Ecologies of Preferences

with Envy as an Antidote to Risk-Aversion in Bargaining

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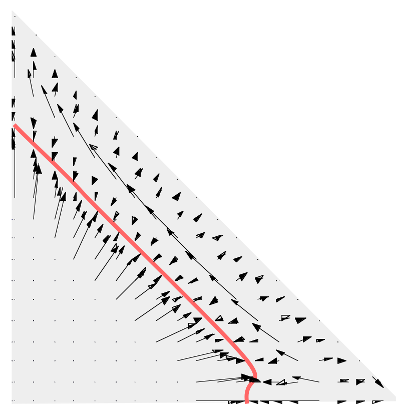

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Abstract

Models have been put forward recently that seem to be successful in explaining apparently anomalous experimental results in the Ultimatum Game, where responders reject positive offers. While imparting fixed preference orders to fully rational agents, these models depart from traditional models by assuming preferences that take account not only of the material payoff to oneself, but also of that which is given to others. However, they leave open the question of how an agent's economic survival is helped by a preference order that advises him to leave money on the table. Our answer is that, indeed, doing so does not help. But that the same envious preference order that ill advises in some circumstances to reject an "insultingly" small offer, advises well in other circumstances, when it helps the same agent to overcome his risk-aversion and to offer a risky, tough offer that yields him a higher expected dollar gain. We show the existence of population distributions where the two effects exactly balance out across different preference types. These distributions are asymptotically stable, stationary, and inefficient, in which different preferences are represented, and where, as commonly observed in an Ultimatum Game, positive offers are made, of which some are rejected with positive probability. Our theory yields new testable hypotheses.

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1 Introduction and Summary

It is by now well documented that in experiments of the Ultimatum Game,[1] subjects do not behave as predicted by standard game theory, when it assumes that players are selfish who care only for their own monetary gains. Instead of the predicted zero offer, subjects consistently offer positive amounts, sometimes as large as 50% of the divided surplus. And instead of the predicted agreement to take anything offered, responders often reject offers as large as 30%. See the surveys by Güth (1995), by Roth (1995), and by Thaler (1988).

This fundamental empirical departure from the predictions of the theory has stimulated attempts to reconcile the theory with the data. One avenue to this end is part of the literature on evolutionary learning. See the books by Fudenberg and Levine (1998), by Samuelson (1998), and by Young (1998), the review by Mailath (1998), and Binmore and Samuelson (1995). This literature asks if and how players learn to play a Nash equilibrium, and if they do, which one of the oftentimes many possible equilibria

[1] In the Ultimatum Game, two players have to agree on how to divide an amount of wealth. One player, designated the offerer, makes a take-it-or-leave-it offer on how to divide the amount. The other player, the responder, either agrees, in which case the amount is divided accordingly, or he rejects the offer, in which case the whole amount is lost to both.

do they play. This approach typically imposes a form of bounded rationality on the players, making it vulnerable to the concern that its agents are implausibly naive. In the Ultimatum Game context, this concern is the difficulty to imagine that responders do not understand that 3 dollars are better than none (Mailath, op. cit.).

A competing approach to the explanation of the Ultimatum Game laboratory findings maintains the classical economic assumption of stable, well defined preference orders that agents strictly follow, but departs from the common assumption of selfishness, assuming instead—based on mounting experimental evidence (see Roth op. cit.) or even introspection—preference orders that take account not only of the material gain to oneself, but also of that which goes to others with whom one is in an economic or social interaction. Bolton and Ockenfels (2000), Fehr and Schmidt (1999), Levine (1997), and Rabin (1993) employ such preferences in their explanation of the experimental results of the Ultimatum and related games. In effect, their answer to the puzzle, why people leave money on the table, is: people do that, because they prefer the outcome whereupon both they and their economic contender get nothing to the outcome where they get unacceptably less than the contender.

While this may well be true, it naturally begs the question, how do preferences that compel an economic agent to leave money on the table help him to survive in a competitive economic environment? In particular, a central hypothesis in economic theory is that firms maximize own value,[2] which is based on the rationale that firms that do not do so, are driven to extinction by competitive market forces. But a firm that rejects a joint project, for instance, because the negotiating partner insists on a large share of the project NPV, does not seem to maximize value.[3] Do such "hotheaded"[4] firms necessarily become extinct?

Not necessarily. Our answer is based on the rigidities inherent in the mental process that translates the emotion[5] of envy[6]—or any other emotion, for that matter—to decision

[2] 'Value maximization' generalizes 'profit maximization' in a dynamic setting with uncertainty.

[3] The common notion is that the Ultimatum Game captures salient aspects of large scale business negotiation. Indeed, breakdown of negotiations over mutually beneficial prospects is a common economic experience. Even if negotiations eventually resume, some value is irrecoverably lost. Noteworthy business negotiations in which ultimatums were made that were rejected generating significant value destruction involved the making of the film *Heaven's Gate* (Bach, 1984), the battle for Eastern Airlines (Bernstein, 1990), and the air traffic controllers' strike (Shostack and Skocik, 1986).

[4] For example, Deal and Kennedy (1982) identify different types of corporate cultures. Among them is the Macho/Tough-guy which thrives on high risks, intense pressure, and quick feedback.

[5] The following is a testimony to the importance of emotions in business by one of its

making. It may best be understood by drawing an analogy to another emotion; that of disgust. In *How the Mind Works*, Pinker (1997) writes (p. 378), “Disgust is a universal human emotion. Like all the emotions, disgust has profound effects on human affairs. During World War II, American pilots in the Pacific went hungry rather than eat the toads and bugs they had been taught were perfectly safe. [R]eassurance by authority or by one’s own beliefs do not disconnect an emotional response.” Disgust implies a preference order over potential foods which in most scenarios enhances survival by preventing a person from making mistakes of eating harmful materials. In some contexts, however, the same disgust-induced preference diminishes survival when it generates mistakes; rejecting what can be eaten, as in the case of the American pilots. What makes disgust an adaptation, though, is that *on average* it enhances survival. As Dawkins (1981) puts it, “However well adapted an animal may be to environmental conditions, those conditions must be regarded as a statistical average. It will usually be impossible to cater for every conceivable contingency of detail, and any given animal will therefore frequently be observed to make ‘mistakes,’ mistakes that can easily be fatal.”

Similarly, we argue, the emotion of envy, like that of disgust, generates a preference order that prevents an economic agent from making mistakes in some economic situations, at the expense of making mistakes in others. Specifically, an envious preference order that ill advises an agent to reject a positive size offer, advises wisely when it helps the same agent to overcome his risk-aversion[7] and offer a risky, tough

chieftains: “Business people are not just managers; they are also human. They have emotions, and a lot of their emotions are tied up in the identity and well being of their business.” From *Only the Paranoid Survive* by Andrew S. Grove, Chairman of the Board of Intel Corporation.

[6] The Oxford English Dictionary defines *envy* as “a feeling of discontent and resentment aroused by and in conjunction with desire for another's advantages or possessions. Can be appeased either by becoming better off than the other or by making the other worse off then oneself.” Parrott (1991) emphasizes the acuteness of this emotion: “At the heart of envy is social comparison. When one’s abilities, achievements, or possessions compare poorly with those of another, there is the potential of decrease in one’s self-esteem and public stature.” See Heider (1958), Silver and Sabini (1978), and Salovey and Rothman (1991). (Reduction in self esteem felt by a responder acceding to a small offer in an ultimatum game may stem from his perception of having been subjugated by the offerer. This element may be considerably muted when the offer is generated by a randomizing device, resulting in an increased readiness to accept such offers, as found in experiments.) In the economic literature, some authors use the terms *disadvantageous inequality aversion* or *fairness seeking* instead of *envy*. We use the last term because it names an emotion, rather than the former two that connote contemplation.

[7] In more general settings than the current, risk aversion has an economic fitness advantage over risk-neutrality and risk-seeking in that the former preference would more likely avert a gambler’s ruin than would the latter two; see Merton and Samuleson (1974). But to keep this paper manageable, we chose not to include these effects in the current model. Instead, we take risk-aversion of agents as

offer to a responder, about whose preference and rejection threshold (the smallest offer the responder would still take) the offerer has only incomplete information. The tough, risky offer then yields the offerer a larger expected dollar gain than would be the case had he been less envious and therefore had offered a generous, less risky offer.[8, 9]

The perfect adaptation would, indeed, have been to engage or disengage an emotional response upon the demands of the circumstances. Engage disgust when food is abundant, turn on envy when playing the offerer; but disengage disgust when food is scarce, turn off envy when playing the responder. However, there are *constraints on perfection*[10] as Dawkins, op. cit., writes in a chapter bearing this title, "It is particularly *in behavior that such mistakes are seen.* The more static attributes of an animal, its anatomical structure for instance, are obviously adapted only to long term average conditions. An individual is either big or small, it cannot change size from minute to minute as the need arises." Similarly, emotions, per definition, are states of mind that are characterized by inflexibility.[11] Paraphrasing Dawkins, an economic agent is either envious or not, he cannot adjust his feelings of envy and alter his attendant preference order with the role he happens to be playing.[12] In fact, this is the position taken by classical economic theory when it assumes, for instance, that a given individual is committed to the *same* Bernoulli utility function, maintaining the same risk attitudes in different situations;

exogenously given. In a separate paper, we endogenize risk-aversion in a model where agents choose from a menu of risky projects.

[8] We adopt, in effect, a basic premise of evolutionary biology that, as Low (2000) states, "No organism, including humans, has evolved to be aware of ultimate selective effects, but only of proximate cues." The evolutionary mechanism is mediated through preferences for proximate cues, and those preferences that enhance ultimate survival will spread in the population. This proximate-ultimate principle was first used by Güth and Yaari (1992) to analyze ecologies of preferences. They called it the "indirect approach," a term often used in subsequent economic literature.

[9] Without reading much into the following result, it is straightforward to show that a Nash bargaining solution would give a risk averse agent more of the pie the greater is the envy that his utility exhibits. So, in the axiomatic bargaining theory too, envy serves as an antidote to risk aversion.

[10] Maynard Smith (1978) writes: "If there were no constraints on what is possible, the best phenotype would live forever, would be impregnable to predators, would lay eggs at an infinite rate, and so on."

[11] Hirschleifer (1987) and Frank (1988) argue that the inflexibility of emotions makes them effective commitment devices. Since we do not introduce reputation effects in our model, the commitment value of emotions does not play a role in it either. Nevertheless, both in the 'emotions as commitments' model, and in ours, the benefits of emotions are seen in the long run, or on average.

[12] Why a sudden change in body size is infeasible in most animal species (some fish species are capable of that) is a physiological question. Similarly, what makes emotions inflexible belongs to the brain sciences. We simply posit that evident inflexibility.

when playing the agent, say, in a principal-agent problem, or when choosing an optimal portfolio of assets for his personal account.

A population in our model comprises firms. This makes the setting more concrete. In particular, it lets us specify the mechanism by which preferences are transmitted in a population. 'Firms' should be understood metaphorically, though, to stand also for other kinds of organizations, like labor unions or HMOs, that when economically successful, tend to increase in size by drawing in more members. Under a less precise specification of the preference transmittal mechanism (eg, economically successful preferences are imitated) which is common in the literature on preference evolution, the analysis applies also to individuals.

The population of firms is partitioned into disjoint classes. Each class, or type, is characterized by a corporate culture which is encapsulated in a preference order[13] held by those acting on a firm's behalf, over monetary gains to the firm and to its potential business partners. The firms are periodically and randomly matched pairwise intra- and inter-classes to negotiate on how to divide positive NPVs from joint ventures using the Ultimatum Game protocol. Each firm accumulates its share of the gains from those projects that are eventually adopted. This setting is in the spirit of the model of pairwise matched decentralized trade as a foundation for competitive equilibrium; see Osborne and Rubinstein (1990).

The wealth accumulated by all firms in a given preference class, divided by the aggregate wealth accumulated by all firms in all classes, is the fraction of total wealth that is controlled by the given preference order. The population distribution in our

[13] We adopt Lazear's (1995) view that "corporate culture acts as an alternative to using the price system with costly monitoring as a motivator. It often is manifested as an attempt to change tastes in the direction desired by the firm instead of compensating workers to take actions to which they are averse. The establishment of a culture generally requires an initial investment that instills a particular set of values in its workers so that they behave in the desired fashion as a natural consequence of *utility maximization*." See also Kandel and Lazear (1992) and Shleifer and Summers (1988) about the importance of corporate culture. [For example, the Wall Street Journal (October 12, 1999) attributes the reason that "the Pentagon is often slow to pursue promising weapons" to its organizational culture of "*risk-aversion, impatience*, and intolerance of failure."] In our model, firms are the carriers of their steady corporate culture from one period to the next. Stinchcombe (1965, 1979) states that firms and other forms of organizations tend to be imprinted by their environmental conditions at founding. He finds that industries formed in previous centuries still reflect today the character of their formative period. According to Ott (1989), corporate culture is maintained by screening of new members, socialization of new and old members, removal of members that deviate, and reinforcement of members behavior in a desired direction. This notwithstanding, corporate culture is probably not capable of molding a "new man." Instead, preferences instilled by corporate culture are patterned on preferences already represented in human populations.

model is the vector of fractions of wealth under the control of the different preference orders. The analysis of the dynamics of these population distributions is the focus of our paper.

Our main finding is that under plausible conditions, among them that all agents are risk averse, there exists a class of population distributions of different types of envy and risk aversion that are stationary, stable, and inefficient (value dissipating). In these populations, as commonly observed in an Ultimatum Game, positive offers are made, of which some are rejected with positive probability.[14] In these populations, each type performs—in expected dollars—worse than other types on some occasions, and better than other types on other occasions. As described above, the more envious makes the mistake of leaving money on the table when responding to a tough offer, but his envy helps him overcome his risk-aversion and make a tough offer that brings him larger expected gains. On the other hand, the less envious performs better when he tends to accept those offers that the more envious rejects, but his lower envy lets his risk-aversion get the better of him, and he makes too generous offers that bring him smaller expected dollar gains than those which a tougher offer would have brought him. In these stable, stationary populations, the better and the worse performances of each type average out to the same inclusive dollar fitness across all types.

Our theory predicts, then, that in those stationary populations distributions, the same agents who tend to make tough offers will also tend to reject such offers, and those who make generous offers will also tend to accede to tough offers. On average, though, there is no monetary advantage to being either a tough or an accommodating type. Interestingly, these two predictions, seem to be consistent with recent ultimatum game experimental results by Eckel and Grossman (2000) who find that the tough and the accommodating types divide along gender lines. They report (i) that "women proposers make more generous offers than men[.] Among responders, women are more likely to accept an offer of a given amount" and (ii) that the average monetary earnings to women and to men are within 5% of each other (their footnote 22).

Another prediction of our model is that controlling for the level of envy (because

[14] In a recent paper, Huck and Oechssler (1999) provide an evolutionary explanation for behavior in the Ultimatum Game which is very different from ours. Their explanation rests on the restrictive assumptions that economic interaction is carried out in a very small group of participants, and that each member of the group plays against *all* others. In their model, the advantage of spiteful relative to accommodating behavior stems from the fact that while the accommodating type is paired with *all* spiteful types, the spiteful type is spared being paired with himself.

envy counteracts risk-aversion), and facing the same distribution of responders, the more risk averse—calibrated independently of the Ultimatum Game—will tend to make more generous offers.

We demonstrate three additional classes of stationary population distributions. One class comprises distributions with a sufficiently large proportion of the most envious type. In these efficient, weakly stable distributions all types prefer to appease the numerous, most envious type by always offering his rejection threshold. Then all types also agree to accept that offer, and they all get the same expected dollar gain, both as offerers and as responders. A second class is a singleton comprising the least envious type monomorphic population distribution. It is efficient and asymptotically stable; its immediate neighborhood serving as its basin of attraction. A sufficient condition for its existence is that the least envious type would *not* be non-envious. If the least envious *is* non-envious, then the third class obtains comprising a continuum of population distributions with sufficiently high proportions of the non-envious. In these *in*efficient, weakly stable distributions all types offer zero, and only the non-envious agree to take the offer.

Interestingly, the last class implies that the non-envious, seemingly "more rational" types would never take over an envious, seemingly "less rational"[15] population—irrespective of risk attitudes. The reason is that as the proportion of the non-envious increases in the population, the whole population—envious and non-envious alike—recognizing the increased chance of being paired with non-envious types who accept any offer, move to take advantage of the latter by lowering their offers gradually (they still risk being paired with another envious) until everyone optimally makes zero offers which are accepted only by the non-envious. But agreeing to accept zero does not help an accommodating non-envious responder. Both the non-envious and the envious perform equally well then, and the population distribution comes to a rest with the envious still present.

Therefore, paradoxically, it necessarily takes some measure of envy for a preference to be able to take over a population – if it does so at all. We show that if those with the least, yet positive, measure of envy comprise a large enough percentage of the population, they *will* take over. The reason is that then all types offer the positive rejection threshold of the numerous least envious, in which case the latter have an

[15] The adjectives *emotional* and *rational* are commonly used as antonyms. It is in this sense that we use the latter here.

advantage as the only responders who agree to take those *positive* offers. (As offerers, all types perform equally then.) In a sense, although no reputation effects are present, the sheer number of the least envious type, and the fact that all of them reject offers up to a positive threshold, act like a collusion to force everyone to offer a positive offer, from which only the least envious benefit.

Although consistent with our argument, it is important to emphasize that we *do not* rely on an evolutionary psychological argument of hysteresis by which adaptations selected for in primeval times still manifest their time lagged effects in modern business environments in defiance of opposite economic selective pressure.Instead, we argue that envious preferences are represented in modern business populations because they *are* adaptations in those modern ecologies[16] of preferences.

* * *

The paper proceeds from the more general to the particular. In the next section, we present the model. We analyze polymorphic populations comprising several type classes in Section 3. A more detailed analysis of dimorphic populations is in Section 4, where we demonstrate the existence of asymptotically stable, stationary, inefficient, dimorphic population distributions. The central role of risk-aversion in generating these population distributions is examined in section 5. In Section 6 we demonstrate numerically and diagrammatically the existence of these distributions in the trimorphic case, indicating their existence in yet higher dimensions. To show that our model is consistent with experimental results, we calibrate it to experimental data in section 7. We conclude in section 8.

2 The Model

Consider an economy populated by a very large number of firms (the Law of Large Numbers applies). Each firm comprises decentralized, identical profit centers or firm

[16] The American Heritage Dictionary defines *ecology* as "the relationship between organisms and their environment." In our context, an ecology would mean the set of agents and their preferences; the economic environment in which they operate, namely, the type of interactions and the population distribution; and the ensuing dynamics of these distributions.

divisions, and every division is headed by a manager.[17]

Wealth accumulates in the economy in the following manner. At the beginning of each period, total firm earnings from the previous period are plowed back into the firm[18] and are distributed equally to firm divisions; w units of perishable capital to each (w is constant across firms and throughout time, and is normalized to less than half a unit). Then divisions from different firms are randomly matched in pairs across firm boundaries to consider identical joint ventures that require as input the w units of capital under the control of each of the matched firm divisions.

Each pair of managers—heading their respective paired divisions—then negotiate how to divide the return form the potential joint venture (normalized to one unit of capital) using an Ultimatum Game procedure. With probability 0.5, one manager assumes the role of the offerer, offering to give x units of wealth to the responding manager, leaving $1 - x$ for the division under the offerer's control. If the responding manager accepts the offer, a contract is signed, and the joint venture is adopted, so that at the end of the period each division receives its contracted allocation. If, on the other hand, the responding manager rejects the offer, then the joint venture is abandoned,[19] and the input capital under each manager's control perishes. At the end of the period, which is also the beginning of the next, the returns from all the firm divisions are pooled; the firm reorganizes into new divisions whose number equals total firm earnings divided by w, the amount allocated to each new division; and the process repeats.

A division manager, having risen through the ranks of the firm, would have assimilated and internalized its *corporate culture*, which, in our context, means having adopted a preference order—common to all managers in his firm—as modus operandi when acting on behalf of his firm (see footnote 13 above). It is assumed that when

[17] To simplify the exposition, we posit the multidivisional structure of firms where business level strategies and all operating decisions are made at the divisional level, and the relationships with the corporate headquarters are limited to corporate planning, budgeting, and the provision of common services (Grant, 1998). The story of the emergence of the divisionalized firm immediately after World War I is told by Alfred Chandler (1929). See also Milgrom and Roberts (1992, p. 540).

[18] We employ the Modigliani-Miller proposition about dividend policy irrelevance. That capital can be transferred from one period to the next through production only is assumed for counting capital in each period more conveniently.

[19] In the U.S. auto parts industry, 126 companies entered into joint ventures with Japanese parts suppliers in order to supply the U.S. plants of Honda, Nissan, and Toyota. Conflicting objectives, divergent management styles, and disputes over quality and labor practices resulted in wide spread failure (Grant,1998; and Business Week, July 24, 1989).

manager i is negotiating with a matched manager j, the former is guided by a preference order over pairs $(M_i, M_j) \in \mathbb{R}^2_+$, where M_i is the allocation of wealth to his own division, and M_j is the allocation to the matched division.[20] It is further assumed that the preference order adopted by all the managers of a firm can be represented by a vNM expected utility over lotteries of such pairs with a continuous Bernoulli utility function $u_i(M_i, M_j)$. Thus, the firms are partitioned into preference classes, or types, indexed by a set I; all firms of type $i \in \mathsf{I}$ have all their division managers operate with the same Bernoulli utility $u_i(M_i, M_j)$.

All utility functions are normalized to have $u_i(0, 0) = 0$, and $u_i(1, 0) = 1$. We will assume that $u_i(x, 1-x)$ increases in x. This means that managers are not altruistic; they always prefer that matched divisions transfer wealth to their own divisions (see below). This also implies that if the graph of $u_i(x, 1-x)$ intersects the x axis, it does so only once – from below. Formally, for any u_i there is a corresponding $x_i \in [0, 1]$ such that $\{x\colon u_i(x, 1-x) < 0\} = [0, x_i)$. This assumption implies a very simple strategy for the manager who responds to an offer that allocates to him x units of wealth. He rejects all offers x smaller than x_i, and accepts any offer equal to or larger than x_i, which will be called the *rejection threshold*.

We will focus on three broad classes of preference characteristics. One is characterized by $u(M_i, M_j) < u(M_i, M_j')$ for all M_i whenever $M_j > M_j'$. An increase in the wealth of the contending manager—holding one's own constant—decreases own utility, which will be interpreted as *envy*. This type of preference implies a positive rejection threshold x_i—because $u(0, 1) < u(0, 0) = 0$ and u is continuous—meaning that the responder rejects positive offers smaller than x_i, preferring that both he and his contender get nothing to a split that gives him a positive amount, but also "too much" to his contender. In fact, it will be convenient to use x_i as a measure of envy, and we will say, as a matter of speech, that preference i is more envious than preference j if $x_i > x_j$.

The second preference type is characterized by $u(M_i, M_j) = u(M_i, M_j')$ for all M_i and all M_j, M_j'. These are the *selfish*, who do not care about how much the contender will have.

The third preferences type is the *benevolent* which is characterized by $u(M_i, M_j) > u(M_i, M_j')$ for all M_i whenever $M_j > M_j'$. The benevolent mildly rejoices in the

[20] This is a reduced form of the preference. When n parties interact, the objects of choice are the n-tuples of monetary payoffs.

good fortunes of his partner, but not as much as he does in his own [$u(x,\ 1-x)$ still increase in x]. By definition, both the benevolent and the selfish set their rejection thresholds to zero. The selfish type is a special case of the benevolent, therefore it will be convenient to designate the set of both types as *non-envious*. Agents in our model could also be allowed to exhibit different characteristics at different wealth levels—envy at low and benevolence at higher levels—without changing our results. But, for simplicity, we will keep the aforementioned classification.

Our analysis aims at demonstrating the existence of ecologies of preferences that reflect economic behavior that is observed in real bargaining situations. To that end, we confine attention to a limited set of preferences that, as modelers, we believe are reasonably good approximations of real preferences. This is the reason, for example, that we a priori exclude non-expected utilities; not because those preferences cannot comprise plausible preference ecologies.

We also exclude preferences that exhibit severe forms of advantageous inequality aversion which have been used by Bolton and Ockenfels (1997) and by Fehr and Schmidt (1999) to explain experimental results of Ultimatum and other games. Operating with such a preference, an agent who is to receive a large share of wealth relative to another agent, prefers to grant part of it to the latter. This is a form of true altruism, to be distinguished from *reciprocal* altruism which is generated by selfish preferences. The reason that we do not include true altruistic preferences of this kind (recall that we do allow benevolence, which is a milder form of advantageous inequality aversion) is that while they may underlie laboratory findings of small monetary stake experiments, being sensitive to framing and to written instructions (Bolton, Katok, and Zwick, 1998) and possibly also to the impact of experimenter observation (Hoffman, McCabe, Shachat, and Smith, 1994), they do not seem to be descriptive of real-world, large scale economic interactions. For example, consumers do not partially refund consumer surplus to competitive producers (think of life-saving antibiotics); university administrators do not ask donors for permission to share windfall donations[21] with other

[21] Sizable donations by wealthy individuals are sometimes cited as manifestation of true altruism; Bill Gates being a favorite example. But the same person is also identified with Microsoft about which US District Judge Thomas P. Jackson ruled in April 2000 that it violated federal antitrust law through a series of acts meant to crush competition in protection of its monopoly in operating system software for personal computers (Boston Globe, May 25, 2000). This, and other examples, demonstrate that people can behave markedly differently inside and outside of business contexts. It is the former context that we are interested in. Also, sizable donations are likely to be the (legitimate) purchase of the goods, prestige and esteem, which are hardly achievable by deferring to a bargaining

universities; and firms winning large contracts do not offer part of the surplus they won (evidenced by increased share prices) to their competitors who lost those contracts.[22] Consistent with this is Camerer and Hogarth's (1999) statement that "when incentives are low, subjects say they would be more risk-preferring and generous than they actually are when incentives are increased."[23]

On the other hand, we include *risk aversion* (in Section 5) as a fundamental preference characteristic, because of its central role in explaining economic phenomena in general, and behavior in bargaining situations with incomplete information, in particular (see Murnighan, Roth, and Schoumaker, 1988).

For ease of notation, if the non-envious types are represented in the population of managers, then they will be indexed by $\{-L, -L+1, ..., 0\}$ with $0 \leq L$. On the other hand, the envious—those with positive rejection thresholds—will be labled by $\{1, ..., I\}$ and will be ordered by increasing rejection thresholds. Thus, $0 = x_{-L} = x_{-L+1} = ... = x_0 < x_1 \leq ... \leq x_I$. By convention, we will denote $x_{I+1} := 1$, and $x_0 := 0$ even when no zero rejection thresholds are represented in the population.

The players, proposing and responding managers alike, do not know the preference type of the matched players. They know only the distribution of such preferences in the population. We are then looking for the perfect Bayesian equilibrium of the ultimatum game. Actually, the informational requirement necessary for this equilibrium is much less demanding. It is sufficient to require that the offerer know only the distribution of rejection thresholds in the population; only those bear upon the optimal offers. By contrast, the equilibrium response, as already discussed, does not depend

opponent.

[22] Recently, a small sample experiment was conducted by Eric Allman, creator of Sendmail, a program that powers 75 percent of all e-mail servers on the Internet. It was not meant to be one, but it could be interpreted as a large monetary stake dictator game experiment. From the Boston Globe (April 24, 2000): "Until recently, Allman never made a dime from Sendmail. But after years of giving free support to Sendmail users, many of whom were Fortune 500 companies, Allman decided to scrape enough money together to give himself a salary and hire a couple of engineers. Hat in hand, Allman asked half a dozen large companies to donate $50,000 each. Nearly all refused." To our query, the reporter, Alex Pham, emailed a reply, "Five companies refused outright and one equivocated. In effect, no commitments." Eric Allman estimated to us the value these six firms received from him over the years in the millions of dollars.

A hypothetical argument that framing is responsible for the dissolution of altruism in the three examples in the text, in Sendmail's case, as well as in other extra-laboratory conditions, should be able to explain why altruism can survive the more conflictive aura that usually pervades a real-world bargaining situation.

[23] As Rideley (1998, p.145) notes, "The more other people practice altruism, the better for us, but the more we and our kin pursue self-interest, the better for us. [ ] Also, the more we posture in favor of altruism, the better for us."

on the population distribution. It depends only on the responder's own preference order.

It will prove useful to denote the offerer's utility of type i from offering x (out of the unit surplus), conditioned on the responder's agreement to take x, by $O_i(x) := u_i(1-x, x)$, and to denote by $\mathsf{R}_i(x) := u_i(x, 1-x)$, the type i responder's utility from responding affirmatively to an offer x.[24] Let p^t denote the population distribution of preference types at time t, with components p_i^t denoting the fraction of type $i \in \mathsf{I}$. To emphasize dependence of certain quantities on the population distribution p^t and to distinguish those from quantities that do not so depend, the former will be superscribed by t in the sequel. Define the function F^t: $[0, 1] \to [0, 1]$ by $F^t(x) := \sum_{i=-L}^{k} p_i^t$ if $x \in [x_k, x_{k+1})$, $(k = 0, ..., I)$. When an offerer of type i offers $x \in [x_k, x_{k+1})$, $(k = 0, ..., I)$, his offer is accepted by all types $j \in \{-L, ..., 0, ..., k\}$ and is rejected by all the rest. Therefore, the probability that an offer x is accepted at time t is $F^t(x)$. The expected utility of type i from offering x at time t is then $F^t(x)O_i(x)$.

The tradeoff in choosing the optimal offer is that increasing the offer x naturally decreases the offerer's share and with it decreases $O_i(x)$. Simultaneously, though, an increased offer x also increases $F^t(x)$, the offerer's chances to solicit a positive response at time t. Note, however, that $F^t(x)$ stays level between one rejection threshold and the next, jumping upwards at rejection thresholds only. Therefore, the optimal offer must be at one of the rejection thresholds. Denote then the expected utility of a type i manager from offering an amount equal to a rejection threshold x_j by $U_i^t(j) := F^t(x_j)O_i(x_j)$; $i \in \{-L, ..., I\}$, $j \in \{0, ..., I\}$. To maximize his expected utility, type i, operating at time t, selects the integer $m^t(i) := \min\{\operatorname{argmax}_{j \in \{0, ..., I\}} U_i^t(j)\}$, and optimally offers $x_{m^t(i)}$ (the "min" breaks possible ties between different optimal offers). In response, types $-L, ..., m^t(i)$ agree to take that offer, because their respective rejection thresholds are smaller than or equal to the offered $x_{m^t(i)}$, while the rest reject it.

Thus, each type i is assigned a pair of strategies; an offer $x_{m^t(i)}$ and a rejection threshold x_i. Together, all these pairs comprise the unique perfect Bayesian equilibrium of the incomplete-information surplus-sharing ultimatum game played at time t.

The rejection threshold depends only on the type's preference. The equilibrium offer, on the other hand, depends both on the type's preference *and* on his belief

[24] Recall that we assume that $\mathsf{R}_i(x)$ increases in x, and, therefore, $O_i(x)$ decreases in x.

about the population distribution. Therefore, as the population distribution changes, so do the beliefs of the different types, who, in response, tend to change their offers—eg, the larger grow the proportions of those with high rejection thresholds, the more generous become the offers—which, in turn, would tend to change the allocation of wealth among the bargaining types, which feeds back to the change of the population distribution.

Consider a particular manager of type i operating at the beginning of period t. With probability 0.5 he assumes an offerer's role in the surplus-sharing ultimatum game. As already mentioned, when this type i optimally offers $x_{m^t(i)}$, an agreement response comes only from types $-L$, ..., $m^t(i)$. So, agreement ensues with probability $\sum_{k=-L}^{m^t(j)} p_k^t$. Type i's expected dollar gain as offerer is then $EDO_i^t := (1 - x_{m^t(i)}) \sum_{k=-L}^{m^t(j)} p_k^t$.

With probability 0.5 the type i manager assumes the role of a responder. With probability p_k^t, he is then matched with an offerer of type k who offers $x_{m^t(k)}$, which the responder accepts iff this offer exceeds his own rejection threshold x_i, ie, iff $i \leq m^t(k)$. Type i's expected dollar gain as responder is then $EDR_i^t := \sum_{k=-L}^{I} p_k^t x_{m^t(k)} \mathbf{1}_{i \leq m^t(k)}$, (where $\mathbf{1}$ is the indicator function). The inclusive expected dollar gain of a type i manager in period t in then $ED_i^t := 0.5EDO_i^t + 0.5EDR_i^t$.

The fraction of total wealth under control of the type i preference evolves as follows. At the beginning of period t, total wealth in the economy is N_t dollars, a very large number, out of which $p_i^t N_t$ dollars are under the control of type i managers, who number $p_i^t N_t / w$ (by assumption, recall, w dollars are allocated to each manager at the beginning of each period). Indeed, both the fraction of type i managers and the fraction of wealth under their control is then p_i^t. At the end of period t, each type i manager, having played the game described above, ends up with ED_i^t dollars in expectation. Therefore, by the Law of Large Numbers, the number of dollars plowed back at the end of period t by all the type i managers into their respective firms is $(p_i^t N_t / w) ED_i^t$. Hence, the fraction of total wealth controlled by the type i preference at the beginning of period $t + 1$ is

$$p_i^{t+1} = \frac{p_i^t ED_i^t}{\sum_{k=-L}^{I} p_k^t ED_k^t}, \quad i \in \mathrm{I}.$$

Denote by $\langle ED^t \rangle$ the denominator in the right hand side of the last equation, which averages out the expected dollar gain across all types, when the distribution vector is p^t. It is easy to see that $p_i^{t+1} \gtreqless p_i^t$ iff $ED_i^t \gtreqless \langle ED^t \rangle$, respectively. If, at a given distribution vector, the equality holds for *all* types, then that distribution vector is *stationary*; it dose not change with time.

We will say that a *population distribution is efficient* if all equilibrium offers made in that population are met by equilibrium assents. Otherwise, if some offers are rejected, we will call the distribution *inefficient*. In the sequel, for ease of notation, we will occasionally drop the time superscript, writing, for example, p_1 instead of p_1^t for the fraction of type 1.

Proposition 1 *A population distribution is efficient, if and only if all types offer the highest rejection threshold. An efficient distribution is also stationary.*

Proof of Proposition 1. If every type offers the highest rejection threshold, then all types agree to accept such offers, and the distribution is efficient. On the other hand, if there is a type that offers less than the highest rejection threshold, then at least the type that uses the highest rejection threshold as its equilibrium response strategy, rejects that offer, which renders the distribution inefficient. Clearly, if every type offers the highest rejection threshold, and, therefore, every type agrees to accept it, then at any one date, all types get the same dollar amount in expectation, namely one half. Therefore, the distribution is also stationary. □

3 Polymorphic Populations

In this section, we investigate the dynamics of polymorphic populations without imposing restrictions on the utilities other than those of the previous section. At this level of generality, we can characterize the dynamics in some specific neighborhoods of the n-dimensional unit simplex, where n is the number of types represented in the population.

The next proposition states that population distributions with a sufficiently large proportion of the most envious type are efficient and Lyapunov[25] stable, where all types prefer to appease the numerous, most envious type by always offering his rejection threshold. The proposition is depicted in Figure 1.

Proposition 2 Let $\{u_i\}_{i \in \mathrm{I}}$ *be the preferences represented in the population, where* $\mathrm{I} = \{i_0, ..., I\}$ *with* $1 \leq I$, *and where* $i_0 = -L \leq 0$ *if non-envious* (benevolent or selfish) *are represented, and* $i_0 = 1$, *if they are not. Let the preferences satisfy* $0 < O_i(x_I)$ *for all* i *in* I; let $\underline{Q} :=$ $\min\{O_i(x_I)/O_i(x_{i_0})\}_{i \in \mathrm{I}}$; *and let* $S(\underline{Q}) := \{(p_{i_0}, ..., p_I) \in \Delta^{\#\mathrm{I}}: p_I \in [1 - \underline{Q}, 1]\}$. *Then every distribution in* $S(\underline{Q})$ *is efficient and stationary, and every distribution in the interior of* $S(\underline{Q})$ *is also Lyapunov stable. Under these distributions, all types offer the highest rejection threshold* x_I, *and all types agree to accept it.*

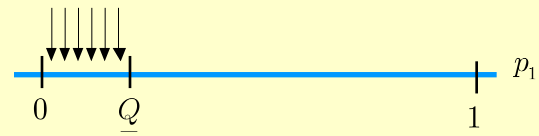


Figure 1. Proposition 2 depicted for dimorphic populations. The proportion p_1 is of the less envious. Perpendicular arrows signify weakly stable distributions.

Proof: In the Appendix.

Next, Proposition 3 states that if the least envious are not non-envious (they employ a positive rejection threshold), then when the proportion of those are sufficiently large, they take over the population. This happens as follows. When the least envious are represented in the population in a sufficiently large proportion, (larger than $\overline{Q}_1$ which is defined in the proposition), all types move to take advantage of this least envious type by offering his rejection threshold, which is the smallest used by any of the types. Therefore, as offerers, all types get the same response—agreement from the least envious and rejection from all the rest—and, therefore, the same expected dollar gain. As a responder, however, the least envious

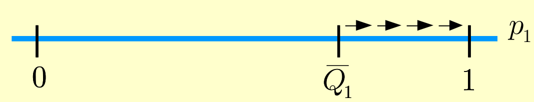


Figure 2. Proposition 3 depicted for dimorphic populations. The proportion p_1 is of the less envious. The distribution $p_1 = 1$ is efficient and asymptotically stable.

[25] No local push away from the distribution.

is offered (for sure) his positive rejection threshold which he agrees to take, while all the rest reject it and get zero for sure. The inclusive dollar gain of the least envious is therefore larger than that of the other types. So this type flourishes. This means that the least envious monomorphic population is asymptotically[26] stable and efficient. These dynamics are depicted in Figure 2.

Proposition 3 *Let only envious types,* $\{u_i\}_{i\in \mathsf{I}}$, *be represented in the population, where* $\mathsf{I} = \{1, ..., I\}$ *with* $2 \leq I$,[27] *and let* $\overline{Q}_1 := \max\{O_i(x_2)/O_i(x_1)\}_{i\in \mathsf{I}}$.[28] *If* $\overline{Q}_1 \leq 1$, *then the monomorphic population distribution comprising only the type* 1 *managers* $(p_1 = 1)$, *who offer and agree to accept the lowest rejection threshold* x_1, *is stationary and efficient. Moreover, if* $\overline{Q}_1 < 1$, *then that monomorphic distribution is also asymptotically stable, and the set* $S(\overline{Q}_1) := \{(p_1, ..., p_I) \in \Delta^I\colon \overline{Q}_1 \leq p_1\}$, *which contains the monomorphic distribution, is contained in the basin of attraction of that distribution.*

Proof: In the Appendix.

Proposition 3 notwithstanding, a monomorphic distribution is not always viable. Suppose that $p_1 = 1$, $x_1 > 0$, but that $O_1(x_1) < 0$. This is a rather severe case of envy, in which the whole monomorphic population prefers to offer zero in equilibrium, and the whole population rejects this offer, becoming extinct in just one period. On the other hand, $O_1(x_1) < 0$ could exist in a polymorphic population. A necessary condition for the latter is that other types exist in the population who find it optimal to offer x_1 or more.

Note that if the proportion of the least envious is smaller than $\overline{Q}_1$, then they do not necessarily take over the population. Proposition 3 is silent about this, and the matter is taken up in the next section, where it is shown that under some plausible conditions the dynamics is trapped in the interior of the unit simplex.

Proposition 4, which is stated next, is similar to Proposition 3, except that the least envious *are non*-envious, whose rejection threshold is zero (as opposed to the least envious of Proposition 3, who use a positive rejection threshold). The intuition behind

[26] Exhibiting a local pull towards the distribution.

[27] All types are envious who reject zero offers.

[28] When the denominator is zero, define the ratio to be either plus or minus infinity depending on the sign of the numerator. When both denominator and numerator are zero, define the ratio to be 1.

Proposition 4 is also similar. When the non-envious are represented in the population in a sufficiently large proportion (larger than $\overline{Q}_0$ which is defined in the proposition), then all types move to take advantage of the non-envious by offering zero. Therefore, as offerers, all types get the same response and the same expected dollar gain. As responders, although the non-envious types agree to take the offer, it is zero dollars that they take, which yields them no advantage over the other types who also get zero by rejecting. The inclusive dollar gain is therefore the same for all types and the population distribution is Lyapunov stationary and *in*efficient. This dynamics is depicted in Figure 3 (compare to Figure 2).

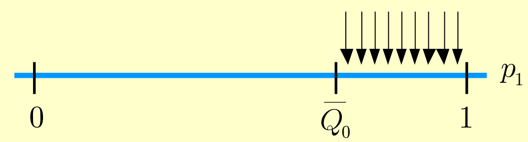


Figure 3. Proposition 4 depicted for dimorphic populations. The proportion p_1 is of the *non*-envious. Perpendicular arrows signify weakly stable distributions.

It is noteworthy that the non-envious act 'rationally' in these stationary states; they offer zero[29] and accept zero. But this behavior—acceding to *zero* offers—does not impart to them any advantage over the envious 'hotheads' who also offer zero, but reject such offers. Therefore, the non-envious 'coolheads' cannot take the population over from the envious 'hotheads.' By contrast, Proposition 3 indicates that it takes some positive envy measure for the least envious 'tepidheads' to be able to take over the population. In a sense, the sheer number of the least envious type, and the fact that all of them reject offers up to a positive threshold, act like a collusion to force everyone to offer a positive offer, from which only the least envious benefit.

Although Propositions 3 and 4 seem to represent two distinct situations, the transition between them is smooth. To see that, note that as their envy measure (rejection threshold) is increased from zero in Proposition 4 to a very small level in Proposition 3, the least envious proceed to take over the population but at a *very slow rate.* Because being of the only type who are ready to take the *very small offer* gives them only a very small expected dollar advantage over the rest. This take-over rate increases as the envy measure of the least envious increases, because they are offered and they agree to take increasingly more dollars.

[29] The non-envious offer zero, because they too take advantage of their own type. When the proportion of the non-envious is relatively small and, therefore, that of the envious is high, the non-envious are likely to make positive offers.

Proposition 4 *Let* $\{u_i\}_{i\in \mathsf{I}}$ *be the preferences represented in the population, which includes both non-envious and envious, ie,* $\mathsf{I} = \{-L, ..., I\}$ *with* $0 \leq L$ *and* $1 \leq I$*. Let* $\overline{Q}_0 := \max\{O_i(x_1)\}_{i\in \mathsf{I}}$*, where the positive* x_1 *is the rejection threshold of the least envious. Then* $\overline{Q}_0 \in (0, 1)$*, and every population distribution in the set* $S(\overline{Q}_0) := \{(p_1, ..., p_I) \in \Delta^{\# \mathsf{I}}: \overline{Q}_0 \leq \sum_{j=-L}^{0} p_j\}$ *is stationary and inefficient. Under these distributions, all types offer zero, and only the non-envious types agree to accept it. Every distribution in the interior of* $S(\overline{Q}_0)$ *is also Lyapunov stable.*

Proof: In the Appendix.

4 Dimorphic Populations

Proposition 4 above demonstrates stable, stationary, inefficient population distributions in which the non-envious types are represented in high proportions, which emboldens everyone to offer zero. But this, in general, is not consistent with observed behavior. Therefore, we now turn to demonstrate stable, stationary, *inefficient* population distributions in which positive offers are rejected with positive probability, and which do not necessarily include non-envious types. This analysis will also facilitate the understanding of the dynamics in situations not covered by Propositions 1 to 4. For tractability, we will focus on dimorphic populations with only two envious types; one characterized by a Bernoulli utility u_1 entailing a rejection threshold x_1, and the other with u_2 and x_2, with $0 < x_1 < x_2$. (Recall, p_1 is the population proportion of type 1, the less envious, in a generic period t.)

Lemma 1 *Let* $\{u_1, u_2\}$ *be the two utility types represented in the population with* $O_i(x) := u_i(x, 1-x)$ *decreasing in* x *and with rejection thresholds* x_i *that solve* $O_i(1 - x) = 0$ $(i = 1, 2,)$*, and which satisfy* $0 < x_1 < x_2 < 1$ (both types are envious). *Denote*

$$q_i := \begin{cases} \dfrac{O_i(x_2)}{O_i(x_1)} & \text{if } O_i(x_1) \neq 0 \\ -\infty & \text{if } O_i(x_1) = 0. \end{cases}$$

The optimal offers of type i are characterized as follows. (i) $q_i < 0$ iff $O_i(x_2) < 0 \leq O_i(x_1)$. *Type i then optimally offers x_1 in any population distribution* $(\forall p_1 \in [0, 1])$. (ii) $0 \leq q_i < 1$ *iff* $0 \leq O_i(x_2) < O_i(x_1)$, *whereupon in a population with $p_1 \in [0, q_i)$, type i offers x_2, and in a population with $p_1 \in [q_i, 1]$, type i offers x_1.* (iii) $1 < q_i$ iff $O_i(x_2) < O_i(x_1) < 0$. *Type i then offers zero dollars in any population.*

Proof: In the Appendix.

According to the lemma, when $q_i \in (0, 1)$, it demarcates the population proportion of the less envious at which type i switches his optimal offer $(i = 1, 2,)$. For p_1 less than q_i, where the proportion of the less envious is relatively small, type i worries about being matched with the more envious type, who can only be appeased by the larger offer x_2. Therefore, type i offers the sure-to-be-accepted x_2 there. For p_1 larger than q_i, where the proportion of the less envious is relatively large, type i worries less about being matched with the more envious type. Type i then takes his chances and offers the smaller, risky offer x_1 in the hope of being matched with the less envious, who agrees to take it. Therefore q_i will be called type i's *offer-switch*. Note, however, that each type's offer-switch is determined by the preferences of both types.

Proposition 5 is the main result in this section. It classifies the dynamics of a dimorphic population distribution into five classes by the envy parameters of the two types. In particular, it gives the conditions under which there is an *asymptotically stable, stationary, inefficient, dimorphic (**ASSID**) population distribution* with both types present, and where, resembling real life and experimental behavior, different size offers are made, and tough offers are rejected with positive probability.

Proposition 5 *Let the conditions of Lemma 1 hold. Denote $q^{\star} := 1 - (x_2 - x_1)$, and $q^{\star\star} := 1 - x_2$. There are five possible configurations of q_1 and q_2, which are classified as follows. If $0 < x_1 < x_2 < 1/2$, then either* (1) $0 \leq q_2 < q_1 \leq 1$ or (2) $0 \leq q_1 \leq q_2 \leq 1$. If $1/2 < x_1 < x_2 < 1$, *then* (3) $1 < q_1$ and $1 < q_2$. *If $0 < x_1 < 1 - x_2 < 1/2 < x_2 < 1 - x_1 < 1$, then* (4) $q_2 < 0 \leq q_1 < 1$. *Finally, if $0 < 1 - x_2 < x_1 \leq 1/2 \leq 1 - x_1 < x_2 < 1$, then* (5) $q_1 < 0 < 1 < q_2$. *Each of the five configurations determines the dynamics of the population distribution as follows.*

(1) *In this configuration,* $p_1^t \in (q_2, \min(q^\star, q_1))$ *implies* $p_1^{t+1} > p_1^t$, *and* $p_1^t \in (\max(q^\star, q_2), q_1)$ *implies* $p_1^{t+1} < p_1^t$.[30] *When* $q^\star \in (q_2, q_1)$, *then* $p_1^t = q^\star$ *implies* $p_1^{t+1} = q^\star$ *for all* t, *meaning that the distribution* $p_1 = q^\star$ *is an ASSID population distribution with the interval* (q_1, q_2) *serving as its basin of attraction. No other distribution is stationary and inefficient. All the distributions with* $p_1 \in [0, q_2]$ *are stationary and efficient. All the distributions with* $p_1 \in [q_1, 1]$ *serve as the basin of attraction for the monomorphic distribution with* $p_1 = 1$, *which is asymptotically stable, stationary, and efficient. In the ASSID distribution, type* 1 *agents, the less envious, offer the conciliatory offer* x_2, *but agree to take even the tough offer* x_1. *In contrast, type* 2 *agents, the more envious, offer the tough offer* x_1, *but reject it as responders, agreeing to take only the conciliatory offer. On average, though, both types get the same dollar amounts.*

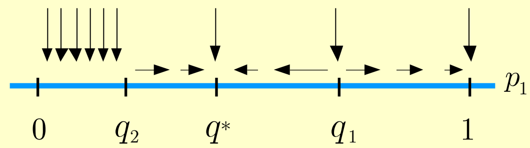


Figure 4. Configuration 1 depicted for the case where q^* falls inside (q_2, q_1). The distribution with proportion $p_1 = q^*$ is then ASSID.

(2) *In this configuration,* $p_1^t \in (q_1, \min(q^{\star\star}, q_2))$ *implies* $p_1^{t+1} < p_1^t$, *and* $p_1^t \in (\max(q^{\star\star}, q_1), q_2)$ *implies* $p_1^{t+1} > p_1^t$. *When* $q^{\star\star} \in (q_1, q_2)$, *then* $p_1^t = q^{\star\star}$ *implies* $p_1^{t+1} = q^{\star\star}$ *for all* t, *meaning that the distribution* $p_1 = q^{\star\star}$ *is an unstable, stationary distribution. All the distributions with* $p_1 \in [0, q_1]$ *are stationary and efficient. All the distributions with* $p_1 \in [q_2, 1]$ *serve as the basin of attraction for the monomorphic distribution with* $p_1 = 1$, *which is asymptotically stable, stationary, and efficient.*

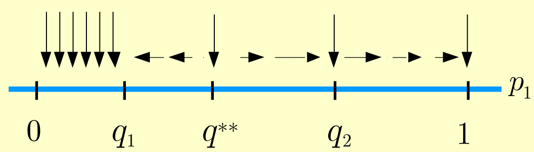


Figure 5. Configuration 2 depicted for the case where q^{**} falls inside (q_1, q_2).

(3) *In this configuration, both types offer zero in order to get sure rejections. The whole population dies out in just one period.*

(4) *To get the dynamics in this configuration, replace the string "*q_2*" in the description of Configuration* 1 *above by the string "zero".*

(5) *In this configuration, the whole unit interval* $[0, 1]$ *serves as the basin of attraction for the monomorphic distribution with* $p_1 = 1$, *which is asymptotically*

[30] When the right side of an interval is equal to or less than the left side, then the empty interval is meant.

stable, stationary, and efficient.

If $x_1 = 0$, *then either* $0 < x_2 \leq {}^1\!/_2$, *whereupon either Configuration* 1 *or* 2 *holds*; *or* ${}^1\!/_2 < x_2 < 1$, *in which case Configuration 4 holds. All the results pertaining to these configurations still hold, except that—according to Proposition 4—all the population distributions* p_1 *in the interval* $(\max(q_1,\ q_2),\ 1]$ *are stationary, stable, and inefficient.*

Proof: In the Appendix.

Figures 4 and 5 depict typical dynamics under Configuration 1 and 2, respectively, using a vector field along the unit interval. For a tail of a vector at p_1^t, its tip is at p_1^{t+1}. Vertical arrows signify zero vectors, and therefore they represent stationary distributions. Whether those distributions are also stable depends on the direction of the arrows in the immediate neighborhood of the stationary point; outward – unstable, inward – asymptotically stable, zero vectors in the neighborhood – Lyapunov stable.

When the ASSID distribution exists, the population proportion of type 1, the less envious, is $p_1 = q^\star = 1 - (x_2 - x_1)$, which is determined solely by the respective rejection thresholds of the two types, and not by any other aspects of the utility functions that generate them. Also, the proportion of each type in the ASSID distribution increases directly with the extent to which own rejection threshold, or degree of envy, exceeds that of the other type.

Proposition 5 also predicts that in an ASSID distribution, the same agents who tend to make tough offers will also tend to reject such offers, and those who make generous offers will also tend to accede to tough offers. On average, though, because the distribution is stationary, there is no monetary advantage to being either a tough or an accommodating type. As noted in our Introduction, these two predictions seem to be consistent with recent ultimatum game experimental results by Eckel and Grossman (2000) who find that the tough and the accommodating types divide along gender lines.

As discussed above, Propositions 3 and 4 indicate that it necessarily takes some positive envy measure for the least envious to be able to take over the population. Proposition 5 clarifies when even that positive envy measure does not help. If the initial population distribution (its p_1) is within the basin of attraction of an ASSID distribution, then the least envious cannot take over the population. Instead, the population is trapped at the ASSID distribution.

5 The Role of Risk-Aversion

Of special interest is the ASSID distribution at $p_1 = q^\star$ under Configurations 1 and 4, where the two types coexist; and where different size offers are made, and tough offers are rejected with positive probability. Note, however, that we have not yet explicitly demonstrated the existence of an ASSID population distribution. To do that; to facilitate further analysis of these ecologies; and, in particular, to examine the interaction between envy and risk aversion that, as will be shown, gives rise to these ecologies, we will consider a class of utilities that allow a degree of separation between envy and risk-aversion characteristics.

To that end, consider utilities of the form $u_i(M_i, M_j) := f_i(g_i(M_i, M_j))$, where $g_i(M_i, M_j) := M_i - \delta_i M_j$, $\delta_i \in (-1, \infty)$,[31] with f an increasing function. To maintain our calibration of the utility, we set $f_i(0) = 0$ and $f_i(1) = 1$. For this functional form of the utility, the rejection threshold and the measure of envy is $x_i = \max\big(\delta_i/(1+\delta_i), 0\big)$ so that δ_i correlates well with the envy measure. Benevolence is then represented by $\delta_i \in (-1, 0)$, selfishness by $\delta_i = 0$, and envy by $\delta_i \in (0, \infty)$. Note that δ_i is positive iff x_i is, in which case $x_i = \delta_i/(1+\delta_i)$. On these occasions, we will use x_i instead of δ_i to parametrize envy in the utility function.

Risk-aversion is modeled as usual by letting the Bernoulli utility u_i be concave on $\mathbb{R}^2_+$.[32] The assumed linearity of the function g_i then makes the concavity of u_i equivalent to the concavity of f_i. Similarly, risk-neutrality is modeled as usual by a linear u_i, which, in turn, is equivalent to the linearity of f_i on $\mathbb{R}$. As is shown next, this characterization of attitudes towards risk of the envious or the benevolent by the

[31] Individuals sporting $\delta_i \in (-\infty, -1]$ give away all their wealth whenever possible. The Talmudic *Wisdom of the Sages* maintains that extreme altruism, "yours is yours, and mine is also yours," is the ideal virtue. Indeed, if everyone is somehow convinced to adopt $\delta_i \in (-\infty, -1]$ and therefore to practice the extreme altruistic virtue, it becomes a stationary state. Nevertheless, it is easily invaded by mere non-envious with $\delta_i \in (-1, 0]$, whereupon the extreme altruists are driven into extinction. Therefore, $\delta_i \in (-\infty, -1]$ is not economically interesting.

[32] This means that a sure convex combination of two pairs $(M_i, M_j) \in \mathbb{R}^2_+$ is preferred by agent i to a lottery having the same two pairs as prizes with probabilities that are equal to the weights in the convex combination.

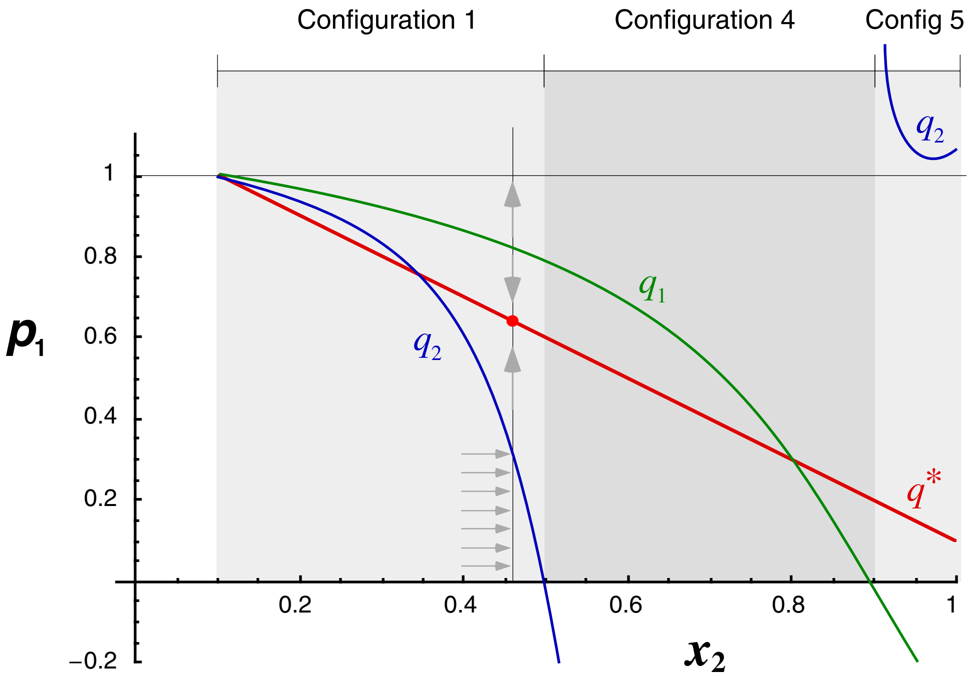


Figure 6. Different configurations for different values of x_2, holding everything else constant. The vector field portraying the dynamics inside the region where Configuration 1 holds, is also shown (same as Figure 4). The dot between the two arrow heads pointing towards each other represents an ASSID distribution. Perpendicular arrows signify weakly stable distributions.

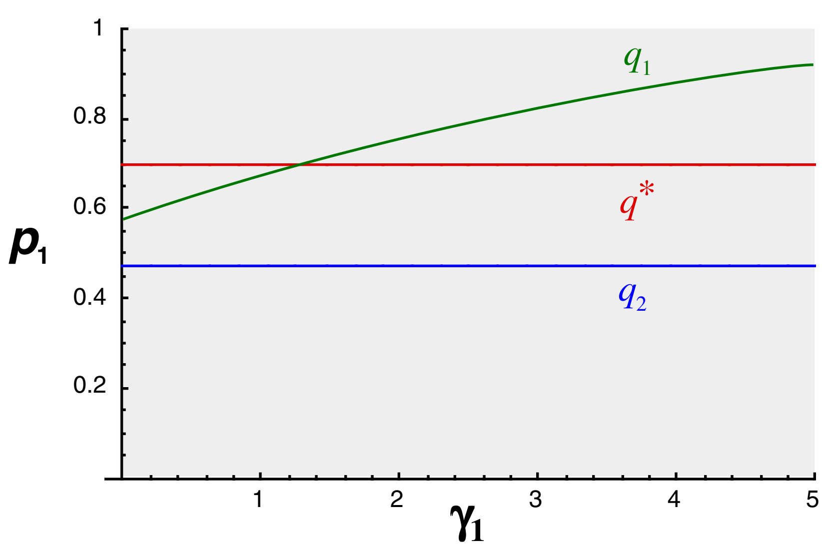


Figure 7. Effect of increase in the risk-parameter of the less envious on Configuration 1.

curvature of the function f_i turns out to be consistent with expected behavior in the Ultimatum Game. In particular, the next proposition is a comparative statics result that demonstrates that for Configurations 1 and 4, which are the ones that can generate an ASSID distribution, as a preference order changes from exhibiting risk-neutrality to risk-aversion, maintaining the same measures of envy of both types and the same population distribution, the optimal offer (weakly) increases. The proposition further shows that a necessary condition for an ASSID distribution to exist is that the less envious type be also risk-averse.

Recall that $O_i(x)$ is the utility of type i when his offer of x is accepted. It is straightforward to see that for the current specialization of the Bernoulli utility, $O_i(x) = f_i\big((1-x_i-x)/(1-x_i)\big)$.

Proposition 6 *Let the Bernoulli utilities of the two types be characterized by the functions* f_1, f_2 *with positive envy parameters* x_1, x_2 *with joint values that correspond to Configurations* 1 *or* 4. *Consider two alternative functions for type* i $(= 1, 2)$, *one linear and the other concave, denoted* f_i^{neutral} *and* f_i^{averse}, *respectively, and let* $\xi(p_1; O_i)$ *denote the optimal offer of type* i *in a population distribution* p_1. *Then*

(a) *For* $i = 1, 2$: $q_i(x_1, x_2; O_i^{\text{neutral}}) < q_i(x_1, x_2; O_i^{\text{averse}})$ *implying, that* $\xi(p_1; O_i^{\text{neutral}}) \leq \xi(p_1; O_i^{\text{averse}})$ *for every* $p_1 \in [0, 1]$.

(b) *If type* 1 *is also risk-neutral, then an ASSID distribution cannot exist. Instead, the interval* $((q_2)^+, 1]$ *becomes the basin of attraction for the monomorphic distribution at* $p_1 = 1$.

Proof: In the Appendix.

Figure 6 about here

Figure 6 is typical.[33] It demonstrates the existence of ecologies that exhibit an ASSID distribution, as well as others which do not. To draw it, we further specialized to a negative exponential Bernoulli utility by taking $f_i(y) := (1 - \exp(-\gamma_i y))/(1 - \exp(-\gamma_i))$, and we selected $x_1 = 0.1$, and risk parameters $\gamma_1 = 3$, $\gamma_2 = 2$. The graphs of q_1, q_2, and $q^\star$ were then drawn as a function of x_2. As x_2 ascends from 0.1

[33] It can be cast as a proposition at a formal cost that exceeds the benefit.

to 1, the following configurations are encountered in that order: first, Configuration 1 with $p_1 = q^\star$ outside (q_2, q_1) and, therefore, no ASSID distribution; then Configuration 1 with an ASSID distribution at $p_1 = q^\star$ inside (q_2, q_1); then Configuration 4 with an ASSID distribution at $q^\star$ inside (q_2, q_1); then Configuration 4 with $q^\star$ outside (q_2, q_1) and, therefore, no ASSID distribution; last, Configuration 5. To get Configuration 2, type 1 must be significantly less risk-averse than type 2, eg, $\gamma_1 = 0$, and $\gamma_2 = 4$. To get Configuration 3, both x_1 and x_2 must be above $^1\!/_2$.

Figure 7 about here

Intuition may be gained by examining Figure 7 which demonstrates the effect of the change in γ_1, the risk-parameter of type 1, on his offer-switch q_1. Here, $x_1 = 0.15$, $x_2 = 0.45$, and $\gamma_2 = 3$. At $\gamma_1 = 0$, type 1 is risk-neutral. Consistent with part (a) of Proposition 6, q_1 is below $q^\star$, and although Configuration 1 is in effect, the ASSID distribution does not exist. As γ_1 rises from zero and type 1 becomes increasingly more risk-averse, q_1 also increases, extending the domain of distributions p_1 in which he offers the conciliatory, riskless offer x_2 (riskless, because all agents of both types agree to take it) and reducing the domain where he offers the tough, risky x_1 offer (risky, because agents of type 2 reject it). Since a change in the offer-switch q_i inside the unit interval has this effect, it is intuitively useful to think of it as a measure of type i's toughness as an offerer; the lower his offer-switch q_i, the tougher he is. Continuing to raise γ_1; when it passes 1.5, q_1 tops $q^\star$, making $p_1 = q^\star$ an ASSID distribution according to Proposition 5.

Now compare the offer-switches; q_1 of type 1 and q_2 of type 2. From $\gamma_1 = 0$ up to $\gamma_1 = 3$, type 2's risk parameter $\gamma_2 = 3$ is *larger* than that of type 1. It may seem surprising, then, that type 2, the *more* risk averse, displays a lower, tougher q_2 than the larger, conciliatory q_1 of type 1. Indeed, based on his risk-aversion alone, type 2 would be expected to mimic type 1 and join him in making the conciliatory, riskless offer x_2. But he does not. Due to his higher measure of envy relative to that of type 1, $x_2 > x_1$, type 2 finds it unacceptable to offer the larger x_2, so he makes the tougher, albeit risky offer x_2, instead. It follows that the same quality of his preference order, *envy*, which coaxes type 2 as a responder to leave money on the table and reject an x_1 offer from another type 2, emboldens him to overcome his risk-averse reservations and make the risky, tough x_1 offer. Whether this behavior is to type 2's (expected dollar) advantage, depends on the population distribution, as explained next.

The ASSID distribution owes its existence to the fact that under Configurations 1 or 4, in a specific region of population distributions, type 2, the more envious and seemingly "less rational," gains overall more expected dollars than type 1, the less envious and seemingly "more rational." According to Proposition 5, under the said configurations, when p_1 is in the interval $(q^\star, q_1)$, type 1 offers the more conciliatory, riskless offer, x_2, and type 2 offers the tough, risky, offer x_1. As a responder under these conditions, type 1 has a clear advantage. Unlike type 2, who "leaves money on that table" in rejecting x_1 (offered by another type 2), type 1 always agrees to accept all the offers that he gets (x_1 from type 2 and x_2 from type 1).[34] However, type 2 has an advantage as an offerer. As described above, buoyed by his elevated degree of envy, type 2 overcomes his risk-aversion and offers the tough offer x_1. Provided that the proportion p_1 of types 1 who accept his tough offer is large enough, specifically $p_1 > q^\star$, type 2 gains an advantage that suffices to compensate him for leaving money on the table as a responder and then some more, resulting in an inclusive expected dollar advantage to type 2 over type 1.[35] Although the two types continue to make their respective offers at population distributions p_1 that are below $q^\star$ (as long as $q_2 < p_1$), there the probability that type 2's tough offer will be accepted is rather low, and type 1 gains more expected dollars than type 2. In between, at $p_1 = q^\star$, is the ASSID distribution, where the inclusive expected dollar gains to both types equalize. A lesson: the economic fitness of a risk-averse type may be helped by a moderate[36] measure of envy.

We can now also explain Part (b) of Proposition 6 that states that risk-neutrality of type 1 destroys the ASSID distribution. Recall that it is necessary for the existence of the ASSID distribution that type 1 offer the conciliatory offer x_2, while type 2 offers the tough x_1 offer. But the only reason that type 1 offers the riskless x_2 is his risk-aversion which, unlike that of type 2, is not counterbalanced by an elevated degree of envy. As his risk-aversion decreases, though, a point is reached—when his

[34] As responders, type 1 gets $p_1 x_2 + (1-p_1)x_1$, while type 2 gets only $p_1 x_2$. See the proof of Proposition 5.

[35] As offerers, type 1 gets $1 - x_2$, while type 2 gets $p_1(1 - x_1)$.

[36] An extremely envious type offers zero in order to get a sure rejection. He then loses the advantage as offerer, and the less envious takes over the population.

decreasing offer-switch q_1 just descends below $q^\star$—where he is not reluctant any more to take on the risk of offering the risky, tough offer x_2. As type 1 does that, joining type 2 in offering x_2, the latter's advantage as the sole offerer of the tough x_2 disappears, and with it disappears the ASSID distribution.

The following point needs to be emphasized. At distributions inside the interval (q_2, q_1), each type plays one role better than his counterpart in terms of dollar gain. The less envious plays better the role of the responder, while the more envious plays better the role of the offerer. Precisely at $q^\star$, the advantage and the disadvantage in the behaviors of each of the two types balance out to produce equal inclusive dollar gains, and, therefore, the ASSID distribution. But why cannot one of the types, the more envious, say, adopt the winning behavior in each role; behaving like the less envious when cast in the responder's role, and like the more envious when cast in the offerer role? He will then gain more. The answer is already provided in the introduction. It is based on the inherent inflexibility of emotions like envy, as manifest in a stable preference order which is independent of the role in which an agent may be cast.

The analysis above yields the following empirical verifiable hypothesis. Facing the same group of responders, holding similar beliefs about the distribution of envy in the group, and controlling for the envy intensity of the offerers; the more risk averse will tend to make more conciliatory offers than the less risk-averse.

6 Trimorphic Population – Numerical Demonstration

The "Dimensionality Curse" kicks in when trying to extend the analysis of Section 5 to ecologies comprising more than two types; the number of configurations explodes. But we conjecture that the intuitions gained in the analysis of dimorphic populations should carry over to polymorphic populations as well. As a probe of this conjecture, we computed numerically and then drew in Figure 8 the vector field describing the population distribution dynamics for a three-type, envious, risk averse population. In this figure, the envy parameters of the three types are $\delta = 0.05$, 0.2, and 0.8, respectively, and the risk parameter is the same $\gamma = 2$ for each. The right triangle drawn is the projection of the three-dimensional simplex onto the p_1–p_2 plane. The points inside the triangle represent stationary distributions. Each side of the triangle then represents

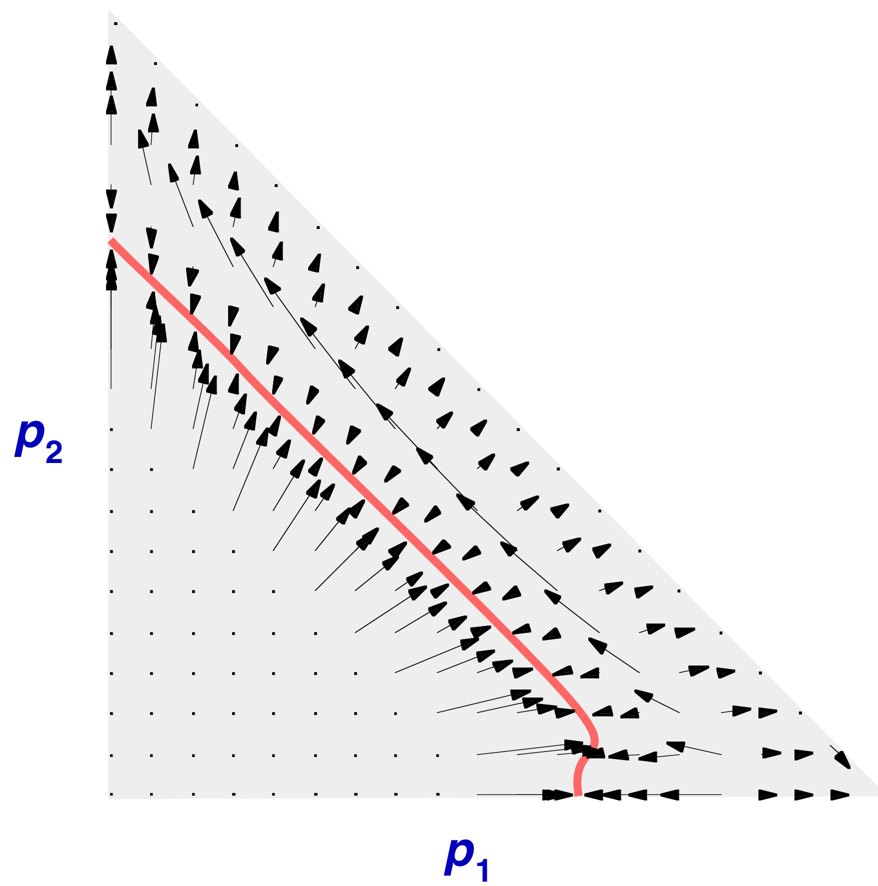


Figure 8. The vector field portraying the dynamics of a population comprising three preference types. The curved line is the locus of ASSID distributions. The dots represent stationary distributions.

a dimorphic population comprising one pair of types out of the three. The dynamics along the three sides conform to those described in Proposition 5. In particular, the dynamics along the two right sides are those of Configuration 1, clearly showing ASSID distributions. The vector field also demonstrates ASSID distributions extending to the interior of the simplex (along the curved line drawn inside the right triangle). Also clearly demonstrated, consistent with Proposition 2, is the set $S(\underline{Q})$ of stationary, stable, efficient distributions surrounding the monomorphic population at $p_3 = 1$ (at the origin).

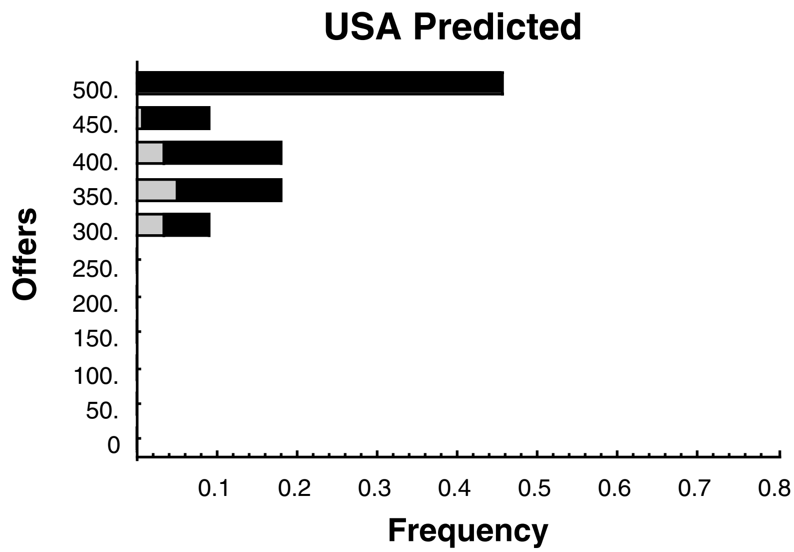
Figure 8 about here

7 Consistency with Experimental Results

The Ultimatum Game was extensively studied experimentally. However, those experiments were not designed to test our theory. For example, in the celebrated experiments performed by Roth, Prasnikar, Okuno-Fujiwara, and Zamir (1991), subjects were told only the outcomes of the games in which they participated; not the sample wide[37] outcomes. The experimenters' intention was to let subjects learn how to play the game; not to let them learn the true distribution of types or of rejection thresholds that they were facing. Nevertheless, since our theory contains many parameters that were not measured, it may not come as a surprise that it is not difficult to calibrate those parameters to reproduce the experimental results.

Accordingly, for each of the four groups of subjects corresponding to the four countries where the experiments were done, we hypothesized a population comprising 11 types with specialized utilities as in Proposition 6 above, all envious with rejection thresholds equally spaced between 10% and 50% of the contested sum, and distributed either uniformly or bell shaped. The risk parameters were taken to be equal for all the types in the same country. Thus, many degrees of freedom were left unused, namely, alternative distributions of types and variable risk parameters for the different envy types. We then adjusted the risk parameter for each country so as to minimize the Kolmogorv-Smirnov statistics that we used to test non-parametrically the closeness of

[37] The distribution of types in the sample of about 30 student subjects may differ from that of the population from which the former is drawn.



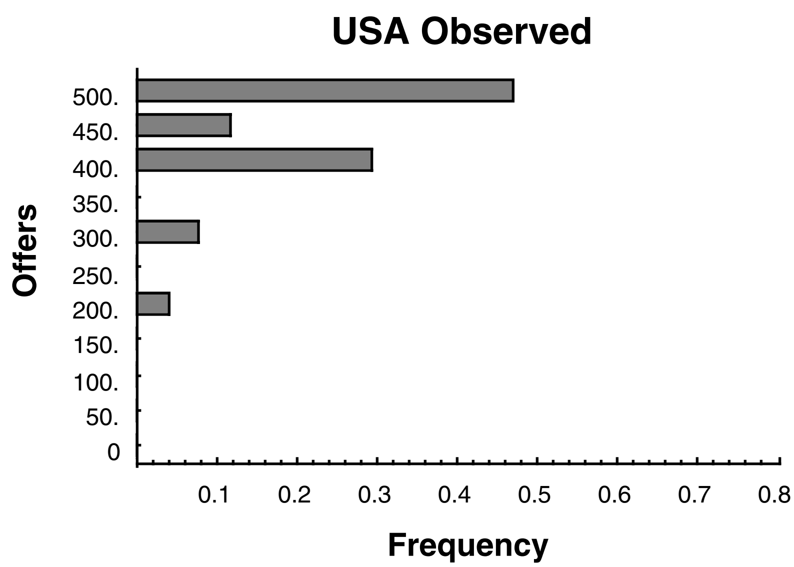


Figure 9. Predicted and observed offer frequencies in the Roth et al USA experiment. The Kolmogorov-Smirnov Statistics is $D(30) = 0.16$. Grays in the predicted graph represent rejection frequencies.

fit between the theoretical and the observed distributions in the last experimental rounds.

Figure 9 about here

In each of the four cases we were able to calibrate the single risk parameter and to choose one of the two alternative distributions so as to get a Kolmogorv-Smirnov statistics that would not have rejected the hypothesis that the observed offers were drawn from the predicted offer distribution at an acceptable level of significance. For illustration, we provide in Figure 9 both the predicted and the observed offer distributions for the USA experiment. A risk parameter of 2.5 and a uniform distribution of response together with the number of subjects which was 30, produced a minimum Kolmogorv-Smirnov statistics of 0.16; a fairly good fit. The theoretical rates of rejection corresponding to each offer are superimposed as light bars at the bases of the dark offer frequency bars. These also seem to be in qualitative agreement with the reported rejection rates (not shown), although we did not attempt to fit those as well. Clear is the regularity by which lower offers are rejected at higher frequencies.

It should be noted that although the utilities we posit in this paper are motivated differently from those posited by Bolton and Ockenfels (1997) and by Fehr and Schmidt (1999), they do share common geometric features; concavity in own monetary gain, in particular. While the concavity of the utilities we posit is rooted in agents' risk-aversion, Bolton-Ockenfels's and Fehr-Schmidt's stem from agents' altruism. This similarity, however, explains why our utilities can also explain the same market games as do Bolton-Ockenfels's and Fehr-Schmidt's utilities.[38] Our utilities do not explain laboratory dictator game results, though. As already discussed in Section 2, our utilities do not feature altruism, because altruism does not seem to be an important factor in real-world business transactions, which were the concern of the current paper.

[38] The details were omitted from this paper after we became aware of Bolton-Ockenfels's and Fehr-Schmidt's papers.

8 Conclusions

Models have been put forward recently that seem to be successful in explaining seemingly anomalous experimental results in the Ultimatum Game. While imparting fixed preference orders to agents, they depart from traditional models by assuming preference orders that take account not only of the material gain to oneself, but also of that which is allocated to others. However, they leave open the question of how is an agent's economic survival helped by a preference order that advises him to reject positive offers, which amounts to leaving money on the table.

Our answer is that, indeed, doing so does not help. But that the same envious preference order that ill advises in some circumstances to reject an 'insultingly' small offer, advises well in other circumstances, when it helps the same agent to overcome his risk-aversion and to offer a risky, tough offer that yields him a better expected dollar gain.

Our main finding is that under plausible conditions, among them that all agents are risk averse, there exists a class of population distributions of different types of envy and risk aversion that are stationary, stable, and inefficient. In these populations, as commonly observed in an Ultimatum Game, positive offers are made, of which some are rejected with positive probability. In these populations, measured in expected dollar gains, each type performs worse than other types on some occasions, and better than other types on other occasions. The more envious makes the mistake of leaving money on the table when responding to a tough offer, but his envy helps him overcome his risk-aversion and make a tough offer that brings him larger expected dollar gains. On the other hand, the less envious performs better when he tends to accept those offers that the more envious rejects, but his lower envy lets his risk-aversion get the better of him, and he makes too generous offers that bring him smaller expected gains than those which a tougher offer would have brought him. In these stable, stationary populations, the better and the worse performances of each type average out to the same inclusive dollar fitness across all types.

We also show that in order for a preference type to be able to take over a population, it must exhibit a positive measure of envy. Our theory also describes other preference ecologies and their population dynamics, and generates testable hypotheses.

Appendix

Proof of Proposition 2. Since, for $i \in \mathrm{I}$, $O_i(x)$ decreases in x, and $x_{i_0} \leq x_k \leq x_I$, then $0 < O_i(x_I) \leq O_i(x_k) \leq O_i(x_{i_0})$ for $k = 0, ..., I-1$. Therefore, $O_i(x_I)/O_i(x_{i_0}) \in (0, 1]$ and $\underline{Q} \in (0, 1]$. Let $p \in S(\underline{Q})$, then the Ith component of p satisfies $p_I \in [1 - \underline{Q}, 1]$, and therefore, $\sum_{j=i_0}^{k} p_j \leq \sum_{j=i_0}^{I-1} p_j = 1 - p_I \leq \underline{Q}$ for $k = i_0, ..., I-1$. Hence, the non-negative expected utility of any type $i \in \mathrm{I}$ from offering x_k ($k = 0, ..., I-1$) under such a distribution is $\left(\sum_{j=i_0}^{k} p_j\right) O_i(x_k) \leq \underline{Q}\, O_i(x_k) \leq \underline{Q}\, O_i(x_{i_0}) \leq O_i(x_I)$, where the latter is the expected utility of type i from offering x_I, which is agreed to by all types when acting as responders. Therefore, for all types, offering x_I dollars under a distribution in $S(\underline{Q})$ dominates offering any other amount (including offering zero to solicit a refusal). The unique perfect Bayesian equilibrium under any distribution in $S(\underline{Q})$ is then for type i to offer x_I and use x_i as its rejection threshold. Since all types offer x_I, which is the highest rejection threshold, then, by Proposition 1, the distribution is both efficient and stationary.

Since $S(\underline{Q})$ is pathwise-connected, then any sufficiently small perturbation to a distribution in the interior of $S(\underline{Q})$ leads to a distribution that is still in the interior, which is, therefore, stationary. Hence, all distributions in the interior are stable (not asymptotically, though). □

Proof of Proposition 3. Suppose $\overline{Q}_1 \leq 1$. Then for any i in I, $O_i(x_2)/O_i(x_1) \leq 1$, and, since O_i decreases and $x_1 \leq x_2$, then two configurations are possible; either (i) $0 \leq O_i(x_2) \leq O_i(x_1)$ or (ii) $O_i(x_2) < 0 \leq O_i(x_1)$. Suppose that configuration (i) holds, then necessarily $0 \leq \overline{Q}_1$. To select his optimal offer, type i compares his expected utility from offering the different possible offers. Offering zero results in sure rejection, and i gets zero expected utility. Offering x_1 solicits agreement only from type 1 managers and gives i an expected utility of $p_1 O_i(x_1) \geq 0$. Offering x_k ($k = 2, ..., I$) solicits agreements only from types 1 to k, which gives i an expected utility of $\left(\sum_{j=1}^{k} p_j\right) O_i(x_k)$. There are two possibilities here; either (i_1) $0 < O_i(x_k)$ or (i_2) $O_i(x_k) \leq 0$. In the first subcase (i_1), under any distribution from $S(\overline{Q}_1)$, the following chained inequality, $0 < \left(\sum_{j=1}^{k} p_j\right) O_i(x_k) \leq O_i(x_k) \leq O_i(x_2) \leq \overline{Q}_1 O_i(x_1) \leq p_1 O_i(x_1)$, implies that type i prefers to offer x_1 to offering either x_k or zero (ties are broken in favor of offering x_1). In the second subcase (i$_2$), under any distribution with $0 < p_1$, the inequalities $\left(\sum_{j=1}^{k} p_j\right) O_i(x_k) \leq 0 \leq p_1 O_i(x_1)$ again imply that i prefers to offer x_1. Suppose that configuration (ii) holds. Then, $x_k \leq x_2$ implies $O_i(x_k) \leq O_i(x_2) < 0 \leq O_i(x_1)$. Again, $\left(\sum_{j=1}^{k} p_j\right) O_i(x_k) < 0 \leq p_1 O_i(x_1)$ implies that i's optimal offer is x_1.

To recap, if $\overline{Q}_1 \leq 1$, then, all types prefer to offer x_1 dollars under any distribution from $S(\overline{Q}_1)$ to offering any other amount. The perfect Bayesian equilibrium is for any type i to offer x_1 and use x_i as his rejection threshold, with the result that all types reject the x_1 offer, but for type 1, who agrees to accept it. Therefore, as offerers, all types get the same dollar amount in expectation, namely, $p_1(1-x_1)$. As responders, however, type 1 gets x_1 dollars for sure, while all the rest surely get zero dollars. If $\overline{Q}_1 < 1$, then distributions exist in $S(\overline{Q}_1)$ that are not the monomorphic distribution, $p_1 = 1$. Under those distributions, at the end of every period, type 1 managers get more dollars than the managers of any other type. Hence, p_1^t, the fraction of wealth under type 1 managers' control, increases to unity in time, while the fractions of wealth under the control of any other type decrease to zero. □

Proof of Proposition 4. Consider an i in I, and a k in $\{1, ..., I\}$. Suppose $0 \leq O_i(x_k)$. Then under any distribution from $S(\overline{Q}_0)$ the expected utility of type i from offering x_k is $\left(\sum_{j=-L}^{k} p_j\right) O_i(x_k) \leq O_i(x_k) \leq O_i(x_1) \leq \overline{Q}_0 \leq \sum_{j=-L}^{0} p_j = \left(\sum_{j=-L}^{0} p_j\right) O_i(0)$,[39] where the latter is the expected utility of type i from offering zero. Alternatively, suppose that $O_i(x_k) < 0$. Then again, $\left(\sum_{j=-L}^{k} p_j\right) O_i(x_k) < 0 < \left(\sum_{j=-L}^{0} p_j\right) O_i(0)$. Therefore, all types, including the non-envious, prefer to offer zero in equilibrium, but only the non-envious agree to accept it. Hence, all types get $\sum_{j=-L}^{0} p_j$ dollars in expectation as offerers, and zero as responders. (The non-envious agree to accept zero, while all the others reject and get zero as well.) Therefore, each type gets the same amount in expectation, namely, $0.5 \sum_{j=-L}^{0} p_j$, so the distribution is stationary and inefficient (because the envious types reject the zero offers). Stability in the interior of $S(\overline{Q}_0)$ is established as in Proposition 2. □

Proof of Lemma 1. The expected utility levels of type i from offering zero, x_1, or x_2, are, respectively, zero, $p_1 O_i(x_1)$, and $O_i(x_1)$. Case (i) implies $O_i(x_2) < 0 \leq p_1 O_i(x_1)$.

[39] Recall, $O_i(0) = u_i(1, 0) = 1$.

In case (ii), $p_1 \in [0, q_i)$ implies $0 \leq p_1 O_i(x_1) < O_i(x_2)$, and $p_1 \in [0, q_i)$ implies $0 \leq O_i(x_2) < p_1 O_i(x_1)$. Case (iii) implies $O_i(x_2) < p_1 O_i(x_1) < 0$. □

Proof of Proposition 5. We will demonstrate that $0 < x_1 < 1 - x_2 < 1/2 < x_2 < 1 - x_1 < 1$ implies Configuration (4). The others are similarly proven. Since $O_1(x)$ is decreasing in x, then $x_1 < x_2 < 1 - x_1$ implies $O_1(x_1) > O_1(x_2) > O_1(1 - x_1) = 0$, which, by Lemma 1, implies $0 \leq q_1 < 1$. Similarly, $O_2(x)$ is decreasing in x, then $x_1 < 1 - x_2 < x_2$ implies $O_2(x_1) > O_2(1 - x_2) = 0 > O_2(x_2)$, which, again by Lemma 1, implies $q_2 < 0$.

The dynamics for Configuration (1), $0 \leq q_2 < q_1 \leq 1$, will be demonstrated. The other configurations are similarly treated. From Lemma 1, for $p_1 \in [0, q_2]$ (proportion of the more envious is large enough) both types offer the more conciliatory offer x_2, and both types agree to accept it. Therefore, the expected dollar gain is the same for both types. Actually, this is a special case of Proposition 2. For $p_1 \in [q_1, 1]$ (proportion of the less envious is large enough) both types offer the same tough offer x_1, which implies that as offerers both get the same $1 - x_1$, but as responders, type 1 gets more, since he accepts all the x_1 offers, while type 2 rejects them all. So type 1, the less envious, has the overall advantage and flourishes to dominate the population completely. This is, actually, a special case of Proposition 3.

Again from Lemma 1, for $p_1 \in (q_2, q_1)$ type 1 offers the conciliatory x_2 and type 2 offers the tough offer x_1. As offerer, type 1 gets assents from both types to his conciliatory offer, and gains $EDO_1 = 1 - x_2$. As responder, type 1 hears x_2 from a type 1 with probability p_1 and x_1 from a type 2 with probability $(1 - p_1)$. Type 1 agrees to take both offers and gains $EDR_1 = p_1 x_2 + (1 - p_1)x_1$. His total gain is $ED_1(p_1) = 0.5(1 - x_2) + 0.5[p_1 x_2 + (1 - p_1)x_1]$. Type 2 offers x_1, only type 1 assents, and type 2 gains $EDO_2 = p_1(1 - x_1)$ as offerer. As responder, type 2 hears similar offers to those that type 1 hears, but he agrees only to x_2 coming form type 1 and gets $EDR_2 = p_1 x_2$. Type 2's total gain is $ED_2(p_1) = 0.5p_1(1 - x_1) + 0.5p_1 x_2$.

If $q^\star = 1 - (x_2 - x_1)$ is inside (q_2, q_1), then the total gains of the two types are equal at $q^\star$, so $p_1 = q^\star$ is a stationary population distribution. At p_1 larger than $q^\star$, $ED_1(p_1) < ED_2(p_1)$, and the inequality is reversed at p_1 smaller than $q^\star$. Therefore, $q^\star$ is also asymptotically stable. □

Proof of Proposition 6. It is easy to see that O_i is concave if and only if f_i is; and, trivially, f_i represents risk-neutrality, meaning $f_i(x) = x$, iff $O_i(x) = (1 - x_i - x)/(1 - x_i)$. Only the $i = 1$ case is proved. The proof of $i = 2$ is similar.

(a) Concavity of $O_1(x)$, which is denoted $O_1^{\text{averse}}(x)$ to signify this, implies that under Configurations 1 and 4 (see Proposition 5), $O_1^{\text{averse}}(x_1)/(1 - x_1 - x_1) < O_1^{\text{averse}}(x_2)/(1 - x_1 - x_2)$ or $q_1(x_1,\ x_2;\ O_1^{\text{neutral}}) = O_1^{\text{neutral}}(x_2)/O_1^{\text{neutral}}(x_1) = (1 - x_1 - x_2)/(1 - x_1 - x_1) < O_1^{\text{averse}}(x_2)/O_1^{\text{averse}}(x_1) = q_1(x_1,\ x_2;\ O_1^{\text{averse}})$. Then, by Lemma 1, for any $p_1 \in [0,\ 1]$, the optimal offer never decreases, as q_1 increases within $(-\infty,\ 1]$.

(b) It is easy to see that $q\star - q_1(x_1,\ x_2;\ O_1^{\text{neutral}}) = 1 - (x_2 - x_1) - (1 - x_1 - x_2)/(1 - x_1 - x_1) = 2x_1(x_2 - x_1)/(1 - 2x_1)$, which is positive under Configurations 1 and 4, which imply $0 < x_1 < x_2 < 1$, and $x_1 < 1/2$. But, by Proposition 5, this violates a necessary condition for the existence of the ASSID distribution. □

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