The Evolution of Status Preferences in Anti-Coordination Games

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Abstract

This paper analyses how risk-taking behaviour and preferences over consumption rank can emerge as an evolutionary stable equilibrium when agents face an anti-coordination task. If in an otherwise homogeneous society information about relative consumption is available, this cannot be ignored. Despite concavity in the objective function, agents are willing to accept risky gambles to differentiate themselves and thus allow for coordination. This suggests status preferences to be salient in settings where miscoordination is particularly costly.

Keywords: relative consumption, evolution, anti-coordination, risk-taking, social status

JEL Codes: C73, D01, D31, H42
1 Introduction

In many economic settings, people’s preferences seem to not only depend on their own allocation but also the allocations of the people around them. In particular, these can take the form of status or rank-dependent preferences as in [Robson (1992)] and [Ray and Robson (2012)]. Explanations for such preferences suggested in the literature include the allocation of goods outside market mechanisms, as described in [Cole et al. (1992)], as well as the information relative consumption might contain about the state of the environment, as in [Samuelson (2004)]. While also employing an evolutionary approach, this paper instead focuses on their role for coordination. It is shown how even in a perfectly equal society, individuals might have a strong incentive to induce variation in consumption by taking risky gambles if this facilitates social interaction and avoids costly conflict. Furthermore, if information on relative consumption is available, it cannot be ignored in an evolutionary stable state. This can lead to preferences over consumption rank. These insights imply more generally that if there is no costless way of coordinating in a society, it is evolutionary optimal for agents to engage in risky behavior to generate signals which then must be heeded by the other agents.

The main idea explored here is that while successful social interaction requires a degree of cooperation, the roles people (or animals) need to take might be asymmetric - not everybody can be a leader at the same time. This is modelled as a 2-player anti-coordination game equivalent to a Hawk-Dove game where a Dove player would rather face a Hawk than a Dove opponent. The focus lies on a one-population scenario where players are ex-ante identical and it is thus challenging for players to coordinate their actions. If individuals successfully coordinate by choosing distinct actions, they receive a positive but unequal payoff. If (anti-) coordination fails, the interaction is not productive. In other words, when players are unable to fill the roles necessary for the interaction, there might be costly conflict which lowers payoffs. In a biological context, this does not necessarily have to be conflict that causes the risk of injury but can also be the case of a ritualized display that requires effort as described in [Smith (1974)] or it might simply be that the task, for example a joint hunt, fails. In the absence of any asymmetries, players randomize over actions. This is inefficient as outcomes where players choose the same action (e.g. both act hawkish or dovish) occur with positive probability. As discussed in [Smith and Parker (1976)], if players have some type of ‘cue’ available as to who takes which role, conflict can be avoided. While previous work analyzes similar settings
with exogenously given cues, it is shown here how these can emerge endogenously. For example, [Herold and Kuzmics (2020)] show how a set of freely available labels in a society can alleviate conflict in an anti-coordination game. The paper at hand, in contrast, shows how players themselves can create such labels and in fact will do so in an evolutionary stable state.

In the model examined here, players are endowed with an identical (subsistence) consumption allocation. They engage in frequent anti-coordination tasks with other players. These capture various social interactions where the roles are somewhat asymmetric. For instance, when several members of a group go hunting together, not everybody can determine where and what to hunt. While these situations are admittedly vastly more complex in the real world, we believe the bilateral anti-coordination game still captures some relevant aspects. The outcomes of these interactions determine the players’ allocations of a second good that will simply be called ‘social capital’ and interpreted as their access to socially awarded prizes like mating or feeding privileges. Both consumption and social capital determine a player’s fitness and thus their reproductive success. Maximizing their fitness is the evolutionary objective of each player. Players further have the possibility to accept gambles over their consumption endowment. For instance, a hunter-gatherer could either forage in a well-known area and obtain a relatively certain payoff or explore new places which is riskier. These gambles are taken to be not inherently beneficial (individual fitness is assumed to be concave in the consumption good), but as will be shown, they can create an observable heterogeneity in the population. This heterogeneity can then take the role of a signal for the coordination problem not unlike the signals analyzed in coordination games with cheap talk, such as in [Banerjee and Weibull (2000)].

As a key distinction, relative consumption here is observable and thus not cheap talk. It is shown that the information provided by relative consumption cannot be ignored in an ESS. When gambles are available, a hierarchical society necessarily emerges where consumption determines roles in the anti-coordination game. And in fact, despite the inefficiency of gambles, a society will achieve higher aggregate fitness than without this possibility for coordination. It is shown further that the ESS choice behaviour over gambles can be represented by rank-dependent utility as in [Ray and Robson (2012)]. The paper thus presents an evolutionary origin for rank-

\(^1\)See [Smith (1979)] for various examples where size determines outcomes in asymmetric interactions even though size is not necessarily correlated with the success in conflict. For instance, [Riechert (1978)] presents a particular example where spiders react to relative size as a cue in bilateral interactions. In the context of the model presented here, differences in consumption could lead to observable differences in size which then are used to correlate actions.
dependent preferences.

Interpreted loosely, the consumption lotteries could very well be a series of antagonistic interactions whose probabilistic outcomes determine access to resources but avoid more serious conflict, as observed in various animal societies. For instance, many primates establish a social hierarchy through (potentially costly) dominance behaviour that then determines access to resources like mating partners. As the outcome of these interactions can entail a degree of randomness and risk of injury, especially for animals of comparable strength, this can be considered a costly lottery. But this avoids more frequent and serious or even lethal conflict when it comes to accessing resources. In other words, a clearly established hierarchy avoids conflict when resources become available. More closely related, the model captures features of observed risk-taking behavior in humans, especially in young male adults, who engage in high-stakes, high-risk activities to obtain social status and thus increase their chances of reproductive success.

The remaining paper is structured as follows: Section 2 presents the basic setting and formalizes the anti-coordination game. Section 3 then develops the key results especially regarding the correlation of actions (Result 1), consumption as a signaling device and choices over lotteries (Result 2) as well as rank-dependent preferences (Result 3). Section 4 concludes.

## 2 The Environment

The population consists of a continuum of agents. Time is discrete and individuals live for one period at the end of which they reproduce according to a reproduction process $f$, which is a mapping:

$$f : \mathbb{R}^2_+ \rightarrow \mathbb{R}_+.$$ 

The inputs represented by the ordered pair $(c, s) \in \mathbb{R}^2_+$ are an individual's resources. $c$ will be interpreted as a standard consumption good and $s$ as a form of social capital. In each period, individuals are endowed with a subsistence amount $c_0 > 0$ of the consumption good. Furthermore, individuals can participate in lotteries over consumption. Besides this, people engage in social interactions through which, if successful, people gain social capital $s$, which allows them to obtain socially awarded

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2 See, for example, Hausfater (1975) for a discussion of hierarchies in male baboons and Abbott and George (1991) for hierarchies in female marmosets.

3 See, for instance, Ellis et al. (2012) for a detailed analysis of risk-taking in young adults.
rewards like influence, or mating partners. The aim is to identify evolutionary stable strategies for the social interactions and choices over lotteries.

I make the following assumptions on the reproduction (or fitness) function $f$:

**Assumption 1.** $f$ is strictly increasing in $c$ and $s$. It is continuous and at least twice differentiable in $c$.

**Assumption 2.** $f$ is strictly concave in $c$. Furthermore, $\lim_{c \to 0} \frac{\partial f(c,s)}{\partial c} \to \infty$ and $\lim_{c \to \infty} \frac{\partial f(c,s)}{\partial c} \to 0$ for every $s \in \mathbb{R}_+$.

### 2.1 The anti-coordination game

As described in the introduction, agents take part in symmetric, 2-player anti-coordination games. Agents interact frequently and randomly with other members of society. The social capital $s$ that an individual receives from this is taken to be the average payoff of all their interactions in a given period. Individuals are anonymous meaning the game has no (ex-ante) uncorrelated asymmetries in the sense of Smith and Parker (1976).

For every such game, the set of players is $N = \{1, 2\}$ and the set of actions $A = \{h, d\}$. Individuals can either take the leading role and act hawkish or defer and act dovish. The general payoff structure is summarized in Table 1. As we are interested in an anti-coordination games where players prefer to take unequal actions, it is required that the payoffs on the off-diagonal are greater than the payoffs on the diagonal or more formally: $s_2 > \max\{s_1, s_4\}$ and $s_3 > \max\{s_1, s_4\}$.

|     | h   | d   |
|-----|-----|-----|
| h   | $s_1$ | $s_2$ |
| d   | $s_3$ | $s_4$ |

Table 1: general payoff matrix

The strategy set of every individual is $\Delta(A) = \{(\sigma_h, \sigma_d) \in \mathbb{R}_+^2 : \sigma_h = 1 - \sigma_d\}$. Mainly for expositional clarity, payoffs from Table 1 will be normalized such that $s_1 = s_4 = 0$ and it is assumed that $s_2 > s_3$. The results, however, go through with the general case of $s_2 \geq s_3$ and $s_3 > \max\{s_1, s_4\}$.

The individual payoffs are then $u(a_i, a_{-i})$ for $a_i \in A$ for each $i \in N$ are such that $u(h, h) = u(d, d) = 0$ and $\bar{s} = u(h, d) > u(d, h) = \underline{s}$ with $\bar{s}, \underline{s} \in \mathbb{R}_{++}$ as in Table 2. The
anti-coordination game can thus be summarized as
\[ \Gamma = \{N, (\Delta(A))_{i \in N}, u\} . \]

The strategy individuals take is interpreted as a ‘gene’. If an individual has \( K \) interactions, then the payoff from those is \( \frac{1}{K} \sum_{k=1}^{K} u(a_i(k), a_j(k)) \) where \( a_i(k) \) is the action of player \( i \) at the \( k \)-th encounter.

\( \Sigma(\sigma_h) \) describes the gene (or strategy) distribution in the population. If \( K \) is large, the payoff of an individual \( i \) with gene \( \sigma^i_h \) approaches
\[
\int \sigma^i_h (1 - \sigma_h) + \frac{s}{2}(1 - \sigma^i_h) \sigma_h d\Sigma(\sigma_h).
\]

This game has the ‘anti-coordination property’ as defined in Kojima and Takahashi (2007), meaning that the support of the mixed equilibrium includes all the worst responses. The only evolutionary stable strategy (ESS) is the interior Nash equilibrium, i.e. \( \sigma_h = \frac{s}{s + t} \). However, this is inefficient as aggregate payoffs are not on the Pareto-frontier. The average payoff is less than the efficient \( \frac{s + t}{2} \) and, in fact, less than \( s \).

A more efficient outcome can be achieved if a correlation device is available. Consider the modified game \( \Gamma_m \) in which both players receive a signal \( m \in M \) before playing.\(^5\) If these are negatively correlated, they can serve to coordinate players’ actions. For simplicity, we can reduce a potentially larger set of signals such that \( M = A \), meaning recommendations are in \{h, d\}. \( \Theta(M) = \Delta(A) = \{(\theta^h, \theta^d) \in \mathbb{R}_+^2 : \theta^d = 1 - \theta^h\} \) is the set of probability distributions over recommendations where the recommendation is a mapping from a common information set to signals. The role of evolution is to select for strategies or genes that translate signals into actions. If we identify the gene by the function \( \tau_i : M \to \Delta(A) \), then a gene that makes individuals strictly follow the recommendation would be \( \tau_i(h) = (1, 0) \neq \tau_i(d) = (0, 1) \) (noting that \( \tau \in \Delta(A) \)).

\(^4\)In evolutionary biology terms, players are ‘behaviourally variable’. Alternatively, one could limit genes to encoding pure strategies. This would be ultimately equivalent but rather than a stable strategy, one would obtain a stable population state where the proportions of genes present equal the randomization probabilities of the stable strategy.

\(^5\)This is in the literature, for instance in Banerjee and Weibull (2000) and Herold and Kuzmics (2020), also called the meta game.
While genes that ignore recommendations and encode strategies as in $\Gamma$ would be $\tau_i(h) = \tau_i(d)$. We can then look for a correlated equilibrium in the sense of [Aumann 1974] that is evolutionary stable. Symmetry, of course, implies that if strictly following a recommendation is an equilibrium, then so is strictly overturning it. As this is just a matter of labeling and the analysis is equivalent, I call both outcomes ‘following the recommendation’. When players ignore the recommendation, I will occasionally refer to this as agents playing $\Gamma$ instead of $\Gamma_M$.

3 Results

3.1 Correlated social interactions

Result 1 shows that if signals are precise enough, evolutionary stability requires recommendations to be followed strictly. Denote with $\theta^d_{|h}$ the probability that a player’s opponent receives the recommendation to act dovish ($m = d$), given that the player received $m = h$ and with $\theta^h_{|d}$ the probability of the opposite situation.

Result 1. In game $\Gamma_m$, a gene $\tau(m) = (1, 0) \neq \tau(m') = (0, 1)$ for $m' \neq m$ inducing a pure strategy is the only ESS if recommendations are sufficiently negatively-correlated. In particular, this is the case if and only if recommendations are such that $\frac{\theta^d_{|h}}{1 - \theta^h_{|d}} > \frac{1}{2}$ and $\frac{\theta^h_{|d}}{1 - \theta^d_{|h}} > \frac{1}{2}$.

Proof. Suppose individuals follow all recommendations with probability $b$. Consider a mutant who instead follows recommendations with probability $a > b$. The expected status payoff the mutant receives given a recommendation $m = d$ is:

$$E[s] = ab\theta^h_{|d} + a(1 - b)(1 - \theta^h_{|d}) + S[(1 - a)b(1 - \theta^h_{|d}) + (1 - a)(1 - b)(\theta^h_{|d})].$$

Equivalently, if $m = h$:

$$E[s] = ab\theta^d_{|h} + a(1 - b)(1 - \theta^d_{|h}) + S[(1 - a)b(1 - \theta^d_{|h}) + (1 - a)(1 - b)(\theta^d_{|h})].$$

The expected payoff of incumbents who receive the recommendation $m = d$ is:

$$E[\bar{s}] = b^2\theta^h_{|d} + b(1 - b)(1 - \theta^h_{|d}) + \bar{s}[(1 - b)b(1 - \theta^h_{|d}) + (1 - b)^2(\theta^h_{|d})].$$

And for $m = h$:

$$E[\bar{s}] = b^2\theta^d_{|h} + b(1 - b)(1 - \theta^d_{|h}) + \bar{s}[(1 - b)b(1 - \theta^d_{|h}) + (1 - b)^2(\theta^d_{|h})].$$

This includes the possibility of misperception of signals.
If (1) and (2) are smaller than \( \frac{s}{2s+3} \), the interior Nash equilibrium payoff in \( \Gamma \), they cannot be ESS. For them to be greater than this at \( b = 1 \), we need \( \theta^h_{id} > \frac{s}{2s+3} \) and \( \theta^d_{ih} > \frac{s}{2s+3} \). Given this, (1) and (2) exceed \( \frac{s}{2s+3} \) if \( b\theta^h_{id} \geq \frac{s}{2s+3} \) and \( b \geq \frac{s}{2s+3} \). But if those hold, then any \( a > b \) dominates \( b \). As it is locally dominated, it is not ESS and it follows directly that randomizing independently of signals over actions cannot be ESS either. In particular, \( a = 1 \) dominates any mixed response and \( a = 1 \) is locally superior. Thus \( a = 1 \) is ESS.\(^7\) Sufficiency follows immediately.

The result - well known in many contexts - demonstrates not surprisingly that if there is a sufficiently precise correlation device available, players must follow the recommendations. If players are assigned a role before the game and these assignments are negatively correlated, it benefits both players to follow these assignments even if a player is assigned the role with the lower payoff (i.e. ‘dovish’). As discussed in Smith and Parker (1976), if there are asymmetries in players not necessarily correlated with the probability of winning a contest (e.g. being the first discoverer of a resource vs. the late-comer), conflict can be avoided. However, such exogenous signals or labels might not always be available to players. The next section discusses how they can arise endogenously.

### 3.2 Correlation through consumption

Even though a correlation device is theoretically beneficial, it might not be readily available. For example, if this was based on genetically determined characteristics, effective coordination would require a large number of variations. Since mutations are considered rare\(^8\), this seems implausible. But if the consumption distribution (or some aspects of it) can serve as a correlation device, no external signals are necessary. As shown in Result[1] these observations do not need to be without mistakes as long as the signals generated by them are sufficiently precise. For simplicity, however, it is assumed that observations are perfectly accurate. The idea is that when two individuals meet, the coordination problem is resolved if the agent with the lower allocation of the observable consumption good defers (or vice versa). This avoids costly miscoordination. If agents follows this strategy, the distribution of the social capital in such a society is directly determined by the distribution of the consumption good.

While a degenerate consumption distribution does not allow for any coordination, individuals can participate in consumption lotteries i.e. distributions over consump-

\(^7\)See Proposition 2.6 in Weibull (1995).

\(^8\)See, for example, Oepe and Hill (2010) for a discussion of population mutations.
tion outcomes. As the utility function is concave in $c$, gambles are costly in terms of expected fitness even when the lotteries are fair. However, the mitigation of miscalculation can compensate for this cost.

**Definition (Lottery).** A fair and bounded consumption lottery $L$ is a probability distribution $\Pr$ over $\mathbb{R}_+$ such that for some bounded interval $V \subset \mathbb{R}_+$ we have $\Pr(V) = 1$ and $\int_V x \, d\Pr(x) = c_L$ where $c_L$ is the cost of the lottery.

Agents choose a lottery $L \in \mathcal{L}$ for which they have to give up some amount $c_L$ of their consumption endowment. All lotteries are taken to be fair and bounded away from 0. Agents can only participate in lotteries they can afford i.e. their consumption exceeds $c_L$. Without loss of generality, we can restrict attention to just affordable lotteries that cost exactly as much as an agent’s endowment. For an endowment $c$, this set is denoted $\mathcal{L}_c$. A degenerate lottery with a single outcome is called trivial which is assumed to be always available.

Fixing strategies for $\Gamma_m$ and a consumption distribution $G$, we can express the obtained social good from a large number of interactions as a function of an agent’s consumption endowment:

$$S_G : \mathbb{R}_+ \rightarrow [\underline{s}, \bar{s}]$$

with the property that $\int S_G(c) \, dG(c) \leq \frac{\underline{s} + \bar{s}}{2}$ - the limit to the aggregate level of the social good in the population. Furthermore, anonymity of agents requires that for any $\epsilon$-mass of agents at some $c$, the maximum social good obtainable is reduced by

$$m \left( \frac{\underline{s} + \bar{s}}{2} - \frac{\epsilon s}{\underline{s} + \bar{s}} \right).$$

In other words, if two agents with the same $c$ meet, they cannot coordinate as there is no differentiating information available and they can obtain at most the interior Nash equilibrium payoff.

While the strategies could depend in more elaborate ways on the consumption distribution, the focus lies on relative consumption as an intuitive coordination device that only requires decentralized information about the ordering of consumption of any two individuals rather than the population as a whole. As mentioned before, for each equilibrium there might be a symmetrical equilibrium with opposite recommendations but, for the more intuitive biological interpretation, I focus on the case.

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$^9$Ever affordable lottery can be written as a just affordable lottery by increasing the price $c_L$ and all outcomes by an equal amount so that the lottery becomes just affordable.
for positive matching: higher relative consumption than one’s opponent implies a recommendation to lead and vice versa. The social good an individual with consumption $c$ obtains can then be expressed as

$$S_G(c) \equiv G^-(c)S + (G(c) - G^-(c))\left(\frac{S}{S + \frac{s}{s}}\right) + (1 - G(c))\frac{s}{s}$$  \hspace{1cm} (4)$$

where $G$ is the cumulative distribution function and $G^-(c)$ is the left-limit of $G$ at $c$. In case all mass is concentrated at one point, the social good obtained is at most the interior Nash equilibrium payoff. But if consumption is dispersed, actions can be conditioned on consumption orderings. In the case of a smooth distribution, the aggregate social good reaches $\frac{s + \frac{s}{s}}{2}$ - the efficient upper-bound.

### 3.3 Choices over lotteries

The focus now lies on identifying the choice behaviour that, together with the strategy in $\Gamma_m$, maximizes an agent’s evolutionary success. Concavity of $f$ in $c$ implies choosing non-trivial lotteries cannot be optimal for agents ignoring recommendations. However, when consumption can serve as a correlation device, this is no longer ESS. As a key result, it is shown that there always exists a non-trivial lottery that makes following recommendations ESS and dominates choosing the trivial lottery.

**Result 2.** For every $c > 0$, there exists a set of lotteries $\mathcal{L}_c$ such that all agents choosing a non-trivial lottery $L \in \mathcal{L}_c$ and following the recommendations generated by the resulting consumption distribution $G$ is evolutionary stable, while choosing the trivial lottery is not.

**Proof.** It follows from Result[1] that following the recommendations for a non-degenerate consumption distribution is ESS. Suppose there exists a non-degenerate $G^*$ with the additional property that $f(c, S_{G^*}(c))$ is convex in $c$ and suppose that $\mathcal{L}_c$ contains this and the trivial lottery. From the presumed convexity we can conclude:

$$\int f(c, S_{G^*}(c))dG^* > f(c_0, S_{G^*}(c_0))$$

where $S_{G^*}$ is defined as in (4). If an $\epsilon$-mass of agents instead chooses the trivial lottery but follows the recommendations, the expected payoff of such an agent is $f(c_0, 1 - G(c_0))$. 

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10 This would be beneficial for aggregate fitness in a society if $c$ and $s$ are complements.
As \( \epsilon \to 0 \), this approaches \( f(c_0, S_G^*(c_0)) \) which is strictly less than the outcome of an agent choosing the non-trivial lottery. Furthermore, the payoff is decreasing in \( \epsilon \).

To see that such a \( G^* \) exists, we can construct an appropriate distribution.

Let \( G^n \) be a distribution with probability mass \( \frac{1}{2n} \) at \( c_0 - \delta \) for some small \( \delta > 0 \) and mass \( 1 - \frac{1}{2n} \) distributed uniformly over \([c_0, c_0 + \frac{\delta}{n}]\) where \( n \) is any positive integer. The expected number of offspring is then

\[
\frac{1}{2n} f(c_0 - \delta, (1 - \frac{1}{2n}) \bar{s} + \frac{\bar{s}}{s + \bar{s}}) + (1 - \frac{1}{2n}) \int_{c_0} f(c, S_{G^n}(c)) \, dc 
\]

which is bounded below by

\[
(1 - \frac{1}{2n}) \int_{c_0} f(c, S_{G^n}(c)) \, dc.
\]

As the integral is itself bounded below by \( f(c_0, S_{G^n}(c_0)) \) and \( f \) is strictly increasing in \( s \), we can conclude there exists an \( N^* \) such that for all \( n > N^* \),

\[
(1 - \frac{1}{2n}) \int_{c_0} f(c, S_{G^n}(c)) \, dc > f(c_0, S_{G^n}(c_0)).
\]

\( G^* \) is then any such lottery with \( n > N^* \). Choosing the trivial lottery leads to a strictly smaller number of offspring. Monotonicity in \( s \) and linearity in \( \epsilon \) imply that choosing the lottery inducing \( G^* \) is ESS while choosing the trivial lottery is not - if everybody follows recommendations. It remains to be shown that following recommendations is indeed ESS while ignoring them is not.

Suppose all agents choose the trivial lottery and ignore recommendations. If an \( \epsilon \)-mass instead chooses the non-trivial lottery inducing \( G^n \) and follows recommendations, the payoff of such agents is at least:

\[
f(c_0 - \delta, (1 - \frac{\epsilon}{2n}) \bar{s} + \frac{\bar{s}}{s + \bar{s}} + \epsilon \bar{s}).
\]

This is increasing in \( \epsilon \). The payoff of any agent at \( c_0 \) ignoring the recommendations is:

\[
f(c_0, \frac{\bar{s}}{s + \bar{s}}).
\]

As \( s > \frac{\bar{s}}{s + \bar{s}} \), for every \( \epsilon \) there exists a \( \delta > 0 \) for which \( 6 > 7 \). No uniform invasion barrier exists. Choosing the trivial lottery and ignoring recommendations is not ESS. The result follows.
Result 2 shows that we can always find a (fair) lottery (and in fact infinitely many lotteries) that generate correlated signals for the anti-coordination game in the form of relative consumption such that players cannot ignore this information and players must prefer this lottery over the trivial lottery. The proof also shows directly that this lottery does not need to generate a smooth distribution. The result can be easily extended to a lottery yielding a finite number of outcomes. We can conclude that it is not optimal for players to free-ride on the information created by others by simply following recommendations but rejecting gambles. And miscoordination does not need to be fully eliminated to achieve an improvement over simply playing $\Gamma$. The remaining section examines the case when the set of lotteries contains all fair and finite gambles.

### 3.4 Rank-order preferences

Suppose now $\mathcal{L}_c$, the set of lotteries available to agents with consumption $c$, includes all fair and bounded lotteries. The final step is to fully characterize the evolutionary stable choice behaviour. It turns out, this takes the familiar form of expected utility over consumption with a rank-based component.

Let $r_G(c)$ be the rank or status an individual with endowment $c$ has in a population with consumption distribution $G$. In case of a smooth distribution, this would be the CDF $G$ evaluated at $c$. If there are mass points in $G$, we simply take this as any convex combination of the left and right limit of $G$. For example, if $G$ is degenerate at $c_0$, than the left-limit of $G$ at $c_0$ would be $G^-(c_0) = 0$ and the right-limit (i.e. the CDF itself) $G(c_0) = 1$. For an equal weighting, this would give a rank of $r_G(c_0) = \frac{1}{2}$.

**Result 3.** There exists a utility function $v(c, r)$ such that choices over lotteries in $\mathcal{L}_c$ consistent with maximizing $E[V(c, L)|G] = \int v(c, r_G(c))dL$ are ESS. Under Assumptions 1 and 2, for any given initial $c_0$, this results in a unique smooth consumption distribution $G'$.

**Proof.** Define the Bernoulli-utility function

$$v : R \times [0, 1] \rightarrow R$$

as follows:

$$v(c, r) \equiv f(c, \frac{s}{s} + r(\frac{s}{s} - \frac{s}{s})).$$  \hfill (8)

It follows from Result 2 that choices maximizing the expectation of (8) cannot result in a mass point at any $c > 0$ as otherwise there exists $L \in \mathcal{L}_{c_0}$ s.t. choosing $L$ leads to
a strict increase in expected offspring. It follows further from Results 1 and 2 that any ESS behaviour must include following recommendations. Maximizing the expected number of offspring is thus equivalent to maximizing (8).

Given Assumptions 1 and 2 and the degenerate initial distribution of consumption at \( c_0 \), all conditions of Proposition 1 (i) of Ray and Robson (2012) are satisfied and thus uniqueness of \( G' \) follows.

Preferences over consumption rank might develop as a response to a coordination problem. Heterogeneity in an observable characteristic like consumption can be induced in a homogeneous environment to resolve the lack of signaling devices caused by exactly that homogeneity. While gambles are wasteful as such - recall that fitness is concave in \( c \) - this is compensated for by the benefit from improved coordination. We might ask if the benefits from improved (anti-)coordination are fully offset by the loss from the gambles on an aggregate level. Corollary 3.1 shows, however, that society is better-off overall.

Denote aggregate fitness (meaning the integral over all individual values of \( f \)) in a society where agents choose according to \( v(c, s) \) as \( V_r \) and in an otherwise equal society where agents do not gamble and simply play \( \Gamma_m \).

**Corollary 3.1.** Aggregate fitness in a society where agents choose according to \( v(c, r) \) and play \( \Gamma_m \) strictly exceed aggregate fitness in a society where agents do not accept any non-trivial lotteries and effectively play \( \Gamma \).

**Proof.** As the available gambles are fair, expected consumption in the society has to be equal the initial endowment \( c_0 \). Accepting any lottery requires at least indifference between the possible outcomes and the current allocation. Denote the lottery generating the (stable) consumption distribution \( G' \) for a given endowment \( c_0 \) as \( L'_{c_0} \). Note that while \( G' \) could be generated by a sequence of different, fair lotteries, it can be equivalently achieved by a single fair lottery. At the initial endowment point, it must be that all agents are indifferent between all outcomes of \( L'_{c_0} \). This means that \( v(c, G'(c)) \) (and by definition thus also \( f \)) is linear over any range of consumption outcomes that are achieved with positive probability. The expected fitness is thus equal to \( f(c_0, S_{G'}(c_0)) \). But as \( f \) is strictly increasing in \( s \) and

\[
\left( \frac{3s}{s + \delta} \right) < \delta < S_{G'}(c_0)
\]

the result follows.
4 Conclusion

This paper presents an evolutionary argument for the prevalence of relative consumption effects. Consumption can serve as a correlation device inducing risk-taking behaviour despite the concavity of the objective function if there is a need to coordinate social interactions. In such an environment, relative consumption information cannot be ignored and preferences over consumption rank can emerge as evolutionary stable choice behaviour. Rank-based utility as in Ray and Robson (2012) can represent the evolutionary optimal choices over lotteries. Despite the homogeneity in endowments, in equilibrium society is hierarchical with an individual’s status determining their actions in social interactions. This increases aggregate fitness relative to a setting where no such relative consumption information is available.
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