Modeling Interactions between Risk, Time, and Social Preferences

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Abstract

Recent studies have observed systematic interactions between risk, time, and social preferences that constitute violations of 'dimensional independence' and are not explained by the leading models of decision making. This note provides a simple approach to modeling such interaction effects while predicting new ones. In particular, we present a model of rational-behavioral preferences that takes the convex combination of 'behavioral' System 1 preferences and 'rational' System 2 preferences. The model provides a unifying approach to analyzing risk, time, and social preferences, and predicts how these preferences are correlated with reliance on System 1 or System 2 thinking.

Keywords: Risk; Time; Social preference; System 1; System 2
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1 Introduction

Many decisions in life involve some combination of risk (e.g., whether to invest in stocks or bonds), time delays (whether to consume now or save for retirement), and resource allocations (whether to split the bill at a restaurant). This casual observation is reflected in the large volume of research spanning decisions involving risk, time, and resource allocations. To study these aspects of decision making, the standard approach in both neoclassical and behavioral economics is to specify a domain (e.g., decisions under risk), and develop a model or experiment which focuses on that domain. This approach encompasses the standard normative models of decision making (e.g., expected utility theory, discounted utility theory), as well as the leading behavioral models (e.g., prospect theory (Kahneman and Tversky, 1979), and rank dependent utility theory (Quiggin, 1982), for decisions under risk, hyperbolic discounting (Loewenstein and Prelec, 1992), and quasi-hyperbolic discounting (Laibson, 1997) for decisions over time, and models of other-regarding preferences (Fehr and Schmidt, 1999; Bolton and Ockenfels, 2000; Charness ad Rabin, 2002) for decisions over allocations).

The 'domain-specific' approach to theory construction helps to 'seal off' and clearly define the boundaries of a model. The domain-specific approach has also been very successful in expanding our knowledge of behavior within each domain. However, recent experimental work has pushed the boundary further and identified systematic interaction effects across decision domains. For instance, Keren and Roelofsma (1995) observed that introducing risk into intertemporal decisions induces more patient behavior. Baucells and Heukamp (2010) and Abdellaoui et al. (2011) observed that people are more risk tolerant toward delayed lotteries. Baucells and Heukamp (2012) discuss empirically observed interactions between payoff magnitude and risk and time preferences. In response to these interaction effects involving risk and time, theories have been recently advanced to model relationships between risk and time preferences (Halevy, 2008; Fudenberg and Levine, 2011; Baucells and Heukamp, 2012; Epper and Fehr-Duda, 2015). Other models have been proposed to unify risk preferences and preferences over allocations or 'social preferences' (Saito, 2013; Lopez-Vargas, 2014). However, there is no unifying framework which simultaneously operates across all three domains. Jullien (2016) provides a survey of work demonstrating interactions between the dimensions of risk, time, and social preferences and proposes to 'see rationality in 3D'. Jullien distinguishes behaviors 'within' dimensions from behaviors 'across' dimensions, and notes:

"'Within' dimensions means that decision problems are of the form, e.g., 'a consequence for sure vs. a bigger consequence with uncertainty' or 'a consequence now vs. a bigger consequence later'", whereas decisions across dimensions include choices such as "'a consequence for sure but later versus another consequence now but with uncertainty.'"

Jullien argues:

"'The proposed distinction between challenges within and across dimensions is more than conceptual, it also delimits a historical rupture between two periods that are nontrivial regarding the debates between behavioral and standard economics. The classical challenges posed by Kahneman, Tversky, Thaler and others focused on interactions within dimensions, posing problems to standard models. The more recent challenges from interactions across dimensions are posing problems to both standard and behavioral economists' models."

Following this line of research, we develop a decision model which predicts systematic interaction effects across the dimensions of risk, time, and social preferences. In light of the preceding comments, we reach a surprising conclusion: A simple way to model the observed interaction effects across the three decision domains is to combine the standard normative and behavioral models. In particular, we propose a parametric dual system model in which a decision maker is driven by the preferences of an intuitive, and affective 'System 1' and a logical, reflective 'System 2'. System 1 is assumed to have prospect theory risk preferences , and to be delay-averse and inequity-averse, whereas System 2 is assumed to have expected utility risk preferences and to be delay-neutral and inequity-neutral. We can view the model developed here as representing 'rational-behavioral preferences,' (RBP) since choice alternatives are evaluated by the convex combination of a rational (System 2) value function and a behavioral (System 1) value function. We will show that the RBP model unifies phenomena that are not accounted for by the standard normative and behavioral models in isolation. In particular, systematic interactions between risk, time, and social preferences arise in the model from the interactions between System 1 and System 2 preferences which can explain empirical violations of the dimensional independence axiom (Keeney and Raiffa, 1993). In addition, the model includes a parameter representing the decision maker's thinking style or 'cognitive type' (the degree to which the decision maker relies on System 2 processing), which is also predicted to be correlated with risk, time, and social preferences, consistent with the experimental evidence.

1.1 Related Literature

There is an expanding literature on the relationships between risk, time, and social preferences. Much of this work is experimental in nature. Given the large literature, we focus our discussion here on alternative theoretical approaches. Halevy (2008) and Epper and Fehr-Duda (2015) provide approaches to unifying risk and time preferences based on the observation that the future is inherently uncertain which they model with a constant stopping probability. Baucells and Heukamp provide a model which accounts for interactions between risk and time preferences, but their approach, like that of Halevy (2008) and Epper and Fehr-Duda (2015) has no implications regarding the relationship between risk preferences, time preferences, and cognitive skills. In addition, these approaches do not account for any of the effects related to social preferences. Saito (2013) and Lopez-Vargas (2014) develop models which account for relationships between risk and social preferences, but their approach does not consider time preferences. Dreber et al. (2014) provide a dual self model that applies to social preferences and time preferences, but their analysis does not consider risk preferences. In contrast, the model developed here applies simultaneously across all three decision domains, demonstrating that the same mechanism that explains interactions between risk and time preferences can also explain interactions between risk and social preferences and between time and social preferences. Moreover, the RBP model has novel implications regarding the relationship between risk, time, and social preferences and reliance on System 1 versus System 2 processing which are supported by recent experimental evidence. However, the RBP model does not account for all systematic interaction effects across decision domains. For instance, the RBP model employs an outcome-based measure of inequity aversion and so cannot account for the observation that people may also have preferences for 'equal opportunities' (Saito, 2013).

2 Dimensional Independence

We study interactions between risk, time, and social preferences. One might consider six pairwise interactions across these domains: (i) risk affects time preference; (ii) time affects risk preference; (iii) risk affects social preferences; (iv) social context affects risk preferences; (v) time affects social preferences; (vi) social context affects time preferences. Additional interaction effects arise when one also considers changes in payoff magnitude. Each of these interaction effects provides a test of the same general principle. This principle, called *dimensional independence* (Keeney & Raiffa, 1993; Bhatia, 2016) states that two attribute dimensions x and y are independent if for all x, y, x', y' an alternative (x, y) is chosen over (x', y) if and only if (x, y') is chosen over (x', y'). This principle reflects the intuition that identical attribute values in a dimension across alternatives will cancel in the evaluation process and not affect decisions. This principle is so basic that it is a general feature of both the leading normative and behavioral decision models.

Table I reveals seven violations of dimensional independence. For each choice between options A and B, the table makes the common dimension explicit. The finding that delay reduces risk aversion holds the time delay fixed for both options in Choice 1 (no delay) and for both options in Choice 2 (3 months). The finding that risk reduces impatience holds the probabilities fixed for both options in Choice 1 (certainty) and for both options in Choice 2 (probabilities of 0.5). The finding that allocations shift risk preference holds the other person's payoff fixed at 9 in Choice 1 and at 16 in Choice 2. The finding that risk reduces inequity aversion holds the probabilities fixed for both options in Choice 1 (certainty) and for both options in Choice 2 (probabilities of 0.5). The behavior that allocations shift time preference holds the other person's payoff fixed at 9 in Choice 1 and at 12 in Choice 2. The finding that delay reduces inequity aversion holds the time delay fixed for both options in Choice 1 (no delay) and for both options in Choice 2 (1 year delay). The finding that payoffs interact with risk and time preferences (subendurance) holds the decision maker's payoff fixed at 100 in Choice 1 and at 5 in Choice 2. Since one dimension is held fixed within each choice, dimensional independence predicts that the values in this fixed dimension can be interchanged without affecting behavior. Yet recent experimental evidence has documented such violations of dimensional independence.

The model developed here of rational-behavioral preferences predicts each of these systematic violations in the direction observed in experiments. Schneider (2018) proposes the special case of the RBP model for choices involving risk and time (but not social) preferences and demonstrates that the model predicts the risk-time interaction effects identified by Keren and Roelofsma (1995), Baucells et al. (2009), and Baucells and Heukamp (2010) in Table 1. In Section 3, we show that the extended RBP model predicts the four additional violations of dimensional independence in Table 1. These violations of dimensional independence predicted by the RBP model imply that both uncertainty and time reduce the propensity for giving in dictator games, and that distributional concerns can shift both risk and time preferences. Of the seven systematic violations of dimensional independence in Table I, five of them cannot be explained when either $\theta = 0$ or $\theta = 1$, requiring the interaction between

System 1 and System 2 within the model presented here. Further, the RBP model makes strong directional predictions as it does not predict the reverse preference patterns. Our modeling approach was merely intended to provide a formal representation of decision making that accounts for both System 1 and System 2 processes. We observe that a simple and even natural specification of this model has the by-product of providing a unified approach to predicting empirical violations of dimensional independence and to modeling interactions between risk, time, and social preferences, as well as predicting their correlations with cognitive reflection.

Table 1. Violations of Dimensional Independence

Behavior	Choice 1	Choice 2
Delay reduces Risk Aversion (Baucells and Heukamp, 2010)	**A. (9, now, 100%)** B. (12, now, 80%)	A. (9, 3 months, 100%) **B. (12, 3 months, 80%)**
Risk reduces Impatience (Keren and Roelofsma, 1995)	**A. (100, now, 100%)** B. (110, 4 weeks, 100%)	A. (100, now, 50%) **B. (110, 4 weeks, 50%)**
Inequality shifts Risk Preference*	**A. (9 self, 9 other, 100%)** B. (16 self, 9 other, 50%)	A. (9 self, 16 other, 100%) **B. (16 self, 16 other, 50%)**
Risk reduces Inequity Aversion (Krawczyk & Le Lec, 2010)*	**A. (5 self, 5 other, 100%)** B. (10 self, 0 other, 100%)	A. (5 self, 5 other, 50%) **B. (10 self, 0 other, 50%)**
Inequality shifts Time Preference*	**A. (9 self, 9 other, now)** B. (12 self, 9 other, 3 months)	A. (9 self, 12 other, now) **B. (12 self, 12 other, 3 months)**
Delay reduces Inequity Aversion (Kovarik, 2009)*	**A. (5 self, 5 other, now)** B. (10 self, 0 other, now)	A. (5 self, 5 other, 1 year) **B. (10 self, 0 other, 1 year)**
Payoffs interact with Risk and Time (Baucells et al., 2009)	**A. (100, 1 month, 100%)** B. (100, now, 90%)	A. (5, 1 month, 100%) **B. (5, now, 90%)**

Modal choice patterns from experiments in bold font; * denotes a prototypical example.

3 Rational-Behavioral Preferences

Let there be a finite set, T, of time periods, a finite set, $\mathcal{M}$, of outcomes with $\mathcal{M} \subset \mathbb{R}$,and a finite set, $\mathcal{I}$, of individuals. Time periods are indexed by $t \in \{0, 1, ..., m\}$ and individuals are indexed by $i \in \{1, 2, ..., n\}$. A consumption allocation consists of an outcome for each individual $i \in \mathcal{I}$,at each time period $t \in$ T. It can be written:

$$x_j := \{(x_{j10}, x_{j20}, ..., x_{jk0}), 0; ...; (\mathrm{x}_{\mathrm{j}1m}, x_{j2m}, ..., x_{jkm}), m\}$$

where x_{jit} is the outcome assigned by consumption allocation x_j to individual i in period t. The decision maker is denoted $i = 1$. Let $\mathcal{X}$ denote a finite set of consumption allocations with consumption allocations indexed by $j \in \{1, 2, ..., k\}$. A stochastic consumption allocation is a lottery over consumption allocations. It is a function $f : \mathcal{X} \to [0, 1]$, with f_j the probability it assigns to consumption allocation x_j. Denote the set of stochastic consumption allocations by $\Delta(\mathcal{X})$.

Schneider (2018) proposes a 'dual process utility' model of risk and time preferences in which a decision maker's preferences over stochastic consumption plans (involving only the decision maker) are given by:

$$\mathrm{V}(f) = (1 - \theta)\mathrm{V}_1(f) + \theta \mathrm{V}_2(f)$$

where $\mathrm{V}_1(f)$ represents System 1 preferences, $\mathrm{V}_2(f)$ represents System 2 preferences, and $\theta \in [0, 1]$ reflects the decision maker's 'cognitive type' (the degree to which the decision maker relies on System 2 (versus System 1) in decision making. Motivated by the intuition that prospect theory is a natural model of System 1 thinking (Kahneman, 2011), Schneider (2018) assumes that System 1 has discounted prospect theory preferences (or for analytical convenience, discounted rank-dependent utility preferences). That is,

$$\mathrm{V}_1(f) = \sum_{\mathrm{t}} \sum_{\mathrm{j}} \delta^{\mathrm{t}} \pi(f_{jt}) u(x_{j1t})$$

for a System 1 discount factor, δ, rank-dependent probability weighting function, π, and utility or value function, u, where $\pi : [0, 1] \to [0, 1]$, is defined such that $\pi(0) = 0$ and $\pi(1) = 1$, and

$$\pi(f(x_{jt})) = w(f(x_{jt}) + \cdots + f(x_{1t})) - w(f(x_{j-1,t}) + \cdots + f(x_{1t})),$$

for $j \in \{1, 2, ..., k\}$, where consumption allocations are ranked according to the discounted utility for System 1 for each sequence such that $\sum_t \delta_1^t u_1(x_{mt}) \leq ... \leq \sum_t \delta_1^t u_1(x_{1t})$.

Schneider assumes discounted expected utility preferences for System 2 in general. To make the model tractable, however, Schneider (2018) demonstrates that all of the behaviors studied in that paper can be explained even with a parameter-free specification for System 2 in which System 2 is both risk-neutral and delay-neutral. That is, System 2 maximizes the undiscounted expected value of a stochastic consumption plan. Indeed, Harrod (1948) has argued that an idealized rational agent would not discount the future due to impatience. The specification for System 2 still permits greater discounting of the future due to the presence of uncertainty, particularly if the future is more uncertain than the present. In this paper, we consider a simple generalization of the dual process utility model to social preferences. Our main new assumption is that System 1 is inequality-averse, whereas System 2 is inequality-neutral. This assumption is motivated by the intuition that System 1 is influenced by emotional factors such as conncerns about fairness, whereas System 2 resembles the textbook economic agent whose utility depends only on its own payoff. In particular, we consider a simple extension of the model in Schneider (2018) to stochastic consumption allocations given by the parametric form in (1):

$$\mathrm{V}(f) = \theta \mathbb{E}\left[f\right] + (1-\theta) \sum_{t} \sum_{j} \delta^{t} \pi(f_{jt}) u(x_{j1t} - \frac{\alpha}{n} \sum_{\mathrm{i}} |x_{jit} - x_{j1t}|) \qquad (1)$$

where $\mathbb{E}\left[f\right]$ is the undiscounted expected value of f to the decision maker and $\alpha \geq 0$ represents the degree of inequity aversion for System 1. One might further simplify (1) by letting $u(x) = x$, such that both systems have linear utility for choices involving only the decision maker. In that case, (1) has three domain-specific parameters (one each for the risk, time, and social preferences of System 1), plus the parameter θ representing the agent's 'cognitive type' that operates across domains.

Note that (1) imposes a duality between Systems 1 and 2: System 1 preferences are non-linear in probabilities and payoffs, delay-averse, and inequity-averse, whereas System 2 preferences are risk-neutral, delay-neutral and inequity-neutral[1]. We refer to (1) as *rational-behavioral preferences* (RBP) since the model evaluates alternatives according to a weighted average of rational System 2 preferences and behavioral System 1 preferences.

4 Risk and Social Preferences

In this section, we apply the RBP model to explain violations of dimensional independence involving risk and social preferences. To analyze the examples from Table I that involve distributional concerns more generally, we consider choices over stochastic consumption allocations of the form $\{(x, y), t, p\}$ which delivers payoff x to the decision maker and y to another person to be received at time t with probability p.

[1] None of these conditions on System 2 is necessary for our results; We only require that System 2 is closer to risk-neutrality, more patient, and less inequity-averse than System 1

4.1 Inequality affects Risk Preference

Bolton and Ockenfels (2010) observed a modal preference for 9 Euros with certainty over a 50% chance of 16 Euros. However, they also observed a modal preference for a 50% chance that the decision maker and a passive recipient each receive 16 Euros (and a 50% chance they each receive nothing) over the decision maker receiving 9 Euros and the recipient receiving 16 Euros with certainty. This preference pattern can hold under (6), due to System 1's inequity aversion even though neither system is risk-seeking toward gains of moderate or high probabilities. Similar behavior in which the social context shifts risk preferences toward less inequity has been observed by Leder and Betsch (2016).

Definition 1 (Effect of inequality on risk preferences). A person exhibits a preference for inequality-reducing lotteries if for all $x > y > 0$,

$$((x, y), t, p) \sim ((y, y), t, 1) \Rightarrow ((x, x), t, p) \succ ((y, x), t, 1) \tag{2}$$

$$((x, x), t, p) \sim ((y, x), t, 1) \Rightarrow ((y, y), t, 1) \succ ((x, y), t, p) \tag{3}$$

Proposition 1: Under the RBP model, a preference for inequality-reducing lotteries holds for all $\theta \in [0, 1)$.

4.2 Risk affects Social Preference

A novel implication of RBP is that risk will interact with social preferences. Under RBP, a decision maker indifferent between splitting $10 evenly with a recipient or keeping all $10 will prefer a 50-50 chance of allocation ($10, $0) or ($0, $0) over a 50-50 chance of ($5, $5) or ($0, $0). That is, introducing risk into a dictator game is predicted to reduce inequity aversion. While we have not seen this precise example, 'probabilistic' dictator games have been conducted by Krawczyk and Le Lec (2010) and Brock et al. (2013). Both studies find that introducing risk into a dictator game decreases giving by the dictator. Exley (2016) also found less charitable giving under risk. Definition 8 provides a simple formalization of reduced dictator giving under risk.

Definition 2 (Effect of risk on social preferences). Risk reduces inequality aversion if for all $x > y > 0$,

$$((x, 0), t, 1) \sim ((x - y, y), t, 1) \Rightarrow ((x, 0), t, 0.5) \succ ((x - y, y), t, 0.5). \tag{4}$$

Proposition 2: Under the RBP model with $w(0.5) < 0.5$, risk reduces inequality aversion if and only if $\theta \in (0, 1)$.

5 Time and Social Preferences

The RBP model further predicts that the social context will affect time preference. We demonstrate these predictions in Sections 5.1 and 5.2.

5.1 Inequality affects Time Preference

An illustrative example from Table III is that a decision maker indifferent between he and another person receiving \$9 today or him receiving \$12 and the other person receiving \$9 in three months is predicted to strictly prefer an allocation in which he and another person each receive \$12 in three months over an allocation in which he receives \$9 today and the other person receives \$12 today. That is, changes in allocations shift preferences toward consumption sequences with lower inequality.

Definition 3 (Effect of inequality on time preferences). A person exhibits a preference for inequality-reducing consumption plans if for all $x > y > 0$,

$$((x, y), t, p) \sim ((y, y), 0, p) \Rightarrow ((x, x), t, p) \succ ((y, x), 0, p) \tag{5}$$

$$((x, x), t, p) \sim ((y, x), 0, p) \Rightarrow ((y, y), 0, p) \succ ((x, y), t, p) \tag{6}$$

Proposition 3: Under the RBP model, a preference for inequality-reducing consumption plans holds for all $\theta \in [0, 1)$.

5.2 Time affects Social Preference

The RBP model also predicts that time will interact with social preferences. For instance, under RBP, a person indifferent between splitting \$10 evenly today with a recipient or keeping all \$10 for himself will strictly prefer to keep all \$10 when the money is to be received after one year. That is, introducing delays into a dictator game reduces inequity aversion. In an experimental study on a 'temporal' dictator game, Kovarik et al. (2009) found that longer delays decrease giving by the dictator. This finding was also observed by Dreber et al. (2014).

Definition 4 (Effect of delay on social preferences). Delay reduces inequality aversion if for all $r > t > 0$ and $x > y > 0$,

$$((x, 0), t, p) \sim ((x - y, y), t, p) \Rightarrow ((x, 0), r, p) \succ ((x - y, y), r, p). \tag{7}$$

Proposition 4: Under the RBP model, delay reduces inequality aversion if and only if $\theta \in (0, 1)$.

The condition that $w(0.5) < 0.5$ is a robust empirical finding in studies of prospect theory (Prelec (1998), Gonzalez and Wu (1999), Wakker (2010)) which holds for typical estimates of the standard inverse-S-shaped probability weighting functions as well as for globally pessimistic weighting functions that are commonly used in theoretical analyses of rank-dependent utility theory.

6 Cognitive Type and Social Preferences

Recent work has documented systematic relationships between risk preferences, time preferences, and cognitive reflection (or other measures of analytical thinking) (e.g., Frederick (2005), Burks et al. (2009), Dohmen et al. (2010, 2018)). In particular, the emerging perspective is that more reflective thinkers (those who rely more on System 2) are both more patient and closer to risk-neutrality than more intuitive thinkers (those who rely more on System 1). Schneider (2018) demonstrates that the special case of the RBP model for choices involving only risk and time preferences predicts these empirically observed correlations. This follows directly from (1) since System 2 has a higher discount factor than System 1 and System 2 is risk-neutral.

The RBP model in (1) makes additional predictions regarding the relationship between the social preferences of agents with different levels of System 2 processing as paramtetrizd by θ. Consider two agents of type θ_1 and θ_2, where $\theta_1 < \theta_2$, with preferences given by (1) and with the same System 1 preferences that have $\alpha_1 = \alpha_2 > 0$. Let $\succsim_1$ and $\succsim_2$ denote the preferences of these agents. Since agents with higher values of θ are less inequity-averse, the RBP model generates novel predictions for both the dictator game and the ultimatuum game. In the dictator game, one participant (the dictator) decides how to allocate a fixed amount of money between himself and a passive recipient. In the dictator game, RBP predicts that agents with high cognitive types (higher θ) give less than agents with lower values of θ. Formally:

Proposition 5 (Cognitive Type and the Dictator Game): Under the RBP model, for the dictator in the dictator game, the propensity to give money decreases with θ. For any $x > y > 0$, if $(x, 0) \sim_1 (x-y, y)$, then $(x, 0) \succ_2 (x - y, y)$.

Empirical support for Proposition 5 comes from an experimental study by Ponti and Rodriguez-Lara (2015) who administered the cognitive reflection test (CRT) due to Frederick (2005) to players that also participated in a dictator game. The CRT is a three-item measure where each question has an intuitive but incorrect answer, and a correct answer which requires a moment of reflection. The test is designed to identify decision makers who rely more on System 1 versus System 2 processing, with higher scores relying more on reflective thinking (System 2). Consistent with Proposition 5, subjects with higher scores on the CRT gave less in the dictator game. Ponti and Rodriguz-Lara comment "Impulsive Dictators show a marked inequity aversion attitude," and that "Reflective Dictators show lower distributional concerns, except for the situations in which the Dictators' payoff is held constant." Cueva et al. (2016) and Capraro et al. (2017) also found low CRT subjects to be more inequity-averse than high CRT subjects in dictator game experiments. Schulz et al. (2014) likewise found that subjects under high cognitive load (a means to increase reliance on System 1) also gave more in a dictator game experiment.

The ultimatum game, a close relative of the dictator game, involves two players who make sequential decisions. The first mover decides how much of a fixed sum to offer the other player. If the other player accepts, the proposed offer is implemented. If the other player rejects the offer, both players receive nothing. The RBP model makes the following prediction for the ultimatum game:

Proposition 6 (Cognitive Type and the Ultimatum Game): Under the RBP model, for the responder in the ultimatum game, the acceptance of unfair offers increases with θ. For any $x > y > 0$, if $(y, x - y) \sim_1 (0, 0)$, then $(y, x - y) \succ_2 (0, 0)$.

That is, RBP predicts people who rely more on System 2 to be more likely to accept unfair offers (i.e., offers with a larger amount for the proposer) in the ultimatum game than those who rely more on System 1. Empirical support for Proposition 6 comes from experiments by Neys et al. (2011) and Calvillo and Burgeno (2015) who each found that higher scoring participants on the cognitive reflection test were more likely to accept unfair ultimatum game offers. The RBP model in (1) thus offers novel and empirically supported predictions of how distributional preferences relate to risk and time preferences, and to the agent's cognitive type.

7 Conclusion

In a review of research across the dimensions of risk, time, and social preferences, Jullien (2016) remarks, "the topic of interactions across dimensions has been understudied in economic theory." Here we presented a model of decision making that predicts relationships between risk, time, and social preferences that have empirical support. In particular, the RBP model predicts systematic violations of dimensional independence in the direction observed in experiments. The RBP model also predicts that decision makers who rely more on System 2 processing will give less money in a dictator game and will be more likely to accept unfair offers in the ultimatum game as observed in recent studies based on the cognitive reflection test. More broadly, RBP enlarges the canvas by accounting for the probabilistic, intertemporal, and social context as part of the description of the decision problem. Doing so enables RBP to explain a variety of context effects while retaining a transitive preference function. As the volume of research in these areas is fast expanding and it may be too early to identify 'canonical' effects, we view RBP as more of a theoretical framework for generating novel predictions and guiding new experiments than as a definitive theory. Theoretical approaches to integrating risk, time, and social preferences must start somewhere, and we have developed RBP as a simple unifying approach to portray rationality in 3D.

Appendix (Proofs of Propositions)

Proposition 1: Under the RBP model, a preference for inequality-reducing lotteries holds for all $\theta \in [0, 1)$.
Proof: To establish (2), we need to show that (8) implies (9)

$$(1-\theta)\delta^{\mathrm{t}}u(y) + \theta y = (1-\theta)w(p)\delta^{\mathrm{t}}u(x - \alpha(x-y)) + \theta px. \tag{8}$$

$$(1-\theta)\delta^{\mathrm{t}}u(y - \alpha(x-y)) + \theta y < (1-\theta)w(p)\delta^{\mathrm{t}}u(x) + \theta px. \tag{9}$$

Note that $u(y - \alpha(x-y)) < u(y)$ and $u(x - \alpha(x-y)) < u(x)$given System 1 is inequity-averse ($\alpha > 0$), and thus (8) implies (9). An analogous argument establishes condition (3). □

Proposition 2: Under the RBP model with $w(0.5) < 0.5$, risk reduces inequality aversion if and only if $\theta \in (0, 1)$.
Proof: To prove sufficiency, we need to show that (10) implies (11):

$$\theta y = (1-\theta)\delta^{\mathrm{t}}[u(x - y - \alpha|x - 2y|)) - u(x - \alpha x)]. \tag{10}$$

$$0.5\theta y > (1-\theta)w(0.5)\delta^{\mathrm{t}}[u(x - y - \alpha|x - 2y|)) - u(x - \alpha x)]. \tag{11}$$

Since $\theta y > 0$, equation (10) implies $u(x - \alpha x) < u(x - y - \alpha|x - 2y|))$.
Since $w(0.5) < 0.5$, after substituting (10) into (11), it follows that (11) holds and $\theta \in (0, 1)$ is sufficient.

Necessity that $\theta \in (0, 1)$ follows since the probability weights cancel when evaluating the two alternatives in the special cases of $\theta = 0$ and $\theta = 1$, and risk does not affect social preferences in those cases. □

Proposition 3: Under the RBP model, a preference for inequality-reducing consumption plans holds for all $\theta \in [0, 1)$.
Proof: To establish (5), we need to show that (12) implies (13)

$$(1 - \theta)w(p)u(y) + \theta py = (1 - \theta)w(p)\delta^{\mathrm{t}}u(x - \alpha(x - y)) + \theta px. \tag{12}$$

$$(1 - \theta)w(p)u(y - \alpha(x - y)) + \theta py < (1 - \theta)w(p)\delta^{\mathrm{t}}u(x) + \theta px. \tag{13}$$

Note that $u(y - \alpha(x - y)) < u(y)$ and $u(x - \alpha(x - y)) < u(x)$given$\alpha > 0$, and thus (12) implies (13). An analogous argument establishes condition (6). □

Proposition 4: Under the RBP model, delay reduces inequality aversion if and only if $\theta \in (0, 1)$.
Proof: To prove sufficiency, we need to show that (14) implies (15):

$$\theta py = (1 - \theta)w(p)\delta^{\mathrm{t}}[u(x - y - \alpha|2y - x|)) - u(x - \alpha x)]. \tag{14}$$

$$\theta py > (1 - \theta)w(p)\delta^{\mathrm{r}}[u(x - y - \alpha|2y - x|)) - u(x - \alpha x)]. \tag{15}$$

Since $\theta py > 0$, equation (14) implies $u(x - \alpha x) < u(x - y - \alpha|2y - x|))$.
Note that (15) holds since $\delta^{\mathrm{r}} < \delta^{\mathrm{t}}$ for all $\delta \in (0, 1)$, and thus $\theta \in (0, 1)$ is sufficient.

Necessity that $\theta \in (0, 1)$ follows since the discount factors of System 1 and System 2 cancel when evaluating the two alternatives in the special cases of $\theta = 0$ and $\theta = 1$, and delay does not affect social preferences in those cases. □

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