BONN ECON DISCUSSION PAPERS

Discussion Paper 5/2003

Learning to Like What You Have - Explaining the Endowment Effect

by

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March 2003

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Learning to Like What You Have – Explaining the Endowment Effect*–

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March 17, 2003

Abstract

The *endowment effect* describes the fact that people demand much more to give up an object than they are willing to spend to acquire it. The existence of this effect has been documented in numerous experiments. We attempt to explain this effect by showing that evolution favors individuals whose preferences embody an endowment effect. The reason is that an endowment effect improves one's bargaining position in bilateral trades. We show that for a general class of evolutionary processes strictly positive endowment effects will survive in the long run.

JEL– classification numbers: C73, C79, D00.
Key words: endowment effect, evolution, bargaining.

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*We thank three very careful referees and the editor for asking some fundamental questions that lead to a quite different paper. Bob Aumann, Ted Bergstrom, Lorne Carmichael, Simon Gächter, Andras Löffler, Clemens Puppe, Frank Riedel, Bill Sandholm and seminar participants at the universities of Bonn, Tilburg, Uppsala, the Stockholm School of Economics, and Penn State University contributed very helpful comments on an earlier version of this paper.

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"I am the most offensively possessive man on earth. I do something to things. Let me pick up an ash tray from a dime–store counter, pay for it and put it in my pocket – and it becomes a special kind of ash tray, unlike any on earth, because it's *mine*."

Ayn Rand (The Fountainhead)

1 Introduction

The endowment effect describes the fact that people demand much more to give up an object than they are willing to spend to acquire it (Thaler, 1980). This phenomenon – that people attach higher values to goods if they are in their possession – is very well established in the experimental literature (see Kahneman *et al.*, 1991, for an overview). In a famous experiment Kahneman *et al.* (1990) distributed coffee mugs to every other student in a classroom. When asked to state their valuations for the mugs, the "mug–owners" had on average a much higher valuation than the other students. In fact, the willingness to accept (WTA) by the mug–owners was about twice as high as the willingness to pay (WTP) by the remaining students. Such extreme differences seem unreasonable but they have been confirmed in countless experiments (see e.g. Knetsch, 1989, or Knetsch and Sinden, 1984) and must by now be accepted as a stylized fact.[1]

The endowment effect is not just an experimental curiosity. As pointed out by Kahneman *et al.* (1990), the endowment effect questions the validity of the Coase Theorem. The Coase Theorem states that the allocation of property rights does not influence the way external effects are internalized by the market. However, if the endowment effect influences the valuations, property rights do matter. One real life example where the endowment effect might play an important role is the market for so–called "reverse mortgages" (see e.g., Weinrobe, 1988). Reverse mortgages are contracts in which a home owner sells back his property to the bank in exchange for an annuity often including a life insurance component. These contracts seem to be sensible instruments if one is risk averse and wants to smooth consumption over the life cycle. Although reverse mortgages are available in the US since 1981, there has been little demand for them (Venti and Wise, 1990). The

[1] Kahneman *et al.* (1990) alone report experiments with more than 700 subjects. The experiments cannot be explained by Hanemann's (1991) observation that WTA and WTP can differ substantially if the goods in question have no good substitutes. All objects used in the experiments were readily available elsewhere.

endowment effect may present an explanation for this lack of demand since it could lead home owners to attach excessively high values to their property.

Knez and Smith (1987) and Coursey *et al.* (1987) challenged the view that the experiments are proof for preferences that depend on endowments. Coursey *et al.* found that the differences between WTA and WTP are smaller when a Vickrey auction is used to determine the valuations or when subjects have the opportunity to gain experience in a market setting – however, substantial differences between WTA and WTP remain.[2] They argue that the observed behavior may be due to the fact that subjects mistakenly apply bargaining behavior which is sensible in normal bargaining situations but inappropriate in the experiments, namely to understate one's WTP and to overstate one's WTA. Coursey *et al.* (1987) conclude that the endowment effect should play a lesser role in market environments or auctions. In reaction to this Kahneman *et al.* (1990) used markets in their experiments and still found a very strong endowment effect. It seems that the observed endowment effect cannot be explained by strategic considerations. Rather, it truly reflects *endowment dependent preferences.*

Preferences of an individual are determined by his genes and/or his socialization. In both cases they can be regarded as the product of an evolutionary process, either biological or cultural. Therefore, if one wants to explain the existence of the endowment effect, one has to ask for the evolutionary benefits of having such preferences. Notice that such reasoning does not imply that the endowment effect is "optimal". Rather, it must have an advantage over preferences without an endowment effect. And this is what we are going to show.[3]

The purpose of our paper is to analyze theoretically whether in a plausible evolutionary environment people are better off with an endowment effect than without. Furthermore, we ask whether plausible evolutionary dynamics lead to populations which exhibit an endowment effect. The advantage of this approach is that it lends transparency and discipline in what one can assume about preferences. It lends transparency because it spells out the assumptions that are required to make such preferences survive. And it lends discipline because it is *not* possible to justify any arbitrary preference

[2] For a critique of the Coursey *et al.* experiment see Knetsch and Sinden (1987).

[3] Of course, one can always think of some features that would be even better than those we observe like even bigger brains or improved night vision for humans. Yet, they have never developed. So, the only meaningful claim one can make is that *if* something has developed and has remained, it must have an edge over features that used to exist. In that sense, we will show that having some endowment effect has been better than having none.

in an evolutionary model (as the critics of this approach sometimes claim). To make this point as stark as possible consider the case of preferences that exclusively attach weight to goods one does *not* own. Clearly, one would be very hard pressed to come up with a plausible evolutionary environment that makes these preferences survive. On the other hand, we will see that a quite plausible evolutionary environment, based on bargaining situations, enhances the development of the endowment effect.

So, let us briefly sketch our model and discuss the realism of its assumptions. There are two groups of individuals endowed with different goods, x–owners and y–owners.[4] Individuals from both populations are randomly matched to engage in bilateral barter. After trade has been completed agents consume their x, y–bundle. Their fitness depends directly on consumption—with more "balanced diets" yielding higher fitness. Individuals' utility may, however, differ from fitness. In particular, individuals may have an increased preference for the good they have been endowed with. While fitness determines their evolutionary success, utility drives the outcome of the trade. In particular, we assume that agents exchange x and y according to the Nash bargaining solution.

In general, developing an endowment effect has two effects in this model. First, an endowment effect distorts the marginal rate of substitution at which a person is willing to trade away from the "objective" marginal rate of substitution given by the fitness function. But secondly, the endowment effect moves the threat point in one's favor. Our main result is that individuals with a strictly positive endowment effect will never die out in the long run. Preferences that exhibit an endowment effect can therefore be explained by the success people endowed with these preferences had in the past.[5]

1.1 Bargaining and evolution

> "Any comprehensive theory of hominid evolution and contemporary human social behavior will rest heavily upon a theory

[4] An alternative interpretation of our model is that agents are each period randomly endowed with one of the two goods and have endowment-contingent preferences.

[5] Notice the difference of this explanation to that of Coursey *et al.* (1987). We do not assume that individuals misrepresent their true valuations for strategic reasons. Crawford and Varian (1979) and Sobel (1982) have shown that in the context of the Nash-bargaining solution there exist strategic incentives to misrepresent the preferences. However, as already mentioned, the endowment effect also shows up in settings where people have no incentives to lie about their preferences, e.g. in market situations. Here, we assume that people behave in accordance with their *true* preferences, and it turns out that people with an endowment effect do better in evolutionary terms than those without.

of resource acquisition."
KAPLAN AND HILL (1992)

Our argument that the endowment effects is a result of evolution operating on preferences requires a number of steps. First, we need to argue that bilateral bargaining is, and always has been, an important feature of human life and that advantageous bargaining outcomes (i.e. more resources) translate into higher survival probabilities and evolutionary success of the individuals endowed with these preferences. Second, we need to show that the endowments effect has an effect on bargaining outcomes.

Evidence from anthropology supports our assumption that groups engaged in barter. In fact, the earliest forms of trade were *between* different tribes, while within tribes exchange took mainly the form of reciprocal gift exchange (Polanyi, 1968; Haviland, 1999). Moreover, anthropologists show that, as in our model, intratribal trade was mainly triggered by "localization of natural resources decree[ing] tribal specialisation" (Herskovits, 1940, p. 17). Distances between tribes that engaged in trade were often huge[6] and given the costs of travelling in ancient times, it seems also safe to assume that traders had very limited choice in choosing their partners which is reflected in our matching assumption.

Another building block is the assumption that fitness is determined by consumption of resources (the agents' "diet"). Studies that prove this link are numerous. First of all, there is ample evidence for a causal relation between dietary deficiencies and own health. Bringer, Lefebvre, and Renard (1999) document, for example, how malnutrition can cause numerous ovulatory disorders which *directly* affect fitness.[7] Links between nutrition and diseases have also been documented for hunter and gatherer societies (see, for example, Armelagos, Barnes, and Lin, 1996). Moreover, there is strong evidence linking dietary deficiencies to the health (and therefore chances of survival) of offspring. Prenatal exposure to famine and, more general, maternal malnutrition have been linked, for example, to diabetes (Petry and Hales, 2000) and to cardiovascular disease in later life (Barker *et al.,* 1993).

The second step of our argument requires connecting endowment preferences to bargaining outcomes. Is it justified to rely on the assumption of bilateral trade and, in particular, on the Nash bargaining solution? In our view the anthropology literature is supportive of these assumptions.

[6] See, for example, Fagan (1991) who deals with ancient trade networks in North America.

[7] For primates (*hanuman langur*) it has also been shown that well-nourished females have a higher probability of conception (Koenig, Borries, Chalise, and Winkler 1997).

First of all, there is strong evidence from nonindustrial societies that exchange happened face to face[8] rather than via anonymous clearing procedures (Haviland, 1999). Concerning trading procedures Haviland (p.198) writes: "Relative value is calculated, and despite an outward show of indifference, sharp trading is the rule (...)." So, bargaining models seem quite appropriate for our study.

Like all solution concepts in cooperative game theory, the Nash bargaining solution is meant as a plausible short cut for situations in which the exact bargaining protocol cannot be specified. The Nash bargaining solution can be supported through the Rubinstein bargaining model (1982). But more importantly in our context, it can be shown to be the outcome of a simple, boundedly rational, adaptive learning process (Young, 1993). Thus, the Nash bargaining solution's implicit assumption that traders recognize each other's type can be seen as a mere short–cut to a fully–fledged dynamic model where agents eventually play as if they were knowing each other's type.[9]

The experimental evidence about the predictive power of the Nash bargaining solution is somewhat mixed. For unstructured bargaining situations the invariance of the outcome with respect to linear transformation of utilities, which is one of the basic assumptions of the Nash bargaining solution, might hold or fail, depending on the information structure and the (a)symmetry (see e.g. Nydegger and Owen, 1975, or Roth and Murningham, 1982). Note that our results should be robust against taking alternative bargaining solutions as long as they depend sufficiently strong on the *status quo ante*. Therefore, it is only important that the bargaining solution depends sufficiently on the threat point.

In contrast to a threat point, an outside option does not influence the subgame perfect equilibrium for structured alternating offer bargaining games

[8] An exception is what anthropologists call "silent trade." Coon (1948), for example, discusses exchange between a forest people and an agricultural people who leave goods to be traded on the boundaries of their areas. Trading here is dynamic and goes through various implicit negotiation stages. First, one group leaves a bundle of goods on the boundary of their territory. Then, the second group arrives, inspects the bundle and leaves a second bundle of goods *without* taking away the first bundle. In the third stage, the first group arrives again and inspects the second bundle. If they are satisfied with the second bundle, they take it and leave. If not, they leave both bundles. It is then up to the second group to either increase its offer or to withdraw it. And so on.

[9] At the cost of higher complexity we could replace the assumption of perfect type recognition by assuming that agents receive noisy signals about others' types. Qualitatively, this would not affect our results. See, for example, Bohnet, Frey, and Huck (2001, Appendix C) who explicitly introduce noisy signals into a model of preference evolution.

(unless it is binding), and this theoretical prediction was experimentally confirmed e.g. by Binmore *et al.* (1991). However, we believe that the initial endowment of agents should be interpreted as a threat point and not as an outside options. An outside option, as the name suggests, is an option that the agent could take up if the bargaining does not lead to a satisfactory outcome. In our case, the agent already owns his initial endowment at the beginning of the bargaining process. Even if the bargaining is framed in the somewhat restrictive framework of alternating offer bargaining, our assumption can be justified either because there may be an exogenous break–down probability (which seems plausible) or by considering the endowment as an inside option (Muthoo, 1999). The latter is justified if hunters and gatherers, say, consume there endowments (and replenish the reserves) as long as there is no agreement. Furthermore, for less structured situations even outside options were found to have a significant impact on the outcome (see Henning–Schmidt, 2001 and Henning–Schmidt *et al.*, 2002). Since such situations seem to better reflect "naturally" occurring bargaining situation, we are quite confident that our modelling choices reflect the decisive aspects of the outcome of bargaining.

1.2 Related literature

There are several papers in the recent literature that study bargaining behavior from an evolutionary viewpoint, e.g. Young (1993), Gale *et al.* (1995), Huck and Oechssler (1999), Ellingsen (1997) and Carmichael and MacLeod (1996). The last three papers are closest to the current paper. Huck and Oechssler (1999) study the evolution of preferences in the Ultimatum Game. Ellingsen's (1997) paper is concerned with the evolution of bargaining behavior in the Nash demand game. In his setup there are two types of players, "rational" (or responsive) types and "obstinate" types. Ellingsen shows that only a mix of responsive types and obstinate types who demand an even split can be evolutionary stable.

In independent work Carmichael and MacLeod (1996) arrive at similar conclusions as the current paper. They show for an example with a square–root fitness function that it may be advantageous to develop an endowment effect in bargaining situations. However, they do not use (static or dynamic) evolutionary concepts. Rather, they look for efficient Nash equilibria, which are, as the recent literature on evolutionary games shows (see e.g. Kandori, Mailath and Rob, 1993), not always the equilibria selected by evolution.

Finally, the current paper is part of a larger literature (beginning with Güth and Yaari, 1992) which is based on the indirect evolutionary approach.[10] A number of contributions have shown that evolution may yield preference that deviate from the underlying fitness function (see e.g. Sethi and Somanathan, 2001, and Heifetz *et al.*, 2002, for quite general formulations). As shown by Ok and Vega–Redondo (2001) and Ely and Yilankaya (2001) all of those approaches require that preferences of opponents' are (at least partly) observable (or that the population is sufficiently small, as in Huck and Oechssler, 1999). See Frank (1988) for arguments why this is often not an unreasonable assumption and Güth, Kliemt, and Peleg (2000) for an evolutionary justification of "type signalling".

The remainder of the paper is organized as follows. In the next section we describe the basics of the model. Then we analyze the bargaining process. In Section 4 we show that the endowment effect is evolutionarily advantageous and in Section 5 we analyze the dynamics of the evolutionary process. In the last section conclusions are drawn. Most proofs are relegated to the Appendix.

2 The model

Consider an economy with two goods, x and y. There are two types of individuals, those who have an endowment of x only, the "x–owners", and those with an endowment of y, the "y–owners".[11] Each individual has an endowment of one divisible unit of his good. We suppose that there is a continuum of individuals of each type with the relative size of the two populations being constant. Individuals from both populations are randomly matched to engage in bilateral trade.

Individuals derive fitness from the consumption of x and y according to the objective fitness function $\overline{F} : [0,1]^2 \to \mathbb{R}$, which is the same for all individuals. We assume that $\overline{F}(\cdot,\cdot)$ is strictly increasing in both arguments, strictly concave, twice continuously differentiable and bounded. The cross–derivative $\overline{F}_{xy}(\cdot,\cdot)$ is (weakly) positive.[12] To avoid boundary solutions, we assume Inada–like conditions, namely that $\overline{F}_x(0,y) = \overline{F}_y(x,0) = \infty$, for all $x, y > 0$.

Individuals also derive subjective utility from the consumption of x and y, which may differ from objective fitness. In particular, we assume that

[10] See also the recent symposium in the *Journal of Economic Theory (2001).*

[11] A referee suggested to analyze a 'symmetrized' game in which an individual may play in both roles (and have an endowment parameter for both roles). This modification does not change our main result. If an endowment parameter of zero is not an equilibrium in our asymmetric game, then it cannot be an equilibrium in the symmetrized game.

[12] This assumption is being used in the proof of Proposition 1.

x–owners may develop a utility function of the form

$$\overline{U}_1(x_1, y_1) := \overline{F}(x_1, y_1) + e_1 x_1.$$

Similarly for y–owners

$$\overline{U}_2(x_2, y_2) := \overline{F}(x_2, y_2) + e_2 y_2.$$

The additional term with the *endowment parameter* e_i signifies an increased preference for the good one owns if $e_i > 0$. We also allow for a negative endowment effect ($e_i < 0$), which is equivalent to having an increased preference for the good one does *not* own. It seems sensible to restrict negative endowment parameters so that goods do not turn into 'bads'. Otherwise, individuals could increase their utility by throwing goods away. Thus, we assume that marginal utilities of both goods are strictly positive for both individuals. Let $I \subset \mathbb{R}$, with 0 in the interior of I, denote an arbitrary compact interval from which e_1 and e_2 are chosen, and which satisfies this requirement.

To keep the problem tractable, we restrict our attention to this class of preferences. But notice that the main result of our paper does not depend on this restriction. Clearly, preferences without an endowment effect ($e_i = 0$) cannot become stable if we allow for a broader class of alternative preferences.

For notational convenience we will from now on work with incremental fitness, which is the difference between $\overline{F}(x, y)$ and the fitness an individual receives from consuming his endowment. For x–owners incremental fitness is

$$F(x, y) := \overline{F}(x, y) - \overline{F}(1, 0)$$

and similarly for y–owners

$$F_2(x, y) := \overline{F}(1 - x, 1 - y) - \overline{F}(0, 1),$$

where we generally drop the subscript "1" , i.e. $x = x_1, F(x, y) = F_1(x, y)$ etc. Furthermore, since total endowment of both goods is one, we can replace x_2 by $1 - x$. Partial derivatives of the y–owner are denoted by $F_{2z}(x, y) := F_z(1 - x, 1 - y)$ for $z = x, y$.

Since affine transformations of the utility function do not affect the analysis, we normalize the utility functions in the following way.

$$U(x, y) := F(x, y) + e_1 x$$

$$U_2(x, y) := F_2(x, y) + e_2(1 - y).$$

Note that with this transformation $U(0, 0) < U(1, 0) = e_1 < U(1, 1)$.

3 The bargaining process

Consider now a bargaining situation in which two individuals, one from each type, are randomly matched to bargain about x and y. Let us denote the feasible set of allocations in utility space by S. Since $\bar{F}(x,y)$ is bounded and strictly concave, S satisfies all standard assumptions, in particular, S is bounded, closed and strictly convex. Due to our normalization the threat point d is simply given by (e_1, e_2).

As usual, the Nash bargaining solution is obtained by maximizing the Nash product

$$N(x,y) := (U(x,y) - e_1)(U_2(x,y) - e_2) = (F(x,y) + e_1 x - e_1)(F_2(x,y) - e_2 y)$$

under the constraints of individual rationality. Let $(x^*(e_1,e_2), y^*(e_1,e_2))$ denote the solution to the problem

$$\arg \max_{(x,y)\in[0,1]^2} N(x,y) \text{ s.t. } U(x,y) \geq e_1 \text{ and } U_2(x,y) \geq e_2. \qquad (1)$$

Note that due to the Maximum Theorem of Berge (1963) $x^*(e_1,e_2)$ and $y^*(e_1,e_2)$ are convex–valued, upper hemi–continuous correspondences. In the following three lemmata we will establish several properties of the Nash bargaining solution which will be useful later on.

Lemma 1 *The Nash bargaining solution* (x^*, y^*) *is unique.*

Proof See Appendix.

Note that uniqueness of the Nash bargaining solution implies that $x^*(e_1,e_2)$ and $y^*(e_1,e_2)$, and hence $F(x^*,y^*)$, are continuous functions in e_1 and e_2.

Lemma 2 *The Nash bargaining solution* (x^*, y^*) *makes both individuals strictly better off than with their initial endowments.*

Proof See Appendix.

Lemma 3 *The Nash bargaining solution* (x^*, y^*) *is always in the interior of* $[0,1]^2$.

Proof See Appendix.

With these lemmata as preparation we can now turn to the question whether an endowment effect proves to be an advantage in evolutionary terms.

4 Does it pay to develop an endowment effect?

The outcome of the Nash bargaining solution depends on the endowment parameters e_1 and e_2. In case of a positive endowment parameter ($e_i > 0$), there are two opposing effects. On the one hand, developing a positive endowment effect changes the threat point in one's favor. But on the other hand, the endowment effect distorts the consumption mix away from the optimal mix (in terms of fitness) since the marginal rates of substitution in terms of fitness and in terms of utility become different.

Now compare an x–owner with endowment parameter $e_1 \leq 0$ and an x–owner with a slightly positive endowment parameter. Which of the x–owners would be better off in these encounters? The next proposition shows that, in fact, it always pays for the x–owner to develop at least a small positive endowment effect. By symmetry the equivalent statement holds for the y–owner. Individuals with a small endowment effect earn more in terms of fitness than others without an endowment effect or with a negative endowment effect. This is due to the fact that the positive effect caused by the improvement of the bargaining position overcompensates the negative effect caused by the distortion of the marginal rate of substitution.

In case of negative endowment parameters both effects point in the same direction as the threat point is moved to one's disadvantage. Thus, it should not be surprising that negative endowment parameters cannot be advantageous.

Proposition 1 *Consider the reduced form fitness function $F(x^*(e_1, e_2), y^*(e_1, e_2))$ resulting from the Nash bargaining solution. Then for all endowment parameters $e_1 \leq 0$ fitness is strictly increasing in e_1.*

Proof See Appendix.

Proposition 1 is concerned with the value of having an endowment effect vis à vis a trading partner with a specific given endowment parameter. In our model, however, the partner is chosen randomly from a population, which is, in general, not monomorphic with respect to the endowment parameter. Hence, one has to analyze the expected value of an endowment effect vis à vis a distribution of different partners, i.e. a distribution of endowment parameters. In the next section we shall analyze the dynamics associated with such a population "fitness game".

5 Evolutionary dynamics

In this section we will introduce evolutionary dynamics in order to investigate whether preferences that embody a strictly positive endowment effect will survive in the long run. In order to define the notion of average fitness in the infinite populations of $x-$ and y–owners, respectively, we need to introduce some notation. Let μ_i be a probability measure on the measure space $(I, \mathcal{B})$, where $\mathcal{B}$ denotes the Borel σ–algebra on I (recall that I is a compact interval in $\mathbb{R}$). We denote by $\Delta(I)$ the set of all probability measures on I. The probability measure μ_i specifies the distribution of endowment parameters ("types") in population i. A population "fitness game" is defined by the pair of probability measures μ_1, μ_2, and by a pair of average fitness functions

$$\begin{aligned} \widetilde{F}_1(e_1, \mu_2) &= \int_I F(x^*(e_1, e_2), y^*(e_1, e_2)) d\mu_2(e_2) \\ \widetilde{F}_2(\mu_1, e_2) &= \int_I F_2(x^*(e_1, e_2), y^*(e_1, e_2)) d\mu_1(e_1), \end{aligned}$$

which specifies the average fitness a type e_i receives in population i given the distribution of types in population j.

The evolutionary dynamics describe how the distribution of types in the two populations changes over time. Let $\omega := (\mu_1, \mu_2)$ be a typical element of $\Delta(I)^2$. We are interested in the behavior of the system of differential equations $\dot{\omega} = (\dot{\mu}_1, \dot{\mu}_2) = \varphi(\omega)$, where $\dot{\mu}_i$ denotes the time derivative of μ_i. The flow of the system starting from an initial state ω^0 is denoted by $\xi^t(\omega^0)$. A state ω is called stationary if $\xi^t(\omega) = \omega$ for all t. A stationary state ω is (Lyapunov) *stable* if for every neighborhood U of ω there exists a neighborhood U' of ω in U such that $\xi^t(\omega^0) \in U$ for all $\omega^0 \in U'$ and $t \geq 0$.[13] It is called unstable otherwise.

It is slightly unfamiliar to study dynamics on the space of signed measures.[14] However, the theory of ordinary differential equations carries over to Banach spaces without any substantial problems. See Oechssler and Riedel (2001) for some mild technical assumptions that ensure existence and uniqueness of trajectories under $\dot{\omega}$. We say that evolutionary dynamics are regular if $\dot{\mu}_i(I) = 0$ and $\dot{\mu}_i(A) = 0$ for all $A \in \mathcal{B}$ with $\mu_i(A) = 0$. Fur-

[13] Neighborhoods are defined with respect to the weak topology (see Oechssler and Riedel, 2002, for details).

[14] Since $\Delta(I)$ is not a vector space, we work with the linear span of Δ, that is the space of all signed measures $\mathcal{M}$. Endowed with the variational norm, $\mathcal{M}$ is a Banach space (see Oechssler and Riedel, 2001).

thermore, we say that dynamics are payoff monotonic if (the set of) types with higher average fitness have higher growth rates, or formally

Definition 1 *A regular dynamic* $\varphi(\omega)$ *is called* payoff monotonic *if for* $i = 1, 2$ *and for all* A *and* $A' \in \mathcal{F}$, *with* $\mu_i(A), \mu_i(A') > 0$,

$$\frac{1}{\mu_i(A)} \int_A \tilde{F}(e_i, \mu_j) d\mu_i(e_i) > \frac{1}{\mu_i(A')} \int_{A'} \tilde{F}(e_i, \mu_j) d\mu_i(e_i) \Leftrightarrow \frac{\dot{\mu}_i(A)}{\mu_i(A)} > \frac{\dot{\mu}_i(A')}{\mu_i(A')}.$$

An example for the class of processes which satisfy the above assumptions is the continuous version of the replicator dynamic, which is defined as[15]

$$\dot{\mu}_i(A) = \int_A \tilde{F}(e_i, \mu_j) d\mu_i(e_i) - \mu_i(A) \int_I \tilde{F}(e_i, \mu_j) d\mu_i(e_i).$$

Most plausible evolutionary or learning processes satisfy payoff monotonicity. In particular, payoff monotonic dynamics can be used to model cultural imitation processes (see Weibull, 1995).

The main question posed in this paper is whether individuals with strictly positive endowment parameters will survive in the long run. The following theorem shows that with any payoff monotonic dynamic individuals with strictly negative endowment parameters will die out asymptotically, that is, for each $e_i < 0$, there is an open neighborhood $\mathcal{N}_{e_i}$, such that $\lim_{t\to\infty} \mu_i^t(\mathcal{N}_{e_i}) = 0$. Given that negative endowment parameters die out, we say that strictly positive endowment parameters *survive* in the long run in population i if μ_i does *not* converge in the weak topology to a point mass on 0, δ_0.[16] If μ_i does not weakly converge to δ_0, then there is an $\varepsilon > 0$ such that $\mu_i^t([-\varepsilon, \varepsilon]) < 1 - \varepsilon$, for all t sufficiently large. Since negative endowment parameters die out, strictly positive endowment parameters survive in the sense that the mass on endowment parameters larger than ε remains bounded away from zero for sufficiently large t. In fact, the following theorem shows something stronger, namely that (δ_0, δ_0) is (Lyapunov) unstable with respect to any payoff monotonic dynamic.

[15] Usually, the replicator dynamics are defined for finite state spaces. See Oechssler and Riedel (2001) for a generalization to continuous state spaces (compare also Friedman and Yellin, 1996, and To, 1999).

[16] Note that since the dynamics are regular, they can only (weakly) converge to a point mass on 0 if 0 is in the support of the initial distribution.

Theorem 1 *Consider an initial state* ω^0 *with* $0 \in supp(\mu_i^0)$*, for* $i = 1, 2$. *Then the following holds with respect to any payoff monotonic dynamic.*

1. *Individuals with strictly negative endowment parameters will die out asymptotically.*
2. *The distribution without endowment effect* (δ_0, δ_0) *is (Lyapunov) unstable.*
3. *Individual with strictly positive endowment parameters will survive in the long run.*

Proof By Proposition 1 endowment parameters $e_i < 0$ are strictly dominated in the fitness game by $e_i = 0$. Hence, by Theorem 4 of Heifetz et al. (2002) they will die out asymptotically. Also by Proposition 1, $(0, 0)$ is not a Nash equilibrium of the fitness game. A necessary condition for (δ_0, δ_0) to be Lyapunov stable with respect to a payoff monotonic process is that $(0, 0)$ is a Nash equilibrium (see Proposition 5 in Oechssler and Riedel, 2002). In particular, no payoff monotonic process can weakly converge to (δ_0, δ_0). Hence, strictly positive endowment parameters survive in the long run. ■

6 Conclusion

We have shown in this paper that an apparent behavioral anomaly, the endowment effect, which has been observed in numerous experiments, can be explained by evolutionary arguments. We have argued that people acquire a preference for goods they own because it helps them in bargaining situations.

This is quite different from the observation that individuals may have strategic incentives to lie about their true preferences. As convincingly argued by Frank (1988) it is not always possible to credibly signal preferences which one does not hold. In our setting individuals behave sincerely according to their preferences. Neither do they lie nor do they commit themselves to non–credible threats. They simply develop an endowment effect because individuals with an endowment effect end up with more resources and therefore higher fitness. Note, however, that overall the endowment effect causes an inefficiency since there is a suboptimal amount of trade. Feasible allocations which would be mutually beneficial in terms of fitness are not implemented due to the bias in preferences.

It is important to notice that once evolution has brought forth preferences with endowment effects, individuals will reveal their endowment effects not only in bilateral trade but also in incentive compatible market situations. The systematic endowment effect observed in market experiments can neither be explained by strategic misrepresentation of preferences nor by erroneous behavior since in the latter case one should also expect to observe negative endowment effects, i.e. the case in which the average WTP is greater than the average WTA. Taking these considerations into account only explanations based on preferences with a 'hard–wired' endowment effects seem to be consistent with experimental data.

Several open questions remain. While we suppose that our results hold true for other cooperative bargaining solutions, this still has to be shown formally. It would also be of interest to consider more general formulations for the utility function. However, as pointed out above, including other utility functions cannot make preferences without an endowment effect stable. Finally, we were not able to prove the existence of a stable state in which all individuals have some fixed endowment parameter for the general case. In our view this is nothing to worry about. In nearly all laboratory experiments there is an enormous variety in subjects' behavior suggesting that theoretical results offering point predictions are doomed to fail.

A Appendix

Proof of Lemma 1

To prove uniqueness suppose there exist two Nash bargaining solutions (x, y) and (x', y'). Since utility functions are strictly concave, both individuals would prefer any convex combination of (x, y) and (x', y') over (x, y) and (x', y'). These convex combinations are feasible which yields a contradiction. ■

Proof of Lemma 2

If Pareto improving allocations exist, the maximized Nash product $N(x^*, y^*)$ must be strictly positive, i.e. both individuals must be strictly better off than with their endowment. Such a Pareto improving allocation exists if the problem

$$\max_{x,y} U_2(x, y) \qquad \text{s.t.} \qquad F(x, y) + e_1 x = e_1$$

has a value $U_2 > e_2$. Let $\widetilde{x}(y)$ denote the x that solves the constraint for a given y. Implicitly differentiating we find that[17]

$$\frac{d\widetilde{x}}{dy} = \frac{-F_y}{F_x + e_1}.$$

Substituting $\widetilde{x}(y)$ into $U_2(x, y)$ and differentiating yields

$$\frac{dU_2}{dy} = -F_{2x}\frac{d\widetilde{x}}{dy} - F_{2y} - e_2.$$

In particular, a Pareto improving allocation exists if

$$\left.\frac{dU_2}{dy}\right|_{y=0} > 0$$

or

$$F_{2x}(1,0)\frac{F_y(1,0)}{F_x(1,0)+e_1} - F_{2y}(1,0) - e_2 > 0.$$

Noting that $F_y(1,0) = \infty$ and $F_{2x}(1,0) = F_x(0,1) = \infty$ implies that this condition is always fulfilled. Hence, $U(x^*, y^*) - e_1 > 0$ and $U_2(x^*, y^*) - e_2 > 0$. ■

Proof of Lemma 3

At any boundary solution one of the individuals, say individual 1, receives nothing of one of the goods. Let us first look at an allocation with $y = 0$. In this case individual 1 is no better off than with his initial endowment, and hence such an allocation cannot be a bargaining solution by Lemma 2. Now turn to an allocation with $x = 0$. For this to be a bargaining solution it must hold that

$$\frac{\partial N(x,y)}{\partial x} = (F_x(0,y) + e_1)(U_2(0,y) - e_2) - (U(0,y) - e_1)F_{2x}(0,y) \leq 0.$$

But since $U_2(x^*, y^*) - e_2 > 0$ and $F_x(0, y) = \infty$, whereas $F_{2x}(0, y) = F_x(1, 1-y)$ is finite, this condition can never be fulfilled. Hence, there cannot be a boundary solution where individual 1 gets nothing. By symmetry, also all boundary solutions with individual 2 getting nothing of one of the goods can not be a solution. Hence, the solution must always be in the interior. ■

[17] Recall that we have assumed that I is bounded below such that the goods always remain "goods". Here, this implies $F_x + e_1 > 0$.

Proof of Proposition 1. By Lemmata 2 and 3 for all e_1, e_2 the solution is interior, and the constraints $U(x, y) \geq e_1$ and $U_2(x, y) \geq e_2$ are not binding. Hence, x^* and y^* are simultaneously determined by the first order conditions, $N_x = 0$, $N_y = 0$. By the implicit function theorem $x^*(\cdot, \cdot)$ and $y^*(\cdot, \cdot)$ are differentiable in e_1 and e_2.[18]

We will show that for all $e_1 \leq 0$

$$\frac{\partial F(x^*(e_1, e_2), y^*(e_1, e_2))}{\partial e_1} = F_x \frac{\partial x^*}{\partial e_1} + F_y \frac{\partial y^*}{\partial e_1} > 0. \tag{2}$$

Differentiating $N_x = 0$, $N_y = 0$ with respect to e_1, we get that

$$\frac{\partial x^*}{\partial e_1} = \frac{N_{ye_1} N_{xy} - N_{xe_1} N_{yy}}{N_{xx} N_{yy} - (N_{xy})^2} \text{ and } \frac{\partial y^*}{\partial e_1} = \frac{N_{xe_1} N_{xy} - N_{ye_1} N_{xx}}{N_{xx} N_{yy} - (N_{xy})^2}. \tag{3}$$

Since the second order necessary condition, $N_{xx} N_{yy} - (N_{xy})^2 \geq 0$, is satisfied at an interior solution,we will show that at $e_1 \leq 0$

$$N_{xe_1}(F_y N_{xy} - F_x N_{yy}) + N_{ye_1}(F_x N_{xy} - F_y N_{xx}) > 0.$$

Since

$$\begin{aligned} N_{xe_1} &= F_2 - e_2 y + F_{2x}(1 - x) > 0 \\ N_{ye_1} &= (1 - x)(F_{2y} + e_2) \geq 0, \end{aligned}$$

it holds that

$$\begin{aligned} N_{xe_1}(-2F_y e_1(F_{2y} + e_2)) + N_{ye_1} 2F_y F_{2x} e_1 &= \\ -2(F_2 - e_2 y) e_1 F_y (F_{2y} + e_2) &\geq 0. \end{aligned}$$

Note that $F_2 > e_2 y$. Otherwise the allocation would not be Pareto improving. Thus, it suffices to show that

$$F_y N_{xy} - F_x N_{yy} > -2F_y e_1 (F_{2y} + e_2) \tag{4}$$

and

$$F_x N_{xy} - F_y N_{xx} > 2F_y F_{2x} e_1. \tag{5}$$

At an interior solution $MRS_1 = MRS_2$, which implies that

$$\frac{F_x + e_1}{F_y} = \frac{F_{2x}}{F_{2y} + e_2}.$$

[18] Strictly speaking, the implicit function theorem requires the second order condition $N_{xx} N_{yy} - (N_{xy})^2$ to be non–zero. We assume this to be satisfied.

Thus, we have

$$F_y F_{2x} = F_x(F_{2y} + e_2) + e_1(F_{2y} + e_2) \tag{6}$$

Given that

$$\begin{aligned} N_{xy} &= F_{xy}(F_2 - e_2 y) + F_{2xy}(F + e_1 x - e_1) \\ &\quad -F_x(e_2 + F_{2y}) - F_y F_{2x} - e_1(F_{2y} + e_2) \end{aligned}$$

we can define

$$N' := -2F_y F_{2x} < N_{xy},$$

where the inequality follows from (6). To verify claim (4) we show that $F_y N' - F_x N_{yy} > -2F_y e_1(F_{2y} + e_2)$ at $e_1 \leq 0$.

$$\begin{aligned} & F_y N' - F_x N_{yy} \\ = \; & 2F_x F_y e_2 + 2F_y(F_x F_{2y} - F_y F_{2x}) \underbrace{-F_x F_{yy}(F_2 - e_2 y)}_{>0} \underbrace{-F_x F_{2yy} F}_{>0}. \end{aligned}$$

By (6) it follows that

$$2F_x F_y e_2 + 2F_y(F_x F_{2y} - F_y F_{2x}) = -2F_y e_1(F_{2y} + e_2),$$

which proves (4).

Equation (5) is satisfied if $F_x N' - F_y N_{xx} > 2F_y F_{2x} e_1$. But this follows immediately:

$$\begin{aligned} & F_x N' - F_y N_{xx} \\ = \; & -2F_x F_y F_{2x} - F_y(F_{2xx} F - 2(F_x + e_1)F_{2x} + F_{xx}(F_2 - e_2 y)) \\ = \; & 2\, F_y F_{2x} e_1 \underbrace{-F_y F_{2xx} F}_{>0} \underbrace{-F_y F_{xx}(F_2 + e_2 y)}_{>0}. \end{aligned}$$

Therefore, fitness is strictly increasing in e_1 for all $e_1 \leq 0$. ■

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