Exogenous endowment - Endogenous reference point*

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Abstract

We develop a reference dependent model with an initial endowment and in a world where alternatives are grouped into categories. The model creates a link between the agent's exogenous endowment and her endogenous reference point. The actual reference point is the best feasible alternative, according to the agent's preferences, which belongs to her endowment's category. This endogenous reference point induces a constraint set from which the final choice is made according to utility maximization. The model gives rise to *category bias* which generalizes the status quo bias by attracting the agent to her endowment's category but not necessarily to the endowment itself. We show that it accommodates recent experimental findings regarding the presence and absence of status quo bias in the realm of uncertainty. We apply the model to a stylized financial setup and show that it may lead to a risk premium even with risk neutral agents.

Keywords: Categories, Status Quo Bias, Reference Dependence, Risk Premium, Revealed Preference.
JEL Codes: D03, D11.

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1 Introduction

Many empirical studies in behavioral economics, psychology and marketing have established that individuals' decisions depend on reference points. One type of reference effects is triggered by the decision maker's possession of a good, i.e., her status quo option or endowment. The status quo bias (Samuelson and Zeckhauser, 1988) and the endowment effect (Thaler, 1980) are two examples where agents' choices and evaluations of goods are influenced by the alternative which they currently own. Reference dependent behavior may also feature in choice situations with no designated reference alternative. One example is the attraction effect (Huber et al., 1982) where the addition of an alternative which is clearly dominated by one alternative in the choice set may shift preferences in the direction of the dominating item. The presence of a non-feasible alternative which the agent can observe but not choose, has also been found to affect choices, a phenomenon known as the phantom effect (Pratkanis and Farquhar, 1992).

While the evidence supporting reference dependence is large, relatively little is known about what determines the reference point. Following the experimental findings, the theoretical literature has largely developed along two paths. According to one approach, the reference point is the agent's exogenous endowment or status quo option. Recent models which take this approach are Ortoleva (2010), Masatlioglu and Ok (2014) and Riella and Teper (2014). The status quo has also been used in many applications of the loss aversion model (Kahneman and Tversky, 1991) as the point from which the agent contemplates gains and losses. According to the second approach, the reference point is determined endogenously either by the decision maker herself, as in Barbos (2010), Guney et al. (2015) and Ok et al. (2015), or by the economic environment as in Koszegi and Rabin (2006).

In this paper we propose to link the two approaches together in a way which seems natural in various choice contexts. The agent's endowment affects the agent's preferences but only insofar as "directing" her to the actual reference point, a point which is similar to her endowment and therefore easily identified in the choice set. To illustrate, consider an agent shopping for a laptop and suppose she currently owns a Mac. As she enters the store, she immediately recognizes a newer version of a Mac which she likes better than her own. This immediate recognition comes from the fact that all Mac laptops share similar features and she is therefore able to identify the best one on the spot. From this point on, if there is a reference point influencing her decisions, it is more likely to be the newly identified Mac than the one she owns. After all, by this stage of the decision process, she has probably made a mental note that she will not be keeping her old Mac and at the very least switch to the new one. Thus the new Mac becomes the agent's new point of perspective from which other alternatives may be considered.

The link from the endowment to the reference point is made possible through added structure we impose on the grand space of alternatives - the structure of disjoint categories. As in the above example, alternatives which belong to the same category will have the interpretation of being easy to compare, as opposed to alternatives which belong to different categories.[1]

Absent an endowment our agent acts as a standard rational decision maker who maximizes a utility function over the set of feasible alternatives. However, given an endowment, our agent follows a 3-step procedure. In the first step, she determines the reference point by identifying the best feasible alternative which belongs to the endowment's category. This alternative, which is immediately recognized due to the ease of comparison within categories, serves as her endogenous reference point while the exogenous endowment becomes irrelevant for the remainder of the choice procedure.

In the second step, the reference effects kick in. The newly identified reference point induces a set of alternatives which the agent considers for the final stage of the decision process. Alternatives that do not belong to this set are excluded from any further consideration. We will think of this set as a "psychological constraint" that may lead the agent to disregard alternatives which would have been chosen absent an endowment. Finally, from this set the agent chooses the best feasible alternative according to her endowment-free utility function. The model imposes a monotonic structure on these constraint sets: Within categories, the better the alternative, the smaller the constraint set it generates. Put differently and more intuitively, our agent considers fewer alternatives for her final choice, the more content she is with her current reference point.

Figure I illustrates this procedure (notice that higher utility corresponds to a higher physical position of the alternative in the figure). Absent an endowment the agent chooses alternative s which carries the highest utility in the entire set. Now suppose that the agent has an initial endowment, denoted by x. In the shaded region we have all alternatives which belong to the endowment's category. The agent first identifies z, which is the best feasible alternative in this category. In turn, z induces a constraint set which contains all alternatives which are deemed "choosable" from its perspective (the striped area). Finally, the agent chooses the best feasible alternative within that set, denoted by s'.

Our model is derived using the revealed preference method. The main behavioral assumption of the model is called *Categorical Referential Equivalence (CRE)*. This novel postulate formally states that, for any set S and any two alternatives x and y in S that belong to the same category, we have $c(S, x) = c(S, y)$. In other words, any two alternatives that share the same category, have the same effect on choice when serving as the endowment. We also impose the *Weak Axiom of Revealed Preference (WARP)* for a given endowment, which translates into the strong rationality structure exhibited by our decision maker. Two more axioms state the extent to which the agent tends to stick to his status quo option. Our main result shows that these four axioms are satisfied if and only if the agent follows the 3-step choice procedure described above.

The model generalizes the well known status quo bias, the behavioral tendency of individuals to stick to their initial endowment (Samuelson and Zeckhauser, 1988). It allows

[1] Such an interpretation is well accepted in the psychology literature as noted by Schwartz (2000): "Within each category, it may be relatively easy to express preferences. Between categories, however, expressing preferences is more problematic."

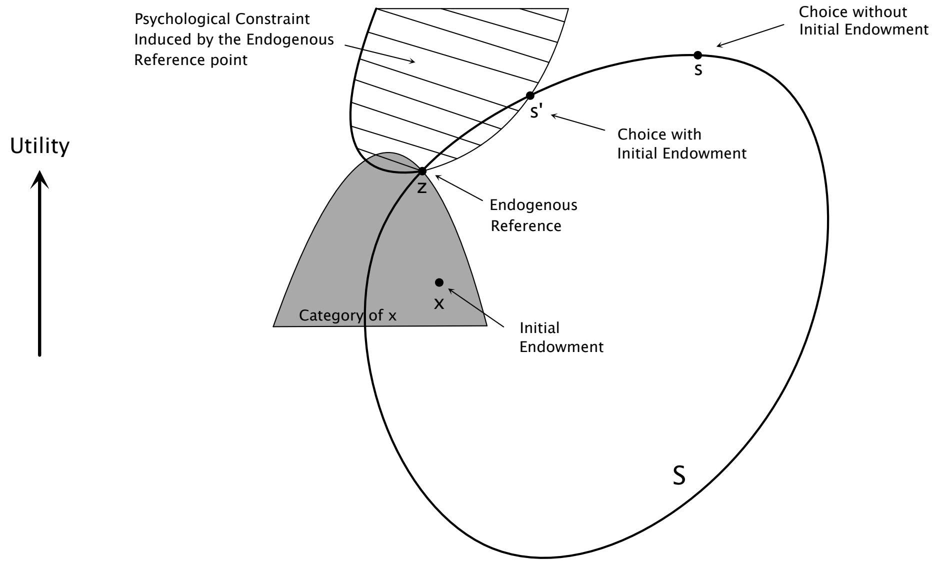

Figure I: Choice Procedure

for such behavior in choice problems where the endowment is also the best feasible option in its category. However, when this is not the case, it predicts what we dub *category bias*, i.e., a tendency to choose alternatives which are "similar" to the endowment (belong to the same category) but not the endowment itself.

One novel prediction which arises from our model, is that when facing alternatives which belong to a single category, our agent will exhibit no behavioral biases. The reason is that she is immediately able to spot the best alternative within a category and in the absence of alternatives from other categories, this step reveals her final choice. In these situations our agent will act as a completely rational agent.

This prediction is in line with recent studies which report mixed evidence regarding the emergence of status quo bias in the world of uncertainty. In a controlled lab environment, Roca et al. (2006) find that when the endowment is ambiguous (a gamble with unspecified probabilities) while the alternative is risky (a gamble with known and specified probabilities) status quo bias is present. Maltz and Romagnoli (2015) support these findings and report the same result when the options' roles are reversed, i.e., the endowment is risky while the alternative is ambiguous. However, they also find that when both options are risky, or both ambiguous, the bias is absent. If one categorizes alternatives in this context into risky gambles and ambiguous gambles, our model is able to accurately predict this pattern of choice behavior. Moreover, other models of choice with initial endowment, such as those based on the loss aversion model of Kahneman and Tversky (1991) and the incomplete preference models a-la Bewley (1986) are unable to accommodate these findings. We further discuss this choice pattern and its relation to our model in section 3.

The suggested procedure also opens a channel for risk premium even in the presence of a risk neutral agent. In a stylized financial application we assume that the agent views her options as grouped into *uncertain investments* and *riskless investments*. If her money is initially deposited in the checking account she may view a riskless investment with a higher interest rate than her checking account as her reference point. In section 4 we show how this may lead the agent to consider only uncertain alternatives which are "very attractive", generating a risk premium in the process.

Our work may be viewed as a bridge between the exogenous reference point approach and the endogenous reference formation approach mentioned above. The closest to our work belongs to the former, and has been introduced by Masatlioglu and Ok (2014). As in our work, their agent is a constrained maximizer but the identity of the reference point that generates the constraint set is different. In their model it is the exogenous endowment, while in ours it typically is not. Specifically, in the presence of at least one alternative which belongs to the endowment's category and is preferred to the endowment by the agent, the reference points in the two models will differ. In these circumstances, the generated constraint sets will also differ, leading in turn to different predictions (see section 2.5).

We also relate to work which introduces categories into the decision making process. Some recent examples include Barbos (2010), Manzini and Mariotti (2012) and Furtado et al. (2015). These models differ significantly from ours as they do not incorporate the agent's endowment into the decision problem and are mainly focused on menu effects in choice. As in Barbos (2010) categories in our setup are exogenous.[2] Thus, we assume that on top of alternatives' intrinsic value and specific characteristics they are also grouped together into disjoint categories by some shared features, such as brand name in our laptop illustration, or country of origin in other applications.[3]

In most contexts mentioned above, categories seem natural and easy to observe. In others however, it may be impossible for an outside investigator to predict a priori what are the categories that the agent views (for example, the color of the product or the brand). In such circumstances one may learn about the categories from the agent's behavior by examining the model's main behavioral postulate, i.e., the CRE axiom. Alternatively, the agent may simply be asked whether some classification of the space of alternatives comes to mind. Once the relevant categories for our decision maker have been sorted out, the model may be applied to derive predictions.

Importantly, even if one finds difficulties in identifying the "correct" categories or if there seem to be no shared features across alternatives, the model may still be applied using

[2] In Barbos (2010) the categories may overlap while in our model they constitute a partition of the space.

[3] This view of categories as separate, disjoint entities is well in line with the classical views of categorization in psychology and philosophy. For a review of theories of categorization in psychology, see for example Smith and Medin (1981) and Komatsu (1992).

the finest partition, i.e., assuming that every category is a singleton. In fact, in this case, the model reduces to the model of Masatlioglu and Ok (2014) and provides predictions which are very well suited to a world in which alternatives do not share common features. Thus, our added structure expands on the existing literature and nests the standard approach (in the sense of no similarity structure on the space of alternatives) as a special case.

The paper proceeds as follows. In section 2 we lay the foundations and state the main result. Later in this section we provide examples and a comparison which highlights the differences between this model and the one derived by Masatlioglu and Ok (2014). Section 3 examines the model's predictions in light of recent findings regarding status quo bias under uncertainty. In section 4 we consider a financial setting, and illustrate how the link to the endogenous reference point can generate a risk premium even when the agent is risk neutral. Section 5 concludes.

2 Model

2.1 The basic framework

Let X be the grand set of alternatives and assume $|X| < \infty$. The members of X are denoted as x, y, z, etc.. We assume there exists an exogenous partition on the set X, denoted by $X = X_1 \sqcup X_2, ..., \sqcup X_n$ for some $n \in \mathbb{N}$. Each cell in the partition should be thought of as a category of goods, i.e., a group of alternatives linked by some characteristic. For every $z \in X$ we denote by X_z the cell in the partition which z belongs to.

Following Masatlioglu and Ok (2014) we designate $\Diamond$ to denote an object which does not belong to X. We let Ω_X denote the set of all nonempty subsets of X. By a choice problem we mean a list (S, σ) where $S \in \Omega_X$ and $\sigma \in S \cup \{\Diamond\}$.[4] The set of all choice problems is denoted by $\mathcal{C}(X)$. The interpretation of a choice problem (S, x) with $x \in S$ is that the decision maker has to choose an alternative from S while currently endowed with $x \in S$. Alternatively, a choice problem $(S, \Diamond)$ is interpreted as a choice from S absent an endowment.[5]

By a choice correspondence in this setup we mean a function $c : \mathcal{C}(X) \to \Omega_X$, such that

$$c(S, \sigma) \subseteq S \quad \text{for every} \quad (S, \sigma) \in \mathcal{C}(X).$$

[4]Note that by this formulation, the endowment is always available for choice.

[5]The symbol $\Diamond$ is convenient as it allows us to describe a choice problem with or without an endowment in a unified manner.

2.2 Axioms

We introduce four axioms. The first is the classical rationality requirement which imposes structure on the agent's behavior given a fixed endowment.

Weak Axiom of Revealed Preference (WARP). *For any* (S,σ) *and* (T,σ) *in* $\mathcal{C}(X)$,

$$c(S,\sigma)\cap T = c(T,\sigma)$$

provided that $T\subseteq S$ *and* $c(S,\sigma)\cap T\neq\emptyset$.

This axiom is a consistency requirement imposed on the agent's behavior and it warrants that utility maximization takes place for any given endowment. Notice that in the absence of an endowment this is the exact same behavioral postulate as the one stated in the classical model of rational choice. Our next axiom links choices across different endowment structures. Specifically, it requires the agent to exhibit a (weak) tendency to choose her endowment.

Weak Status Quo Bias (WSQB). *For any* $x,y\in X$,

$$y\in c(\{x,y\},x) \quad \textit{implies} \quad y\in c(\{x,y\},\Diamond)$$

and

$$y\in c(\{x,y\},\Diamond) \quad \textit{implies} \quad y\in c(\{x,y\},y.)$$

This property was originally introduced by Masatlioglu and Ok (2014). It is a natural postulate to impose on an agent who may be vulnerable to the status quo bias. Put simply, it states that serving as an endowment can only enhance an alternative's possibility of being chosen over another. More specifically, if y is chosen over x when x is the status quo option then it must also be chosen over x in the absence of a status quo option. The second part is similar - if y is revealed preferred to x without a status quo option then it must also be revealed preferred to it when acting as the status quo.[6] It is important to note that the axiom is stated in a "weak" fashion which allows the decision maker to exhibit, or not to exhibit status quo bias, depending on the alternatives at hand. Specifically, a rational agent who completely ignores her endowment will satisfy this axiom.

The first two axioms are independent of the underlying category structure imposed on the space of alternatives. Our next behavioral assumption, which we consider the main axiom of our model, links choice behavior across different endowments from the same category. Put succinctly, it states that two alternatives which belong to the same category will have the same effect on choice when serving as an endowment.

[6] For a more elaborate discussion of this axiom see Masatlioglu and Ok (2014).

Categorical Referential Equivalence (CRE). *For any given* $S \in \Omega_X$,

$$c(S, x) = c(S, y)$$

provided that $x, y \in S \cap X_x$.

According to CRE, whether the agent is shopping for a laptop while currently endowed with an old MAC or in the possession of a newer MAC should have no effect on her final choice, as long as both MACs are available for choice. If WSQB is viewed as weakly highlighting the status quo option in the decision maker's mind then, combined with CRE, it implies that this option weakly highlights its category rather than itself. This axiom is at the heart of the model and the representation to follow and is novel as far as we know.

The last axiom describes situations in which the presence of a status quo option would not have any effect on choice. Roughly, it states that if the status quo option belongs to a "bad" enough category the decision maker will disregard it.

Categorical Status Quo Irrelevance (CSQI). *For any given* (S, x), *suppose that* $c(T, x) \nsubseteq X_x$ *for every subset* T *of* S *such that* $[S \cap X_x] \subset T$. *Then* $c(S, x) = c(S, \Diamond)$.

Suppose the decision maker faces a choice problem (S, x). Moreover, suppose that for any subset T of S, that contains all alternatives in S which belong to x's category and at least one alternative which does not, the decision maker chooses at least one alternative outside the category of x. According to CSQI, the choice from (S, x) will be the same as the choice from $(S, \Diamond)$. In other words, if the agent chooses "outside" her endowment's category whenever possible, her endowment would be irrelevant.[7]

Remark 1. The four axioms are logically independent as proven in Appendix B.

2.3 Partial Characterization

We start by stating a lemma en route to our main representation theorem.

Lemma 1 *Let* X *be a non-empty finite set such that* $X = X_1 \sqcup X_2, ..., \sqcup X_n$ *for some* $n \in \mathbb{N}$. *Let* c *be a choice correspondence on* $\mathcal{C}(X)$. *If* c *satisfies WARP, WSQB, CRE and CSQI, then there exists a (utility) function* $U : X \to \mathbb{R}$ *and a self-correspondence* Q *on* X *such that for every* $S \in \Omega_X$

$$c(S, \Diamond) = \arg\max U(S) \qquad \text{(i)}$$

[7]This axiom is related in its flavor to axiom SQI in Masatlioglu and Ok (2014). Their axiom roughly states that if the endowment is revealed to be "bad enough" the agent will ignore it. Instead, CSQI states that the agent will ignore her endowment if its category is revealed to be "bad enough". As it turns out, neither axiom implies the other. See Appendix C for details.

and for every $(S, x) \in \mathcal{C}(X)$,

$$c(S, x) = \arg\max U(S \cap Q(z)) \tag{ii}$$

where $z \in \arg\max U(S \cap X_x)$. *Moreover, for any* $x_1, x_2 \in X$ *such that* $x_1 \in X_{x_2}$

$$U(x_1) \geq U(x_2) \iff Q(x_1) \subseteq Q(x_2). \tag{iii}$$

Lemma 1 provides sufficient conditions for the choice procedure outlined in the introduction. To understand the representation, let c be a choice correspondence on $\mathcal{C}(X)$, U a real function on X, Q a self-correspondence on X and suppose that the representation holds for any choice problem $(S, \sigma) \in \mathcal{C}(X)$. Facing a choice problem without an initial endowment, the agent settles her problem by maximizing the utility function U. That is, in this case, her final choice is the solution to the problem:

$$\text{Maximize } U(\omega) \text{ subject to } \omega \in S.$$

In turn, when facing a choice problem with a given status quo option, say (S, x) the agent proceeds in steps. First, she identifies the best alternative in S that belongs to the same category as x which we denote by z. We can think of the decision maker as starting off by making an "easy" evaluation, i.e., only considering alternatives which are (according to our category interpretation) easy to compare to x. Formally, z is the solution to the following maximization problem:

$$\text{Maximize } U(\omega) \text{ subject to } \omega \in S \cap X_x.$$

Once this step is complete the agent ignores her initial endowment and treats z as her endogenous reference point. This point induces a "psychological constraint set" $Q(z)$ outside of which all alternatives are excluded from any further consideration. Put differently, the agent forms the set $S \cap Q(z)$ from which the final choice will be made. (This set is non-empty since $z \in S$ and by (ii) and the fact that $\{x\} = c(\{x\}, x)$ we have $x \in Q(x)$ for every $x \in X$).

Finally, the agent evaluates all alternatives in the set $S \cap Q(z)$ and chooses the best one according to her reference free utility function U. Formally:

$$\text{Maximize } U(\omega) \text{ subject to } \omega \in S \cap Q(z).$$

If only z belongs to $S \cap Q(z)$ then the decision maker will pick z, thus exhibiting "category bias". If in addition $z = x$, i.e., x is the best alternative in $S \cap X_x$, the agent will exhibit status quo bias. On the other hand, if there are other alternatives in $S \cap Q(z)$ besides z, she may or may not choose within her endowment's category.[8]

[8] This may be a good stage to mention the "as-if" nature of our exercise. In some cases the agent may actually eliminate alternatives outside some consideration set. However, even if the agent does not reason in those terms, if her behavior abides to our axioms one can describe her choices as if following the procedure of Lemma 1.

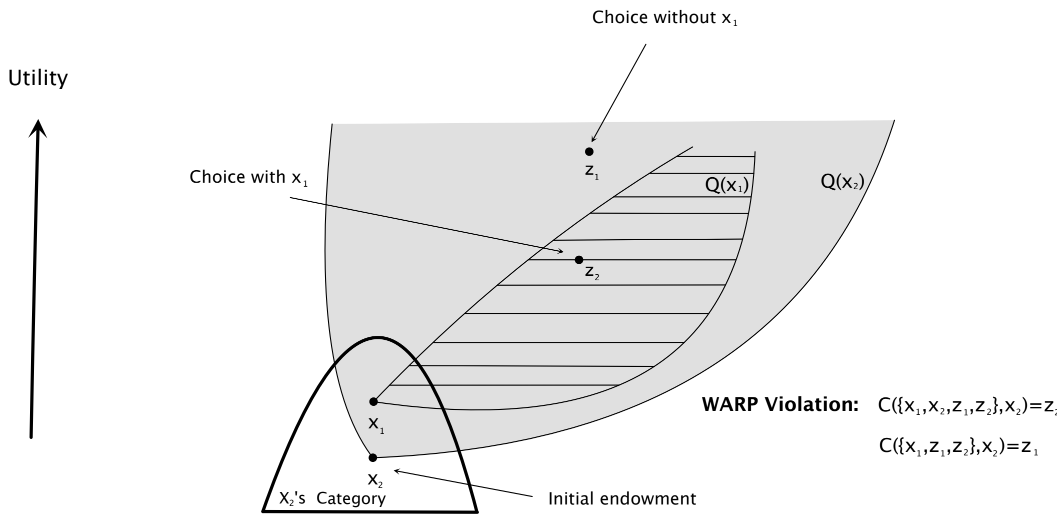

Figure II: Violation of WARP

Property (iii) imposes structure on the relationship between the constraint set Q and the utility function U. It states that within a category, the constraint sets are monotonically ordered. Specifically, they shrink as one considers reference points with higher utility. This highlights the intuition that there will be fewer alternatives to consider the more satisfied the agent is with her reference.[9]

In summary, the role of the exogenous endowment x amounts to highlighting the category to which it belongs and "directing" the decision maker to the best feasible alternative in that category to be treated as an endogenous reference point. The role of the endogenous reference point z is to generate the constraint set $Q(z)$. The reference effects kick in whenever the constraint set eliminates alternatives which are utility superior to z.

2.4 Characterization of the Main Model

Lemma 1 provides sufficient conditions for the existence of U, Q and the representation given by equations (i),(ii) and property (iii) to hold. However, one can easily provide an example to show that they are not necessary for this type of representation. In fact, the only axiom that is not satisfied by this representation is WARP as shown by the following example illustrated in Figure II.

[9]This property may be formally stated as within category negative comonotonicity of U and Q.

Consider a world of four alternatives grouped into two categories. Formally, $X = \{x_1, x_2\} \sqcup \{z_1, z_2\}$. As can be seen in the figure, the utility ranking of the alternatives is $U(z_1) > U(z_2) > U(x_1) > U(x_2)$ (as in Figure I, a higher location on the figure translates to a higher utility). In addition $Q(x_2) = X$ and $Q(x_1) = \{x_1, z_2\}$. In this case we have $c(\{x_1, x_2, z_1, z_2\}, x_2) = \{z_2\}$, but removing x_1 from the choice set leads to $c(\{x_1, z_1, z_2\}, x_2) = \{z_1\}$ violating WARP in the process.

This example illustrates some type of non-monotonicity in the set $Q(x)$ which is allowed by our choice procedure. Although the monotonicity implied by property (iii) of Lemma 1 is satisfied (indeed, $Q(x_1) \subset Q(x_2)$) there is a violation of monotonicity with respect to alternatives which are considered from the point of view of x_1. While $z_2 \in Q(x_1)$ we see that $z_1 \notin Q(x_1)$ although z_1 is better than z_2 in the endowment-free sense. Moreover, z_1 is considered from the point of view of $x_2 \in X_{x_1}$ which, roughly speaking, means that from the "point of view of the category of x_1" the agent does consider z_1.

In this section we impose a condition which strengthens the relationship between U and Q, and rules out this type of behavior. It states that, if $z \notin X_x$ is considered from the point of view of x then so will other alternatives outside of X_x as long as: (1) they carry higher utility than z, and (2) they are considered from the point of view of *some* alternative in x's category. Formally, suppose that, as in Lemma 1, U is a real function on X and Q is a self-correspondence on X.

Definition 1 *We say that Q is U-**monotonic with respect to dissimilar alternatives** if for every $x_1 \in X$ and $z_1, z_2 \notin X_{x_1}$ such that:*

1. $U(z_1) \geq U(z_2)$
2. $z_2 \in Q(x_1)$
3. $z_1 \in Q(x_2)$ *for some* $x_2 \in X_{x_1}$,

we have $z_1 \in Q(x_1)$.

This condition, though slightly lengthy to spell out, is in fact quite intuitive. To illustrate, suppose our agent considers a small size jeep from the perspective of her family car where our categories are {*jeeps*} and {*family cars*}. Would she also consider a large jeep from this perspective? If the large jeep is better than the small one in the endowment-free sense *and* would be considered from the point of view of *some* family car, then the answer is yes. Thus the definition requires that the large jeep not only carries higher utility then the small one for it to be considered but also that it is deemed choosable from the "family cars category's perspective." We are now ready to state our main result.

Theorem 1 *Let X be a non-empty finite set such that $X = X_1 \sqcup X_2, ..., \sqcup X_n$ for some $n \in \mathbb{N}$. Let c be a choice correspondence on $\mathcal{C}(X)$. Then c satisfies WARP, WSQB, CRE and CSQI if, and only if, there exists a (utility) function $U : X \to \mathbb{R}$ and a self-correspondence Q on X such that for every $S \in \Omega_X$*

$$c(S, \Diamond) = \arg\max U(S) \tag{1}$$

and for every $(S, x) \in \mathcal{C}(X)$,

$$c(S, x) = \arg\max U(S \cap Q(z)) \tag{2}$$

where $z \in \arg\max U(S \cap X_x)$ and

(a) For any $x_1, x_2 \in X$ such that $x_1 \in X_{x_2}$

$$U(x_1) \geq U(x_2) \iff Q(x_1) \subseteq Q(x_2).$$

(b) Q is U-monotonic with respect to dissimilar alternatives.

The representation given in Theorem 1 describes the exact same choice procedure as in Lemma 1. The only difference (except for it being a characterization) is that it imposes more structure on the relationship between U and Q. First, as in Lemma 1 they satisfy negative comonotonicity within categories, i.e., the better the alternative the smaller the constraint set it induces. Second, it requires the type of monotonicity of Q with respect to U given by Definition 1.

Remark 2. [Illustration of properties (*a*) and (*b*)] Another way to view the structure imposed by properties (a) and (b) on the constraint set Q is the following: Let $x \in X$. Starting within the category X_x, $Q(x)$ may be thought of as the upper contour set of x, that is $Q(x) \cap X_x = x^{\uparrow} \cap X_x$, where $x^{\uparrow} = \{z \in X | U(z) \geq U(x)\}$. Now consider x_1 which is the worst alternative according to U in X_x. By property (a), $Q(x_1)$ is the largest constraint set generated by any member of X_x. $Q(x) \cap X_x^c$ is a subset of $Q(x_1) \cap X_x^c$ with the following structure: It contains all alternatives in $Q(x_1) \cap X_x^c$ with utility above a certain threshold. In Figure III we provide an illustration for the structure of the Q sets **outside the category of** x. The largest set is generated by x_1 (the area striped by the horizontal lines) while $Q(x) \cap X_x^c = \{z \in Q(x_1) \cap X_x^c | U(z) \geq U(z_1)\}$ (the striped area above the horizontal line passing through z_1). Finally, $Q(x_2) \cap X_x^c = \{z \in Q(x_1) \cap X_x^c | U(z) \geq U(z_2)\}$ is the smallest constraint set (the area striped with 3 different lines) . Notice that alternatives y_1, y_2 and y_3 that do not belong to $Q(x_1) \cap X_x^c$ do not belong to the other constraint sets either, no matter how high their utility level.

Remark 3. [Minimal structure on (U, Q)] Properties (a) and (b) define pairs (U, Q) which represent a choice correspondence satisfying the above axioms through equations (1)

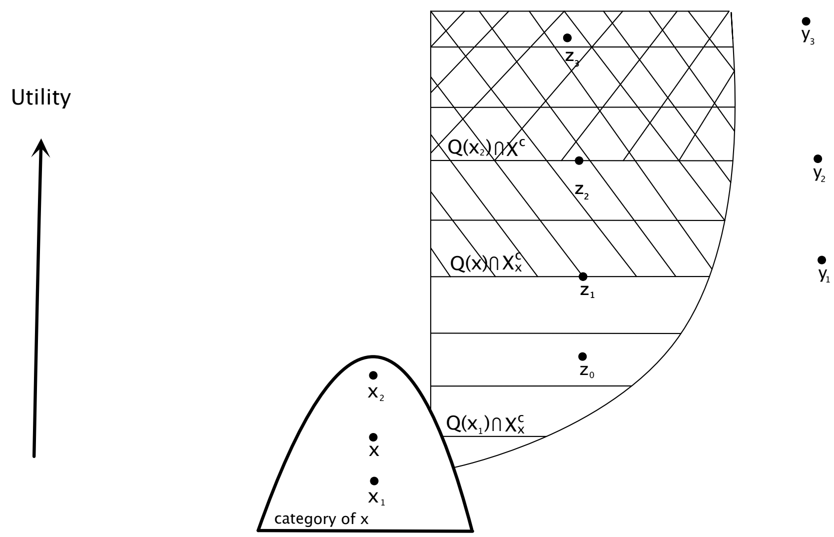

Figure III: Structure of constraint set Q outside the reference point's category

and (2). Yet, one can require less demanding properties which define a larger set of such pairs. The weakest properties required from such a "representing pair" are the following (property b remains unchanged):

(a') For any $x_1, x_2 \in X$ such that $x_1 \in X_{x_2}$

$$U(x_1) \geq U(x_2) \implies Q(x_1) \cap X_{x_2}^c \cap x_1^{\uparrow} \subseteq Q(x_2) \cap X_{x_2}^c \cap x_2^{\uparrow}$$

where $x^{\uparrow} = \{z \in X | U(z) \geq U(x)\}$, for every $x \in X$.

(a") $Q(x) \supseteq \{x' \in X_x | U(x') = U(x)\}$, for every $x \in X$.

(b) Q is U-monotonic with respect to dissimilar alternatives.

Property (*a'*) states that the comonotonic relationship between U and Q is essential only outside the reference point's category and may be weakened to a one-sided implication. Moreover, alternatives with utility levels below that of the reference point may be added to the constraint set with no effect on choice (as the final stage of the procedure is utility maximization, such alternatives are later ignored by the agent). Property (*a"*) states that within the reference point's category, the only alternatives which must be included in the constraint set are those with the same utility as the reference point. Since the reference point is the maximal feasible option in its category, adding alternatives with lower (or higher) utility within that category, will have no effect on the actual constraint.[10]

Remark 4. [Uniqueness] The weaker conditions discussed in the above remark lead us to the uniqueness structure of the representation: Let U and U' be two real functions on X, and let Q and Q' be two self-correspondences on X such that the representation described in Theorem 1 holds, for both (U, Q) and (U', Q'). Then, and only then, there is a strictly increasing map $f : U(X) \to \mathbb{R}$ such that $U' = f \circ U$ and,

- $Q(x) \cap X_x^c \cap x^{\uparrow} = Q'(x) \cap X_x^c \cap x^{\uparrow},\ \forall x \in X.$
- $Q(x) \cap Q'(x) \supseteq \{x' \in X_x | U(x') = U(x)\},\ \forall x \in X.$

In other words, the utility function is unique up to a strictly positive transformation, as in standard utility representations. For any reference point, the constraint sets must agree outside its category when restricted to alternatives ranked higher than the reference itself. In addition they must both contain all alternatives within the reference's category which carry the same utility as the reference point.

2.5 A Comparison to Masatlioglu and Ok (2014)

As discussed earlier, the above model (referred to in this section as the *category bias model*) shares similar features with the model of Masatlioglu and Ok (2014) (henceforth the *status quo bias model* or in short *SQB model*). In this section we briefly describe the main representation of the SQB model and outline the similarities as well as main distinctions between the two models.

The decision maker in the SQB Model behaves as if she has a (utility) function U and a self-correspondence Q on X and her choices from any choice problem (S, σ) are described by:

$$c(S, \lozenge) = \arg\max U(S) \tag{3}$$

and,

$$c(S, x) = \arg\max U(S \cap Q(x)) \tag{4}$$

Both models represent choices as arising from simple utility maximization in the absence of an endowment and they both share the constrained maximization step in the presence of one. The main difference between the two lies in which alternative generates the constraint set. In the SQB Model it is the exogenous endowment while in our model it is the endogenous reference point which may or may not be the endowment. When facing choice sets in which the exogenous endowment is the best feasible alternative (in

[10] In Theorem 1 we chose the most concise and intuitive properties (in our opinion) which describe the essential structure of the relationship between U and Q even though they are not the minimal ones required.

the endowment-free sense) in its category, it will also be the alternative that generates the constraint set. Specifically, this occurs when it is the only available alternative in that category. Thus, in the case of the finest partition on X the models coincide. However, when a utility improving alternative in its category is available, our decision maker will abandon her exogenous endowment and treat a different alternative as her reference point. The constraint set will be induced by that reference point rather than the endowment.

The category bias model also adds structure to the functional representation. Specifically, within a category, the better the alternative - the smaller the constraint set it generates. As discussed earlier, this property has an intuitive flavor: the more content the agent with her current reference, the less alternatives she will consider from its perspective.

The models make different predictions in the presence of a non-trivial partition on X. To illustrate, consider a decision maker facing three job opportunities: An academic position in a top university (A), an academic position in a small university (a) and a consultant position at a private firm (P). The categories in this simplified example will naturally be *academic jobs* and *non-academic jobs*. Assume that when the agent considers the positions while unemployed she ranks the private firm on top, then the more prestige academic job followed by the small university.

Suppose further that when the agent is working at the small university, she feels drawn to academia and reveals it by choosing (A) from these three options. Given the above, what would the agent choose when currently at the small university and facing an offer only from the private firm?

According to both models the first ranking reveals that $U(P) > U(A) > U(a)$. According to the SQB Model, that combined with the second choice is only compatible with (P) not being considered from the point of view of (a), i.e., $P \notin Q(a)$. This implies the academic job at the small university would be chosen over the consultant position if only the two were available. Formally,

$$c(\{a, P\}, a) = \{a\}.$$

This observation highlights a certain rigidity of the SQB Model. If the less prestige academic position, (a), highlights academia so that the agent reverses her choices between (A) and (P) compared to the choice when unemployed, it must cause the same type of reversal between (a) and (P). This seems quite unreasonable in situations in which the endowment is an "inferior option" in the utility sense which nevertheless generates a liking to alternatives of similar nature. The added category structure proposed here, allows this attraction to alternatives of similar nature without leading to the less plausible choice reversal. Specifically, the category bias model breaks the link between the two choice reversals since the constraint set is generated by the academic job at the top university (A) rather than by (a). Specifically, the agent disregards (P), from the point of view of the highly prestige academic job (A) which belongs to the same category (academia) as her current position. Thus, after observing the second choice we may only conclude that

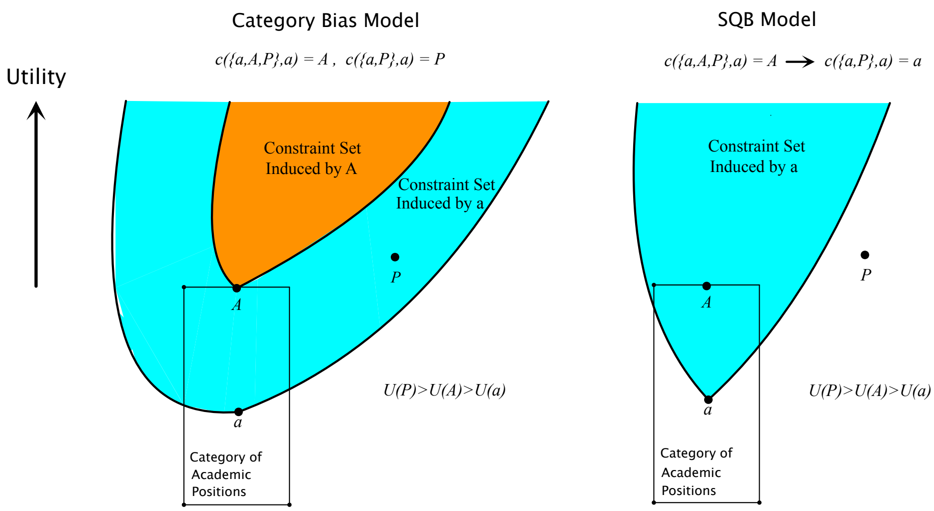

Figure IV: SQB Model and Category Bias Model

$P \notin Q(A)$. Hence, it is completely plausible that $P \in Q(a)$, in line with the monotonic structure of the constraint sets $[Q(A) \subseteq Q(a)]$. In this case, our model predicts

$$c(\{a, P\}, a) = \{P\}.$$

Thus, the category bias model allows to relax the rigidity of the SQB Model through the first step of the choice procedure, namely the link between the exogenous endowment and the endogenous reference point. It is only from the latter's perspective that some alternatives are being excluded from the final maximization stage. Figure IV illustrates the different constraint sets implied by the above choices according to the two models.

It is important to note that even if we add the category structure to the SQB Model and impose that for every alternative $x \in X$ we have $X_x \subseteq Q(x)$ we will still obtain the same rigidity in terms of the predictions described above. This is due to the fact that the agent's ranking when unemployed alongside her choice when employed in (a) would still imply $P \notin Q(a)$. Thus, the main difference between the two models is generated by the first step of the choice procedure rather than simply the added category structure of our framework.

2.6 Examples

This section presents a few examples that illustrate the type of choice behavior allowed by our model.

Example 1. *(Rational Choice)* A decision maker who is not vulnerable to any reference effects and simply maximizes utility can be described by our model. In fact, we can describe such an agent by imposing two different restrictions - one on the exogenous partition, the other on the endogenous constraint set.

- **Example 1.1** *(Coarsest Partition Rational Choice)* Consider the coarsest exogenous partition on the grand set X where all alternatives belong to a single category. Suppose the agent faces choice problem (S, x). In the first step of her choice procedure, she identifies the best feasible alternative in x's category, say alternative z, which in this example is the best alternative overall in S. Since $z \in Q(z)$, our agent will consider z in her final maximization stage (perhaps alongside other alternatives) and choose it as she would absent an endowment.

- **Example 1.2** *(Largest Constraint Set Rational Choice)* Our agent may also act as a utility maximizer when the partition on X contains more than one category. This may be the case if her constraint set is so large that she considers the whole space X from the viewpoint of every alternative. Formally, we describe such behavior by setting $Q(x) := X$, for every $x \in X$. Here, the endogenous reference has no bite in terms of choice since the decision maker deems all alternatives choosable prior to arriving at her final choice.

Example 2. *(No Extreme Status Quo Bias)* Our decision maker cannot exhibit extreme status quo bias, i.e., $c(S, x) = \{x\}$ for every choice problem (S, x). To this end, consider two alternatives in the same category x_1 and x_2 and assume $U(x_1) > U(x_2)$.[11] If the agent faces the problem (S, x_2) where $x_1 \in S$, she will never keep x_2 as her final choice. Rather, she will choose from $S \cap Q(z)$, where $z \in X_{x_1}$ and $U(z) \geq U(x_1)$. Since $z \in Q(z)$, x_2 will not be chosen at her final maximization stage.[12]

Example 3. *(Brand Loyalty / Switching Costs)* A natural interpretation of exogenous categories in our framework is that of brand names within a specific product market (goods of the same brand are easier to compare due to their similar features while across brands the comparison may be harder). Given this interpretation, our model gives rise to psychological switching costs where some goods of a competing brand may have been chosen before the

[11] This is without loss of generality. If $U(x_1) = U(x_2)$ in this example, the agent will still not end up choosing her endowment alone.

[12] The SQB model of Masatlioglu and Ok (2014) allows as a special case for extreme status quo type of behavior, hence this example is another illustration of the difference between the two models in the presence of a non-trivial partition.

agent's initial purchase but may not be considered ex post. This naturally leads to brand loyalty, i.e., individuals' tendency to repurchase products of the same brand over and over again. Notice the agent may well switch among different goods (thus not exhibiting status quo bias) but she is more likely to stick to her current brand.

Example 4. *(Extreme Category Bias)* Consider a decision maker who is extremely vulnerable to category bias. Such an agent may be described by our model when setting $Q(x) \subseteq X_x$ for every $x \in X$, which implies she would never leave her endowment's category. In the context of our previous example, such a consumer would be 100 percent loyal to her brand.

Example 5. *(No Cycles)* Our choice model does not allow the agent to exhibit cycles. For instance, for any distinct alternatives x, y and z, the agent cannot make the following choices: $\{y\} = c(\{x, y\}, x), z \in c(\{y, z\}, y)$ and $x \in c(\{x, z\}, z)$. For, if she does, these statements would entail $U(y) > U(x)$, $U(z) \geq U(y)$ and $U(x) \geq U(z)$, yielding a contradiction. Note that we reach this contradiction regardless of the category structure on the space. Thus, a decision maker described by our model exhibits a certain level of rationality which prevents her from exhibiting cyclic choices.[13]

3 Status Quo Bias Under Uncertainty: Findings and Predictions

The status quo bias (SQB) is a well known behavioral phenomenon originally introduced by Samuelson and Zeckhauser (1988) which describes decision makers' tendency to not give up their initial endowment. Over the past 30 years evidence for this bias has emerged from a wide range of markets and for different types of goods.[14]

Despite the abundance of evidence in support of the bias, some experimental studies have shown that its emergence is context dependent. One example comes from the endowment effect literature in the world of uncertainty. In this literature the bias takes the form of a gap between the minimum compensation demanded by an agent for a good that she owns and the maximum price she is willing to pay for the same good (Thaler, 1980). Many studies report this gap for risky lotteries, i.e., gambles which pay monetary outcomes with

[13]Notice that the choices $c(\{x, y\}, x) = \{x\}, c(\{y, z\}, y) = \{y\}$, and $c(\{x, z\}, z) = \{z\}$ are compatible with our model. However, this is not considered a cycle because the decision maker always keeps her endowment. We consider a cycle in this setup when the decision maker switches away from her status quo option in different choice problems ending up with the same alternative she originally possessed.

[14]See among many others: Knetsch (1989) as well as Knetsch and Wong (2009) who study the phenomenon in the lab using everyday ordinary goods, Madrian and Shea (2001) and Choi et al. (2004) for a close examination of 401(K) retirement plans, Johnson and Goldstein (2003) for a study on organ donations and Kempf and Ruenzi (2006) for evidence from mutual fund markets.

known probabilities, as well as for ambiguous bets, i.e., gambles which pay monetary payoffs contingent on realizations of states which have no specified probabilities.[15] However, as one would expect, such a gap does not arise in evaluations of fixed monetary payoffs as shown by Kahneman et al. (1991).

More recently, Maltz and Romagnoli (2015) test directly for SQB in the world of uncertainty and find that when the endowment and the alternative are risky lotteries, the bias is absent.[16] They also report its absence when both alternatives are ambiguous bets. However, they find that when the endowment is risky and the alternative ambiguous, or vice versa, the bias emerges, a finding supported by Roca et al. (2006). Table I summarizes these experimental findings alongside those from the endowment effect literature. It reports whether SQB is present or absent for all combinations of the type of endowment and alternative in the world of uncertainty.[17] The table reveals a pattern which can be described using the notion of categories: when the endowment and alternative belong to the same category, i.e., monetary payoffs, risky lotteries or ambiguous bets, SQB is absent. When they belong to different categories, the bias emerges.

The model suggested in this paper is able to predict these findings using the interpretation of categories suggested above. Facing choice problems in which alternatives belong to the same category, our agent is able to compare options easily and arrives at her final choice unaffected by her endowment. However, when the choice set contains alternatives from different categories, comparisons are no longer so simple. In such contexts, a reference point arises and induces a constraint set for consideration. When there are only two feasible alternatives (the endowment and another alternative) which belong to different categories, as in the experimental SQB literature, the reference point is, in fact, the endowment itself. Therefore, the constraint set induced by it may very well lead the agent to exhibit SQB.

Other well known paradigms of choice with initial endowment are unable to predict the pattern observed in Table I. Specifically, models based on the loss aversion approach by Kahneman and Tversky (1979, 1991),where losses loom larger than gains, typically predict the bias in each of the table's entries. Alternatively, models of incomplete preferences in the spirit of Bewley (1986) predict a bias only in the presence of ambiguity.[18] Thus, they would fail to predict the bias when the endowment is a monetary payoff and the alternative

[15] See for example Knetsch and Sinden (1984), Eisenberger and Weber (1995) and Isoni et al. (2011).

[16] Dean (2008) and Ren (2014), who study the effect of the size of the choice set on SQB, also find that for small choice sets consisting of risky lotteries the bias is weak and sometimes absent.

[17] One has to be slightly careful in interpreting evidence of an endowment effect for gambles as status quo bias between gambles and monetary payoffs. The reason is that when studying the endowment effect for a gamble subjects are typically asked how much they would pay to purchase the gamble or how much they would accept to give it up. However, there is no "neutral" frame in which subjects are simply asked to choose between a monetary amount and the gamble. As pointed out by Kahneman et al. (1991) the gap is mostly (but not entirely) due to the higher evaluation of owners rather than a lower evaluation of the non-owners. In this table we interpret these findings as evidence of at least some disparity arising in both types of frames compared to the neutral one.

[18] For example the models by Ortoleva (2010) and Mihm and Ozbek (2012).

		Alternative		
		Monetary Payoff	**Risky Lottery**	**Ambiguous Bet**
	Monetary Payoff	*NO SQB*	*SQB*	*SQB*
SQ	**Risky Lottery**	*SQB*	*NO SQB*	*SQB*
	Ambiguous Bet	*SQB*	*SQB*	*NO SQB*

Experimental evidence from the endowment effect literature and SQB experiments. The row and column represent the type of status quo option (SQ) and alternative respectively. Each entry specifies whether SQB was found for that SQ-Alternative pair.

Table I: SQB Findings under Uncertianty

a risky lottery and vice versa. They would also fail to predict the absence of the bias in the all-ambiguous bottom right entry of the table.[19]

4 An Application: A Novel Source of Risk Premium

We now turn to apply our representation to the analysis of a stylized financial setup.[20] In this example we will describe an agent who not only follows the procedure described in Theorem 1 but also has more structure on her constraint sets. This structure has been developed by Ortoleva (2010) in his model accounting for SQB under uncertainty. His model describes a constrained maximizer who takes her endogenous endowment as her reference point, very much like the SQB model of Masatlioglu and Ok (2014). However, his setup uses a more structured space which translates into added structure on the constraint set. In his paper, he uses the example we are about to borrow to show how a status quo biased agent may generate risk premium even if she is risk neutral as long as she is "pessimistic enough" in a manner to be described below. Using our model with categories, we will show that such premium may be generated for a risk neutral agent even if we relax the degree of pessimism.

Consider an economy in which there is one risk neutral representative agent (with $U(x) = x$), a government bond and a stock. There are two possible states of the world:

[19] For a more elaborate discussion regarding these findings and their relation to the two types of approaches see Maltz and Romagnoli (2015).

[20] The example setup is taken from an earlier version of Ortoleva (2010) available at http://gtcenter.org/Archive/Conf07/Downloads/Conf/Ortoleva498.pdf.

s_g, the good state, and s_b, the bad state. The bond is traded for the price p_b and yields, with certainty, \$$B$. The stock, priced at p_{st}, yields payoffs \$$M$ and \$$m$, respectively, in the two states of the world, where $m < B < M$. The representative agent currently holds her money in the checking account which yields no interest and can choose whether to buy the stock, the bond, or not to invest (keep the money in the checking account). To keep the analysis simple, we assume that only one of these three actions can be taken. We take the categories in this setup to be *uncertain investments* (stock) and *riskless investments* (Bond and Checking).

More formally, define $S := \{s_g, s_b\}$; $X := \mathbb{R}$ and $\mathcal{F}$ the set of all acts, that is the set of all functions from S into X. We focus on the preferences over three acts: buy the stock, st; buy the bond, b; keep the money in the checking account, c. For any given M, B, m, p_{st}, p_b, these acts are defined as: $c(s) := 0$ for all $s \in S$; $b(s) := B - p_b$ for all $s \in S$; $st(s_g) := M - p_{st}$ and $st(s_b) := m - p_{st}$. Suppose there is a market prior ρ (that the agent uses when choosing absent an endowment) such that $\rho(s_g)M + \rho(s_b)m = B$.

The agent makes choices according to the procedure described in Theorem 1 with additional structure on her correspondence Q. Formally, the agent has a set Π of possible priors over the states which are interpreted as a set of possible models of the world in her mind. We assume the agent uses ρ absent an endowment and we note that according to Ortoleva (2010) we have that $\rho \in \Pi$.[21] For any act f the agent's constraint set is defined by:

$$Q(f) := \{g \in \mathcal{F} | E_\pi(g) > E_\pi(f) \text{ for all } \pi \in \Pi\}$$

where E is the expectation operator. Suppose f is the act serving as the agent's endogenous reference point. Before arriving at her final choice, she considers only those investments that generate a higher expected payoff than f according to every model of the world she has in mind. If no available investment satisfies this condition, she chooses f. If some investments satisfy this condition, she chooses the best among them according to the market prior ρ. Define as $\underline{\pi}$ the prior in Π which assigns the lowest probability to s_g.

We will now analyze the agent's choices in this environment given that

$$p_b < \underline{\pi}(s_g)M + \underline{\pi}(s_b)m < B \tag{5}$$

First notice that since $B > p_b$ the bond is a better investment than leaving the money in the checking account. Second, recall that the agent's exogenous endowment is the checking account but her endogenous reference is the bond since it is the best feasible alternative in the endowment's category (of riskless investments). In order for the stock to be traded it must be considered from the bond's perspective. If $p_b = p_{st}$ we have from (5)

$$\underline{\pi}(s_g)M + \underline{\pi}(s_b)m - p_{st} < B - p_b$$

[21] Moreover, his representation ensures that ρ is in the relative interior of Π.

which means, in other words, $s \notin Q(b)$ and the stock would not be traded.

Therefore if the stock is traded in the market we must have $s \in Q(b)$ which in our context translates into

$$\underline{\pi}(s_g)M + \underline{\pi}(s_b)m - p_{st} > B - p_b$$

which implies $p_{st} < p_b$. The implication is that the stock must be priced below the price of the bond for it to be sold although the bond and the stock have the same expected payoff according to the prior ρ which the agent uses when she has no status quo option.

Let us now compute the risk premium in this economy. For the bond, the rate of return is simply $r_b := \frac{B-p_b}{p_b}$. The stock's rate of return according to the market is

$$r_{st} := \frac{\rho(s_g)M + \rho(s_b)m - p_{st}}{p_{st}} = \frac{B - p_{st}}{p_{st}}.$$

As $p_{st} < p_b$, we obtain $r_{st} > r_b$. Thus we find a positive risk premium in this economy, even though the agent is risk neutral.

As noted earlier, a risk premium in this setting can also be generated by the model of Ortoleva (2010). The difference is that in his model, the agent needs to exhibit a higher degree of pessimism than that ascribed to her by (5). Specifically, in order to deliver a premium in that model, one needs to change (5) into

$$\underline{\pi}(s_g)M + \underline{\pi}(s_b)m < p_b < B \tag{6}$$

This implies that in the case of $p_b = p_{st}$, the agent would not choose the stock over the checking account even if those were the only available options. Thus, her $\underline{\pi}$ needs to assign a lower probability to s_g than that required by (5). In other words, Ortoleva (2010) shows how the channel of SQB may lead to risk premium given a sufficiently high degree of pessimism as reflected through the agent's endogenous "worst case scenario" probability.

Our model allows generating a risk premium through the category channel while relaxing the agent's pessimism. Specifically, in the first step of the choice procedure the bond becomes the agent's reference point. In turn, the bond sets a "higher bar" for the stock if it is to be chosen compared to the "bar" that would have been set if the checking account acted as reference. This requires the stock to be more attractive in order to be chosen - driving its price down and generating a risk premium. Importantly, using parameters that satisfy inequality 5 but not 6, our model would generate a risk premium while Ortoleva (2010) would not.[22] That is the sense in which our model provides a novel source of risk premium.

[22]Masatlioglu and Ok (2014) provide a similar application in the world of risk but no uncertainty. As in Ortoleva (2010) they show how the channel of SQB may lead the agent to exhibit risk averse behavior in the presence of a non-risky endowment even when she is risk neutral absent an endowment. Our source of risk premium may be added to their set up as well. Specifically, one can find parameter values for which our model would generate a risk premium when the agent currently holds money in the checking account, while the SQB model of Masatlioglu and Ok (2014) would not. Once again, the channel for this premium comes from the bond serving as the endogenous reference point rather than the checking account.

If this market is studied using the standard expected utility model, it may seem as if the agent is risk averse. In fact, if she is risk averse, the risk premium we calculated would be even higher, due to the agent's endogenous reference point's constraint set as well as her degree of risk aversion. Thus, if the observer ignored the choice procedure suggested in our model and the role of the categories in this setup, she would consider the agent as much more risk averse than she actually is. In the macro-finance literature this is known as the equity premium puzzle (Mehra and Prescott, 1985), where very high levels of risk aversion are required to reconcile the risk premium observed in financial markets. Ortoleva (2010) provides the SQB channel as a possible missing ingredient to the puzzle requiring a certain degree of pessimism in the process. Our model adds the category channel which supports the emergence of a risk premium while allowing for both more reasonable levels of risk aversion and pessimism.

5 Conclusion

We develop a model of choice with initial endowment and in the presence of alternatives that are grouped into disjoint categories. When our agent starts off with an exogenous endowment, it is linked at the first stage of the choice procedure to an endogenous reference point. The reference point induces a constraint set from which the agent makes her final choice by maximizing her endowment-free utility.

The choice procedure suggested in this work may be considered as a bridge between two approaches to reference dependent choice. One considers the reference point an endogenous construct while the other turns to the exogenous endowment as the natural candidate to create reference effects. According to our model, the endowment does affect choice but in a more indirect way than that suggested by the latter approach. Its role amounts to highlighting the category to which it belongs, directing the agent to the best feasible alternative in that category in the process. From this stage onwards, the endowment becomes irrelevant, while the newly identified point serves as her reference point.

The model generalizes the status quo bias phenomenon allowing the agent to be attracted to her endowment's category rather than the endowment itself, a phenomenon we dub *category bias*. We show its flexible reference effects and compare it to the status quo bias model of Masatlioglu and Ok (2014). Recent findings regarding the presence and absence of status quo bias in the world of uncertainty are shown to be well accommodated by the suggested procedure. Finally, we provide a simple illustration of how category bias can generate risk premium even with risk neutral agents.

6 Appendix

A Proof of Theorem 1

We first prove the "if" part of the theorem. Let $U : X \to R$ be a function and Q a self-correspondence on X, that satisfy properties (a) and (b) and take any choice correspondence c on C(X) that satisfies (1) and (2) for any $(S, \sigma) \in \mathcal{C}(X)$. We first make the following observations:

Claim 1.1. For every $x_1, x_2 \in X_{x_1}$, $U(x_1) = U(x_2) \ \Rightarrow Q(x_1) = Q(x_2)$.

Proof of Claim 1.1. Follows immediately from property (a).

Claim 1.2. $x \in Q(x)$ for every $x \in X$.

Proof of Claim 1.2. Since c is a choice correspondence on $\mathcal{C}(X)$, we must have $c(\{x\}, x) = \{x\}$ for any $x \in X$. Our claim thus follows from (2).

WARP. For the case in which $\sigma = \Diamond$ it is trivial. So take $x \in X$ and choice problems $(S, x), (T, x)$ such that $T \subseteq S$ and $c(S, x) \cap T \neq \emptyset$.
Case 1: $\arg\max U(S \cap X_x) \cap \arg\max U(T \cap X_x) \neq \emptyset$. In view of claim 1.1 and (2) this is obvious.
Case 2: $\arg\max U(S \cap X_x) \cap \arg\max U(T \cap X_x) = \emptyset$. Let $\bar{z} \in \arg\max U(S \cap X_x)$ and $z \in \arg\max U(T \cap X_x)$. By case 2, $U(\bar{z}) > U(z)$. Let $y \in c(S, x) \cap T$. By (2), $y \in \arg\max U(S \cap Q(\bar{z}))$. Thus, $y \in T \cap Q(\bar{z})$. By property (a), $Q(\bar{z}) \subseteq Q(z)$. Therefore, $y \in T \cap Q(z)$. Let $t \in \arg\max U(T \cap Q(z))$. We are to show that $U(y) \geq U(t)$.

2.1. $y \in X_x$. In this case, $y \in \arg\max U(S \cap X_x)$. Since $T \subseteq S$ this implies $y \in \arg\max U(T \cap X_x)$, contradicting case 2.

2.2 $y \notin X_x$. By the choice of t, $U(t) \geq U(y)$. If $t \in X_x$, then $U(\bar{z}) > U(z) \geq U(t)$. We obtain $U(y) \geq U(\bar{z}) > U(t)$, a contradiction. Therefore $t \notin X_x$ and by property (b) we obtain $t \in Q(\bar{z})$. Hence, $t \in S \cap Q(\bar{z})$ and so $U(y) \geq U(t)$.

To show the second inclusion, let $y \in c(T, x)$. By (2) $y \in \arg\max U(T \cap Q(z))$. Let $q \in \arg\max U(S \cap Q(\bar{z})) \cap T$. Since $Q(\bar{z}) \subseteq Q(z)$ it follows that $q \in T \cap Q(z)$. By choice of y, we have $U(y) \geq U(q)$. We are thus left to show that $y \in S \cap Q(\bar{z})$. Since $y \in T \subseteq S$, this reduces to $y \in Q(\bar{z})$. We consider the following three cases:

2.3. $q \in X_x$. We must have $q \in \arg\max U(S \cap X_x)$ which in turn implies that $q \in \arg\max U(T \cap X_x)$ contradicting case 2.

2.4. $q \notin X_x, y \notin X_x$. Since $q \in Q(\bar{z})$, $y \in Q(z)$, and $U(y) \geq U(q)$ we can use property (b) to obtain $y \in Q(\bar{z})$.

2.5. $q \notin X_x, y \in X_x$. Since $y \in T$ we have $y \in T \cap X_x$. By case 2, $U(\bar{z}) > U(y)$. By claim 1.2 $\bar{z} \in Q(\bar{z})$ and hence $\bar{z} \in S \cap Q(\bar{z})$. We obtain $U(q) \geq U(\bar{z}) > U(y)$, a contradiction.

WSQB. Take any $x, y \in X$ and suppose that $x \in c(\{x, y\}, y)$. By (2), $x \in \arg\max U(\{x, y\} \cap Q(z))$ where $z \in \arg\max U(\{x, y\} \cap X_y)$. If $y \in \arg\max U(\{x, y\} \cap X_y)$, we have $x \in Q(y)$. By claim 1.2 we obtain $U(x) \geq U(y)$, which by (1) is equivalent to $x \in c(\{x, y\}, \lozenge)$. If $y \notin \arg\max U(\{x, y\} \cap X_y)$ then $x \in X_y$ and $U(x) > U(y)$ which by (1) yields $c(\{x, y\}, \lozenge) = \{x\}$. On the other hand, if $x \in c(\{x, y\}, \lozenge)$, that is, $U(x) \geq U(y)$, then $x \in \arg\max U(\{x, y\} \cap X_x)$. and in view of claim 1.2, $x \in \arg\max U(\{x, y\} \cap Q(x))$. By (2) we obtain $x \in c(\{x, y\}, x)$ as we sought.

CSQI. Take any $(S, x) \in \mathcal{C}(X)$ and let $z \in \arg\max U(S \cap X_x)$. Suppose that $c(T, x) \nsubseteq X_x$ for every subset T of S such that $[S \cap X_x] \subset T$. If S is a singleton we have $c(S, x) = \{x\} = c(S, \lozenge)$ because c is a choice correspondence. If S is not a singleton then, by hypothesis, $y \in c(\{y\} \cup (S \cap X_x), x)$ for every $y \in S \setminus X_x$. That is, $y \in Q(z)$ for every $y \in S \setminus X_x$. Moreover, by claims 1.1 and 1.2 we obtain $\arg\max U(S \cap X_x) \subseteq Q(z)$. Note that

$$S = [S \setminus X_x] \cup [\arg\max U(S \cap X_x)] \cup [(S \cap X_x) \setminus (\arg\max U(S \cap X_x))].$$

Denote the sets in the decomposition by A, B and C respectively. We have already obtained $A \subseteq Q(z)$ as well as $B \subseteq Q(z)$. Note that

$$\arg\max U(S) = \arg\max U(S \setminus C).$$

Hence,

$$\begin{aligned}
&c(S, x) = \arg\max U(S \cap Q(z)) = \arg\max U([A \cup B \cup C] \cap Q(z)) = \\
&\arg\max U([A \cap Q(z)] \cup [B \cap Q(z)] \cup [C \cap Q(z)]) = \\
&\arg\max U([A \cap Q(z)] \cup [B \cap Q(z)]) = \arg\max U(A \cup B) = \\
&\arg\max U(A \cup B \cup C) = \arg\max U(S) = c(S, \lozenge)
\end{aligned}$$

where the fourth equality follows from $z \in B \cap Q(z)$ and $U(z) > U(c)$ for every $c \in C$.

CRE. Let $S \in \Omega_X$ such that $x, y \in S \cap X_x$. Take any $z \in \arg\max U(S \cap X_x)$. By (2) $c(S, x) = \arg\max U(S \cap Q(z)) = c(S, y)$, as we sought.

We now move to prove the "only if" part of Theorem 1.[23] Let c be a choice correspondence on $\mathcal{C}(X)$ that satisfies WARP, WSQB, CSQI and CRE. Define the binary relation $\succsim$ on X

[23] This part also provides the proof for Lemma 1.

by

$$y \succsim x \text{ if and only if } y \in c(\{x, y\}, \Diamond)$$

Using a standard argument based on WARP it can easily be shown that $\succsim$ is a complete preorder on X and that

$$c(S, \Diamond) = \{\omega \in S : \omega \succsim x \text{ for all } x \in S\} \text{ for every } S \in \Omega_X.$$

Furthermore since X is finite there exists a real function U on X such that $y \succsim x$ if and only if $U(y) \geq U(x)$ for any $x, y \in X$. Therefore:

$$c(S, \Diamond) = \arg\max \{U(\omega) : \omega \in S\} \text{ for every } S \in \Omega_X.$$

Claim 1.3. Let $X_i \subset X$ be a cell in the partition. Take any $S \in \Omega_X$ such that $S \subseteq X_i$. Then, $c(S, s) = c(S, \Diamond)$ for every $s \in S$.

Proof of Claim 1.3. Let $S \in \Omega_X$ be as in the claim and take any $s \in S$. For the first inclusion let $y \in c(S, s)$ and take any $z \in c(S, \Diamond)$. By CRE, $y \in c(S, z)$. By WARP we obtain $y \in c(\{y, z\}, z)$ and by WSQB we have that $y \in c(\{y, z\}, \Diamond)$. Applying WARP again we get $y \in c(S, \Diamond)$. The second inclusion follows similar arguments.

Claim 1.4. Let $X_i \subset X$ be a cell in the partition. For any $x, y \in X_i$ and $z \in X$ we have:

$$x \in c(\{x, y\}, \Diamond) \text{ and } z \in c(\{x, z\}, x) \Rightarrow z \in c(\{y, z\}, y).$$

Proof of Claim 1.4. Let $x, y \in X_i$ and $z \in X$. If $z \in X_i$ then by claim 1.3 and WARP the proof is complete. So suppose $z \notin X_i$. Consider the following three cases:

Case 1: $z \in c(\{x, y, z\}, y)$. WARP implies $z \in c(\{y, z\}, y)$ as we sought.

Case 2: $x \in c(\{x, y, z\}, y)$. By CRE $x \in c(\{x, y, z\}, x)$. WARP implies:

$$c(\{x, y, z\}, x) \cap \{x, z\} = c(\{x, z\}, x).$$

By assumption $z \in c(\{x, z\}, x)$ so we conclude $z \in c(\{x, y, z\}, x)$. By CRE once again we have that $z \in c(\{x, y, z\}, y)$ and we are back in Case 1 and so $z \in c(\{y, z\}, y)$.

Case 3: $y \in c(\{x, y, z\}, y)$. CRE implies $y \in c(\{x, y, z\}, x)$. By WARP $y \in c(\{x, y\}, x)$. By assumption $x \in c(\{x, y\}, \Diamond)$. Using WSQB we obtain $x \in c(\{x, y\}, x)$. Combining, we obtain $c(\{x, y\}, x) = \{x, y\}$. Using WARP once again we have

$$c(\{x, y, z\}, x) \cap \{x, y\} = c(\{x, y\}, x) = \{x, y\}.$$

We may conclude $x \in c(\{x, y, z\}, x)$ and using CRE that $x \in c(\{x, y, z\}, y)$ which brings us back to Case 2. Conclusion: $z \in c(\{y, z\}, y)$ which completes the proof of Claim 1.4.

Now define

$$Q(x) := \{y \in X : y \in c(\{x, y\}, x)\}.$$

Claim 1.5. U and Q are categorically-negatively-comonotonic.

Proof of Claim 1.5. Take $x_1, x_2 \in X$ such that $x_1 \in X_{x_2}$. Suppose $U(x_1) \geq U(x_2)$. By the first part of the proof, $x_1 \in c(\{x_1, x_2\}, \Diamond)$. If $y \in Q(x_1)$ then $y \in c(\{y, x_1\}, x_1)$. By Claim 1.4, $y \in c(\{y, x_2\}, x_2)$ thus by defintion $y \in Q(x_2)$. Now suppose that $U(x_1) > U(x_2)$. Following the same steps we have that $Q(x_1) \subseteq Q(x_2)$. Note that, by definition $x_2 \in Q(x_2)$. If $x_2 \in Q(x_1)$ then $x_2 \in c(\{x_1, x_2\}, x_1)$. By WSQB, $x_2 \in c(\{x_1, x_2\}, \Diamond)$. But by first part of the proof this is true iff $U(x_2) \geq U(x_1)$, a contradiction. Thus, we conclude $Q(x_1) \subset Q(x_2)$.

Claim 1.6. Q is U-monotonic with respect to dissimilar alternatives.

Proof of Claim 1.6. Let $z_2 \in X$. Take any $y, x \notin X_{z_2}$ such that:

- $U(y) \geq U(x)$
- $x \in Q(z_2)$
- $y \in Q(z_1)$ for some $z_1 \in X_{z_2}$.

We are to show that $y \in Q(z_2)$. By definition and the earlier part of the proof, our assumptions can be rewritten as $y \in c(\{y, z_1\}, z_1), x \in c(\{x, z_2\}, z_2), y \in c(\{x, y\}, \Diamond)$. If $z_1 \in c(\{z_2, z_1\}, \Diamond)$ then $U(z_1) \geq U(z_2)$. By Claim 1.5 we have $Q(z_1) \subseteq Q(z_2)$ and thus $y \in Q(z_2)$ as we sought. So suppose $c(\{z_2, z_1\}, \Diamond) = \{z_2\}$. Define $A = \{x, y, z_2, z_1\}$. We examine the following four cases:

Case 1: $y \in c(A, z_2)$. WARP implies $y \in c(\{y, z_2\}, z_2)$ so $y \in Q(z_2)$ as we sought.

Case 2: $z_1 \in c(A, z_2)$. By CRE $z_1 \in c(A, z_1)$. WARP implies

$$c(A, z_1) \cap \{y, z_1\} = c(\{y, z_1\}, z_1).$$

By assumption $y \in c(\{y, z_1\}, z_1)$ and thus $y \in c(A, z_1)$ Using CRE once again we have $y \in c(A, z_2)$ and we are back to Case 1 which completes the proof.

Case 3: $x \in c(A, z_2)$. CRE implies $x \in c(A, z_1)$ and using WARP:

$$c(A, z_1) \cap \{x, z_1, y\} = c(\{x, z_1, y\}, z_1). \tag{7}$$

Thus $x \in c(\{x, z_1, y\}, z_1)$. We also have by WARP that $x \in c(\{x, z_1\}, z_1)$ and by assumption $y \in c(\{y, z_1\}, z_1)$. We can thus use CSQI with respect to the choice problem $(\{x, z_1, y\}, z_1)$ to obtain

$$c(\{x, z_1, y\}, z_1) = c(\{x, z_1, y\}, \Diamond) \tag{8}$$

Now if $y \in c(\{x, y, z_1\}, \Diamond)$, (7) and (8) imply that $y \in c(A, z_1)$ and using CRE we are back to Case 1. If $x \in c(\{x, z_1, y\}, \Diamond)$ then by WARP and the assumption $y \in c(\{x, y\}, \Diamond)$ we may conclude that $y \in c(\{x, z_1, y\}, \Diamond)$ once again. Finally, suppose $z_1 \in c(\{x, z_1, y\}, \Diamond)$. By WARP

$$c(\{x, z_1, y\}, \Diamond) \cap \{z_1, y\} = c(\{z_1, y\}, \Diamond). \tag{9}$$

By assumption $y \in c(\{z_1, y\}, z_1)$ and hence by WSQB $y \in c(\{z_1, y\}, \Diamond)$. By (9) we have yet again $y \in c(\{x, z_1, y\}, \Diamond)$.

Case 4: $z_2 \in c(A, z_2)$. WARP alongside our assumption that $x \in c(\{x, z_2\}, z_2)$ implies $x \in c(A, z_2)$ which brings us back to Case 3 and completes the proof of Claim 1.6.

We are left to show (2), that is

$$c(S, x) = \arg\max U(S \cap Q(z)), \text{ where } z \in \arg\max U(S \cap X_x).$$

Take any $(S, x) \in \mathcal{C}(X)$ and $z \in \arg\max U(S \cap X_x)$. By CRE $c(S, x) = c(S, z)$. We now prove two final claims.

Claim 1.7. $c(S, z) = c(S \cap Q(z), z)$.[24]

Proof of Claim 1.7. Let $T := S \cap Q(z)$, and pick any $y \in c(S, z)$. By WARP $y \in c(\{y, z\}, z)$ and hence $y \in Q(z)$. which implies $y \in T$. Conclusion: $c(S, z) \subseteq T$. Therefore $c(S, z) \cap T = c(S, z)$, and since c is a choice correspondence, this is a non-empty set. Apply WARP to conclude that $c(S, z) = c(S, z) \cap T = c(T, z)$ and we are done.

Claim 1.8. $c(S \cap Q(z), z) = c(S \cap Q(z), \Diamond)$.

Proof of Claim 1.8. If $S \cap Q(z) \subseteq X_x$ then by claim 1.3 we are done. So Suppose $S \cap Q(z) \nsubseteq X_x$. Take any $T \subseteq S \cap Q(z)$ such that $[(S \cap Q(z)) \cap X_x] \subset T$. We wish to show that $c(T, z) \nsubseteq X_x$. There exists $\omega \in T$ such that $\omega \notin X_x$ and $\omega \in Q(z)$. By definition of $Q(z)$, we have

$$\omega \in c(\{\omega, z\}, z). \tag{10}$$

[24] This claim and its proof are identical to claim 1.3 (in the proof of Theorem 1) and its proof in Masatlioglu and Ok (2014).

Suppose $c(T,z) \subseteq X_x$. Take any $y \in c(T,z)$. $c(T,z) \cap \{y,z,\omega\} \neq \emptyset$. We may apply WARP to obtain $c(T,z) \cap \{y,z,\omega\} = c(\{y,z,\omega\},z)$. Thus, given our assumption, we have $c(\{y,z,\omega\},z) \subseteq X_x$. This means that

$$\omega \notin c(\{y,z,\omega\},z). \tag{11}$$

Moreover, $y \in c(\{y,z,\omega\},z)$. We may apply WARP once more to get

$$c(\{y,z,\omega\},z) \cap \{y,z\} = c(\{y,z\},z). \tag{12}$$

$z \in X_x$ and by assumption also $y \in X_x$ and thus in view of Claim 1.3, $c(\{y,z\},z) = c(\{y,z\},\Diamond)$. Combined with (12), we may conclude

$$c(\{y,z,\omega\},z) \cap \{y,z\} = c(\{y,z\},z) = c(\{y,z\},\Diamond).$$

By the fact that $z \in \arg\max U(S \cap X_x)$ and $y \in X_x$ we have that $z \in c(\{y,z\},\Diamond)$. Therefore, $z \in c(\{y,z,\omega\},z)$. Apply WARP once again to obtain $c(\{y,z,\omega\},z) \cap \{z,\omega\} = c(\{z,\omega\},z)$. By (11) this implies that $\omega \notin c(\{z,\omega\},z)$. Hence, $c(\{z,\omega\},z) = \{z\}$ which contradicts (10).
Conclusion: $c(T,z) \not\subseteq X_x$. Thus we may apply CSQI to conclude that Claim 1.8 holds.
Together with Claim 1.7 and CRE we obtain:

$$c(S,x) = c(S,z) = c(S \cap Q(z),z) = c(S \cap Q(z),\Diamond)$$

which in view of (1) completes the proof of Theorem 1.

B Proof of Independence of Axioms

Let $X = \{x_1, x_2, y\}$ with the following partition $X = \{x_1, x_2\} \sqcup \{y\}$.

Define c on $\mathcal{C}(X)$ as follows:

$$c(S,\Diamond) = S, \ \forall S \in \Omega_X \setminus \{x_1, y\}, \text{ and } c(\{x_1,y\},\Diamond) = \{y\},$$

and whenever x_1 or x_2 are the endowment the choices are made by picking the best alternatives according to the preference relation $x_1 \sim x_2 \succ y$. Finally, when y is the endowment the choice follow according to $y \succ x_1 \sim x_2$.
This choice correspondence satisfies CRE, WSQB and CSQI but does not satisfy WARP.

Next, consider c on $\mathcal{C}(x)$ defined by: With no endowment choices are made by picking the best alternatives according to the following ordering: $y \succ x_1 \sim x_2$, and

$$c(S,\omega) = S, \quad \forall (S,\omega) \in \mathcal{C}(X) \text{ where } \omega \in \{x_1,x_2\}, \text{ and } c(S,y) = \{y\}, \quad \forall (S,y) \in \mathcal{C}(X).$$

This choice correspondence satisfies CRE, WARP and WSQB but not CSQI.

If we define c on $\mathcal{C}(X)$ as follows:

$$c(S, \Diamond) = S, \ \forall S \in \Omega_X, \text{ and } \ c(S, \omega) = \{\omega\}, \quad \forall (S, \omega) \in \mathcal{C}(X) \text{ where } \omega \in X.$$

We obtain that it satisfies WARP, WSQB, CSQI but not CRE.

Finally, define c on $\mathcal{C}(X)$ as follows: With no endowment choices are made by picking the best alternatives according to the following ordering: $x_1 \sim x_2 \succ y$, and

$$c(S, \omega) = \{\omega\}, \quad \forall (S, \omega) \in \mathcal{C}(X) \text{ where } \omega \in \{x_1, y\},$$

and when x_2 is the endowment the choice are made by following $x_1 \succ x_2 \succ y$. This choice correspondence satisfies WARP, CRE and CSQI but fails WSQB.

C CSQI and SQI

We first introduce formally axiom SQI as taken from Masatlioglu and Ok (2014).

Status Quo Irrelevance (SQI) [Masatlioglu and Ok (2014)]. *For any given (S, x), suppose that $c(T, x) \neq \{x\}$ for every non-singleton subset T of S with $x \in T \subseteq S$ and that $\{y\} = c(\{y, x\}, \Diamond)$ for some $y \in S$. Then, $c(S, x) = c(S, \Diamond)$.*

We will actually consider the relationship between our CSQI and a slightly different version of SQI which we call SQI*:

Status Quo Irrelevance* (SQI*). *For any given (S, x), suppose that $c(T, x) \neq \{x\}$ for every non-singleton subset T of S with $x \in T \subseteq S$. Then, $c(S, x) = c(S, \Diamond)$.*

As pointed out by Masatlioglu and Ok (2014) their model satisfies this slightly stronger version of irrelevance (does not require $\{y\} = c(\{y, x\}, \Diamond)$ for some $y \in S$) which will be the target of our comparison.

Let $X = \{x_1, x_2, y\}$ with the following partition $X = \{x_1, x_2\} \sqcup \{y\}$.

We first show that CSQI $\not\Longrightarrow$ SQI*. Suppose that whenever the agent faces no endowment or whenever endowed with x_2 or y she chooses according to the following preference relation: $y \succ x_2 \succ x_1$. When endowed with x_1 her choice follows $y \succ x_2 \sim x_1$. This choice correspondence satisfies CSQI. However, $c(\{x_1, x_2\}, x_1) = \{x_1, x_2\}$ yet $c(\{x_1, x_2\}, x_1) \neq c(\{x_1, x_2\}, \Diamond)$ violating SQI*.

We now turn to show that SQI* $\not\Longrightarrow$ CSQI. Suppose that whenever the agent faces no endowment or whenever endowed with x_2 or y she chooses according to the following preference relation: $x_2 \succ y \succ x_1$. When endowed with x_1 her choice follows $y \succ x_1 \succ x_2$. It is easy to check that this choice correspondence satisfies SQI* (the only interesting case to check is when x_1 is the endowment but in this case $c(\{x_1, x_2\}, x_1) = \{x_1\}$ and so SQI* holds vacuously for the sets $\{x_1, x_2\}$ and X. For the set $\{x_1, y\}$ it also holds since $c(\{x_1, y\}, x_1) = c(\{x_1, y\}, \Diamond)$. However, $c(X, x_1) = \{y\}$ so the antecedent of CSQI holds for this choice problem. Yet, $c(X, x_1) = \{y\} \neq \{x_2\} = c(X, \Diamond)$.

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