Will Equity Evolve?
- An Indirect Evolutionary Approach -

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May 2002

Abstract

It has been claimed that people often prefer equity-like considerations and tend to ignore strategic aspects in fair division problems. Here, this is explored by analyzing whether or not such a behavioral disposition is evolutionarily stable. The answer, however, is ambiguous: Both, reacting to and neglecting strategic aspects can be evolutionarily stable strategies when power discrepancies are minor. Equity, in particular, is restricted to situations where structural asymmetries are subtle.

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1. Introduction

Experimental evidence in fair division problems has been puzzling economists because the decisions taken by the players seem incompatible with narrow rationality. The Ultimatum Game is a case in point. Here, a proposer is asked to divide a given amount of money between him- or herself and another person (the responder) who may then accept this offer or not. If the responder does not accept the proposed division, both players are left with nothing. Although offers in the Ultimatum Game are essentially "take-it-or-leave-it" offers, and offering a marginal amount should suffice to make the responder accept, the proposer offers on average between 30 and 40 percent of the amount at stake, the 50:50 split often being modal (Camerer and Thaler 1995: 210).

One explanation for the observed anomaly is that the proposer may be led by equity considerations (see e.g. Selten 1978, and Güth 1994). The relevance of such internalized norms of equity and fairness is, among others, underlined by experimental evidence from the so-called Dictator Game where, again, a proposer is asked to divide a given amount between him- or herself and another player. Unlike in the Ultimatum Game, however, the other player cannot veto this decision, but has to accept whatever is being offered by the proposer (the "dictator"). Still, the proposer passes a positive amount to the responder, and even in Dictator Games a "concentration of offers of equal division" has been observed (Roth 1995: 270).

Unconditional equity considerations, however, cannot be "the whole story", as offers in the Dictator Game are still "not quite as fair" as those in the Ultimatum Game (Camerer 1997: 169). In addition to being motivated by equity considerations, the proposer is obviously also aware of the strategic aspects of the game when making an offer. The results of Güth and van Damme (1998), who introduce a third, but inactive, (dummy) player in the Ultimatum Game setting, are illustrative: While the proposer offers about 30 percent of the amount at stake to the responder whose veto would leave all of them with nothing, he or she offers only 5-10 percent to the dummy.[1] Undoubtedly, the former is in a better

[1] The nonstudent participants in the newspaper experiment of Güth, Schmidt and Sutter (2002), however, have treated the dummy more generously.

bargaining position than the latter and consequently receives a larger share. The results of Suleiman (1996), who systematically varies the bargaining position of the responder, hint in the same direction: The more far-reaching the responder's veto rights, the larger the share offered to him or her (see also the results of Güth and Kovács 2000).

In this paper we contribute to the discussion on equity-driven vs. strategic players by analyzing whether one or the other behavioral disposition is evolutionarily stable in a Nash-Demand Game environment with varying conflict payoffs. We proceed as follows: Section 2 presents the Nash-Demand Game and characterizes equity-driven (U-type) vs. strategic players (I-type) as well as their strategies. In Section 3 we analyze the evolutionary game and identify evolutionarily stable strategies. Section 4 contains a short summary.

2. The bargaining model

As is usual in evolutionary game theory (e.g. Weibull 1997), we consider a symmetric two-person situation. More specifically, we assume that two players, 1 and 2, can share a unit "pie", for example a positive amount of money. The strategic aspect to which parties may or may not react when bargaining are the conflict payoffs c_i which are stochastic *iid*-variables (**i**ndependently and **i**dentically **d**istributed) with

$$c_i = \begin{cases} c & \textit{with probability} \quad 1-p \\ c+e & \textit{with probability} \quad p \end{cases}$$

for both players $i = 1, 2$ where $0 \leq c < 1/2$. Here e with

$$0 < e < 1 - c$$

expresses some extra profit in case of conflict. p is a generic probability in the sense of

$$0 < p < 1.$$

We assume that the negotiation result is the bargaining solution suggested by Nash (1950 and 1953).[2] According to this concept the outcome for player $i = 1, 2$ is

$$u_i = \frac{1 + c_i - c_j}{2}$$

with $j \neq i$ if both players pay attention to the possible asymmetry of conflict payoffs.

Two players who refrain from doing so, for instance by implicitly assuming $c_i = c_j$, split the pie equally (see Homans, 1961, for an early reference for equity theory), i.e., $u_i = 1/2$ for $i = 1, 2$. If player i, who cares for differences in conflict payoffs, confronts a player j, who does not and therefore demands 1/2, conflict results for $c_i = c + e$ with probability $p(1-p)$. With probability $(1-p)p$ player i's demand and payoff is $\frac{1-e}{2}$. Otherwise they share equally. Thus player $i's$ payoff expectation is

$$p(1-p)(c+e) + (1-p)p\frac{1-e}{2} + p^2\frac{1}{2} + (1-p)^2\frac{1}{2} = \frac{1 - p(1-p)(1-2c-e)}{2},$$

and player $j's$ payoff expectation is:

$$p(1-p)c + (1-p)p\frac{1}{2} + p^2\frac{1}{2} + (1-p)^2\frac{1}{2} = \frac{1 - p(1-p)(1-2c)}{2}.$$

In what follows, a player who does not care for strategic aspects, that is who always demands 1/2, is called a U-type. Players who react to asymmetries in conflict payoffs are named I-types.[3] Our analysis above determines the bargaining outcome and thus the solution payoffs for all possible type constellations, namely, the ones where both are of the same type, (U,U) or (I, I), and the ones where types differ. With the help of these results we define an evolutionary game for studying the Darwinian competition of U- and I-types.

[2] More specifically, the noncooperative procedure is the so-called Nash-demand game according to which both parties simultaneously determine their payoff demands. It is assumed that each party obtains what it demanded if demands are feasible, that is in case of an anticonflict (the sum of demands is smaller than the pie) an inefficiency results.

[3] One possible interpretation of U-types is that they are **u**ninformed. Since they do not care for asymmetries in conflict payoffs, they do not inform themselves about conflict payoffs. Similarly, I-types would be **i**nformed.

3. The evolutionary game

Indirect evolution (see Güth and Yaari, 1992, and Güth and Kliemt, 1998) allows to combine strategic deliberation and evolutionary adaptation over time. For the example at hand strategic deliberation is captured by applying the so-called Nash-bargaining solution where a player i may respect or neglect a possible asymmetry of conflict payoffs. When analyzing whether U- or I-types become relatively more frequent, we measure evolutionary or reproductive success by the expected solution payoff as derived above.[4] Furthermore, the possible mutants are just the two types, U and I, as specified above. Thus, the evolutionary game is as represented in the following table:

	I	U
I	1/2	$\frac{1-p(1-p)(1-2c-e)}{2}$
U	$\frac{1-p(1-p)(1-2c)}{2}$	1/2

Table 3.1: Row player's reproductive success

For $2c < 1$ and $p \in (0,1)$ the only best response to I is I. Similarly, U is the only best response to itself if $2c < 1 - e$. This proves (see App.)

Proposition 1: Only the two monomorphisms, i.e., the universal U- or I-type, are evolutionarily stable strategies if $2c < 1 - e$, whereas for $1 - e < 2c < 1$ this holds only for the I-type (figure 3.1).[5]

Thus, a society with low conflict payoffs in the sense of $2c+e < 1$ has two coexisting stable monomorphisms. In such a monomorphic population a rare mutant will

[4] One possible justification for relying on expected rather than actual payoffs for measuring reproductive success is to assume random matching in an infinite population.

[5] An evolutionarily stable strategy of a symmetric two-person game is a best reply to itself and, in case of a multiple of such best replies, better against another such strategy than is the strategy under consideration (see Weibull 1997). Clearly, U(I) is the only best reply to U(I) and thus evolutionarily stable. In the App. it is shown that the third mixed strategy equilibrium is unstable.

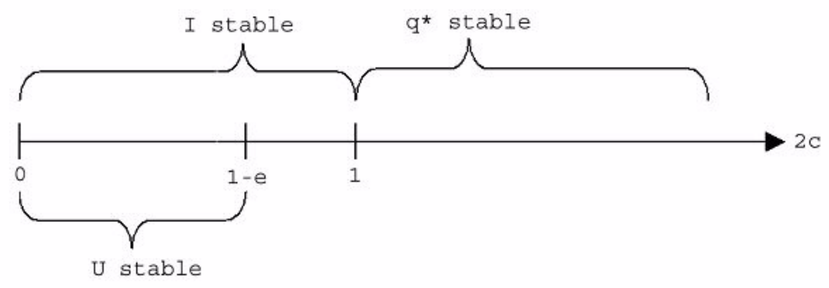

Figure 3.1:

earn a lower reproductive success than the nearly universal other type so that the rare mutant type will sooner or later disappear. From an evolutionary perspective one can therefore justify both types of behavior

- universal equity as well as
- universal attention to strategic aspects

as stable behavioral dispositions if conflict payoffs are sufficiently low. For intermediate conflict payoffs with $1 > 2c > 1 - e$ only the I-monomorphism is stable. Sooner or later a situation will arise where players universally react to differences in conflict payoffs. For $2c > 1$ there exists a mixed strategy equilibrium with a population share

$$q^* = \frac{2c + e - 1}{4c + e - 2}$$

of I-types in the population. In such a bimorphic population, both types I and U would fare equally well. For such a situation to be stable[6] one needs that q^* earns in a q-monomorphic population more than q. Since this requirement always holds (see App.) we have shown

[6]We assume a continuous mutant space $q \in [0, 1]$ rather than the discrete one of $\{I, U\}$, or $\{q = 1, q = 0\}$.

Proposition 2: For $2c > 1$ the only evolutionarily stable constellation is the mixed equilibrium strategy q^*.

Let us finally employ random mutation in the sense that every individual adopts their non-best reply type with a small positive mutation probability ε where random mutation satisfies the iid-assumption, that is where random mutation occurs independently and with the same ε-probability for all individuals in the population. It has been shown (Kandori, Mailath and Rob 1993) that over an ultra-long evolutionary process this leads to the risk dominant strict equilibrium. Now the (symmetric) strict equilibrium strategy I risk dominates the (symmetric) strict equilibrium strategy U in the symmetric evolutionary game with $2c + e > 1$ (see Harsanyi and Selten 1988, who provide an axiomatic characterization of risk dominance for such games which can be used constructively to derive this condition) if

$$p(1-p)(1-2c-e) < p(1-p)(1-2c)$$

which always holds for $p \in (0, 1)$ and $e > 0$. This proves

Proposition 3: Random mutation as assumed by Kandori, Mailath and Rob (1993) ultimately leads to the I-monomorphism.

For the propagators of equity-driven U-type behavior this seems to be bad news. One may, however, question that random mutation satisfies an iid-assumption, which implies that a monomorphic population, albeit with very small probability, can switch over to another monomorphism. This is clearly not in line with genetic evolution and, even for cultural evolution, is a very unlikely case.

4. Conclusions

Both social conventions,

- generally relying on equity in spite of possible asymmetries in bargaining power as captured by conflict payoffs and

- paying attention to strategic details like conflict payoffs, which according to the Nash (1950 and 1953)-bargaining solution, will not become factual if such aspects are generally considered,

are self-stabilizing social norms with generic attraction sets (when conflict payoffs are low). What this illustrates is basically that the general disposition to rely on equity, or to consider the specific aspects of a given situation, are stable social conventions (see Sugden 2001). Deviating from such an otherwise uniformly accepted convention typically causes conflict or other inefficiencies (e.g. not distributing all that is available, see above for the case when an I-type i with $c_i = c$ confronts a U-type j with $c_j = c + e$), which means that interaction partners are less successful than when conforming to what is usual. Random mutation in the sense of Kandori, Mailath and Rob (1993) yields in the ultra-long horizon the I-monomorphic population where strategic aspects are universally neglected.

Of course, conflict payoffs are just one strategic aspect which one may or may not neglect. Other possible asymmetries could concern bargaining power as captured by the asymmetric Nash-bargaining solution, the local rate of substitution (the slope of the utility frontier at the Nash-bargaining solution) in an NTU (**n**on-**t**ransferable **u**tility) situation, etc. Universally regarding or neglecting such aspects would also be social conventions which are self-stabilizing since rare norm deviations imply worse results.

5. Appendix: Derivation of evolutionarily stable strategies (ESS)

A symmetric evolutionary game can be described by $(M, R(.))$ where M is the mutant or strategy set and $R(m, \widetilde{m})$ the (reproductive) success function assigning to an m-type who confronts an $\widetilde{m}$-type (or an $\widetilde{m}$-monomorphic population) its success for all possible pairs $(m, \widetilde{m})$ with $m, \widetilde{m} \in M$. In our case $M = Q = [0, 1]$ according to which one is an I-type or U-type with probability q, $1-q$, respectively, and $R(q, \widetilde{q})$ is simply the expected profit of player 1 playing q when confronting a player 2 who uses $\widetilde{q}$ (random matching in an infinite population justifies using expected rather than actual payoff as success measure).

For an evolutionarily stable strategy (ESS) $m^* \in M$ one must have (see Weibull 1997 for a discussion) that

1. $R(m^*, m^*) \geq R(m, m^*)$ for all $m \in M$, i.e., m^* must be a best reply to an m^*-monomorphic population or, due to the symmetry of the evolutionary game $(M, R(.))$, this means that (m^*, m^*) is a symmetric equilibrium, and
2. for all $m \in M$ with $R(m, m^*) = R(m^*, m^*)$ one must have $R(m^*, m) > R(m, m)$, i.e., if an alternative best reply to m^* spreads out, it will be crowded out again since it meets its own type with positive probability.

Application: For $2c < 1 - e$ the pure strategy U, or $q = 0$, is a strict equilibrium of the game in Table 3.1 and thus an ESS. For $2c < 1$ this is true for I, or $q = 1$. For $1 - e < 2c < 1$, furthermore, (I, I), or $(q, q) = (1, 1)$, is the only equilibrium. What remains to be analyzed is the evolutionary stability of the (symmetric) mixed strategy equilibrium (q^*, q^*) which, for $2c < 1 - e$, coexists with the two strict equilibria and, for $2c < 1$, is the only equilibrium of the evolutionary game. Note that, by the very definition of a symmetric strategy equilibrium (q^*, q^*) with $q^* \in [0, 1]$, every other mixed strategy $q \in [0, 1]$ is a best reply to q^*. Thus, we have to explore condition 2. of an ESS. Note further that we only have to consider cases $p \in (0, 1)$ where both (I and U) types coexist in the population and are thus comparable in their success. For the case at hand and $q \neq q^*$ we get

$$\begin{aligned} R(q^*, q) - R(q, q) &= (q^* - q)p(1 - p)\left[2c + e - 1 - (4c + e - 2)q\right] \\ &= (q^* - q)p(1 - p)F(q) \end{aligned}$$

with $F(q) = 2c + e - 1 - (4c + e - 2)q$.

Clearly, $F(q^*) = 0$ for $q^* = (2c + e - 1)/(4c + e - 2)$.

Thus, for $2c < 1 - e$ where $F(0) = 2c + e - 1 < 0$ one must have $F'(q) > 0$ to prove that q^* is unstable $(R(q^*, q) - R(q, q) \leq 0)$ which follows from the linearity of $F(q)$ in q. For $2c > 1$ one has $F(0) = 2c + e - 1 > 0$ and thus $F'(q) < 0$ implying $R(q^*, q) > R(q, q)$ for all $q \in [0, 1]$ with $q \neq q^*$.

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