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Georgios Gerasimou

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A Behavioural Model of Choice in the Presence of Decision Conflict*

Georgios Gerasimou†

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Abstract

This paper proposes a model of choice that does not assume completeness of the decision maker's preferences. The model explains in a natural way, and within a unified framework of choice when preference-incomparable options are present, four behavioural phenomena: the attraction effect, choice deferral, the strengthening of the attraction effect when deferral is permissible, and status quo bias. The key element in the proposed decision rule is that an individual chooses an alternative from a menu if it is worse than no other alternative in that menu and is also better than at least one. Utility-maximising behaviour is included as a special case when preferences are complete. The relevance of the partial dominance idea underlying the proposed choice procedure is illustrated with an intuitive generalisation of weakly dominated strategies and their iterated deletion in games with vector payoffs.

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†School of Economics & Finance, University of St Andrews. Email address: gg26@st-andrews.ac.uk.

1 Introduction

People are often faced with decision problems in which every feasible option has something superior to all others. Consumer products may have conflicting values across different, equally relevant attributes. Election candidates may have agendas or characteristics that are considered to be better in some important respects and worse in others relative to those of the competing candidates. Policy makers may have to choose from a set of feasible plans even when any two of them generate severe trade-offs. When a decision maker has no clear way of resolving such trade-offs and is unable to find a most preferred option, she could be referred to as being in *decision conflict*.[1]

Decision conflict with two alternatives is typically modelled by letting the agent's preferences be *incomplete*, in which case the alternatives can be declared *incomparable*. When preferences are incomplete and a most preferred option does not exist in a given menu, it is not clear how the agent does or should decide which option to choose, if any, from that menu. A natural rule to consider is the one whereby she chooses a feasible alternative that is preference-undominated. This procedure has been extensively analysed in the literature, and as shown in Schwartz (1976) and Eliaz and Ok (2006), among others, it could result in considerably consistent behaviour (although obviously not a utility-maximising one).

Despite its normative appeal, this benchmark model makes predictions that are often descriptively inaccurate. A case in point is the well-known *attraction effect* (Huber, Payne, and Puto, 1982) discussed below. The paper's first contribution is the modification of the benchmark model in a minimal way that allows for a simple explanation of the above robust phenomenon. Specifically, the new model predicts that a decision maker chooses one of the undominated feasible options that are also preferred to *at least one* other feasible alternative. The addition of this *partial dominance* requirement acts as an intuitive tie breaker that helps the decision maker choose from the set of mutually incomparable undominated options. In menus where it is not satisfied, the proposed model's predictions coincide with those of the benchmark model in that any feasible option may be chosen. The consistency axioms that characterise the choice procedure are three intuitive generalisations of WARP.

Next, the model is extended in a way that establishes its robustness with respect to the assumption that the decision maker is always able to find something to choose. Specifically, it predicts that the agent chooses an alternative from a menu if *and only if* it has the two properties mentioned above. If no feasible option satisfies both the undomination and partial dominance criteria, the prediction is that the agent avoids/defers choice. From a modelling point of view, the act of not choosing anything is captured by a choice correspondence that takes the empty set as its value at the relevant menus. I provide an argument of why this is a suitable modelling approach when choice deferral is driven by incomparability (as opposed to, say, undesirability)

[1] This term is widely used by psychologists and consumer/marketing researchers to describe such situations. In the philosophy of choice literature, the term "unresolved conflict" has been used synonymously by Levi (1986).

of the alternatives. This variant of the proposed model explains the observed strengthening of the attraction effect in situations where people are not forced to choose (Dhar and Simonson, 2003). Also, unlike the model's original version where the agent's preferences are acyclic, in this version they are merely asymmetric. As a consequence, preference cycles are now permissible and they too can cause choice avoidance by rendering the undomination criterion impossible to satisfy for all alternatives.

The second extension builds on the expanded choice domain suggested by Masatlioglu and Ok (2005) which allows for studying the agent's behaviour in decision problems that possibly include an observable *status quo* option. An example of a problem with a status quo is one of an insurance policy holder who is given the chance to change it for a different policy. Inaction here is associated with maintaining the status quo. By contrast, when presented with the problem of choosing between the same two policies but is not endowed with any of them, the problem is one without a status quo and inaction is associated with choice deferral.[2]

In decision problems without a status quo, the second extension of the model essentially coincides with the previous one, except that acyclicity of the agent's preferences is now restored and therefore universal incomparability in a menu is the only reason of choice avoidance in that menu. In decision problems with a status quo on the other hand, the modified model predicts that a feasible alternative other than the status quo is chosen if and only if it is undominated *and also dominates the status quo*. As such, it features a special, reference-dependent application of the original partial dominance model, one where the status quo option is the specific alternative that must be dominated instead of some arbitrary feasible one. The final prediction is that the status quo option is choosable (and in fact, uniquely so) if and only if it is merely undominated. As a consequence, this expanded model explains the phenomenon of *status quo bias* (Knetsch and Sinden, 1984; Knetsch, 1989; Samuelson and Zeckhauser, 1988) along the lines of the choice procedure that was informally discussed in Bewley (1986) and Mandler (2004). Interestingly, it does so in a way that allows for a striking connection between this phenomenon and the attraction effect to be made, while it also allows for a formal distinction between status quo bias and the related but ultimately different concept of choice deferral. To my knowledge, it is the first and so far the only model in the literature that achieves all the above in a unified way.

A common feature shared by all three versions of the proposed model of partial dominance, and one that they also share with the benchmark model of mere undomination, is that in decision problems where the agent's preferences happen to be complete, they all prescribe choice of the (single) most preferred feasible alternative. As such, all models include rational choice and utility maximisation as a special case. The precise ways in which the models' axiomatic systems must be strengthened for them to deliver rational choice are pinned down with three novel characterisations of such behaviour, one that is permissive of indifference, one that is not, and a third one that

[2]The literature of status-quo biased choice that started with Masatlioglu and Ok (2005) has not allowed for the possibility of deferral in problems without a status quo. This possibility will be permissible in the relevant model below.

applies to problems with or without a status quo (and which rules out indifference).

The paper also attempts to answer the question of how one can recover an agent's true preferences by observing her choices when it is assumed to be known a priori that she employs the partial dominance choice procedure to make decisions. A set of conditions are given under which if an alternative is never chosen in the presence of some other alternative, then this fact correctly reveals a preference for the latter over the former. This revelation criterion coincides with the one proposed by Bernheim and Rangel (2009) for the choices of bounded-rational decision makers. Finally, the general economic relevance of the key idea in the baseline model of choice with partial dominance is illustrated with an application on strategic choice in games with vector payoffs. Specifically, I use the partial dominance requirement to generalise the concept of a weakly dominated strategy in games with scalar payoffs and I draw some analogies between the two cases and the relation between Nash equilibria and profiles that survive iterated deletion of such strategies.

2 Choice with Partial Dominance

2.1 Preliminaries

I name the decision maker *Evy*. The grand set of all alternatives that Evy may be presented with is denoted X and is assumed finite and with at least three elements. The collection of menus of alternatives drawn from X is denoted $\mathcal{M}$. For simplicity, I assume throughout that $\mathcal{M}$ includes all nonempty subsets of X (with suitable adjustments all results go through without this assumption). Evy's preferences on X are captured by the binary relation $\succ$. When $x \succ y$ is the case it is understood that x is preferred to y or, equivalently, that y is *dispreferred* to x. The notation $x \not\succ y$ is used if x is *not preferred* to y.

Evy's choice behaviour is described by a choice correspondence $C : \mathcal{M} \twoheadrightarrow X$, which is a mapping satisfying $C(A) \subseteq A$ for all $A \in \mathcal{M}$. Although the literature almost always takes nonempty-valuedness to be a defining characteristic of a choice correspondence, one observes that since the empty set is a subset of every set the above definition does not a priori restrict C to be nonempty-valued. Moreover, nonempty-valuedness imposes the nontrivial behavioural restriction that Evy is able to find a choosable option in every menu. In this paper I treat nonempty-valuedness as an explicit behavioral axiom (more discussion is provided below):

Decisiveness (DEC)
If $A \in \mathcal{M}$, then $C(A) \neq \emptyset$.

According to the original statement of the Weak Axiom of Revealed Preference (WARP) provided by Samuelson (1938) in the context of consumer demand and which

remains relevant in the present abstract choice framework even with DEC not a priori assumed, if some alternative x is chosen over another alternative y in an *arbitrary* menu, then y is never choosable in a menu where x is feasible:

Weak Axiom of Revealed Preference (WARP)
If $x \in C(A)$, $y \in A \setminus C(A)$ *and* $x \in B$, *then* $y \notin C(B)$.

Since the aim of the paper is to present a model that is more descriptive than normative, WARP will be relaxed in several ways in what follows. The first is by means of the following axiom:

ReWARP
If $C(\{x, y\}) = x$ *and* $x \in B$, *then* $y \notin C(B)$.

Although ReWARP places fewer restrictions than WARP, one could think of the two axioms as conveying the same normative message, namely that *"if x is revealed preferred to y, then y is not choosable in the presence of x"*. The difference lies in the fact that the former does so using a narrower definition of revealed preference than the latter. According to this line of reasoning one would think of WARP as taking x to be revealed preferred to y if there is *an arbitrary* menu where x is chosen over y, and of ReWARP as doing the same only when x is chosen over y in the binary menu $\{x, y\}$. Choice-based inferences concerning preference between x and y are not affected by the presence of alternatives other than x and y in the latter situation, whereas they potentially are in the former. On these grounds one could therefore argue that a better indication of Evy's preference for x over y would come from knowing that $C(\{x, y\}) = x$ rather than knowing that there is some menu A where x is choosable and y is not.[3]

The second weakening of WARP is presented next, which, like ReWARP, relates behaviour in binary and non-binary menus:

DeWARP
If $x \in C(A)$ *and* $y \in A \setminus C(A)$, *then* $y \notin C(\{x, y\})$.

While ReWARP predicts that choice of one alternative over another in a binary menu will not be weakly reversed in a larger menu, DeWARP makes the opposite prediction. Yet, although the restrictions of ReWARP are both normatively appealing and at the same time permissive of descriptively intuitive WARP violations, those imposed by

[3]It is worth noting that under the DEC axiom, ReWARP is equivalent to Sen's (1977) *Property* $\alpha 2$, which states that if $x \in C(A)$ and $y \in A$, then $x \in C(\{x, y\})$. Sen introduced this axiom as a weakening of the well-known *Property* α or *Contraction Consistency* (see footnote 5). However, $\alpha 2$ is logically distinct from both WARP and ReWARP if DEC is not assumed. By contrast, ReWARP is weaker than WARP whether DEC is assumed or not, and admits an interpretation that is generally distinct from that of $\alpha 2$.

DeWARP seem to retain primarily the normative component of WARP. Specifically, if one accepts that x chosen over y from a non-binary menu is not necessarily indicative of a clear preference for x over y because of the presence of other alternatives that may influence choice, then the prediction of y not being choosable in $\{x, y\}$ once such a choice has been made is probably too strong.

When taken together, the types of consistency violations that are prevented by ReWARP and DeWARP do not exhaust all possible WARP violations, regardless of whether DEC holds or not. For instance, choices $x = C(\{x, y, z\})$ and $y = C(\{w, x, z\})$ are permissible by both axioms but not by WARP. Interestingly though, whenever behaviour is decisive, WARP is satisfied if and only if both DeWARP and ReWARP are satisfied.

Proposition 1
The following are equivalent for a choice correspondence $C : \mathcal{M} \twoheadrightarrow X$:

(a) C satisfies DEC and WARP.

(b) C satisfies DEC, DeWARP and ReWARP.

(c) C is rationalized by a weak order.[4]

The equivalence between (a) and (b) in Proposition 1 provides a novel characterization of utility maximization (generally with indifference) by decomposing WARP into two distinct components in a way analogous to Sen's (1971) decomposition of WARP into *Contraction* and *Expansion Consistency*.[5] Both these characterizations are valid only under the assumption that DEC hods. Compared to Sen's decomposition where the axioms place restrictions in arbitrary menus, the one above identifies a specific complementary relationship between the requirements for consistency from binary to large menus and vice versa that is both necessary and sufficient for *general* choice consistency to come about. The new characterisation can also be thought of as providing a novel set of normative criteria relative to which the predictions of various behavioural models of choice can be evaluated. Specifically, if a choice model leads to violations of both Contraction and Expansion Consistency, one might be inclined to think of it as a model of severely irrational behaviour. Such a model could, however, still conform with the intuitive and normatively appealing ReWARP axiom and hence retain a non-trivial rationality element that might be suppressed if Sen's characterisation is the only one considered.[6]

The last axiom of this subsection imposes a behavioural restriction of a different nature:

[4] That is, there exists a reflexive, total and transitive relation $\succsim$ on X such that, for all $A \in \mathcal{M}$, $C(A) = \{x \in A : x \succsim y \text{ for all } y \in A\}$.

[5] *Contraction Consistency*: If $x \in C(A)$, $B \subset A$ and $x \in B$, then $x \in C(B)$. *Expansion Consistency*: If $x, y \in C(A)$, $B \supset A$ and $x \in C(B)$, then $y \in C(B)$.

[6] This is in fact the case for the model presented below.

Choice Implies Rejection (CIR)
If $|A| > 1$*, then* $C(A) \subset A$*.*

CIR is weaker than the often-used "single-valuedness" assumption which renders C a choice function. Like that assumption, however, it adheres to a strict interpretation of the concept of choice, according to which "choosing something" coincides with "choosing something over something else". When Evy adopts it, then in menus with more than one option she either chooses an alternative and rejects at least another, or she chooses nothing. As a consequence, the only possibility where everything in a menu is choosable under CIR is at singleton menus. Only in the case of binary menus, however, does this axiom restrict choices to be single-(if nonempty-)valued.

As shown next, CIR and DEC together make WARP and ReWARP equivalent, and either of these two axiomatic systems characterizes utility-maximizing behavior with no indifference ties.

Proposition 2
The following are equivalent for a choice correspondence $C : \mathcal{M} \twoheadrightarrow X$*:*

(a) C *satisfies CIR, DEC and WARP.*

(b) C *satisfies CIR, DEC and ReWARP.*

(c) C *is rationalized by a strict linear order.*[7]

Although Propositions 1 and 2 are of some independent interest, their primary usefulness in this paper lies with the fact that they establish the precise connections between the two modes of rational choice (i.e. with or without indifference, respectively) and the behavioural model that is developed below.

2.2 The Baseline Model

This subsection borrows DEC and ReWARP from the preceding one and introduces a few more behavioural axioms before discussing the decision rule that is jointly characterized by them. The first axiom is one that relaxes DeWARP when DEC holds. In order for the way in which it does so to be clear, it will be useful to restate DeWARP in the following (under DEC, equivalent) way, and rename it accordingly:

Rejection Consistency (RC)
If $x \in C(A)$ *and* $C(A) \subset A$*, then* $C(\{x, y\}) = x$ *for all* $y \in A \setminus C(A)$*.*

Under Decisiveness, RC is the logical contrapositive of DeWARP. Without DEC, however, RC is generally stronger. Indeed, in that case one may be able to find a menu

[7] That is, there exists an asymmetric, total and transitive relation $\succ$ on X such that, for all $A \in \mathcal{M}$, $C(A) = \{x \in A : y \not\succ x \text{ for all } y \in A\}$.

A and an alternative y in A such that $C(A) \subset A$, $y \in A \setminus C(A)$ and $C(\{x, y\}) = \emptyset$ for some $x \in C(A)$. These choices conform with DeWARP but violate RC.

The behavioural restriction imposed by RC (which also justifies the axiom's name) is that every alternative that is chosen over some other one(s) in a menu should continue to be chosen over *each* of these rejected alternatives in the relevant binary menus. While this restriction is normatively appealing, it essentially requires that choice of an alternative reflects preference over every rejected alternatives. This prediction is questionable from a descriptive point of view. It is very often the case that an alternative will be rejected even if a single feasible option can be found that is preferred to it. Similarly, an option may be chosen even if it is preferred to some but not necessarily all rejected alternatives. One could therefore relax RC by modifying it along these lines:

Weak Rejection Consistency (WRC)
If $x \in C(A)$ and $C(A) \subset A$, then $C(\{x, y\}) = x$ for some $y \in A \setminus C(A)$.

WRC is clearly weaker than RC whether DEC holds or not. As mentioned above, when Evy chooses x from A it is obviously more likely that this choice reflects a preference for x over *some* rather than *every* alternative rejected in A. One also notes that while WRC implies that every alternative that is choosable from a menu A must be chosen over some A-rejected alternative in the relevant binary menu, the axiom allows for some alternative to be A-rejected even if no alternative in A is chosen over it in a binary menu.

The final weakening of WARP that is employed here is a generalization of the well-known "Property γ" or "Expansion" axiom.[8]

Weak Expansion (WEXP)
If $A_1, \ldots, A_k \in \mathcal{M}$ are such that $x = C(A_1)$, $|A_1| > 1$, and for $i \neq 1$ either $x \in C(A_i)$ or $C(A_i') = \emptyset$ for all $A_i' \subseteq A_i$ with $x \in A_i'$, then $x \in C(\bigcup_{i=1}^{k} A_i)$.

Standard "Expansion" states that if an alternative is choosable from every member of a given collection of menus, then it is also choosable from the bigger menu that comes about by joining all individual ones. It is implied by WARP under Decisiveness and is generally distinct from WARP otherwise. WEXP is weaker than "Expansion" when DEC holds and distinct from it otherwise. Indeed, for an alternative to be choosable from the union of all menus in a given collection it is no longer sufficient that it be merely choosable from each menu in the collection. It must also hold that the alternative in question is *uniquely* chosen from at least one of these menus (and that this menu is not the relevant singleton). When Decisiveness is not satisfied, the latter requirement is essentially coupled by a non-rejection one. Indeed, to ensure that

[8] See Sen (1971) and Manzini and Mariotti (2007), respectively.

an alternative is choosable from the union of all menus in that case, it is required that it also be either chosen from all other menus or nothing be chosen from these menus and each of their submenus that include the alternative. Intuitively, decision problems where the latter happens are considered to be "neutral" when assessing the extent to which the alternative is choosable in the expanded menu.[9]

The main result of this subsection characterises the proposed choice procedure in terms of Decisiveness and three of the WARP generalisations that were introduced above.

Proposition 3
The following are equivalent for a choice correspondence $C : \mathcal{M} \twoheadrightarrow X$*:*

(a) C *satisfies* DEC, ReWARP, WEXP *and* WRC.

(b) There exists an acyclic relation $\succ$ *on* X *such that, for all* $A \in \mathcal{M}$,

$$C(A) = A \quad \Longleftrightarrow \quad x \not\succ y \text{ and } y \not\succ x \text{ for all } x, y \in A \tag{1a}$$

$$C(A) \subset A \quad \Longleftrightarrow \quad C(A) = \left\{ x \in A : \begin{array}{ll} z \not\succ x & \text{for all } z \in A \\ & \text{and} \\ x \succ y & \text{for some } y \in A \end{array} \right\} \tag{1b}$$

In this model Evy is portrayed as an individual who decides procedurally, yet with a single incomplete and acyclic preference relation describing her tastes.[10] Her actions depend on whether the menu that she is presented with contains alternatives that are preference-ranked or not. If not, then all alternatives in the menu are mutually incomparable and, since the assumption that she always chooses something is built in the model by means of DEC, this leads to all feasible alternatives being choosable. This feature of the model is captured by (1a).

If, however, a preference comparison between some alternatives in the menu does exist, then Evy proceeds in two steps. First, she elicits those options in the menu that are *undominated* according to her preferences. In view of acyclicity, this set is nonempty. Then, she searches within this smaller set of alternatives for ones that also *dominate* some other feasible option(s). Since at least one preference comparison between two alternatives exists in the menu by assumption, this set is also nonempty. Evy's choice is an element of this smaller set. This reasoning is captured by (1b).

[9] It is noted that although standard Expansion can be equivalently stated in terms of two menus (i.e. "$x \in C(A)$ and $x \in C(B)$ implies $x \in C(A \cup B)$" is equivalent to "$x \in C(A_i)$ for all $i \leq k$ implies $x \in C(\bigcup_{i=1}^{k} A_i)$"), this is not true of WEXP. In particular, the statement "$x = C(A)$ and $x \in C(B)$ implies $x \in C(A \cup B)$" does not generally imply the statement "$x = C(A_1)$ and $x \in C(A_i)$, $i \neq 1$, implies $x \in C(\bigcup_{i=1}^{k} A_i)$".

[10] The study of two-stage procedural choice rules that are based on distinct binary relations was pioneered by Manzini and Mariotti (2007) and further developed by Tyson (2008), Manzini and Mariotti (2012a), Masatlioglu, Nakajima, and Ozbay (2012), Apesteguia and Ballester (2013) and Cherepanov, Feddersen, and Sandroni (forthcoming). Although conceptually relevant to this body of work, my model is more in line with traditional revealed preference theory in the sense that it predicts the existence of a single preference relation with which the decision maker chooses, with no other "shortlisting" binary relation potentially influencing her final choice.

I will refer to both a choice correspondence C that is characterized by the axioms of Proposition 3 and to the alternatives that are choosable according to such a correspondence as *partially dominant* (PD). Also, if C is a PD choice correspondence and $\succ$ is the preference relation that is associated with it in the sense of (1), then I will say that $\succ$ *induces* or *generates* C.

Similar to models of incomplete preferences where the only requirement for an alternative to be chosen is that it be undominated,[11] the ones declared choosable by a PD choice correspondence are *not* preferred in general to those that are rejected. Remarkably, however, unlike such models, this can be the case here even in menus where C is single-valued.

Moreover, similar to the above mentioned class of models, a PD choice correspondence reduces to one that is generated by utility maximization in the special case where the generating preference relation is complete. Indeed, the situation of universal incomparability described in (1a) is ruled out from the outset in such a case, while for every menu A, an alternative x in A satisfies (1b) if and only if it is in fact preferred to all other alternatives in A. As known from Proposition 2, the axiomatic system of Proposition 3 must be strengthened with the addition of the CIR axiom for it to deliver this model of rational choice. In that case, both WRC and WEXP are implied by CIR, DEC and ReWARP.

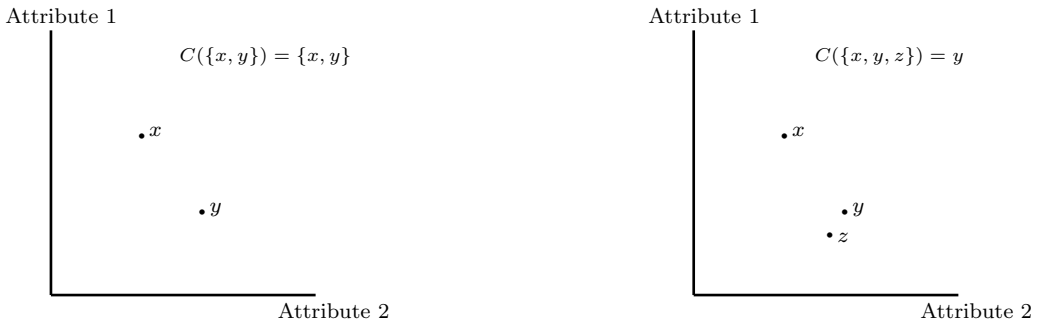
A feature of the PD model that is somewhat surprising at first sight is that it predicts less consistency in Evy's cross-menu behaviour than do models of which the only criterion for choice is undomination, even though she is actually portrayed as seeking *more reasons* in the former model before considering an alternative to be choosable from a menu. More specifically, despite the fact that Evy will never choose a dominated option by following (1), her choices across menus may violate the "Contraction Consistency" axiom, which undomination-based models obey. For example, suppose w, x, y, z are alternatives for which $w \succ x$, $y \succ z$ and no comparison is possible in all other pairs derived from this four-element set. Since w and y are undominated in the menu $\{w, x, y, z\}$ and both dominate something there, $C(\{w, x, y, z\}) = \{w, y\}$. Now consider the menu $\{w, y, z\}$. Since w is merely undominated here, whereas y is still both undominated and partially dominant, $C(\{w, y, z\}) = y$.

Despite this "normative shortcoming", the model is capable of explaining the well-known *attraction* (or *asymmetric dominance*) *effect* (Huber, Payne, and Puto, 1982) in a simple way. The classic version of the attraction effect goes as follows: When two conflicting multi-attribute alternatives x and y are feasible, both of them are equally likely to be chosen; but when a third option z that is worse in all attributes by y but not by x is added to the menu, y is significantly more likely to be chosen. A deterministic interpretation of this pattern would be that both options are choosable in the first menu, i.e. $C(\{x, y\}) = \{x, y\}$, and only y is choosable in the expanded menu, i.e. $C(\{x, y, z\}) = y$. Since this pattern violates WARP, it readily follows that the effect lies outside the reach of any model of rational choice. However, the model

[11] See Schwartz (1976) and Eliaz and Ok (2006) for some characterisations.

that is based on mere undomination is also inadequate here, as it would pick both x and y in menu $\{x, y, z\}$. By contrast, the predictions of the PD model coincide with the empirical observations: Due to conflict, x and y are incomparable in the first menu and hence either of them may be chosen, as per (1a); and although x remains undominated in the second menu, since only y is both undominated and partially dominant (i.e. with respect to z), this is the only choosable option here (see Fig. 1).

Figure 1:
The attraction effect



The PD model, however, is general enough to also explain potential "idiosyncratic" attraction effects that are based on more subjective dominance relations. For instance, if Evy's incomplete preferences differ from those captured by the usual, coordinate-dominance partial ordering and there are alternatives x, y and z where x and y and also x and z are incomparable while y is preferred to z, an idiosyncratic attraction effect would occur if both x and y were choosable from the menu $\{x, y\}$ and y was the unique choosable option in the menu $\{x, y, z\}$, as also predicted by the model.

The PD choice procedure shares some features with the one proposed by Lombardi (2009). The latter also postulates the existence of a single, acyclic and generally incomplete preference relation, a preference-undominated element of which is chosen by the decision maker from every menu. However, for an undominated option to be choosable in Lombardi's model it is required that the set of all feasible alternatives that are dispreferred to it be not properly included in the set corresponding to some other undominated option. This model too can explain the attraction effect, but in a more complicated way.

Another choice procedure that accommodates the attraction effect is the one axiomatized by de Clippel and Eliaz (2012). This postulates the existence of two distinct strict preference orderings, and also that the agent calculates the pair of numbers (called "scores") that correspond to the feasible options that are inferior to a given alternative according to each ordering. The model predicts that the agent chooses one of the feasible options with the greatest minimum score. Finally, the attraction effect can also be accommodated by the model of reference-dependent choice proposed by Ok, Ortoleva, and Riella (2012), which predicts that the presence of certain alternatives (e.g. a decoy) in a menu restricts the set of feasible options over which the agent

maximises a preference relation, thereby favouring the chances that some alternatives will be chosen.

2.3 Preference Elicitation

If an outside observer somehow knows that Evy's decision rule coincides with the one put forward in the PD model, is it possible for the observer to elicit Evy's underlying preferences by looking at her choices from various menus? As discussed in Bernheim and Rangel (2009), Manzini and Mariotti (2012a) and Rubinstein and Salant (2012) among others, being able to answer questions of this kind is of considerable interest, for example because they in principle provide guidance for assessing the effect that different choices of a social planner might have for a given agent's welfare.

If observations are available from all binary menus, then the task at hand is straightforward. If such observations are missing, however, it is not obvious if and under what conditions this can be done. In this section I provide a set of conditions under which a priori knowledge of the fact that Evy conforms to the model is sufficient for a complete elicitation of her possibly incomplete preferences.

Consider two alternatives $x, y \in X$. For an outside observer to be able to conclude that Evy prefers x to y it is clearly necessary that, for all menus B, if $y \in C(B)$ holds, then $x \notin B$ also holds. It was argued by Bernheim and Rangel (2009) that this condition is a reasonable definition of revealed preference (in this case of x over y) and was also shown that the associated binary relation is generally acyclic. Yet, in the case of the PD model this condition is clearly not sufficient for accurate preference elicitation. For instance, if $X = \{w, x, y, z\}$, $x \succ w$, $x \succ z$, $y \succ z$ and incomparability prevails in all other pairs, then Evy's behaviour is as follows: $C(\{w, x, y\}) = C(\{w, x, z\}) = C(\{x, y, z\}) = C(\{w, x, y, z\}) = x$ and $C(\{w, y, z\}) = y$. Although y is never chosen in the presence of x in this example, it is false that this reveals x to be preferred to y.

In view of the above, a question that naturally arises is whether under certain restrictions the statement "y is never chosen over x" is true if and only if the statement "x is preferred to y" is true. The next result identifies three such restrictions.

Proposition 4
Let $\mathcal{N}$ be a collection of menus that necessarily includes all those with exactly three elements.
Let $C : \mathcal{N} \twoheadrightarrow X$ be a PD choice correspondence and $\succ$ the (unknown) acyclic relation that generates it. Assume that there exists some $q \in X$ that is known to be $\succ$-incomparable to all other elements of X.

Then, for all $x, y \in X$, statements (a) and (b) below are equivalent:

(a) $x \succ y$.

(b) There is no $A \in \mathcal{N}$ such that $y \in C(A)$ and $x \in A$.

The first restriction of Proposition 4 is a domain one: Observations from all trinary menus are available. The second restriction is that Evy's preferences have the particular characteristic of there being at least one alternative q that cannot be compared to anything else. The final restriction is that the outside observer is not completely agnostic about Evy's preferences in the sense that they know beforehand that such an alternative q exists, and also which particular alternative that is.

The latter two restrictions are particularly demanding and limit the generality of this result. There are cases, however, where even these restrictions can be satisfied. For instance, when an outside observer (an experimenter, say) is interested in knowing Evy's preferences over the main apple varieties, they can let the grand choice set X consist of one apple from each main variety and also include in it something that stands a good chance of being considered incomparable to all apples, like a lettuce.

2.4 Choice Deferral and Strengthening of the Attraction Effect

Choice theorists have traditionally assumed that decision makers are able to find something to choose in every possible menu of alternatives. The PD model laid out above is in line with this tradition. However, it is well known from introspection, casual empiricism and numerous experimental studies conducted primarily by psychologists and marketing researchers (Zakay, 1984; Tversky and Shafir, 1992; Greenleaf and Lehmann, 1995; Dhar, 1997; Luce, 1998; Dhar and Simonson, 2003; Anderson, 2003) that, for a number of reasons, people often choose nothing when faced with some menus of alternatives. One such reason is decision conflict, which in this paper manifests itself as incomparability. The obvious way to model this source of choice avoidance or deferral is to assume that in every menu where there is a complete lack of comparability the agent chooses none of the feasible options. It is shown in this subsection that the key idea of the PD model can be preserved even when the Decisiveness axiom is relaxed to make deferral permissible.

More specifically, I model choice avoidance by letting Evy's choice correspondence be empty-valued at all relevant menus. This modelling approach is natural, yet not very commonly adopted in the literature. Some relevant exceptions are the papers by Hurwicz (1986) and Clark (1995).[12] I presume that this hesitation is very likely due to the argument that, since not choosing is itself a choice, a specific alternative capturing "no choice" could be included in every menu and the choice correspondence should then assign this option whenever it is understood that the agent avoids choosing.[13] This argument is perfectly reasonable in cases where avoidance is caused, say, by the unattractiveness of the feasible alternatives. In this case the individual may well be a utility maximizer who can compare the option of choosing nothing with all

[12] Gaertner and Xu (2004) use empty-valuedness to model avoidant behavior that is due to procedural aspects of choice. Gerasimou (2012) generalizes Arrow's (1959) model of rational choice with one that preserves WARP consistency and at the same time allows for deferral in those (and only those) menus where a most preferred alternative does not exist due to preference incompleteness.

[13] Another reason might be the perceived very close relationship between a choice correspondence and the budget correspondence in textbook consumer theory, which is nonempty-valued by construction. It is important to keep in mind, however, that the latter is a special case of the former.

other options, and decide according to whether "no choice" corresponds to the highest achievable utility level or not.[14]

When avoidance is exclusively due to the agent's inability to make preference comparisons and all choice objects are desirable, however, I claim that this alternative approach does a disservice. To illustrate, consider four "real" options w, x, y and z and let also d stand for the no-choice option. Suppose the individual cannot compare x and y and, as a consequence, avoids choosing either of them when these are the only available options. One understands that d is chosen over both x and y here. Suppose also that the individual prefers x to w and z, and therefore chooses x from the menu that consists of these three options. In this case x is chosen over d. Modeled like this, the above behavior should lead one to conclude that the decision maker is inconsistent, since her choices violate WARP. In reality, however, she is simply maximizing her preferences: She is choosing the most preferred option in the second menu, and is cautiously avoiding choice in the absence of a preference comparison in the first menu. Hence, the conclusion of inconsistency here is presumably unwarranted. It stems from the fact that the no-choice option d is treated just like every other alternative, even though when the individual actually chooses it, she doesn't do so because it is preferred to the other options, as is the case with avoidance caused by unattractiveness. Adopting the empty-valuedness approach eliminates this problem. With it, the question of whether behavior is, say, WARP-rational or not is answered by checking for violations of the axiom that occur only in menus where the individual does choose.[15] Finally, it is also worth noting that support to the "empty-set" approach towards modelling indecision-driven choice avoidance has recently been provided also in Kreps (2012, pp. 20-21).

Coming back to the task at hand, to explain avoidant behaviour within the general framework of the PD model it suffices to remove DEC and replace it with the (logically distinct) CIR axiom. The following result obtains in this case:

Proposition 5
For a choice correspondence $C : \mathcal{M} \twoheadrightarrow X$ the following are equivalent:

(a) C satisfies CIR, ReWARP, WEXP *and* WRC.

(b) There exists an asymmetric relation $\succ$ on X such that, for all $A \in \mathcal{M}$ with $|A| > 1$,

$$C(A) = \left\{ x \in A : \begin{array}{ll} z \not\succ x & \text{for all } z \in A \\ & \text{and} \\ x \succ y & \text{for some } y \in A \end{array} \right\} \tag{2}$$

In this extension of the PD model Evy is portrayed as a cautious decision maker

[14] See Manzini and Mariotti (2012b) for a stochastic choice model of limited attention where avoidance is modelled in this way.

[15] Buturak and Evren (2010) study choice avoidance in a utility-maximizing model of preference for flexibility, in which they assume that the choice correspondence takes a specific value when the agent defers. As they exclude deferral observations from the consistency analysis of the agent's behaviour, their approach is essentially identical to the empty-set approach that I am adopting in this paper (although the source of deferral is obviously different).

who chooses nothing from a menu unless she can find a feasible option that is both undominated and partially dominant. The fact that the relation $\succ$ here is merely asymmetric and hence possibly cyclic implies that, in addition to incomparability, inconsistency too is a potential source of deferral. Indeed, the presence of a preference cycle causes failure to meet the undomination requirement, while, as before, in the event of an absence of preference comparisons it is the PD condition that fails to be met. Whether one thinks of the possibly cyclic nature of Evy's preferences here as a virtue or an anomaly of the model, it is worth mentioning that acyclicity of these preferences is restored in the augmented model presented in the next section, without this affecting in any way Evy's ability to defer choice.

Experimental findings reported in Dhar and Simonson (2003) suggest that the attraction effect, as measured by the difference in the choice probabilities of the target option before and after the introduction of an option that serves as a decoy for it, actually becomes stronger when subjects are *not* forced to choose than when they are forced to do so. This is due to the fact that many subjects choose nothing from the pure-conflict menu where the decoy is absent and at the same time most subjects choose the option that dominates the decoy when the latter is introduced. In the language of the above extension, this observed strengthening of the attraction effect can be modelled by letting the set of choosable options be empty in the first (binary) menu, and let its value be the target option in the expanded menu. Similar to the way in which the original attraction effect is explained by the baseline PD model in the special case where preferences coincide with the usual partial ordering, this finding too can be captured by the extended model in the same special case.

As shown in Proposition 2, if Evy's choices conform with the axioms that characterise this model and she is in addition decisive, then she becomes a strict utility maximiser. Equivalently, if her preferences are complete, then choosing according to (2) coincides with choosing the single most preferred alternative according to a complete strict ordering.

2.5 Status Quo Bias, Choice Deferral and Partial Dominance

In this last subsection I extend the choice domain along the lines suggested by Masatlioglu and Ok (2005) to allow it to also include decision problems that feature an explicit, exogenous and observable *status quo*.[16] The motivation for this domain expansion is that it will then be possible to apply the key idea of the PD model in a natural way and formalize the choice procedure that was first suggested by Bewley (1986) and was also discussed at length (but not formalised) by Mandler (2004). In Mandler's paper, arguments for the rationality of this procedure are made, and also for its suitability in modelling the phenomenon of *status quo bias*.

Status quo bias refers to the observation that decision makers are much more likely

[16] See Salant and Rubinstein (2008) and Bernheim and Rangel (2009) for an analysis of choice and welfare when decisions are influenced by additional factors (called "frames" in the former work and "ancillary conditions" in the latter), of which an example is the presence of a status quo option.

to choose an option from a menu when that option is their status quo (or, depending on the problem, their endowment) than when it is not (Knetsch and Sinden, 1984; Knetsch, 1989; Samuelson and Zeckhauser, 1988). Loss aversion is one explanation for the occurrence of the phenomenon (Tversky and Kahneman, 1991; Kőszegi and Rabin, 2006). Another explanation, discussed in Mandler (2004), is that people's preferences are generally incomplete and they choose to maintain the status quo unless they find something preferred to it, in which case they give it up for one of these alternatives. In view of incompleteness, the latter may not happen very frequently, hence the observed bias. I formalise this explanation below, and obtain it as a special case of the PD choice procedure.

Let $\mathcal{S}$ be the collection of all pairs $(A, \diamond)$ and (A, s), where A is a menu in $\mathcal{M}$. The pair $(A, \diamond)$ denotes Evy's decision problem of choosing from A when there is no status quo (for example, Evy chooses between three insurance policies x, y and s without currently having one). The pair (A, s) on the other hand stands for her problem of choosing from A when the alternative $s \in A$ is her status quo (modifying the previous example, Evy now chooses between maintaining policy s or abandoning it for x or y). A generic decision problem will be denoted by (A, p) (i.e. when $p \in A$ or $p = \diamond$).

A choice correspondence in this context is a mapping $C : \mathcal{S} \twoheadrightarrow X$ that satisfies $C(A, p) \subseteq A$ for all $(A, p) \in \mathcal{S}$. Imposing nonempty-valuedness of C for all decision problems with a status quo is obviously necessary for ensuring conceptual relevance and internal consistency. As above, however, C will not a priori be restricted to be nonempty-valued in problems without a status quo.

The axioms discussed below include restatements of some of the axioms that were introduced above as well as some novel ones.

Status-Quo Independence (SIND)
If $x \in C(A, s)$ and $x \neq s$, then $x \in C(A, \diamond)$.

The behavioral requirement imposed by SIND is that whenever Evy is faced with a decision problem with a status quo and considers an alternative other than the status quo to be choosable, then she should also choose that alternative when faced with the same menu and there is no status quo. If Evy were not to abide by this axiom, she would be exhibiting a counter-intuitive cross-decision-problem inconsistency. Moreover, in view of the evidence for status quo bias one might expect the presence of a status quo to make it more difficult for Evy to declare choosable some other feasible option. Once this has happened, however, one would also expect the choosability of such an option to be maintained (if not increased) in the absence of the potentially "gravitating" forces that a status quo option may exercise on her.

Consistent Strict Inferiority (CSI)
If $C(\{x, s\}, \diamond) = x$, then $C(\{x, s\}, s) = x$.

Before discussing this axiom it is useful to first note that one natural interpretation of the statement $C(\{x, s\}, \diamond) = x$ is that the agent would always choose x when faced with the decision problem $(\{x, s\}, \diamond)$. This interpretation is to be contrasted with that corresponding to the statement $C(\{x, s\}, \diamond) = \{x, s\}$. Moreover, together with the absence of an alternative with the status quo property, the fact that the menu involved in this problem is a binary one makes it natural to interpret $C(\{x, s\}, \diamond) = x$ as suggestive of a strict preference of Evy for x over s. The CSI axiom then states that if she considers s to be strictly inferior to x, she also does so when s is the status quo.

Does the imposition of CSI alone invalidate attempts to model experimental evidence suggesting that people are status quo biased? It is often the case that the bias is observed when choice is made from menus where no alternative is objectively superior to the alternative that subsequently becomes the status quo (e.g. mugs vs candy bars in Knetsh, 1989). In the case of a binary such menu, the observed behavior is explainable by letting $C(\{x, s\}, \diamond) = \{x, s\}$. CSI allows for the compatibility between this choice and $C(\{x, s\}, s) = s$, a combination that indeed corresponds to status-quo biased behaviour. Seen in this way, the axiom can be thought of as ruling out potentially extremely strong status quo biases that are capable of overturning strict preference, but is absolutely permissive of such biases when the two alternatives in question are possibly indifferent or incomparable.

Two of the axioms that were introduced in previous subsections are restated next in a way that makes their restrictions applicable to both types of decision problems.

ReWARP*
If $C(\{x, y\}, p) = x$ *and* $y \in C(A, p)$, *then* $x \notin A$.

CIR*
If $(A, p) \in \mathcal{S}$ *is such that* $|A| > 1$, *then* $C(A, p) \subset A$.

ReWARP* ensures that the kind of consistency restrictions imposed by ReWARP are in place within any collection of decision problems with the same status quo, or without one. Obviously, the axiom does not restrict behaviour across decision problems with a different status quo. CIR* on the other hand extends CIR by requiring Evy never to let herself be in a situation where she might choose anything from a menu, whether the menu is endowed with a status quo option or not.

The remaining two of the original axioms, WEXP and WRC, are borrowed from above without any essential modification (the only change is that $A \in \mathcal{M}$ becomes $(A, \diamond) \in \mathcal{S}$). Thus, restating them is redundant.

Proposition 6
The following are equivalent for a choice correspondence $C : \mathcal{S} \twoheadrightarrow X$:

(a) C satisfies CIR, CSI, ReWARP*, SIND, WEXP and WRC.*

(b) There exists an acyclic relation $\succ$ on X such that, for all $(A, p) \in \mathcal{S}$,

$$C(A, \diamond) = \emptyset \iff x \not\succ y \text{ and } y \not\succ x \text{ for all } x, y \in A \tag{3a}$$

$$C(A, \diamond) \neq \emptyset \iff C(A, \diamond) = \left\{ x \in A : \begin{array}{ll} z \not\succ x & \text{for all } z \in A \\ & \text{and} \\ x \succ y & \text{for some } y \in A \end{array} \right\} \tag{3b}$$

$$C(A, s) \neq s \iff C(A, s) = \left\{ x \in A : \begin{array}{ll} z \not\succ x & \text{for all } z \in A \\ & \text{and} \\ x \succ s & \end{array} \right\} \tag{3c}$$

$$C(A, s) = s \iff z \not\succ s \text{ for all } z \in A. \tag{3d}$$

The first two elements of this model, (3a) and (3b), are almost identical to (1a) and (1b) in the baseline PD model, and they dictate Evy's behaviour in decision problems without a status quo. The difference is that instead of considering everything to be choosable in a menu where no preference comparison can be made, Evy here chooses nothing from such a menu. Moreover, unlike the original deferral-permissive variant of the model that is captured by (2), decision conflict is the *only* reason why deferral takes place here, as is evident from (3a). This is due to the fact that Evy's preferences in the model are acyclic and therefore, unlike Proposition 5 where preferences were merely asymmetric, deferrals here cannot occur due to a cycle. The latter two elements of the model, (3c) and (3d), formalize the incomplete-preference-based explanation of status quo bias that was mentioned above.

Proposition 6 provides a model that explains in a natural way, and within a unified framework of choice with incomplete preferences, the attraction effect, deferral,[17] the strengthening of the attraction effect when deferral is allowed, and status quo bias, while it also allows for a clear distinction to be made between the related but different phenomena of choice deferral and status quo bias. To the best of my knowledge, this is the first and so far the only model in the literature that achieves all the above simultaneously, and it does so without employing multiple (possibly reference-dependent) preference relations.

The link between (3b) and (3c) in the model is of particular interest. It shows that Evy's decision to abandon the status quo follows a special application of the PD choice

[17]The model can obviously be modified so that deferral is not permissible. For that to happen, CIR* must apply only to problems with a status quo and DEC must also be assumed. In this case, (3a) and (3b) become (1a) and (1b) of the baseline model.

procedure: For a feasible alternative other than the status quo to be choosable it must be universally undominated on the one hand and partially dominant on the other, but the latter must happen not with respect to some arbitrary feasible alternative, but rather with respect to the status quo option. Thus, the model features a reference-dependent, special application of the PD procedure when it comes to the decision of giving up the status quo, and reveals a surprising connection between the potential drivers of the two phenomena. At the same time, status quo bias is captured by the fact that in all problems that feature a relevant status quo the latter is uniquely chosen if and only if it is merely undominated in the menu. That is, the status quo need not be preferred to anything else for it to be maintained.

This model too includes utility maximisation as a special case:

Proposition 7
The following are equivalent for a choice correspondence $C : \mathcal{S} \twoheadrightarrow X$:

(a) C satisfies CIR, CSI, DEC, ReWARP* and SIND.*

(b) C is rationalized by a strict linear order.

This result complements Propositions 1 and 2 by identifying the precise way in which the axioms of the behavioural model must be strengthened to characterise rational choice in this expanded domain.

With regard to the related literature, in addition to models of loss-aversion and reference-dependent preferences (Tversky and Kahneman, 1991; Kőszegi and Rabin, 2006) that explain status quo bias, starting with the work of Masatlioglu and Ok (2005) an alternative approach to modelling the phenomenon has involved suitable aggregation of multiple functions that jointly represent the agent's preferences. Like the one developed above, such models have typically treated the status quo as exogenously given (Masatlioglu and Ok, 2005, 2012; Ortoleva, 2010; Dean, 2008). However, in the decision rule axiomatised in Ok, Ortoleva, and Riella (2012) the "reference point", which may or may not be interpretable as a status quo, is also allowed to arise endogenously, as in Kőszegi and Rabin (2006).

3 Application: Iterative Dominance in Games with Vector Payoffs

An important simplifying assumption at the heart of game theory is that the players' payoffs can be accurately captured by a real number. This assumption is not without limitations. For example, a firm's choice of a pricing strategy, together with the strategies chosen by its competitors, determines the firm's current profits as well as its expected discounted future profits. The firm in turn may care about both in a way that makes it impossible for it to compare payoff vectors that generate conflict

between present and future profits.

While the more general framework where a player's payoffs are captured by real vectors may add some realism to the analysis, it is also significantly less tractable since the players' preferences can no longer be represented by utility functions. In this subsection I show that the concept of a weakly dominated strategy and of iterated elimination of such strategies in standard games with scalar payoffs can be generalised to become applicable in games with vector payoffs in a way that closely resembles the key idea underlying the PD choice procedure. I then show by means of simple examples that this generalised concept can be helpful in analysing games with vector payoffs too.

A normal form *vector game* $\mathcal{G}$ is a collection $\{(S_i), (v_i)\}_{i\in\mathcal{I}}$, where $\mathcal{I} = \{1, \ldots, I\}$ is the set of players, S_i is the strategy set of player $i \in \mathcal{I}$, $S = \prod_{i=1}^{I} S_i$ and $v_i : S \to \mathbb{R}^n$ is player i's payoff function, with $n \geq 2$. Players' self-interestedness is ensured by assuming that the payoff vectors are ordered by the usual, coordinate-dominance partial ordering. For $x, y \in \mathbb{R}^n$, write $x > y$ if $x_i \geq y_i$ for all $i \leq n$, with strict inequality for some i, and $x \not> y$ when $x > y$ is not true.

If player i has two strategies s_i and s_i' such that $v_i(s_i, s_{-i}) > v_i(s_i', s_{-i})$ for every $s_{-i} \in S_{-i}$, it is natural to think of s_i' as being *strictly dominated* by s_i and to expect the player never to use this strategy. Strictly dominated strategies, however, are seldom present even in games with scalar payoffs and are even more rare in vector games. A weaker criterion of strategy domination is therefore due.

Definition
A strategy $s_i \in S_i$ is partially dominated *for player i if there exists $s_i' \in S_i$ such that*

$$\begin{array}{lcll} v_i(s_i, s_{-i}) & \not> & v_i(s_i', s_{-i}) & \text{for all } s_{-i} \in S_{-i} \\ & & \text{and} & \\ v_i(s_i', s_{-i}) & > & v_i(s_i, s_{-i}) & \text{for some } s_{-i} \in S_{-i} \end{array} \tag{4}$$

A player's strategy is partially dominated (*p-dominated*) by another strategy if it yields a strictly lower payoff vector than the latter for some rival strategy profile, and for no such profile does it result in a strictly higher payoff vector. One readily notes that when $n = 1$ and the game reduces to one with scalar payoffs, the notion of a partially dominated strategy does indeed coincide with that of a *weakly dominated strategy*. A partially *dominant* strategy can be defined analogously and generalise the idea of a weakly dominant strategy.

Similar to the case of standard games with scalar payoffs, it is of interest to study the connection between strategy profiles that survive iterated deletion of partially dominated strategies and Nash equilibria in vector games. The requirement of Nash equilibrium that no player should have a profitable deviation given the strategies of the other players has been extended in a natural way to vector games, with a profitable

deviation defined in the above sense of coordinate-wise vector dominance. Formally, a strategy profile $s \in S$ is a *Nash equilibrium* here if for all $i \in \mathcal{I}$, $v_i(s_i', s_{-i}) \not\succ v_i(s_i, s_{-i})$ holds for all $s_i' \in S_i$. Indeed, if s is such a strategy profile, then a deviation by some player will either result in an unambiguously worse payoff or in a gain in some dimension(s) and a loss in some other(s). Obviously, when $n = 1$ this definition reduces to that of standard Nash equilibrium.

Just like the case of games with scalar payoffs, it is well-known that a vector game may not have an equilibrium in pure strategies.[18] However, just like the case of iterated elimination of weakly dominated strategies in games with scalar payoffs, iterated elimination of partially dominated strategies in vector games can be useful for equilibrium selection when multiple equilibria exist. Moreover, just like the benchmark class of games, the order of elimination is important for the strategy profiles that survive when the process terminates. Similar also to the benchmark case, equilibria may exist where players employ a p-dominated strategy. An example of a simple vector game that illustrates all three points is presented below.

	L	R
U	$(0,2),(0,1)$	$(0,1),(1,0)$
D	$(1,1),(0,0)$	$(0,0),(0,1)$

Both (U, L) and (U, R) are equilibria in this game. Only (U, R) survives iterated elimination of partially dominated strategies when one starts the deletion process by removing L as p-dominated by R, and then D as dominated by U in the remaining game. When one starts the process by deleting D as p-dominated by U, then both (U, L) and (U, R) survive. In equilibrium (U, L), the column player plays a p-dominated strategy.

The final point of similarity between iterated deletion of weakly dominated and p-dominated strategies is that both processes may terminate without eliminating all non-equilibrium profiles. An example of a vector game with this property is the following.

	L	C	R
U	$(0,2),(0,0)$	$(0,1),(1,0)$	$(2,1),(0,0)$
C	$(1,0),(2,1)$	$(1,0),(1,1)$	$(1,2),(2,1)$
D	$(1,1),(0,0)$	$(0,0),(0,0)$	$(1,2),(0,0)$

Here, D is p-dominated by U and no further elimination can be made in the game that remains. However, at (C, C) the column player has a profitable deviation to both L and R, and at (U, R) (s)he has a profitable deviation to C.

To further strengthen the connection between rejection of p-dominated strategies (or choice of p-*dominant* strategies) in a vector game and the baseline PD procedure

[18] See Shapley (1959) for a set of conditions that ensure the existence of mixed strategy equilibria in zero-sum vector games. See also Bade (2005) for an analysis of the equilibria in general games where players' preferences are incomplete.

of Proposition 3, define the binary relation $\succ_i$ over S_i for player i by

$$s_i \succ s_i' \iff v_i(s_i, s_{-i}) > v_i(s_i', s_{-i}) \text{ for some } s_{-i} \in S_{-i} \tag{5}$$

Since the relation $\succ_i$ is defined over S_i and not over S, it can be thought of as a restricted version of the player's preferences over strategy profiles that focuses on the player's own strategy set. One notes that this relation is irreflexive and incomplete, but not necessarily asymmetric. Nevertheless, cases where asymmetry is violated, although problematic, could be treated as instances of incomparability that arise in addition to those that come about naturally by the incompleteness of that relation.

Let $\mathcal{S}_i$ be the collection of all non-empty subsets of S_i. Player i's choice correspondence here is a mapping $C_i : \mathcal{S}_i \twoheadrightarrow S_i$ such that $C(S_i^{\mathcal{G}'}) \subseteq S_i^{\mathcal{G}'}$ and $C(S_i^{\mathcal{G}'}) \neq \emptyset$ for all $S_i^{\mathcal{G}'} \in \mathcal{S}_i$, where $S_i^{\mathcal{G}'} \subseteq S_i$ is the strategy set of player i in game $\mathcal{G}'$. This modelling approach allows for all players to start with the original game $\mathcal{G}$ where their strategy sets are S_i for $i \in \mathcal{I}$, and for these sets to "shrink" as elimination of p-dominated strategies starts taking place.

If player i maximises the relation $\succ_i$ as in (1) to choose a strategy in a vector game $\mathcal{G}$, then by applying (1b) she will choose one of those that remain once her p-dominated strategies have been eliminated from $\mathcal{G}$. If she can eliminate no such strategies and neither can any other player in the game, (1a) is the relevant choice rule, and it predicts that any strategy may be chosen.

4 Concluding Remarks

This paper contributes to the growing literature of behavioural choice theory by proposing and characterising a novel choice procedure that is based on a special kind of preference maximisation which reduces to rational choice when preferences are complete. The key element in it is the combination of the benchmark criterion of preference undomination with that of partial preference dominance. Although the proposed model is one of bounded-rational choice, the sole source of bounded rationality is incompleteness of the decision maker's preferences. As a consequence, in decision problems where the agent's preferences happen to be complete, the model predicts utility-maximising behaviour. Three novel characterisations of rational choice are provided, in the standard domain as well as in the expanded one of Masatlioglu and Ok (2005), which identify the precise connections between utility maximisation and the various versions of the model.

The theoretical framework developed in this paper is able to explain in a unified way, and with minimal deviations from the predictions of rational choice, the attraction effect, status quo bias, choice deferral that is caused by decision conflict, and finally the strengthening of the attraction effect when deferral is allowed. Moreover, the model's central idea was shown to be relevant for explaining status quo bias along the lines of the incomparability-based decision rule suggested by Bewley (1986) and

Mandler (2004), thereby establishing a surprising link between two seemingly distinct behavioural phenomena (attraction effect vs. status quo bias) and also clarifying the difference between related but distinct phenomena that are associated with inaction (choice deferral vs. status quo bias).

Finally, it was shown that the model's key idea is applicable in strategic situations where the players' payoffs are vectors rather than scalars. In particular, the concept of a weakly dominated strategy in standard games was generalised to that of a partially dominated strategy in games with vector payoffs, and some analogies were drawn regarding the relationship between Nash equilibria and strategy profiles that survive iterated deletion of such strategies in games with scalar and vector payoffs. Thus, perhaps rather paradoxically, a choice model that builds on the premise that behaviour is imperfectly rational may turn out to be (directly or indirectly) helpful in the task of making rational predictions in the above class of very simple games that have this additional complexity.

Appendix A: Proofs

Proof of Proposition 1:

It is trivial that (a) implies (b) and well-known that (c) implies (a). All that remains is to show that (b) implies (c). Define the relation $\succsim$ on X by $x \succsim y$ if $x \in C(\{x, y\})$. Since all binary menus are included in $\mathcal{M}$ and DEC holds, $\succsim$ is complete. Suppose $x \succsim y$ and $y \succsim z$ and assume to the contrary that $x \not\succsim z$. Completeness implies $z \succ x$, i.e. $C(\{x, z\}) = z$. By assumption, $A := \{x, y, z\} \in \mathcal{M}$ and $C(A) \neq \emptyset$. It follows from ReWARP that $x \notin C(A)$. Suppose $y \in C(A)$. Since $x \in A \setminus C(A)$ and $y \in C(A)$, it follows from DeWARP and DEC that $C(\{x, y\}) = y$. This contradicts the postulate $x \succsim y$. Similarly, $z \notin C(A)$. Thus, $x, y, z \notin C(A)$, which contradicts DEC. This establishes that $x \succsim z$ and therefore that $\succsim$ is also transitive, hence a weak order.

Now let $x \in C(A)$ and suppose there exists $y \in A$ such that $y \succ x$. Since $C(\{x, y\}) = y$, $y \in A$ and $x \in C(A)$, this contradicts ReWARP. Thus, $x \succsim y$ for all $y \in A$. Conversely, suppose $x \succsim y$ for all $y \in A$ and suppose $x \notin C(A)$. From DEC, $z \in C(A)$ for some $x \neq z \in A$. Since $z \in C(A)$, $x \in A \setminus C(A)$ and $x \in C(\{x, z\})$ by assumption, DeWARP is contradicted. Thus, $\succsim$ rationalizes C. ■

Proof of Proposition 2:

It is obviously true that (a) implies (b) and easy to show that (c) implies (a). I will prove that (b) implies (c). Define $\succ$ by $x \succ y$ if $C(\{x, y\}) = x$. This relation is asymmetric. Let $w, z \in X$. From the full domain assumption, DEC and CIR it follows that $C(\{w, z\}) = w$ or $C(\{w, z\}) = z$ and therefore $w \succ z$ or $z \succ w$. Hence, $\succ$ is complete. Now suppose $x \succ y$ and $y \succ z$ and assume to the contrary that $x \not\succ z$. From completeness, $z \succ x$. Since $\{x, y, z\} \in \mathcal{M}$ by assumption and $C(\{x, y, z\}) \neq \emptyset$ from DEC, if x, y or z is in $C(\{x, y, z\})$, then in view of $z \succ x$, $x \succ y$ and $y \succ z$,

respectively, ReWARP is violated. It follows then that $x \succ z$, and therefore that $\succ$ is also transitive.

Suppose there exists $A \in \mathcal{M}$ with $x, y \in C(A)$ for some $x \neq y$. Since $\{x, y\} \in \mathcal{M}$ and $x \succ y$ or $y \succ x$, this violates ReWARP. Hence, C is single-valued. Finally, let $A \in \mathcal{M}$ and $x \in A$ be such that $y \not\succ x$ for all $y \in A$. Suppose $C(A) = z \neq x$. From completeness of $\succ$ it follows that $z \succ x$ or $x \succ z$. The former contradicts the postulated maximality of x in A. Together with $C(A) = z$, the latter contradicts ReWARP. Thus, $C(A) = x$. ■

Proof of Proposition 3:

Suppose there exists an acyclic relation $\succ$ on X such that (1) holds. Let $C(A) = \emptyset$ for some $A \in \mathcal{M}$. Clearly, $C(A) \subset A$. It follows then from (1b) that there is no $x \in A$ such that (i) $z \not\succ x$ for all $z \in A$, and (ii) $x \succ y$ for some $y \in A$. Since $\succ$ is acyclic, there exists $x \in A$ that satisfies (i). It follows then that there is no $x \in A$ satisfying (ii). These two facts in turn imply that $x \not\succ y$ and $y \not\succ x$ for all $x, y \in A$. But in this case (1a) ensures that $C(A) = A$. Since $A \neq \emptyset$ for all $A \in \mathcal{M}$, this is a contradiction. Hence, DEC is satisfied.

Assume that ReWARP is violated. There exist $x, y \in X$ and $A \in \mathcal{M}$ such that $C(\{x, y\}) = x$, $x \in A$ and $y \in C(A)$. From $C(\{x, y\}) = x$ and (1b) it follows that $x \succ y$. Since $y \in C(A)$ it also follows from (1a) or (1b) (if $C(A) = A$ or $C(A) \subset A$, respectively) that $x \not\succ y$. This is a contradiction.

Now let $A_1, \ldots, A_k \in \mathcal{M}$ be such that $A \neq \{x\}$, $x = C(A_1)$ and $x \in C(A_i)$, $2 \leq i \leq k$. Define $A := \bigcup_{i=1}^{k} A_i$. It is implied by (1b) and $C(A_1) = x$ that $z \not\succ x$ for all $z \in A_1$ and $x \succ y$ for some $y \in A_1$. Moreover, $x \in C(A_i)$ and (1a) or (1b) (depending on whether $C(A_i) = A_i$ or $C(A_i) \subset A_i$, respectively) imply $z \not\succ x$ for all $z \in A_i$. Thus, $z \not\succ x$ for all $z \in A$ and $x \succ y$ for some $y \in A$. From (1b), this implies $x \in C(A)$. Hence, WEXP is satisfied.

Finally, suppose $x \in C(A)$ and $C(A) \subset A$. Then (1b) implies $x \succ y$ and hence $C(\{x, y\}) = x$ for some $y \in A$. From (1b) it also follows that $y \notin C(A)$. Thus, WRC is also satisfied.

Conversely, assume that DEC, ReWARP, WEXP and WRC hold. Define the relation $\succ$ on X by $x \succ y$ if $C(\{x, y\}) = x$. By definition, $\succ$ is asymmetric. Suppose $\succ$ is not acyclic. There exist $x_1, x_2, \ldots, x_k \in X$ such that $x_1 \succ x_2 \succ \ldots \succ x_k \succ x_1$. By assumption, $B := \{x_1, x_2, \ldots, x_k\} \in \mathcal{M}$, while DEC implies $C(B) \neq \emptyset$. Thus, $x_i \in C(B)$ for some $i \leq k$. From the $\succ$-cycle above it follows that there is $x_j \in B$ such that $x_j \succ x_i$, i.e. $C(\{x_i, x_j\}) = x_j$. This contradicts ReWARP.

Suppose $A \in \mathcal{M}$ is such that $x \not\succ y$ and $y \not\succ x$ for all $x, y \in A$. From DEC, $C(A) \neq \emptyset$. Let $x \in C(A)$ and $C(A) \subset A$. If $|A| = 2$, then $A = \{x, y\}$ for some $y \in X$, and $x \succ y$ obviously holds, a contradiction. Suppose $|A| > 2$. From WRC, there exists $y \in A \setminus C(A)$ such that $x \succ y$. This is also a contradiction. It holds, therefore,

that $C(A) = A$. In the other direction, let $C(A) = A$ and suppose $x \succ y$ for some $x, y \in A$. Since $y \in C(A)$ by assumption, this is a violation of ReWARP. Hence, (1a) is established.

To establish (1b), let $C(A) \subset A$ for some $A \in \mathcal{M}$. Suppose $x \in C(A)$. If $z \succ x$ for some $z \in A$, then ReWARP is violated. Moreover, $x \in C(A)$, $C(A) \subset A$ and WRC together imply $x \succ y$ for some $y \in A \setminus C(A)$. Thus, $x \in C(A)$ and $C(A) \subset A$ implies $z \not\succ x$ for all $z \in A$ and $x \succ y$ for some $y \in A$. In the other direction, suppose there is $x \in A$ such that $z \not\succ x$ for all $z \in A$ and $x \succ y$ for some $y \in A$. This implies $C(\{x, y\}) = x$ for some $y \in A$ and, in view of DEC, $x \in C(\{x, z\})$ for all $z \in A$. Let $F := \{x, y\}$ and label all other elements in A by $z_1, \ldots, z_k$. Also, let $G_i := \{x, z_i\}$. Since $x = C(F)$, $x \in \bigcap_{i=1}^{k} C(G_i)$ and $\bigcup_{i=1}^{k} G_i \cup F = A$, it follows from WEXP that $x \in C(A)$. Finally, suppose $C(A)$ consists of all $x \in A$ with the above two properties and assume to the contrary that $C(A) = A$. Since there exist $x, y \in A$ such that $C(\{x, y\}) = x$ by assumption, while $y \in C(A) = A$ is also true by assumption, ReWARP is violated. Hence, $C(A) \subset A$. ■

Proof of Proposition 4:

Since C is PD, it is trivial that (a) implies (b). For the converse implication, suppose that for all $A \in \mathcal{N}$ such that $y \in C(A)$, it holds that $x \notin A$. Consider the menu $\{x, y, q\}$, which, by assumption, is in $\mathcal{N}$. Since q is $\succ$-incomparable to everything in X and C is PD, it follows from (1) that $q \in C(\{x, y, q\})$ only if $C(\{x, y, q\}) = \{x, y, q\}$. But since $x \in \{x, y, q\}$, from the assumption above we know $y \notin C(\{x, y, q\})$. Thus, $C(\{x, y, q\}) \neq \{x, y, q\}$ and hence $q \notin C(\{x, y, q\})$. It follows then that $C(\{x, y, q\}) = x$. The universal non-comparability of q and (1b) now imply $x \succ y$. ■

Proof of Proposition 5:

The arguments in Proposition 3 establish necessity of the axioms here as well. For the sufficiency of the axioms, recall that the relation $\succ$ defined as in the proof of Proposition 3 is asymmetric by definition. Let $A := \{x_1, \ldots, x_k\}$, $k \geq 2$, where $x_1, \ldots, x_k \in X$. Without loss of generality suppose $x_1, x_2 \in A$ are such that $z \not\succ x_1$ for all $z \in A$ and $x_1 \succ x_2$. It holds that $C(\{x_1, x_2\}) = x_1$ and $C(\{x_1, x_i\}) \neq x_i$ for all $2 \leq i \leq k$. Repeated application of WEXP establishes that $x_1 \in C(A)$. Conversely, consider $A \in \mathcal{M}$, $|A| > 1$, and let $x \in C(A)$. If $z \succ x$ for some $z \in A$, ReWARP is violated. Hence, $z \not\succ x$ for all $z \in A$. Moreover, it follows from CIR that $C(A) \subset A$ and from WRC that $x \succ y$ for some $y \in A \setminus C(A)$. This establishes (2). ■

Proof of Proposition 6:

It is straightforward to verify that (3) implies the axioms. For the converse, define the (asymmetric) relation $\succ$ on X by $x \succ y$ if $C(\{x, y\}, \diamond) = x$. Suppose $x \succ y$, $y \succ z$ and $z \succ x$ for some $x, y, z \in X$. Consider $(\{x, y, z\}, x) \in \mathcal{S}$. By assumption,

$C(\{x,y,z\},x) \neq \emptyset$. Suppose $x \in C(\{x,y,z\},x)$. Since $z \succ x$ together with CSI implies $C(\{x,z\},x) = z$, this violates ReWARP. Suppose $y \in C(\{x,y,z\},x)$ instead. It follows from SIND that $y \in C(\{x,y,z\},\diamond)$ too. But since $x \succ y$ holds, this too violates ReWARP. Hence, $y \notin C(\{x,y,z\},x)$. A symmetric argument also establishes that $z \notin C(\{x,y,z\},x)$. It follows then that $C(\{x,y,z\},x) = \emptyset$, a contradiction. Therefore, $\succ$ is acyclic.

Given that the axioms subsume those of Proposition 5, it follows trivially from that result that (3b) holds for all problems $(A,\diamond)$ in $\mathcal{S}$. It also follows from Proposition 5 and acyclicity of $\succ$ that (3a) holds too for all $(A,\diamond) \in \mathcal{S}$.

Now consider $(A,s) \in \mathcal{S}$. Suppose $x \in C(A,s)$ for some $x \neq s$. Assume to the contrary that there exists $y \in A$ such that $y \succ x$. It follows from $x \in C(A,s)$, $x \neq s$ and SIND that $x \in C(A,\diamond)$. But since $y \succ x$, this contradicts ReWARP. Thus, $x \in C(A,s)$ and $x \neq s$ implies $y \not\succ x$ for all $y \in A$. Moreover, it follows from CIR that $C(\{x,s\},s) \subset \{x,s\}$. Suppose $x = C(\{x,s\},s)$. Then, SIND implies $x \in C(\{x,s\},\diamond)$. Since $s \not\succ x$ and (3b) together imply $s \notin C(\{x,s\},\diamond)$, it follows that $x = C(\{x,s\},\diamond)$, or $x \succ s$. Conversely, if $C(A,s)$ consists of all $x \in A$ such that $y \not\succ x$ for all $y \in A$ and $x \succ s$, then ReWARP ensures that $C(A,s) \neq s$. This establishes (3c).

To also establish (3d) suppose $(A,s) \in \mathcal{S}$ is such that $y \not\succ s$ for all $y \in A$ and assume to the contrary that $x \in C(A,s)$ for some $x \neq s$. It follows from above that $x \succ s$, a contradiction. Since $C(A,s) \neq \emptyset$, this implies $s = C(A,s)$. Conversely, suppose $C(A,s) = s$ and let $x \succ s$ for some $x \in A$. CSI implies $C(\{x,s\},s) = x$. ReWARP then also implies $s \notin C(A,s)$, a contradiction. ■

Proof of Proposition 7:

The proof that (b) implies (a) is straightforward and omitted. For the converse, define the (asymmetric) relation $\succ$ on X as in the preceding proof. It follows from DEC and CIR that $x \succ y$ or $y \succ x$ for all $x,y \in X$. Hence, $\succ$ is complete. Suppose $x \succ y$, $y \succ z$ and $x \not\succ z$. Completeness implies $z \succ x$, i.e. $C(\{x,z\},\diamond) = z$. By assumption, $(\{x,y,z\},\diamond) \in Z$. Moreover, DEC implies $C(\{x,y,z\},\diamond) \neq \emptyset$. If $C(\{x,y,z\},\diamond) = x$, then $z \succ x$ violates ReWARP. The cases where $C(\{x,y,z\},\diamond) = y$ and $C(\{x,y,z\},\diamond) = z$ are similarly ruled out. Thus, $x \succ z$ and $\succ$ is also transitive, hence a strict linear order.

Consider $(A,\diamond) \in Z$. Suppose that $C(A,\diamond) = x$ and let y be the $\succ$-maximal element of $\succ$ in A. Assume to the contrary that $x \neq y$. Completeness of $\succ$ implies $y \succ x$. Since $C(A,\diamond) = x$ and $y \in A$ by assumption, this violates ReWARP. Thus, $x = y$.

Next, let $(A,s) \in Z$ and define x and y as above. Consider the case where $y \neq s$ first. By way of contradiction, suppose $x \neq y$. Completeness of $\succ$ and the definition of y imply $y \succ x$ and $y \succ s$. Let $x \neq s$. From SIND, $x = C(A,s)$ implies $x = C(A,\diamond)$. Since $y \succ x$ and $y \in A$ by assumption, $x = C(A,\diamond)$ violates ReWARP. Thus, $x = s$. In this case, it follows from CSI and $C(\{x,y\},\diamond) = y$ that $C(\{s,y\},s) = y$. Since $y \in A$ and $s = x = C(A,s)$ by assumption, this violates ReWARP. Thus, $x = y$.

Consider finally the case where $y = s$. Suppose $x \neq y$. From the definition of y $(= s)$ one has $s \succ x$. From the definition of x one also has $C(A, s) = x$. Since $x \neq s = y$, it follows from SIND and $x = C(A, s)$ that $x = C(A, \diamond)$. In view of $s \succ x$ and $s \in A$, this violates ReWARP. Thus, $x = y$ and (1) is established for all $(A, p) \in Z$. ■

Appendix B: Axiom Independence

The tightness of the axiomatic systems of Propositions 3, 5 and 6 is established here by means of counterexamples. Straightforward modifications of these also establishes the tightness of the axiomatic systems in Propositions 1, 2 and 7.

For the first two results, let $X = \{w, x, y, z\}$ and $\mathcal{M} = \{A : A \neq \emptyset,\ A \subseteq X\}$. Each of the following cases provides an example where choices satisfy all but one axiom (for brevity I ignore choice from singletons by assuming that the feasible option is always chosen):

Proposition 3 (DEC, ReWARP, WEXP, WRC)

Not DEC:

$$C(\{w,x\}) = w,\ \ C(\{w,y\}) = C(\{w,z\}) = \emptyset,$$
$$C(\{x,y\}) = \{x,y\},\ \ C(\{x,z\}) = \emptyset,\ \ C(\{y,z\}) = y$$
$$C(\{w,x,y\}) = C(\{w,y,z\}) = \{w,y\},\ \ C(\{w,x,z\}) = w,\ \ C(\{x,y,z\}) = y$$
$$C(X) = \{w,y\}$$

Not ReWARP

$$C(\{w,x\}) = w,\ \ C(\{w,y\}) = \{w,y\},\ \ C(\{w,z\}) = \{w,z\},$$
$$C(\{x,y\}) = \{x,y\},\ \ C(\{x,z\}) = x,\ \ C(\{y,z\}) = y$$
$$C(\{w,x,y\}) = C(\{w,y,z\}) = \{w,y\},\ \ C(\{w,x,z\}) = \{w,x\},\ \ C(\{x,y,z\}) = y$$
$$C(X) = \{w,x,y\}$$

Not WEXP

$$C(\{w,x\}) = w,\ \ C(\{w,y\}) = \{w,y\},\ \ C(\{w,z\}) = \{w,z\},$$
$$C(\{x,y\}) = \{x,y\},\ \ C(\{x,z\}) = x,\ \ C(\{y,z\}) = y$$
$$C(\{w,x,y\}) = C(\{w,y,z\}) = w,\ \ C(\{w,x,z\}) = w,\ \ C(\{x,y,z\}) = y$$

$$C(X) = w$$

Not WRC

$$C(\{w,x\}) = w,\ \ C(\{w,y\}) = \{w,y\},\ \ C(\{w,z\}) = \{w,z\},$$

$$C(\{x,y\}) = \{x,y\},\ \ C(\{x,z\}) = x,\ \ C(\{y,z\}) = \{y,z\}$$

$$C(\{w,x,y\}) = C(\{w,y,z\}) = \{w,y\},\ \ C(\{w,x,z\}) = w,\ \ C(\{x,y,z\}) = y$$

$$C(X) = \{w,y\}$$

Proposition 5 (CIR, ReWARP, WEXP, WRC)

Not CIR

See example for "Not DEC" above.

Not ReWARP

$$C(\{w,x\}) = w,\ \ C(\{w,y\}) = C(\{w,z\}) = \emptyset,$$

$$C(\{x,y\}) = \emptyset,\ \ C(\{x,z\}) = x,\ \ C(\{y,z\}) = y$$

$$C(\{w,x,y\}) = C(\{w,y,z\}) = \{w,y\},\ \ C(\{w,x,z\}) = \{w,x\},\ \ C(\{x,y,z\}) = y$$

$$C(X) = \{w,x,y\}$$

Not WEXP

$$C(\{w,x\}) = w,\ \ C(\{w,y\}) = C(\{w,z\}) = \emptyset,$$

$$C(\{x,y\}) = \emptyset,\ \ C(\{x,z\}) = x,\ \ C(\{y,z\}) = y$$

$$C(\{w,x,y\}) = C(\{w,y,z\}) = w,\ \ C(\{w,x,z\}) = w,\ \ C(\{x,y,z\}) = y$$

$$C(X) = w$$

Not WRC

$$C(\{w,x\}) = w,\ \ C(\{w,y\}) = \emptyset,\ \ C(\{w,z\}) = \emptyset,$$

$$C(\{x,y\}) = \emptyset,\ \ C(\{x,z\}) = x,\ \ C(\{y,z\}) = \emptyset$$

$$C(\{w,x,y\}) = C(\{w,y,z\}) = \{w,y\},\ \ C(\{w,x,z\}) = w,\ \ C(\{x,y,z\}) = y$$

$$C(X) = \{w,y\}$$

Proposition 6 (CIR*, CSI, ReWARP*, SIND, WEXP, WRC)

Now let $X = \{w, x, y\}$ and let Z be the union of the following collections of sets:

$$\Big\{(\{w\}, \diamond), (\{x\}, \diamond), (\{y\}, \diamond), (\{w, x\}, \diamond), (\{w, y\}, \diamond), (\{x, y\}, \diamond), (\{w, x, y\}, \diamond)\Big\},$$

$$\Big\{(\{w\}, w), (\{w, x\}, w), (\{w, y\}, w), (\{w, x, y\}, w)\Big\},$$

$$\Big\{(\{x\}, x), (\{w, x\}, x), (\{x, y\}, x), (\{w, x, y\}, x)\Big\},$$

$$\Big\{(\{y\}, y), (\{w, y\}, y), (\{x, y\}, y), (\{w, x, y\}, y), \Big\}$$

Not CIR*

$$C(\{w, x\}, \diamond) = \{w, x\}, \quad C(\{w, y\}, \diamond) = w, \quad C(\{x, y\}, \diamond) = x, \quad C(\{w, x, y\}, \diamond) = \{w, x\},$$

$$C(\{w, x\}, w) = C(\{w, y\}, w) = C(\{w, x, y\}, w) = w,$$

$$C(\{w, x\}, x) = \{w, x\}, \quad C(\{x, y\}, x) = x, \quad C(\{w, x, y\}, x) = w$$

$$C(\{w, y\}, y) = C(\{w, x, y\}, y) = w, \quad C(\{x, y\}, y) = x$$

Not ReWARP*

$$C(\{w, x\}, \diamond) = C(\{w, x, y\}, \diamond) = w, \quad C(\{w, y\}, \diamond) = C(\{x, y\}, \diamond) = y$$

$$C(\{w, x\}, w) = C(\{w, x, y\}, w) = w, \quad C(\{w, y\}, w) = y$$

$$C(\{w, x, y\}, x) = x, \quad C(\{w, x\}, x) = w, \quad C(\{x, y\}, x) = y$$

$$C(\{w, y\}, y) = C(\{x, y\}, y) = C(\{w, x, y\}, y) = y.$$

Not CSI

$$C(\{w, x\}, \diamond) = \emptyset, \quad C(\{w, y\}, \diamond) = C(\{w, x, y\}, \diamond) = w, \quad C(\{x, y\}, \diamond) = x$$

$$C(\{w, x\}, w) = C(\{w, y\}, w) = C(\{w, x, y\}, w) = w,$$

$$C(\{w, x\}, x) = C(\{w, x, y\}, x) = w, \quad C(\{x, y\}, x) = x$$

$$C(\{w, y\}, y) = C(\{x, y\}, y) = C(\{w, x, y\}, y) = y$$

Not SIND

$$C(\{w, x\}, \diamond) = C(\{x, y\}, \diamond) = C(\{w, x, y\}, \diamond) = x, \quad C(\{w, y\}, \diamond) = \emptyset$$

$$C(\{w,x\},w) = C(\{w,x,y\},w) = x, \quad C(\{w,y\},w) = w$$
$$C(\{w,x\},x) = C(\{w,x,y\},x) = w, \quad C(\{x,y\},x) = x$$
$$C(\{w,y\},y) = C(\{w,x,y\},y) = y, \quad C(\{x,y\},y) = x$$

Not WEXP

$$C(\{w,x\},\diamond) = C(\{w,y\},\diamond) = \emptyset, \quad C(\{x,y\},\diamond) = x, \quad C(\{w,x,y\},\diamond) = \emptyset,$$
$$C(\{w,x\},w) = C(\{w,x,y\},w) = C(\{w,y\},w) = w$$
$$C(\{w,x\},x) = C(\{w,x,y\},x) = C(\{x,y\},x) = x$$
$$C(\{w,y\},y) = C(\{w,x,y\},y) = y, \quad C(\{x,y\},y) = x$$

Not WRC

$$C(\{w,x\},\diamond) = C(\{x,y\},\diamond) = \emptyset, \quad C(\{w,x,y\},\diamond) = \{w,x\}, \quad C(\{w,y\},\diamond) = w$$
$$C(\{w,x\},w) = C(\{w,x,y\},w) = C(\{w,y\},w) = w$$
$$C(\{w,x\},x) = C(\{w,x,y\},x) = C(\{x,y\},x) = x$$
$$C(\{w,y\},y) = C(\{w,x,y\},y) = w, \quad C(\{x,y\},y) = y$$

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