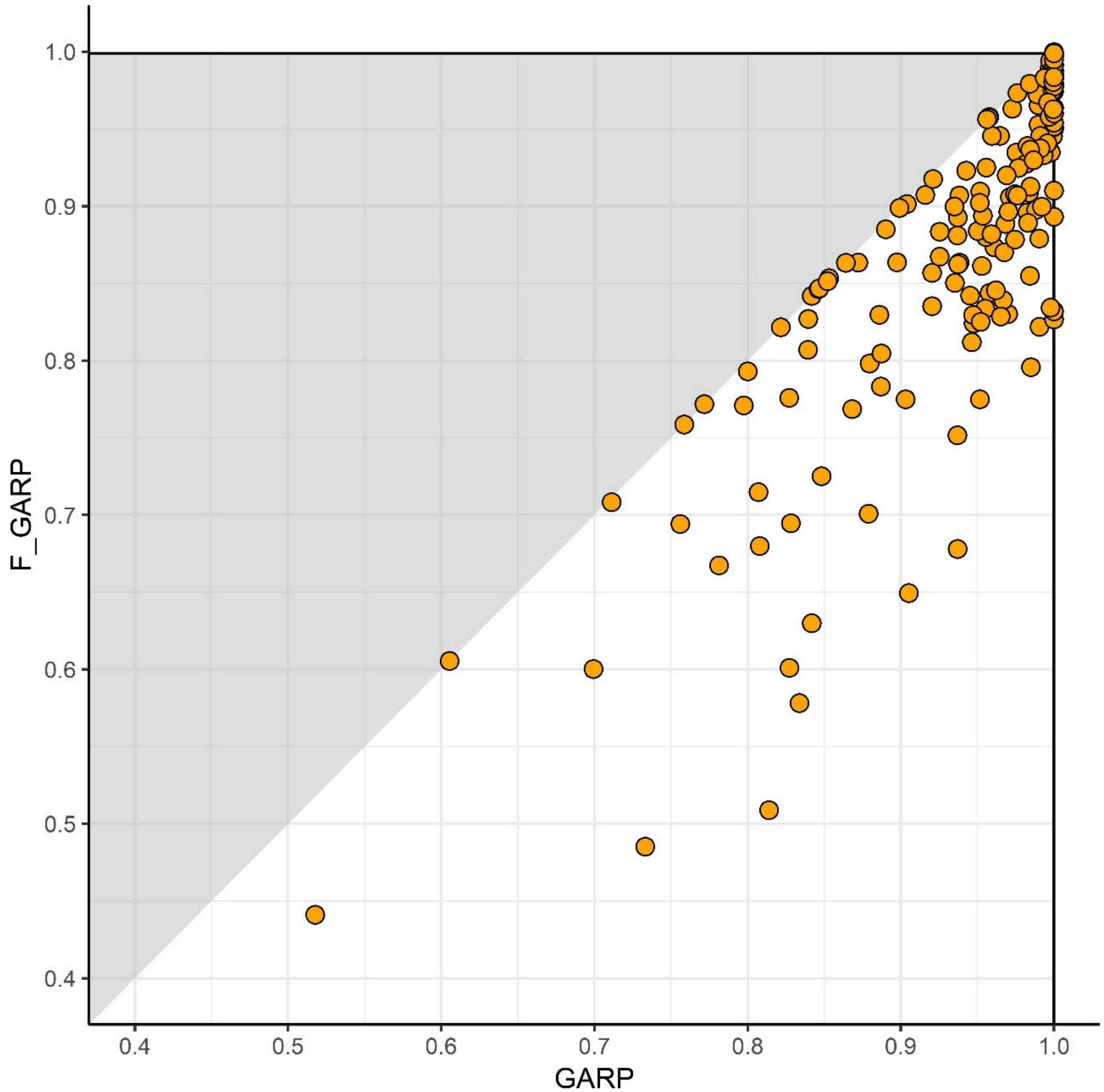
The sources of the relationship (cont.)

	(5) Have stocks	(6) Fraction in stocks	(7) Have a house	(8) Fraction in house
CCEI	0.167	0.001	0.352**	0.324**
	(0.163)	(0.050)	(0.152)	(0.129)
Log 2008 household income	0.148***	0.013	0.134***	0.096***
	(0.031)	(0.009)	(0.029)	(0.024)
Female	0.007	0.009	-0.038	-0.066
	(0.050)	(0.013)	(0.050)	(0.043)
Partnered	0.005	-0.007	0.207***	0.127***
	(0.049)	(0.014)	(0.051)	(0.044)
# of children	0.003	0.000	0.048**	0.063***
	(0.026)	(0.007)	(0.020)	(0.019)
Age	Y	Y	Y	Y
Education	Y	Y	Y	Y
Occupation	Y	Y	Y	Y
Constant	-3.152*	-0.317	-1.047	-1.151
	(1.856)	(0.398)	(1.760)	(1.419)
R^2	0.079	0.002	0.148	0.123
# of obs.	514	514	479	479

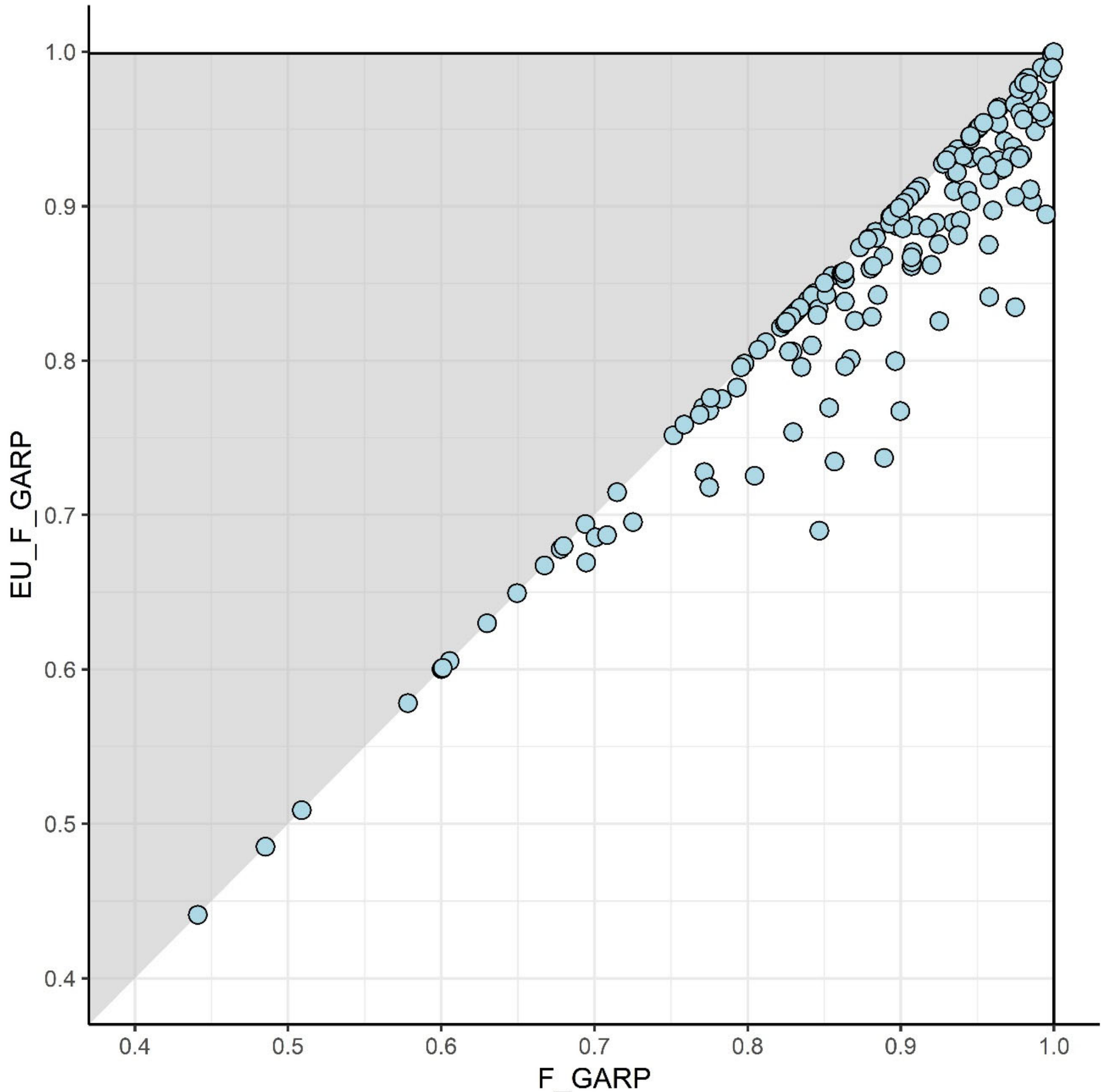
A comprehensive nonparametric test

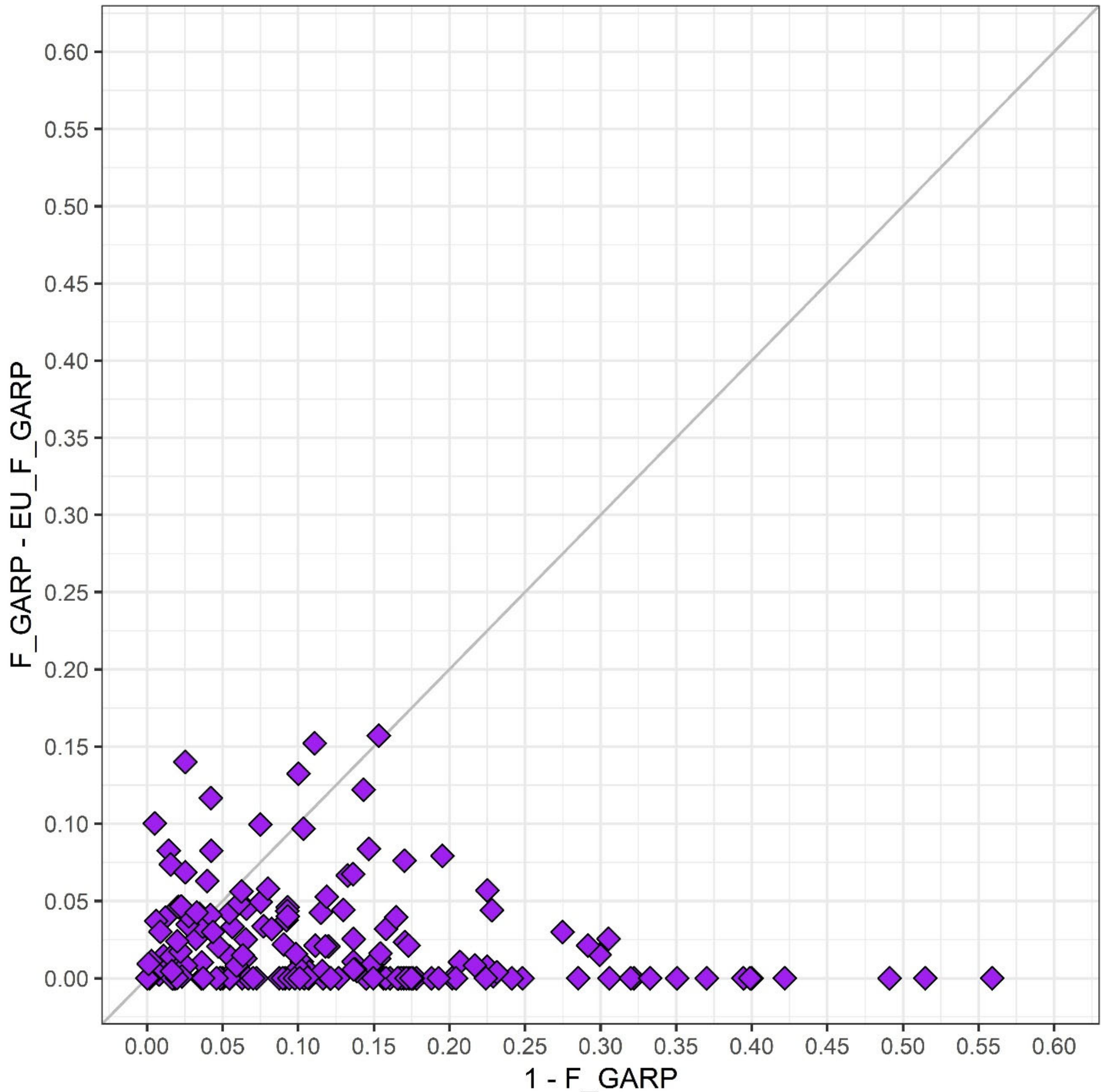
Test complete representations of preferences rather than focusing on individual axiom(s) (comprehensive) and make no auxiliary functional form assumptions (nonparametric):

- utility maximization (rationalizability)
- stochastically monotone utility maximization (FOSD-rationalizability)
- expected utility maximization (EU-rationalizability)

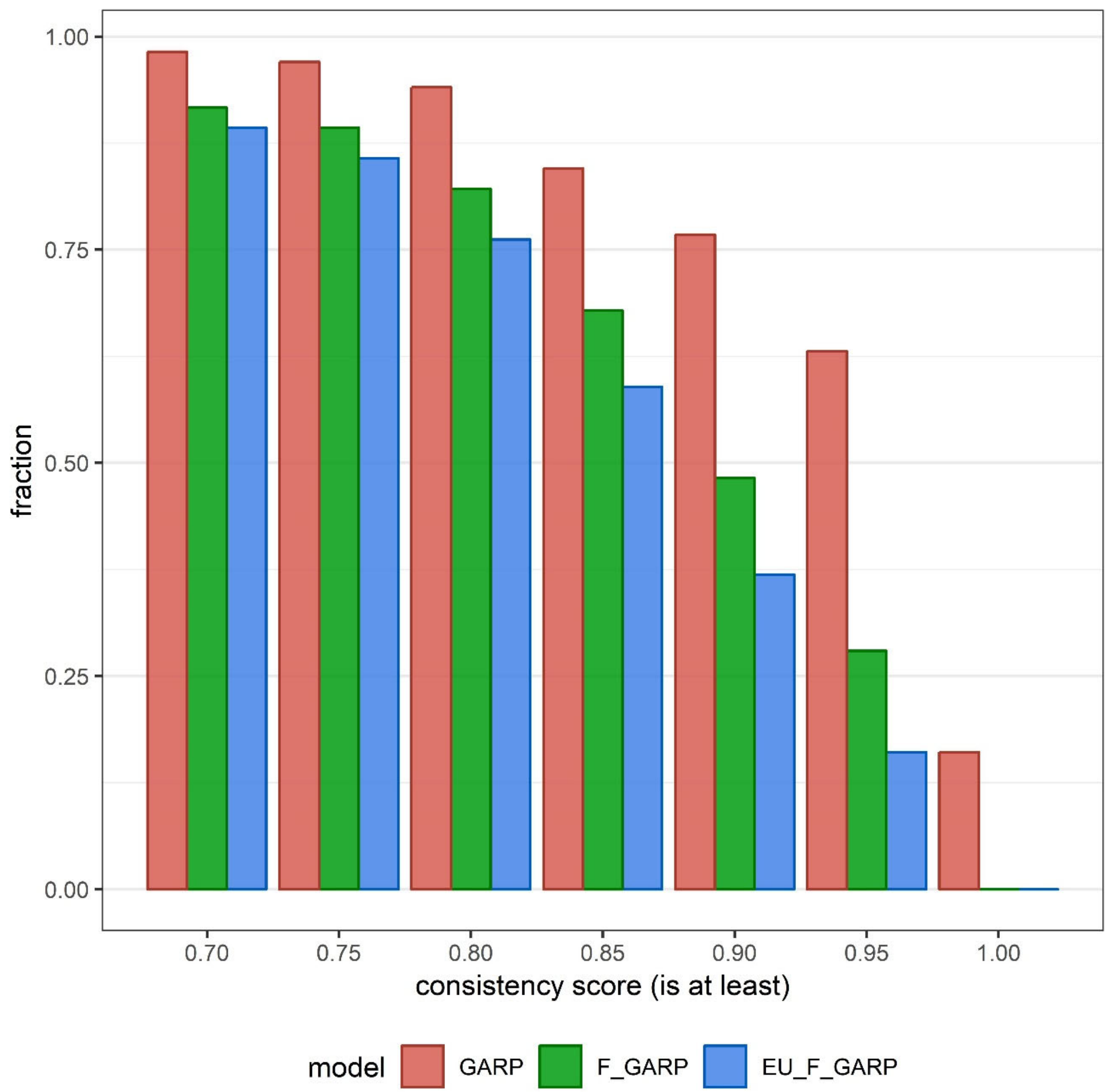


F_GARP
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.4
0.5
0.6
0.7
0.8
0.9
1.0
GARP


EU_F_GARP
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.4
0.5
0.6
0.7
0.8
0.9
1.0
F_GARP



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
F_GARP - EU_F_GARP
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
1 - F_GARP



1.00
0.75
0.50
0.25
0.00
fraction
0.70
0.75
0.80
0.85
0.90
0.95
1.00
consistency score (is at least)
model
GARP
F_GARP
EU_F_GARP

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

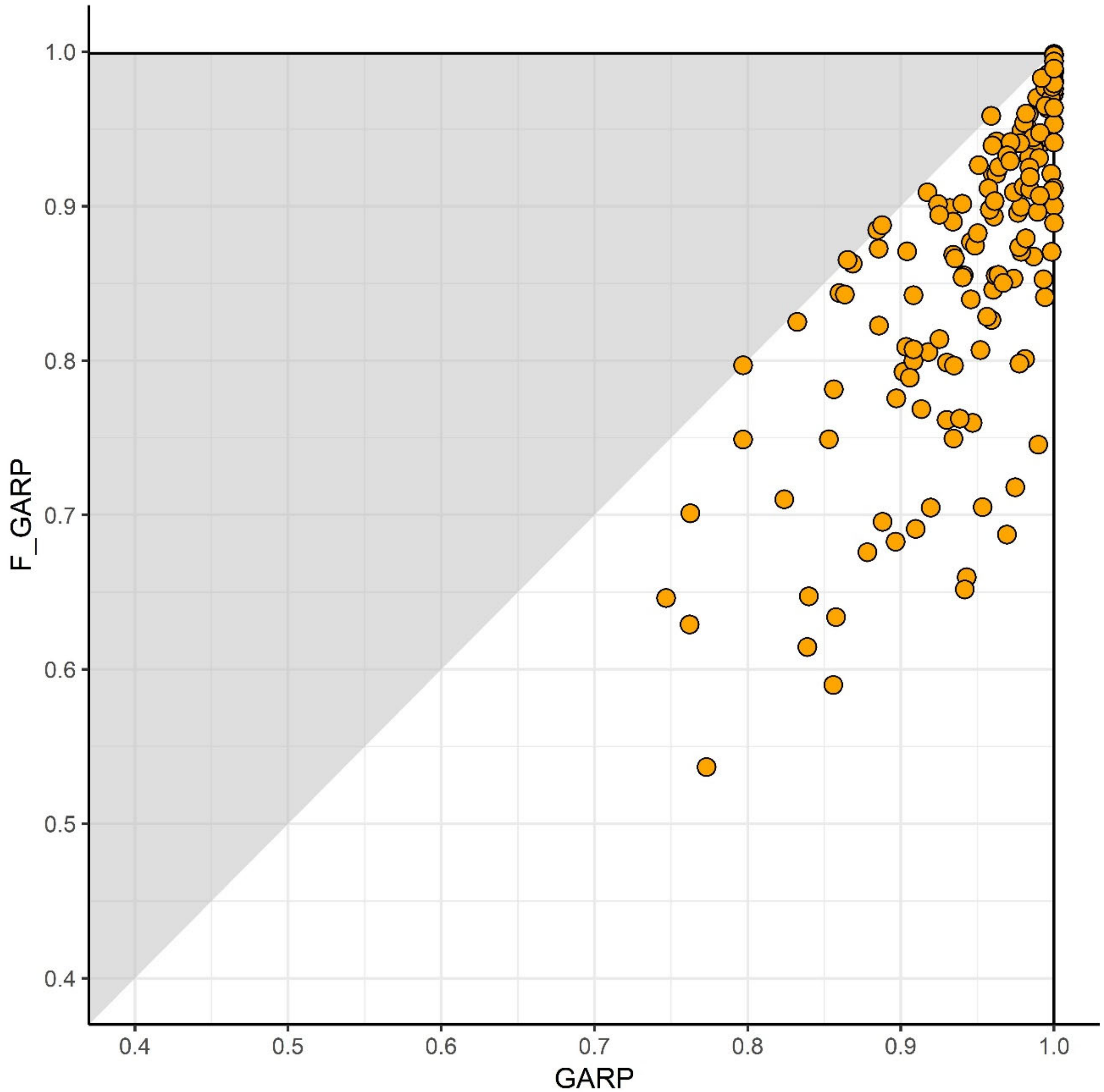
Consider the following four two-color Ellsberg-type urns (Halevy, 2007):

I. 5 red balls and 5 black balls

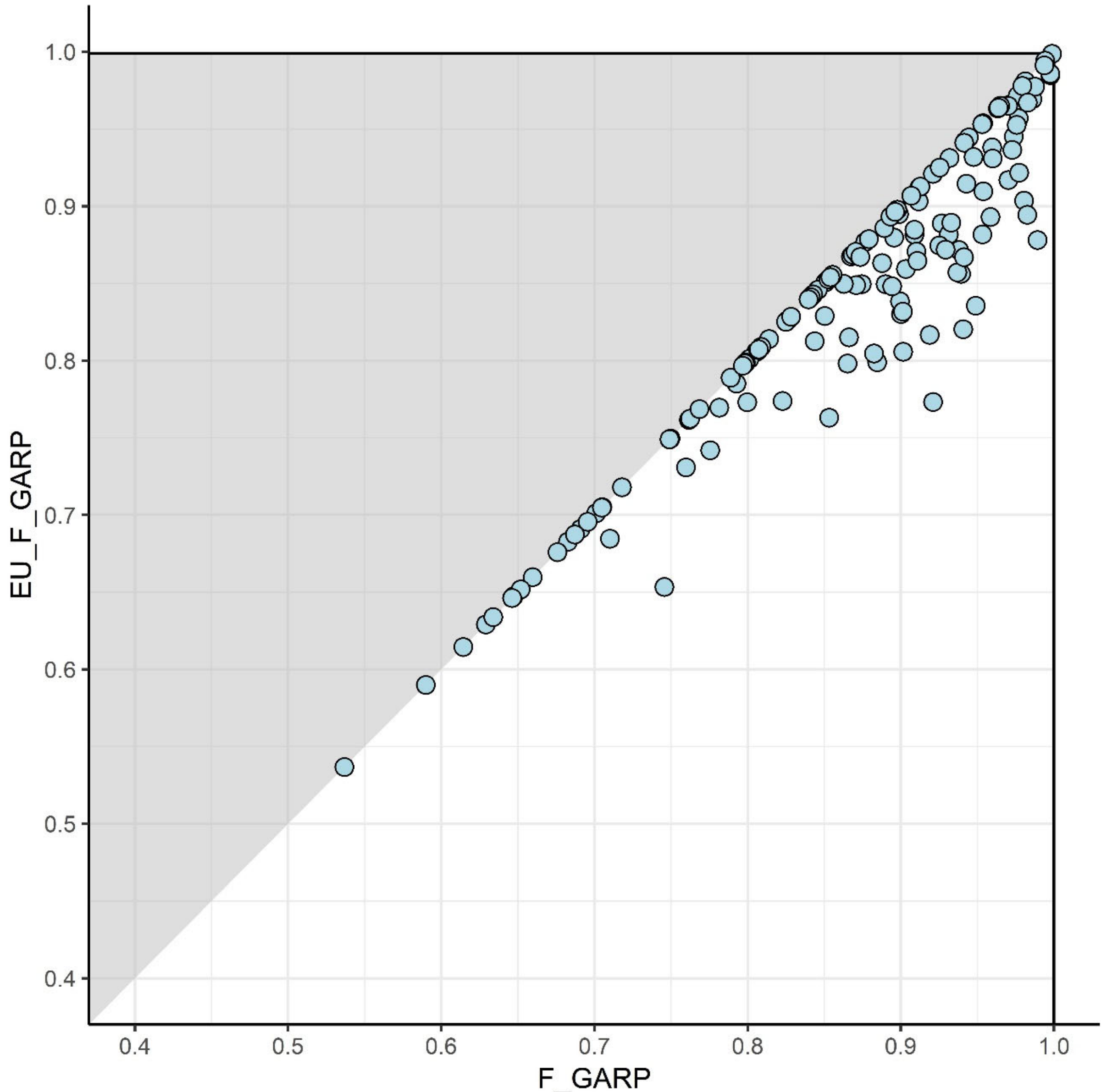
II. an unknown number of red and black balls

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

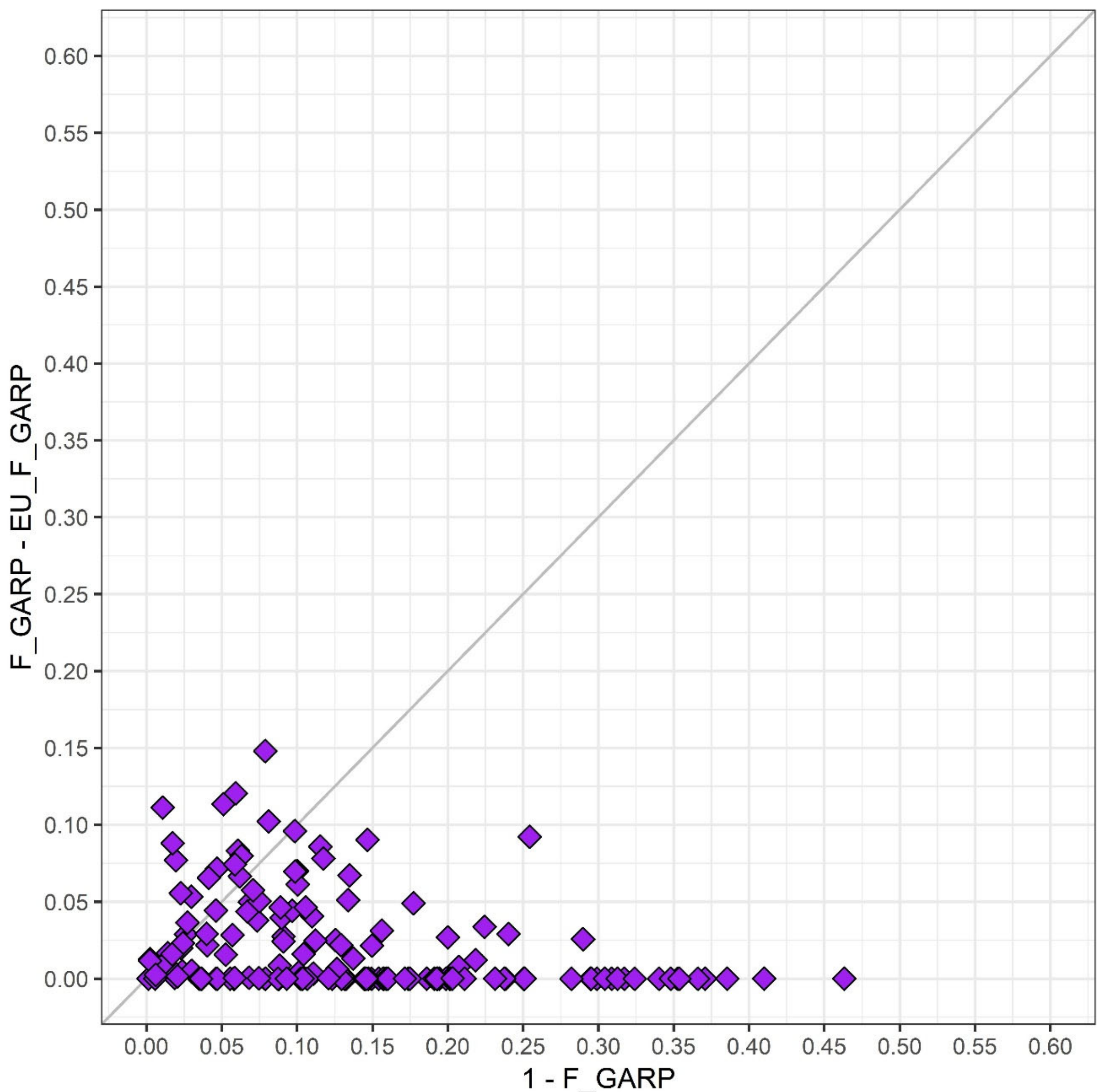
IV. a bag containing 2 tickets with the numbers 0 and 10; the number written on the drawn ticket determines the number of red balls



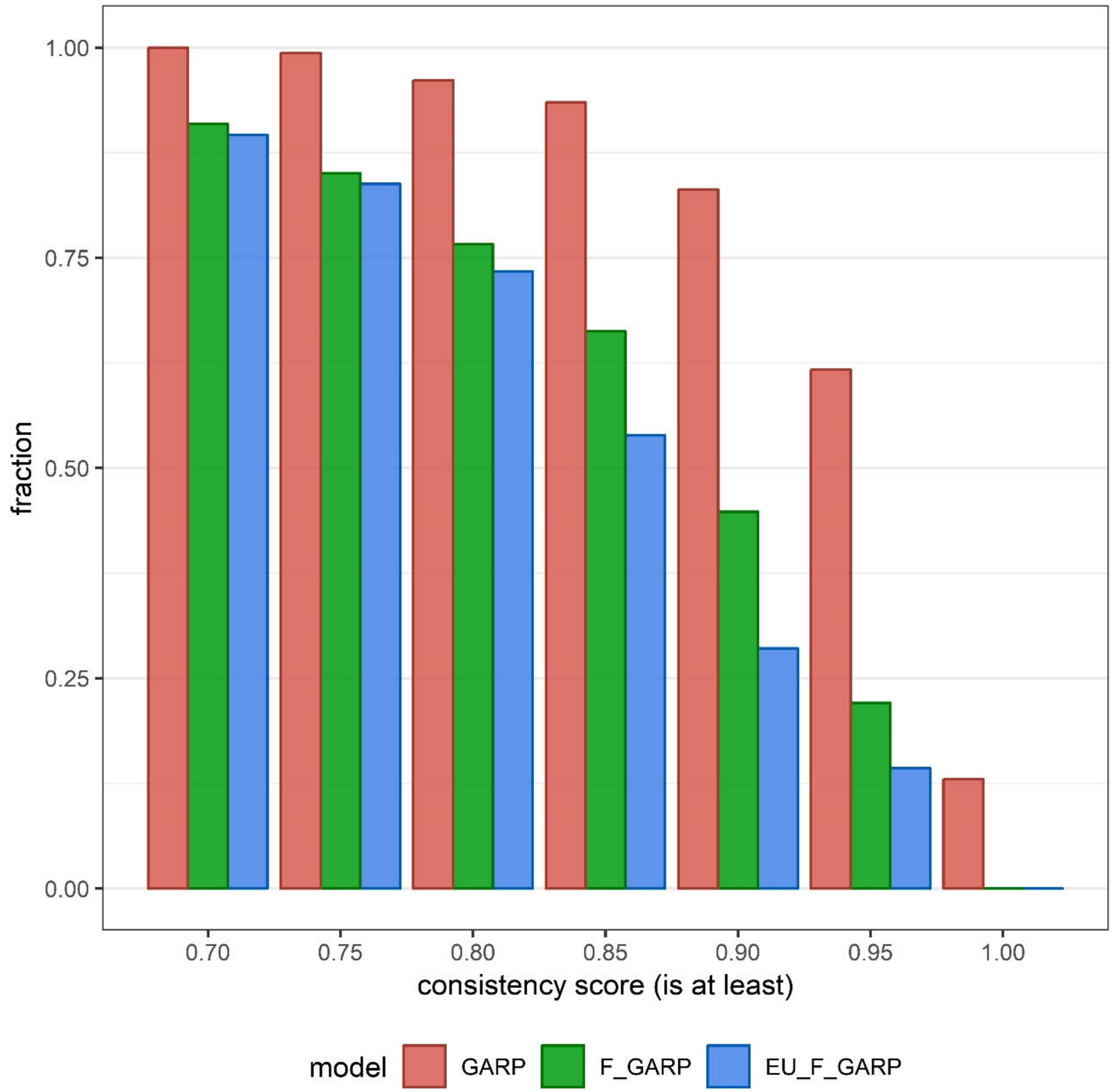
1.0
0.9
0.8
0.7
0.6
0.5
0.4
F_GARP
0.4
0.5
0.6
0.7
0.8
0.9
1.0
GARP



1.0
0.9
0.8
0.7
0.6
0.5
0.4
EU_F_GARP
0.4
0.5
0.6
0.7
0.8
0.9
1.0
F_GARP



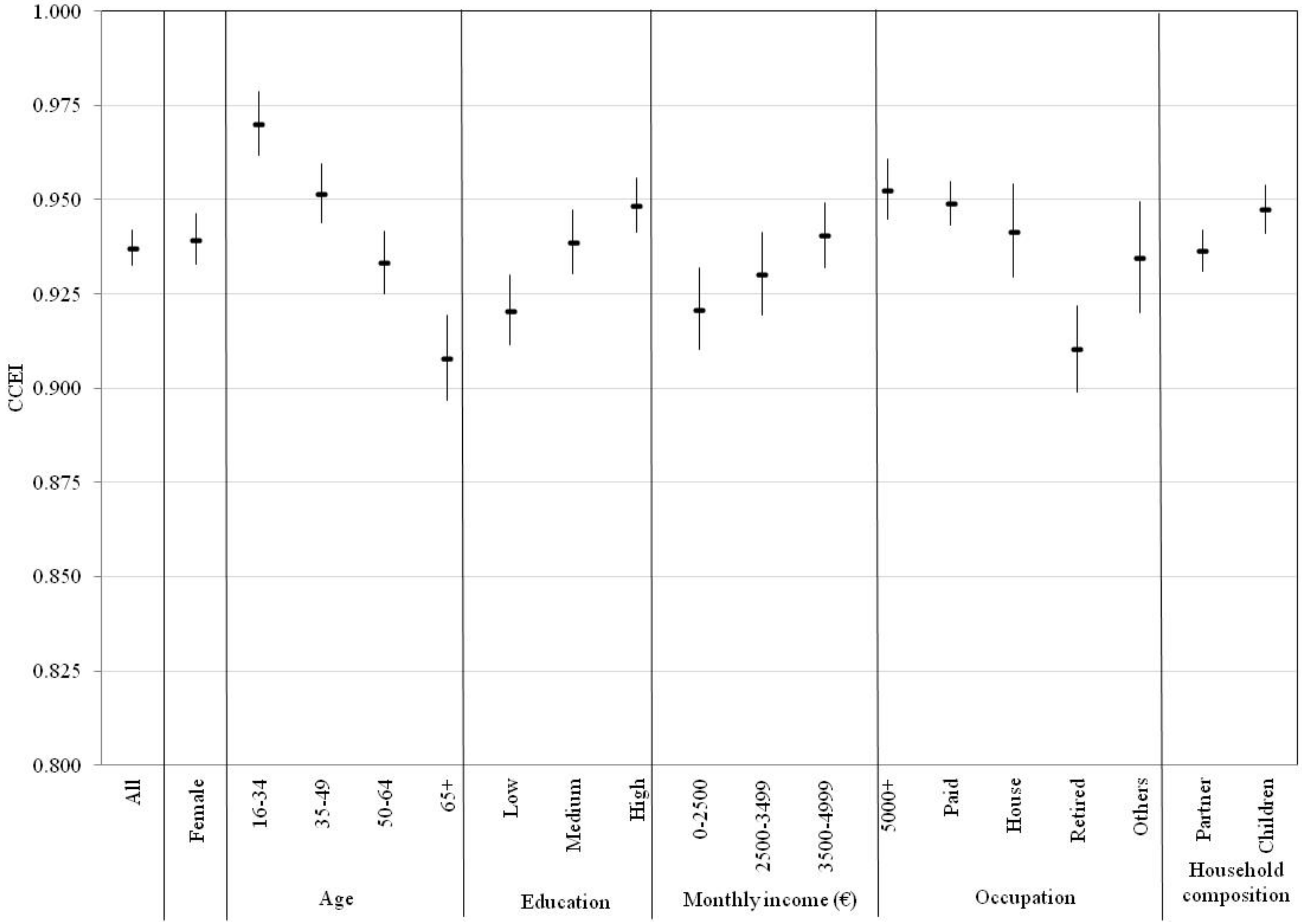
F_GARP - EU_F_GARP
1 - F_GARP
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
0.55
0.60



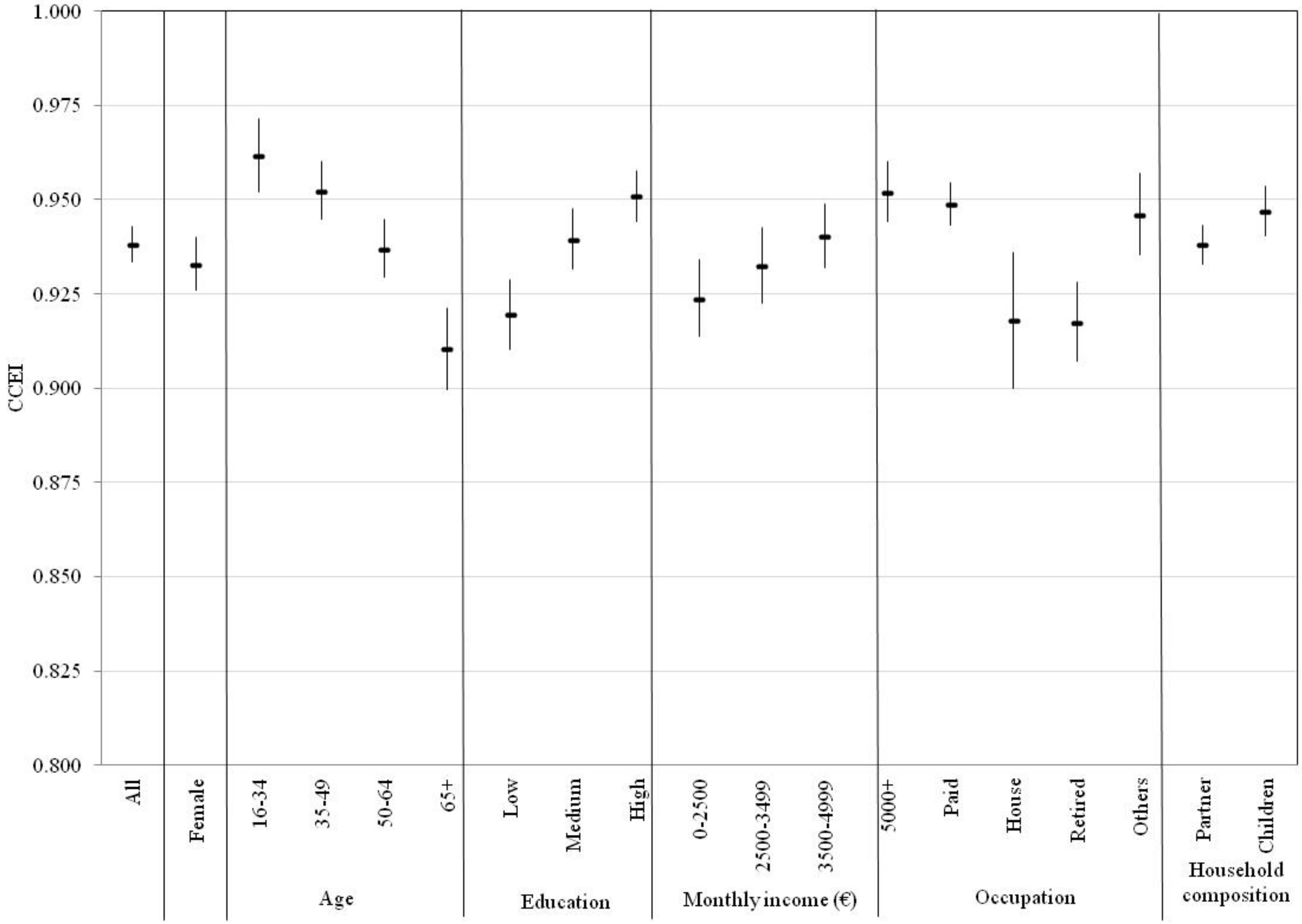
fraction
1.00
0.75
0.50
0.25
0.00
0.70
0.75
0.80
0.85
0.90
0.95
1.00
consistency score (is at least)
model
GARP
F_GARP
EU_F_GARP

Time preferences

Mean CCEI scores: income in a few days and income 60 days after that



Mean CCEI scores: income in 60 days and income another 60 days after that



Stationarity, time invariance, and time consistency

- Time discount rates decline as tradeoffs are pushed into the temporal distance.
  - Subjects often choose the larger and later of two rewards when both are distant in time, but prefer the smaller and earlier one as both rewards draw nearer to the present.

- Interpreted as non-constant time discounting, these preference reversals have important implications.
  - Under standard assumptions, non-constant time discounting implies time-inconsistency – self-control problems and a demand for commitment thus emerge.

Stationarity

$\succsim_t$ is stationary if for every $t, t' \geq 0$ and $\Delta_1, \Delta_2 \geq 0$

$$(x, t+\Delta_1) \sim_t (x', t+\Delta_2) \Longleftrightarrow (x, t'+\Delta_1) \sim_t (x', t'+\Delta_2).$$

Ranking does not depend on the distance from t. Tested in the standard static experiment.

Time invariance

$\{\succsim_t\}_{t=1}^{T}$ is time-invariant if for every $t, t' \geq 0$ and $\Delta_1, \Delta_2 \geq 0$

$$(x, t+\Delta_1) \sim_t (x', t+\Delta_2) \Longleftrightarrow (x, t'+\Delta_1) \sim_{t'} (x', t'+\Delta_2).$$

Ranking does not depend on a calendar time (payments are evaluated relative to a "stopwatch time").

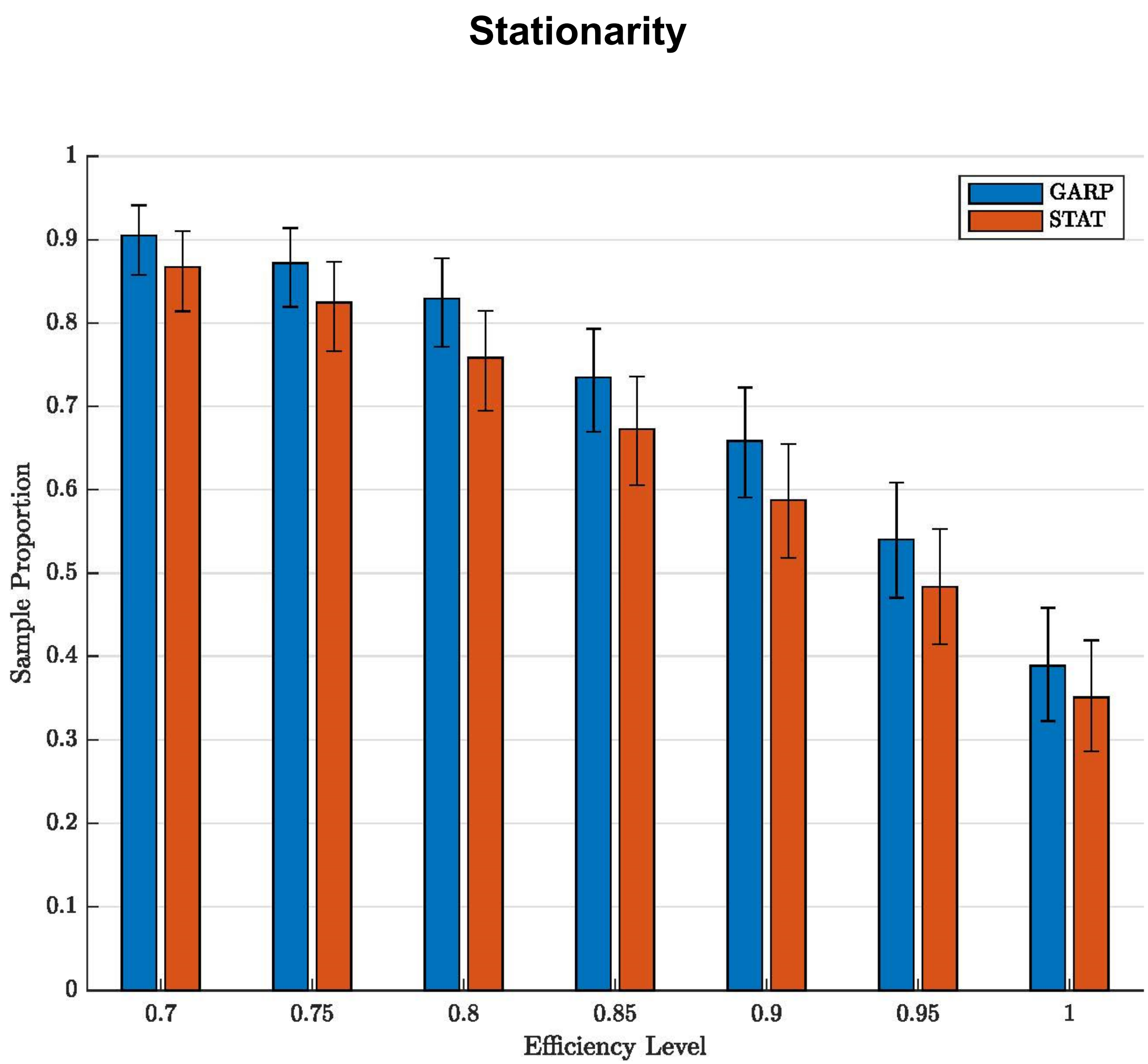
Time consistency

$\{\succsim_t\}_{t=1}^{T}$ is time-consistent if for every $t, t' \geq 0$ and $\Delta_1, \Delta_2 \geq 0$

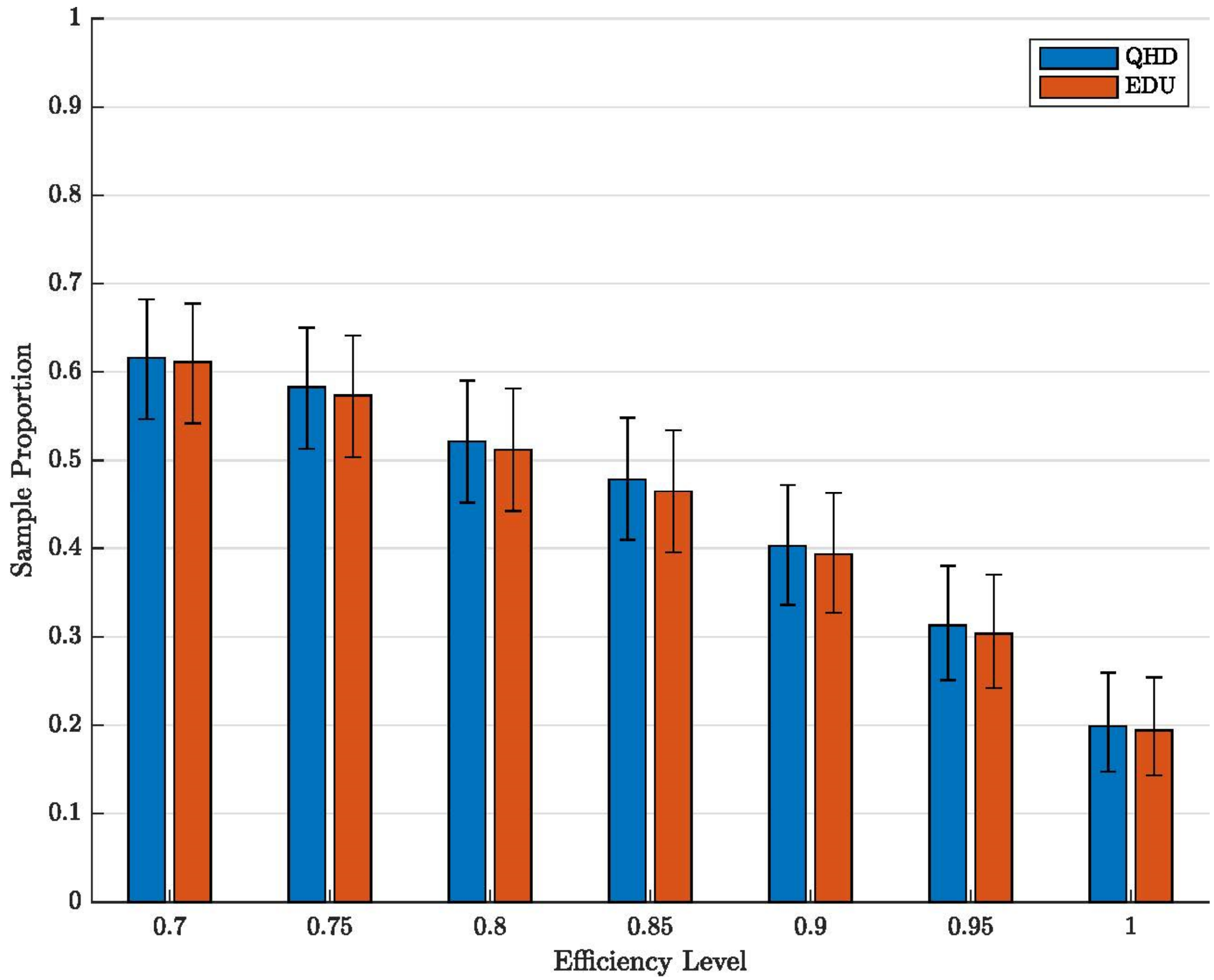
$$(x, t+\Delta_1) \sim_t (x', t+\Delta_2) \Longleftrightarrow (x, t+\Delta_1) \sim_{t'} (x', t+\Delta_2).$$

Ranking does not change as the evaluation perspective changes from t to t'. Time consistency precludes dynamic preference reversals.

$\Longrightarrow$ These properties are pair-wise independent, but any two properties imply the third (Halevy, 2014)


Stationarity
GARP
STAT
Sample Proportion
Efficiency Level
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.7
0.75
0.8
0.85
0.9
0.95
1

Exponential vs. quasi-hyperbolic



What can we learn from machine learning?!

- Economics revolves around constructing parameter estimates of the underlying utility function and using those to forecast behavior in new situations.

- Machine learning algorithms are built solely for the purpose of extrapolation by seeking functions that predict better than economic models out of sample.

$\Longrightarrow$ The entire promise of machine learning rests on the assumption (promise?) that it is better than the classical theory-driven approach for extrapolation...

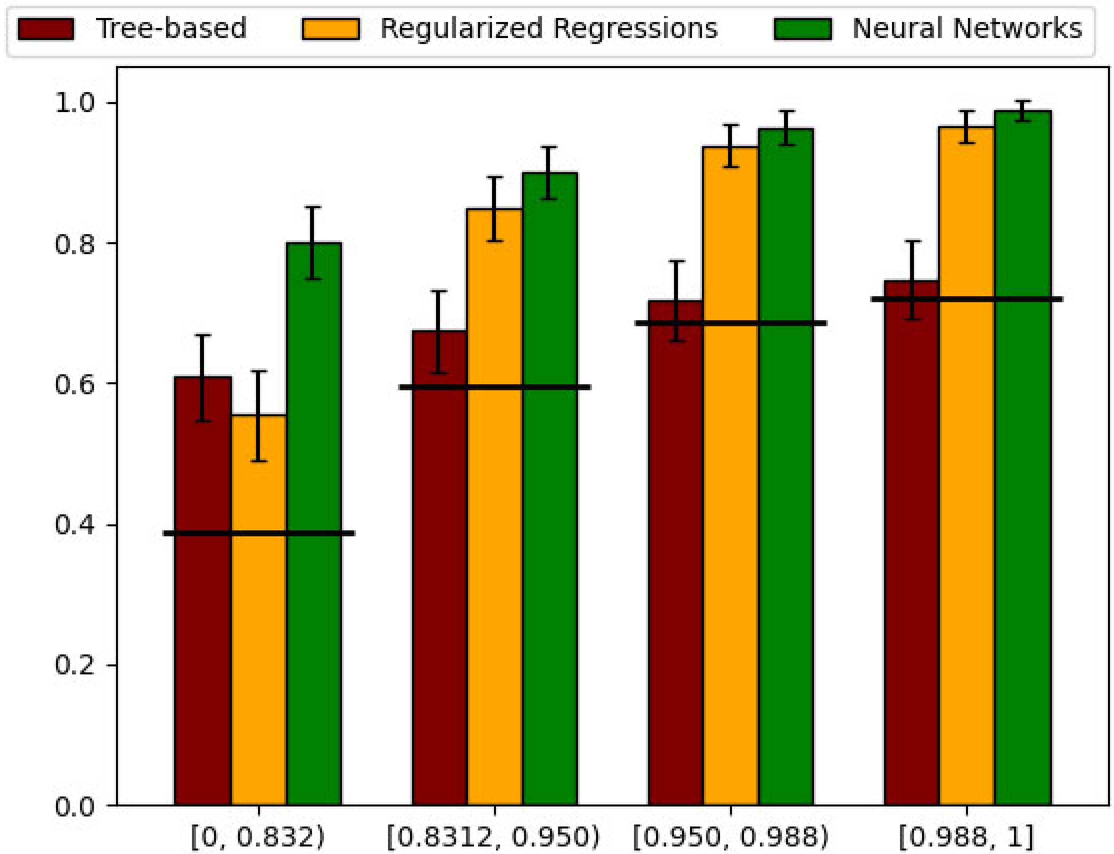
Completeness and restrictiveness

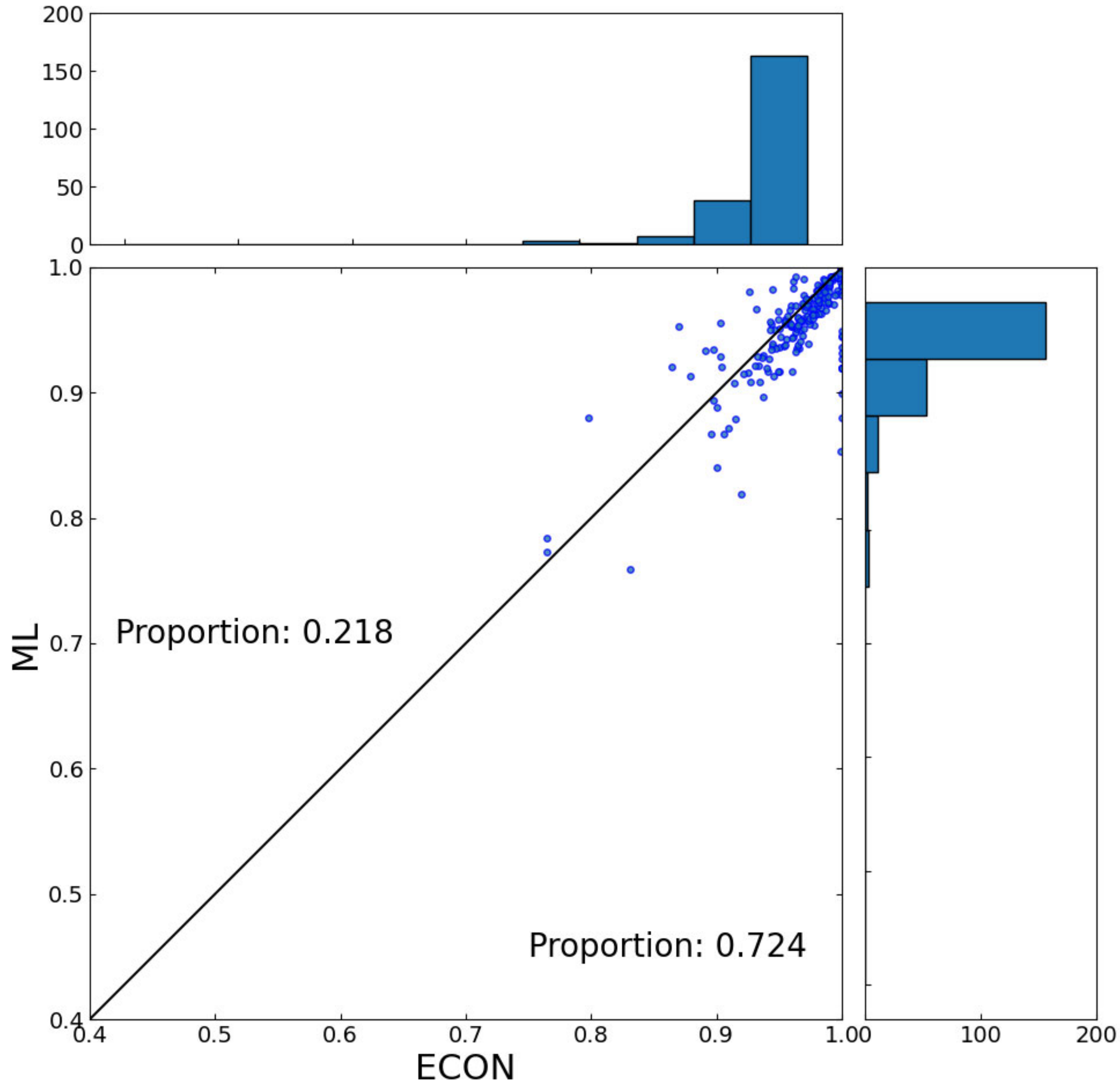
Fudenberg et al. (2020, 2022) propose a method to use machine learning techniques to evaluate prediction accuracy and flexibility:

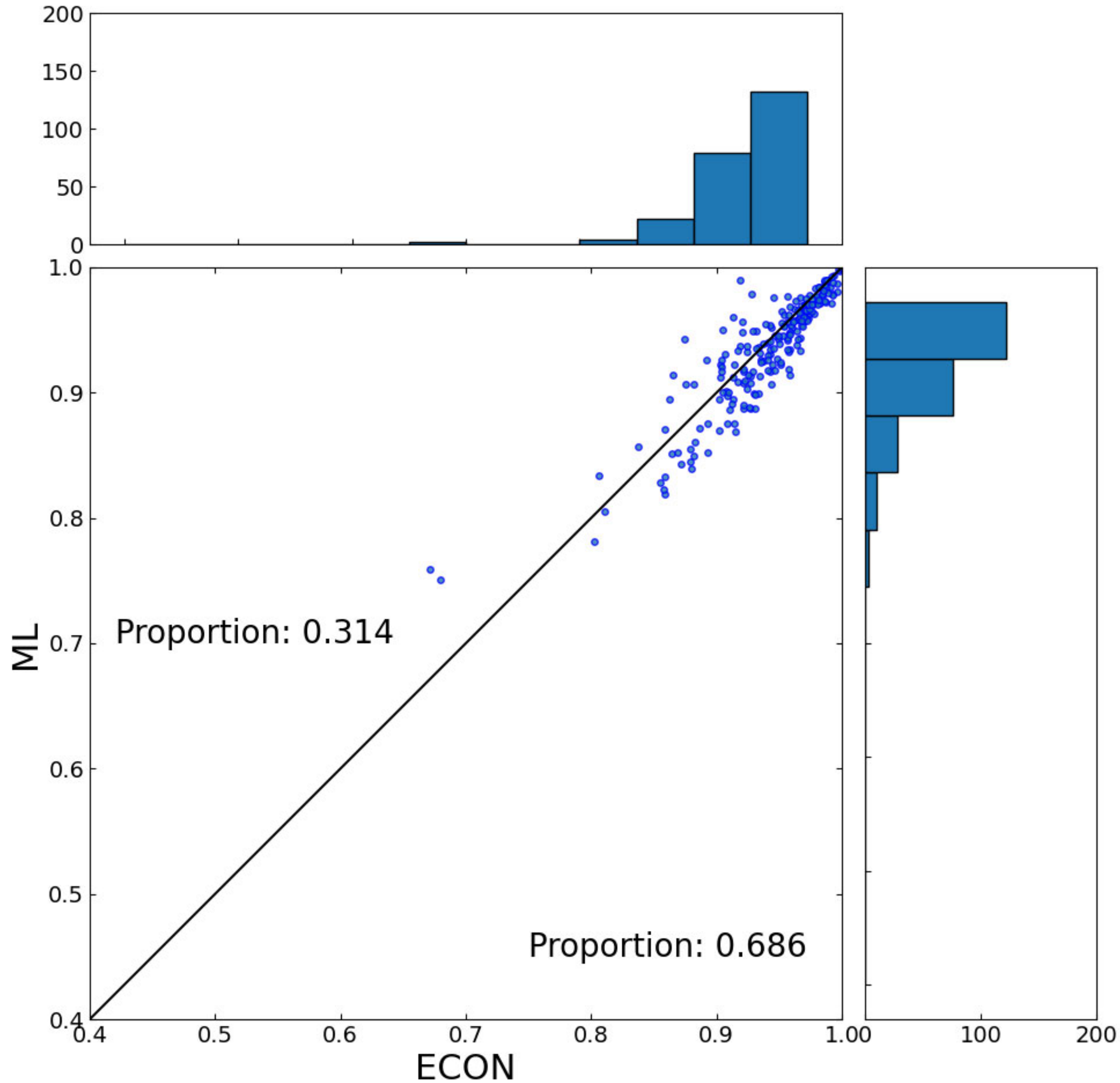
– The completeness of a model is the fraction of the predictable variation in the data that the model captures.

– The restrictiveness of a model discern completeness due to the "right" regularities by evaluating its completeness on arbitrary data.

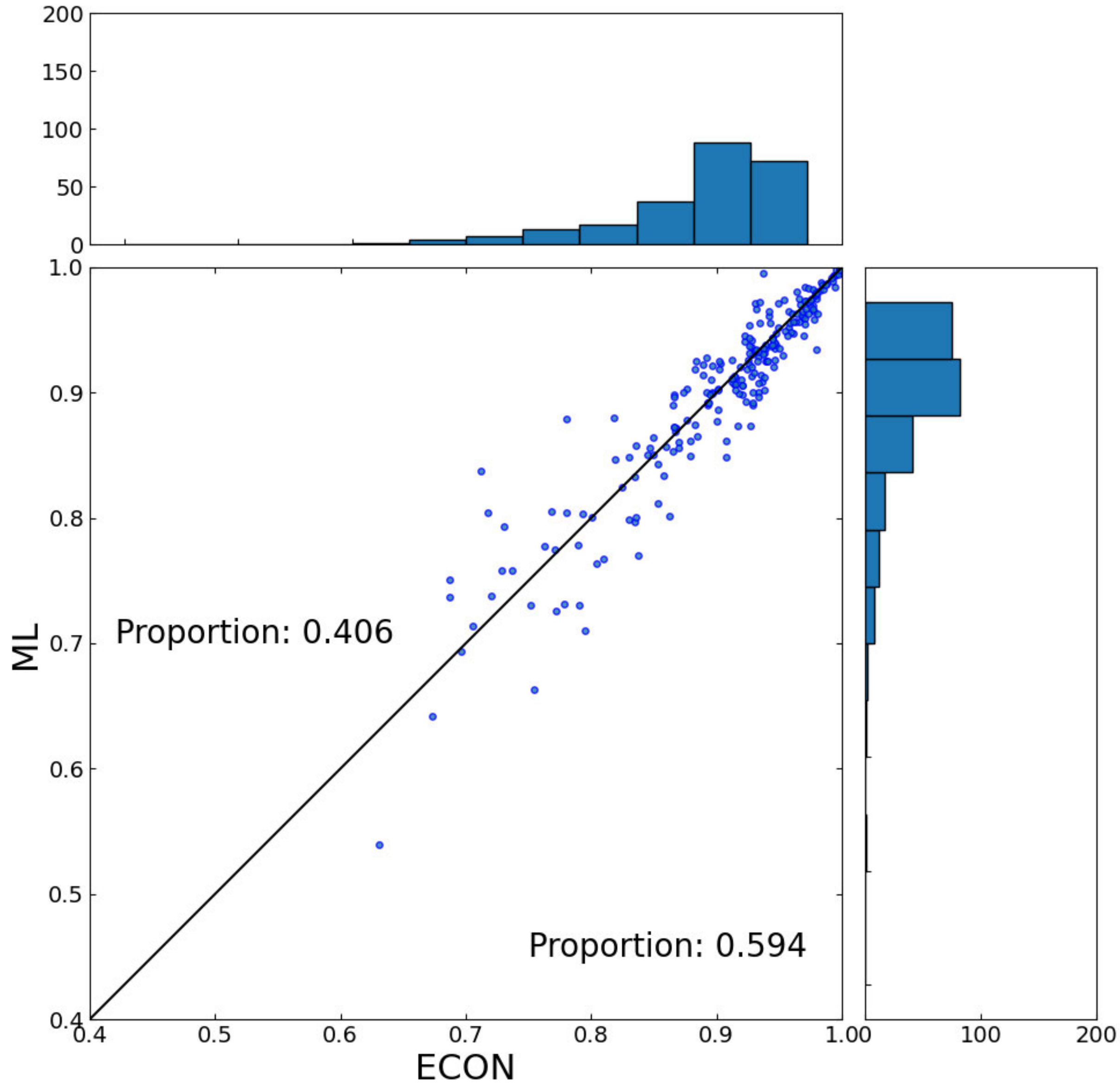
$\Longrightarrow$ An unrestrictive model can be complete on any possible data, so the fact that it is complete on the actual data is uninstructive.

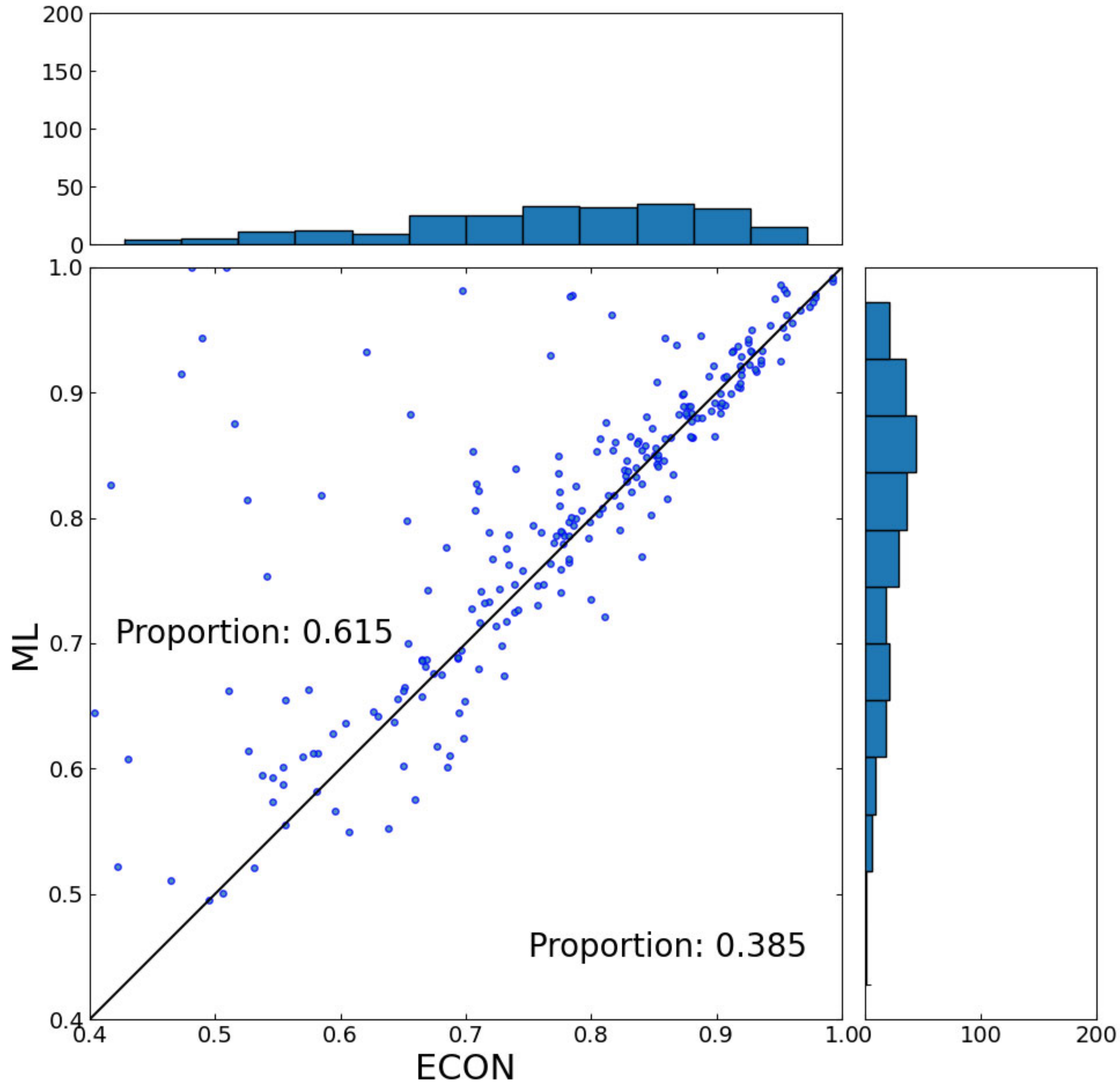

Tree-based
Regularized Regressions
Neural Networks
1.0
0.8
0.6
0.4
0.2
0.0
[0, 0.832)
[0.8312, 0.950)
[0.950, 0.988)
[0.988, 1]


200
150
100
50
0
1.0
0.9
0.8
0.7
0.6
0.5
0.4
ML
Proportion: 0.218
Proportion: 0.724
0.4
0.5
0.6
0.7
0.8
0.9
1.00
100
200
ECON



200
150
100
50
0
1.0
0.9
0.8
0.7
0.6
0.5
0.4
ML
Proportion: 0.314
Proportion: 0.686
0.4
0.5
0.6
0.7
0.8
0.9
1.00
100
200
ECON


200
150
100
50
0
1.0
0.9
0.8
0.7
0.6
0.5
0.4
ML
Proportion: 0.406
Proportion: 0.594
0.4
0.5
0.6
0.7
0.8
0.9
1.00
100
200
ECON



200
150
100
50
0
1.0
0.9
0.8
0.7
0.6
0.5
0.4
ML
Proportion: 0.615
Proportion: 0.385
0.4
0.5
0.6
0.7
0.8
0.9
1.0
ECON
0
100
200

Model	Average Completeness	ECON Win Rate Against Model	ECON winrate over ML by quartile of economic rationality				ECON relative improvement over ML by quartile of economic rationality				Restrictiveness
			1st	2nd	3rd	4th	1st	2nd	3rd	4th	
ECON	89.8% [89.1%, 90.5%]	-	-	-	-	-	-	-	-	-	23.4%
LASSO	78.0% [76.9%, 79.0%]	88.6%	71.3%	91.2%	93.8%	98.3%	5.0%	9.2%	11.8%	21.6%	29.3%
LASSO+	78.3% [77.2%, 79.3%]	87.3%	65.8%	91.2%	94.2%	98.3%	3.4%	9.1%	11.9%	21.7%	27.1%
Ridge	82.1% [81.2%, 82.9%]	88.0%	67.9%	88.3%	96.3%	99.6%	1.6%	6.1%	8.1%	15.2%	27.1%
Mean	86.9% [86.1%, 87.7%]	84.4%	77.1%	88.3%	85.8%	86.5%	2.7%	3.7%	2.7%	2.5%	17.4%
Linear	83.6% [82.5%, 84.6%]	86.5%	80.8%	85.8%	87.1%	92.4%	10.1%	5.7%	4.4%	4.5%	7.6%
SVR	86.0% [85.2%, 86.8%]	88.5%	80.0%	90.4%	87.5%	96.2%	3.6%	3.9%	3.3%	4.4%	15.1%
RF	88.4% [87.7%, 89.1%]	79.8%	69.6%	78.7%	80.4%	90.7%	0.3%	1.6%	1.6%	2.1%	16.8%
NN	79.7% [78.4%, 80.8%]	91.2%	79.6%	90.0%	95.8%	99.6%	5.7%	9.0%	9.2%	16.8%	20.4%

Takeaways

1. Violations of independence need not be the most important factors when it comes to failures of EU under risk (and ambiguity).

2. Instead, the failures appear to be more basic – conditional on obeying GARP and FOSD, the majority of subjects also obey EU.

$\Rightarrow$ Light paternalism – even light paternalistic policies should only be put into play when welfare judgments tend to be relatively straight-forward (Loewenstein and Haisley, 2008).