Path Dependence Without Denying Deliberation - An Exercise Model Connecting Rationality and Evolution -

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January 29, 2004

Abstract

Traditional game theory usually relies on commonly known decision rationality meaning that choices are made in view of their consequences (the shadow of the future). Evolutionary game theory, however, denies any cognitive deliberation by assuming that choice behavior evolves due to its past success (the shadow of the past) as typical in evolutionary biology. Indirect evolution does not consider the two opposite approaches as mutually exclusive but allows to combine them in various ways (Berninghaus et al., 2003). Here we provide a simple application allowing any linear combination of rational deliberation and path dependance, i.e. of the two "shadows".

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1. Introduction

Human life has developed in its early stages in closely knit societies, e.g. larger families or tribes (what is already true for primate species, see, for instance, Goodall, 1971, de Waal, 1982). It therefore is a natural idea to assume that behavior in such closely knit societies has evolved in a process of evolutionary selection rather than being rationally chosen. In modern societies we still interact with people who are closely related but also deal with strangers. Applying the same modes of behavior in anonymous interaction like when being related is by no means obvious (even in animal species one finds context dependent behavior, e.g. Kummer, 1992). Rather than relying on some, e.g. via social norms, preprogrammed behavior people could cognitively perceive how related they are and behave differently when interacting with more or less related others.

To analyze the coexistence of preprogrammed behavior on the one hand and of rationally deliberating on the other hand we distinguish an interval of close relatedness (or kinship degree) for which behavior is determined by evolutionary selection as well as an interval of loose relatedness where behavior is derived by (common knowledge of) rational decision making. As in most studies of evolutionary selection we rely on symmetric encounters of two individuals who each determine the behavior of one firm. This allows to define relatedness or kinship degree by one's share of the other firm's profit. Relatedness is closest when both individuals obtain half of both profits and lowest if neither individual participates in the other firm's profit. Whereas closely related individuals rely on evolved behavior, i.e. behavior has to satisfy the requirements of evolutionary stability, only loosely related individuals rationally deliberate their choices by carefully considering how related they are. It will be demonstrated that the result, e.g. whether one gains from more evolution and less deliberation or not, depends crucially on the measure of reproductive or evolutionary success.

More basically, our analysis demonstrates that strategic interaction cannot only be determined by assuming either commonly known rationality, as in orthodox game theory, or evolutionary selection alone, as in evolutionary game theory, but by combining the two approaches in all possible ways (see Berninghaus et al., 2003, for only two intermediate steps of combining the two approaches). Thus it is possible to decide for the example at hand which choices will be rationally decided (the shadow of the future) and which choices should rather evolve (via path dependence, resp. the shadow of the past).

2. The basic model

As usual in evolutionary biology (see Hammerstein and Selten, 1994, and Weibull, 1995, for surveys) we consider a symmetric (two-firm) game in normal form $G = (\pi_i, \pi_j; S_i, S_j)$ with

$$\pi_i(s_i, s_j) = \pi_j(s_j, s_i) \text{ for all } s_i \in S_i, s_j \in S_j$$

so that we can write $\pi(s, s)$ in case of equal behavior $(s_i = s = s_j)$ and

$$S_i = [0, 1/2] = S_j.$$

As a specific case[1] we will rely on

$$\pi_i(s_i, s_j) = (1 - s_i - s_j)\, s_i.$$

An individual confronts a continuum of such games which are defined by the (kinship) relatedness $t \in [0, 1/2]$ of the interacting players i and j. Via relatedness individual i does not only gain from firm i whose policy s_i individual i determines but also from the other firm j according to

$$u_i^t(s_i, s_j) = (1 - t)\, \pi_i(s_{i,} s_j) + t \cdot \pi_j(s_j, s_i).$$

One obvious interpretation of t is that individual i is the majority shareholder of firm i and thus determining s_i and only a minority shareholder of firm j and thus without influence on the behavior s_j of firm j.

[1] Any symmetric Cournot-duopoly market with quadratic profits can be reduced without loss of generality to such a description since one can freely choose the monetary unit as well as the unit(s) of sales amounts.

The continuous transition from complete teleology (for all $t \in [0, 1/2]$ the choices are rationally decided) to direct evolution (for all $t \in [0, 1/2]$ the choices evolve) relies on a threshold $\tau \in [0, 1/2]$ in the sense that for all $t \leq \tau$ one relies on commonly known decision rationality whereas for $t > \tau$ one assumes that the choices s_i, s_j will evolve. From

$$\frac{\partial}{\partial s_i} u_i^t (s_i, s_j) = 0 = \frac{\partial}{\partial s_j} u_j^t (s_{i,} s_j)$$

and the obvious symmetry of the solution $s_i^* (t) = s^* (t) = s_j^* (t)$ for $t \leq \tau$ we can determine the payoffs

$$u^t (s^* (t), s^* (t)) \text{ for } t \leq \tau.$$

In our specific example one derives

$$s^* (t) = \frac{1-t}{3-2t} \text{ and } u^t (s^* (t), s^* (t)) = \pi (s^* (t), s^* (t)) = \frac{1-t}{(3-2t)^2} \text{ for } t \leq \tau.$$

For $t > \tau$ the decisions $s_i (t), s_j(t)$ are evolving where we, as a first case, assume that (reproductive) success is purely measured by the own firm's profit.[2] Thus for $t > \tau$ an evolutionarily stable strategy $s^* \in [0, 1]$ must satisfy

(i) $\pi (s^*, s^*) \geq \pi (s, s^*)$ for all $s \in [0, 1]$ and

(ii) for any s with equality in (i) also $\pi (s^*, s) > \pi (s, s)$.

Note that any strict equilibrium (s^*, s^*) of G satisfies the conditions of an evolutionarily stable strategy s^*. Thus for $t > \tau$ the evolutionarily stable behavior is given by the unique strict equilibrium (s^*, s^*) of G which, in the case of our example, relies on

$$s^* = 1/3 \text{ and } \pi (s^*, s^*) = \frac{1}{9}.$$

Thus the overall payoff U depends on τ as

$$U^* (\tau) = \int_0^{\tau} \pi (s^* (t), s^* (t)) \, dt + \int_{\tau}^{1/2} \pi (s^*, s^*) \, dt.$$

[2] Since individual i decides about the policy s_i of firm i, one can simply assume that the sales policy is imitated which renders its firm more profitable.

In our example this corresponds to

$$U^*(\tau) = \int_0^{\tau} \frac{1-t}{(3-2t)^2}dt + \int_{\tau}^{1/2} \frac{1}{9}dt$$

$$= \frac{1-2\tau}{18} + \frac{1-\tau}{2(3-2\tau)} - \frac{\ln(6-4\tau)}{4} + \frac{\ln 6}{4} - \frac{1}{6}.$$

Clearly, the function $U^*(\tau)$ expresses how the profits $U_i(\tau) = U(\tau) = U_j(\tau)$ of the two interacting firms depend on the interval $[0, \tau]$ of low relatedness degrees t so that firms strategically react to their mutual relatedness and on the interval $[\tau, 1/2]$ of strong relatedness so that behavior evolves rather than being rationally chosen.

Since we assumed that in the case of evolution (reproductive) success is the profit of the own firm, the evolutionarily stable behavior s^* is less cooperative than the rational choice $s^*(t)$ due to

$$\pi(s^*, s^*) < \pi(s^*(t), s^*(t)) \text{ for all } 0 < t \leq \tau.$$

One may argue that this contradicts our intuition for the effects of relatedness or kinship (see, for instance, Trivers, 2002). Let us therefore assume that (reproductive) success is not the profit of one's own firms but rather of both firms. Clearly, then the unique evolutionarily stable strategy s^+ is the one maximizing the sum

$$\pi_i(s_i, s_j) + \pi_j(s_j, s_i)$$

what implies $s^+ = 1/4$ and $\pi^+ = 1/8$ in our example. Thus $U(\tau)$ becomes now

$$U^+(\tau) = \int_0^{\tau} \frac{1-t}{(3-2t)^2}dt + \int_{\tau}^{1/2} \frac{1}{8}dt$$

$$= \frac{1-2\tau}{16} + \frac{1-\tau}{2(3-2\tau)} - \frac{\ln(6-4\tau)}{4} + \frac{\ln 6}{4} - \frac{1}{6}.$$

Now $U^+(\tau)$ decreases with τ whereas $U^*(\tau)$ is increasing with τ. This illustrates that whether one gains from more evolution and less deliberation depends crucially on the definition of (reproductive) success which, via path dependence, determines which behavior is selected.

3. Conclusions

The main motivation for this study is a methodological one. We want to illustrate by a simple example that one can substitute continuously (commonly known) rational deliberation by adaptative behavior and vice versa. Thus the question is not whether one wants to rely on perfect rationality, i.e. the shadow of the future, or evolutionary selection, i.e. the shadow of the past, but rather for each behavioral aspect whether it is deliberated or just evolving.

The class of games that has been considered is, of course, rather special. To generalize our results one could, for instance, allow for complementary as well as substitute products of the two firms. The only difficulty here is to obtain a closed form-formula for $U(\tau)$. There may be other contexts where a similar continuous transition from othodox to evolutionary game theory may be interesting. The general intuition could be that one relies on adaption when there is little structural knowledge about the decision environment and that deliberation is determining choice behavior when one is better informed how success depends on choices.

References

[1] Berninghaus, S., Güth, W., Kliemt, H. (2003). From teleology to evolution: Bridging the gap between rationality and adaptation in social explanation. *Journal of Evolutionary Economics* 13(4), 385-410.

[2] De Waal, F. (1982). Chimpanzee Politics. London.

[3] Goodall, J. (1971). In the Shadow of Man. London.

[4] Hammerstein, P., Selten, R. (1994). Game theory and evolutionary biology, in: *Handbook of Game Theory.* Vol. 2, eds. Aumann, R. and Hart, S., North-Holland, 929-993.

[5] Kummer, H. (1992). Weiße Affen am Roten Meer - Das soziale Leben in der Wüste. Zürich

[6] Trivers, R. L. (2002). Natural Selection and Social Theory. Selected Papers of Robert Trivers. New York: Oxford University Press.

[7] Weibull, J. (1995). Evolutionary Game Theory. Massachusetts: MIT Press. *Finanzarchiv* 58: 188-206.