SOCIAL (P)REFERENCES:

Testing Peer-Dependent Reference Points

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! PRELIMINARY, PLEASE DO NOT CIRCULATE !

Abstract

Individual decisions are often thought to be made based solely on personal gain, but recent experimental and empirical evidence challenges this assumption. We present a new model that incorporates social aspects of decision-making under uncertainty. Our model proposes two innovative specifications for decision-makers with allocational concerns, as their certainty equivalent may not be unique. Our research offers insight into the impact of peer effects on individual choices under risk, and we highlight the importance of precise specification of a peer-dependent certainty equivalent. Our findings suggest potential implications for various domains of economics. We also propose an experimental design to further explore predictions on peer effects.

JEL Classification codes: C91, D01, D11, D31, D81, D83, D91

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1 Introduction

Reference-dependent utility and loss aversion have been used in a wide range of topics to explain consumer behavior [e.g., in industrial organization as Heidhues and Kőszegi, 2008; Rosato, 2016, labor contracts as Herweg et al., 2010, asset pricing as Abel, 1990, and financial markets as Gottlieb, 2012]. Contrary to classic economic theories, reference-dependent decision-makers evaluate personal outcomes relative to a reference point. Moreover, loss aversion implies that losses relative to the reference point loom larger than gains of equal size. These two features have greatly enhanced our understanding of individuals' attitudes towards risk: for instance, they predict first-order risk aversion, i.e., decision-makers show risk aversion already for small risks – a finding that is hard to reconcile with classic economic models [Rabin, 2013]. As the examples above show, this has crucial implications in many economic settings. A key question when studying reference-dependent decision-makers is: what influences an individual's reference point?

Candidates for individual reference points oftentimes include the status quo or rational expectations. However, findings of individuals comparing themselves with others when forming a decision also suggest that the social environment may affect an individual's reference point [see, e.g., Festinger, 1954; Clark and Oswald, 1996; Neumark and Postlewaite, 1998]. For example, suppose we interpret the social environment as an individual's exogenous peer group in a particular economic setting. In that case, this raises questions about how reference-dependent preferences link to social preferences and, ultimately, how the social environment influences an individual's risk preferences.

The growing literature on social preferences extends standard economic theories where agents are unaffected by others by allowing for social comparisons and preferences over allocations [for an overview, see, e.g., Fehr and Schmidt, 2006]. Hence, in social preference models, an individual's utility depends not only on his own outcome but also on the outcome of his peer. Moreover, these theories distinguish between situations where decision-makers are worse off than their peer, which we will refer to as *unfavorable* inequality, and situations where decision-makers are better off, which we label as *favorable* inequality. Furthermore, many experimental studies show that social preferences affect individual behavior, suggesting that distributional concerns play an essential role in individual decision-making. However, as we argue below, many of the stylized facts of peer effects in choices that involve risk are hard to reconcile with these existing models, and their extensions to uncertainty are not straightforward [Saito, 2013]. In this paper, we derive a model that combines theories of reference-dependent choice with social preferences to bridge this gap.

The link between the social environment and an individual's risk preferences can have crucial implications for many current economic issues. For example, do inequality-reducing policies (e.g., redistributive tax systems) enhance or reduce an individual's willingness to take risks? In this way, make social reference points boost or setback the effectiveness of such policies? Alternatively, in a development context, would encouraging one farmer to use a novel technology (e.g., a sustainable fertilizer or a modern harvesting machine) by an NGO motivate or dissuade other farmers in the area to take up these methods as well? Recent research from the lab and the field has led to a growing body of evidence that shows how distinct social settings can immediately shape an individual's risk attitudes [e.g., Linde and Sonnemans, 2012; Schwerter, 2022; Exley, 2016; Lien and Zheng, 2015; Lindskog et al., 2022]. Existing approaches of reference-dependent utility focus only on self-centered decision-makers and, hence, do not take distributive aspects into account.

This paper presents a novel theory of peer-dependent reference points. Building on recent developments in the literature on reference-dependent decision-making and social preferences, we propose a model that can be characterized as a sum of three components. To illustrate this, let L be a monetary lottery and $s \in \mathbb{R}$ represents peer earnings. Then, a decision-maker's utility of playing lottery L given he expects to play lottery L and his peer obtaining s is given by

$$U(L, s|L, s) = \text{A} + \text{B} + \text{C},$$

where A is a personal utility component, B a peer-outcome component, and C an interaction term that is only present when ranks can reverse by playing L. Since A and B contain different utility weights also marginal utility differs for personal earnings and peer earnings, resulting in different effects on individual choice when peer outcomes change.

Depending on the type of certainty equivalent used to discuss an individual's risk preferences, our model predicts peer effects when social rankings can change but no peer effects when peers are 'unreachable' such that rankings remain unaffected. This seems consistent with most empirical findings in which economic agents compare themselves to others within their income bracket, but not with people who have an income high above or largely below their earnings. Furthermore, our model predicts that this peer effect leads to discouragement in risk-taking. For example, when an agent suddenly gets the possibility to fall behind his peer by taking a lottery, he tends to secure his earnings by accepting less risk due to personal risk aversion. In the same vein, an agent who gets the possibility to overtake his peer accepts less risk when the risky prospect tends to make him worse off.

In addtion, we propose a novel experimental strategy to test our model's predictions, measuring individual risk-taking through Multiple Price Lists (MPLs)..[1] Our 2×3 factorial design allows us to isolate peer effects in settings where social ranks cannot change, by comparing different scenarios where peers are ensured to be either worse or better off than the decision maker. Ultimately, to test our hypothesis that peer effects become present once social ranks can reverse, we include an additional treatment stage where a decision maker can reverse their relative position (vis-à-vis his peer) by choosing riskier prospects. We also plan to run a control experiment where decision makers face MPLs in isolation to rule out other potential factors. The experiment will be conducted in Spring 2023.

The remainder of the paper is organized as follows. The next section gives a brief overview of the related literature. We carve out stylized facts that are hard to reconcile with existing theories of reference dependence or social preferences. Throughout this paper, we will interchangeably use the terms social preferences, distributive concerns or allocational preferences when referring to social concerns that reflect peer effects. Subsequently, we outline our model in Section 3. Moreover, since a person's certainty equivalent does not necessarily need to be unique under social preferences, we propose two novel notions of certainty equivalence to discuss individual risk

[1] Note that the experiment will be conducted in Spring 2023. For the current version of this paper, we added detailed information about the experimental design, intended data collection and our planned analysis.

preferences when agents have distributive concerns in Section 4: while one of them (the *Egalitarian Certainty equivalent*, or E-CE) compares a personal-lottery-and-fixed-peer-earnings pair with an egalitarian allocation for sure, the other concept (named the *Secluded Certainty Equivalent*, or S-CE) helps to discuss risk preferences when peer earnings are held constant. Section 5 studies various implications of our model. In particular, following the previous literature, we broadly discuss a decision-maker's risk preferences by looking at how a decision-maker's utility is affected once peer earnings change. In this, we show that –depending on the right parametrization of social preferences– all of the findings documenting peer effects in the past experimental economics literature can be rationalized. We then continue to discuss the sensitivity of individual risk preferences to the specification of a given certainty equivalent. In particular, after establishing conditions under which different types of certainty equivalent notions yield the same predictions, we first discuss risk preferences in E-CE situations. Based on our *Equivalence of Certainty Equivalents* condition, we then continue to rationalize additional experimental findings through the lens of our model. Next, we look at peer effects on a person's S-CE and show that peer effects can have an *encouragement* and a *discouragement effect* on individual risk-taking behavior. Our experimental strategy is displayed in Section 6. Section 7 concludes. All proofs are relegated to the mathematical appendix.

2 Related literature

Most decisions under risk are evaluated not only by their potential counterfactuals with respect to own forgone earnings but also relative to other people's earnings [Schwerter, 2022]. It is thus natural to consider social preferences and risk-taking behavior simultaneously when evaluating a choice under risk in most economic decisions.

We first discuss the literature branches on reference-dependent and social preferences before bringing them together. This allows us to stress shortcomings in both branches and visualizes what is required to identify overlaps in their research interests.

2.1 Reference-dependent choice and loss aversion

Most of the literature studying reference-dependent preferences relies on exogenous reference points [e.g., Kahneman and Tversky, 1979; Tversky and Kahneman, 1991; Schwerter, 2022; Gamba et al., 2017; Lindskog et al., 2022]. Although this type of reference point adds to our understanding of an individual's decision-making process (e.g., by entailing loss aversion or status quo bias), it fails to explain how reference points adjust to the economic environment. In contrast, we build on the framework of Kőszegi and Rabin [2006, 2007] that allows for an endogenous reference point.

Further, past research focused on a status quo-based reference point as in Kahneman and Tversky [1979]. However, this notion cannot find a reasonable explanation for disposition effects in the absence of physical endowments.[2] Consequently, recent research [most notably Kőszegi and Rabin, 2006 and Abeler et al., 2011] argues in favor of an *expectations-based* reference point. This expectations-based reference point is more consistent with the experimental findings.[3] Our model incorporates an expectations-based reference point that allows us to study how perceived changes in peer earnings affect individual choices under risk.

However, all these theories of reference-dependent preferences assume almost exclusively self-centered, utility-maximizing decision-makers and, hence, do not take any distributional aspects into account.

2.2 Literature on social preferences

Social preferences have been widely studied both in theoretic models and empirically [for an overview, see, e.g., Fehr and Schmidt, 2006]. For example, Charness and Rabin [2002] tested different types of social preferences theories in a laboratory set-

[2]For instance, an employee who expects a 10-percent wage gain but only gets a 5-percent wage gain would perceive this gain of 5 percent as a loss. Status quo-based theories fail to explain this event because the wage gain has not been realized yet.

[3]Note that the results from Markle et al. [2018], who explore goals as reference points in marathon runners, can be interpreted in a sense in which goals parallel a runner's expectation. Indeed, if one interprets negative departs from the goal as a form of disappointment, then disappointment aversion makes the same predictions as rational expectations. Besides that –and for further empirical results– see Farber [2008], Ericson and Fuster [2011] and Pope and Schweitzer [2011].

ting.[4] In a more rigid framework, Fehr and Schmidt [1999], study the implications of inequality aversion under certainty. However, these standard social preferences theories only consider individual preferences over certain payoffs. Our model builds on these theories by embedding them into a model of reference-dependent decision-making. This allows us to extend social preferences to risky environments and to study peer effects on individual choices under risk.

Another important dimension of social preferences is intentions [see, e.g., Dufwenberg and Kirchsteiger, 2004; Falk and Fischbacher, 2006]. For instance, Dufwenberg and Kirchsteiger [2004] study how the interpretation of intentions affects individual choices in strategic environments. But since our focus lies on peer effects in a non-strategic setting, in this paper we abstract from concerns that might arise due to beliefs about choice motives.

2.3 Overlaps of the two literature branches

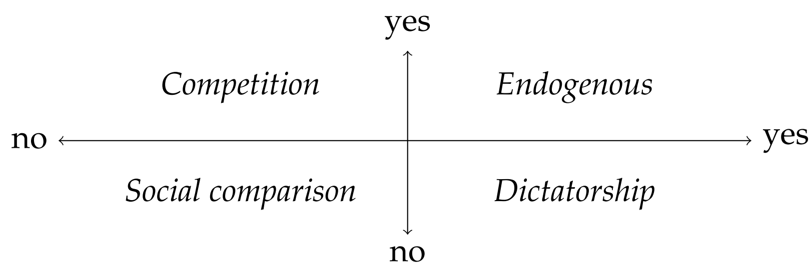
Both the literature branches of reference-dependent decision-making and social preferences proliferated in the past decades. However, their overlap is still an understudied research field, and existing theories of reference-dependent utility cannot fully explain how the economic outcomes of peers can change an individual's risk attitudes. Only a few, most notably Schwerter [2022], conducted experiments on the impact of social comparison on reference-dependent risk attitudes. Nevertheless, these works use exogenous social reference points without incorporating social preferences explicitly.[5]

2.4 Overview of the experimental evidence

Peer effects have also been documented in experiments, ranging from impacts on lottery choices to effort tasks. We follow Lindskog et al. [2022] and present this literature based on the nature of peer effects (see Figure 1), which divides experimental

[4] Moreover, they developed a utility function that can represent various types of social preferences (depending on the parameter choice).

[5] Exceptions are Müller and Rau [2019] and Lindskog et al. [2022]. However, Müller and Rau [2019] restrict themselves to the case where agents are inequality averse as Fehr and Schmidt [1999]. In contrast, our framework allows for various social preferences.



Horizontal dimension: Decision-makers can influence peer outcomes.

Vertical dimension: Peers can influence their own outcomes.

Figure 1: Overview of the Experimental literature.

results into four different categories: dictatorship, competition, social comparison, and an endogenous case.[6]

Dictatorship. Much of the past literature studied social contexts where one individual can affect the outcome of others but where others cannot influence their own outcome [see, e.g., Brennan et al., 2008; Brock et al., 2013; Rohde and Rohde, 2011], which we call the dictatorship case [following Lindskog et al., 2022, bottom right sector of Figure 1]. For example, Brennan et al. [2008] and Brock et al. [2013] study altruistic motives where subjects can choose the amount of risk they want to impose on others. Even though they find that allocational concerns are detectable when monetary payoffs are common knowledge, they seem to vanish once uncertainty is introduced. Their results conclude that there is no link between individual risk attitudes and distributional concerns. In a related study, Rohde and Rohde [2011] compare decision-makers' risk-taking behavior for others with risk-taking for themselves. Even though subjects are risk-averse, they find no significant difference between these two situations.

Competition. Other experimental studies focus on situations where peer outcomes depend on the risk chosen by the decision-maker [upper left sector of Figure 1; e.g., Lahno and Serra-Garcia, 2015; Gantner and Kerschbamer, 2018; Viscusi et al., 2011; Chao et al., 2017; Dijk et al., 2014; Fafchamps et al., 2015]. For exam-

[6]Except for the endogenous case, we provide a brief overview of experimental findings for these different cases. In the endogenous case, both decision-makers and peers can affect each other's outcomes. However, previous research has not studied this case (most likely because testing predictions in this scenario remains difficult).

ple, in a choice task where subjects choose after observing how peers choose (but do not know the associated outcome), Lahno and Serra-Garcia [2015] and Gantner and Kerschbamer [2018] find that decision-makers tend to imitate their peers by replicating their choices. While Lahno and Serra-Garcia [2015] suspect such behavior arises from social norms, Gantner and Kerschbamer, 2018 concludes that subjects have convex distributional preferences. Dijk et al. [2014] and Fafchamps et al. [2015] test the implications of status concerns. In their experiments, which consist of repeated rounds where round-specific outcomes are public knowledge, they find that risk-taking increases when peers perform better –a finding they dub the *keeping-up-with-the-winners effect*. Even though not very clear, they hypothesize that social comparison may explain individual risk-taking choices (alongside guilt or learning effects) in these cases.

Social Comparison. Our paper focuses on the interaction between distributional preferences and risk-taking when decision-makers cannot influence what others get. Hence, in such social comparison situations (see lower left sector in Figure 1), decision-makers make risky choices while observing a fixed peer outcome [see, e.g., Linde and Sonnemans, 2012; Schwerter, 2022; Gamba et al., 2017; Müller and Rau, 2019; Lindskog et al., 2022; Lien and Zheng, 2015; Dalmia and Filiz-Ozbay, 2021; Buser, 2016; Schmidt et al., 2019]. Linde and Sonnemans [2012] and Müller and Rau [2019] study individual risk-taking when social ranks are fixed. Subjects make risky choices knowing they are either in a social loss context (where the decision-maker is ensured to have less than his peer) or in a social gain context (where he is ensured to have more than his peer). While Linde and Sonnemans [2012] document stronger risk aversion in the social loss context and less risk aversion in the social gain context, Müller and Rau [2019] elicit risk preference independently from inequity aversion to predict behavior in a context of social losses and a social gains, respectively. They find that subjects take more risks when they are ahead of their peers (compared to the social losses). And although the context somewhat differs, the experimental designs of Linde and Sonnemans [2012] and Gamba et al. [2017] are very similar.[7] In contrast

[7] In their experiment, Gamba et al. [2017] focus on peer effects on effort tasks. Other studies that look at effort tasks and peer effects include Dalmia and Filiz-Ozbay [2021]; Buser [2016]; Schmidt et al. [2019].

to Linde and Sonnemans [2012], however, Gamba et al. [2017] find increased risk-taking in the social loss context (compared to a social gain), which is also observed in large social gains. In the experiment by Schwerter [2022], subjects make lottery choices while facing a mean-variance trade-off: larger outcomes are linked to more risk. By varying peer earnings, he finds that subjects choose larger upsides when peer earnings are high (compared to when peer earnings are low).

3 Model

Our model combines two types of preferences: reference-dependent decision-making and social preferences. The broad idea of the model is to embed allocational concerns in reference-dependent choices. We first describe how our model captures allocational concerns (or social preferences) before presenting the encompassing model of reference-dependent decision-making. We close this section by proposing two novel notions of certainty equivalence in the multi-person context.

3.1 Social preferences

We model social preferences based on the model by Charness and Rabin [2002], where a decision-maker evaluates an allocation between him and a peer. Following Charness and Rabin's [2002] notation, let $x \in \mathbb{R}$ be the decision-maker's payoff while his peer obtain the amount $s \in \mathbb{R}$. We define stand-alone utility of an allocation $a = (x, s)$ as $u(a)$ and assume it to be linear such that $u(a)$ may be characterized by

$$u(a) = u(x, s) = \begin{cases} \sigma s + (1 - \sigma)x & \text{if} \quad x \leq s \\ \varrho s + (1 - \varrho)x & \text{if} \quad x > s \end{cases} \tag{1}$$

where $\sigma, \varrho \in \mathbb{R}$ are preference parameters that describe different types of social preferences. Like Charness and Rabin [2002], we assume that a decision-maker is relatively more concerned about his own outcome when he is behind than when ahead of his peer:

A1. $\sigma \leq \varrho$.

Table 1: Overview of different types of social preferences and their preference weights.

Social preferences	Parameters (weights)
Self-centered preferences	$\sigma = \varrho = 0$
Competitive preferences	$\sigma \leq \varrho < 0$
Inequality aversion (difference aversion)	$\sigma < \varrho \leq 1$
Social welfare preferences (efficiency preferences)	$0 < \sigma \leq \varrho \leq 1$

Given its characterization, $u(a)$ is a linear combination of the two outcomes x and s and can represent various social preferences based on parameters σ and ϱ.

Letting $\sigma = \varrho = 0$, for instance, mimics *self-centered preferences* as in classic economic theory that does not take peer outcomes into account. A specification of $\sigma \leq \varrho < 0$ represents *competitive preferences* since decision-makers put a positive weight on personal outcomes and a negative weight on what peers get, resulting in a disutility from peer earnings when they receive a positive outcome. In addition, $\sigma < 0 < \varrho \leq 1$ captures *inequality aversion* (or *difference aversion*), where both positive as well as negative departures from an egalitarian allocation are perceived as unpleasant. Note, however, that since under inequality aversion $|\sigma| \neq |\varrho|$ is possible, a decision-maker can feel different about an unequal allocation that puts him behind and an unequal allocation that makes him relatively better off than his peer for the same level of inequality. Finally, another specification is *social welfare preferences* (or *efficiency preferences*), which correspond to $0 < \sigma \leq \varrho \leq 1$. Under social welfare preferences, a decision-maker enjoys Pareto improvements[8] for himself and his peer. Hence, although preference parameters may differ when being better or worse off than the peer under inequality aversion, a decision-maker with social welfare preferences puts positive weights on his and his peer's payoff. Table 1 summarizes the presented types of social preferences. For the remainder of the paper, we assume that agents have allocational concerns, i.e., $\rho, \sigma \neq 0$.

[8] We define Pareto improvements as increases in the overall surplus for both agents.

3.2 Reference-dependent preferences

To incorporate reference-dependent preferences, we build on the theory by Kőszegi and Rabin [2006, 2007]. For our purpose, let $a \in \mathbb{R}$ be an outcome allocation and $r \in \mathbb{R}$ a decision-maker's reference allocation, respectively. Hence, for the two-person case, an allocation $a = (x, s)$ bears the stand-alone utility $u(a)$ such that $u(a) = u(x, s)$ is defined as in the subsection above. Thus, following Kőszegi and Rabin [2006, 2007], a decision-maker who evaluates an allocation a relative to r has the following overall utility:

$$U\big(u(a)|u(r)\big) = u(a) - \mu\big(u(a) - u(r)\big), \tag{2}$$

where the first term of the overall utility $U(u(a)|u(r))$ represents stand-alone utility $u(a)$ from the allocation a while the second term $\mu(u(a) - u(r))$ is a function that captures gain-loss sensations from comparing allocation a with allocation r and satisfies the following properties:

A2. $\mu(c)$ is strictly increasing and continuous $\forall c$, twice differentiable $\forall c \neq 0$ and $\mu(0) = 0$.

A3. $c' > c > 0 \;\Rightarrow\; \mu(c') + \mu(-c') < \mu(c) + \mu(-c)$.

A4. $\big(\lim_{c\to 0} \mu'(-|c|)\big) / \big(\lim_{c\to 0} \mu'(|c|)\big) \equiv \lambda > 1$.

A5. $\mu''(c) \leq 0 \;\forall c > 0$ and $\mu''(c) \geq 0 \;\forall c < 0$.

Notice that in this framework, these assumptions correspond to Kahneman and Tversky's [1979] *value function* defined on $(c - r)$. A3 captures loss aversion for large stakes and A4 for small stakes. A5 captures diminishing sensitivity, saying that marginal changes in gain-loss sensations decrease in the distance to the reference point. As an approximation for small stake changes, however, we will depart from diminishing sensitivity in our analysis and assume

A5′. $\mu''(c) = 0 \;\forall c \neq 0$.

One major advantage of this framework is that it allows for stochastic reference points and outcomes: if an allocation a is drawn according to the probability measure F and the reference allocation according to G, overall utility can be expressed as

$$U(F|G) = \iint U\big(u(a)|u(r)\big)\, dG(r)\, dF(a). \tag{3}$$

In order to discuss a person's risk preferences with social concerns, we use the equilibrium notions of the *Choice-Acclimating Personal Equilibrium* (CPE) as proposed by Kőszegi and Rabin [2007], under which the reference point endogenously adjusts to the given choice problem:

Definition 1 (Choice-Acclimating Personal Equilibrium (CPE)). *For any choice set D, $F \in D$ is a* Choice-Acclimating Personal Equilibrium (CPE) *if for all other $F' \in D$, it holds*

$$U(F|F) \geq U(F'|F').$$

As stated by Kőszegi and Rabin [2007], the CPE solution concept applies to situations where a person can reflect on his choice in advance and anticipates it. Thus, our subsequent analysis assumes that decision-makers make their choices deliberately.

Based on the outlined model, we study peer effects on a person's risk preferences in more detail in the remainder of the paper. However, before doing so, we first provide a short example of how our model and its underlying intuition work. We then propose two novel notions of certainty equivalence in the next section and establish a formal link that connects them.

Example 1 (Binary lottery where ranks can reverse). Let L be a binary lottery over monetary outcomes $\underline{x}, \overline{x} \in \mathbb{R}$ that are realized with probability $p \in (0,1)$ and $1-p$, respectively. Assume without loss of generality that $\underline{x} < \overline{x}$. Denote peer earnings by $s \in [\underline{x}, \overline{x}]$. Hence, if $\underline{x}$ is realized, the decision-maker ends up in a situation of unfavorable inequality behind his peer, and in a situation of favorable inequality when $\overline{x}$ is realized.

In a CPE situation, the decision-maker expects to play lottery L while his peer obtains s. Hence, in CPE, the allocation (L, s) acts as his reference point, and overall utility is given by

$$\begin{aligned} U(L,s|L,s) = {} & p[\sigma s + (1-\sigma)\underline{x}] + (1-p)[\varrho s + (1-\varrho)\overline{x}] \\ & + \eta\Big(pp\big[(\sigma s + (1-\sigma)\underline{x}) - (\sigma s + (1-\sigma)\underline{x})\big] \\ & \quad p(1-p)\big[(\sigma s + (1-\sigma)\underline{x}) - (\varrho s + (1-\varrho)\overline{x})\big]\lambda \\ & \quad (1-p)p\big[(\varrho s + (1-\varrho)\overline{x}) - (\sigma s + (1-\sigma)\underline{x})\big] \\ & \quad (1-p)(1-p)\big[(\varrho s + (1-\varrho)\overline{x}) - (\varrho s + (1-\varrho)\overline{x})\big]\Big). \end{aligned} \tag{4}$$

The first line is the decision-maker's expected stand-alone utility. The remaining lines are his gain-loss sensations when comparing different outcomes with their counterfactual realizations. In the second line the decision-maker compares the allocation $(\underline{x}, s)$ realized with probability p, with expecting it (he expects it with probability p). Given that with probability p^2, the decision-maker anticipates this allocation correctly, evaluating the difference between the allocation and the expected allocation leads to neither gains nor losses. Hence, in this case, gain-loss sensations are equal to zero. The third line compares a potential realization of $(\underline{x}, s)$ with expecting to get $(\overline{x}, s)$. Since $\overline{x} > \underline{x}$ and $\varrho \geq \sigma$, this feels like a loss. Hence, due to loss aversion, this term is weighted with $\lambda > 1$. The fourth line compares a potential realization of $(\overline{x}, s)$ with the expectation to get $(\underline{x}, s)$. For the same reasons above, getting the larger $\overline{x}$ while expecting to be worse off than the peer feels like a gain. Finally, the last line compares getting $(\overline{x}, s)$ with expecting to get $(\overline{x}, s)$. Like in the second line, this feels neither like a loss nor a gain.

As a result, overall utility can be summarized as

$$\begin{aligned} U(L, s|L, s) = \; & p[\sigma s + (1-\sigma)\underline{x}] + (1-p)[\varrho s + (1-\varrho)\overline{x}] \\ & - \eta(\lambda - 1)p(1-p)\Big[(\varrho s + (1-\varrho)\overline{x}) - (\sigma s + (1-\sigma)\underline{x})\Big]. \end{aligned} \tag{5}$$

And since we assume that utility is approximately linear, we can separate his utility in three parts:

$$U(L, s|L, s) \; = \sigma s + (1-\sigma)U(L|L) - (\varrho - \sigma)\underbrace{\frac{\overline{x} - s}{U(L|L)}\frac{\partial U(L|L)}{\partial \overline{x}}}_{\equiv \overline{\varepsilon}(s)} U(L|L). \tag{6}$$

The first part reflects a peer-outcome component equal to peer earnings s weighted by the social preference parameter σ. The second part represents a personal utility component equal to the utility of playing lottery L in CPE absent of peers, weighted with marginal utility $(1-\sigma)$. Finally, the last term is an interaction term. It corresponds to the elasticity of utility for the positional concern of being ahead of the peer, which is weighted by the difference in marginal utility of social preferences.

4 Certainty equivalence

Before analyzing different choice settings with our model in the next section, we first present two novel concepts of certainty equivalence over monetary outcomes in $\mathbb{R}$.[9] Introducing these novel concepts helps better discuss an agent's risk preferences since the extension of the certainty equivalent to the multi-person setting is not straightforward. Moreover, as we will show, the certainty equivalent does not necessarily need to be unique when agents have distributive concerns.[10] First, however, we follow the literature on reference-dependent decision-making by assuming that an individual's gain-loss sensations for personal earnings are somewhat moderate.[11]

A6. $\eta(\lambda - 1) < 1$.

Our first specification of the certainty equivalent, the *Egalitarian Certainty Equivalent* (E-CE), makes the decision-maker indifferent between receiving an egalitarian allocation for sure and taking a binary lottery with fixed peer earnings:

Definition 2 (Egalitarian Certainty Equivalent (E-CE))**.** *Let $L = (p, \underline{x}; 1-p, \overline{x})$ be a binary lottery with possible outcomes $\underline{x}, \overline{x} \in \mathbb{R}$ realised with probability $p \in (0,1)$ and $1-p$, respectively, and let $s \in \mathbb{R}$ be fixed peer earnings. Then, the* Egalitarian Certainty Equivalent (E-CE) *in a CPE is*

$$\dot{c}(L,s) = \begin{cases} \varrho s + (1-\varrho)U(L|L) & \text{if } s < \underline{x} \\ \sigma s + (1-\sigma)U(L|L) - (\varrho - \sigma)\overline{\varepsilon}(s)U(L|L) & \text{if } \underline{x} \leq s \leq \overline{x} \\ \sigma s + (1-\sigma)U(L|L) & \text{if } s > \overline{x} \end{cases}$$

where $U(L|L)$ is overall utility from L in a CPE absent of peers and $\overline{\varepsilon}(s) = \frac{\overline{x}-s}{U(L|L)} \frac{\partial U(L|L)}{\partial \overline{x}}$.

[9]Although our framework can also describe more general cases with many goods, we restrict ourselves to outcomes x and s in $\mathbb{R}$ to simplify the presentation of our results.

[10]For instance, under inequality aversion, a decision-maker can be indifferent between a (favorable) allocation a where he ends up ahead of his peer or another (unfavorable) allocation a' that sets him up behind since he generally dislikes inequality by definition.

[11]This assumption ensures that a person derives more utility from an outcome than from the gain-loss sensations that are caused by this outcome. Conversely, $\eta(\lambda - 1) > 1$ implies that individual behavior is entirely driven by gain-loss sensations, which ultimately predicts extreme risk aversion for all choices and, hence, no risk-taking.

Notice that since $u(a)$ is separable for any allocation a, we can express the E-CE as a sum. Therefore, when ranks cannot reverse (i.e., $s \notin [\underline{x}, \overline{x}]$), the E-CE consists of two parts: a peer-utility part derived from peer earnings s, and a personal-utility part from the lottery L faced by the decision-maker. Hence, we can isolate utility derived from peer earnings (captured by the first part) and self-centered preferences (second part). However, when ranks can reverse (i.e., $s \in [\underline{x}, \overline{x}]$), there is an additional third part that we label the *overhaul effect* (given that it only appears when ranks can reverse). The overhaul effect is the product of three terms. The first term captures the utility from playing L absent of peers. The second term is the elasticity of $U(L|L)$ concerning how much L can make the decision-maker better off than his peer. The last term, $(\varrho - \sigma)$, reflects a difference in marginal utilities for peer earnings, comparing being ahead to being behind the peer. Finally, since the E-CE provides the same outcome for the decision-maker and the peer for sure, the E-CE is unique by definition.

Of course, one might argue that another specification of the certainty equivalent might be more apt. For instance, decision-makers do not influence peer earnings in most economic situations. In principle, a worker cannot change his colleague's wage by his performance at most workplaces, and a student does not influence his fellow student's grades unless they perform in teams. Similarly, a small-scale farmer does not affect his neighbor's crops by using a new method to dig over his field. Furthermore, consumers do not change other consumers' items in their shopping cart by the items on their grocery list (provided they buy household quantities and products are abundant). Likewise, a young graduate's career choice will most likely have no impact on the career path of an established researcher. Given that peer earnings can vary under the E-CE, we propose another version of the certainty equivalent, the *Secluded Certainty Equivalent* (S-CE), which conveys the idea of evaluating a lottery when peer earnings are kept constant.

Definition 3 (Secluded Certainty Equivalent (S-CE))**.** *Let $L = (p, \underline{x}; 1-p, \overline{x})$ be a binary lottery with possible outcomes $\underline{x}, \overline{x} \in \mathbb{R}$ realised with probability $p \in (0,1)$ and $1-p$, respectively, and let $s \in \mathbb{R}$ be fixed peer earnings. Then, the* Secluded Certainty Equivalent

(S-CE) *in a CPE is*

$$\ddot{c}(L,s)=\begin{cases}U(L|L) & \text{if } s<\underline{x}\\ U(L|L)-\frac{\varrho-\sigma}{1-\varrho}\underline{\varepsilon}(s)U(L|L) & \text{if } \underline{x}\leq s\leq\overline{x} \text{ and } \ddot{c}(L,s)>s\\ U(L|L)-\frac{\varrho-\sigma}{1-\sigma}\overline{\varepsilon}(s)U(L|L) & \text{if } \underline{x}\leq s\leq\overline{x} \text{ and } \ddot{c}(L,s)\leq s\\ U(L|L) & \text{if } s>\overline{x}\end{cases}$$

where $U(L|L)$ is overall utility from L in a CPE absent of peers and $\overline{\varepsilon}(s)=\frac{\overline{x}-s}{U(L|L)}\frac{\partial U(L|L)}{\partial\overline{x}}$ and $\underline{\varepsilon}(s)=\frac{s-\underline{x}}{U(L|L)}\frac{\partial U(L|L)}{\partial\underline{x}}$.

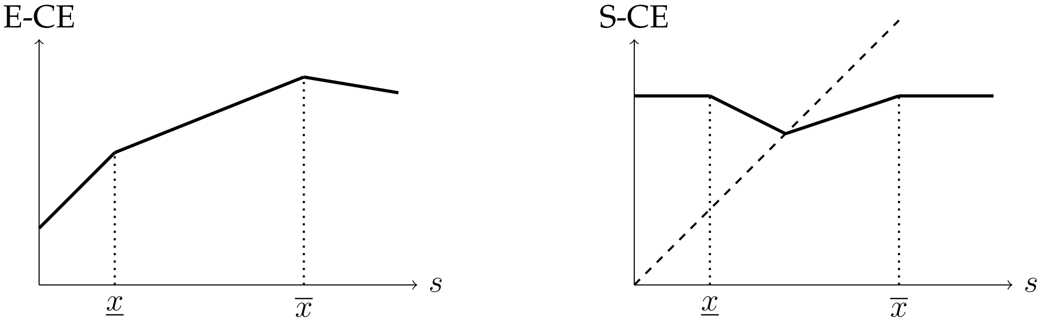
Similar to the E-CE, a genuine requirement for this definition of the certainty equivalent is that it is unique, i.e., the S-CE is either above or below s, but it is never both at the same time. However, while this second definition seems to apply to all types of social preferences outlined above, there are two allocations when ranks can reverse under lottery L under which an agent happens to be indifferent if $\underline{x}<s<\overline{x}$ (as visible in Definition 3). The following proposition establishes that when a decision-maker's personal concerns for being behind his peer are sufficiently weak, the unique S-CE is above peer earnings s.

Proposition 1 (S-CE Uniqueness)**.** *Let $L=(p,\underline{x};1-p,\overline{x})$ be a binary lottery with possible outcomes $\underline{x},\overline{x}\in\mathbb{R}$ realised with probability $p\in(0,1)$ and $1-p$, respectively, and let $s\in[\underline{x},\overline{x}]$ be fixed peer earnings. Then there exists $z\in\mathbb{R}$ such that the* Secluded Certainty Equivalent (S-CE) *is equal to peer earnings s. Moreover, the* S-CE *in a CPE is unique and above s if and only if*

$$\frac{1-\varrho}{1-\sigma}>z \quad \text{where } z=\frac{\underline{\varepsilon}(s)}{\overline{\varepsilon}(s)}>0,$$

where $\underline{\varepsilon}(s)=\frac{\partial U(L|L)}{\partial\underline{x}}\frac{s-\underline{x}}{U(L|L)}$. Conversely, if $(1-\sigma)/(1-\varrho)>z$, the S-CE *is below peer earnings s.*

In other words, the marginal rate of substitution for personal earnings must be inferior to the elasticity ratio of net social positions: the decision-maker needs to put more weight on personal earnings when ahead relative to when he is behind his peer than the changes in utility he senses when his relative position (with respect to his peer) improves. Conversely, if the inequality in Proposition 1 turns around, the unique S-CE lies below peer earnings s. Note that z is decreasing in s. Thus,



(a) Egalitarian Certainty Equivalent (E-CE) (b) Secluded Certainty Equivalent (S-CE)

Figure 2: Certainty equivalents of an inequality averse agent.

if peer earnings increase, a decision-maker has to be less concerned about himself when falling behind his peer for his S-CE to above s, because else taking more risk becomes less affordable, and the S-CE falls below s, accordingly.

However, by the same reasoning, Proposition 1 tells us that for a given lottery, when peer earnings s increase, a decision-maker's S-CE could first increase such that it stays above s and then fall once s becomes too large. Hence, a decision-maker's S-CE can first rise and then fall in s under lotteries that allow for rank reversal. We plot both specifications of the certainty equivalent in Figure 2.

These two novel characterizations of certainty equivalence are most likely an inexhaustive list of possible certainty equivalents. There might well be better versions of certainty equivalents that are far more suitable in different settings. For instance, one could imagine other certainty equivalents under which personal and peer earnings are negatively correlated. Likewise, one might want to consider the impact of negative peer earnings under certainty. However, as a first pass, we believe that our two new specifications can capture many economic situations involving a social dimension in decision-making. Moreover, we believe they are especially applicable to most choice environments where peers only provide a 'signal' to the decision-maker who has either none or only a limited impact on his peer's outcome. Furthermore, as our analysis below shows, the proposed notions of certainty equivalence are well-suited to sufficiently discuss an agent's risk preferences.

But first, we establish that our certainty equivalents are well-behaved. In particular, the next propositions show that an agent's E-CE and S-CE are monotonic in personal payoffs and continuous in peer earnings.

Proposition 2 (Monotonicity)**.** *Both the* E-CE *and the* S-CE *are monotonically increasing in personal earnings* $\underline{x}$ *and* $\overline{x}$*, and in the probability* $(1-p)$ *for lottery upsides* $\overline{x}$*.*

Proposition 3 (Continuity)**.** *Consider the* E-CE *and* S-CE *as defined in Definitions 2 and 3, respectively. Both the* E-CE *and* S-CE *are continuous in peer earnings* s*.*

Put differently, Proposition 2 tells us that the decision-maker enjoys having more rather than less for both specifications of the certainty equivalent. Together with the uniqueness property in Proposition 1, this establishes that both the E-CE and the S-CE are well-behaved. Moreover, Proposition 3 shows that both certainty equivalents are well-behaved with regard to peer earnings. Figure 2 shows a graphical representation of both certainty equivalents and their continuity in peer earnings s.

As discussed above, we acknowledge that one might have other types of certainty equivalents in mind when studying peer effects on risk-taking behavior that are very distinct from our two notions. However, even though we only specified the concepts of E-CE and S-CE based on our belief that they are the aptest for experiments, we want to highlight how all types of such 'peer certainty equivalents' are related to each other. Namely, as the last result of this section, we present how all notions of peer certainty equivalence are linked together. In particular, our following proposition shows that when peer earnings are kept constant under the certainty equivalent, all specifications of certainty equivalents entailing peer earnings are equivalent.

Proposition 4 (Equivalence of Certainty Equivalents)**.** *Consider any two certain allocations* $a' = (c', s')$ *and* $a'' = (c'', s'')$ *with* $c', c'' \in \mathbb{R}$ *being personal payoffs and* $s', s'' \in \mathbb{R}$ *being peer earnings. If for any lottery* L *and peer earnings* $s \in \mathbb{R}$ *it holds* $u(c', s') = U(L, s|L, s)$ *and* $u(c'', s'') = U(L, s|L, s)$ *such that* c' *is the personal payoff in certainty equivalent* a' *and* c'' *is the personal payoff in certainty equivalent* a''*, respectively, then*

$$\frac{\partial c'}{\partial s} \propto \frac{\partial c''}{\partial s}.$$

Proposition 4 states that changing the measure of risk preferences in peer situations does not matter if we keep peer earnings fixed in the certainty equivalents. When peer earnings remain unchanged in safe allocations, peer effects arising from changes in peer earnings in the risky choice problem forecast the same qualitative change in safe personal payoffs a decision-maker demands in how his own payoff under certainty should vary to adjust for such changes, no matter what type of certainty equivalent is used.

Given this equivalence statement, we will shed light on how personal risk preferences change when peer earnings vary. In particular, we first study the effect of changes in pear earnings on individual utility before examining how distributive certainty equivalents impact individual risk-taking behavior.

5 Peer effects on risk-taking

In this section, we apply our model developed in Section 3 to various choice settings. Following the previous literature, we first study how changes in peer earnings affect a person's utility [see, e.g., Schwerter, 2022; Lindskog et al., 2022; Müller and Rau, 2019; Gamba et al., 2017; Dalmia and Filiz-Ozbay, 2021; Lien and Zheng, 2015]. Next, we show that by looking only at changes in utility, our proposed model can rationalize all of the reported findings in Section 2.4. In more detail, we will then study risk-taking behavior under both novel notions of certainty equivalence from Section 4. In particular, we carve out the implications of changes in peer outcomes while changing the certainty equivalent accordingly.

5.1 Raising peer earnings

Before analyzing a person's risk preferences, let us first characterize the utility a decision-maker obtains from a binary lottery L over monetary outcomes while facing peer earnings $s \in \mathbb{R}$. Formally, let L be a binary lottery with possible outcomes $\underline{x}, \overline{x} \in \mathbb{R}$ realized with probability $p \in (0,1)$ and $1-p$, respectively. For the remaining analysis, recall that given that $u(a)$ is piece-wise defined (for peer earnings being either below or above personal earnings), a person's utility from playing L depends on the level of s.

We first discuss a person's risk preferences when ranks cannot reverse, i.e., peer earnings are either strictly below or strictly above a decision-maker's earnings. When peer earnings are always below personal earnings, i.e., $s_1 \equiv s < \underline{x}$, individual utility from L in CPE is equal to this:

$$U(L, s_1|L, s_1) = \varrho s_1 + (1-\varrho)U(L|L). \tag{7}$$

Likewise, when peer earnings are always above personal earnings, i.e., $s_2 \equiv s > \overline{x}$, the decision-maker's utility from L in CPE is

$$U(L, s_2|L, s_2) = \sigma s_2 + (1-\sigma)U(L|L). \tag{8}$$

Thus, the effect of raising peer earnings is equal to the marginal utility attributed to peer earnings and depends on the decision-maker's distributive preferences (as visible in equation 1). For instance, a person with competitive preferences will always dislike increases in peer earnings, no matter if the peer is better or worse off than the decision-maker (in terms of payoffs). However, an inequality-averse person prefers increases in peer earnings s when peers are worse off and dislikes increases in peer earnings when peers are better off. Moreover, decision-makers with efficiency preferences will always like improvement in peer earnings, given that such improvement increases the entire surplus for both persons.

When peer earnings fall in between the potential outcomes of lottery L, i.e., $s_3 \equiv s \in [\underline{x}, \overline{x}]$, a decision-maker's utility in CPE from lottery L is

$$U(L, s_3|L, s_3) = \sigma s + (1-\sigma)U(L|L) - (\varrho - \sigma)\overline{\varepsilon}(s_3)U(L|L)$$
$$\text{where} \quad \overline{\varepsilon}(s_3) = \frac{\overline{x} - s_3}{U(L|L)} \frac{\partial U(L|L)}{\partial \overline{x}}. \tag{9}$$

Therefore, when ranks can reverse, an additional term enters into a person's utility. Thus, while the utility change due to higher peer earnings when ranks cannot reverse is equal to a person's marginal utility for peer earnings, in situations where ranks can reverse, higher peer earnings give rise to an *overhaul effect*. Note that this overhaul effect is independent of a person's social preferences type and stems from the elasticity of utility with respect to gains under lottery upsides – weighted with the utility premium from being ahead, $(\varrho - \sigma)$.

Intuitively, while higher peer earnings decrease a person's advantage in absolute terms in case the decision-maker ends up ahead, it also decreases the sensation of a potential loss in case the decision-maker ends up behind the peer. Hence, since the decrease in the feeling of potential losses is greater than the decrease in the distance in earnings once the decision-maker ends up ahead of his peer, the overall effect is positive. As a result, due to the overhaul effect, higher peer earnings render the lottery more attractive. The following proposition summarizes these findings.

Proposition 5 (Overhaul Effect)**.** *Let L be a binary lottery with potential outcomes $\underline{x}, \overline{x} \in \mathbb{R}$ realized with probability $p \in (0,1)$ and $1-p$, respectively. Moreover, let peer earnings $s \in [\underline{x}, \overline{x}]$. Then the overall utility from playing L in CPE is*

$$U(L, s|L, s) = \sigma s + (1-\sigma)U(L|L) - (\varrho - \sigma)\overline{\varepsilon}(s)U(L|L).$$

where the last term is non-decreasing in s for $\varrho = \sigma$, and increasing whenever $\varrho > \sigma$.

When does the overhaul effect dominate a person's risk-taking behavior? In general, for the overhaul effect to dominate a person's risk-taking behavior, it needs to hold that

$$\sigma + (\varrho - \sigma)\frac{\partial U(L|L)}{\partial \overline{x}} > 0. \tag{10}$$

While changes in stand-alone utility from peer earnings s can be positive or negative (depending on the decision-maker's social preferences), the overhaul effect indeed dominates when the decision-maker's weight for peer earnings σ is sufficiently large (i.e., σ is not too negative), or

$$\varrho > \sigma\left(1 - \frac{1}{\frac{\partial U(L|L)}{\partial \overline{x}}}\right), \tag{11}$$

where the term in parentheses on the right-hand side is negative for any $p \in (0,1)$. Thus, a person needs to be sufficiently less concerned about himself when he ends up behind for him to take more risks. This has two effects: first, when σ is sufficiently large, stand-alone utility does not decrease a lot when the decision-maker ends up behind. In addition, this also means that gain-loss sensations become less painful. Since both of these effects point in the same direction, this implies that ending up behind the peer is less painful. Hence accepting risk becomes more affordable. As a result, the overhaul effect prevails, which results in greater risk acceptance.

Proposition 6 (Prevailing Overhaul Effect)**.** *Let L be a binary lottery with potential outcomes $\underline{x}, \overline{x} \in \mathbb{R}$ realized with probability $p \in (0,1)$ and $1-p$, respectively. Moreover, let peer earnings $s \in [\underline{x}, \overline{x}]$. The* Overhaul effect *dominates if and only if*

$$\varrho > \sigma\zeta \quad \textit{where } \zeta \equiv 1 - \frac{1}{\frac{\partial U(L|L)}{\partial \overline{x}}} < 0.$$

As visible in Proposition 6, the overhaul effect can only dominate a person's risk-taking behavior as long as the person has no competitive feelings towards his peer since this would imply $0 > \varrho > \sigma$. In fact, being too much concerned about personal earnings when behind implies that risk-taking becomes less affordable, since this reduces both stand-alone utility and gain-loss utility.

Many experiments report that individuals take more risk when peer earnings increase. For instance, Müller and Rau [2019] conduct a lab experiment and compare lottery choices in situations where subjects can earn at most as much as their peers to situations where they can earn at least as much as their peers. Assuming that subjects are inequality averse, they find that subjects take more risk in the former situation than in the latter one. Translating this to our framework, we need to compare a choice problem with $s = \overline{x}$ to another choice problem with $s = \underline{x}$, where the lottery is kept constant. Since subjects take more risk when peer earnings are high, this corresponds to the condition of the overhaul effect as in Proposition 6.

Similarly, Linde and Sonnemans [2012] compare peer effects in settings where rankings cannot be reversed. In their experiment, they study risk-taking in situations where peer earnings lie either above $\overline{x}$ or below $\underline{x}$ to choices where $s \in (\underline{x}, \overline{x})$. They find that decision-makers tend to accept less risk when peers are ahead, and more when they are behind. In our framework, this corresponds to

$$U(L, s_1|L, s_1) > U(L, s_2|L, s_2) \tag{12}$$

where $s_1 = \underline{x}$ and $s_2 \in (\underline{x}, \overline{x})$, which implies

$$\sigma(1 - \zeta) > \varrho. \tag{13}$$

Notice that this finding is both in line with all types of social preferences except social welfare preferences and with our discussion of the overhaul effect above. Hence, our framework can accommodate both of these findings.

In the remaining part of this section, we will first study peer effects on the E-CE, followed by an additional analysis of peer effects on the S-CE. Whereas risk preferences do not change in E-CE situations relative to our discussion about personal preferences, the subsequent analysis incorporates changes in peer earnings in the certainty equivalent. Therefore, we deliberately depart from our result in Proposition 4 to capture additional implications of redistributions. But like our previous analysis, we identify conditions for a decision-maker's social preference that demonstrate how higher peer earnings can affect an individual's risk-taking incentives.

5.2 E-CE situations

The E-CE in Definition 2 compares any given personal-lottery-and-peer-earnings pair with a safe allocation that yields the same outcome for both the decision-maker and his peer. In that sense, a decision-maker does not only choose between a lottery and a safe option for himself but between two different allocations.

What happens when decision-makers are ensured to be better off, but peer earnings are raised to such a level that decision-makers suddenly can fall behind their peers? In a related experiment, Schwerter [2022] compares risk-taking in these two distinct choice settings. In one treatment, decision-makers are ensured to be better off than their peers, and in another one peer earnings fall between the potential lottery outcomes (denoted as the LO and the HI treatment, respectively). He finds that decision-makers tend to accept more risks in the HI treatment. If we assume that lotteries in both treatments are approximately the same, then it needs to hold that $U(L, s_2|L, s_2) > U(L, s_1|L, s_1)$ for $s_1 < \underline{x}$ and $s_2 \in [\underline{x}, \overline{x}]$. Our following proposition shows that such changes can lead decision-makers to accept more risk if they dislike falling behind sufficiently much.

Proposition 7 (E-CE Risk Acceptance to rank reversal)**.** *Risk-taking increases in* E-CE *situations when peer earnings increase from $s_1 < \underline{x}$ to $s_2 \in [\underline{x}, \overline{x}]$ if and only if*

$$\varrho > \sigma \cdot w \quad \textit{where } w = \frac{U(L|L)(1 - \overline{\varepsilon}(s_2)) - s_2}{U(L|L)(1 - \overline{\varepsilon}(s_2)) - s_1} < 0.$$

Proposition 7 shows that if a person accepts more risk in such E-CE situations, he necessarily has to have sufficiently strong fairness concerns when he ends up ahead. This is at the heart of the E-CE definition, which compares any given choice situation with an egalitarian allocation. Therefore, higher peer earnings automatically translate to a higher E-CE: in this way, the decision-maker can 'compensate' his peer for forgone earnings by demanding a higher E-CE.

Similarly, when peer earnings increase even further such that peers get 'out of reach,' decision-makers may accept even more risk:

Proposition 8 (E-CE Risk Acceptance from rank reversal)**.** *Risk-taking increases in* E-CE *situations when peer earnings increase from $s_2 \in [\underline{x}, \overline{x}]$ to $s_3 > \overline{x}$ if and only if*

$$\varrho > \sigma \cdot w' \quad \textit{where } w' = 1 - \frac{s_3 - s_2}{U(L|L)\,\overline{\varepsilon}(s_2)} \; < \; 0.$$

As for the previous case, a decision-maker accepts more risk only if his distaste for ending up behind is sufficiently weak. As a result, ending up behind is less costly –both in stand-alone utility and gain-loss sensations– which makes taking risks more affordable. Again, this renders L more attractive.

Our next Lemma creates a link between risk-taking when raising peer earnings enables rank reversal (Proposition 7) and risk-taking when peer earnings increase even more such that a decision-maker is ensured to be worse off than his peer (Proposition 8).

Lemma 1 (E-CE Risk behavior)**.** *Let L be a binary lottery with potential outcomes $\underline{x}$ and $\overline{x}$ realized with probability $p \in (0,1)$ and $1-p$, respectively, and let $s_1 < \underline{x}$, $s_2 \in [\underline{x}, \overline{x}]$, and $s_3 > \overline{x}$ be peer earnings for three different choice settings. Then, if*

$$\frac{\overline{\varepsilon}(s_2)}{\overline{\varepsilon}(s_1) - \underline{\varepsilon}(s_1)} > \frac{s_3 - s_2}{s_3 - s_1}$$

the threshold terms from Propositions 7 and 8 are such that $w < w'$ for $\overline{\varepsilon}(s_1) = \frac{\overline{x} - s_1}{U(L|L)} \frac{\partial U(L|L)}{\partial(\overline{x} - s_1)}$ and $\underline{\varepsilon}(s_1) = \frac{s_1 - \underline{x}}{U(L|L)} \frac{\partial U(L|L)}{\partial \underline{x}}$.

Lemma 1 establishes different relations between Proposition 7 and Proposition 8, depending on a person's social preferences and the marginal utility for gains. If marginal utility for gains is sufficiently high, a decision-maker with social welfare preferences (where $\varrho \geq \sigma > 0$) will always accept more risk when peer earnings increase. This follows from the non-positivity of w and w', respectively, and stems from the fact that social welfare preferences imply a taste for improvement in earnings for all agents (decision-maker and peer). Therefore, two motives become visible. First, a decision-maker wants to compensate his peer for forgone earnings by taking the lottery. Second, ending up behind his peer hurts less since its marginal utility is still positive, which increases risk acceptance.

Inequality aversion ($\varrho > 0 > \sigma$), on the other hand, implies that when a person is willing to accept more risk when ranks can be reversed, he will also accept more risk when peers are ensured to be better off. Importantly, however, the converse does not always hold: when ranks can be reversed, an inequality-averse person who feels that getting a particular lottery is relatively unfair (compared to getting fixed earnings as his peer does) will also dislike it when others obtain even more. Likewise, suppose that person feels that being endowed with another lottery makes him relatively better off than his peer (who receives fixed earnings) when ranks can change. In that case, that person will also accept less risk when the lottery makes him better off than his peer for sure.

Similarly, a competitive person ($0 > \varrho \geq \sigma$) willing to accept more risk when peers are ensured to be better off will also accept more risk when ranks can change. Given that ending up behind creates a negative externality for the decision-maker, agents who 'compete' with their peers try to avoid falling behind their peers.

As a result, higher peer earnings, therefore, have two effects in E-CE situations. First, higher peer earnings give room for a *compensation effect*: depending on the social preferences, an agent must adjust the certainty equivalent. This follows directly from raising peer earnings under the certainty equivalent specification to match increases in peer earnings in the lottery problem.

So far, we have analyzed risk preferences when decision-makers do not only choose for themselves but simultaneously for their peers. In contrast, our next section studies individual risk preferences when peer earnings remain exogenous: we examine how peer earnings affect risk preferences when peer earnings are kept constant between the lottery choice and a safe option.

5.3 S-CE situations

As discussed in the above, the E-CE compares any given personal-lottery-and-peer-earnings pair with a safe allocation that yields the same outcome for both the decision-maker and the peer. But what are the implications of raising peer earnings on individual risk-taking while everything else is held constant? To the best of our knowledge, we are the first to look at peer effects in this setting.

We now show how peer earnings can affect a person's risk-taking behavior when peer earnings are kept constant for the risky choice and the certainty equivalent allocation. In contrast to E-CE situations where peer earnings vary with the certainty equivalent, S-CE situations allow us to disentangle peer effects on individual risk-taking behavior from peer effects that arise from changing the certain allocation as well (a feature inherent to the E-CE).

As seen in Definition 3, peer earnings do not affect the certainty equivalent when ranks cannot be reversed. This is a good thing. As long as a person is ensured to be better or worse off, peer earnings or income redistributions have a negligible impact on individual choices under risk. For example, a wealthy investor is unlikely to change his portfolio choices when he donates money to the poor. Likewise, jobless individuals, who obtain unemployment benefits paid by better-off individuals, will not suddenly become risk-seekers when they look for jobs. More importantly, however, are implications of redistributions or changes in peer earnings that allow for social ranking changes. The following Proposition capture a person's behavior in such situations. In particular, it shows that in situations where rank reversal is possible, peer earnings can incentivise an individual to take more risk (*encouragement effect*). However, if peer earnings are too low under the same conditions, they can lead to a *discouragement effect*.

Proposition 9 (S-CE Encouragement and Discouragement Effect)**.** *Consider the* S-CE *as defined in Definition 3. Let $L = (p, \underline{x}; 1-p, \overline{x})$ be a binary lottery with possible outcomes $\underline{x}, \overline{x} \in \mathbb{R}$ realised with probability $p \in (0,1)$ and $1-p$, respectively. Moreover, let $s, s' \in [\underline{x}, \overline{x}]$ be two fixed peer earnings with $s < s'$. If Proposition 1 holds for s but not for s', then*

$$\frac{d\ddot{c}(L,s)}{ds} > 0 \quad \textit{and} \quad \frac{d\ddot{c}(L,s')}{ds'} \leq 0. \tag{14}$$

Both the encouragement and discouragement effect are visible in Figure 2b. The S-CE first decreases below the level when ranks cannot reverse in the interval $(\underline{x}, \ddot{c})$ (visualizing the discouragement effect), and then rises back to the initial level when the decision-maker's peer becomes 'out of reach' (discouragement effect). Notice that these effects are independent of ϱ and σ. Hence, they generalize to all types of social preferences a decision-maker might have.

More interestingly, however, Proposition 9 forecasts that in S-CE situations, peer effects can be ambiguous, a priori. However, overall risk-taking is lower when ranks can reverse compared to settings where no rank reversal is possible. This follows from the S-CE's definition, which requires a change in peer earnings in both allocations, the lottery allocation (L, s) and safe allocation $(\ddot{c}, s)$.

To see this, suppose that $\ddot{c}$ is a S-CE to any binary lottery L and peer earnings s and $\ddot{c} \leq s$, such that the decision-maker is indifferent between taking the safe $\ddot{c}$ and playing the lottery:

$$\sigma s + (1-\sigma)\ddot{c} = \sigma s + (1-\sigma)U(L|L) - (\varrho - \sigma)\overline{\varepsilon}(s)U(L|L). \tag{15}$$

Therefore, increasing peer earnings has effects on both sides of the equation. Moreover, to accept more risk, utility of this lottery should increase. Hence, for L to be more attractive, it must be that $\ddot{c}$ is greater than $U(L|L)$. However, since the last term is positive, this cannot be. As a result, since $\ddot{c} \geq U(L|L)$, there is less risk-taking when peer earnings increase compared to situations where ranks cannot reverse. Given that changes in peer earnings typically occur after a redistribution, we label this the *redistribution effect*.

Notice further that the predictions of Proposition 9 are in stark contrast to our previous results when discussing peer effects in E-CE situations or on a decision-maker's utility absent of a certainty equivalent. In fact, given that no previous model of social reference points discusses peer effects on individual risk preferences using a certainty equivalent notion, these findings also differ substantially from the existing literature. More importantly, therefore, these implications of peer effects on the S-CE have not been tested yet (at least our awareness).

Most importantly, given that both effects arise when ranks can reverse, the implications of the encouragement and discouragement effect can be pretty substantial in their economic relevance. Thus, neglecting these implications can lead to undesirable results in individual risk-taking. For instance, in their working paper version, Gamba et al. [2017] point to the Federal Reserve Board's *Guidance on Sound Incentive Compensation Policies* [2010], which states that payment schemes of investment banks employees should "provide employees incentives that appropriately balance risk and reward" [Federal Register, 2010, p. 36396]. Hence, policymakers need to be careful in assessing situations and designing new policies since raising peer earnings can lead to unintended effects on risk-taking behavior with detrimental consequences in S-CE situations.

6 Experiment

In this section, we present an experimental strategy, consisting of two experiments – a peer experiment and a control experiment, to test our predictions about the S-CE. In particular, we outline our 2×3 experimental design, how to make peers sufficiently relevant for decision-making subjects, and discuss our targeted sample as well as how we intend to collect and store our generated data. First, however, it is worth noting that even though the experiments have not been conducted yet, they will take place in the period of June to July 2023. We already obtained approval from our institution's ethics board to conduct the experiment, and pre-registered it along an established pre-analysis plan.[12]

6.1 Overview of the experimental design

Measuring individual choices in a social context requires at least two subjects per observation: a decision-maker (DM) and a peer. To increase the number of observations, we plan to implement a within-subjects design, where DMs face risky choice problems in the form of multiple price lists (MPLs, see below) while peers receive a fixed payment. DMs will see the associated MPLs on a computer screen and their peers' earnings in each stage. As argued in Section 5, our model predicts peer effects in S-CE situations only when ranks can reverse. We hence derive the following two hypotheses:

Hypothesis 1. *When ranks cannot reverse, DMs' choices do not exhibit a peer effect.*

Hypothesis 2. *When ranks can reverse, DMs' choices exhibit a peer effect.*

To test these two hypotheses, we outline our peer experiment (whose schematic procedure is depicted in Figure 3), followed by an explanation of our proposed method to collect information about subjects' individual risk preferences. In total, there will be three stages in our experiment: in Stage A, the DMs' potential payments will be strictly above peer earnings; in Stage B, DMs' potential payments will

[12]The experiment is pre-registered at the AEA's Registry. For further info, please consult https://www.socialscienceregistry.org/trials/11107.

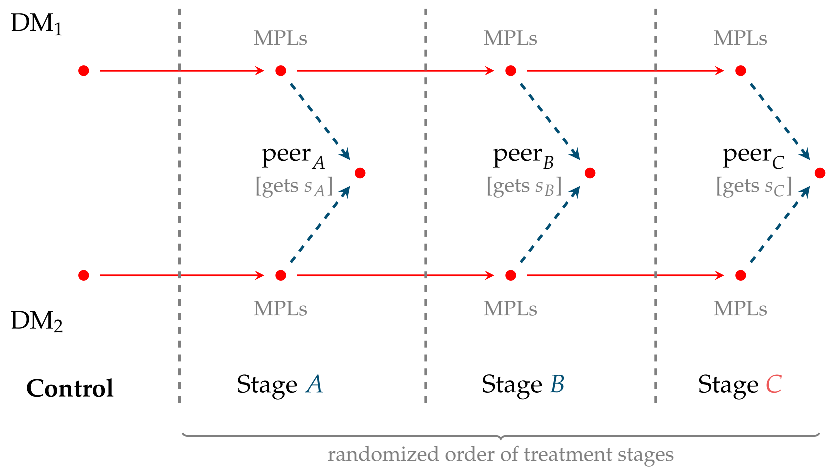


Figure 3: Design of the experimental procedure.

be strictly below peer earnings; and in Stage C, peer earnings will be between the potential payments that the DM can obtain (see Table 2).

To rule out the anchoring effects and other factors that can have an influence on DM's choices beyond peer effects, we plan to run a control experiment absent of peers. We first describe our main experiment, the *peer experiment*, before outlining the control experiment.

6.2 Outline of the peer experiment

While choice problems remain constant for the DM throughout the different stages, only peer earnings are exogenously varied. Therefore, by comparing the different stages in our experiment, we can analyze i) how choice behavior differs when rank-

Table 2: Overview of payments per experimental stage. Peer earnings are denoted by s, downsides (upsides) for the DM lottery are denoted by $\underline{x}$ ($\overline{x}$).

Stages		Peer earnings
A	DMs ensured to be better off than peers	$s < \underline{x} < \overline{x}$
B	DMs ensured to be worse off than peers	$s > \overline{x} > \underline{x}$
C	Rank reversal possible	$\underline{x} < s < \overline{x}$
Control	No peer present	$s \in \{\emptyset\}; \underline{x} < \overline{x}$

ings can be changed, DMs are ensured to be ii) worse off, or iii) better off than their peers. The stages (named A, B, and C respectively in Figure 3) of the experiment will be randomized across sessions. Potential lottery and peer earnings for each stage of the experiment are displayed in Table 2.

As discussed in the next subsection, we intend to run another MPLs session absent of peers to collect information about individual risk preferences. This allows us to use individual risk preferences as a control variable later in our analysis, and to rule out potential confounding factors that might affect our identification.

Since each DM needs to be paired with a peer, we propose a design that limits the number of participants while keeping the experiment clear and straightforward. The peer experiment will be conducted in sessions of five participants: two DMs and three peers (one peer in each stage). Roles are randomly assigned. Assigned DMs go through each stage and respond to different MPLs while being informed about stage-specific peer earnings. To incentive DMs' choices, their final payments will then be picked randomly from one of the MPLs that they answered in the previous stages. Peers will receive their fixed earnings.

The main advantage of this design is that it limits the number of peers necessary for each observation: based on this many-to-one matching, there is precisely one peer for each DM per stage, and no DMs face the same peer more than once. This rules out potential strategic or reputational concerns DMs might have if they were confronted with the same peer twice. To make sure that at each point in time the two DMs' choices are independent from each other at every stage, we will make sure that two different DMs do not know that they will have been paired with the same peer at any given stage. This can be implemented, for instance, by forbidding participants to talk during the experiment.

6.3 Eliciting risk preferences using multiple price lists

DMs will face multiple price lists (MPLs) [see, e.g., Binswanger, 1980; Holt and Laury, 2002; Drichoutis and Lusk, 2016; Gächter et al., 2021] while observing peer earnings on a computer screen in the experiment. In these MPLs, DMs must choose between a 50/50 lottery over monetary outcomes and a fixed amount of money.

While the lottery remains unchanged in an MPL, the fixed amount of money increases. Subjects, therefore, have to decide whether they take the lottery or the fixed payment. As a result, MPLs allow us to observe switching points in subjects' choices. Based on these switching points, we can then derive a subject's risk preferences from the amount of money that makes them indifferent between accepting the lottery and receiving payment for sure. Finally, as aforementioned, we will introduce variation by changing the level of peer earnings such that decision-making subjects are either ensured to be better off, ensured to be worse off, or such that social ranking in terms of earnings can change with the lottery outcome. Based on these different peer earnings levels, we have three different treatment stages.

MPLs is a well-established method to elicit individual risk preferences and it bears several advantages. Most importantly for our subjects, MPLs are easy to understand and encourage truthful answers. Consequently, MPLs limit the scope for confusion, picking answers randomly, or not revealing their true preferences. As an advantage on the experimenter side, MPLs are also easy to implement since they require only one lottery. In addition, studies comparing different elicitation methods argue that MPLs are very robust tools to measure individual risk preferences. [13]

6.4 Peer relevance

To observe peer effects on individual choices, subjects need to be aware that peers exist. Therefore, we need to ensure that DMs notice their peers while making decisions. While this is a major concern for the peer experiment, our control experiment rules out potential impacts that might arise from peer effects.

As outlined above, DMs face MPLs at each stage of the experiment on a computer screen in the lab. Therefore, to make peers present, we intend to display the stage-specific fixed peer earnings next to each MPL problem and highlight them to make sure that DMs cannot ignore them. Hence, peer earnings act as a signal.

Many of the studies that are closest related to ours implement peer effects in this way [see, e.g., Schwerter, 2022; Andersson et al., 2016; Bolton and Ockenfels, 2010], and employ a between-subject design [except for Andersson et al., 2016]. Other stud-

[13] See Csermely and Rabas [2016] and Crosetto and Filippin [2016] for an overview.

ies exploring peer effects on individual choice use different interaction tasks to make peers more relevant. Gamba et al. [2017] implement a competitive task between DMs and their peers before DMs can make a decision. Others, such as Müller and Rau [2019], use dictator and ultimatum games in between decision tasks, and Linde and Sonnemans [2012] present portraits of their peers in addition to that.

However, all these methods have potential drawbacks since they can influence DMs' attitudes towards their counterparts. For instance, DMs could, in principle, feel to reciprocate kindness towards their peer if the peer acted kind in one of the previous interaction tasks. Similarly, selfish peer behavior in the interaction task could trigger envy motives or punishment behavior. Evidence for such effects has been reported in numerous empirical studies and their directions are often unclear and difficult to interpret [see, e.g., Charness and Rabin, 2002; Andreoni, 1995; Gächter and Herrmann, 2009]. Moreover, being exposed to uncontrollably many personal characteristics [as with a portrait in Linde and Sonnemans, 2012] can also have divergent effects on how subjects perceive and feel towards their peers [see, e.g., Goldin and Rouse, 2000] – besides harming anonymity between participants.

Given that we allow for different social preferences, we plan to abstain from such interaction tasks and follow the first strand of studies that use peer earnings as a mere cue.

6.5 Control experiment

Of course, there might be other factors that drive our results. To eliminate the scope of these factors and to make our identification strategy more robust, we plan to conduct a control experiment that holds everything constant except peers. In principle, we cannot rule out that differences in DMs' choices depend on their lottery choice in a previous stage, due to peer effects or other factors that we do not observe. Therefore, establishing the control experiment creates a counterfactual to which we can to compare lottery choices from the peer experiment.

Our control experiment will replicate the peer experiment with one crucial exception: it will exclude peers. During the control experiment, subjects will face the same lottery sequence as during the peer experiment. Moreover, subjects will be ex-

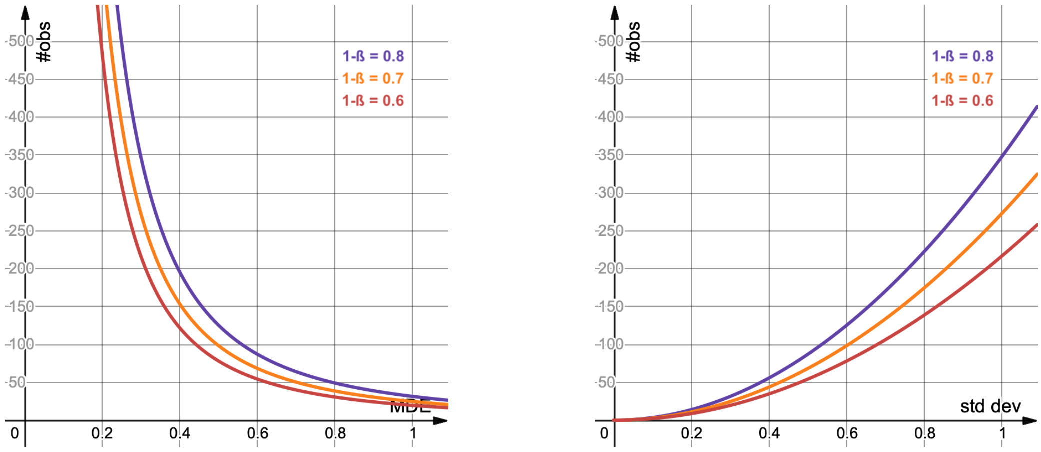


Figure 4: Sample size for different levels of statistical power. Sample size depending on the MDE for a standard deviation equal one (left), and depending on the standard deviation for MDE=0.3 (right).

posed to a non-social cue that acts as an anchor. This cue allows us to keep other factors in place while peer effects are ruled out by design. In the control experiment, subjects will face the same amount of lotteries as during the different stages of the peer experiment. To make the control experiment a sound counterfactual for the peer experiment, we will keep the same sequence of lotteries as in the peer experiment (i.e., the first lottery in the control experiment will also be the first lottery of the peer experiment).

6.6 Sampling

We will conduct our experiment in the Louvain EconLab at UCLouvain, Belgium. In line with the lab's guidelines, we will use the lab's database to recruit participants. Our sample will, therefore, primarily consist of university students. Importantly, however, the lab recruits subjects irrespective of their stydy year or majors.

The exact sample size is yet to be defined. For the moment, we ran some power calculations to display the effects of different levels of statistical power, the minimum detectable effect size (MDE), and the standard deviation. As visible in Figure 4, the sample size is increasing in the level of statistical power as well as the standard deviation and decreasing in the MDE.

However, we plan to conduct a trial run with around 50 subjects by the end of

February 2023. Although this trial run will most likely be overpowered, it will be helpful to calibrate further details of our experiment and determine the exact sample size we need to target. Similar experiments use a sample of around 250 subjects [see, e.g. Schwerter, 2022]. Note that the sample size is this large because each observation requires two subjects: a DM and a peer.

6.7 Data collection and processing

Our primary variable of interest is subject MPL choices in each treatment stage of the experiment. This information will be collected anonymously, only linked to subject identifiers and additional demographic data that does not allow any personal trace-back. Demographic data can entail information about a subject's gender, age, and student profile (subject major and starting year of studies) and could be used as control variables for the subsequent analysis. Names and other personal information that is not relevant to our study will be censored.

At the beginning of the experiment, subjects will first have to sign a form clarifying the privacy policy for the collected data. If subjects disagree, they can cancel their participation in the experiment. Beyond that, subjects will be free to leave the experiment at any point in time if they wish.

All data collected and results from the subsequent analysis will be documented exclusively on an external hard drive by the experimenters. Therefore, all data collected during the study will stay anonymous. Furthermore, we will ensure that no link exists between the personal data in the participants' database of the lab and the data collected during our study.

6.8 Data analysis

As mentioned earlier, our variable of interest is subject MPL choices in each treatment stage of the experiment. Our analysis, hence, focuses on peer effects on these choices. To test our first hypothesis, we will compare DM choices when peers are ensured to be better off with DM choices when peers are ensured to be worse off in the peer experiment. This allows us to examine whether there is a statistical difference between the two choice settings. Moreover, we will compare DMs choices in these two settings with choices in the control experiment to rule out potential anchoring effects that might arise from a previous stage.

Similarly, for our second hypothesis, we will compare DM choices when ranks can reverse to i) DM choices when peers are ensured to be worse off, and ii) DM choices when peers are ensured to be better off in the peer experiment. Likewise, we will also test for statistically significant differences between DM choices when ranks can reverse in the peer experiment with choices in the control experiment.

Since our planned study represent an analysis and a comparison of laboratory experiments, our results are prone to the standard criticism that is raised against laboratory studies in terms of generalizability and the magnitude of the observed effects [see, e.g., Levitt and List, 2007; Kessler and Vesterlund, 2015].

We acknowledge that the magnitude of effect we will observe in our setting will most likely differ in real world applications. However, our analysis will focus only on qualitative results as only the sign of the observed effect matters. Moreover, our experiment takes place in a controlled environment where other sources of influence are limited to a large extend. While both these considerations might reduce the generalizability of our results, they remain observable nonetheless. In particular, given that field experiments tend to be very noisy for many reasons, a lab experiment constitutes a first pass of testing this theory of social preferences under uncertainty.

7 Discussion and conclusion

Our proposed model can explain various findings in the experimental literature on social comparisons (as listed in Section 2) when looking only at how a person's utility responds to changes in peer earnings. For example, in a related study, Lindskog et al. [2022] find that a person's risk-taking behavior is affected by his desire to get ahead of others. Given that most of our results of peer effects on individual choice depend on the distance between the social preference parameters ϱ and σ, we replicate this finding.

More importantly, these results remain valid even when we look at situations where decision-makers choose between lotteries and a safe, egalitarian allocation, as is the case for the E-CE. However, when peer earnings are kept fixed, as in the S-CE, we observe that higher peer earnings can lead to two diverging effects: a discouragement and an encouragement effect that incentivize less and more risk-taking, respectively. However, due to the redistribution effect, we predict less risk-taking in S-CE situations where ranks can reverse, as is the case when ranks remain fixed. Yet, another question is: when is what certainty equivalent specification most apt to describe peer effects on individual choice?

Our proposed experiment will test different settings where peer effects are, in principle, at least conceivable. To the best of our knowledge, other existing theories of social reference points only look at changes in utility once peer effects arise. This corresponds to our discussion of risk preferences in Section 5.1. Moreover, given the result of Proposition 4, this approach is also equivalent to looking at E-CE situations. However, in most cases, one might intuitively think an S-CE specification is more realistic than an E-CE: Once peer earnings are raised, so they are in both contingencies, irrespective of whether the decision-maker has chosen the lottery or the safe outcome. However, most of the existing findings can be explained by looking only at peer effects on individual utility. Our experiments will hence complement the current body of knowledge by investigating peer effects in cases where the S-CE specification might be more apt.

While we intended to rationalize risk-taking behavior in a social context, our analysis remains extendable in various directions. One pursuable way would be to introduce reciprocity concerns as Charness and Rabin [2002] or Dufwenberg and Kirchsteiger [2004] did. One way to incorporate reciprocity concerns would be by changing an agent's social preferences. For instance, one could let a decision-maker's concerns about distributional aspects decrease once peers act selfishly or reject kind offers (as frequently observed in ultimatum games). As proposed by Charness and Rabin [2002], this change of preferences could be captured by an additional parameter that adjusts preferences as soon as a person feels unfairly treated.

Moreover, we applied our model in a social context where peers acted in the most passive way, namely in social comparison situations. However, the analysis becomes more complicated if we allow for peer activity. Linked to the discussion about reciprocity, how are individual risk attitudes affected when peers behave unkindly towards decision-makers? Moreover, in an even broader sense, how does peer behavior interfere with personal decision-making under uncertainty? Not only did we make simplifying assumptions about behavior, but also the rigidity of this particular social context limits the applicability of our analysis. It would be more desirable to have a more general approach accommodating strategic concerns to address these questions.

And although the behavioral implications of our model seem to be consistent with findings from the lab, some of the underlying parameters remain difficult to estimate. While the reference-dependent framework incorporates diminishing sensitivity (which can be estimated directly from choice data), measuring precisely the 'degree' of a person's loss aversion remains more challenging. One way out, in fact, is the method for a parameter-free estimation of loss aversion in a given choice problem provided by Abdellaoui et al. [2007]. However, their approach requires a very large sample size. Alternatively, Abdellaoui et al. [2008] developed another way to estimate loss aversion, but at the cost of further assumptions.

Finally, many of our predictions are based on assumptions about a decision-maker's social preferences. Much like a person's feelings towards losses, estimating a person's social preferences posits another obstacle to empirically testing this model. Charness and Rabin [2002] estimate parameters of social preferences in various tests and games. Although their extensive analysis looks pretty accurate, it remains confined to the lab. However, in comparison to alternative theories of social reference points, the presented approach makes further-reaching predictions at the cost of two additional parameters.

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Mathematical appendix

Proposition 1 (S-CE Uniqueness)

Proof. We prove this proposition in two steps: first, we show that when ranks cannot reverse, the S-CE is unique. Second, we show that when $(1-\varrho)/(1-\sigma) > z$, then the S-CE is also unique when the social ranking can change under a binary lottery L.

Step 1. Uniqueness of the S-CE when ranks cannot reverse.
When ranks cannot be reversed, the S-CE is unique by definition. Hence, for $s \notin [\underline{x}, \overline{x}]$, the S-CE is unique.

Step 2. Uniqueness of the S-CE when ranks can reverse.
When ranks can reverse, the S-CE can be either below or above $s \in [\underline{x}, \overline{x}]$. Denote these two S-CEs by $\ddot{c}_1 \equiv \ddot{c}(L,s)$ s.t. $\ddot{c}(L,s) \leq s$ and $\ddot{c}_2 \equiv \ddot{c}(L,s)$ s.t. $\ddot{c}(L,s) > s$, respectively. Suppose first that the S-CE to L, s is $\ddot{c}_1$. Since $\ddot{c}_2 > s \geq \ddot{c}_1$, it must also hold that $\ddot{c}_2 > \ddot{c}_1$. Hence, it holds

$$\sigma s + (1-\sigma)\ddot{c}_1 \equiv \sigma s + (1-\sigma)U(L|L) - (\varrho - \sigma)\overline{\varepsilon}(s) \tag{16}$$

and

$$\sigma s + (1-\sigma)\ddot{c}_2 > \sigma s + (1-\sigma)U(L|L) - (\varrho - \sigma)U(L|L)\overline{\varepsilon}(s). \tag{17}$$

Since

$$\ddot{c}_2 \equiv U(L|L)\left(\frac{1-\sigma}{1-\varrho} - \frac{\varrho-\sigma}{1-\varrho}\overline{\varepsilon}(s)\right) - \frac{\varrho-\sigma}{1-\varrho}s, \tag{18}$$

we can rearrange term in the previous inequality, which then yields

$$\frac{1-\varrho}{1-\sigma} > -\frac{\underline{\varepsilon}(s_2)}{\overline{\varepsilon}(s_2)} > 0, \tag{19}$$

and the term on the RHS is equal to z in Proposition 1. Therefore, if $(1-\varrho)/(1-\sigma) > z$, then it cannot be that $\ddot{c}_1$ is the S-CE.

Alternatively, suppose that the S-CE to this lottery L with s is $\ddot{c}_2$. Then

$$\varrho s + (1-\varrho)\ddot{c}_2 \equiv \sigma s + (1-\sigma)U(L|L) - (\varrho - \sigma)\overline{\varepsilon}(s) \tag{20}$$

and

$$\varrho s + (1-\varrho)\ddot{c}_1 < \sigma s + (1-\sigma)U(L|L) - (\varrho - \sigma)\overline{\varepsilon}(s), \tag{21}$$

where, again, the last inequality yields (after plugging in $\ddot{c}_1$)

$$\frac{1-\varrho}{1-\sigma} > -\frac{\underline{\varepsilon}(s_2)}{\overline{\varepsilon}(s_2)} > 0, \tag{22}$$

and the term on the RHS is equal to z in Proposition 1. Therefore, if $(1-\varrho)/(1-\sigma) < z$, then it cannot be that $\ddot{c}_2$ is the S-CE. Hence, if $(1-\sigma)/(1-\varrho) \neq z$, the S-CE is either $\ddot{c}_1$ or $\ddot{c}_2$ but not both. As a result, if $(1-\sigma)/(1-\varrho) \neq z$, the S-CE is also unique when ranks can reverse. By the same reasoning, it holds that $(1-\sigma)/(1-\varrho) = z$ implies that $\ddot{c}_1 = \ddot{c}_2$. □

Proposition 2 (Monotonicty)

Proof. We divide this proof in two steps. First, we establish that the E-CE is monotonic. Next, we show that also the S-CE in monotonic.

Step 1. Monotonicity of the E-CE.

Recall that the E-CE for any binary lottery L and peer earnings s is defined as

$$\dot{c}(L,s) = \begin{cases} \varrho s + (1-\varrho)U(L|L) & \text{if } s < \underline{x} \\ \sigma s + (1-\sigma)U(L|L) - (\varrho - \sigma)\overline{\varepsilon}(s)U(L|L) & \text{if } \underline{x} \leq s \leq \overline{x} \\ \sigma s + (1-\sigma)U(L|L) & \text{if } s > \overline{x} \end{cases}$$

whose the derivatives with respect to $\underline{x}$ and $\overline{x}$ are positive, and the derivative with respect to p is negative. This proves the statement for the E-CE.

Step 2. Monotonicity of the S-CE.

As for the E-CE, recall that the S-CE is defined as follows:

$$\ddot{c}(L,s) = \begin{cases} U(L|L) & \text{if } s < \underline{x} \\ U(L|L) + \frac{\varrho-\sigma}{1-\varrho}\underline{\varepsilon}(s)U(L|L) & \text{if } \underline{x} \leq s \leq \overline{x} \text{ and } \ddot{c}(L,s) > s \\ U(L|L) - \frac{\varrho-\sigma}{1-\sigma}\overline{\varepsilon}(s)U(L|L) & \text{if } \underline{x} \leq s \leq \overline{x} \text{ and } \ddot{c}(L,s) \leq s \\ U(L|L) & \text{if } s > \overline{x} \end{cases}$$

Much like in Step 1, also the derivatives of the S-CE with respect to $\underline{x}$ and $\overline{x}$ are positive, while its derivative with respect to p is negative. This implies that the S-CE is increasing in personal earnings and decreasing in the probability of lottery downsides. Together with Step 1, this proves the statement of Proposition 2. □

Proposition 3 (Continuity)

Proof. We structure the proof in two parts. We first show that the E-CE is (semi-) continuous s, followed by the equivalent demonstration for the S-CE. We denote peer earnings for the cases where they lie i) below the decision-maker's earnings by s_1, ii) between the decision-maker's earnings by s_2 (and $s_2' > s_2$ for the S-CE), and iii) above the decision-maker's earnings by s_3. Without loss of generality, define s_2 such that $\ddot{c}(L,s) > s_2$ and s_2' such that $\ddot{c}(L,s) \leq s_2'$.

Part 1. Continuity of the E-CE.

Let us divide this part of the proof in two steps. We start with continuity from $s_1 < \underline{x}$ to $s_2 \in [\underline{x}, \overline{x}]$, and continue with continuity of $s_2 \in [\underline{x}, \overline{x}]$ to $s_3 > \overline{x}$ in Step 2.

Step 1. Continuity of the E-CE from $s_1 < \underline{x}$ to $s_2 \in [\underline{x}, \overline{x}]$.

To show continuity in s, let both s_1, s_2 approach $\underline{x}$ such that in the limit it holds $s_1 = s_2 = \underline{x}$. Then

$$\lim_{s_1 \to \underline{x}} \dot{c}(L, s_1) = \varrho \underline{x} + (1-\varrho) U(L|L). \tag{23}$$

Similarly,

$$\lim_{s_2 \to \underline{x}} \dot{c}(L, s_2) = \sigma \underline{x} + (1-\sigma) U(L|L) - (\varrho - \sigma)(\overline{x} - \underline{x}) \frac{\partial U(L|L)}{\partial \overline{x}}, \tag{24}$$

which, after rearranging terms, reveals that it is equal to $\varrho \underline{x} + (1-\varrho) U(L|L)$. Therefore

$$\lim_{s_1 \to \underline{x}} \dot{c}(L, s_1) = \lim_{s_2 \to \underline{x}} \dot{c}(L, s_2). \tag{25}$$

This proves continuity for the E-CE from $s < \underline{x}$ to $s \in [\underline{x}, \overline{x}]$.

Step 2. Continuity of the E-CE from $s_2 \in [\underline{x}, \overline{x}]$ to $s_3 > \overline{x}$.

To show continuity in s, let both s_2, s_3 approach $\overline{x}$ such that in the limit it holds $s_2 = s_3 = \overline{x}$. Continuity from $s_2 \in [\underline{x}, \overline{x}]$ to $s_3 > \overline{x}$ then requires that

$$\lim_{s_2 \to \overline{x}} \dot{c}(L, s_2) = \lim_{s_3 \to \overline{x}} \dot{c}(L, s_3). \tag{26}$$

Notice that

$$\lim_{s_2 \to \overline{x}} \dot{c}(L, s_2) = \sigma \overline{x} + (1-\sigma) U(L|L) + (\varrho - \sigma)(\overline{x} - \overline{x}) \frac{\partial U(L|L)}{\partial \overline{x}} \tag{27}$$

collapses to $\sigma \overline{x} + (1-\sigma) U(L|L)$. In a similar fashion,

$$\lim_{s_3 \to \overline{x}} \dot{c}(L, s_3) = \sigma \overline{x} + (1-\sigma) U(L|L). \tag{28}$$

Hence, the claim above is true. In combination with Step 1, we therefore conclude that the E-CE is continuous in s.

Part 2. Continuity of the S-CE.

We prove the continuity of the S-CE by relying on our result of Proposition 1. This allows us to proceed in the following way; let us divide this part of the proof in three steps. We start with continuity from $s_1 < \underline{x}$ to $s_2 \in [\underline{x}, \overline{x}]$, and continue with continuity of $s_2 \in [\underline{x}, \overline{x}]$ to $s_2' \in [\underline{x}, \overline{x}]$ in Step 2. We close this proof by showing continuity from $s_2' \in [\underline{x}, \overline{x}]$ to $s_3 > \overline{x}$.

Step 1. Continuity of the S-CE from $s_1 < \underline{x}$ to $s_2 \in [\underline{x}, \overline{x}]$.

Let both s_1, s_2 approach $\underline{x}$ such that in the limit it holds $s_1 = s_2 = \underline{x}$. We then obtain for $s_1 < \underline{x}$

$$\lim_{s_1 \to \underline{x}} \ddot{c}(L, s_1) = U(L|L). \tag{29}$$

Similarly, for $s_2 \in [\underline{x}, \overline{x}]$ we have

$$\lim_{s_2 \to \underline{x}} \ddot{c}(L, s_2) = U(L|L) - \frac{\varrho - \sigma}{1 - \varrho} \underline{\varepsilon}(\underline{x}) U(L|L), \tag{30}$$

which can be simplified to $U(L|L)$ since $\underline{\varepsilon}(\underline{x}) = (\underline{x} - \underline{x})/U(L|L) * \partial U(L|L)/\partial \underline{x} = 0$. Therefore, also

$$\lim_{s_1 \to \underline{x}} \ddot{c}(L, s_1) = \lim_{s_2 \to \underline{x}} \ddot{c}(L, s_2). \tag{31}$$

Hence, the S-CE is continuous when raising $s_1 < \underline{x}$ to $s_2 \in [\underline{x}, \overline{x}]$.

Step 2. Continuity of the S-CE from $s_2 \in [\underline{x}, \overline{x}]$ to $s_2' \in [\underline{x}, \overline{x}]$.

Let both s_2, s_2' approach each other such that in the limit it holds $s_2 = s_2'$. Continuity then requires

$$\lim_{s_2 \to s_2'} \ddot{c}(L, s_2) = \lim_{s_2' \to s_2} \ddot{c}(L, s_2'). \tag{32}$$

Without loss of generality, keep s_2 fixed and let s_2' approach s_2. Then

$$\ddot{c}(L, s_2) = U(L|L) - \frac{\varrho - \sigma}{1 - \varrho} \underline{\varepsilon}(s_2) U(L|L) \tag{33}$$

and

$$\lim_{s_2' \to s_2} = U(L|L) - \frac{\varrho - \sigma}{1 - \sigma} \overline{\varepsilon}(s_2) U(L|L). \tag{34}$$

Since Proposition 1 shows that there exist a $(1 - \varrho)/(1 - \sigma) = z$, for $(1 - \varrho)/(1 - \sigma) = z$ the equation above holds indeed true. Hence, the S-CE is continuous in s for $s_2, s_2' \in [\underline{x}, \overline{x}]$.

Step 3. Continuity of the S-CE from $s_2' \in [\underline{x}, \overline{x}]$ to $s_3 > \overline{x}$.

Finally, let s_2' and s_3 approach $\overline{x}$ such that in the limit it holds $s_2' = s_3 = \overline{x}$. Then

$$\lim_{s_2' \to \overline{x}} \ddot{c}(L, s_2') = U(L|L) - \frac{\varrho - \sigma}{1 - \sigma} \overline{\varepsilon}(\overline{x}) U(L|L), \tag{35}$$

where $\overline{\varepsilon}(\overline{x}) = 0$. Hence, $\lim_{s_2' \to \overline{x}} \ddot{c}(L, s_2') = U(L|L)$. Moreover,

$$\lim_{s3 \to \overline{x}} \ddot{c}(L, s_3) = U(L|L). \tag{36}$$

Since

$$\lim_{s_2' \to \overline{x}} \ddot{c}(L, s_2') = \lim_{s3 \to \overline{x}} \ddot{c}(L, s_3), \tag{37}$$

therefore, also when raising $s_2' \in [\underline{x}, \overline{x}]$ to $s_3 > \overline{x}$, the S-CE is continuous. Together with the Steps 1 and 2, Step 3 shows continuity of the S-CE in s. Given both certainty equivalents' continuity in s, we therefore conclude that Proposition 3 is true. □

Proposition 4 (Equivalence of Certainty Equivalents)

Proof. Consider the two certain allocations $a' = (c', s')$ and $a'' = (c'', s'')$. Without loss of generality, assume that

$$u(a)' = \varrho s' + (1 - \varrho) c' \quad \text{and} \quad u(a'') = \sigma s'' + (1 - \sigma) c'', \tag{38}$$

and suppose both of them are equal to $U(L, s|L, s)$. Next, we structure our proof in three cases, each with its specific $U(L, s|L, s)$: first, one in which $s < \underline{x}$, second, another where $s \in [\underline{x}, \overline{x}]$, and lastly another case where $s > \overline{x}$.

Step 1. Equivalence when $s < \underline{x}$.

Consider first

$$c' = \frac{\varrho}{1 - \varrho} s + U(L|L) - \frac{\varrho}{1 - \varrho} s' \tag{39}$$

and

$$c'' = \frac{\varrho}{1 - \sigma} s - \frac{1 - \varrho}{1 - \sigma} U(L|L) - \frac{\sigma}{1 - \sigma} s'', \tag{40}$$

whose derivatives are equal to

$$\frac{\partial c'}{\partial s} = \frac{\varrho}{1 - \varrho} \quad \text{and} \quad \frac{\partial c''}{\partial s} = \frac{\varrho}{1 - \sigma}, \tag{41}$$

respectively. Note that $\partial U(L, s|L, s)/\partial s = \varrho$. Hence, all derivatives are proportional to each other.

Step 2. Equivalence when $s \in [\underline{x}, \overline{x}]$.

Consider now

$$c' = \frac{\sigma}{1-\varrho}s + \frac{1-\sigma}{1-\varrho}U(L|L) - \frac{\varrho-\sigma}{1-\varrho}\overline{\varepsilon}(s)U(L|L) - \frac{\varrho}{1-\varrho}s' \tag{42}$$

and

$$c'' = \frac{\sigma}{1-\sigma}s + U(L|L) - \frac{\varrho-\sigma}{1-\sigma}\overline{\varepsilon}(s)U(L|L) - \frac{\sigma}{1-\sigma}s'', \tag{43}$$

whose derivatives are, respectively

$$\frac{\partial c'}{\partial s} = \frac{1}{1-\varrho}\left(\sigma s + (\varrho-\sigma)\frac{\partial U(L|L)}{\partial \overline{x}}\right)$$
$$\text{and} \quad \frac{\partial c''}{\partial s} = \frac{1}{1-\sigma}\left(\sigma s + (\varrho-\sigma)\frac{\partial U(L|L)}{\partial \overline{x}}\right). \tag{44}$$

Step 3. Equivalence when $s > \overline{x}$.

Lastly, take

$$c' = \frac{\sigma}{1-\varrho}s + \frac{1-\sigma}{1-\varrho}U(L|L) - \frac{\varrho}{1-\varrho}s' \tag{45}$$

and

$$c'' = \frac{\sigma}{1-\sigma}s - U(L|L) - \frac{\sigma}{1-\sigma}s'', \tag{46}$$

whose derivatives are equal to

$$\frac{\partial c'}{\partial s} = \frac{\sigma}{1-\varrho} \quad \text{and} \quad \frac{\partial c''}{\partial s} = \frac{\sigma}{1-\sigma}, \tag{47}$$

respectively. Note that $\partial U(L,s|L,s)/\partial s = \sigma$. Hence, all derivatives are proportional to each other. This completes the proof.

□

Proposition 5 (Overhaul Effect)

Proof. We first show that overall utility in CPE when ranks can reverse is indeed equal to the one displayed in 5. We then prove that its last term is increasing in peer earnings s.

Step 1. Overall utility when ranks can reverse.

Overall utility from L when $s \in [\underline{x}, \overline{x}]$ in CPE is

$$U(L,s|L,s) = p[\sigma s + (1-\sigma)\underline{x}] + (1-p)[\varrho s + (1-\varrho)\overline{x}]$$
$$- \eta(\lambda-1)p(1-p)[\varrho s + (1-\varrho)\overline{x} - \sigma s - (1-\sigma)\underline{x}], \tag{48}$$

where the first line corresponds to stand-alone utility and the second to gain-loss utility. Note that since $\varrho \geq \sigma$, there exists an $a \in \mathbb{R}_+$ such that $\varrho = \sigma + a$. Hence, we can rewrite overall utility as

$$\sigma s + (1-\sigma)U(L|L) - (\varrho - \sigma)(\overline{x} - s)(1-p)[1 - \eta(\lambda - 1)p], \tag{49}$$

where the last term can be reformulated –since $(1-p)[1-\eta(\lambda-1)p] = \partial U(L|L)/\partial \overline{x}$– by multiplying $U(L|L)/U(L|L)$ such that

$$\sigma s + (1-\sigma)U(L|L) - U(L|L)\overline{\varepsilon}(s), \tag{50}$$

with $\overline{\varepsilon}(s) = [(\overline{x} - s)/U(L|L)] * [\partial U(L|L)/\partial \overline{x}]$. This completes this part of the proof.

Step 2. Overhaul Effect.

Consider the last term in Step 1 of this proof:

$$(\varrho - \sigma)\overline{\varepsilon}(s). \tag{51}$$

Its derivative with respect to s is

$$(\varrho - \sigma)\frac{\partial U(L|L)}{\partial \overline{x}}. \tag{52}$$

Notice that $\varrho \geq \sigma$ by assumption A1. From Proposition 2, we know that $\partial U(L|L)/\partial \overline{x} > 0$. Hence, this term is non-decreasing in s whenever $\varrho = \sigma$ and increasing in s else. Together with Step 1, this proves the claimed statement. □

Proposition 6 (Prevailing Overhaul Effect)

Proof. We make this proof by contradiction. Suppose that

$$\varrho > \sigma\zeta, \tag{53}$$

where ζ is defined as above. From Proposition 5, we know that

$$U(L, s|L, s) = \sigma s + (1-\sigma)U(L|L) - U(L|L)\overline{\varepsilon}(s), \tag{54}$$

whose derivative with respect to s yield

$$\sigma + (\varrho - \sigma)\frac{\partial U(L|L)}{\partial \overline{x}}. \tag{55}$$

Suppose the derivative is positive. Then rearranging terms brings

$$\varrho > \sigma\left(1 - \frac{1}{\frac{\partial U(L|L)}{\partial \overline{x}}}\right). \tag{56}$$

Note that since the second term on the RHS corresponds to ζ, this contradicts our initial assumption. □

Proposition 7 (E-CE Risk Acceptance to rank reversal)

Proof. The E-CE for a situation $s_1 < \underline{x}$ is equal to

$$\varrho s_1 + (1-\varrho)U(L|L). \tag{57}$$

Similarly, the E-CE for the case of $\underline{x} \leq s_2 \leq \overline{x}$ is defined as

$$\sigma s_1 + (1-\sigma)U(L|L) - (\varrho - \sigma)(1-p)(\overline{x} - s_2)\frac{\partial U(L|L)}{\partial \overline{x}}. \tag{58}$$

We first show that $w \leq 0$. Notice that since $\eta(\lambda - 1) \leq 1$, the denominator of w is positive. Moreover, since $s_2 \geq p\underline{x} + (1-p)s_2$ for any $p \in (0,1)$ and $\eta(\lambda-1) > 0$, the enumerator is non-positive. Therefore, w is non-positive.

We now prove Proposition 7 by contraposition. Assume first that our claim does not hold, i.e.,

$$\sigma \cdot w > \varrho \quad \text{where } w = -\frac{(s_2 - \underline{x})\frac{\partial U(L|L)}{\partial \underline{x}}}{(s_2 - s_1) - (s_2 - \underline{x})\frac{\partial U(L|L)}{\partial \underline{x}}} \leq 0 \tag{59}$$

After rearranging terms several times, we obtain that

$$\varrho s_1 + (1-\varrho)U(L|L) > \sigma s_1 + (1-\sigma)U(L|L) - (\varrho - \sigma)(1-p)(\overline{x} - s_2)\frac{\partial U(L|L)}{\partial \overline{x}}, \tag{60}$$

which is the opposite our of initial condition. This completes the proof. □

Proposition 8 (E-CE Risk Acceptance from rank reversa)

Proof. By using the initial condition that the E-CE for peer earnings $s_2 \in [\underline{x}, \overline{x}]$ is lower than for the case when $s_3 > \overline{x}$ while L is kept constant, the proof of Proposition 8 is analogous to the proof of Proposition 7. □

Lemma 1 (E-CE Risk behavior)

Proof. We proof the claim from Lemma 1 by contradiction. Assume that $w \geq w'$ and take the following expression as our initial condition

$$(\overline{x} - s_2)\frac{\partial U(L|L)}{\partial \overline{x}} > \left[(\overline{x} - s_1)\frac{\partial U(L|L)}{\partial \overline{x}} - (s_1 - \underline{x})\frac{\partial U(L|L)}{\partial \underline{x}}\right]\frac{s_3 - s_2}{s_3 - s_1}. \tag{61}$$

After rearranging terms, we then get

$$\frac{U((L|L) - s_2 - (\overline{x} - s_2)\frac{\partial U(L|L)}{\partial \overline{x}}}{U(L|L) - s_1 - (\overline{x} - s_2)\frac{\partial U(L|L)}{\partial \overline{x}}} < 1 - \frac{s_3 - s_2}{(\overline{x} - s_2)\frac{\partial U(L|L)}{\partial \overline{x}}}, \tag{62}$$

where it is easily verified that the LHS corresponds to w and the RHS to w'. Hence, $w < w'$. But this yields a contradiction since we initially assumed that $w \geq w'$.

Moreover, note that

$$(\overline{x} - s_1)\frac{\partial U(L|L)}{\partial \overline{x}} - (s_1 - \underline{x})\frac{\partial U(L|L)}{\partial \underline{x}} > 0. \tag{63}$$

This becomes visible as soon as we rearrange terms such that the LHS becomes

$$\frac{1}{U(L|L)}\left[U(L|L) - s_1\right], \tag{64}$$

because since $s_1 < \underline{x}$, the expression immediately above is greater than

$$\frac{1}{U(L|L)}\left[U(L|L) - \underline{x}\right]. \tag{65}$$

And since

$$\frac{1}{U(L|L)}\left[U(L|L) - \underline{x}\right] = \frac{\overline{x} - \underline{x}}{U(L|L)}\frac{\partial U(L|L)}{\partial \overline{x}} > 0, \tag{66}$$

also

$$(\overline{x} - s_1)\frac{\partial U(L|L)}{\partial \overline{x}} - (s_1 - \underline{x})\frac{\partial U(L|L)}{\partial \underline{x}} > 0. \tag{67}$$

□

Proposition 9 (S-CE Encouragement and Discouragement Effect)

Proof. We proof Proposition 9 in two steps. We first prove that $d\ddot{c}(L,s)/ds > 0$, followed by the proof that $d\ddot{c}(L,s')/ds' \leq 0$.

Step 1. Proof for s.

Assume first that Proposition 1 holds. Hence, $\varrho > \sigma$. The S-CE given s is

$$\ddot{c}(L,s) = U(L|L)\frac{\varrho - \sigma}{1 - \sigma}\overline{\varepsilon}(s)U(L|L), \tag{68}$$

whose derivative is

$$\frac{d\ddot{c}(L,s)}{ds} = 0 + \frac{\varrho - \sigma}{1-\sigma}\frac{\partial U(L|L)}{\partial \overline{x}}, \tag{69}$$

where the second term is positive. Hence, $d\ddot{c}(L,s)/ds > 0$.

Step 2. Proof for s'.

Similar to Step 1, the S-CE given s' is

$$\ddot{c}(L,s') = U(L|L) + \frac{\varrho - \sigma}{1-\varrho}\underline{\varepsilon}(s)U(L|L). \tag{70}$$

Notice that since Proposition 1 does not hold, the case of $\varrho = \sigma$ is possible. Therefore, if $\varrho = \sigma$, then $d\ddot{c}(L,s)/ds' = 0$. If $\varrho > \sigma$, then taking the derivative with respect to s' yields

$$\frac{d\ddot{c}(L,s)}{ds'} = 0 - \frac{\varrho - \sigma}{1-\varrho}\frac{\partial U(L|L)}{\partial \underline{x}}. \tag{71}$$

Notice that since $\varrho > \sigma$, it holds that the second term is negative. Hence, $d\ddot{c}(L,s)/ds' < 0$. Together with Step 1, this proves the stated claim of Proposition 9.

□