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Tiomkin School of Economics
Advanced Microeconomics
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Confronting Theory with Experimental Data and vice versa
Risk and Time Preferences

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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:

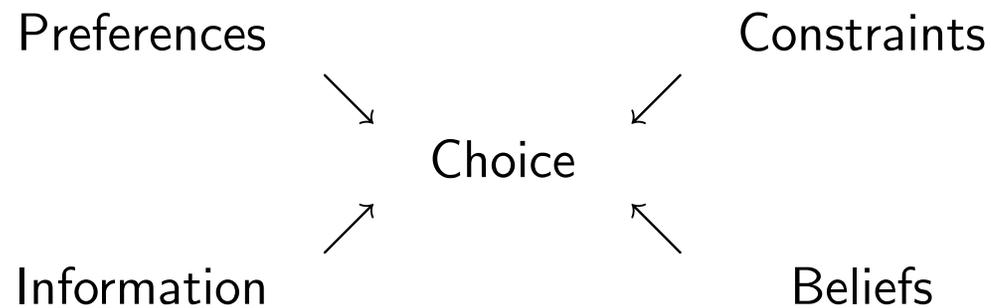
A. descriptive (how people actually choose)

B. prescriptive (as a practical aid to choice)

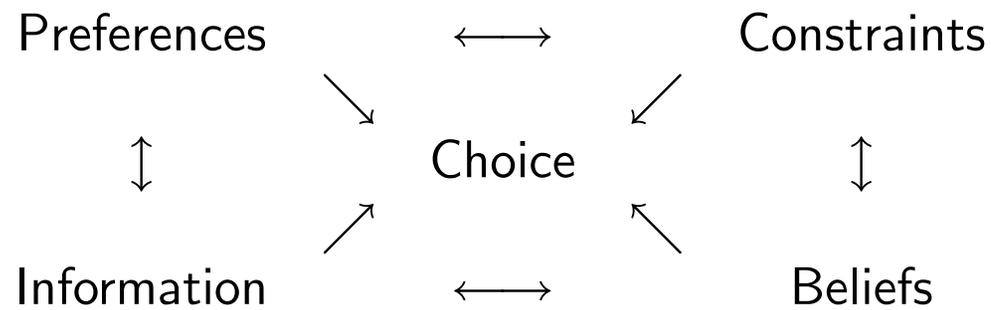
C. normative (how people ought to choose)

Decision making under certainty and uncertainty

The “standard” theory of the economic agent (consumer, manager, policy maker) is best understood as follows:



Behavioral economics incorporate more “realistic” assumptions about decision making based on findings in psychology and related fields:



The fundamental tradeoffs in life

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

risk	\iff	return
today	\iff	tomorrow
self	\iff	others

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?

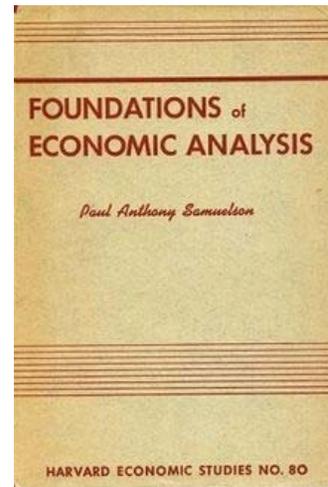
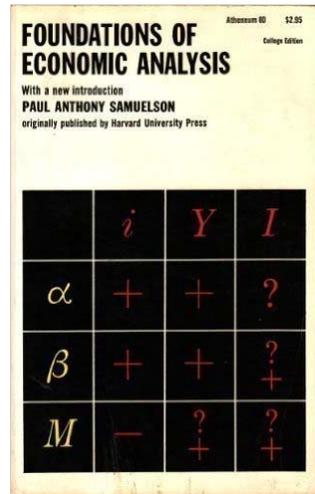
IV Linkages

- 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...).



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

if $x_1 \geq y_1$ and $x_2 \geq y_2$ 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.

Objectives

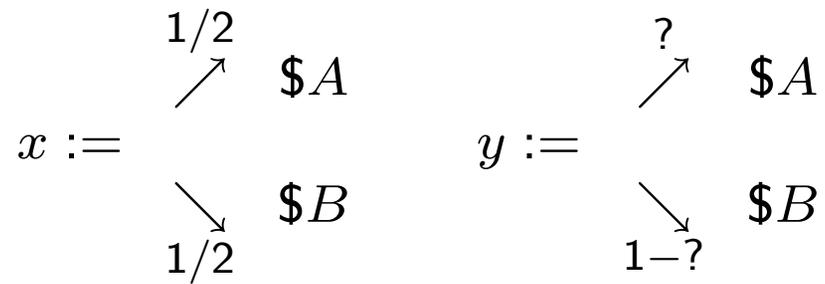
- Illustrate that agents (consumers and managers) frequently make decisions with uncertain consequences.
- Facing uncertain choices, maximizing the Expected Utility is how agents ought to choose.
- Individual behavior is often contrary to the assumptions of Expected Utility Theory.

Life is full of lotteries :-)

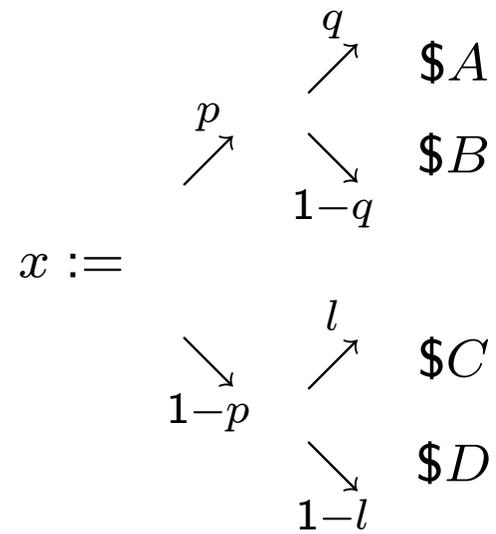
$$x := \begin{array}{l} \nearrow^p \quad \$A \\ \searrow \quad \$B \\ 1-p \end{array}$$

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

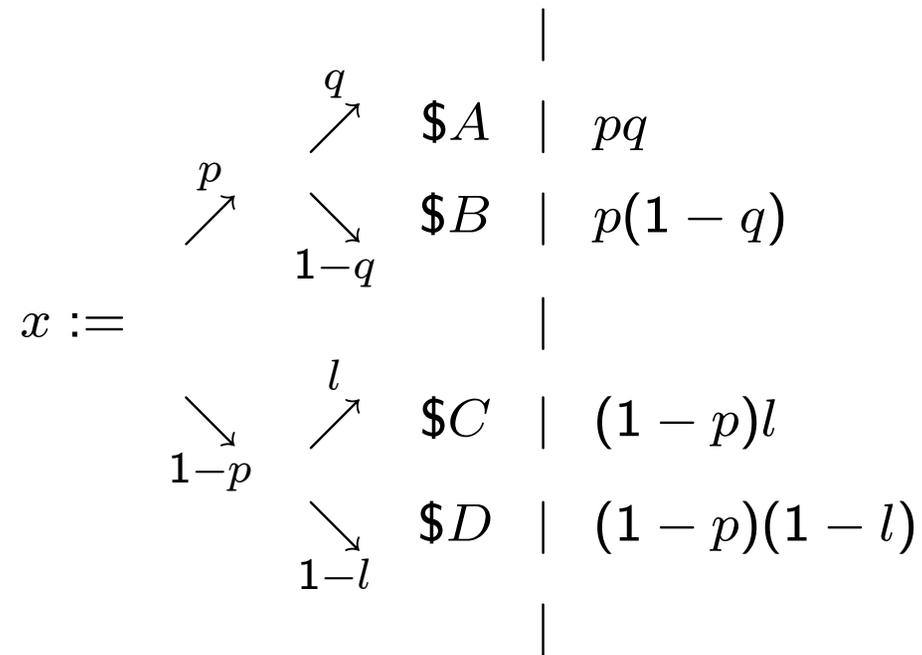
A risky lottery (left) and an ambiguous lottery (right)



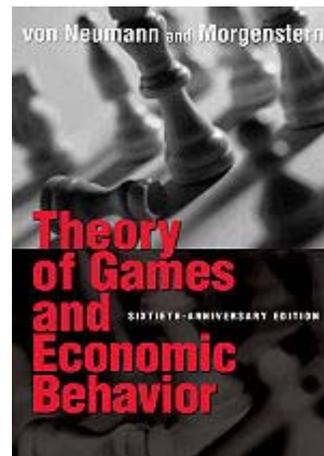
A compounded lottery

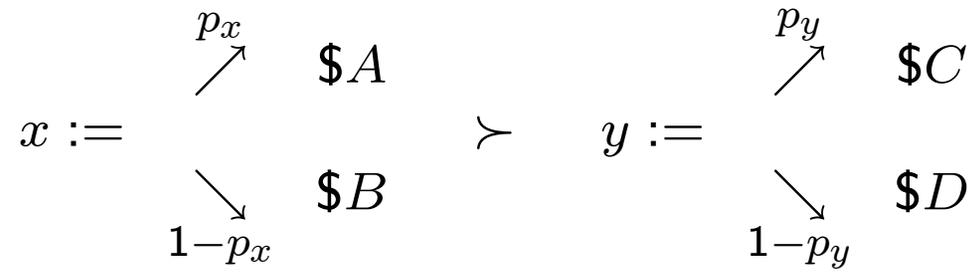


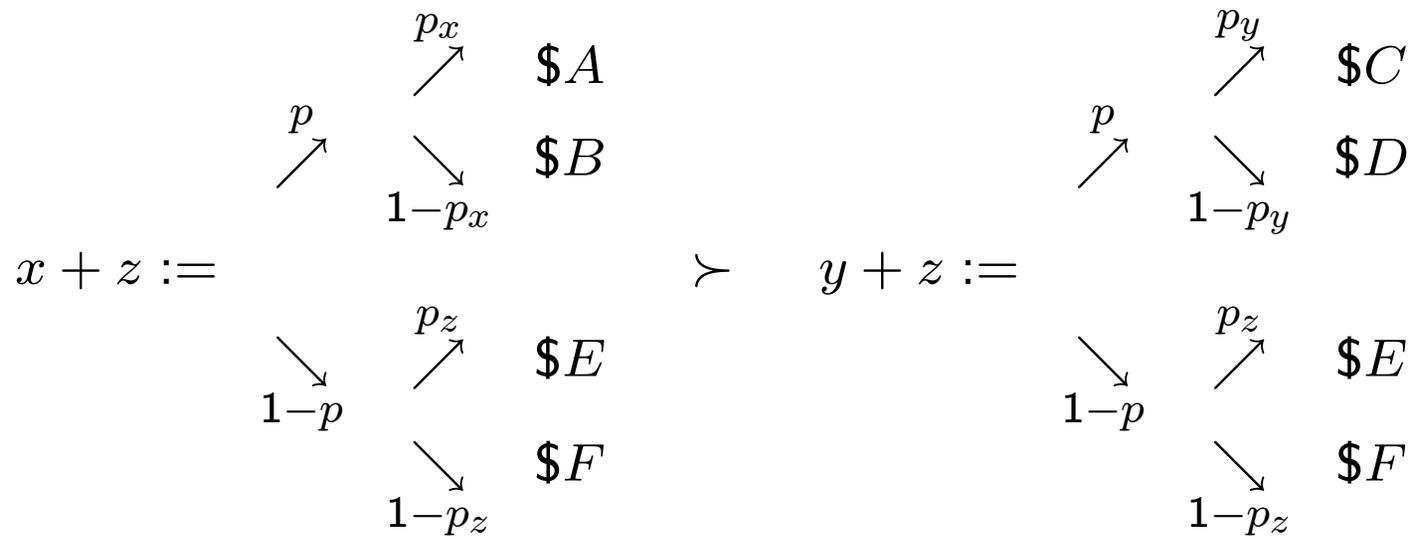
The reduction of a compounded lottery



The paternity of decision theory and game theory (1944)



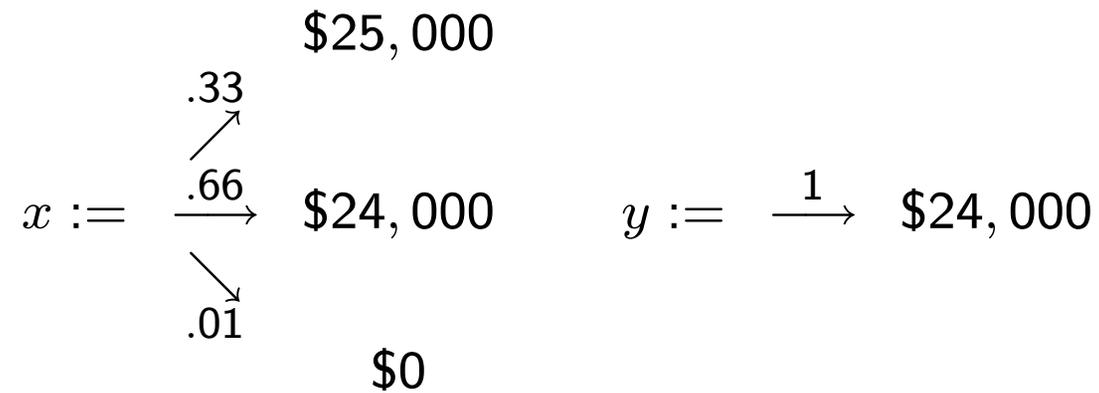




von Neumann and Morgenstern Expected Utility Theory (EUT)

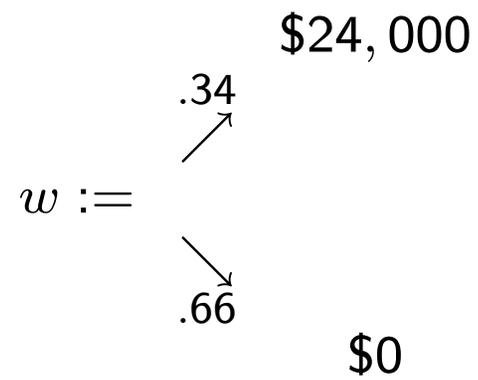
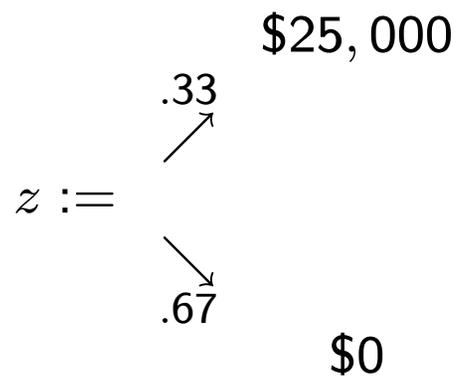
Allais (1953) I

– Choose between the two gambles:

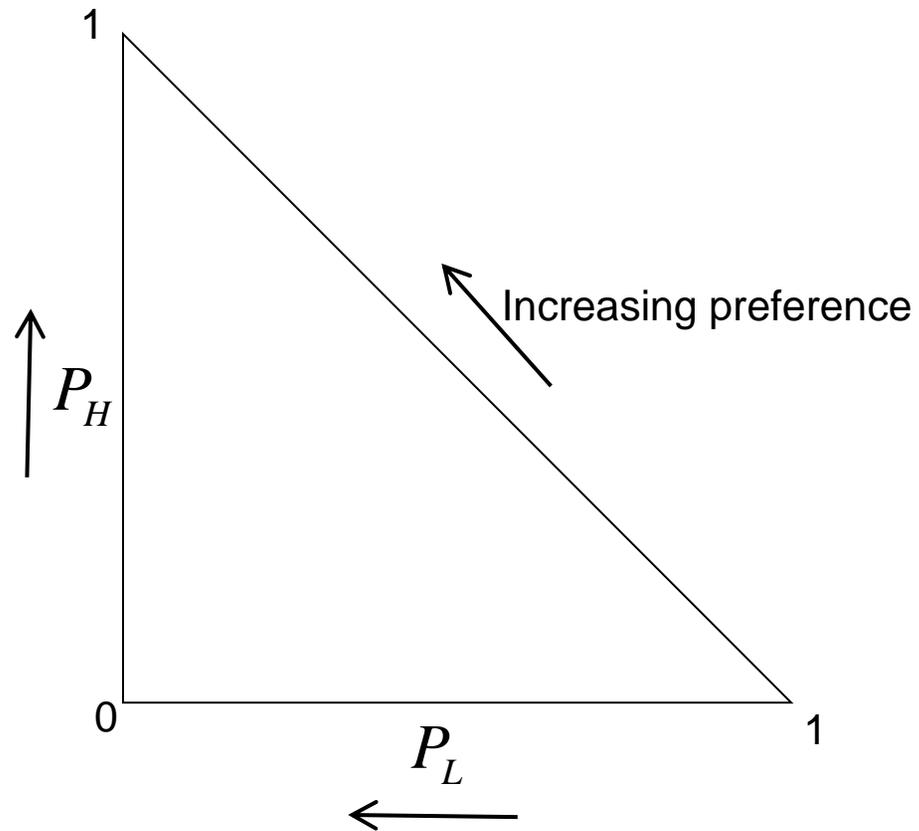


Allais (1953) II

– Choose between the two gambles:

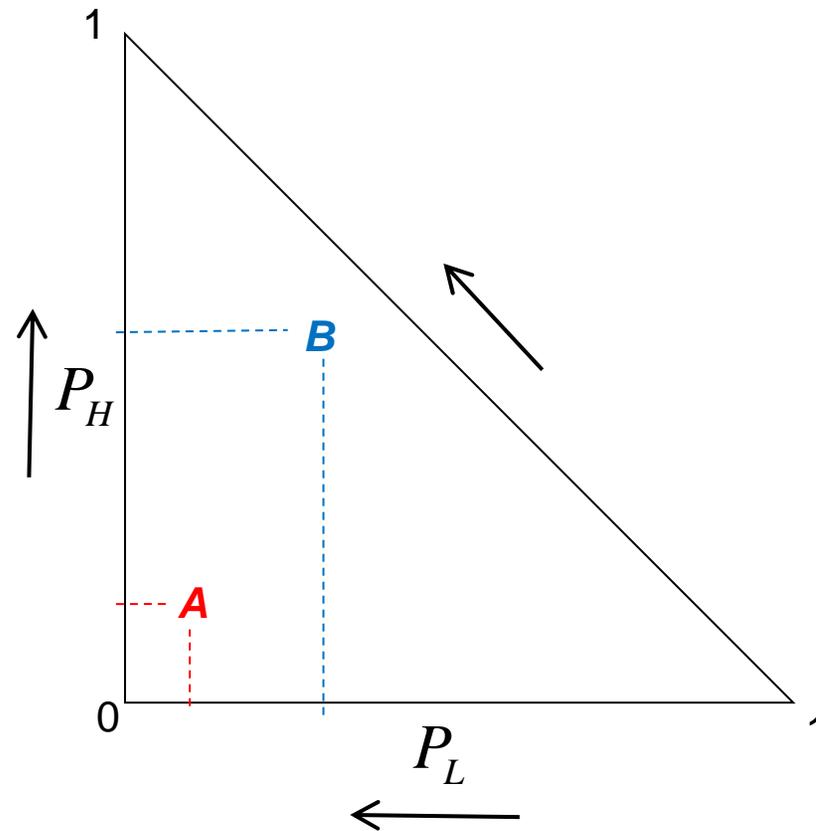


The (Marschak-Machina) probability triangle



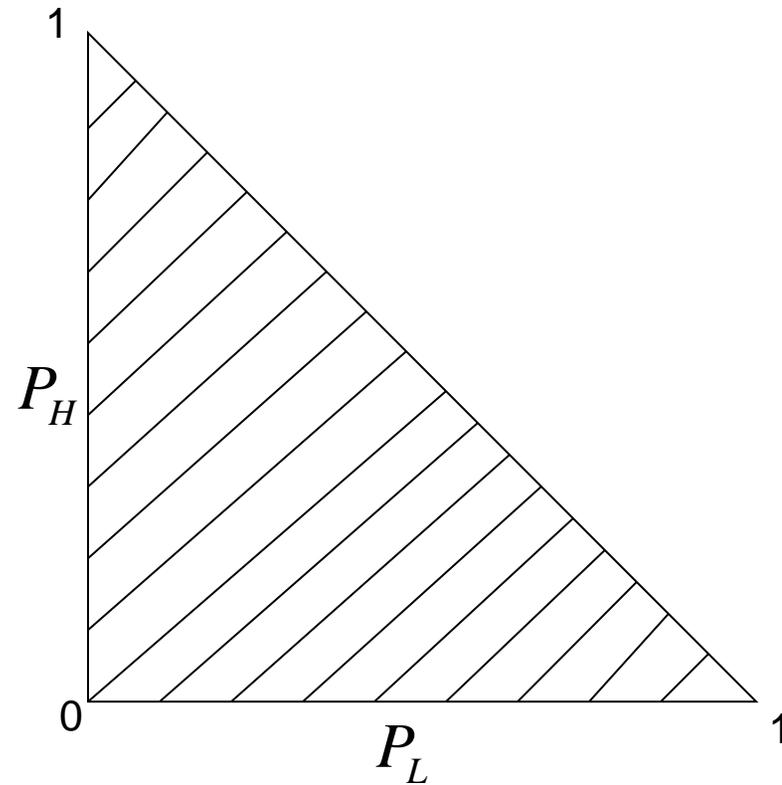
Consider three monetary payouts H , M , and L where $H > M > L$

Risk profiling



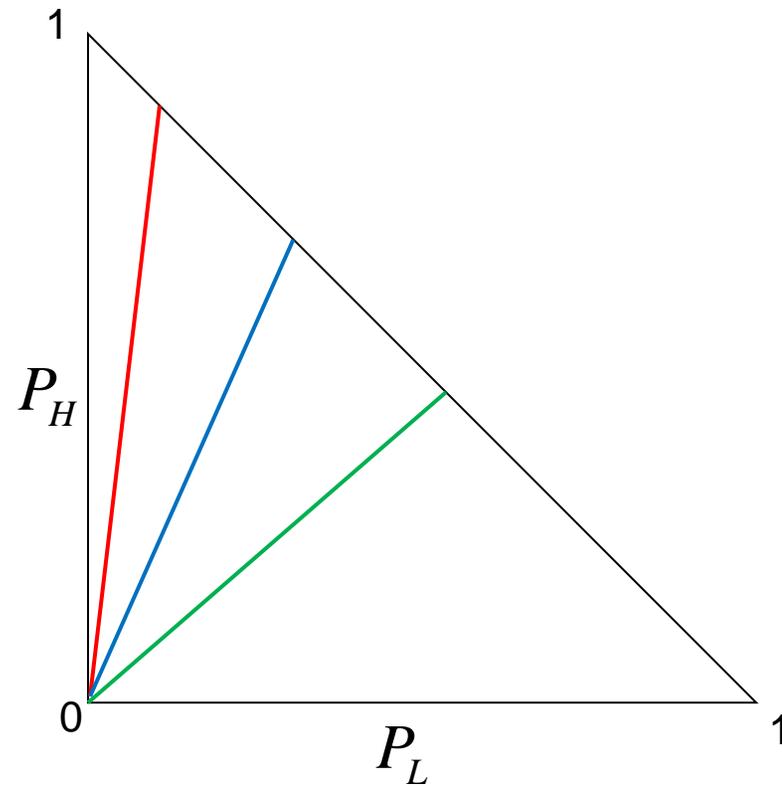
A “complete” risk profiling requires knowing all possible comparisons like between **A** and **B**.

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



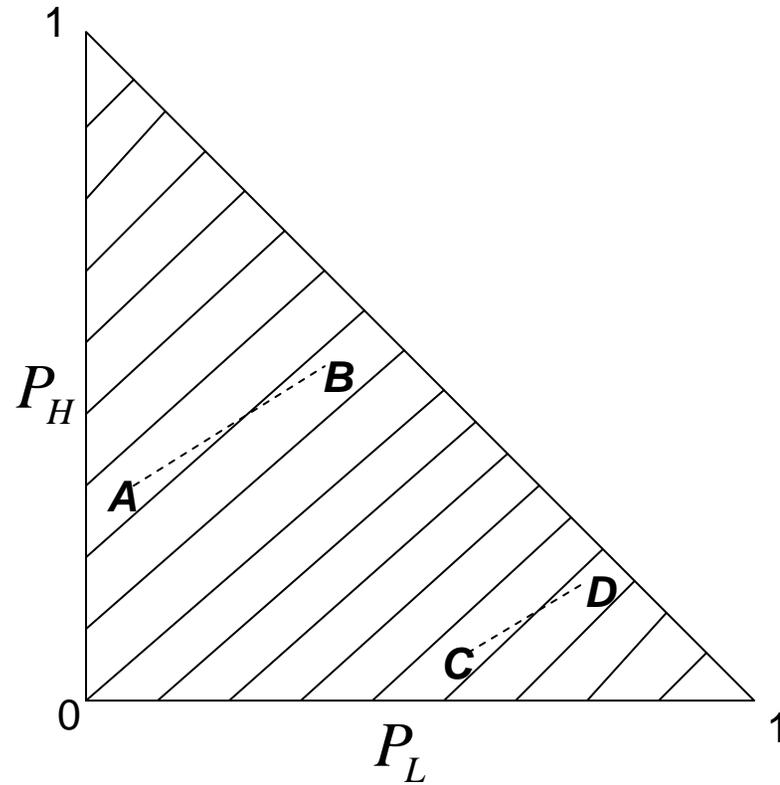
Expected Utility Theory (EUT) requires that indifference lines are parallel

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 betweenness, and approximate EU maximization inside the triangle...*

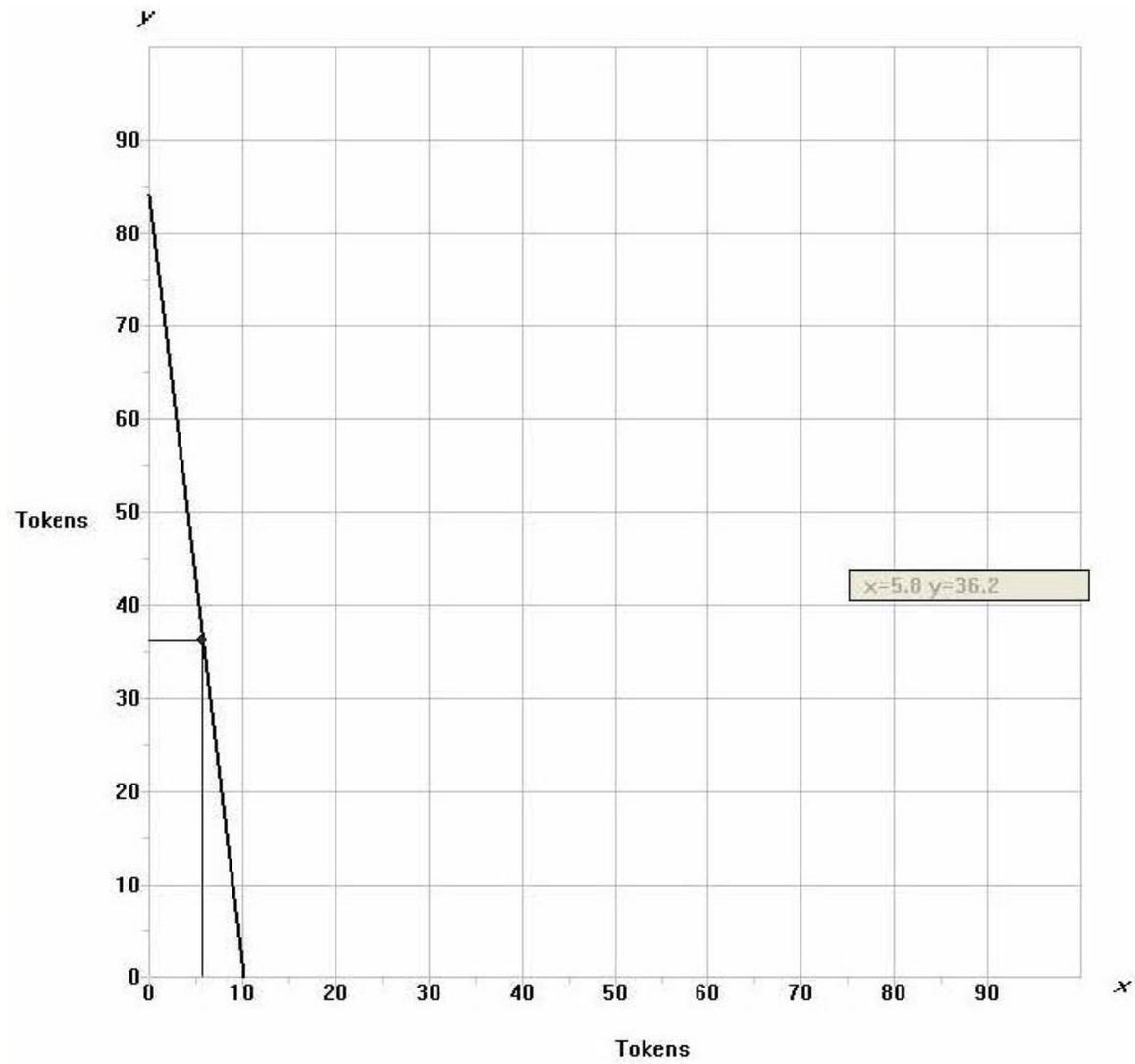
A not-so-new experimental design

An experimental design that has a couple of innovations:

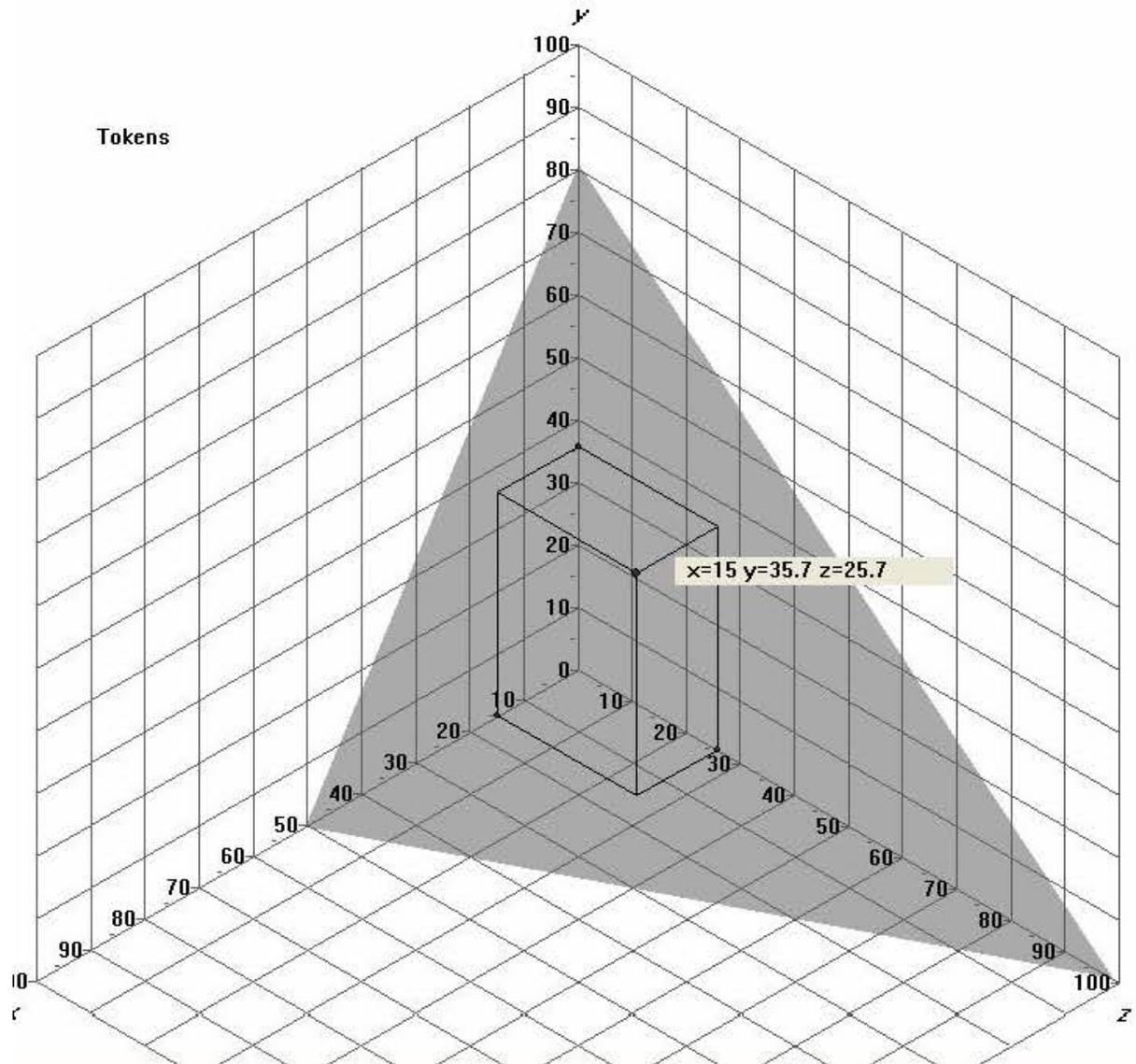
- A selection of a bundle of contingent commodities from a budget set (a portfolio choice problem).
- A large menu of decision problems that are representative, in the statistical sense and in the economic sense.
- A graphical experimental interface that allows for the collection of a rich individual-level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

⇒ 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

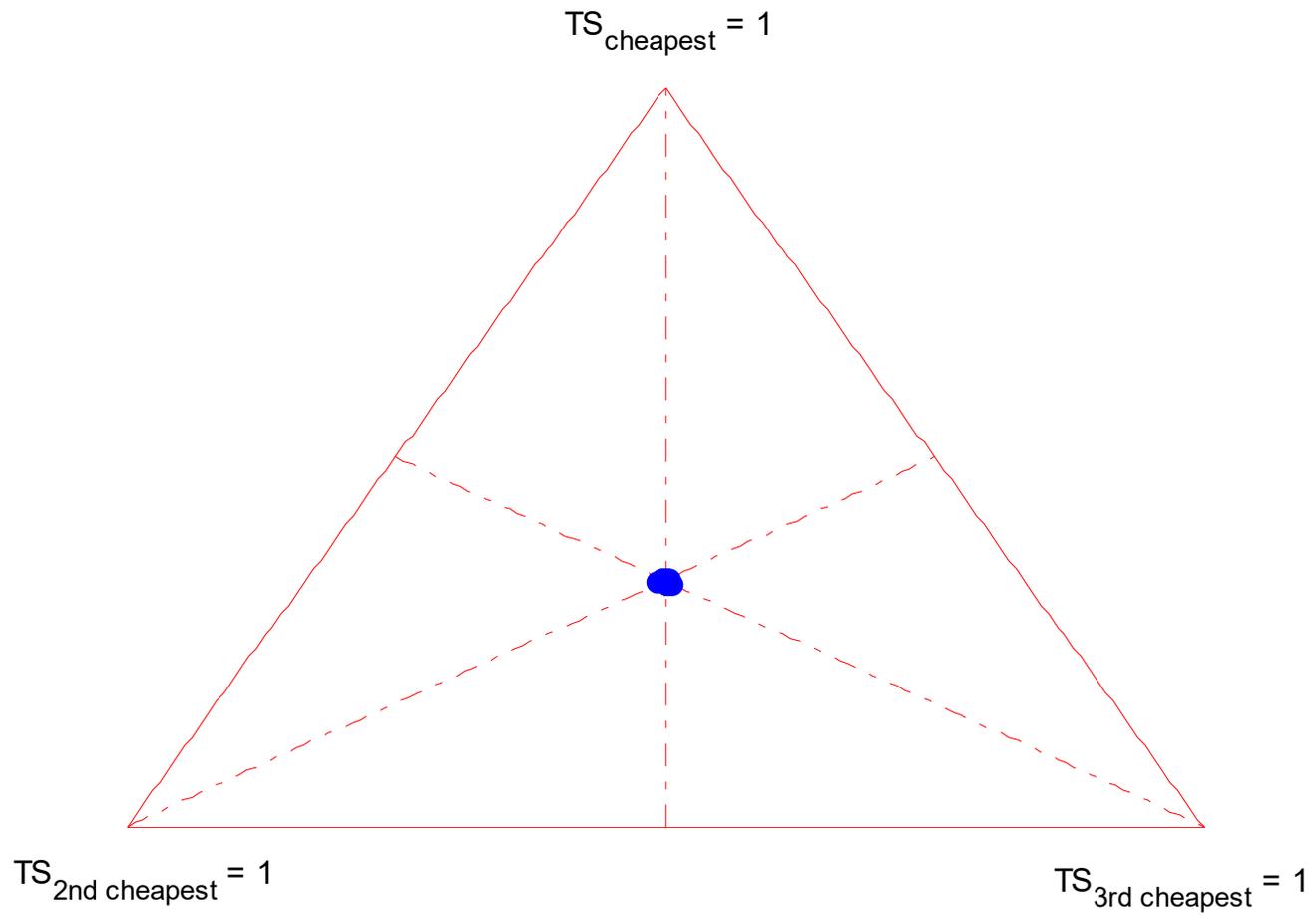


3D experimental interface

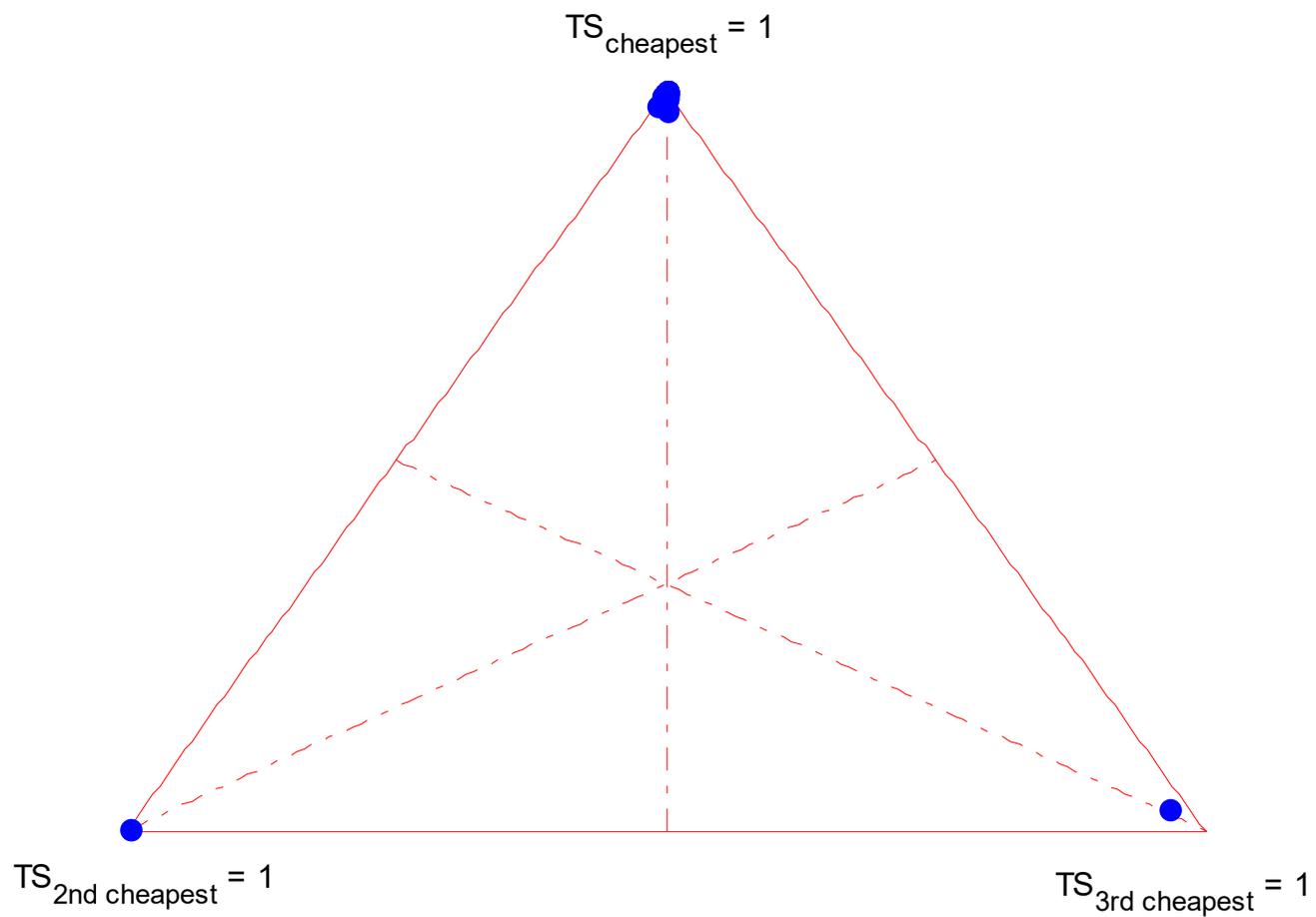


Individual behaviors

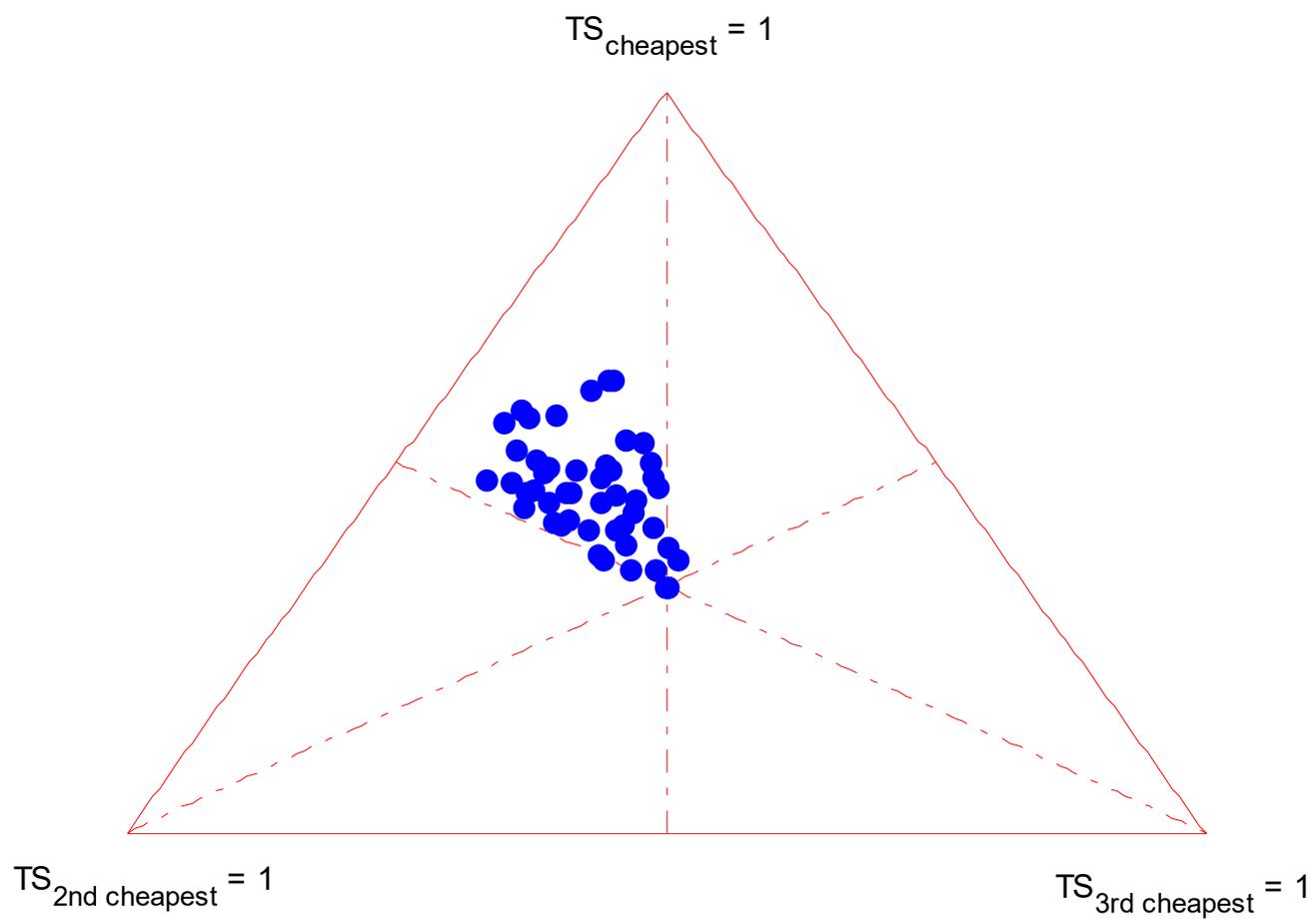
Token Shares for Subject ID 35



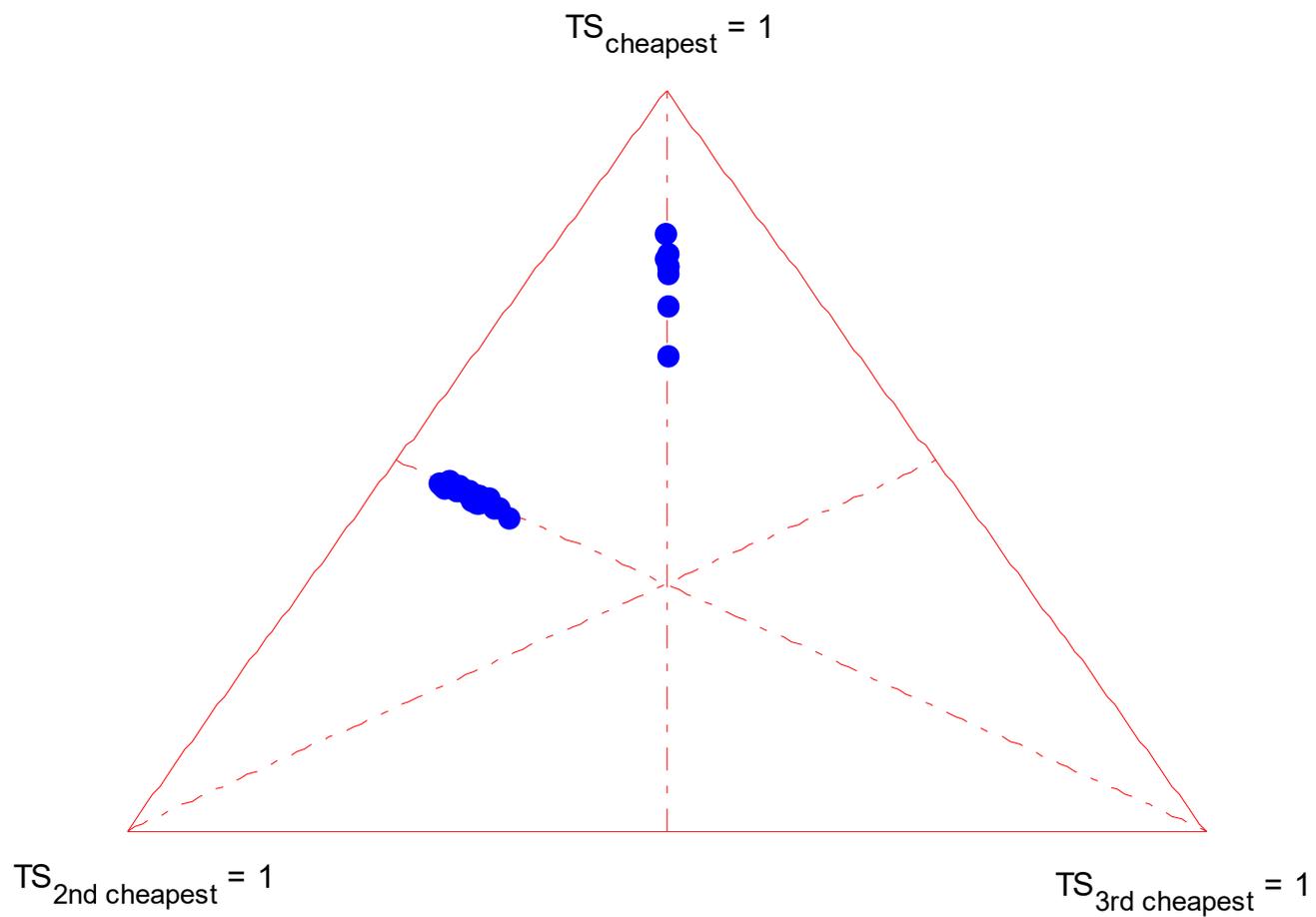
Token Shares for Subject ID 13



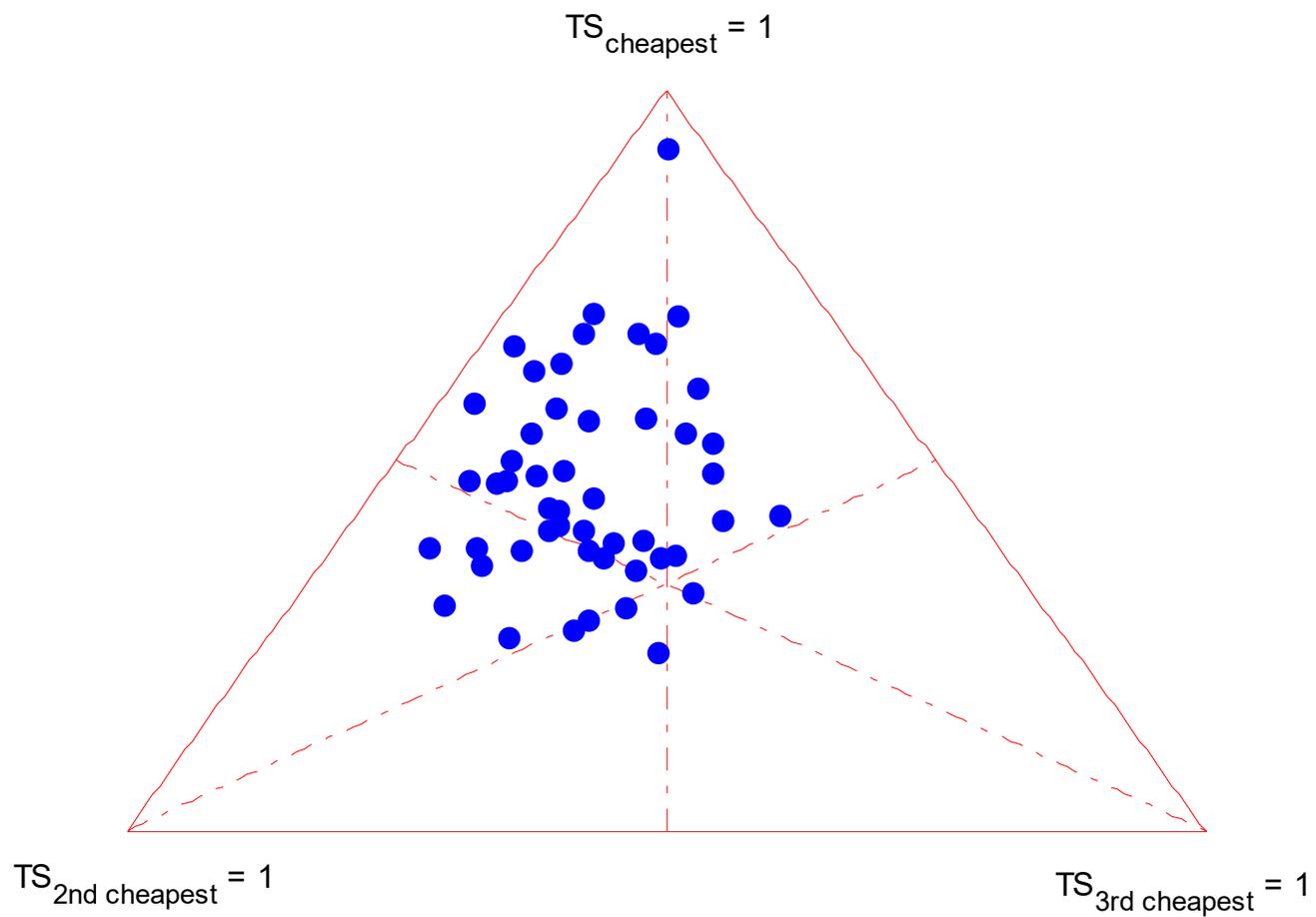
Token Shares for Subject ID 25



Token Shares for Subject ID 27



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).

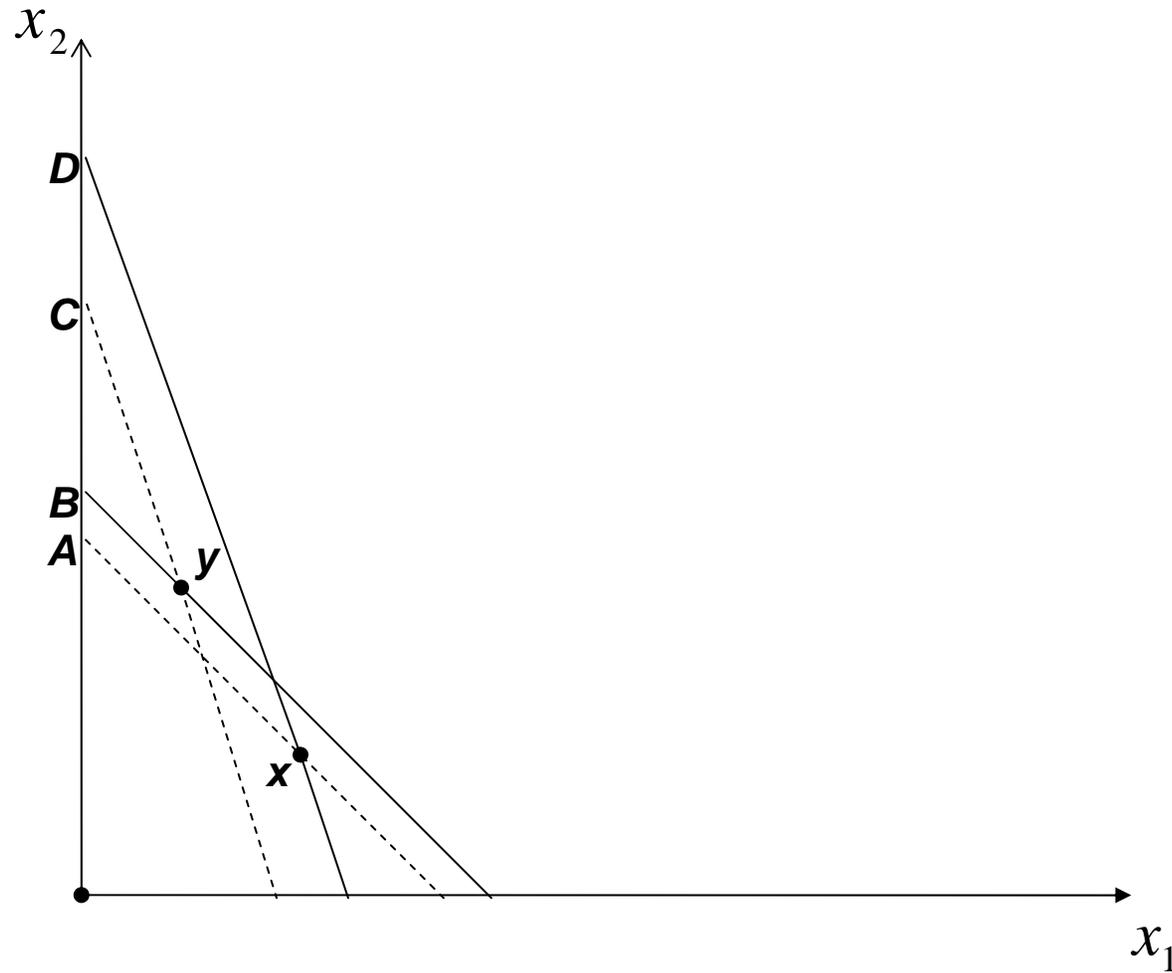
Afriat's Theorem *The following conditions are equivalent:*

- *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.*

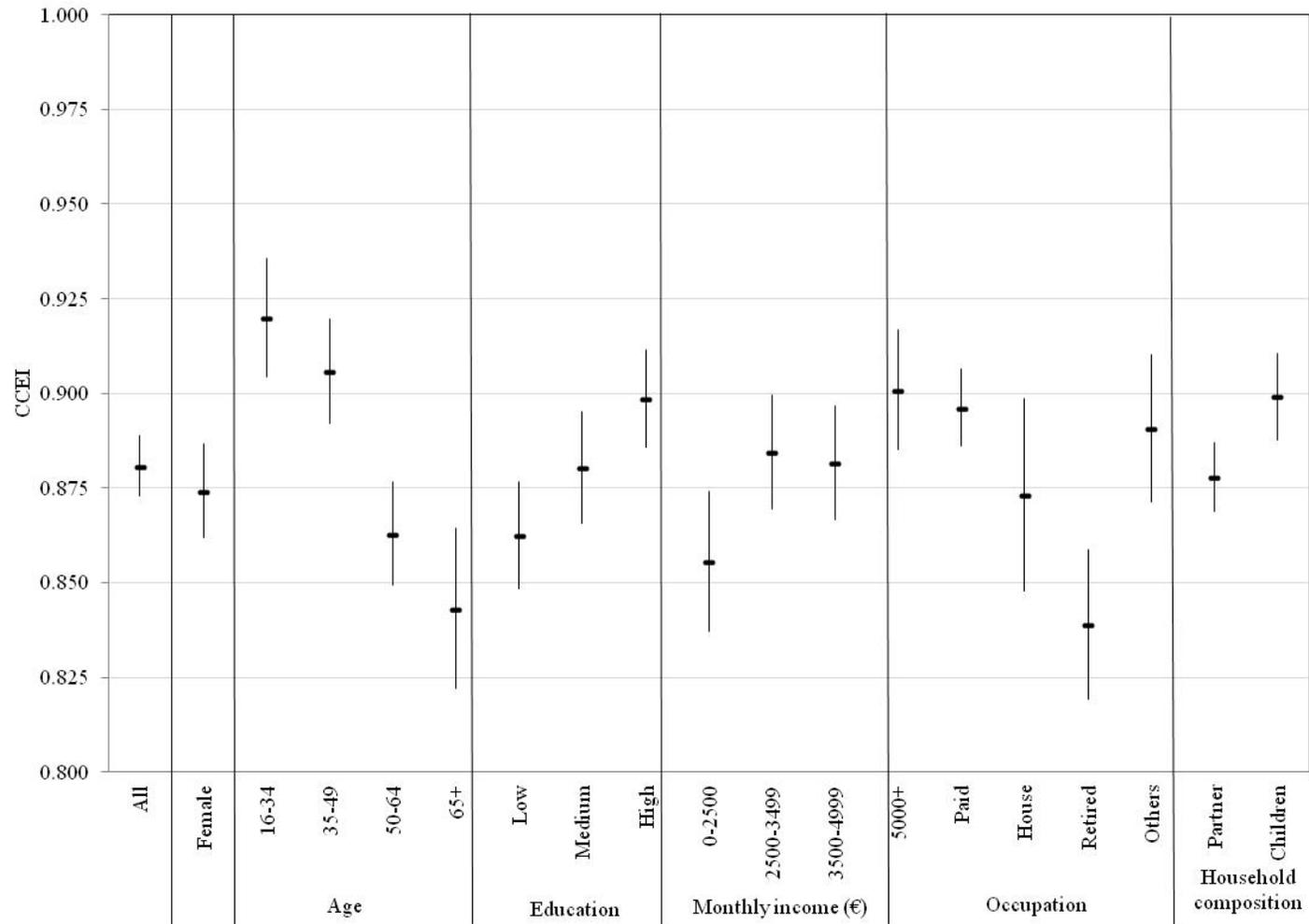
The CCEI is bounded between zero and one. The closer it is to one, the smaller the perturbation required to remove all violations and thus the closer the data are to satisfying GARP.

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.

Homo Economicus: equiprobable lotteries



Wealth differentials

- ⇒ The heterogeneity in wealth is not well-explained either by standard observables (income, education, family structure) or by standard unobservables (intertemporal substitution, risk tolerance).
- ⇒ 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** (0.566)	1.109** (0.534)	101888.0* (52691.9)
Log 2008 household income	0.584*** (0.132)	0.606*** (0.126)	
2008 household income			1.776*** (0.4)
Female	-0.313* (0.177)	-0.356** (0.164)	-32484.3* (17523.9)
Partnered	0.652*** (0.181)	0.595*** (0.171)	46201.9*** (17173.7)
# of children	0.090 (0.093)	0.109 (0.086)	14078.6* (8351.5)
Age	Y	Y	Y
Education	Y	Y	Y
Occupation	Y	Y	Y
Constant	6.292 (6.419)	0.469 (3.598)	76214.4 (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** (0.570)	1.318** (0.574)	1.925*** (0.672)	1.888*** (0.652)	1.441** (0.578)
Log household income					
2008	19.770 (14.629)	1.000 .	0.544*** (0.137)	0.285* (0.165)	0.616*** (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 (0.181)	-0.201 (0.173)	-0.337* (0.185)	-0.296 (0.186)	-0.321* (0.176)
Partnered	0.598*** (0.181)	0.561*** (0.178)	0.734*** (0.192)	0.707*** (0.193)	0.641*** (0.179)
# of children	0.091 (0.092)	0.101 (0.096)	0.018 (0.099)	0.031 (0.095)	0.088 (0.093)
Age	Y	Y	Y	Y	Y
Education	Y	Y	Y	Y	N
Occupation	Y	Y	Y	Y	Y
Constant	-47.059 (46.275)	0.864 (6.545)	5.354 (6.93)	3.016 (7.109)	6.398 (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** (0.568)	1.396** (0.568)	1.404** (0.569)	1.214* (0.625)	1.237** (0.623)
Risk tolerance					
Quantitative (experiment)	-0.768 (0.714)	-0.808 (0.711)	-0.766 (0.718)		
Qualitative (survey)		0.017 (0.074)	0.023 (0.076)		
Qualitative (survey) missing		-0.190 (0.335)	-0.162 (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*** (0.132)	0.578*** (0.131)	0.572*** (0.133)	0.443*** (0.123)	0.434*** (0.123)
Female	-0.316* (0.177)	-0.310* (0.181)	-0.323* (0.181)	-0.415** (0.186)	-0.417** (0.186)
Partnered	0.655*** (0.181)	0.658*** (0.181)	0.642*** (0.182)	0.686*** (0.204)	0.687*** (0.205)
# of children	0.086 (0.093)	0.087 (0.093)	0.083 (0.093)	0.075 (0.102)	0.083 (0.102)
Age	Y	Y	Y	Y	Y
Education	Y	Y	Y	Y	Y
Occupation	Y	Y	Y	Y	Y
Constant	6.840 (6.361)	6.883 (6.357)	6.496 (6.395)	3.777 (15.258)	4.411 (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* (0.712)	1.401* (0.729)	1.269* (0.729)	1.177** (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*** (0.132)	0.388* (0.155)	0.383* (0.154)	0.577*** (0.132)
Female	-0.314* (0.177)	-0.218 (0.212)	-0.207 (0.211)	-0.292* (0.176)
Partnered	0.653*** (0.181)	0.907*** (0.230)	0.926*** (0.228)	0.690*** (0.181)
# of children	0.089 (0.093)	0.105 (0.114)	0.096 (0.113)	0.091 (0.092)
Age	Y	Y	Y	Y
Education	Y	Y	Y	Y
Occupation	Y	Y	Y	Y
Constant	6.237 (6.424)	10.056 (6.976)	8.355 (6.990)	6.855 (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 (0.032)	-0.098* (0.057)	-0.047 (0.053)	-0.162* (0.097)
Log 2008 household income	0.001 (0.002)	-0.029** (0.013)	0.003 (0.010)	-0.068*** (0.021)
Female	0.007 (0.005)	0.023 (0.020)	0.014 (0.019)	0.038 (0.033)
Partnered	-0.005 (0.004)	-0.031 (0.020)	0.017 (0.022)	-0.054 (0.033)
# of children	0.000 (0.001)	-0.004 (0.010)	-0.025* (0.014)	-0.043*** (0.013)
Age	Y	Y	Y	Y
Education	Y	Y	Y	Y
Occupation	Y	Y	Y	Y
Constant	0.998*** (0.172)	0.106 (0.822)	1.126 (0.848)	1.448 (1.288)
R^2	-0.007	0.021	-0.011	0.083
# of obs.	512	512	502	502

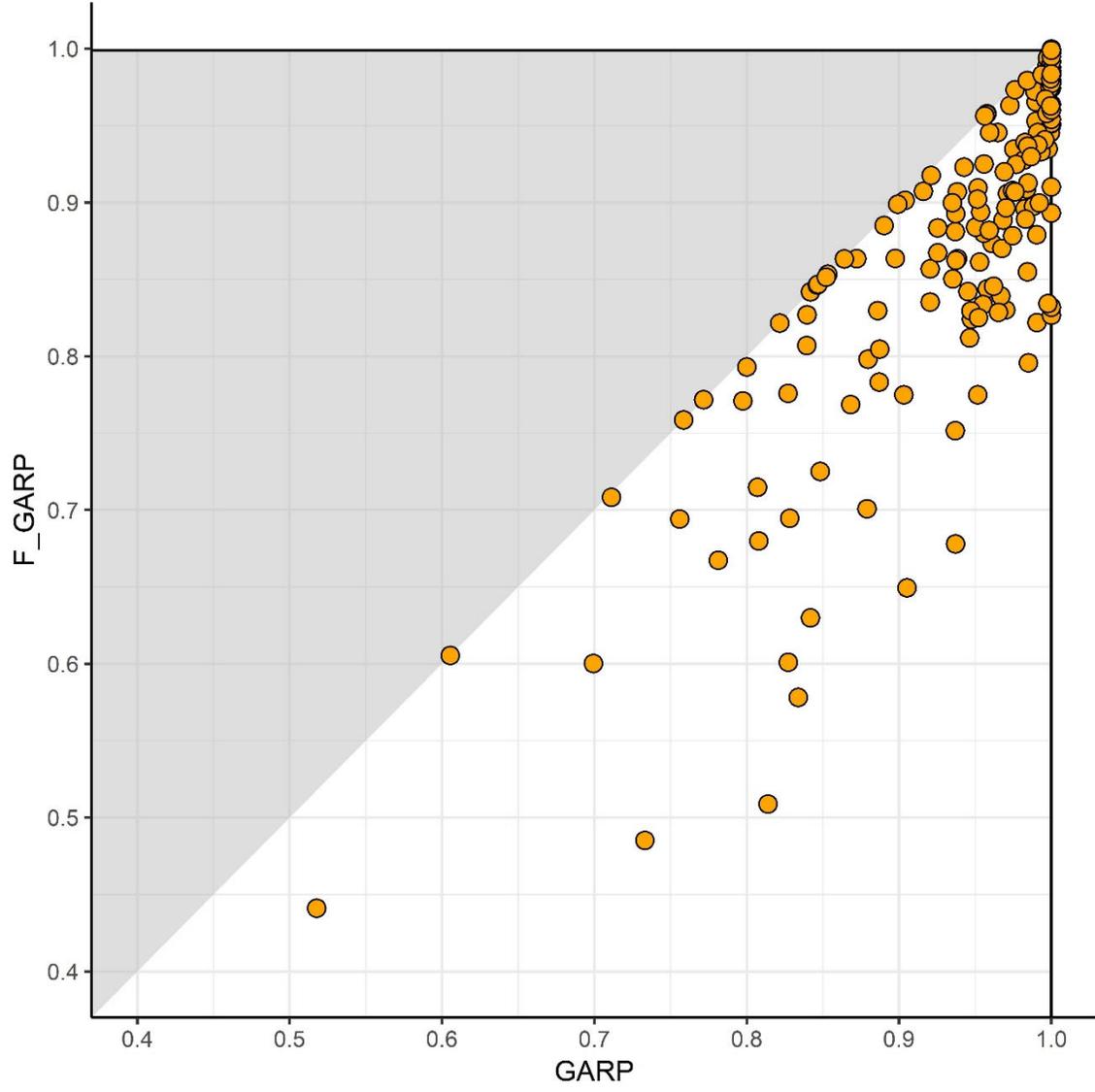
The sources of the relationship (cont.)

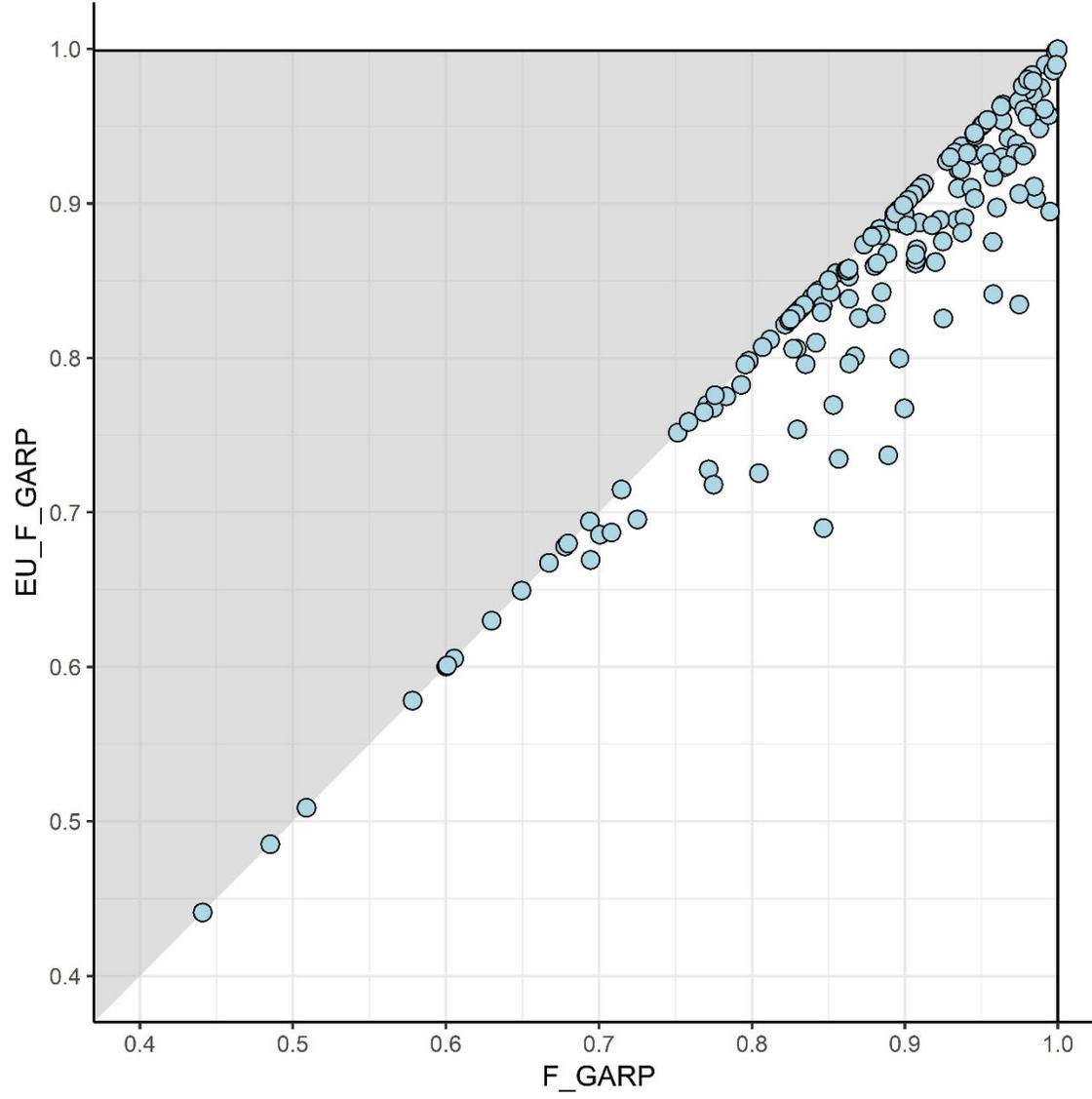
	(5)	(6)	(7)	(8)
	Have stocks	Fraction in stocks	Have a house	Fraction in house
CCEI	0.167 (0.163)	0.001 (0.050)	0.352** (0.152)	0.324** (0.129)
Log 2008 household income	0.148*** (0.031)	0.013 (0.009)	0.134*** (0.029)	0.096*** (0.024)
Female	0.007 (0.050)	0.009 (0.013)	-0.038 (0.050)	-0.066 (0.043)
Partnered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

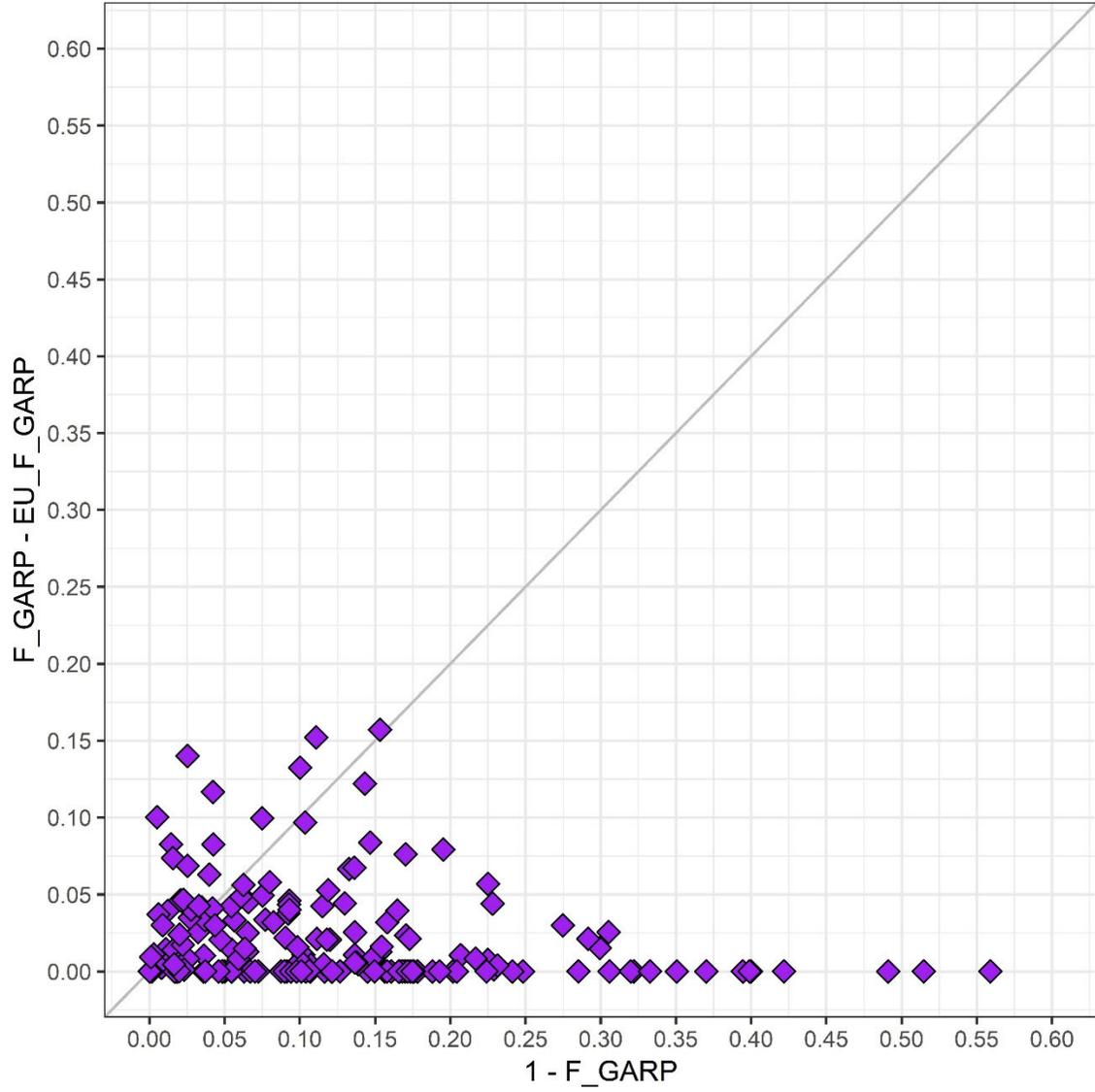
A comprehensive nonparametric test

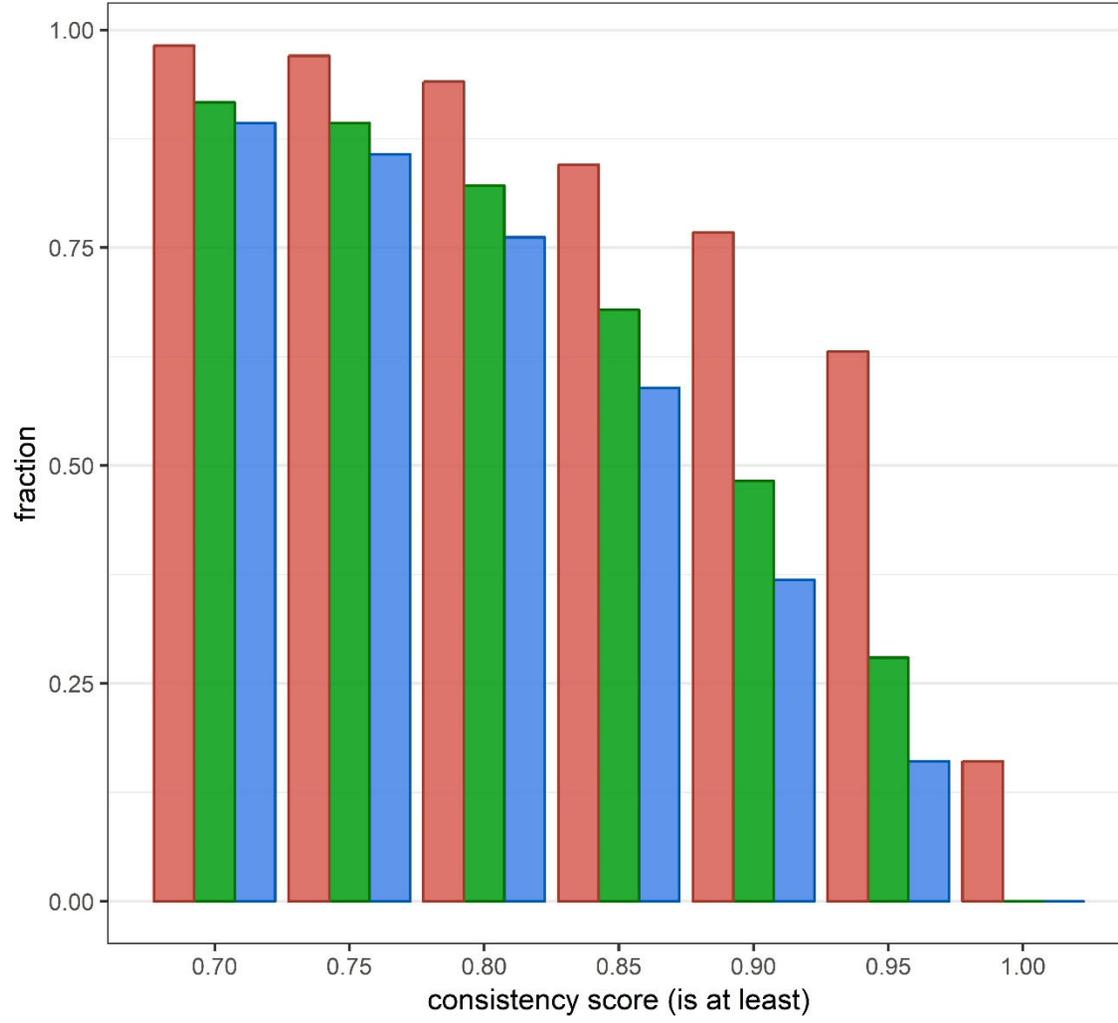
Test complete representations of preferences rather than focusing on individual axiom(s) (comprehensive) and make no auxiliary functional form assumptions (nonparametric):

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









model GARP F_GARP EU_F_GARP

Ambiguity aversion

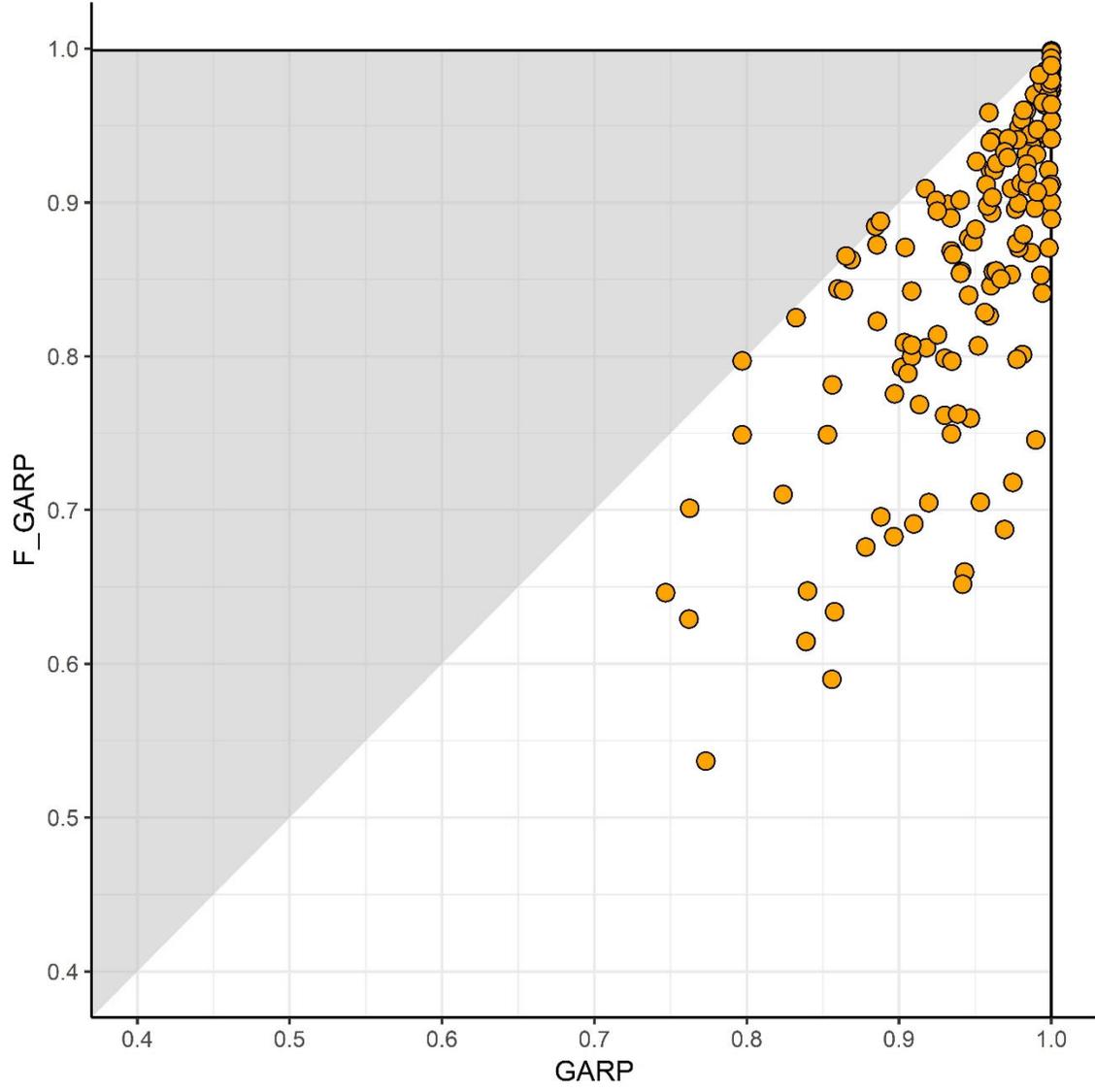
Ambiguity aversion

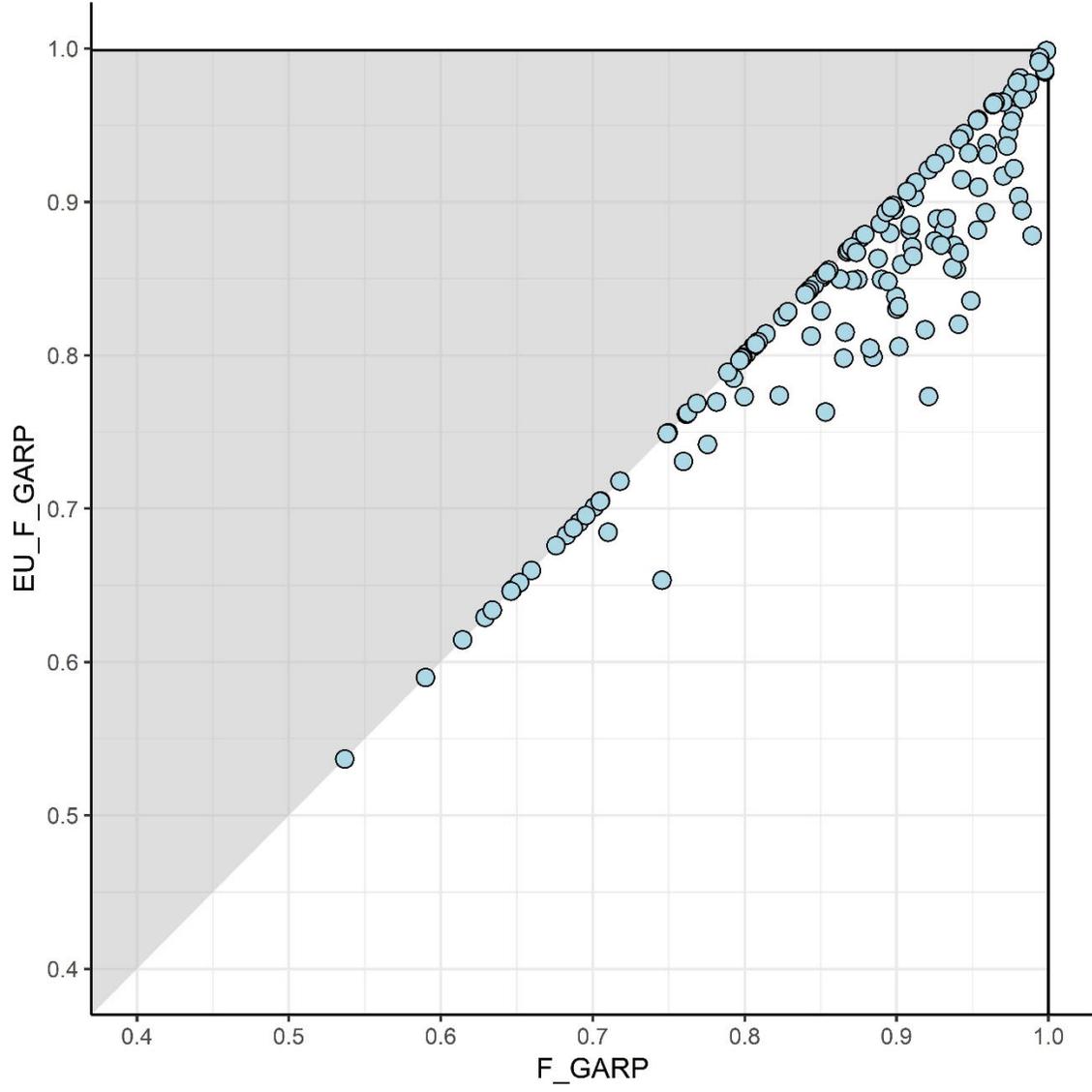
- The distinction between settings with risk and ambiguity dates back to at least the work of Knight (1921).
- Ellsberg (1961) countered the reduction of subjective uncertainty to risk with several thought experiments.
- A large theoretical literature (axioms over preferences) has developed models to accommodate this behavior.

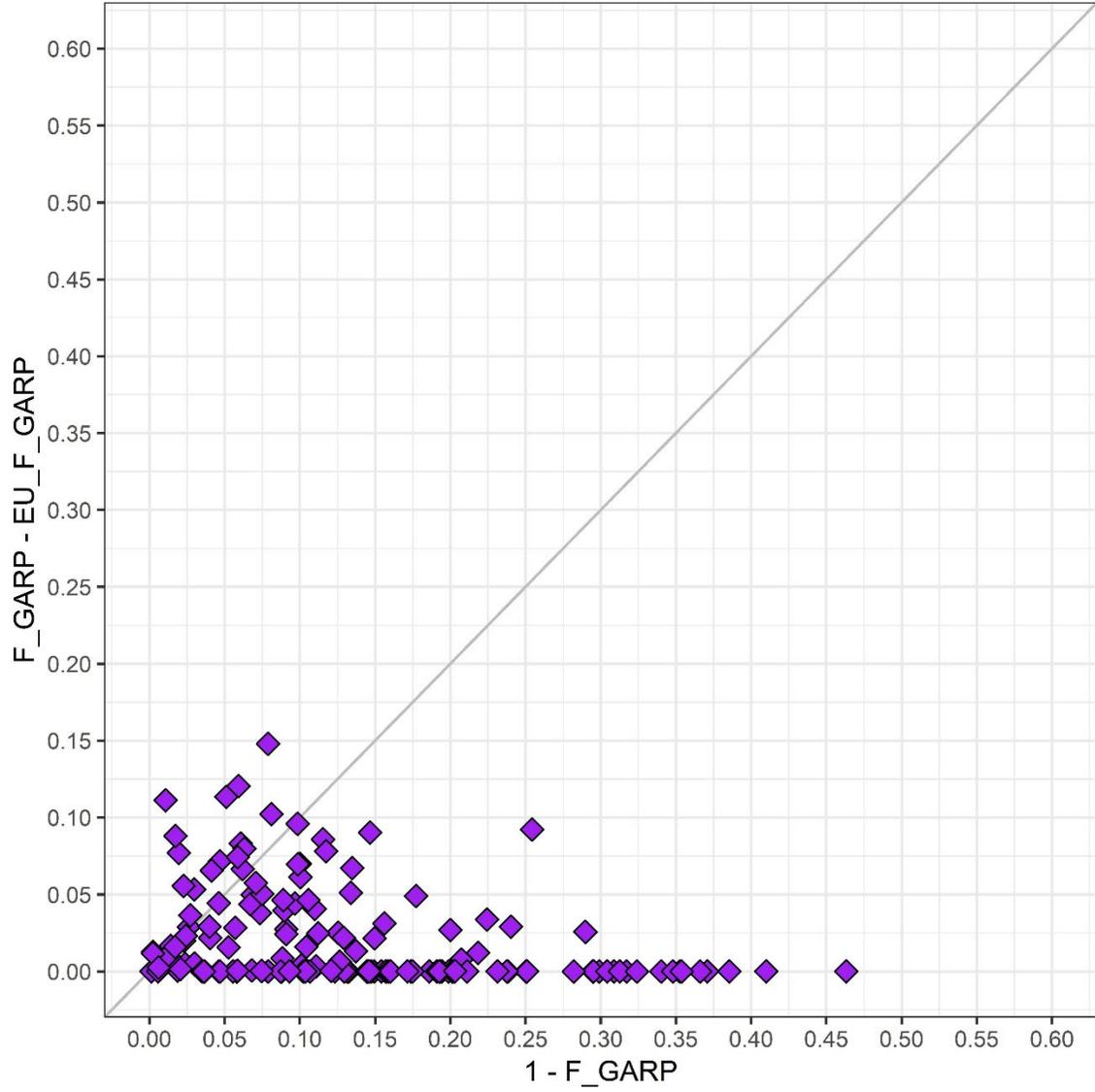
Experiments à la Ellsberg

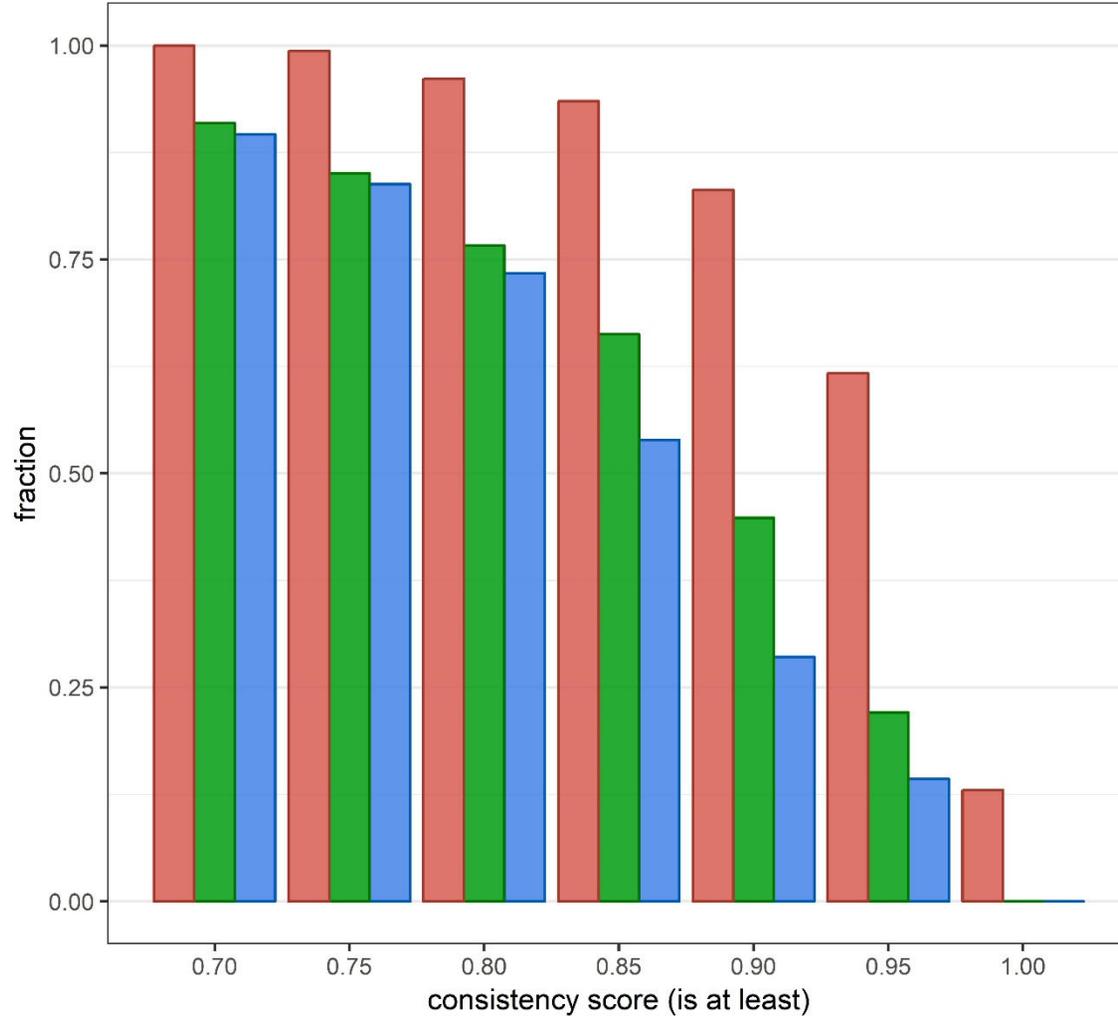
Consider the following four two-color Ellsberg-type urns (Halevy, 2007):

- 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





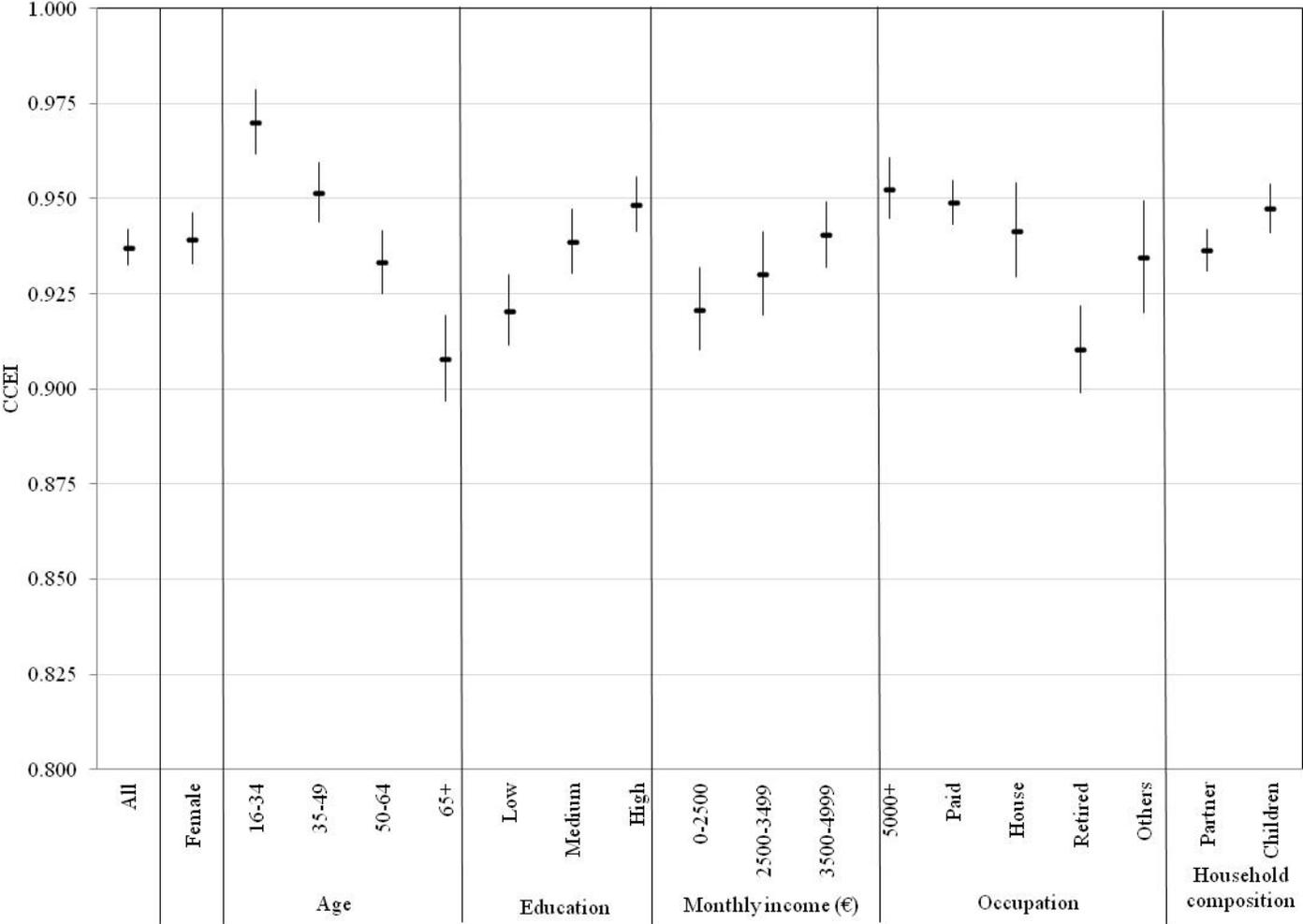




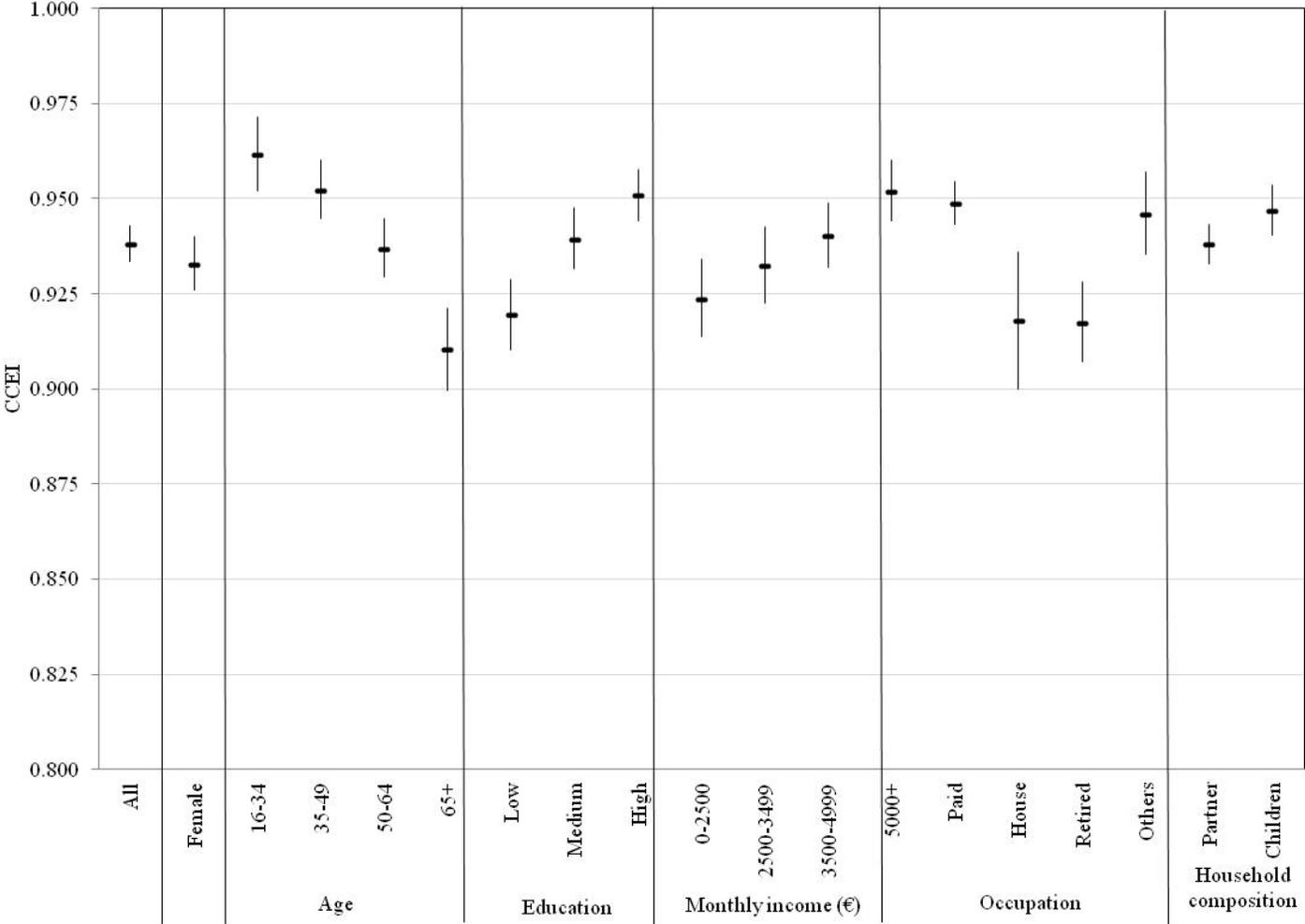
model GARP F_GARP EU_F_GARP

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 $\Delta_1, \Delta_2 \geq 0$

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

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 $\Delta_1, \Delta_2 \geq 0$

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

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

Time consistency

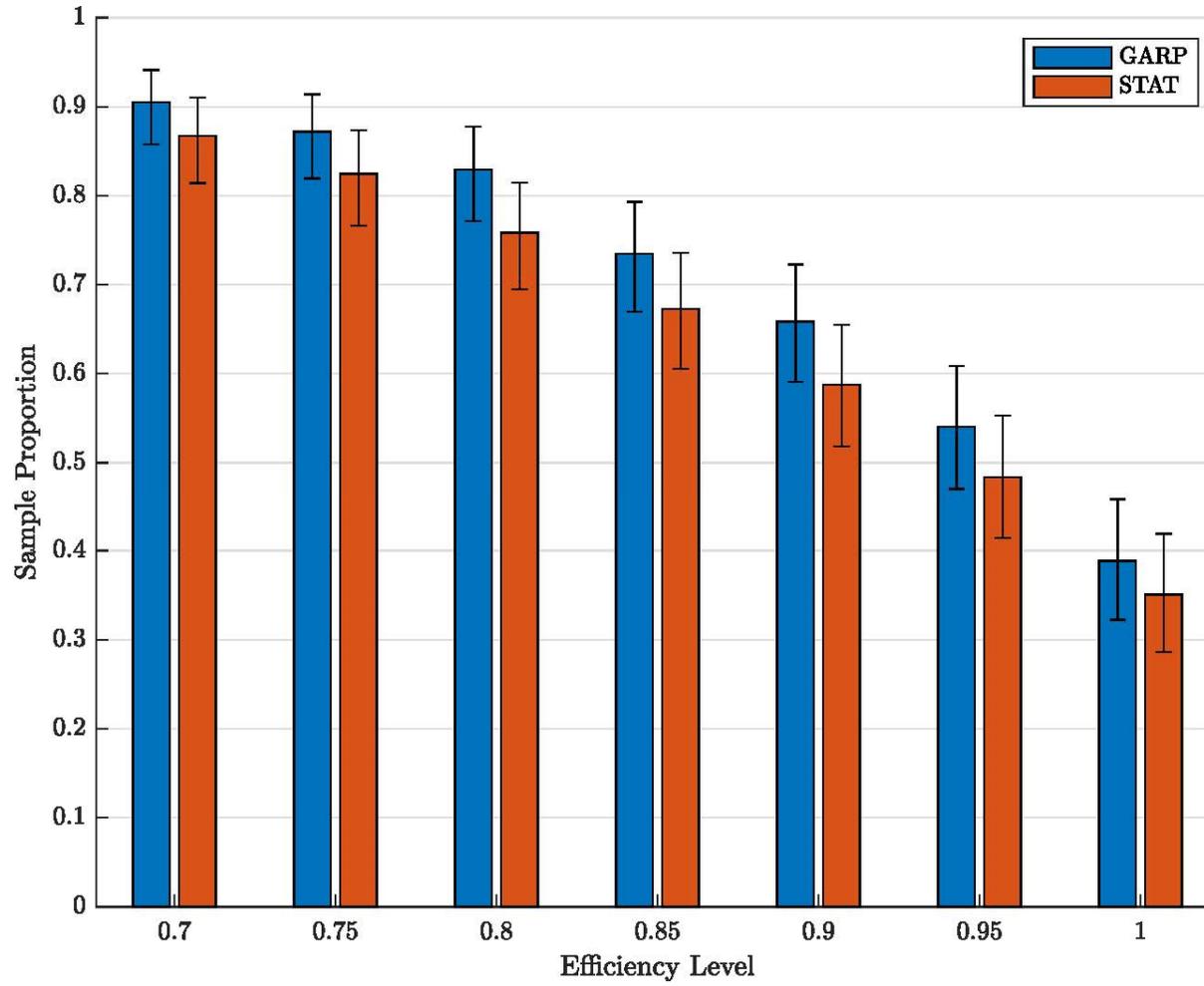
$\{\succsim_t\}_{t=1}^T$ is time-consistent if for every $t, t' \geq 0$ and $\Delta_1, \Delta_2 \geq 0$

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

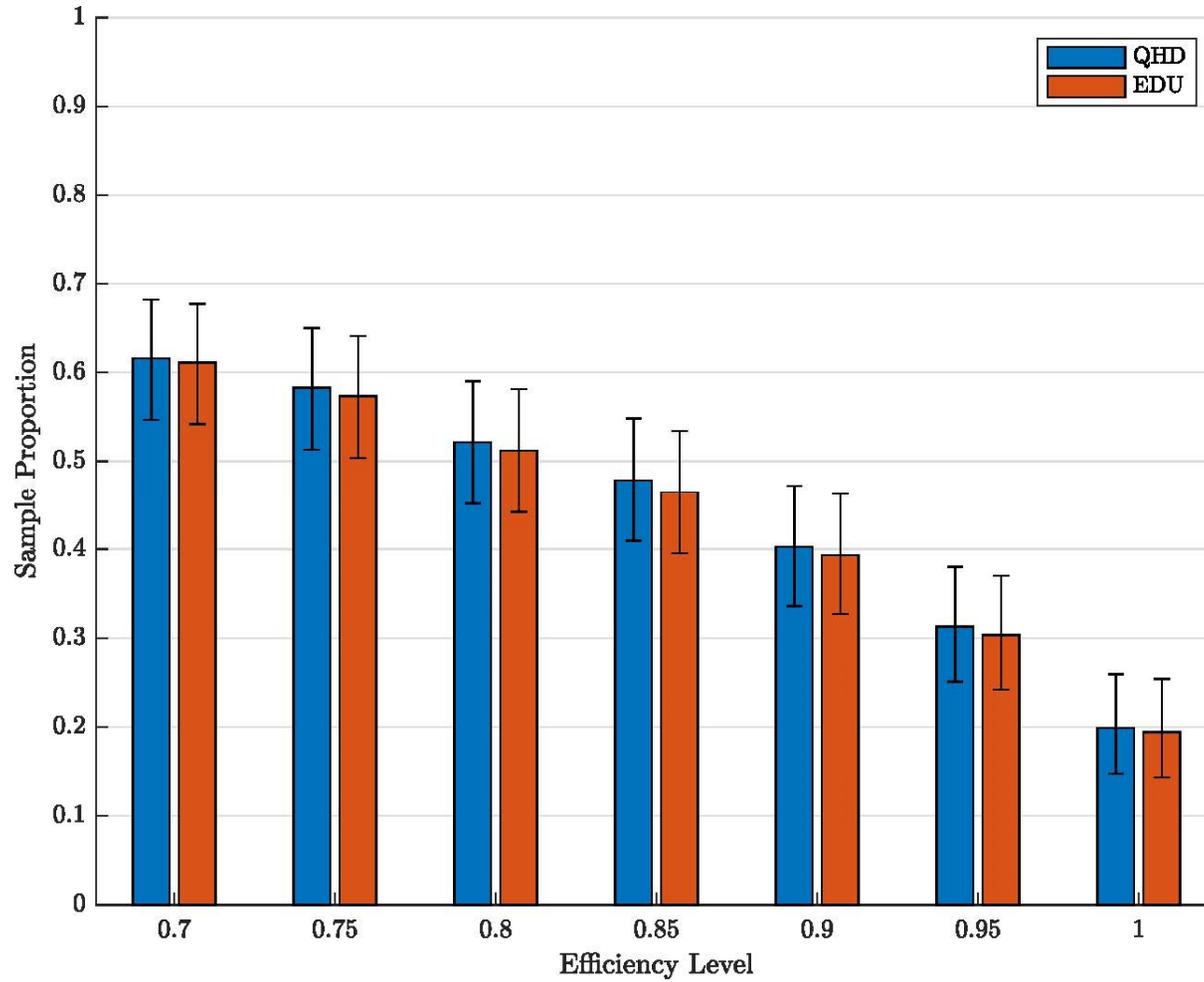
Ranking does not change as the evaluation perspective changes from t to t' . Time consistency precludes dynamic preference reversals.

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

Stationarity



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.

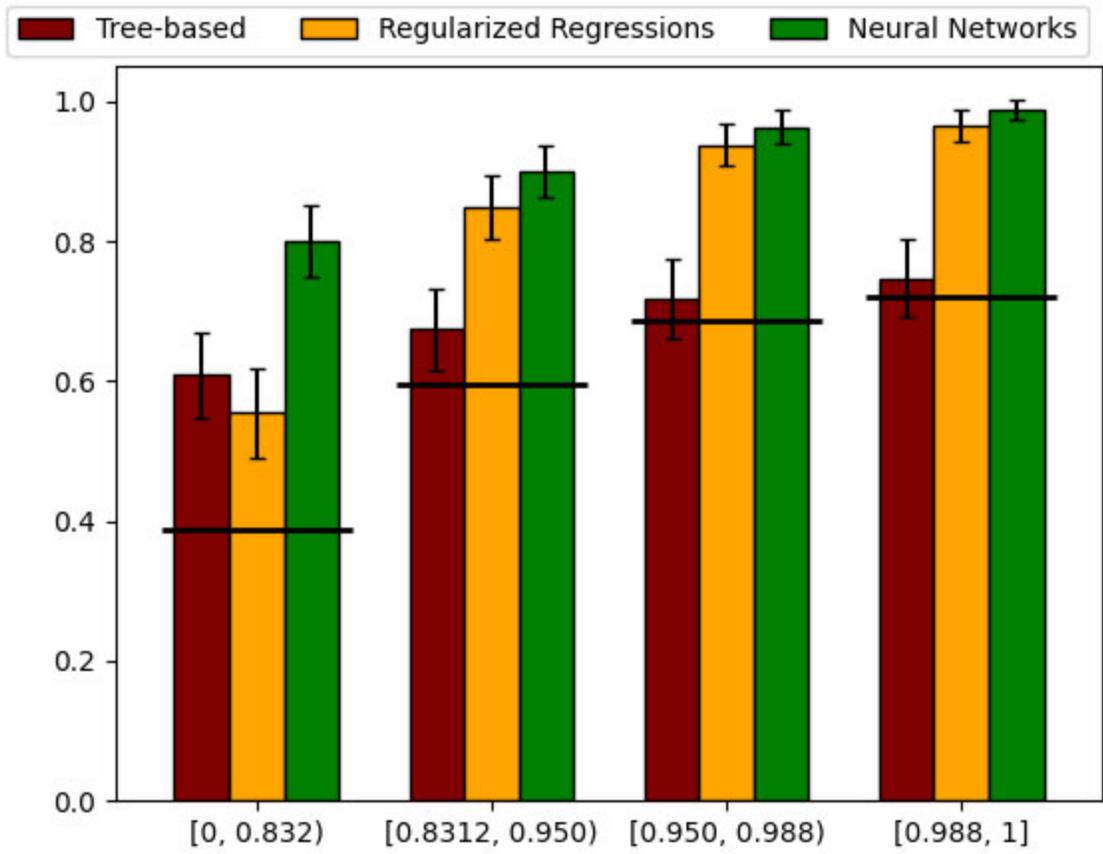
⇒ The entire promise of machine learning rests on the assumption (promise?) that it is better than the classical theory-driven approach for extrapolation...

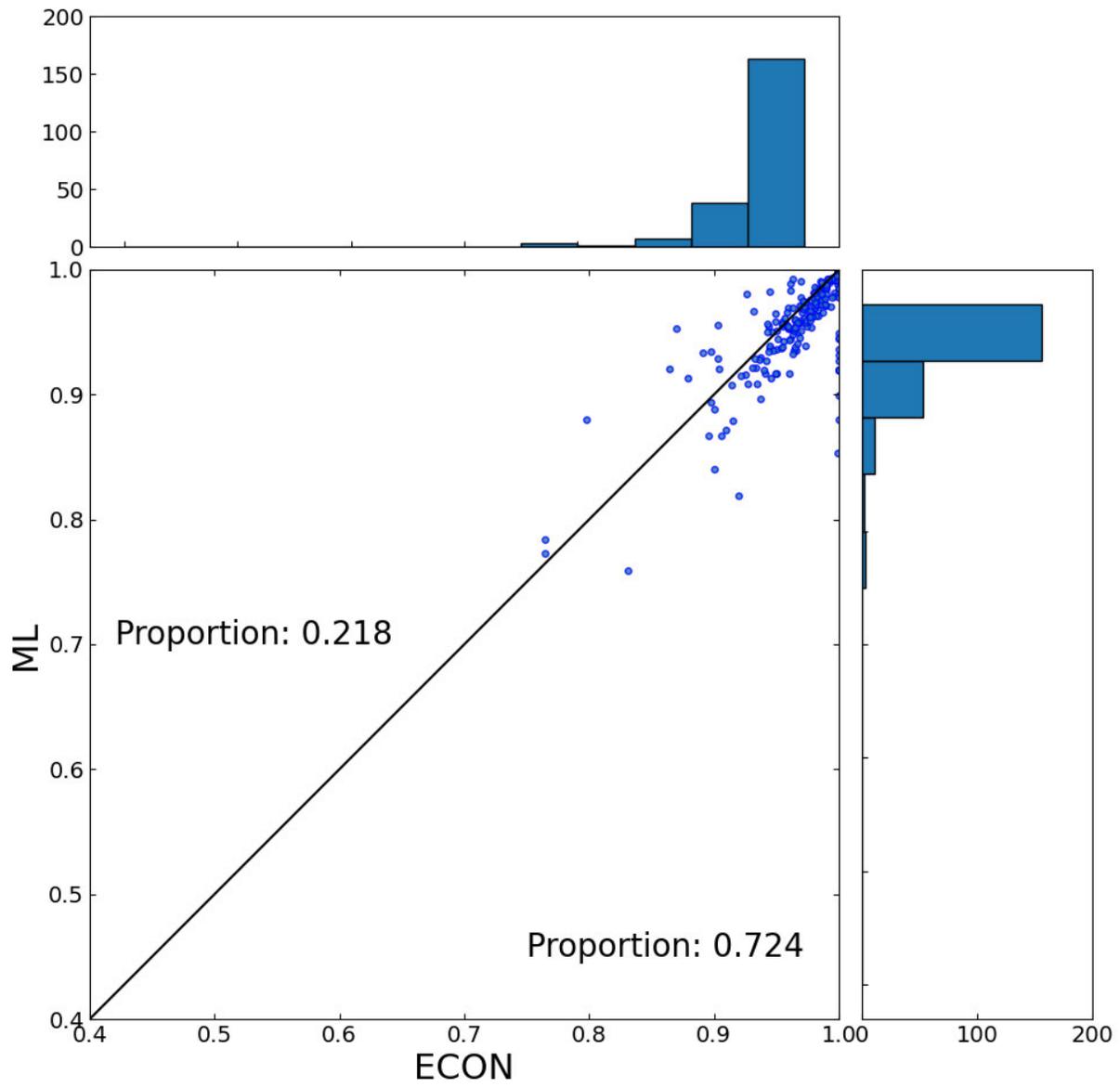
Completeness and restrictiveness

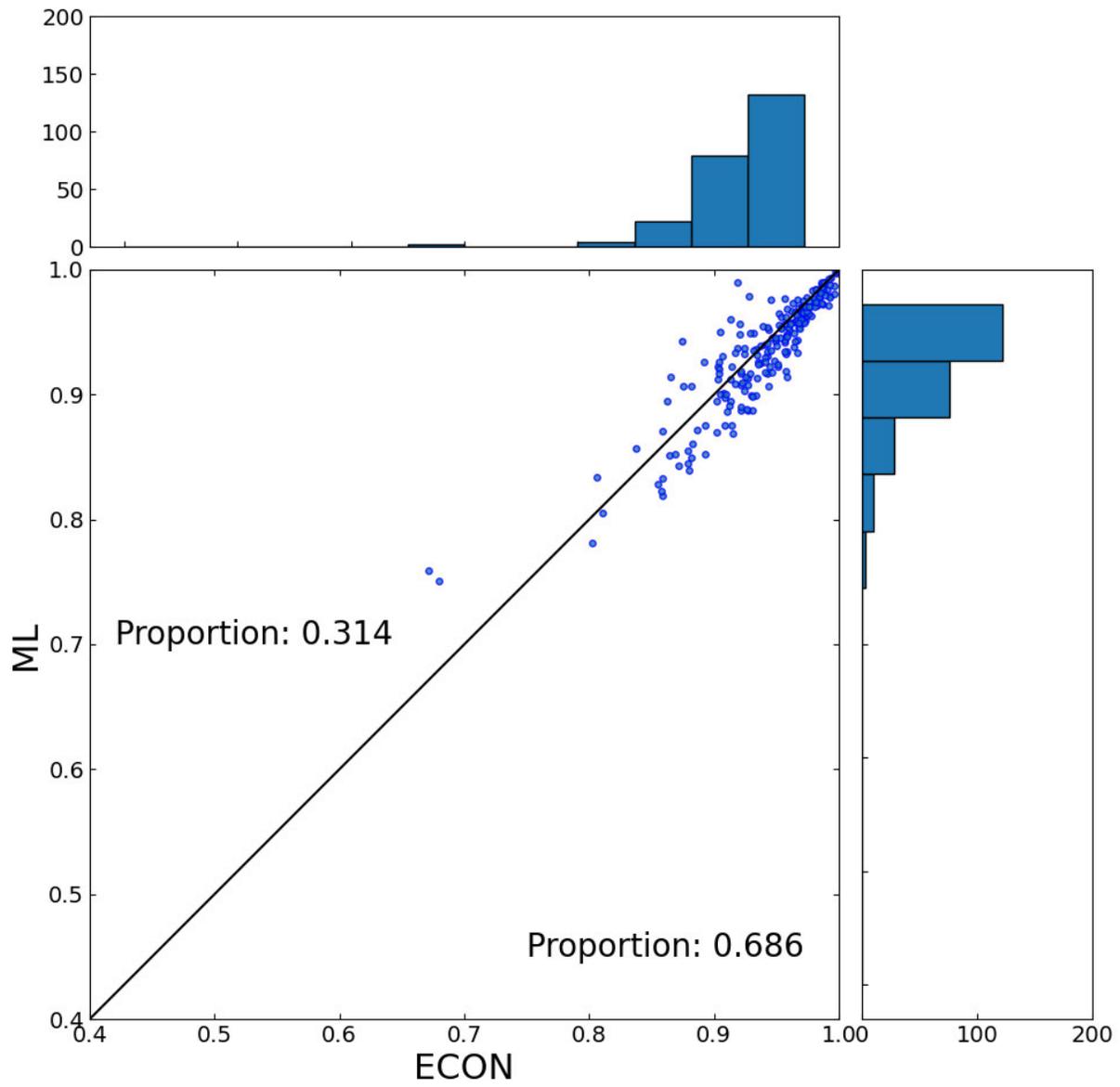
Fudenberg et al. (2020, 2022) propose a method to use machine learning techniques to evaluate prediction accuracy and flexibility:

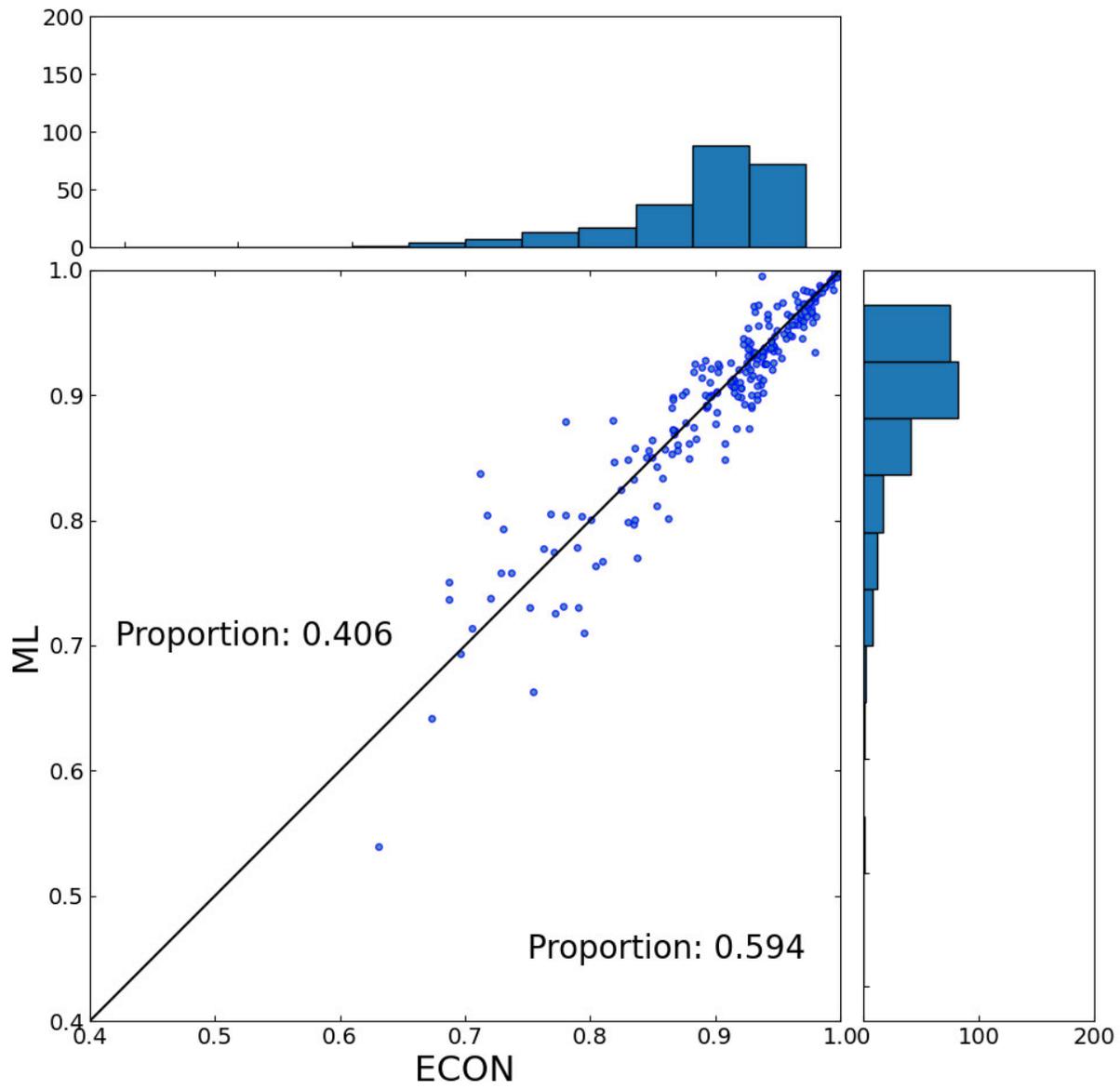
- The completeness of a model is the fraction of the predictable variation in the data that the model captures.
- The restrictiveness of a model discern completeness due to the “right” regularities by evaluating its completeness on arbitrary data.

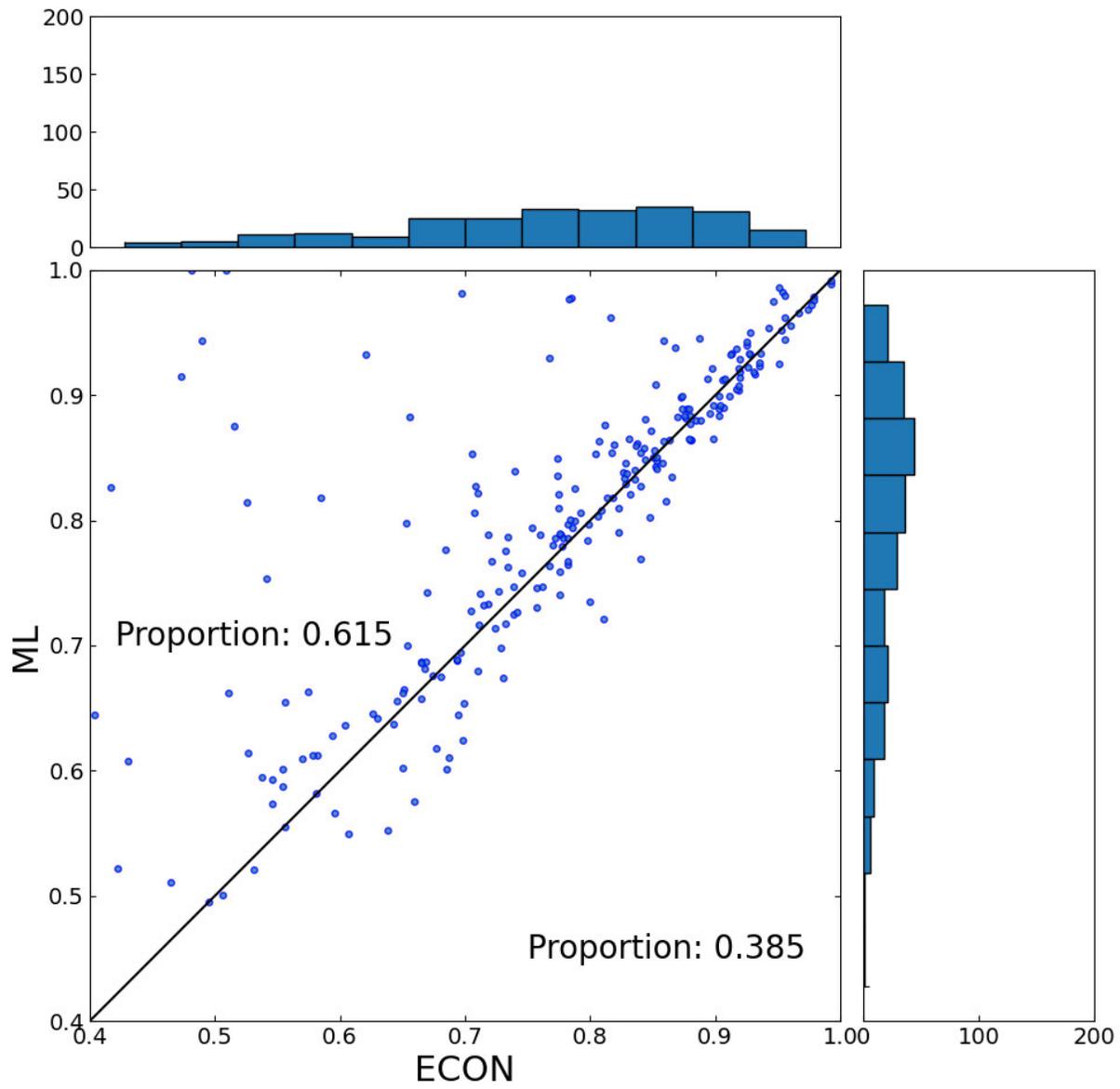
⇒ An unrestrictive model can be complete on any possible data, so the fact that it is complete on the actual data is uninformative.











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.
- ⇒ 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).