Behavioural attainability of evolutionarily stable strategies in repeated interactions

Ralph Dobler & Mathias Kölliker

University of Basel, Zoological Institute, Evolutionary Biology
Vesalgasse 1, 4051 Basel, Switzerland

Introduction

Theory for the evolution of social interactions often neglects the dependence of behaviour on previous encounters. In reality, such dependences are likely to be widespread, generating complex behavioural dynamics which have to be considered to understand the evolution of repeated social interactions.

The Model

Supply function: S = g(D), demand function: D = f(S). Behavioural stability of dynamic interactions (Figure 1): Converging interactions represent behaviourally stable strategies (BSSs).

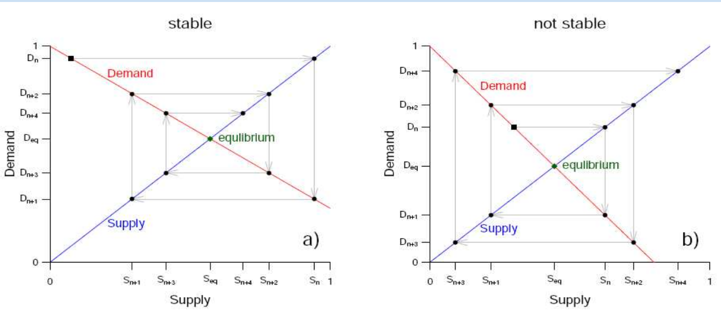

Figure 1: Dynamics of repeated interactions. The demand function and the inverted supply function are superimposed to illustrate the interaction graphical (Hussell, 1988). a) A behaviourally stable parent-offspring interaction converges toward the equilibrium. b) An interaction that diverges away from the equilibrium is behaviourally not stable.

General stability conditions for a behavioural interaction at the equilibrium (following Otto & Day (2007) for discrete-time dynamic systems):

$$-1 < f'(S_{eq})g'(D_{eq}) < 1$$

Stability conditions hold over the whole value range for linear and power functions (numerical simulations). Half of the function combinations of supply and demand converge and represent BSSs (Figure 2).

Application of the BSS concept on current ESS models (Mock & Parker, 1997) revealed that ESS are not necessarily behaviourally stable (equilibria behaviourally not attainable (Table 1)).

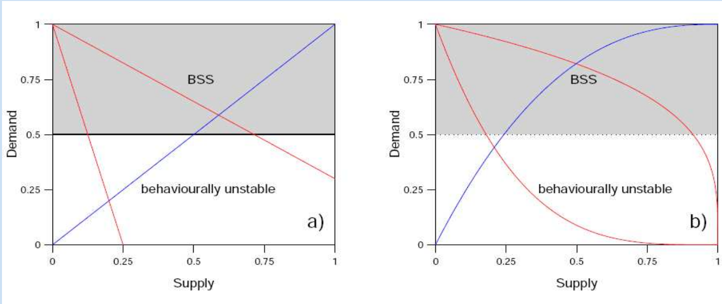

Figure 2: Supply and demand functions (reaction norms) intersecting in the grey shaded area fulfil the stability conditions and represent behaviourally stable strategies (BSSs). a) linear functions, b) power functions.

Table 1: Behaviourally attainability of ESS. The behavioural attainability of ESS depends on the combination of begging costs and benefit of provisioning. 'Yes': ESS and BSS; 'no': ESS but no BSS; 'NA': ESS outside value range.

Provisioning benefit parameter q	Begging cost parameter p: -0.05	-0.1	-0.15	-0.2	-0.25	-0.3	-0.35	-0.4	-0.45	-0.5
0.5	*NA*	YES	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
1	*NA*	YES	YES	YES	YES	YES	YES	no	no	no
1.5	*NA*	YES	YES	YES	YES	YES	YES	no	no	no
2	*NA*	YES	YES	YES	YES	YES	YES	no	no	no
2.5	*NA*	YES	YES	YES	YES	YES	YES	no	no	no
3	*NA*	YES	YES	YES	YES	YES	YES	no	no	no
3.5	*NA*	YES	YES	YES	YES	YES	YES	no	no	no
4	*NA*	YES	YES	YES	YES	YES	YES	no	no	no
4.5	*NA*	YES	YES	YES	YES	YES	YES	no	no	no

Conclusions

Behaviourally stability of the equilibrium and hence the behavioural stability of the strategy (BSS) is a necessary condition for an ESS to be evolutionarily stable in a stricter sense. Supply and demand functions (behavioural reaction norms, Smiseth *et al*., 2008) have to evolve over time to reach evolutionary stability. This is not restricted to the context of parent-offspring interactions but can be applied to any fast-responding short-term interaction.

Acknowledgements

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References

Hussel, D.J.T., 1988. Supply and demand in tree swallow broods: a model of parent-offspring food-provisioning interactions in birds. *AmNat* 131, 175-202.

Mock, D. & Parker, G., 1997. The evolution of sibling rivalry. Oxford Series in Ecology and Evolution. Oxford University Press. Oxford, UK.

Otto, S.P. & Day, T., 2007. A biologist's guide to mathematical modeling in ecology and evolution. Princeton University Press, Princeton, NJ.

Smiseth, P.T., Wright, J. & Kölliker, M., 2008. Parent-offspring conflict and co-adaptation: behavioural ecology meets quantitative genetics. *ProcB* 275, 1823-1830.