Understanding the Reference Effect[*]

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Abstract

This paper explores how a reference point affects individual preferences. While reference-dependence is extensively studied, very little is known regarding the impact of reference points on individual choice behavior when the reference point itself is abandoned. We show that reference-dependence is not limited to the endowment effect and status quo bias — choices appear to be influenced by reference points, even when agents do not stick to the reference point itself (*Reference Effect*). In a laboratory experiment, we find that approximately half of all subjects exhibit some reference-dependence. Moreover, we show that the leading models of reference-dependence make contradictory predictions regarding the reference effect. We find that some of these reference-dependent models are capable of explaining most of our data. Understanding the impact of reference points on individual's choice has important policy implications including how default options are determined such as with 401(k) retirement plans.

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1 Introduction

Many experimental and field studies have shown that preferences are influenced by reference points - a pattern called reference-dependence.[1] Studies show that people often stick to their default options (status quo bias), and that an individual's perceived value of a good seems to increase when the good is in the individual's possession (endowment effect). In this paper we focus on a different, yet important, aspect of reference-dependence. We study situations in which reference points alter one's choices even when agents do not stick to the reference point itself (*Reference Effect*). We consider exogenously determined reference points and show that existing models of reference-dependence make different predictions regarding the reference effect.[2] We provide a laboratory experiment that deepens our understanding of the reference effect and allows us to contrast leading models of reference-dependent choice behavior.

To illustrate the reference effect, consider the following set of two dimensional consumption bundles: $\{\mathbf{x}, \mathbf{y}, \mathbf{r}, \mathbf{s}\}$ where $x_2 > r_2 > y_2 > s_2$ and $y_1 > s_1 > x_1 > r_1$. While $\mathbf{x}$ dominates $\mathbf{r}$ but not $\mathbf{s}$, $\mathbf{y}$ dominates $\mathbf{s}$ but not $\mathbf{r}$. When the reference point is dominated by one of the options but not the other, the dominating option is an improvement in both dimensions whereas the other option includes a gain in one dimension with a loss in the other dimension. Empirical evidence suggests that $\mathbf{x}$ is more likely to be chosen from the set $\{\mathbf{x}, \mathbf{y}, \mathbf{r}\}$ when $\mathbf{r}$ is the endowment, whereas $\mathbf{y}$ is more likely to be chosen from the set $\{\mathbf{x}, \mathbf{y}, \mathbf{s}\}$ when $\mathbf{s}$ is the endowment.[3] Although the reference points $\mathbf{r}$ and $\mathbf{s}$ are not chosen (since they are both dominated), they affect observed choices.

There are a variety of models of reference-dependent choice which capture the reference effect. The first group of models of reference-dependent decision making we consider is the *loss aversion models* originally proposed by Tversky and Kahneman (1991). In the loss aversion models, a decision maker has a different utility function

[1] Horowitz and McConnell (2002) provide a review of experimental studies. Examples of field evidence include Madrian and Shea (2001), Johnson and Goldstein (2003), Johnson et al. (1993), Park et al. (2000), Chaves and Montgomery (1996), and Johnson et al. (2006).

[2] Recently, Köszegi and Rabin (2006), Masatlioglu and Nakajima (2007), and Ok, Ortoleva and Riella (2007) propose different reference-dependent models in which reference points are endogenously determined.

[3] See Tversky and Kahneman (1991) and Herne (1998).

for each reference point. In particular, people weigh gains and losses associated with different options against their current endowment. Importantly, perceived losses relative to the reference point are weighed more heavily than perceived gains. The second line of models that we consider, the *status quo constraint models*, have been recently introduced by Masatlioglu and Ok (2005, 2007). In the status quo constraint setting, individual's choices are constrained by their reference point. Unlike the loss aversion models, in the status quo constraint models, the fundamental utility function does not change with the reference point.

Since these choice models differ with respect to their basic structure and the methodology with which they are derived, the first part of the paper is devoted to the construction of a framework in which it is possible to study these models in a unified manner. We show that while these models were constructed to explain the same choice anomalies, they make contradictory predictions regarding the reference effect. The second part of the paper provides a discussion of our experimental approach and lists our findings. In our experiment, we elicit the preferences of each participant over two consumption bundles with and without reference points. Reference points are always dominated by at least one of the bundles. As we move the reference point, the theoretical predictions of the reference-dependent choice models under consideration diverge from each other. We then compare the experimental evidence with the predictions of the reference-dependent models. We document whether a subject's ranking of the consumption bundles varies as the reference point changes, and we ask whether the observed variation is consistent with any of the models.

In our experimental data approximately half of all subjects exhibit some reference-dependence. Put differently, roughly half of the participants displayed behavioral patterns inconsistent with the classical choice theory. This finding sheds light on the recent discussion of whether reference-dependence exists. Experimental findings of Plott and Zeiler (2005, 2007) challenge the previous empirical evidence of reference-dependent choice behavior. In particular, these papers argue that endowment effect is driven by subjects' misconceptions and experimental procedures. We show that individuals may have reference-dependent behavior even if they do not exhibit the endowment effect—in our data, individual choices appear to be influenced by the reference points, even when the reference point itself is not chosen. Moreover, the critiques presented in Plott and Zeiler (2005, 2007) do not apply to our experimental design.[4]

In terms of the reference-dependent models themselves, we conclude that both modeling frameworks may play an important role in explaining actual choice behavior. We show that the restricted versions of these models perform significantly better than the classical choice theory. More striking, the general versions of these models are capable of explaining most of our data. While the status quo constraint models perform slightly better than the loss aversion models, we find evidence supporting both groups of models. Typically, subjects that are inconsistent with loss aversion exhibit behavior that is consistent with the status quo constraint. Conversely, subjects that exhibit behavior inconsistent with the status quo constraint models often have behavioral patterns that are consistent with loss aversion.

Our experimental findings may also help improve economic policies which impose default options. One example is the selection of default options in 401(k) plans. Choi *et al.* (2001) shows that automatic enrollment in a 401(k) has a dramatic impact on retirement savings behavior: under automatic enrollment, 401(k) participation rates reach 80% on average, and three years after automatic enrollment approximately half of the participants had not changed their low default savings rates and conservative default investment vehicles. More strikingly, the asset allocations of those workers who have not stuck with their default plan are nevertheless heavily affected by the automatic enrollment default fund (Madrian and Shea (2001), Choi et al. (2004), Beshears et al. (2006)). Our experimental results confirm that reference points may alter decisions even when they are not chosen and shed light on the interaction of a default allocation and employee savings. By developing a better understanding of default options and their impacts on the asset allocations, employers may be able to help their employees

[4]List (2003, 2004) show the endowment effect disappears if the subjects have prior experience in trading environments. Although the reference effect may also diminish with experience, we believe that many real life choices are made without much experience.

to achieve desired retirement goals.

The paper is organized as follows. In Section 2, we describe the reference-dependent choice models in more detail. In Section 3, we discuss some of the predictions of the models that we should make use of in our subsequent experiments. The experimental design and procedures that we follow are explained in Section 4.1. We present our experimental results in Section 4.2. We conclude our discussion in Section 5.

2 Theoretical Analysis

In this section, we contrast the leading reference-dependent choice models from a theoretical viewpoint. Our primary goal is to provide a framework that would allow one to study such models in a unified manner, thereby identifying their differences with respect to structure, methodology and predictions.

2.1 Loss Aversion Models

Tversky and Kahneman (1991), hereafter T-K, provides a behavioral model that extends prospect theory to the case of riskless consumption bundles with n observable attributes. For expositional purposes, we assume here that $n = 2$, i.e. a generic element $\mathbf{x} = (x_1, x_2)$ is a two-attribute consumption bundle. T-K assumes that for each reference point $\mathbf{r} = (r_1, r_2)$ the decision maker has a particular preference relation $\succeq_{\mathbf{r}}$ which is represented by a utility function $U_{\mathbf{r}} : \mathbb{R}^2_+ \to \mathbb{R}$. For any $\mathbf{x} = (x_1, x_2) \in \mathbb{R}^2_+$,

$$U_{\mathbf{r}}(\mathbf{x}) = F(v_1(x_1, r_1), v_2(x_2, r_2)) \tag{1}$$

where $v_i(x_i, r_i)$ is a real-valued function, $i = 1, 2$, and F is a strictly increasing and continuous value function. In words, $U_{\mathbf{r}}(\mathbf{x})$ represents the utility of $\mathbf{x}$ when it is evaluated relative to reference point $\mathbf{r}$. Here $v_i(x_i, r_i)$ compares $\mathbf{x}$ and $\mathbf{r}$ with respect to the ith attribute, or more precisely, quantifies the advantages (disadvantages) of x_i relative to r_i if $x_i > r_i$ (if $x_i < r_i$). In addition to reference-dependence, T-K assumes that preferences satisfy (1) loss aversion: people are more sensitive to losing money than they are to gaining the same amount of money, and (2) diminishing sensitivity: marginal values of both gains and losses decrease with their distance from the reference point. In what follows, we will refer to this model as the *loss aversion* (LA) model.

To demonstrate loss aversion and diminishing sensitivity in terms of functional properties, we consider the following widely used formulation;[5]

$$U_{\mathbf{r}}(\mathbf{x}) = g_1(u_1(x_1) - u_1(r_1)) + g_2(u_2(x_2) - u_2(r_2)) \tag{2}$$

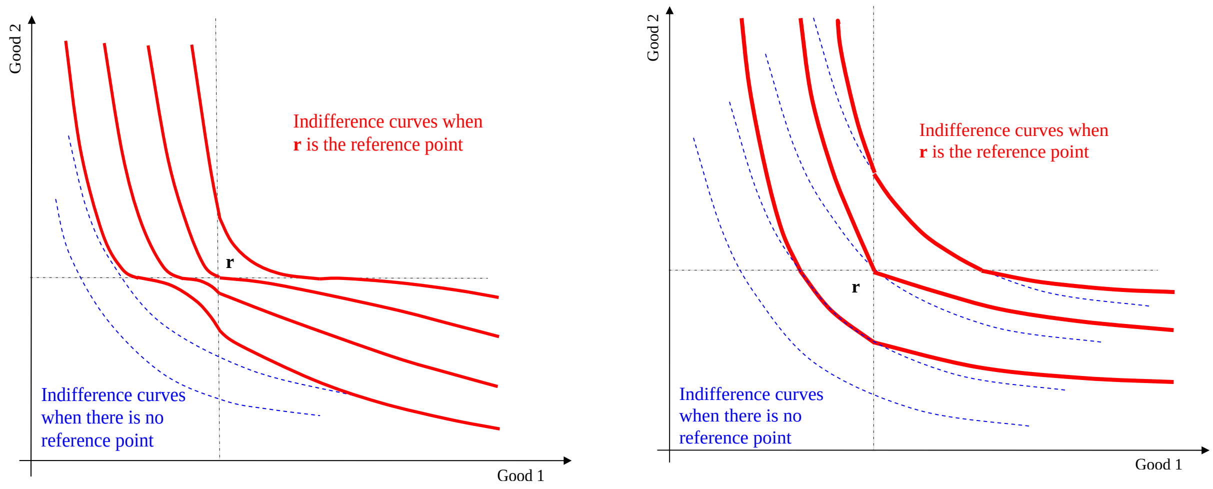
where g_i is a strictly increasing and continuous function on $\mathbb{R}$ that acts as the value function for the i^{th} attribute, $i = 1, 2$. The functional form exhibited in (2) allows one to endow various properties of g_i with nice interpretations. The assumptions $g_i(0) = 0$ and $g_i(a) < -g_i(-a)$, for each $a \neq 0$, capture the phenomenon of loss aversion. As in prospect theory, this model posits that each value function is *S-shaped* and is steeper in the case of losses than it is in the case of gains. Concavity of $g_i(a)$ for $a > 0$ implies diminishing sensitivity for gains, and convexity of $g_i(a)$ for $a < 0$ implies diminishing sensitivity for losses.

T-K also proposes a more restrictive version of (2) in which both $g_i|_{\mathbb{R}_+}$ and $g_i|_{\mathbb{R}_-}$ are assumed to be linear functions. We call this model the *additive constant loss aversion* (CLA) model. In this restrictive model, the linearity of g_i implies that the sensitivity to a given gain/loss on dimension i does not depend on whether the reference bundle is distant or near in that dimension.

Since many real life decisions do not include a status quo, a comprehensive decision-making model should be able to also make predictions when there is no reference point. Although T-K does not discuss this actuality, it seems that in practice the LA and CLA models are commonly adapted to cover such situations by setting $\mathbf{r} = (0, 0)$ and $u_i(0) = 0$, $i = 1, 2$, a convention that we shall adopt here as well.

Figure 1 illustrates how a reference point affects preferences of a decision maker

[5] Our experimental results are based on the general model.



(a) The LA model

(b) The CLA model

Figure 1: The LA and CLA models

in the LA and CLA models.[6] Dashed lines represent indifference curves when there is no reference point; thick lines represent indifference curves when there is a reference point, denoted by **r**. Note that the indifference curves for both models are kinked at the consumption bundles along both the vertical and horizontal straight lines passing through reference point **r**.

Needless to say, the loss aversion model provides a nice behavioral explanation for empirical and experimental irregularities that seem to do with reference-dependent behavior.[7] Unfortunately, this comes at the cost of a drastic deviation from the canonical rational choice theory, and more important, not all of its implications are in concert with the empirical facts: (i) the loss aversion model permits non-convex indifference curves and intransitive preferences (Munro and Sugden (2003)), (ii) it is impossible to make welfare comparisons under this model (Mandler (2004)), and (iii) it necessitates a discrepancy between willingness-to-accept (WTA) and willingness-to-pay (WTP)

[6]Figure 1(a) is based on equation (2) where $u_i(b) = b^\beta$, $g_i(a) = a^\alpha$ when $a \geq 0$, $g_i(a) = -\lambda a^\alpha$ when $a < 0$ for $i = 1, 2.$ and $\lambda > 1 > \alpha, \beta > 0$. In Figure 1(b), g_1 and g_2 are taken to be linear.

[7]For example, a wide range of studies demonstrate that willingness-to-accept (WTA) highly exceeds willingness-to-pay (WTP) for consumption goods (among numerous studies, Kahneman, Knetsch and Thaler (1990), Knetsch and Sinden (1984), Knetsch (1989) and Bateman *et al.* (1997)). These results have been interpreted as a strong support for the loss aversion phenomenon.

(Plott and Zeiler (2005) and List (2003, 2004)).

In addition, Sagi (2006) points out the LA model predicts not only the status quo bias but also *status quo aversion*. Sagi (2005) says that in the LA model "... a decision maker has a choice between two prospects, selects one which subsequently becomes the new reference point, and then regrets her initial choice."[8] Hence, the LA model makes the prediction which is just opposite of what T-K initially intended to explain.

The culprit here is the interaction of loss aversion and diminishing sensitivity across different dimensions. In the prospect theory, multidimensional aggregation of loss aversion and diminishing sensitivity does not constitute a problem as there is only one dimension (attribute) of goods, namely money. By contrast, extending the prospect theory to the case of consumption bundles (as in the loss aversion models) runs into the difficulty of aggregating convex and concave functions across multiple dimensions. This results in choice cycles and status quo aversion. The linearity of the CLA model prevents these two shortcomings.

Next, we describe status quo constraint models and discuss their pros and cons.

2.2 Status Quo Constraint Models

Because of the shortcomings mentioned above, reference-dependence has been commonly treated as a violation of rationality in the literature on consumer choice. Recently, however, Masatlioglu and Ok (2005, 2007), hereafter M-O (2005, 2007), has brought a new perspective on modeling reference-dependence.[9] In these models, as opposed to the earlier approach, status quo does not affect the underlying utility function of the agent but instead imposes a psychological constraint on what the decision maker can choose.

The model of M-O (2005), hereafter the SQB model, is derived through behavioral axioms in the tradition of the classical revealed preference theory. In particular, the primary descriptive axiom of M-O (2005) is so-called "status quo bias" – an alternative

[8] Crockett (2006) points out similar status quo aversion. He shows that, under certain conditions, the LA model predicts high volumes of trade in a simple exchange economy.

[9] See Gursel (2007), Kawai (2006), and Houy (2006) for extensions and variations of this model.

is more likely to be chosen when it is the default option of a decision maker.

The SQB model maintains that a decision maker evaluates all choice alternatives according to a well-defined material preference or a utility function,[10] $U : \mathbb{R}^2 \rightarrow \mathbb{R}$. If there is no status quo (reference point), the agent solves her problem by maximizing her utility function over all feasible alternatives. When there is a reference point, say $\mathbf{r}$, the decision maker follows a simple two-stage procedure: (i) elimination and (ii) optimization. In the elimination stage, the decision maker utilizes her psychological constraint set, $\mathcal{Q}(\mathbf{r})$, to discard all feasible alternatives that do *not* belong to this set. Then, in the optimization stage, she chooses the alternative that maximizes her utility function from the alternatives that survive this elimination.

Essentially, agents maximize their utility functions subject to a psychological constraint imposed by the status quo. In particular, agents solve the following maximization problem given budget set B:

$$\begin{aligned} &\max \quad U(\mathbf{x}) \\ &\text{s.t. } \mathbf{x} \in B \cap \mathcal{Q}(\mathbf{r}). \end{aligned} \tag{3}$$

The formulation above makes it transparent that the SQB model is a "*constrained utility maximization model*," where the constraint set, $\mathcal{Q}$, is induced by one's reference point. Even though the SQB model follows a fairly simple procedure, the psychological constraint set merits some explanation. The set $\mathcal{Q}(\mathbf{r})$ represents the set of alternatives for which the decision maker is willing to abandon her status quo $\mathbf{r}$. The psychological constraint set satisfies the following properties:

(i) Strict Improvement: if $\mathbf{x} \in \mathcal{Q}(\mathbf{r})\backslash\{\mathbf{r}\}$, then $U(\mathbf{r}) < U(\mathbf{x})$

(ii) Attainability of Status Quo: $\mathbf{r} \in \mathcal{Q}(\mathbf{r})$,

(iii) Consistency: $\mathbf{r} \in \mathcal{Q}(\mathbf{r}')$ implies $\mathcal{Q}(\mathbf{r}) \subset \mathcal{Q}(\mathbf{r}')$.

Condition (i) guarantees that if someone prefers an alternative to the status quo, such alternative must yield higher utility to the agent.[11] Condition (ii) says that the

[10] While the SQB model applies in any arbitrary finite choice space X, it can be easily extended to uncountable spaces by imposing a continuity assumption.

[11] This property prevents potential cycles: If $\mathbf{x}$ is chosen in some budget set when $\mathbf{y}$ is the status quo, $U(\mathbf{y}) < U(\mathbf{x})$,

status quo is always included in its psychological constraint, i.e., every status quo is as good as itself. Finally, Condition (iii) dictates that if $\mathbf{r}$ is revealed to be better than the status quo ($\mathbf{r}'$), then any element that is preferred to $\mathbf{r}$ when $\mathbf{r}$ is the status quo must be revealed to be better than $\mathbf{r}'$ when $\mathbf{r}'$ is the status quo.

One interpretation is that the decision maker has multiple selves, say self 1 and self 2. While self 1 values the first attribute more than the second one, self 2 puts more weight on the second attribute relative to the first one. The decision maker sticks to her status quo unless both selves are willing to move away from it. Put differently, if an alternative, say $\mathbf{x}$, provides higher utilities for both self 1 and self 2, then both selves agree that $\mathbf{x}$ is better than the status quo. Consequently, the constraint set consists of these alternatives that are preferred by both selves:

$$\mathcal{Q}(\mathbf{r}) = \{\mathbf{x} \in \mathbb{R}^2 |\ u_1(\mathbf{x}) \geq u_1(\mathbf{r}) \text{ and } u_2(\mathbf{x}) \geq u_2(\mathbf{r})\}, \tag{4}$$

where a strictly increasing function, u_i, represents the utility of self i, $i = 1, 2$.[12] Moreover, the material utility U is an aggregation of these utility functions of the two selves.

Figure 2 demonstrates the SQB model. The shaded region containing the reference point represents $\mathcal{Q}(\mathbf{r})$. Since the material preference is not affected by reference points, in this model the thick indifference curves (with reference point) coincide with the thin indifference curves (without reference point). Thick indifference curves, however, are only defined within the psychological constraint set, $\mathcal{Q}$, since any point outside of the mental constraint set is dominated by the reference point.

Unlike loss aversion models, the SQB model does not permit preference cycles. More importantly, the model allows us to construct a transitive ranking that can be used to carry out meaningful welfare analysis.[13]

and $\mathbf{z}$ is chosen in some budget set when $\mathbf{x}$ is the status quo, $U(\mathbf{x}) < U(\mathbf{z})$, then it is impossible that $\mathbf{y}$ is chosen in any budget set when $\mathbf{z}$ is the status quo.

[12] As we mentioned in footnote 10, here the choice space is assumed to be $\mathbb{R}^2$. Given this additional algebraic structure, it is reasonable to assume that $\{\mathbf{x} \in \mathbb{R}^2 |\ x_1 \geq r_1 \text{ and } x_2 \geq r_2\} \subset \mathcal{Q}(\mathbf{r})$. That is, the constraint set includes the alternatives which dominate the reference point $\mathbf{r}$ in the usual sense.

[13] To see this, define a "welfare" ranking by the following way: $\mathbf{x}$ is "strictly better" than $\mathbf{y}$ ($\mathbf{x} \succ \mathbf{y}$) if and only if $\mathbf{x}$ is

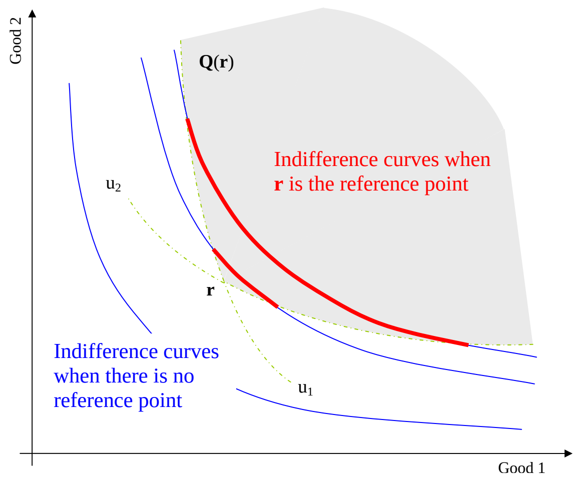


Figure 2: The SQB model

M-O (2007) has recently provided two extensions of the SQB model – in this paper, we refer to the first model as the general SQB (GSQB) model and the second model as the procedural reference-dependent choice (PRD) model. We will discuss them in turn.

While sharing the positive aspects of the SQB model, the GSQB model, is consistent with both the *presence* and *absence* of a gap between WTA and WTP.[14] The GSQB model is exactly the same as the SQB model except that the psychological constraint set need not satisfy Condition (iii), consistency. The GSQB model enjoys more explanatory power compared to the SQB model. However, these two models have limitations. Both the SQB and GSQB models necessitate that the relative ranking of two alternatives is not affected by the presence of a status quo when they both dominate the status quo point. In other words, these models do not allow for an inferior reference alternative to act as a reference for the agent in a way that possibly changes the comparative evaluation of dominating alternatives, what we call "*inferior reference effect.*" Because

uniquely chosen from $\{\mathbf{x}, \mathbf{y}\}$ when $\mathbf{y}$ is the status quo. Then the SQB model implies that there is no alternative $\mathbf{z}$ such that $\mathbf{y}$ is chosen from $\{\mathbf{x}, \mathbf{y}, \mathbf{z}\}$ when $\mathbf{z}$ is the status quo. Hence, independent of status quo, $\mathbf{x} \succ \mathbf{y}$ entails that whenever $\mathbf{x}$ and $\mathbf{y}$ are available, sometimes $\mathbf{x}$ is chosen but not $\mathbf{y}$, or otherwise neither are chosen. Condition (iii) guarantees that $\succ$ is transitive. Therefore, $\succ$ can be used for welfare comparisons.

[14]For a detail explanation, see Masatlioglu and Ok (2007).

of that, these models fall short of being a satisfactory model of reference-dependent decision making.

The PRD model allows for the inferior reference effect. The PRD model resembles the SQB model; yet it functions through two psychological constraint sets $\mathcal{Q}^1(\mathbf{r})$ and $\mathcal{Q}^2(\mathbf{r})$ for a given reference point, $\mathbf{r}$. In the PRD model, given a reference point, say $\mathbf{r}$, either $\mathcal{Q}^1(\mathbf{r})$ or $\mathcal{Q}^2(\mathbf{r})$ will be utilized in the elimination stage. The decision maker uses $\mathcal{Q}^1(\mathbf{r})$ as the constraint set if $B \cap \mathcal{Q}^1(\mathbf{r}) \neq \{\mathbf{r}\}$, i.e. there is an alternative in B that is "obviously" superior to $\mathbf{r}$ for the decision maker. Then she proceeds to the optimization stage, as in the SQB model. If there is no common element in B and $\mathcal{Q}^1(\mathbf{r})$ other than $\mathbf{r}$, then the decision maker relaxes her mental constraint set to a larger set $\mathcal{Q}^2(\mathbf{r})$, and employs $\mathcal{Q}^2(\mathbf{r})$ in the elimination stage. Therefore, at the optimization stage, the decision maker settles her problem upon searching for alternatives in $B \cap \mathcal{Q}^1(\mathbf{r})$ if $B \cap \mathcal{Q}^1(\mathbf{r}) \neq \{\mathbf{r}\}$, otherwise in $B \cap \mathcal{Q}^2(\mathbf{r})$ (see Figure 3). More formally, the optimization problem of the decision maker in the PRD model can be written as follows:[15]

$$
\begin{aligned}
&\max \quad U(\mathbf{x}) \\
&\text{s.t.} \quad \begin{cases} \mathbf{x} \in B \cap \mathcal{Q}^1(\mathbf{r}) & \text{if } B \cap \mathcal{Q}^1(\mathbf{r}) \neq \{\mathbf{r}\} \\ \mathbf{x} \in B \cap \mathcal{Q}^2(\mathbf{r}) & \text{otherwise.} \end{cases}
\end{aligned} \tag{5}
$$

$\mathcal{Q}^1$ is more restrictive than $\mathcal{Q}^2$, i.e., $\mathcal{Q}^1(\mathbf{r}) \subset \mathcal{Q}^2(\mathbf{r})$ for all $\mathbf{r}$. One can think of $\mathcal{Q}^1(\mathbf{r})$ as the set of alternatives which dominate reference point $\mathbf{r}$ in an obvious way; no cognitive effort is needed to figure out the domination. By contrast, $\mathcal{Q}^2(\mathbf{r})$ consists of those alternatives the dominance of which over $\mathbf{r}$ is less straight forward for the individual; at least some cognitive work on the part of the individual is needed to discern this dominance. $\mathcal{Q}^2(\mathbf{r})$ can be thought as the constraint set, $\mathcal{Q}(\mathbf{r})$, defined in the SQB model.

The main criticisms of these two papers stem from limiting their attention to the case where the reference point is always within the set of alternatives. However, M-

[15] As in the SQB model, both $\mathcal{Q}^1$ and $\mathcal{Q}^2$ satisfy Condition (i)-(iii) and $\mathcal{Q}^1(\mathbf{r}) \subset \{\mathbf{x} \in R^2 | \ x_1 \geq r_1 \text{ and } x_2 \geq r_2\} \subseteq \mathcal{Q}^2(\mathbf{r})$.

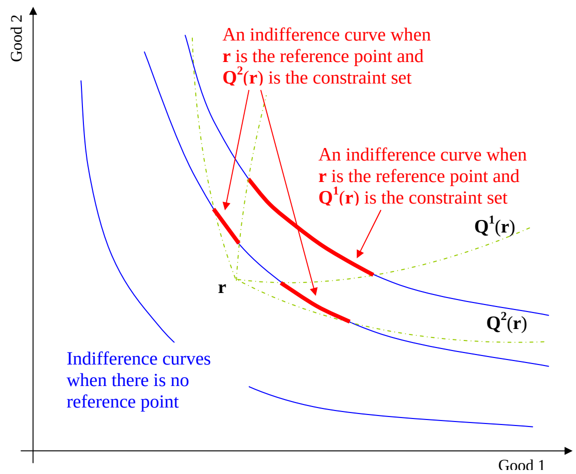


Figure 3: The PRD model

O (2005, 2007) argue that in many real life decision situations the reference point is available to the decision maker.[16] For example, when people contemplate among several 401(k) retirement plans, the default option (the reference point) is one of the options that is already available to them.

2.3 Related Models on Reference-Dependent Behavior

Other theoretical works in this field include, but not limited to, Munro and Sugden (2003), Sugden (2003) and Sagi (2006). Like T-K, these models posit that a decision maker may have different preference relations $\succeq_{\mathbf{r}}$, one for every given reference point.[17]

Munro and Sugden (2003) proposes a class of tractable utility functions that incorporate reference-dependence, which they call the *reference-dependent constant elasticity of substitution* (CES) utility function,

$$U_{\mathbf{r}}(\mathbf{x}) = A(\mathbf{r}) \left(\gamma_1 r_1^{\rho-\beta} x_1^{\beta} + \gamma_2 r_2^{\rho-\beta} x_2^{\beta} \right)^{1/\beta}$$

[16] Bleichrodt (2007) also argues that in realistic cases, reference point is always an element of the decision maker's opportunity set and provides a version of prospect theory in which the reference point is *always* one of the available acts.

[17] Apesteguia and Ballester (2004) follows a dual axiomatic approach: they study both reference-dependent *choice behavior*, and reference-dependent *preferences*.

where $\gamma_1 + \gamma_2 = 1$, $1 > \rho \geq \beta > -\infty$, and A is a strictly positive and continuous function. When $\mathbf{r} = (0, 0)$ is the reference point, the reference-dependent CES utility function implies that any two consumption bundles would be indifferent to each other. Therefore, it is not entirely clear to us how to extend the model in the absence of a reference point. Since this is essential for our experimental investigation, we will exclude this model from our comparisons.

Sugden (2003) provides an axiomatic model of reference-dependent subjective expected utility by allowing the reference point to be an act or lottery. However, Sugden's model maintains that the relative ranking of two constant acts is independent of the reference point. Since according to this model there is no reference-dependence in the case of riskless choice problems, we also exclude Sugden's model in our comparisons.

The anchored preference of Sagi (2006), within the context of choice under risk, is another model of reference-dependent choice.[18] We will present here a version of Sagi's model for riskless choice model. Given a reference point, $\mathbf{r}$, this model maintains that an individual maximizes the following utility function:

$$U_{\mathbf{r}}(\mathbf{x}) = \min \{u_1(\mathbf{x}) - u_1(\mathbf{r}), u_2(\mathbf{x}) - u_2(\mathbf{r})\} \tag{6}$$

where u_i is a continuous and bounded utility function on $\mathbb{R}^2_+$, $i = 1, 2$.

This model is intended to capture anomalies for risky alternatives which have an additional structure compared to riskless consumption bundles. Hence Sagi's model has little predictive power when it is forced to apply to riskless choice problems. Consequently, this model is not considered in our experimental analysis.[19]

3 Theoretical Predictions

So far, we have constructed a framework on which it is possible to study different reference-dependent choice models in a unified manner and have provided a discussion

[18] See Giraud (2006) for an extension of this model.

[19] Sagi's model makes no distinctive prediction in our experiment.

of their natures. Although they explain the same choice anomalies, we show, in this section, that they make different predictions even in a simple decision environment. This allows us not only to understand these models better but also to design an experiment that can distinguish among them.

Figure 4 is constructed to illustrate this simple decision environment, a two-attribute commodity space. In the graph, two consumption bundles denoted by $\mathbf{x}$ and $\mathbf{y}$ are positioned so that neither dominates the other, i.e., each has a superior dimension and the reference points are denoted by $\mathbf{r_i}$ for $i = 1, 2$.

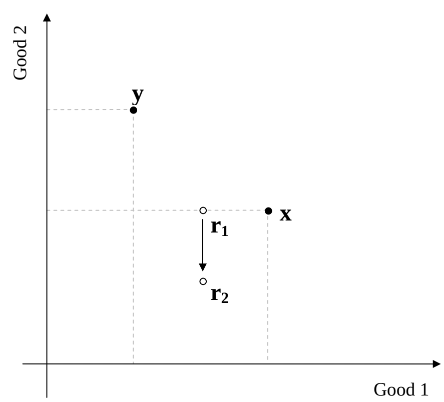


Figure 4: A Simple Decision Environment

We explain the theoretical predictions for the case of switching the reference point from $\mathbf{r_1}$ to $\mathbf{r_2}$. All proofs are provided in Appendix A. In the LA model, switching from $\mathbf{r}_1$ to $\mathbf{r}_2$ favors $\mathbf{x}$. In other words, it is more likely that $\mathbf{x}$ is preferred to $\mathbf{y}$ when the reference point is $\mathbf{r}_2$ compared to $\mathbf{r}_1$. The reasoning behind this prediction is due to the diminishing sensitivity. That is, the difference between $\mathbf{x}$ and $\mathbf{y}$ on good 2 has a greater impact on preference if viewed from $\mathbf{r_1}$ than from $\mathbf{r_2}$. If we consider the CLA model, where there is no diminishing sensitivity, then there is no change in the relative ranking of $\mathbf{x}$ and $\mathbf{y}$ as we move the reference point.

Next, we show that the SQB model favors $\mathbf{y}$ when the reference point moves from $\mathbf{r}_1$ to $\mathbf{r_2}$. Before we proceed, note that by monotonicity, $\mathbf{r}_1$ is an element of $\mathcal{Q}(\mathbf{r}_2)$.[20] Then,

[20]Monotonicity is not one of the assumptions of the SQB model since it applies to any arbitrary choice space. Once

by the status quo bias axiom, it follows that $\mathcal{Q}(\mathbf{r}_1)$ is a subset of $\mathcal{Q}(\mathbf{r}_2)$. To illustrate our claim above, assume that the decision maker prefers $\mathbf{x}$ to $\mathbf{y}$ when the reference point is $\mathbf{r}_1$.[21] Since the decision maker uses her material preferences (preferences without any reference point) in order to finalize her choice problem, we investigate two cases: (i) if $\mathbf{x}$ is preferred to $\mathbf{y}$ when there is no reference point, moving from $\mathbf{r}_1$ to $\mathbf{r}_2$ does not affect the relative ranking of $\mathbf{x}$ and $\mathbf{y}$, since $\mathbf{x} \in \mathcal{Q}(\mathbf{r}_1) \subset \mathcal{Q}(\mathbf{r}_2)$, and (ii) if, instead, she prefers $\mathbf{y}$ to $\mathbf{x}$ when there is no reference point, it must be the case that $\mathbf{y} \notin \mathcal{Q}(\mathbf{r}_1)$. The latter case is illustrated in Figure 5 in which the thick line passing through $\mathbf{y}$ represents the indifference curve of U and the regions above the thin lines passing through $\mathbf{r_1}$ and $\mathbf{r}_2$ are the psychological constraint sets, $\mathcal{Q}(\mathbf{r}_1)$ and $\mathcal{Q}(\mathbf{r}_2)$, respectively. Since $\mathcal{Q}(\mathbf{r}_1) \subset \mathcal{Q}(\mathbf{r}_2)$, $\mathcal{Q}(\mathbf{r}_2)$ may include $\mathbf{y}$ as an element, as in Figure 5. If this is the case, $\mathbf{y}$ is preferred to $\mathbf{x}$ when $\mathbf{r}_2$ is the reference point since indifference curves are not affected by the reference point. Therefore, the SQB model favors $\mathbf{y}$.

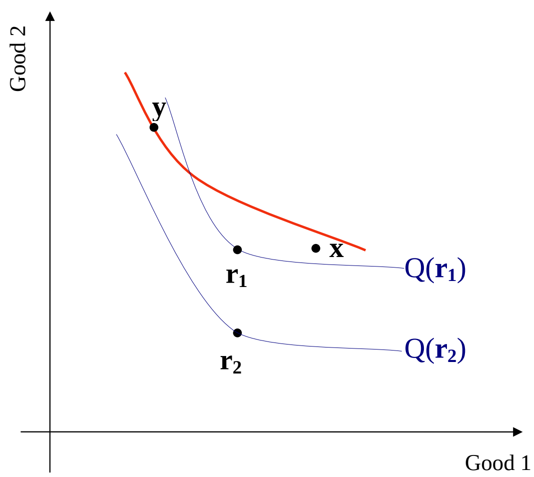


Figure 5: A Graphical Demonstration for the SQB Model

For this particular case, the predictions of the GSQB and PRD models go either way (as explained in Appendix A). This means that these two models do not restrict choice behavior for this case. In the next section, we provide a discussion of our experimental

the choice space is endowed with an order structure, as in $\mathbb{R}^2$, it is natural to assume that if an alternative dominates the reference point in the usual sense, the reference point will be discarded to acquire the dominating alternative.

[21] We omit the case where $\mathbf{y}$ is preferred to $\mathbf{x}$ when the reference point is $\mathbf{r}_1$, since it is easy to see that the relative ranking of $\mathbf{y}$ and $\mathbf{x}$ would not change when the reference point is $\mathbf{r}_2$ (due to Condition (iii)).

approach.

4 Experimental Analysis

In the light of the theoretical findings, we construct an experiment where the leading reference-dependent choice models can be distinguished. We first explain the experimental design, and then the results follow.

4.1 Experimental Design

We conducted individual decision making experiments at the Center for Experimental Social Science (C.E.S.S.) at New York University. There were a total of 99 subjects. The experiment was conducted by using the z-Tree software and lasted approximately for half an hour. Subjects earned $14 on average including the $7 show-up fee and also some Belgian chocolates. Each subject answered 16 questions, related to two different research projects, with only one of them randomly selected at the end of the experiment to determine the payoff. Among these 16 questions, on average 9 of them are relevant for this paper.

Our experiment is closely related to Herne (1998). Unlike Herne's experiment, each session consists of two parts. In the first part, subjects have to answer a couple of questions in which they need to make a choice between two consumption bundles, say $\mathbf{x}$ and $\mathbf{y}$, with no reference point.[22] In the second part, they answer the same questions but with a reference point. Reference points are always dominated by at least one of the alternatives. As the location of the reference point is changed, the theoretical predictions of the reference-dependent choice models under consideration differ. For any *given* subject, we examine whether her ranking of $\mathbf{x}$ and $\mathbf{y}$ varies as the reference point changes, and if so, whether this variation is consistent with any of the reference-dependent choice models. Consequently, we precisely calculate the proportion of people that are consistent with each model.

[22] The first part of the experiment is performed in order to relate the choices of subjects with and without status quo.

Figure 6 demonstrates the experimental environment. Each bundle consists of a combination of money and a number of Belgian chocolate boxes.[23] In the graph, two chocolate-money bundles, $\mathbf{x}$ and $\mathbf{y}$ are located so that neither dominates the other. Then we have eight reference points denoted by $\mathbf{r_i}$ for $i = 0, \ldots, 7$. Here not having any reference point is treated as if the reference point is the origin, i.e., $\mathbf{r_0} = (0, 0)$.

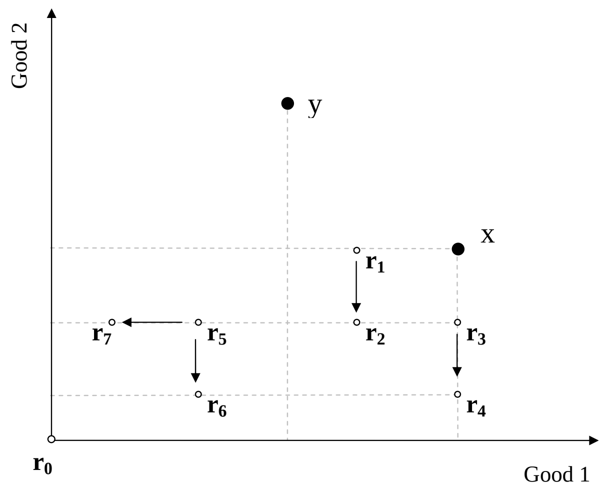


Figure 6: Experimental Environment

The reference points, $\mathbf{r_i}$ for $i = 1, \ldots, 4$, are positioned under the assumption that the agent prefers $\mathbf{y}$ over $\mathbf{x}$ when there is no reference point. (If the opposite holds, then these reference points would be placed symmetrically to the left of $\mathbf{y}$.) More specifically, we first derive each subject's preferences over $\mathbf{x}$ and $\mathbf{y}$ (at $\mathbf{r_0}$). If the option $\mathbf{y}(\mathbf{x})$ is preferred, than in another question[24] the third option, $\mathbf{r_i}$, which is dominated by the other alternative $\mathbf{x}(\mathbf{y})$, is introduced to the choice problem as their endowment/status quo.[25]

The locations of the other reference points ($\mathbf{r_i}$ for $i = 5, 6, 7$) are independent of the relative rankings of $\mathbf{x}$ and $\mathbf{y}$. While $\mathbf{r_i}$ for $i = 1, \ldots, 4$ are dominated by $\mathbf{x}$ but are not dominated by $\mathbf{y}$, the others are dominated by both $\mathbf{x}$ and $\mathbf{y}$. When subjects are

[23]Each box contains 3 chocolates, and can also be purchased from stores outside. It may be that the price of the chocolate box is approximately known to some of the subjects. Since we have a within-subjects design, this should not bias our experimental findings towards any particular theory of reference-dependence.

[24] This did not follow immediately.

[25] This design leaves more room for preference reversals, and hence yields a larger set of relevant data.

provided with a reference point ($\mathbf{r_i}$ for $i = 1, \ldots, 7$), they are asked whether to keep that or to change it for one of the two other alternatives, $\mathbf{x}$ or $\mathbf{y}$. Since all the reference points are dominated by $\mathbf{x}$ and/or $\mathbf{y}$, we would expect that they will never be chosen.

We are interested in examining the impact of moving the reference points in the direction of arrows as well as the impact of adding a reference point to the choice problem (see Figure 6). In order to do that we will repeat the same chocolate-money bundle three times corresponding to three different reference points, with one of them being the origin (no reference point).[26]

In our experiment, there were 5 sessions with approximately 20 subjects in each. Table 2 demonstrates the selected treatments in each session that lead us to test the models of reference-dependence. For example, in Session 1, the impact of changing the location of the reference point from $\mathbf{r_1}$ to $\mathbf{r_2}$, and from $\mathbf{r_3}$ to $\mathbf{r_4}$ as well as the impact of having a reference point on individual choice behavior are tested. The within-subjects design allows us to identify whether for a given subject one of the models could accommodate the subject's choice behavior.[27] So we will have a better understanding of the reference effect.

To get a more concrete idea of the design, consider the following questions used in the experiment that changes the location of the reference point from $\mathbf{r_0}$ to $\mathbf{r_1}$ and then to $\mathbf{r_2}$. As a first stage, the decision maker is offered to make a choice among the following two bundles: \$6.10 and 5 chocolate boxes versus \$7.90 and 2 chocolate boxes. If she prefers the first over the second bundle, then at a later stage of the experiment, the same decision maker will be given an endowment of \$7.90 and 1 chocolate box, which is dominated by \$7.90 and 2 chocolate boxes. Then, she is to make a choice on either to keep her endowment, or switch to either one of the two previously mentioned bundles. Figure 7 provides a graphical illustration of this question. The same question

[26] The order of the reference points changes from one session to another.

[27] One may object to this design, saying that individuals may try to be consistent in their choices and therefore this may reduce the occurrence of preference reversals. However, this should not have any effect on the comparison between the reference-dependent choice models. Moreover, it is unlikely that the subjects remember their previous choices, since these questions are separated from each other and, throughout the experiment, once subjects make their decisions, they cannot go back.

is repeated one last time for $\mathbf{r_2} = (\$7.30, 1)$. In the experiment subjects did not see the graphical representations. Appendix B provides a screenshot.

Table 2: Experimental Design

	Sessions				
	1	2	3	4	5
$(\mathbf{r_0}, \mathbf{r_1})$				✓	✓
$(\mathbf{r_0}, \mathbf{r_2})$	✓	✓	✓		✓
$(\mathbf{r_0}, \mathbf{r_5})$		✓	✓		
$(\mathbf{r_0}, \mathbf{r_1}, \mathbf{r_2})$	✓	✓		✓	
$(\mathbf{r_0}, \mathbf{r_3}, \mathbf{r_4})$	✓		✓	✓	
$(\mathbf{r_0}, \mathbf{r_5}, \mathbf{r_6})$		✓			✓
$(\mathbf{r_0}, \mathbf{r_5}, \mathbf{r_7})$			✓	✓	
# of subjects	20	20	20	19	20

Note that in the experiment, we create hypothetical reference points, by telling them that \$7.30 and 1 chocolate box are theirs to keep, i.e. we do not give them anything until the end of the experiment. However, while this should not affect the comparison between the reference-dependent models, the reference effect would only be stronger, had we endowed them with the bundles.[28]

We now turn to the theoretical predictions. The classical choice theory predicts that reference points, $\mathbf{r_i}$ for $i = 1, ..., 7$, do not affect the relative ranking of $\mathbf{x}$ and $\mathbf{y}$. All the reference-dependent models allow for a change in the relative ranking of alternatives when a reference point $\mathbf{r}_i$, $i = 1, ..., 4$, is added to the choice problem. However, models of reference-dependence make different predictions when a reference point $\mathbf{r}_i$, $i = 5, 6, 7$, is added to the choice problem. Moreover, when the location of the reference point is changed, reference-dependent models differ the most.

[28]Loewenstein and Adler (1995) show that hypothetical ownership creates less endowment effect. However, this doesn't mean that hypothetical ownership does not create reference-dependence. In fact, in a companion paper, Masatlioglu and Uler (2006), we show that a status quo has a stronger impact on individual choice behavior compared to a decoy option, where a decoy option is introduced without imposing an ownership.

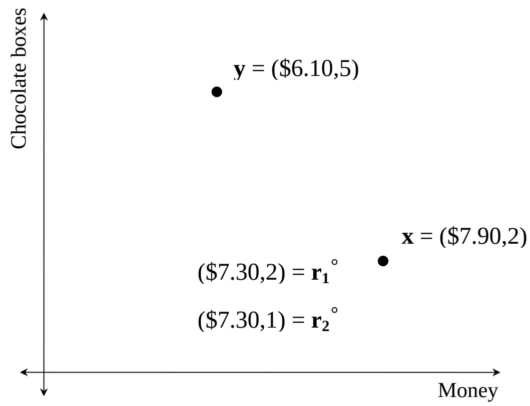


Figure 7: A Sample Question from the Experiment

Theoretical predictions of the reference-dependent models for switching the reference points are summarized in Table 3. These predictions are derived in a similar fashion to Section 3. The predictions presented in Table 3 are based on the assumption that option $\mathbf{y}$ is chosen over $\mathbf{x}$ when there is no reference point. In Table 3, "**-**" represents the case where models predict no change in the relative ranking of $\mathbf{y}$ and $\mathbf{x}$ after moving the reference point. We say a model "favors $\mathbf{x}$", indicated by "$\mathbf{x}$" in the table, if the new allocation of the reference point decreases the attractiveness of $\mathbf{y}$ relative to $\mathbf{x}$. Similarly, "favors $\mathbf{y}$" means that the attractiveness of $\mathbf{y}$ increases. Finally, "I" represents the cases where the models are indecisive, i.e., they have no particular prediction.

With help of Table 3, we can generalize these predictions of the models so that they do not depend on the initial preference among $\mathbf{x}$ and $\mathbf{y}$ with no reference point. Hence, we will use the following five predictions while analyzing the data. We use the following terminology: we say "a subject exhibits preference reversal at $\mathbf{r}$" if the subject reveals that their relative ranking of the two options changes from $\mathbf{r_0}$ to $\mathbf{r}$. When a reference point is dominated by the unchosen option but not the chosen one (($\mathbf{r_0} \to \mathbf{r}_i$), where $i = 1, ..., 4$), all the reference-dependent models allow preference reversal, i.e., we cannot distinguish between these models. However, this is not the case for ($\mathbf{r_0} \to \mathbf{r}_i$), where $i = 5, 6, 7$ (Group 1). Moreover, we provide the predictions of the models when the location of the reference point is changed (Group 2).

Table 3: Predictions of Reference-Dependent Models Under Consideration

		Tversky-Kahneman		Masatlioglu-Ok		
		CLA	LA	SQB	GSQB	PRD
Group 1	$\mathbf{r}_0 \to \mathbf{r}_5$	-	*I*	-	-	*I*
	$\mathbf{r}_0 \to \mathbf{r}_6$	-	*I*	-	-	*I*
	$\mathbf{r}_0 \to \mathbf{r}_7$	-	*I*	-	-	*I*
Group 2	$\mathbf{r_1} \to \mathbf{r}_2$	-	**x**	**y**	*I*	*I*
	$\mathbf{r}_3 \to \mathbf{r}_4$	-	**x**	**y**	*I*	**y**
	$\mathbf{r}_5 \to \mathbf{r}_6$	-	**x**	-	-	*I*
	$\mathbf{r}_5 \to \mathbf{r}_7$	-	**y**	-	-	*I*

I: "Indecisive" **-** : "no changes" **x**: "favors **x**" and **y**: "favors **y**"

1. When a reference point is dominated by both alternatives (Group 1), the CLA, SQB and GSQB models predict no preference reversal – the decision maker should stick with her earlier choice.[29] Therefore, comparing the choice behavior of agents when there is no reference point and when there is one ($\mathbf{r_5}$, $\mathbf{r_6}$, or $\mathbf{r_7}$) provides a very though test for the CLA, SQB and GSQB models. On the other hand, the other models do not make any particular predictions in this type of switches. These models, nevertheless, have strong explanatory power.

The following four predictions are related to Group 2.

2. The LA model predicts at least as many preference reversals at $\mathbf{r_2}$ as at $\mathbf{r_1}$. In contrast, the SQB model predicts the same amount or fewer preference reversals at $\mathbf{r_2}$ than at $\mathbf{r_1}$. The GSQB and PRD models are indecisive.

3. The LA model predicts at least as many preference reversals at $\mathbf{r_4}$ as at $\mathbf{r_3}$.

[29] We assume agents are not indifferent between any two consumption bundles. Of course, allowing for indifference improves the explanatory power of the CLA, SQB and GSQB models. However, then they lose their predictive powers, although the predictions of the other models are not affected from this.

In contrast, the SQB and PRD models predicts the same amount or fewer preference reversals at $\mathbf{r_2}$ than at $\mathbf{r_1}$. The GSQB model is indecisive.

4. Independent of the location of the reference points ($\mathbf{r_i}$, $i = 1, \ldots, 4$), the CLA model predicts no change in the preferences of subjects when the reference points are moved in a way described above.

5. The LA model predicts that $\mathbf{r_6}$ favors the option with more money compared to $\mathbf{r_5}$ and that $\mathbf{r_7}$ favors the option with more chocolate compared to $\mathbf{r_5}$. The CLA, SQB and GSQB models predict no change in preferences when the reference points are dominated by both alternatives; the PRD model is indecisive.

Another observation is that SQB and PRD models do not imply increasing, constant or diminishing sensitivity. Note that we do not test the effect of moving the reference point from $\mathbf{r_2}$ to $\mathbf{r_3}$. In this case the loss aversion assumption and the SQB axiom agree, and GSQB and PRD are indecisive. Therefore we cannot distinguish between the reference-dependent models.[30] Next, we report the experimental results.

4.2 Results

4.2.1 Explanatory Power of the Models

First, we explore to what extent the classical choice theory can accommodate our experimental data. To do this, we examine how many individuals' behavior is consistent with classical choice theory. Remember that each person is going through different treatments. We say an individual is consistent with the classical choice theory if her choices are consistent with this theory at all times. For example, if we see preference reversals at $\mathbf{r_2}$ compared to her choice with no reference point, then we say this individual displays a choice pattern inconsistent with classical choice theory.

[30] Although Tversky and Kahneman suggest that money spent to buy goods is not coded as a loss, Bateman et al. (2005) shows that loss aversion applies to any loss from the reference point, including money outlays. Also see Kalyanaram and Little (1994), Kalwani et al. (1990), Mayhew and Winer (1992), and Putler (1992).

What we find is that 52% of all subjects exhibit some reference-dependence. Put differently, roughly half of the time, we observe behavioral patterns inconsistent with classical choice theory. Our experimental findings do not contradict the results of Plott and Zeiler (2005, 2007). In our experiment, individual choices appear to be influenced by the reference points, even when the subjects do not choose the reference point itself. In other words, reference-dependence is not confined to the endowment effect in general.

Now, we focus our attention on reference-dependent models. Similarly, we say an individual is accommodated by a particular theory if her choices are consistent with this theory at all times.[31] For example, a subject's choice behavior cannot be explained by the CLA and SQB models if the subject displays a preference reversal at $\mathbf{r_2}$ but not at $\mathbf{r_1}$. This choice behavior is, nevertheless, consistent with the LA, GSQB and PRD models.

We see that the PRD and LA models explain approximately 90 percent of the participants (see Table 4). Out of 99 individuals, 86 individuals are consistent with both models, and 5 subjects cannot be explained by any model.[32] While there are 6 participants who can be explained with PRD but not LA, only 2 participants can be accommodated by LA but not PRD. Wilcoxon test shows that this difference is not statistically significant ($p = 0.16$). The SQB model can explain the behavior of 67 subjects. There are 7 participants that can be explained by the GSQB model but not by the SQB model. The GSQB model performs significantly better than the SQB model ($p = 0.01$). 64 participants can be explained by the CLA model. The SQB model performs slightly better than the CLA model ($p = 0.08$). Only 48 people are consistent with the predictions of the classical choice theory.[33] Finally, the CLA

[31] Our qualitative results do not change much when we allow for subjects to make one mistake. When we allow for more than one mistake, even the classical choice theory explains more than 70% of the data.

[32] 3 of these subjects picked dominated options, and 2 of them behaved consistent with the PRD in some cases and the LA in some other situations.

[33] Out of these 48 people 43 of them always choose an option with more money. One reason for this could be that they focus on maximizing their monetary earnings from the experiment and they don't care their chocolate earnings. Although this behavior is consistent with the classical choice theory, it doesn't imply that these subjects are not reference-dependent in a different environment which does not include money.

model accommodates the data significantly better than the classical choice theory ($p = 0.005$).[34]

Table 4: Explanatory Power of the Models (in percentages)

Tversky-Kahneman		Masatlioglu-Ok			Classical
CLA	LA	SQB	GSQB	PRD	Theory
65	89	68	75	93	48

Next we investigate the impact of moving the reference point from one location to the other where the models differ the most. Table 5 summarizes the explanatory power of the models for each treatment. We report the percentages of subjects that can be explained by each model. It can be seen that the PRD and LA have strong explanatory powers. Although the CLA, SQB and GSQB models can explain less data compared to these models, they can accommodate significantly more data compared to the classical choice theory.

Table 5: Explanatory Power of the Models When Reference Point Is Moved (in %)

		Tversky-Kahneman		Masatlioglu-Ok			Classical
	N	CLA	LA	SQB	GSQB	PRD	Theory
$(\mathbf{r}_0, \mathbf{r}_1, \mathbf{r}_2)$	59	78	93	81	97	97	56
$(\mathbf{r}_0, \mathbf{r}_3, \mathbf{r}_4)$	59	90	97	93	100	93	69
$(\mathbf{r}_0, \mathbf{r}_5, \mathbf{r}_6)$	40	75	95	75	75	100	75
$(\mathbf{r}_0, \mathbf{r}_5, \mathbf{r}_7)$	39	67	92	67	67	100	67

We now exclude the 3 subjects that picked dominated options from the analysis. First we consider the movement from $\mathbf{r_1}$ to $\mathbf{r_2}$ (in treatment $(\mathbf{r_0}, \mathbf{r_1}, \mathbf{r_2})$). After we elicit the preference between $\mathbf{x}$ and $\mathbf{y}$ when there is no reference point, we find out that 15 out of 57 subjects reveal opposite preferences between the two options whenever $\mathbf{r_1}$ is

[34] When we allow for one mistake, the explanatory powers of CLA, LA, SQB, GSQB and PRD are 80%, 98%, 81%, 86%, 99% respectively. The explanatory power of the classical choice theory is only 63%. Reference dependent models perform significantly better than the classical choice theory (p-values are zero).

the new reference point (see Table 6). This number becomes 22 when the reference point is $\mathbf{r_2}$. This finding supports the LA model since this model predicts that the number of preference reversals at $\mathbf{r_2}$ should be at least as many as $\mathbf{r_1}$. In order to test the significance of this difference, we do the following for each individual. At each choice problem, we put 1 when there exists a preference reversal and 0 when there is no change in her choice. When we test the equality of the matched pairs of observations by using the Wilcoxon test, we see that this difference is significant at the 5% level ($p = 0.035$). This supports the diminishing sensitivity hypothesis of T-K at least for this particular case, while the GSQB and PRD models will also be consistent with it. On the other hand, the SQB and CLA models are not able to explain this result.

Table 6: Preference Reversals Under Different Treatments

	$\mathbf{r_1} \to \mathbf{r}_2$		$\mathbf{r_3} \to \mathbf{r_4}$		$\mathbf{r_5} \to \mathbf{r_6}$		$\mathbf{r_5} \to \mathbf{r_7}$	
# of subjects	57		58		38		38	
	$\mathbf{r_1}$	$\mathbf{r}_2$	$\mathbf{r_3}$	$\mathbf{r_4}$	$\mathbf{r_5}$	$\mathbf{r_6}$	$\mathbf{r_5}$	$\mathbf{r_7}$
No Switch	42	35	44	42	32	30	25	27
Switch	15	22	14	16	6	8	11	9

Note that when we constructed Table 4, we assumed individuals are not indifferent between the two options when there is no reference point. One might argue that switching from one option to the other can simply be attributed to subjects being indifferent between these two options, not due to the reference effect. However, our analysis for the case of moving the reference point from $\mathbf{r_1}$ to $\mathbf{r_2}$ controls for that, where classical choice theory makes correct predictions only 57% of the time (Table 6). If our results had driven by the indifference argument, then we should have observed no statically significant difference in the number of preference reversals at $\mathbf{r_1}$ and $\mathbf{r_2}$. In contrast, our analysis shows that we can strongly reject the hypothesis that the number of preference reversals are the same.

When the location of the reference point is moved from $\mathbf{r_3}$ to $\mathbf{r_4}$, we find that 14 and 16 subjects out of 58 switch their decisions at $\mathbf{r_3}$ and $\mathbf{r_4}$, respectively. Although there are more preference reversals at $\mathbf{r_4}$, this difference is not significant ($p = 0.41$). Therefore, all models predict equally well.

Now we look at the region where the reference points are strictly dominated by the two alternatives and investigate the impact of adding a reference point. Compared to $\mathbf{r_0}$ there are 6 switches at $\mathbf{r_5}$ and 8 switches at $\mathbf{r_6}$ out of the 38 cases in the ($\mathbf{r_0}$, $\mathbf{r_5}$, $\mathbf{r_6}$) treatment. Similarly, for the ($\mathbf{r_0}$, $\mathbf{r_5}$, $\mathbf{r_7}$) treatment, we see that there are 11 switches at $\mathbf{r_5}$, and at $\mathbf{r_7}$ there are 9 switches compared to $\mathbf{r_0}$. These preference reversals are not consistent with the SQB, GSQB and CLA models (if we assume the subjects are not indifferent between the given two options).

In addition we investigate moving the reference point from $\mathbf{r_5}$ to $\mathbf{r_6}$ (treatment ($\mathbf{r_0}$, $\mathbf{r_5}$, $\mathbf{r_6}$)). At $\mathbf{r_5}$ there are 30 subjects (out of 38) who choose the option with more money. The number of subjects who choose the option with more money does not change as the reference point is moved to $\mathbf{r_6}$. Similarly we look at switching the reference point from $\mathbf{r_5}$ to $\mathbf{r_7}$ (treatment ($\mathbf{r_0}$, $\mathbf{r_5}$, $\mathbf{r_7}$)). Out of 38 people 4 people choose the option with more chocolate at $\mathbf{r_5}$ and also at $\mathbf{r_7}$. These results are consistent with all reference-dependent models under consideration, although the CLA, SQB and GSQB models make better predictions for these cases.

4.2.2 Measuring the Predictive Success Rates for Each Model

In this section we take into account the "predictive power" of the models. Although the CLA, SQB and classical choice theory do not have high explanatory power, they have strong predictive power. We compare the models by using a measure of predictive success which was first introduced by Selten and Krischker (1983).[35] Selten and Krischker defines the measure as the difference between the hit rate and area:

$$m = r - a$$

[35] See Selten (1991) for a detailed explanation of this measure.

where m = measure of predictive success, r = hit rate, and a = area. The hit rate is the percentage of correct predictions and the area is the relative size of the predicted region within the set of all possible outcomes. Since the PRD and LA cannot always make precise predictions, they have relatively high area.[36] This may imply a very low measure of predictive success for these models compared to the CLA, SQB or classical choice theory. In our experiment, the area of theories is different for each session since subjects go through different treatments. Therefore, we compute the predictive success rates of each model for each session.

Table 7: Measure of Predictive Success

	Tversky-Kahneman		Masatlioglu-Ok			Classical
	CLA	LA	SQB	GSQB	PRD	Theory
Session 1	0.67	0.88	0.68	0.87	0.90	0.40
Session 2	0.43	0.75	0.44	0.54	0.81	0.25
Session 3	0.63	0.85	0.69	0.69	0.88	0.50
Session 4	0.49	0.76	0.57	0.56	0.75	0.42
Session 5	0.87	0.90	0.87	0.87	0.87	0.85
Average	0.62	0.83	0.65	0.71	0.84	0.48

Table 7 shows that the LA and PRD have a higher predictive success compared to other models of reference-dependence. Moreover, the predictive success rates of all of the reference-dependent models are superior in every treatment to that of the classical choice theory.

5 Conclusion

Our experimental data shows that only around 48 percent of the data is consistent with the predictions of classical choice theory. In our experiments, we do not observe the endowment effect or the status quo bias. However, we found strong evidence on the

[36] However, note that when we say these models are indecisive, we don't mean that these models don't restrict the choice in any way. In fact, they never allow for the dominated option to be chosen.

existence of the reference effect: reference points alter one's choices even when agents do not choose the reference point itself. Therefore, we conclude that reference-dependence can exist without the endowment effect or status quo bias. Our experimental design can also distinguish between the models of reference-dependence. We first provide a framework which allows us to study the leading reference-dependent models in a unified manner, thereby identifying their differences with respect to structure, methodology and predictive power. Then, we show that these models provide different predictions regarding the reference effect. We find that both the PRD and LA models explain approximately 90 percent of the data. These models are superior to the CLA, SQB, GSBB and classical choice theory even when we take into account the predictive power of the models.

Our paper has implications regarding the economics policies that impose default options such as retirement plans. Beshears et al. (2006) shows that while 86 % of employees who were subject to automatic enrollment have some of their assets allocated to the default fund, this number is only 10 % for employees who were not subject to automatic enrollment (they were hired and initiated savings plan participation before automatic enrollment). They conclude that the automatic enrollment tends to anchor employee asset allocations on the automatic enrollment default asset allocation. Our findings confirm that default options may have a strong impact on the choices, even when they are not chosen. Therefore, one should take the reference effect into account while setting up default options, such as with 401(k) plans.

Appendix

A. Theoretical Predictions

Tversky and Kahneman's Loss Aversion Models

We demonstrate the theoretical predictions for the case of switching the reference point from $\mathbf{r_1}$ to $\mathbf{r_2}$. In the LA model, the utility gains of $\mathbf{x}$ and $\mathbf{y}$ from switching are $U_{\mathbf{r_2}}(\mathbf{x}) - U_{\mathbf{r_1}}(\mathbf{x}) = g_2(u_2(x_2) - u_2(r_{22}))$ and $U_{\mathbf{r_2}}(\mathbf{y}) - U_{\mathbf{r_1}}(\mathbf{y}) = g_2(u_2(y_2) - u_2(r_{22})) - g_2(u_2(y_2) - u_2(r_{12}))$, respectively. All utility differences are in terms of the second dimension since $\mathbf{r}_{11} = \mathbf{r}_{21}$, and are gains rather than losses since $u_2(y_2) > u_2(r_{12}) = u_2(x_2) > u_2(r_{22}) > 0$. Note that there exists $1 > \alpha > 0$ such that $u_2(x_2) - u_2(r_{22}) = \alpha(u_2(y_2) - u_2(r_{22}))$.

The concavity of $g_i|_{\mathbb{R}_+}$[37] implies that

$$\begin{aligned} g_2(u_2(x_2) - u_2(r_{22})) &= g_2(\alpha(u_2(y_2) - u_2(r_{22}))) \\ &\geq g_2(u_2(y_2) - u_2(r_{22})) - g_2((1-\alpha)(u_2(y_2) - u_2(r_{22}))) \\ &= g_2(u_2(y_2) - u_2(r_{22})) - g_2(u_2(y_2) - u_2(r_{12})), \end{aligned}$$

since $u_2(x_2) = u_2(r_{12})$ and $u_2(x_2) - u_2(r_{22}) = \alpha(u_2(y_2) - u_2(r_{22}))$ together imply that $u_2(y_2) - u_2(r_{12}) = (1-\alpha)(u_2(y_2) - u_2(r_{22}))$. Hence we have

$$U_{\mathbf{r}_2}(\mathbf{x}) - U_{\mathbf{r}_1}(\mathbf{x}) \geq U_{\mathbf{r}_2}(\mathbf{y}) - U_{\mathbf{r}_1}(\mathbf{y}).$$

This means that switching from $\mathbf{r}_1$ to $\mathbf{r}_2$ favors $\mathbf{x}$.[38]

In the CLA model, we have $U_{\mathbf{r}_2}(\mathbf{x}) - U_{\mathbf{r}_1}(\mathbf{x}) = u_2(x_2) - u_2(r_{22}) = u_2(y_2) - u_2(r_{22}) - u_2(y_2) + u_2(r_{12}) = U_{\mathbf{r}_2}(\mathbf{y}) - U_{\mathbf{r}_1}(\mathbf{y})$. Therefore, there is no change in the relative ranking

[37] If f is an increasing concave function and $f(0) = 0$, then we have $f(\alpha x) \geq \alpha f(x)$ for all $1 \geq \alpha \geq 0$ and $x \geq 0$. Then we have $f(\alpha x) \geq \alpha f(x) = f(x) - (1-\alpha)f(x) \geq f(x) - f((1-\alpha)x)$.

[38] Where we take the reference alternative as given, Köszegi and Rabin (2006) takes the following form of reference-dependent utility function:

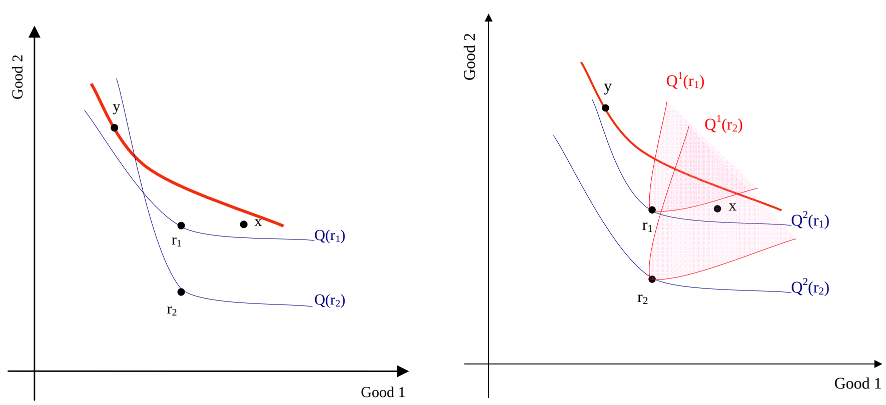
$$U_{\mathbf{r}}(\mathbf{x}) = \sum_i u_i(x_i) + \sum_i g(u_i(x_i) - u_i(r_i))$$

where the first component represents the consumption utility and the second component is the gain-loss utility. Even though this functional form is different than the LA model, the effect of moving the reference point on the relative ranking of two alternatives is the same among these models.

of $\mathbf{x}$ and $\mathbf{y}$ as we move the reference point.

Masatlioglu and Ok's Models

As we have discussed earlier, the SQB model favors $\mathbf{y}$ when the reference point moves from $\mathbf{r}_1$ to $\mathbf{r_2}$. Next, we investigate the predictions of the GSQB and PRD models. Since the SQB model is a special case of both the GSQB and PRD models ($\mathcal{Q}$ satisfies Condition (iii) and $\mathcal{Q} = \mathcal{Q}^1 = \mathcal{Q}^2$, respectively), both of them also favor $\mathbf{y}$ for some cases. The question is then, "Is it possible to find some cases where both of them favors $\mathbf{x}$?" The answer is yes.



(a) The GSQB model (b) The PRD model

Figure 8: A Graphical Demonstration for the GSQB and PRD Models

To show that the SQB model favors $\mathbf{y}$ above, we utilize the condition (iii). Since the GSQB model does not require this condition, it also allows cases where the decision maker chooses $\mathbf{x}$ in the same situation. To illustrate this, assume that the decision maker prefers $\mathbf{y}$ to $\mathbf{x}$ both when the reference point is $\mathbf{r}_1$ and there is no reference point. Moreover, since the GSQB model does not satisfy Condition (iii), it is possible to have $\mathbf{x} \in \mathcal{Q}(\mathbf{r}_2)$ and $\mathbf{y} \notin \mathcal{Q}(\mathbf{r}_2)$, which is illustrated in Figure 8(a). Hence $\mathbf{x}$ is preferred to $\mathbf{y}$ when $\mathbf{r}_2$ is the reference point since $\mathbf{x}$ is the only element in $\mathcal{Q}(\mathbf{r}_2)\setminus\{\mathbf{r}_2\}$. After all, it is plausible that $\mathbf{x}$ appears better when one looks at the situation "from $\mathbf{r_2}$." Therefore, the GSQB model might favor $\mathbf{x}$.

Now, we illustrate the predictions of the PRD model when the reference point moves from $\mathbf{r}_1$ to $\mathbf{r_2}$. We show the possibility that while $\mathbf{y}$ is preferred to $\mathbf{x}$ when the reference point is $\mathbf{r_1}$, $\mathbf{x}$ is preferred to $\mathbf{y}$ when the reference point is $\mathbf{r}_2$. To demonstrate this, consider a case where $\mathbf{x}, \mathbf{y} \in \mathcal{Q}^2(\mathbf{r_1}) \setminus \mathcal{Q}^1(\mathbf{r_1})$, $\mathbf{x} \in \mathcal{Q}^1(\mathbf{r}_2)$ and $\mathbf{y} \notin \mathcal{Q}^1(\mathbf{r_2})$ (see Figure 8(b)).[39]

First, consider the budget set $B_1 = \{\mathbf{r_1}, \mathbf{x}, \mathbf{y}\}$ at reference point $\mathbf{r_1}$. Since $\{\mathbf{r_1}\} = B_1 \cap \mathcal{Q}^1(\mathbf{r_1})$, (5) implies that the decision maker solves her optimization problem by utilizing $\mathcal{Q}^2(\mathbf{r}_1)$, that is, $\max_{\mathbf{z} \in B_1 \cap \mathcal{Q}^2(\mathbf{r_1})} U(\mathbf{z})$. Note that $U(\mathbf{y}) > U(\mathbf{x})$ since $\mathbf{x}$ lies below the indifference curve passing through $\mathbf{y}$, as shown in Figure 8(b). This fact together with $\{\mathbf{x}, \mathbf{y}\} \subset B_1 \cap \mathcal{Q}^2(\mathbf{r_1})$ imply that, given budget set B_1, $\mathbf{y}$ is selected over $\mathbf{x}$ when the reference point is $\mathbf{r_1}$. Next, we consider the budget set $B_2 = \{\mathbf{r_2}, \mathbf{x}, \mathbf{y}\}$ at reference point $\mathbf{r_2}$. Since $\{\mathbf{r_2}\} \neq B_2 \cap \mathcal{Q}^1(\mathbf{r_2})$, (5) implies that her optimization problem is:

$$\max_{\mathbf{z} \in B_2 \cap \mathcal{Q}^1(\mathbf{r_2})} U(\mathbf{z}).$$

Since $\{\mathbf{r_2}, \mathbf{x}\} = B_2 \cap \mathcal{Q}^1(\mathbf{r}_2)$, $\mathbf{x}$ is chosen over $\mathbf{y}$ when the reference point is $\mathbf{r_2}$. Therefore, for this case, the PRD model favors $\mathbf{x}$. Therefore, we conclude that the GSQB and PRD models have no predictive power when the reference point moves from $\mathbf{r}_1$ to $\mathbf{r_2}$.

B. A Screenshot

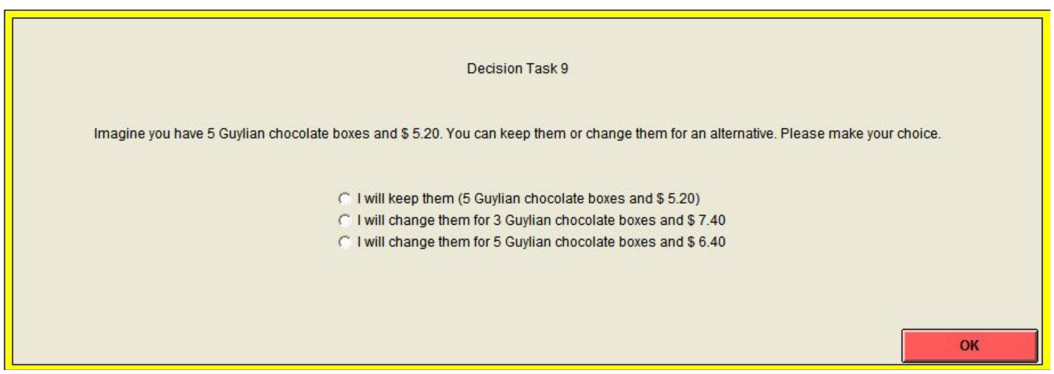


Figure 9: A screenshot from the experiment

[39]While the thick line passing through $\mathbf{y}$ represents the indifference curve of U, the (shaded) regions above the thin lines passing through $\mathbf{r_1}$ and $\mathbf{r_2}$ are the psychological constraint sets, $\mathcal{Q}^2(\mathbf{r_1})$ ($\mathcal{Q}^1(\mathbf{r}_1)$) and $\mathcal{Q}^2(\mathbf{r}_2)$ ($\mathcal{Q}^1(\mathbf{r}_2)$), respectively.

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