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Jan Heufer
Paul van Bruggen

Erasmus School of Economics, Erasmus University Rotterdam, and Tinbergen Institute, The Netherlands.

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Burg. Oudlaan 50
3062 PA Rotterdam
The Netherlands
Tel.: +31(0)10 408 8900
Fax: +31(0)10 408 9031

Afriat in the Lab*

Jan Heufer[a] and Paul van Bruggen[b]

[a,b]Erasmus School of Economics and Tinbergen Institute, Rotterdam

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Abstract

Varian (1988) showed that the utility maximization hypothesis cannot be falsified when only a subset of goods is observed. We show that this result does not hold under the assumptions that unobserved prices and expenditures remain constant. These assumptions are naturally satisfied in laboratory settings where the world outside the lab remains unchanged during the experiment. Hence for so-called induced budget experiments the Generalized Axiom of Revealed Preference is a necessary and sufficient condition for utility maximization in general, not just in the lab. Lab experiments are therefore a valid tool to put the utility maximization hypothesis to the test.

JEL classification: C14; C91; D11; D12.
Keywords: Afriat's Theorem; Experimental Economics; GARP; Revealed Preference; Utility Maximization.

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*Erasmus School of Economics and Tinbergen Institute, Erasmus University, 3000 DR Rotterdam, The Netherlands. [a]heufer@ese.eur.nl. [b]p.vanbruggen@ese.eur.nl.

1 Introduction

In the past twenty years, laboratory experiments have become an important tool for economists to test theories and elicit preferences. They allow for greater control in eliminating confounding factors than the use of field data, and for collecting data where no or only incomplete data exists in the field and for more accurate data where there is serious measurement error. So-called induced budget experiments, in which subjects are asked to make choices from budgets provided by the experimenter, make particular use of the opportunity to collect data that is otherwise difficult to come by.[1] Such experiments have become increasingly popular.[2]

Choices on such budgets can be tested for consistency with the Generalized Axiom of Revealed Preference (GARP), which is a necessary and sufficient condition for the existence of a utility function that rationalizes the observed choices (Afriat 1967; Varian 1982). Choices on budgets with many different prices carefully designed by the experimenter, potentially to maximize test power, and collected under clean laboratory conditions will provide well-suited data for this test. Experiments therefore seem to offer a unique opportunity to put the utility maximization hypothesis to the test as observing a violation of GARP falsifies the hypothesis.

However, testing a data set for consistency with GARP only characterizes utility maximization when the demand for all available goods is observed. Varian (1988) shows that if we only observe demand for a subset of goods, then GARP is no longer necessary. In his conclusion, Varian (1988) calls his finding "a negative result, similar in spirit to the Sonnenschein-Mantel-Debreu results" (p. 184) and laments "[t]he sad fact" that unless the entire demand is observed, the utility maximization hypothesis imposes no restrictions on observable data. Based on the same result, Cox (1997) argues that if only demand data on a subset of goods is available, tests "cannot discriminate between inconsistencies with the utility hypothesis and inconsistencies with weak separability" (p. 1055). For complete data to actually test utility maximization, he points to the data collected by Battalio et al. (1973) in a token economy established in a psychiatric ward with long-term patients.

Clearly even the best laboratory experiments can only include a small subset of goods available to subjects before and after the experiment. It therefore seems necessary to include the caveat that the analysis of experimental data is only about a sub-utility

[1] To the best of the authors' knowledge, the term 'induced budget experiment' was introduced by Banerjee and Murphy (2011) "[t]o contrast them from *induced value* experiments, i.e. those in which demand and supply are determined by the experimenter and the object of interest is the performance of an allocation mechanism" (p. 3864).

[2] Examples include Sippel (1997), Harbaugh and Krause (2000), Mattei (2000), Andreoni and Miller (2002), Février and Visser (2004), Fisman et al. (2007), Choi et al. (2007), Dickinson (2009), Banerjee and Murphy (2011), Camille et al. (2011), Dawes et al. (2011), Visser and Roelofs (2011), Bruyneel et al. (2012), Becker et al. (2013), Burghart et al. (2013), Ahn et al. (2014), and Choi et al. (2014).

function for goods in the lab. However, we will show that this is not the case: Our theorem shows that consistency with GARP of the observed data is still a necessary and sufficient condition for utility maximization over all (observed and unobserved) goods if unobserved prices and expenditure remain constant. As the world outside the lab typically remains unchanged during the course of an experiment, these conditions are naturally satisfied. Thus, consistency with GARP of the choice set collected in the lab is still a necessary and sufficient condition for the maximization of a utility function over all goods, and the utility maximization hypothesis can be falsified using laboratory experiments.

Section 2 recalls Varian's (1988) results and introduces our new theorem. Section 3 discusses the implications for experimental research. Section 4 concludes.

2 Testing Utility Maximisation with Subsets of Goods

Let $\mathbb{R}^k_+$ be the *consumption space*, where $k \geq 2$ is the number of different goods. A decision maker *demands* a bundle of goods $\mathbf{x}^i \in \mathbb{R}^k_+$ when facing the *price vector* $\mathbf{p}^i \in \mathbb{R}^k_{++}$ such that *expenditure* equals $\mathbf{p}^i\mathbf{x}^i$. We then say that $(\mathbf{x}^i, \mathbf{p}^i)$ constitutes one *observation*, although we will later assume that we do not necessarily observe all parts of $\mathbf{x}^i$ and $\mathbf{p}^i$. We assume that we have N observations, and the entire set of observations is denoted by $\Omega = \{(\mathbf{p}^i, \mathbf{x}^i)\}_{i=1}^N$.

We partition the set of goods and prices into two sets each, consisting of $\ell \geq 1$ and $m \geq 1$ goods and prices each, respectively, with $\ell + m = k$. For the goods, let

$$\begin{aligned}
\mathbf{y}^i &= (y^i_1, \ldots, y^i_\ell),\\
\mathbf{z}^i &= (z^i_1, \ldots, z^i_m),\\
\mathbf{x}^i &= (y^i_1, \ldots, y^i_\ell, z^i_1, \ldots, z^i_m),
\end{aligned}$$

and for the prices, let

$$\begin{aligned}
\mathbf{q}^i &= (q^i_1, \ldots, q^i_\ell),\\
\mathbf{r}^i &= (r^i_1, \ldots, r^i_m),\\
\mathbf{p}^i &= (q^i_1, \ldots, q^i_\ell, r^i_1, \ldots, r^i_m).
\end{aligned}$$

Later, $\mathbf{y}^i$ and $\mathbf{q}^i$ will typically be observed demand and prices, while $\mathbf{z}^i$ and $\mathbf{r}^i$ may or may not be observed. Let $\Omega_y = \{(\mathbf{q}^i, \mathbf{y}^i)\}_{i=1}^N$.

An observation $\mathbf{x}^i$ is *directly revealed preferred* to $\mathbf{x}$, written $\mathbf{x}^i \,\mathrm{R}^0\, \mathbf{x}$, if $\mathbf{p}^i\mathbf{x}^i \geq \mathbf{p}^i\mathbf{x}$. It is *revealed preferred* to $\mathbf{x}$, written $\mathbf{x}^i \,\mathrm{R}\, \mathbf{x}$, if $\mathbf{x}^i \,\mathrm{R}^0\, \mathbf{x}^a$, $\mathbf{x}^a \,\mathrm{R}^0\, \mathbf{x}^b$, …, $\mathbf{x}^c \,\mathrm{R}^0\, \mathbf{x}$; in that case, R is called the *transitive closure* of R^0. It is *strictly directly revealed preferred* to $\mathbf{x}$, written $\mathbf{x}^i \,\mathrm{P}^0\, \mathbf{x}$, if $\mathbf{p}^i\mathbf{x}^i > \mathbf{p}^i\mathbf{x}$. A utility function $u : \mathbb{R}^L_+ \to \mathbb{R}$ *rationalizes* Ω if $u(\mathbf{x}^i) \geq u(\mathbf{x})$ whenever $\mathbf{x}^i \,\mathrm{R}\, \mathbf{x}$. The set Ω satisfies the *Generalized Axiom of Revealed*

Preference (GARP) if $\mathbf{x}^i \,\mathrm{R}\, \mathbf{x}^j$ implies $\left[\text{not } \mathbf{x}^j \,\mathrm{P}^0\, \mathbf{x}^i\right]$. GARP completely characterizes the utility maximization hypothesis, as Afriat's Theorem shows.

Afriat's Theorem (Afriat 1967, Diewert 1973, Varian 1982) *The following conditions are equivalent:*

1. *The set of observations Ω satisfies GARP.*
2. *There exists a continuous, non-satiated, monotonic, and concave utility function that rationalizes Ω.*

However, Varian (1988) found that if demand for even just one good is not observed, GARP loses all bite, as the following theorem shows.

Theorem 1 (Varian 1988) *Suppose we observe Ω_y and $\{\mathbf{r}^i\}_{i=1}^N$ but not $\{\mathbf{z}^i\}_{i=1}^N$. Then we can always find $\{\mathbf{z}^i\}_{i=1}^N$ such that Ω satisfies GARP regardless of whether or not Ω_y satisfies GARP.*

Varian's (1988) proof of Theorem 1 was incomplete; recently van Bruggen (2016) provided a new proof. Note that Theorem 1, as well as Theorem 2 below, are slightly more general versions than the ones stated by Varian (1988) who formulates the results in terms of a single unobserved commodity (i.e., $\ell = 1$). The versions here follow from simple extensions of Varian's (1988) proof.

If demand for all goods is observed but the prices for some of the goods are unobserved, then GARP only maintains its bite for those subsets of the data where demand is the same for all goods for which prices are unknown, as the next theorem shows. This condition is very strong; it seems fairly implausible that a researcher would observe demand without observing prices and that this demand remains constant. In any case, researchers will typically not know in advance whether demand will be constant and can therefore not rely on it.

Theorem 2 (Varian 1988) *Suppose we observe Ω_y and $\{\mathbf{z}^i\}_{i=1}^N$ but not $\{\mathbf{r}^i\}_{i=1}^N$. For every subset $\mathcal{I}$ of indices $\{1, \ldots, N\}$ such that $\mathbf{z}^i = \mathbf{z}^j$ for all $i, j \in \mathcal{I}$, $\{(\mathbf{p}^i, \mathbf{x}^i)\}_{i\in\mathcal{I}}$ satisfies GARP if and only if $\{(\mathbf{q}^i, \mathbf{y}^i)\}_{i\in\mathcal{I}}$ satisfies GARP. For every $\mathcal{J} \subseteq \{1, \ldots, N\}$ such that $\mathbf{z}^i \neq \mathbf{z}^j$ for all $i \neq j$, $i, j \in \mathcal{J}$, we can always find $\{\mathbf{r}^i\}_{i\in\mathcal{J}}$ such that $\{(\mathbf{p}^i, \mathbf{x}^i)\}_{i\in\mathcal{J}}$ satisfies GARP regardless of whether or not $\{(\mathbf{q}^i, \mathbf{y}^i)\}_{i\in\mathcal{J}}$ satisfies GARP.*

In what follows, we assume that unobserved prices and unobserved expenditure are the same for all observations, while allowing for unobserved demand to change. Our theorem shows that these assumptions restore the power of GARP. While the assumptions may sound implausible, we will argue in Section 3 that they are typically satisfied in laboratory experiments.

Theorem 3 *Suppose we only observe Ω_y, and that $\mathbf{r}^i = \mathbf{r}^j = \mathbf{r}$ and $\mathbf{r}\,\mathbf{z}^i = \mathbf{r}\,\mathbf{z}^j$ for all i, j. Then Ω satisfies GARP if and only if Ω_y satisfies GARP.*

Proof of Theorem 3 Let R_y^0 be the directly revealed preference relation on $\mathbb{R}_+^\ell \times \mathbb{R}_+^\ell$ that is constructed using Ω_y, that is, $\mathbf{y}^i\,\mathrm{R}_y^0\,\mathbf{y}^j$ if $\mathbf{q}^i\mathbf{y}^i \geq \mathbf{q}^i\mathbf{y}^j$, and let R_y be the transitive closure of R_y^0. Let P_y^0 be the corresponding strictly directly revealed preference relation, that is, $\mathbf{y}^i\,\mathrm{P}_y^0\,\mathbf{y}^j$ if $\mathbf{q}^i\mathbf{y}^i > \mathbf{q}^i\mathbf{y}^j$. We have that $\mathbf{x}^i\,\mathrm{R}^0\,\mathbf{x}^j$ if

$$\begin{aligned} & \mathbf{p}^i\mathbf{x}^i \geq \mathbf{p}^i\mathbf{x}^j \\ \Leftrightarrow\ & \mathbf{q}^i\mathbf{y}^i + \mathbf{r}\mathbf{z}^i \geq \mathbf{q}^i\mathbf{y}^j + \mathbf{r}\mathbf{z}^j, \end{aligned}$$

and with $\mathbf{r}\mathbf{z}^i = \mathbf{r}\mathbf{z}^j$ we obtain $\mathbf{q}^i\mathbf{y}^i \geq \mathbf{q}^i\mathbf{y}^j$ which is the condition for $\mathbf{y}^i\,\mathrm{R}_y^0\,\mathbf{y}^j$. Thus, $\mathbf{x}^i\,\mathrm{R}^0\,\mathbf{x}^j$ if and only if $\mathbf{y}^i\,\mathrm{R}_y^0\,\mathbf{y}^j$, and similarly, $\mathbf{x}^i\,\mathrm{P}^0\,\mathbf{x}^j$ if and only if $\mathbf{y}^i\,\mathrm{P}_y^0\,\mathbf{y}^j$. Then a violation of GARP based on R and P^0 (i.e., Ω violates GARP) implies a violation of GARP based on R_y and P_y^0 (i.e., Ω_y violates GARP) and vice versa. Thus, [Ω violates GARP] $\Leftrightarrow$ [Ω_y violates GARP] and therefore also [Ω satisfies GARP] $\Leftrightarrow$ [Ω_y satisfies GARP]. ■

For Theorem 3, we assumed that outside spending is fixed. What about the situation where observed spending is fungible with outside expenditure, so that part of the observed wealth can be saved (captured by $s^i \in \mathbb{R}_+$ with an associated price of one) to be spent on unobserved consumption? The following theorem shows that also in this case GARP based on observed demand is necessary and sufficient for utility maximization over all goods. It will also be useful for the interpretation in terms of induced budget experiments in Section 3.

Theorem 3′ *Suppose we observe $\Omega_s = \{((\mathbf{q}^i, 1), (\mathbf{y}^i, s^i))\}_{i=1}^N$, where s^i is money not spent on goods $\mathbf{y}^i$ and which will be spent on $\mathbf{z}^i$ together with outside wealth. Suppose that $\mathbf{r}^i = \mathbf{r}^j = \mathbf{r}$ and $\mathbf{r}\,\mathbf{z}^i - s^i = \mathbf{r}\,\mathbf{z}^j - s^j$ for all i, j. Then Ω satisfies GARP if and only if Ω_s satisfies GARP.*

Proof of Theorem 3′ Let R_s^0 be the directly revealed preference relation on $\mathbb{R}_+^{\ell+1} \times \mathbb{R}_+^{\ell+1}$ that is constructed using Ω_s, that is, $(\mathbf{y}^i, s^i)\,\mathrm{R}_s^0\,(\mathbf{y}^j, s^j)$ if $\mathbf{q}^i\mathbf{y}^i + s^i \geq \mathbf{q}^i\mathbf{y}^j + s^j$, and let R_s be the transitive closure of R_s^0. Let P_s^0 be the corresponding strictly directly revealed preference relation, that is, $(\mathbf{y}^i, s^i)\,\mathrm{P}_s^0\,(\mathbf{y}^j, s^j)$ if $\mathbf{q}^i\mathbf{y}^i + s^i > \mathbf{q}^i\mathbf{y}^j + s^j$. We have that $\mathbf{x}^i\,\mathrm{R}^0\,\mathbf{x}^j$ if

$$\begin{aligned} & \mathbf{p}^i\mathbf{x}^i \geq \mathbf{p}^i\mathbf{x}^j \\ \Leftrightarrow\ & \mathbf{q}^i\mathbf{y}^i + \mathbf{r}\,\mathbf{z}^i \geq \mathbf{q}^i\mathbf{y}^j + \mathbf{r}\,\mathbf{z}^j. \end{aligned}$$

By adding $s^i - s^i$ on the left and $s^j - s^j$ on the right hand side we obtain

$$\mathbf{q}^i\mathbf{y}^i + s^i + \mathbf{r}\,\mathbf{z}^i - s^i \geq \mathbf{q}^i\mathbf{y}^j + s^j + \mathbf{r}\,\mathbf{z}^j - s^j,$$

and with $\mathbf{r}\,\mathbf{z}^i - s^i = \mathbf{r}\,\mathbf{z}^j - s^j$ we obtain $\mathbf{q}^i\mathbf{y}^i + s^i \geq \mathbf{q}^i\mathbf{y}^j + s^j$ which is the condition for $(\mathbf{y}^i, s^i)\,\mathrm{R}_s^0\,(\mathbf{y}^j, s^j)$. Thus, $\mathbf{x}^i\,\mathrm{R}^0\,\mathbf{x}^j$ if and only if $(\mathbf{y}^i, s^i)\,\mathrm{R}_s^0\,(\mathbf{y}^j, s^j)$, and similarly, $\mathbf{x}^i\,\mathrm{P}^0\,\mathbf{x}^j$ if and only if $(\mathbf{y}^i, s^i)\,\mathrm{P}_s^0\,(\mathbf{y}^j, s^j)$. A violation of GARP based on R and P^0 (i.e., Ω violates GARP) therefore implies a violation of GARP based on R_s and P_s^0 (i.e., Ω_s violates GARP) and vice versa. Thus, [Ω violates GARP] $\Leftrightarrow$ [Ω_s violates GARP] and therefore also [Ω satisfies GARP] $\Leftrightarrow$ [Ω_s satisfies GARP]. ■

Theorem 3′ demonstrates that the crucial point of Theorem 3 is not that expenditure on unobserved demand is constant, but that the *unobserved* component is constant. When there are differences in the expenditure on goods $\mathbf{z}$ but we know exactly what these differences are (in the form of observable savings s), then the implications are the same as in the case where the entire expenditure on unobserved demand is constant.

3 Implications for Laboratory Experiments

To discuss the implications of Theorem 3 for experimental research, we start with a closer look at the kind of experiments we have in mind. In an induced budget experiment, the experimenter first chooses the goods subjects can demand in the experiment. These can be tangible consumption goods (e.g., as in Sippel 1997 or Février and Visser 2004) or more abstract, such as distributions of money (e.g., Andreoni and Miller 2002 or Fisman et al. 2007). The experimenter then chooses several price vectors and expenditures, and subjects are presented the corresponding budgets and asked to make a choice on each budget. These experiments typically use a random lottery incentive mechanism where at the end of the session one randomly chosen budget is implemented. This is important because for most conclusions drawn from the data generated in this way to be valid, we need to assume that subjects choose bundles from each budget separately instead of making one choice on an aggregated budget. If subjects are expected utility maximizers, the random lottery incentive mechanism guarantees this. Empirically, Hey and Lee (2005) found generally reassuring evidence suggesting that subjects do indeed separate questions in experiments.

In terms of our terminology and notation in Section 2, an induced budget experiment delivers a set of N choices, $\{\mathbf{y}^i\}_{i=1}^N$, from budgets over ℓ goods. The set of price vectors $\{\mathbf{q}^i\}_{i=1}^N$ and maximal expenditures are chosen by the experimenter. With the random lottery incentive mechanism, subjects can, for each of the N budgets, make plans about how to spend their money on the m goods outside the lab after the experiment is over if that particular budget is the one that is implemented. Thus, in addition to choosing $\mathbf{y}^i$ for each of the N budgets, subjects plan to buy the bundle $\mathbf{z}^i$ at prices $\mathbf{r}^i$. Neither the $\mathbf{z}^i$ nor the $\mathbf{r}^i$ are observable to the experimenter.

For all practical purposes, the world outside the lab typically remains unchanged during the course of an experiment. It is therefore reasonable to assume that prices for goods outside the lab remain constant. In any case, subjects typically do not have the opportunity to follow price changes outside the lab while participating in an experiment. We therefore argue that assuming $\mathbf{r}^i = \mathbf{r}^j = \mathbf{r}$ for all i, j is justified.

In most experiments, subjects need to spend their endowment on the goods offered in the lab. If that is the case, and if the goods available in the lab are tangible consumption goods, then subjects' expenditure on goods outside the lab should remain constant, even if subjects plan to buy different bundles of goods outside the lab depending on which lab budget is implemented. Then $\mathbf{r}\,\mathbf{z}^i = \mathbf{r}\,\mathbf{z}^j$ for all i, j, and therefore, the conditions for Theorem 3 are naturally met for induced budget experiments.

It is not essential that subjects spend their full endowment in the lab. Consider the case where subjects do not need to spend everything on the goods in the lab and are instead allowed to take unspent money home. Apart from the amount the subject takes home, which may depend on the implementation of a particular budget, spending outside the lab remains constant. Thus we have that $\mathbf{r}\,\mathbf{z}^i - s^i = \mathbf{r}\,\mathbf{z}^j - s^j$ and Theorem 3′ shows that the implications for GARP still hold.

Goods in the lab are not always typical consumption goods. For example, Andreoni and Miller (2002) introduced a generalized dictator game in which subjects had to distribute money between themselves and another anonymous subject, interpreted as two different goods. There were different transfer rates, interpreted as prices, such that subjects had to choose allocations from a standard competitive budget. Fisman et al. (2007) also included a second recipient of money, such that subjects had three goods available. At the end of both experiments, one budget was randomly drawn and subjects were paid the amount of money they had allocated to themselves.

Our theorem can also be applied to such experiments. Using the notation of Theorem 3′, we can interpret $\mathbf{y}^i$ as the allocation of money to recipients, and s^i as the money subjects keep for themselves and receive at the end of the experiment. There is no loss of generality due to the normalization of the price for s, as one can use the relative price of giving for $\mathbf{y}$. The observed demand in the lab can then be modelled as $\Omega_s = \{((\mathbf{q}^i, 1), (\mathbf{y}^i, s^i))\}_{i=1}^N$, and the results of our theorem follow.

4 Conclusion

In Section 3 we argued that the conditions of Theorem 3 or Theorem 3′ are naturally met in induced budget experiments. Thus, the power of Afriat's Theorem fully applies to the demand data observed in the lab: Testing the data for consistency with GARP is necessary and sufficient for utility maximization in general, even though we only observe demand for a subset of goods.

A lot of the recent revitalisation of and increased interest in revealed preference theory appears to be because of the tools offered by experimental economics. Indeed, we find that there are good reasons to be optimistic about applying revealed preference theory to experimental data. While it remains lamentable that we can technically never falsify utility maximization with typical household demand data, the problem is ameliorated for experimental data. Laboratory experiments are therefore a uniquely powerful tool to test the hypothesis of utility maximization.

References

Afriat, S. N. (1967). The construction of utility functions from expenditure data. *International Economic Review*, 8(1):67–77.

Ahn, D., Choi, S., Gale, D., and Kariv, S. (2014). Estimating ambiguity aversion in a portfolio choice experiment. *Quantitative Economics*, 5(2):195–223.

Andreoni, J. and Miller, J. (2002). Giving according to garp: An experimental test of the consistency of preferences for altruism. *Econometrica*, 70(2):737–753.

Banerjee, S. and Murphy, J. H. (2011). Do rational demand functions differ from irrational ones? Evidence from an induced budget experiment. *Applied Economics*, 43(26):3863–3882.

Battalio, R. C., Kagel, J. H., Winkler, R. C., Fisher, E. B. J., Basmann, R. L., and Krasner, L. (1973). A test of consumer demand theory using observations of individual consumer purchases. *Western Economic Journal*, 11(4):411–428.

Becker, N., Häger, K., and Heufer, J. (2013). Revealed notions of distributive justice II: Experimental analysis. *Ruhr Economic Papers*, #444, TU Dortmund University, Discussion Paper. working paper.

Bruyneel, S., Cherchye, L., Cosaert, S., De Rock, B., and Dewitte, S. (2012). Are the smart kids more rational? KU Leuven Discussion Paper Series 12.16.

Burghart, D. R., Glimcher, P. W., and Lazzaro, S. C. (2013). An expected utility maximizer walks into a bar... *Journal of Risk and Uncertainty*, 46(3):215–246.

Camille, N., Griffiths, C. A., Vo, K., Fellows, L. K., and Kable, J. W. (2011). Ventromedial frontal lobe damage disrupts value maximization in humans. *The Journal of Neuroscience*, 31(20):7527–7532.

Choi, S., Fisman, R., Gale, D., and Kariv, S. (2007). Consistency and heterogeneity of individual behavior under uncertainty. *American Economic Review*, 97(5):1921–1938.

Choi, S., Kariv, S., Müller, W., and Silverman, D. (2014). Who is (more) rational? *American Economic Review*, 104(6):1518–1550.

Cox, J. (1997). On testing the utility hypothesis. *The Economic Journal*, 107:1054–1078.

Dawes, C. T., Loewen, P. J., and Fowler, J. H. (2011). Social preferences and political participation. *Journal of Politics*, 73(3):845–856.

Dickinson, D. L. (2009). Experiment timing and preferences for fairness. *The Journal of Socio-Economics*, 38(1):89–95.

Diewert, W. E. (1973). Afriat and revealed preference theory. *Review of Economic Studies*, 40(3):419–425.

Février, P. and Visser, M. (2004). A study of consumer behavior using laboratory data. *Experimental Economics*, 7(1):93–114.

Fisman, R., Kariv, S., and Markovits, D. (2007). Individual preferences for giving. *American Economic Review*, 97(5):1858–1876.

Harbaugh, W. T. and Krause, K. (2000). Children's altruism in public good and dictator experiments. *Economic Inquiry*, 38(1):95–109.

Hey, J. D. and Lee, J. (2005). Do subjects separate (or are they sophisticated)? *Experimental Economics*, 8(3):233–265.

Mattei, A. (2000). Full-scale real tests of consumer behavior using experimental data. *Journal of Economic Behavior & Organization*, 43(4):487–497.

Sippel, R. (1997). An experiment on the pure theory of consumer's behavior. *The Economic Journal*, 107(444):1431–1444.

van Bruggen, P. (2016). A comment on revealed preference with a subset of goods. *Tinbergen Institute Discussion Paper*, TI 2016-068/I.

Varian, H. R. (1982). The nonparametric approach to demand analysis. *Econometrica*, 50(4):945–972.

Varian, H. R. (1988). Revealed preference with a subset of goods. *Journal of Economic Theory*, 46(1):179–185.

Visser, M. S. and Roelofs, M. R. (2011). Heterogeneous preferences for altruism: gender and personality, social status, giving and taking. *Experimental Economics*, 14(4):490–506.