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On Evolutionary Stability of Spiteful Preferences^α

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Abstract

The paper analyzes under what conditions spiteful preferences are evolutionarily stable applying the indirect evolution approach. With a quadratic material payoff function, spiteful preferences are evolutionarily stable for a large set of parameters. It is shown that strategic substitutability or complementarity is endogenous property of the game played with evolutionarily stable preferences. Its relation to properties of the material payoff function is analyzed. Finally, it is shown that with incomplete information only selfish preferences are evolutionarily stable.

Keywords: indirect evolution, spite, endogenous preferences.
JEL Codes: C72, A13

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1 Introduction

A fundamental assumption in economics is that economic agents care only about their own utility. This point was defended by Alchian (1950) and Friedman (1953) by stating that if it were not the case, agents not maximizing their utility would be eliminated by evolution. It has been shown recently that in a strategic interaction context with complete information this is not necessarily true (see, e.g. Bester and Güth (1998) and Koçkesen et al. (1997)) while an incomplete information setting supports the claim (see Ely and Yilankaya (1997)).

This paper applies the indirect evolution approach to games which can arise from differentiated products oligopoly games. However, we abstract from oligopoly setting and focus more on certain properties of the game and the payoff function. The indirect evolution approach, initiated by Güth and Yaari (1992), works on preferences rather than on strategies. Given players' preferences, they play an equilibrium of the game with their subjective preferences. Given equilibrium strategies, one can calculate the fitness of a player by substituting the equilibrium strategies into the material payoffs game. The evolution will select the preferences that have higher fitness. We are interested in stationary points of evolutionary process, that is such preferences that are robust to invasion of a small number of mutants. These points are the evolutionarily stable strategies of a game where the strategy sets are possible preferences and the payoffs are the material payoffs corresponding to the equilibrium strategies of the game with given preferences.

Thus, the evolution is assumed to work in a large population of players who are randomly matched to play a two-player game. In the game they are either able to find an equilibrium or learn to play it sufficiently fast so that the evolution works on the equilibrium outcomes. In the duopoly context the evolution can be interpreted as a cultural phenomenon changing preferences (priorities) of a given firm as it observes a number of other firms in other duopoly markets.

Bester and Güth (1998) have analyzed the model but they restricted preferences to a convex combination of egoistic (maximizing own profits) and altruistic (maximizing sum of profits) preferences. In a quadratic setting they showed that altruism is evolutionarily stable with strategic complements. With strategic substitutes no altruism survives and egoistic preferences are evolutionarily stable. The last result appears because the preference parameter is restricted to lie between egoistic and altruistic values. We remove

this restriction on preference parameter by introducing spiteful preferences. The spiteful preferences resemble negative reciprocity like altruism resembles positive reciprocity and therefore they are not uncommon. Moreover, they are linked with imitative behavior which was analyzed, for example in Vega-Redondo (1997). We show that (partially) spiteful preferences are evolutionarily stable when egoism was stable in Bester and Güth (1998).

Further, strategic complementarity or substitutability, represented by the slope of the reaction functions, can be an endogenous property of the game. The game played with evolutionarily stable preference parameters is determined endogenously here and, therefore, strategic complementarity or substitutability of it is a result of the evolution rather than the cause determining what evolutionarily stable preferences are. The basic element of the analysis is the material payoff function. Its properties, such as sub- or supermodularity can provide some light for the result. We will see, however, that they are not always enough to provide an unambiguous answer for games going beyond standard differentiated product games but have similar structure.

Finally, in the preferences of the opponent are not known, we will show that then maximizing the material payoffs is the only evolutionarily stable preferences and, therefore, with incomplete information the claim of Alchian (1950) and Friedman (1953) is valid in the context analyzed in the paper. An open question remains if it is true in general.

We proceed as following. In Section 2 we include spiteful preferences in Bester-Güth framework while keeping other restrictions intact. In Section 3 we relax some other assumptions and illustrate that strategic complementarity or substitutability is endogenously determined. Section 4 considers the model with incomplete information. Some conclusions are drawn in Section 5.

2 The Bester-Güth Model with Spiteful Preferences

2.1 The Indirect Evolution

Here we formulate shortly how the indirect evolution works for general games. In following subsection we analyze the model of Bester and Güth (1998) with quadratic functions.

Güth and Yaari (1992) initiated the indirect evolution approach to the evolution of preferences in games. Consider a symmetric two-player game G with strategy sets S_1 and S_2 . The payoffs $U_1(s_1; s_2); U_2(s_1; s_2)$ are the material payoffs or the fitness of players 1 and 2. Let W be a set of possible preferences.

Consider now a game G^0 with the same strategy sets but with players having preferences represented by payoff functions $V_1(s_1; s_2); V_2(s_1; s_2)$. We can find an outcome of G^0 which is considered plausible. If G^0 has a unique equilibrium, it is natural to assume that the equilibrium will be played. Even if G^0 does not have an equilibrium or has multiple equilibria, there are ways to select one of them, e.g. by learning processes (see, for instance, Kandori et al. (1993)). We will address this problem in the particular example later.

Assume that for any given pair of preferences $V_1; V_2$ from W a unique outcome of the game is found, together with corresponding strategies $s_1^*; s_2^*$. Then one can find the fitness of a player with given preferences by substituting the equilibrium strategies into the material payoff function. Let us denote the resulting function for player 1 by $U_1^*(V_1; V_2)$. The material payoff for player 2 is found by symmetry.

Define an evolutionary game Γ as a symmetric game with strategy sets W and with payoff function $U_1^*(V_1; V_2)$. The definition of evolutionary stability for one population symmetric games is standard (see, e.g. Weibull (1995))

Definition 2.1 Strategy V^* is evolutionary stable if

- (i) $U_1^*(V^*; V^*) > U_1^*(V; V^*) \forall V \neq V^*$
- (ii) if $U_1^*(V^*; V^*) = U_1^*(V; V^*)$ then $U_1^*(V^*; V) > U_1^*(V; V)$

The evolutionarily stable preferences are the ones which are evolutionarily stable in Γ .

Definition 2.2 Preferences V^* are evolutionarily stable if they are evolutionary stable strategy in Γ .

Thus, finding the evolutionarily stable preferences allows us to say which preferences are robust with respect to a invasion of a small number of mutants in a large population with random matching. Evolutionary stability does not necessary guarantee that an evolutionary process will converge to the evolutionarily stable strategy. It can also happen that there is no evolutionarily stable strategy. However, we will see that this concept allows us to draw some conclusions in certain games.

2.2 The Quadratic Example

Let G be a symmetric game with strategy sets of all nonnegative real numbers. Let $x \geq 0$ be the strategy of Player 1 and $y \geq 0$ be the strategy of Player 2. The material payoffs of the game are given by

$$U_1(x; y) = x(ky + m - x); U_2(x; y) = y(kx + m - y) \quad (1)$$

where $0 < k < 1$; $k \neq 0$; $m > 0$. These restrictions will guarantee the uniqueness of equilibrium together with assumptions on preference parameters later.

The players do not necessarily maximize their material payoffs. The set of possible preferences consists of following linear combinations of own and opponent's payoffs:

$$V_1(x; y) = U_1(x; y) + \alpha U_2(x; y); V_2(x; y) = U_2(x; y) + \beta U_1(x; y) \quad (2)$$

where $\alpha, \beta \in [-1; 1]$ are preference parameters. Thus the set W corresponds to the interval $[-1; 1]$. This formulation is slightly different from the one of Bester and Güth (1998) but easier to work with. The bounds on the parameters will guarantee uniqueness of the equilibrium but we will relax them later.

If $\alpha = 0$, player 1 maximizes material payoffs. $\alpha > 0$ means that the player is altruistic that is takes into account the opponent's profit with a positive value, while $\alpha < 0$ represents spiteful preferences that is ones where opponent's profit reduces one's utility. The same description is valid for player 2's parameter β . The parameters α, β are common knowledge for the players. This assumption is important and the consequences of its relaxation will be analyzed in Section 4.

The players maximize their corresponding subjective utility functions $V_1; V_2$ with parameters α, β . The reaction functions derived from the first order conditions (second order conditions are always satisfied) are

$$x = \frac{k(\alpha + 1)y + m}{2}; y = \frac{k(\beta + 1)x + m}{2} \quad (3)$$

The slope of the reaction functions depends only on k since $\alpha + 1$ is always nonnegative. If $k > 0$ then the reaction functions are upward sloping, thus strategies are complements. If $k < 0$, the reaction functions are downward sloping and strategies are substitutes.

The unique equilibrium of the game is given by

$$x^*(\theta; -) = \frac{m(k(\theta + 1) + 2)}{4 - k^2(\theta + 1)(- + 1)}; y^*(\theta; -) = \frac{m(k(- + 1) + 2)}{4 - k^2(\theta + 1)(- + 1)} \quad (4)$$

Given the equilibrium strategies the fitness of a player is the material payoff she gets in the equilibrium. This defines an evolutionary game on preferences.

The material payoff of player 1 as a function of preference parameters and the implied equilibrium strategies of both players is

$$U_1^*(\theta; -) = \frac{m^2(k(\theta + 1) + 2)(k^2\theta(- + 1) + k(\theta - 1) - 2)}{(4 - k^2(\theta + 1)(- + 1))^2} \quad (5)$$

while the material payoff function of player 2 satisfies $U_2^*(-; \theta) = U_1^*(\theta; -)$.

An evolutionarily stable strategy for the game Γ on preference parameters is a parameter θ^* satisfying

- (a) $U_1^*(\theta^*; \theta^*) \geq U_1^*(\theta; \theta^*) \quad \forall \theta$
- (b) if $U_1^*(\theta^*; \theta^*) = U_1^*(\theta; \theta^*)$ then $U_1^*(\theta^*; \theta) > U_1^*(\theta; \theta)$.

To check the necessary condition for the condition (a), requiring a symmetric equilibrium of the evolutionary game Γ , we fix the second argument of $U_1^*(\theta; -)$, find maxima of it with respect to the first argument and equate the arguments. The first order condition is

$$\theta^* = \frac{k(- + 1)(k + 2)}{-k(k - 2) + k^2 - 2k - 4} \quad (6)$$

After equating $-$ to θ^* , possible candidates for evolutionarily stable strategies are

$$\theta_1^* = \frac{k + 2}{k}; \theta_2^* = \frac{k}{2 - k} \quad (7)$$

The boundary values $\theta^* = -1$ and $\theta^* = 1$ are possible candidates too. Consider $- = -1$. Then $U_1^*(0; -1) - U_1^*(-1; -1) = \frac{m^2(k+2)^2}{16} - \frac{m^2(k+1)}{4} = \frac{m^2k^2}{4} > 0$ if $k \neq 0$. Thus, $\theta^* = -1$ cannot be evolutionarily stable as it is not a best reply against itself in the evolutionary game Γ . If $- = 1$ then $\frac{\partial U_1^*(\theta; 1)}{\partial \theta} \Big|_{\theta=1} = -\frac{m^2k^2}{8(k+1)(k-1)^2} < 0$ thus $U_1^*(\theta; 1)$ is decreasing in θ around $\theta = 1$. Since $U_1^*(\theta; 1)$ is continuous, it implies that there exist an $\theta^0 < 1$

such that $U_1^a(\bar{r}; 1) > U_1^a(1; 1)$. Thus, $\bar{r} = 1$ is not a best reply against itself either and, therefore, is not evolutionarily stable.

Note that for $\frac{1}{2} < k < 1$ $\bar{r}_1^a$ is never between -1 and 1 thus we can ignore it. Condition (a) of evolutionary stability for $\bar{r}_2^a$ says

$$\begin{aligned} U_1^a\left(\frac{k}{2-k}; \frac{k}{2-k}\right) &> U_1^a(\bar{r}; \frac{k}{2-k}) \quad \Leftrightarrow 0 > 8\bar{r} \quad (1) \\ \frac{m^2(k+2)(k-2)}{16(k-1)} &> \frac{m^2(k+2)(k-2)(k^2(\bar{r}+1)^2-4)}{4(k^2(\bar{r}+1)+2k-4)^2} \quad \Leftrightarrow 0 > 8\bar{r} \quad (2) \\ (k^2(\bar{r}+1)+2k-4)^2 &> (k^2(\bar{r}+1)^2-4)4(k-1) \quad \Leftrightarrow 0 > 8\bar{r} \quad (3) \\ (k(\bar{r}+1)-2)^2 &> 0 > 8\bar{r} \end{aligned}$$

The last inequality is always satisfied and turns to equality only when $\bar{r} = \frac{k}{2-k}$. This means that $\bar{r}_2^a$ is the unique best response against itself and, therefore, evolutionarily stable. We have

Proposition 2.1 The unique evolutionarily stable preference parameter is $\bar{r}^a = \frac{k}{2-k}$.

This result extends the Bester-Güth example to spiteful preferences. For positive k the result is the same. Some amount of altruism is evolutionarily stable. News comes when k is negative. If $k < 0$ then $\bar{r}^a < 0$. This means that spiteful preferences are evolutionarily stable when material payoff function is sub-modular and, given the restrictions on the parameters, therefore the strategies of the game G are strategic substitutes. An interesting difference between positive and negative values of k is that as $k \rightarrow 1$, $\bar{r}^a \rightarrow 1$, that is altruism becomes "perfect" as degree of complementarity between strategies becomes perfect, while if $k \rightarrow \frac{1}{3}$, $\bar{r}^a \rightarrow \frac{1}{3}$, that is the spite does not gain full strength even when degree of substitutability is perfect. These results are illustrated in Figure 1.

An implication of the above result is that in games with strategic substitutes it pays to be spiteful i.e. to care also about relative payoff, though to a certain degree. In a Cournot oligopoly, for example, it is evolutionarily stable to have preferences not only over own profit but also over market share since maximizing own market share implies minimizing the one of the opponent and therefore minimizing opponent's profit (see Dufwenberg and Güth (1997)). In a Bertrand oligopoly it works the other way round. In our model it is evolution that makes certain preferences proliferate. If a player

Figure 1: Evolutionarily stable preferences

could choose and commit to certain preferences, she might rationally want to have preferences that do not maximize own profit but a combination of own and opponent's profits.

3 Further Extensions

We will stay in the framework of quadratic functions of Bester-Güth example while removing parameter restrictions.

A logical step further than extension of the preferences to include spiteful ones is to remove restrictions on the preference parameter altogether thus allowing it to vary from -1 to $+1$. When α can vary between -1 to $+1$, we can represent preferences from pure spite, i.e. minimizing opponent's payoff ($\alpha = -1$), to relative profit maximization ($\alpha = -1$), to maximizing own material payoff ($\alpha = 0$), to maximizing sum of the payoffs ($\alpha = 1$), to pure altruism, i.e. maximizing other's payoff ($\alpha = +1$). This range covers a much larger span of preferences than the original Bester-Güth model.

There are two problems with this extension. The first one is that if one keeps the restrictions $x \geq 0; y \geq 0$ then corner solutions appear too often. This will require further assumptions on the cases with no or more than one equilibria than the ones in the following paragraph. This will make the analysis more complicated without changing qualitative results. Furthermore, the assumption of nonnegative strategy space comes from oligopoly interpretation of the game. However, if one keeps strictly to oligopoly interpretation,

one has to check also nonnegativity of variables representing both quantities and prices. This will complicate analysis even further and lead to cases where no obvious extension of the evolutionary game to cases with no equilibria will be possible. Therefore we remove the nonnegativity restriction altogether and will consider as strategy space the whole real line.

The second problem is that it might happen that there is no equilibrium of the game with given preference parameters, or there is more than one (continuum) of equilibria. In such a case the evolutionary game $\dot{x}$ is not well defined. A possible approach is to extend the fitness function $U_1^a(\theta; -)$ to such preference parameters by continuity.

From equilibrium strategies equation (4) the game with preference parameters $\theta^0, -^0$ does not have a unique equilibrium if $4\beta > k^2(\theta^0 + 1)(-^0 + 1) = 0$. For such $\theta^0, -^0$ we extend the fitness function by continuity in the first argument as $U_1^a(\theta^0; -^0) = \lim_{\theta \rightarrow \theta^0} \lim_{- \rightarrow -^0} U_1^a(\theta; -)$. This limit always exists on the extended real line. We choose the continuity in the first argument since an evolutionarily stable strategy is a best reply to itself and with continuous function it is easier to find best replies.

Given this extension of the fitness function, the evolutionary game is well defined and we can apply the concept of evolutionarily stable strategy. All the derivations of the previous section come through except that now there are no boundary candidates and that $\theta_1^a = \beta \frac{k+2}{k}$ from (7) is a legitimate candidate for an evolutionarily stable strategy. With the above extension $U_1^a(\theta; \beta \frac{k+2}{k}) = \frac{m^2}{4} \theta$. Condition (a) for evolutionary stability is satisfied with equality for any θ . However, $U_1^a(\beta \frac{k+2}{k}; 0) = 0 < U_1^a(0; 0) = \frac{m^2}{(k+2)^2}$, thus condition (b) is not satisfied and $\theta_1^a = \beta \frac{k+2}{k}$ is not evolutionarily stable. The proof of evolutionary stability of $\theta_2^a = \frac{k}{2\beta k}$ comes through. We have

Proposition 3.1 Even with unrestricted preference parameters the unique evolutionarily stable preference parameter is $\theta^a = \frac{k}{2\beta k}$.

Notice that the slopes of the reaction functions (3) depend now on the preference parameters in an essential manner. Depending whether the preference parameter is smaller or larger than β , the game changes from one with strategic complements to one with strategic substitutes and vice versa depending on the sign of k . This indicates that the feature of strategic complementarity or substitutability is determined endogenously, depending on which value of the preference parameter is evolutionarily stable. A more fundamental feature is whether the material payoff function $U(x; y)$ is

sub- or super-modular. With $\frac{1}{2} < k < 1$ if the function is sub-modular ($\frac{\partial^2 U}{\partial x \partial y} = k < 0$) then the game with evolutionarily stable preference parameters exhibits strategic substitutes, while if the function is super-modular ($\frac{\partial^2 U}{\partial x \partial y} = k > 0$), the strategies of the resulting game are complements. A natural question to ask is whether this property holds in general, namely for other values of k .

The parameter k measures the degree of interdependence between players' strategies. High value of k shows high degree of interdependence, which do not occur in classical differentiated Cournot and Bertrand games but can occur in other economic games and, therefore, can be of interest.

Given the extension of the fitness function, the evolutionary game on preference parameters is well defined for any k . Thus we only have to check the two possible candidates for evolutionarily stable preference parameters from (7). The above proof that $\theta_1^* = \frac{k+2}{k}$ is not evolutionarily stable works for any $k \neq 0$. Therefore, we are left with only $\theta_2^* = \frac{k}{2-k}$ to check.

The second order condition for θ_2^* to be a best reply against itself requires that

$$\frac{\partial^2 U_1^*(\theta; \theta_2^*)}{\partial \theta^2} \Big|_{\theta=\theta_2^*} < 0 \iff \frac{k^2 m^2 (k+2)(k-\frac{1}{2})^5}{512(1-k)^3} < 0$$

The last inequality holds when $k \in [\frac{1}{2}; 1] \cup [2; +\infty)$. For other values of k θ_2^* is a strict local minimum therefore it cannot be evolutionarily stable. For boundaries one can check that when $k = \frac{1}{2}$ θ_2^* is evolutionarily stable while if $k = 1$ and $k = 2$ θ_2^* is not evolutionarily stable. This gives us the following

Proposition 3.2 There is

- (i) unique evolutionarily stable preference parameter $\theta^* = \frac{k}{2-k}$ if the parameter $k \in [\frac{1}{2}; 1) \cup [2; +\infty)$;
- (ii) no evolutionarily stable preference parameter otherwise.

While for $k \in [\frac{1}{2}; 1]$ the result is a natural extension of the previous result, indicating that evolutionarily stable preference parameter has some degree of spite ($\theta^* = \frac{1}{2}$ when $k = \frac{1}{2}$), a new result appears when $k > 2$. θ^* is negative and larger than one in absolute value when $k > 2$. Thus, a large degree of spite, up to minimizing opponent's payoff ($\theta^* \rightarrow -\infty$ when $k \rightarrow 2$ from above) is evolutionarily stable when the degree of interdependence between players' strategies is high, though it is a positive interdependence!

The result also shows that the question posed above has a negative answer. For some k outside $(\frac{1}{2}, 1)$ interval no evolutionarily stable preference parameter exists, so we cannot say anything about properties of the game played with the evolutionarily stable preferences. More important, when $k > 2$, the material payoff function $U(x; y)$ is super-modular while the game with evolutionarily stable parameter θ^* exhibits strategic substitutes. Thus, the property of perceived strategic substitutability or complementarity of the game played with evolutionarily stable preferences is determined endogenously and it does not have one-to-one relation with sub- or super-modularity of the material payoff function.

4 Incomplete Information

In all of the above it was assumed that the players knew each other preferences. This assumption is rather strong. In this section we relax the complete information assumption. Instead we will assume that players know the distribution of preferences in the population. Thus, each encounter is a Bayesian game where the set of types is a set of possible preferences and the payoff to each type is given by its corresponding subjective utility function V .

To analyze the evolutionary stability of certain preference parameter θ we will consider an invasion by a small number of mutants with some other preference parameter θ^0 . The proportion ϵ of mutants is common knowledge and arbitrarily small. Thus, we have a Bayesian game with two types $T = \{\theta, \theta^0\}$, with prior on the set of types $f_1, \dots, f_n$, and with the payoff functions for the two types

$$V_\theta(x; y) = U_1(x; y) + \theta U_2(x; y)$$

$$V_{\theta^0}(x; y) = U_1(x; y) + \theta^0 U_2(x; y)$$

where $U_i(x; y)$ are given in (1).

We are looking for a symmetric equilibrium of the game. In the equilibrium we can calculate the material payoffs of the two types. Denote the expected material payoff of the type θ in the equilibrium by U_θ^* and that of mutant type θ^0 by $U_{\theta^0}^*$. Since ϵ is arbitrarily small we can take limit when $\epsilon \rightarrow 0$.

Definition 4.1 A preference parameter θ^* is evolutionarily stable with incomplete information if $\lim_{\epsilon \rightarrow 0} U_{\theta^*}^* > \lim_{\epsilon \rightarrow 0} U_{\theta^0}^*$ for any mutant type θ^0 .

Let us denote the strategy of player 1 by $(x_{\otimes}; x_{\otimes^0})$ where $x_{\otimes}$ is strategy when the player is of type $\otimes$ and $x_{\otimes^0}$ is the strategy when the player is of mutant type $\otimes^0$. Let $(y_{\otimes}; y_{\otimes^0})$ be the strategies for player 2. To find an equilibrium one has to solve

$$\begin{aligned} \max_{x_1, x_2} & (1 - \alpha)^2 V_{\otimes}(x_{\otimes}; y_{\otimes}) + (1 - \alpha) \alpha V_{\otimes}(x_{\otimes}; y_{\otimes^0}) + \\ & + \alpha (1 - \alpha) V_{\otimes^0}(x_{\otimes^0}; y_{\otimes}) + \alpha^2 V_{\otimes^0}(x_{\otimes^0}; y_{\otimes^0}) \end{aligned} \quad (8)$$

and corresponding problem for player 2 which we omit because of symmetry. The solution of the problems leads to

$$\begin{aligned} x_{\otimes} &= \frac{m(\alpha k + \alpha^0 k + 2)}{2(\alpha k(1 - \alpha) + \alpha^0 k(1 - \alpha^0) + 2)}; \\ x_{\otimes^0} &= \frac{m(\alpha k(1 - \alpha) + \alpha^0 k(1 - \alpha^0) + 2)}{2(\alpha k(1 - \alpha) + \alpha^0 k(1 - \alpha^0) + 2)}. \end{aligned} \quad (9)$$

These are the strategies of the two types in the symmetric equilibrium. The limit of the expected material payoff of type $\otimes$ in the equilibrium

$$\lim_{\alpha \rightarrow 0} (1 - \alpha) U_1^{\pi}(x_{\otimes}; x_{\otimes^0}) + \alpha U_1^{\pi}(x_{\otimes}; x_{\otimes}) = \frac{m^2(1 - \alpha k)}{(\alpha k + k + 2)^2} \quad (10)$$

while the limit of the expected material payoff for type $\otimes^0$ is

$$\lim_{\alpha \rightarrow 0} (1 - \alpha) U_1^{\pi}(x_{\otimes^0}; x_{\otimes}) + \alpha U_1^{\pi}(x_{\otimes^0}; x_{\otimes^0}) = \frac{m^2(\alpha k + \alpha^0 k + 2)(\alpha k + \alpha^0 k + 2)}{4(\alpha k + k + 2)^2} \quad (11)$$

The difference between the two is

$$\begin{aligned} \lim_{\alpha \rightarrow 0} U_{\otimes}^{\pi} - \lim_{\alpha \rightarrow 0} U_{\otimes^0}^{\pi} &= \frac{k^2 m^2(\alpha^2 - \alpha^0^2)}{4(\alpha k + k + 2)^2} > 0 \quad () \\ \alpha^2 - \alpha^0^2 &> 0 \quad () \quad j \alpha^0 j > j \alpha j \end{aligned} \quad (12)$$

Therefore, we have

Proposition 4.1 The only evolutionarily stable preference parameter with incomplete information is $\alpha^{\pi} = 0$.

For any other $\theta \neq 0$ a mutant with the preference parameter closer to 0 achieves a higher payoff. Thus, with incomplete information only preferences which coincide with the material payoff survive evolutionary pressure thus supporting the claim of Alchian (1950) and Friedman (1953). A similar result that with incomplete information the material payoff preferences are evolutionarily stable under certain conditions was obtained also in Güth and Peleg (1997) and Ely and Yilankaya (1997). One of the conditions was the existence of a pure equilibrium. My conjecture is that with a mixed equilibrium involved in indirect evolution results might be different.

5 Conclusion

The indirect evolution approach helps to address the question which preferences will survive evolutionary pressure. However, one should not artificially restrict preference parameters. In this paper we extended the model of Bester and Güth (1998) to a larger set of preference parameters. We have shown that when spiteful preferences are allowed they can be evolutionarily stable for a large set of values of the parameter of the material payoff function.

The set of preferences was still restricted to a linear combination of own and opponent's profits. Of course, other preferences are possible, and even more interesting to analyze, for example, more "sympathetic" preferences of Rabin (1993) or more "emphatic" preferences of Bolle (1991) that might be evolutionarily stable in place of spiteful or altruistic preferences. The focus of the analysis was, however, on spiteful preferences and their ability to survive evolution in the given class of preferences.

Admittedly, this model still analyzes specific forms of the material payoff function and preference function. Already in this restricted framework there is a variety of results showing that some basic properties of the material payoff function used in literature on preference formation are not enough to draw general conclusions. The properties of the game played with the evolutionarily stable preferences may be different from the properties of the material payoff game.

The persistence of spiteful preferences, found in this paper, may be explained by the fact that a "spiteful" player gets higher payoff than a "normal" player for a rather general class of games. An analysis of interdependent preferences can be found in Koçkesen et al. (1997) though this result should be taken with caution as it does not necessarily mean that "spiteful" players will

wipe out "normal" ones. Much depends on the exact formulation of the model. In the random matching setting there is a counter-balancing effect that "spiteful" players cooperate less with each other than "normal" players. The result of evolutionary process depends much on the parameters of the material payoff function.

Preferences, different from maximizing own material payoff, are evolutionarily stable when players know each other preferences. In an incomplete information setting only maximizing preferences survive. This result is of a general character and supports the claim of Alchian (1950) and Friedman (1953) that rationality will be selected by evolution. Thus, the informational issues play a large role in the determination of the outcomes of the evolutionary process. This question deserves further research.

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