# Territorial Bargaining

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**Abstract**

We examine an evolutionary model of preferences in a society where resources are finite. Agents who develop better strategies for bargaining and trading will grow to dominate the population. We show that successful agents will have preferences that exhibit the "endowment effect". The social institution of private property emerges spontaneously. Agents decisions will be subject to "framing" effects, and we are able to make some predictions as to the frames that will be salient in given situations. The model makes a clear distinction between individual welfare and revealed preferences. Nonetheless, it may still be possible to recover information about individual welfare from behavioral data.

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He will not go behind his father's saying,
And he likes having thought of it so well
He says again, "Good fences make good neighbors."
*From "Mending Wall" by Robert Frost*

# 1 Introduction

The study of property rights is central to economics because it is central to the process of free exchange. In order to trade we must first of all have the right to keep what we are offering to give away. Since respect for property is not a part of standard consumer preferences, the State has a major role to play in any economic model of a free economy. We need government to establish and enforce an allocation of property rights.[1]

But respect for property does seem to be incorporated into our preferences, particularly when the stakes are small. For most of us there is a huge difference between what we own and what we do not own. We would be offended if someone were to reach into our pocket and take a dollar without asking. We might even expend resources worth more than a dollar to reclaim it. Yet we would not exert nearly as much effort to pick up a dollar that we know belongs to someone else.

This type of behavior is consistent with "loss aversion" as studied by Kahneman and Tversky (1979). We show in this paper that respect for property is linked to a number of other phenomena that we observe in human decision making, including "framing" effects, intransitive revealed preferences and the importance of "fairness" in bargaining. All of these phenomena are best understood as an evolutionary response in human behavior to the problem of survival in an economic environment.

Evolutionary ideas have been a part of economics for some time (Alchian (1950)), but so far they have had little impact on the theory of preferences.[2] One reason may be the

[1] See Alchian (1965) and Demsetz (1967) for discussions of property rights with references to the early literature.

[2] These ideas are infecting the other social sciences as well. Best known is the work of Wilson (1975), who coined the term "Sociobiology". The mechanisms studied by Wilson are explicitly genetic, as are those studied by Cosmides and Tooby (1994) under the name "Evolutionary Psychology". Boyd and Richerson (1985) lay the foundation for theories of cultural evolution. In Economics, Frank (1988) and Hirshleifer (1984) suggest that the emotions allow agents to make and communicate their commitments. See also MacLeod (1996) and Conlisk (1996) for references to models where evolutionary ideas are applied to models

widespread belief that evolutionary models have little empirical content. No-one disputes the idea that humans beings are a product of evolution. But even if we accept that individual preferences are an adaptation to some ancient environment, the details of this lifestyle and the precise adaptive problems that it presented are quite unknowable. Indeed, one suspects that there is a plausible human society that, had it existed for long enough, could have produced just about any conceivable characteristic of current human psychology. The problem becomes even more serious when the path dependence of many evolutionary processes is considered.

We face this issue by making very minimal and uncontroversial assumptions about the economic environment. The important ones are that humans had to compete for finite resources, had the ability to take violent actions, and had the opportunity to realize gains from trade. The enduring nature of these constraints suggests that the behaviors we uncover are likely to be adaptive to the present day.

We will also be addressing directly the argument that rationality is adaptive in economic environments. Of course in an evolutionary context it makes little sense to assume that rationality could be unbounded (Simon (1982)). However, we do assume that Nature can create agents who always manage to realize all the available gains from trade when they meet each other. These agents are "rational bargainers". Nature can also create people who are more disagreeable, and who will walk away from a deal if the offered outcome is "unfair". These agents are "fair bargainers". This paper's predictions about property rights, framing effects and disagreement follow from the result that fair bargainers will be more successful in evolutionary competition than completely rational bargainers.

We begin by examining a matching model where pairs of agents must decide how to divide a surplus. Agents are endowed with a certain bargaining ability, and may be completely agreeable in a sense that will be precisely defined. However, they may also be disagreeable, in that they can make and carry out a commitment to walk away if the offered outcome is "unfair". We show first that if the surplus is known, the outcome will be determined entirely by fairness norms, and bargaining ability per se has little evolutionary value. If rational bargaining takes time, or is otherwise costly, then fairness norms can play an efficiency enhancing role.

We then extend the model to allow for uncertainty in the size of the bargaining

of learning and bounded rationality.

surplus, and show that some disagreement is likely even in cases where the surplus is known ex ante to be nonnegative. Even though it is possible for Nature to create agents who never disagree when they meet each other, these agents will not be able to invade the disagreeable equilibrium population. Here, fairness norms may not be efficiency enhancing, although they nonetheless survive evolutionary competition.

The model is then extended to a trading situation. Each match is now an Edgeworth Box trading opportunity, and the challenge is for the two agents to exploit the available gains from trade. Our two main results are in this section. First, under realistic conditions each agent will behave as if he "owns" his endowment, and will respect the other's claim to his endowment. Property rights emerge spontaneously. Second, agents will behave as if their preferences exhibit the "endowment effect", even though their underlying fitness ordering does not. The theory is therefore consistent with much of the experimental evidence on "framing" and predicts that in trading situations revealed preferences will be intransitive.

A final section explores the implications of these results. Of particular interest is the possibility of recovering information about underlying fitness from behavioral data, and the possibility of using the model to predict which frames will be salient in particular situations.

## 2 The Basic Model

We study an economy with a continuum of agents indexed by $i \in [0, 1]$, with total mass equal to one. Time is discrete. At the beginning of a period each agent matches up with one other agent. Matching is anonymous and there is no unemployment. At the end of each period the fraction $(1 - \rho)$ of the agents die, and are replaced with new, unmatched agents at the beginning of the next period.

The basic problem facing the agents in the economy is to gain a share of the finite resources that are available each period. The resources appear in the form of a surplus $S$ available to matched pairs of agents. The agents receive the surplus if and only if they can agree to its division. The bargaining or other behavior within a match is subject to no formal rules. To fix ideas, one might think of a pair of hunters who have just killed an animal, and must agree to its division before it gets dragged away by a hyena.

Agents are born with an ability to bargain effectively over any unclaimed surplus and an ability to make and communicate the intention to walk away from the match if they are not being offered what they feel they "deserve". Initially we will call this an emotional commitment, but this is only an interpretation. Another is that preferences, as revealed by behavior, do not reflect underlying fitness. Agents who walk away are behaving as if their alternative provides them with more fitness than it really does.

Agent $i$ enters the market endowed with a level of bargaining ability $\theta^i$. We assume for simplicity that $\theta^i$ is discrete, and that $\theta^i \in \Theta = \{1, 2, 3, ..., N\}$. The proportion of agents of ability $r$ in a population is denoted by $q_r$. The distribution of bargaining ability is assumed to be renewed each generation. This means that even if more able bargainers do better in equilibrium, the distribution of ability will not converge to $\theta^i = N \; \forall i$ [3]. The agent's commitment level is denoted by $\sigma^i$. The commitment level evolves non-stochastically. It does not change over the lifetime of an agent, although population averages may change as agents die and are replaced.

The stages in the history of a match can be summarized as follows.

1. Individuals $i$ and $j$ are matched at the beginning of a period.

2. Agents then play a bargaining game with the following rules

   (a) If no agreement is reached, each agent gets her alternative, normalized to zero.

   (b) Otherwise, the share going to agent $i$ is given by

$$S^i = \sigma^i + \frac{\theta^i}{\theta^i + \theta^j} \left( S - \left( \sigma^i + \sigma^j \right) \right) \tag{1}$$

   where $S - (\sigma^i + \sigma^j) \geq 0$, since an agreement is reached.

3. Agents consume their share.

4. A fraction $(1 - \rho)$ of the agents die, and are replaced with new agents.

[3] Even though there are advantages to having certain skills such as intelligence, speed or agility, we do not observe that all individuals have the same skills. Presumably there are benefits to diversity among one's offspring when the environment may change, but we do not know of any work that makes this point.

The bargaining game being studied here is formally a Nash demand game followed by bargaining over any remaining surplus[4]. Before the bargaining begins, an agent makes a commitment $\sigma^i$, which is what he feels he "deserves" from this bargain. If it turns out that $S - (\sigma^i + \sigma^j) > 0$ then both agents are getting more than they feel they deserve, and what remains is divided up according to the relative bargaining skills (ability) of the two partners. While there may be costs of negotiation and of maintaining an emotional commitment that effect the evolutionary dynamics, these are each set to zero for simplicity.[5]

In our model a disagreeable person is one that makes a demand *ex ante* that will not be revised *ex post*. There has been a tendency in game theory to suppose that individuals are unable to make such commitments, but rather after the fact would act 'rationally'. However, any of us who have raised children know that Nature can create agents who will undertake to destroy any available surplus rather than be forced to accept a share that is too small. In our framework the question is not whether or not this behavior is possible, but only whether it will survive evolutionary competition with more "rational" agents.[6]

The assumption that agreement is needed for the surplus to be realized is meant to capture in a simple way the fact that violence is always a possibility in a trading or bargaining situation. As emphasized by Umbeck (1978) in his study of the California gold rush, the potential for violence is an essential part of any understanding of property rights. In the last section of the paper we briefly explore the effects of changing the technology of conflict.

For simplicity agents do not play mixed strategies, although there may be a mix of strategies present in a population. Since matching is anonymous we can simply keep track of the distribution of strategies, based on ability levels. Let $\sigma_n$ denote a strategy played by

[4] See Binmore (1981), Osborne and Rubinstein (1994) and the references therein for dicussions of the Nash bargaining game. For all that follows the only assumption we need is that increases in the threat point $\sigma$ increase the amount one gets from those bargains that nonetheless reach agreement. This is true in a wide variety of bargaining environments, including random assignment from within the feasible set, and the case where all unclaimed amounts are lost.

[5] It is not clear whether Nature finds it more difficult to equip agents with the ability to make commitments or the ability to bargain effectively. Our results will hold even when commitment is more costly, so long as the relative cost of commitment is not too great.

[6] "Rational" agents are those who set $\sigma = 0$. They reach agreement with everyone and when they meet themselves the surplus is split according to their relative bargaining strengths.

an individual of ability $n$. Then $u(\sigma_n, \sigma_r^{'})$ denotes the payoff to an individual with ability $n$ playing strategy $\sigma$ against an agent with ability $r$ playing strategy $\sigma^{'}$. Let $\Sigma$ denote the set of possible strategies.

We assume that at any time there is at most a finite number of strategies present in a population. Let $\widetilde{E}_n = \{p^{\sigma_n}\}_{\sigma_n \in \Sigma_n}$ denote a population profile of agents of ability $n$, where $p^{\sigma_n}$ denotes the proportion of the agents with ability $n$ using strategy $\sigma_n$ and $\Sigma_n \subset \Sigma$ is the finite set of strategies that are used with positive probability. The overall population profile is given by $\widetilde{E} = \{\widetilde{E}_1, \widetilde{E}_2, ...\widetilde{E}_N\} \in \Delta(\Sigma)^N$, where $\Delta(\Sigma)$ is the set of possible population profiles for agents of a given ability. Let $E^{\sigma}$ be the population where all agents play the strategy $\sigma$.

An agent's expected payoff in any period depends on the strategy she is using and the profile of abilities and strategies in the population. Denote the period expected payoff to strategy $\sigma_n$ by

$$V^{\sigma_n}(\tilde{E}) = \sum_{r \in \Theta} \sum_{p^{\sigma_r} \in \tilde{E}_r} u(\sigma_n, \sigma_r) p^{\sigma_r} q_r. \tag{2}$$

There are many ways to define evolutionary stable populations in this setup. The preferred approach would be to explicitly define the dynamic selection process that weeds out unsuccessful strategies. For human populations we are nowhere near consensus on how these dynamics should be modelled[7]. An alternative approach, made popular by Maynard-Smith (1982), is to use a static equilibrium concept that requires the population to be robust against new entrants. But the concept due to Maynard Smith, the evolutionarily stable strategy, often does not exist in games where complex behavior is possible. Furthermore, there is no consensus on an appropriate alternative concept, or even on the idea that evolutionary models should have equilibria.

One property that all concepts of evolutionary stability share is that they are Nash equilibria. In addition when one permits communication between agents before the playing of the stage game, several of the concepts select the most efficient outcome in the game. When the most efficient outcome is a Nash equilibrium, therefore, it is often evolutionarily stable. (See Weibull (1995) for a good discussion of these issues and references to the relevant literature.)

In this paper we will characterize the most efficient outcomes in the set of Nash

[7] See Boyd and Richerson (1985) for a review of different possible models. See also Young (1996)

equilibria. This approach is consistent with the evolutionary views of Alchian (1950) and Hayek (1982) who suggest that over time competition selects efficient and stable institutions. We shall see that in some cases the most efficient Nash equilibria are not first best, and the departures from full efficiency are interesting and empirically relevant.

**Definition 1** *The set of best replies of an individual of ability $n$ to a population profile $\widetilde{E}$ is defined by:*

$$BR_n(\tilde{E}) = \left\{\sigma_n \in \Sigma \middle| V^{\sigma_n}(\tilde{E}) \geq V^{\sigma_n'}(\tilde{E}), \forall \sigma_n' \in \Sigma\right\}. \tag{3}$$

*A population profile $\widetilde{E}$ forms a Nash equilibrium iff $\Sigma(E_n) \subseteq BR_n(E)$, for all $n \in \Theta$. Let $\Omega \subset \Delta(E)^N$ be the set of population profiles that form Nash equilibria.*

Since matching is anonymous, then at every Nash equilibrium all agents of the same ability obtain the same payoff, denoted $V^r\left(\tilde{E}\right)$. If not then the individual with the lower payoff could increase her return by switching to the actions of a more successful strategy. Let

$$V(\tilde{E}) = \sum_{r \in \Theta} V^r(\tilde{E}) q_r. \tag{4}$$

denote the expected payoff of an individual about to be born into the population. With this function we define the concept of a stable population.

**Definition 2** *A population profile $\tilde{E} \in \Omega$ is stable if $V\left(\tilde{E}\right) \geq V\left(\tilde{E}'\right)$, for all $\tilde{E}' \in \Omega$.*

A population is stable if there does not exist another population that forms a Nash equilibrium and makes agents better off.

**Proposition 1** *There is a unique stable population at which every agent sets $\sigma = S/2$.*

**Proof.** In the bargaining game the maximum total payoff is $S$, and given that every agent obtains the same payoff in equilibrium the maximum expected payoff must be $S/2$. This can be achieved if each agents demands $S/2$. Clearly this is a Nash equilibrium. To show that it is the unique efficient equilibrium, first observe that if some agents demand an amount greater than $S/2$ there will be some disagreement in equilibrium and thus the outcome could not be efficient. Now suppose that all agents demand $S/2$ or less, with some agents choosing to demand strictly less. These latter agents can increase their demands without affecting the probability of agreement. Increasing their demands will strictly increase their payoff, thus this could not be an equilibrium.

■

Note that even though agents have different bargaining abilities, in the efficient equilibrium they all demand an equal share. When the surplus is known with certainty, the norms of "fairness" that emerge place no weight on bargaining ability.

If agents are of two identifiable types that are in fixed proportions (e.g. males and females) then efficient "systemic discrimination" equilibria are also possible. For example, one group could claim $\underline{\sigma} = S/3$ and the other $\overline{\sigma} = 2S/3$ in those situations where they meet each other, and $S/2$ when they meet themselves. In such a society agents in the oppressed group expect less out of life and do not refuse to take what is offered them. If they do claim more than their meagre share, agents in the favored group get upset and refuse to cooperate. While it is difficult to predict the equilibrium share we can predict that at any given time it will be hard to change, as members of the dominant group feel quite justified in defending their position.

Even in the anonymous case there are asymmetric Nash equilibria where one group of agents plays a "strong" strategy (i.e. $\sigma^* > S/2$) and another group plays a "weak" strategy $\sigma_*$ with $\sigma^* + \sigma_* = S$. When strong types meet each other there is disagreement, but when strong meets weak, strong does better. The Nash equilibrium is characterized by a fraction $p = 2\sigma_*/(S - C(S - 2\sigma_*))$ of weak types, with each type earning $p\sigma^*$ in equilibrium. However given that there is no agreement when strong types meet, the equilibrium is inefficient.

Notice that if a new strategy enters that can display its intention to demand $S/2$, then both the weak and strong types will do better if they play fair against these players. In this way the more efficient convention, since it is itself a Nash equilibrium, could invade a population where there is some disagreement[8].

[8] In the anonymous game strategies that display an intention to demand more than $S/2$ will be successful only if they cannot be mimicked. See Weibull (1995) for review of how one may model communication that would result in entry by such a fairness norm, and Carmichael and MacLeod (1994) for an application to the problem of gift exchange. Ellingsen (1995) provides a model that is similar to ours up to this point.

# 3 Uncertainty

We have shown that a willingness to disagree is evolutionarily viable in a context where there is ultimately no disagreement. Indeed, if there are costs to *ex post* negotiation then fairness norms will be efficiency enhancing, since no negotiation actually takes place.

Suppose now that the surplus is unknown to the two agents at the time that they are bargaining. This is quite a different situation. In our hunting example, it is not enough to have the size of the animal unknown before the match, since the solution can be to divide the animal evenly, whatever its size. A better example is a trading situation where the surplus is generated by an exchange of consumption goods, and the underlying fitness of the agents is private information. Agents must bargain over the terms and amount of trade (which determine fitness levels), and may decide to walk away if these terms are not acceptable.

There are two potential sources of uncertainty in a trading game. The first is in gains from trade, which depend on the fitness functions of the trading partners. Agents will know their own gains, but not those of their partners. The second is in the endowments that each partner brings to the trade. In this Section, to illustrate the basic ideas, we address these issues separately, and in a simple one-dimensional fashion. We begin with uncertainty in the gains from trade.

## 3.1 Gains From Trade

Suppose that the total surplus $S$ in any bargain is given by $\alpha v$, where $v$ is a random variable distributed according to density function $f(v)$ that is continuous on its support $[0, 1]$, and $\alpha$ is a positive parameter. Note that $v$ is always nonnegative, reflecting the fact that gains from trade are always nonnegative. However, it is still the case that disagreement leads to each agent getting nothing.

Let $\sigma^T = \sigma^n + \sigma'^r$ denote the total demanded by the two agents, and since it is clear each agent will demand at least zero we assume this directly. The fitness of an agent with ability $n$ in a match with an agent of ability $r$ is given by:

$$u(\sigma^n, \sigma'^r) = \int_{\frac{\sigma^T}{\alpha}}^{1} \left(\sigma^n + \gamma^{nr}(\alpha v - \sigma^T)\right) dF(v), \qquad (5)$$

where $\gamma^{nr} \in (0, 1) = \theta^n / (\theta^n + \theta^r)$ is the relative ability of the first agent with respect to the second.[9] This can be rewritten as:

$$u(\sigma^n, \sigma'^r) = \left(1 - F\left(\frac{\sigma^T}{\alpha}\right)\right)(+(1-\gamma^{nr})\sigma^n - \gamma^{nr}\sigma'^r) + \gamma^{nr}\alpha \int_{\frac{\sigma^T}{\alpha}}^{1} vf(v)\,dv \tag{6}$$

so that the expected return to agent $i$ is given by:

$$\sum_{r\in\Theta}\sum_{p^{\sigma_r}\in\tilde{E}_r}\left(\left(1 - F\left(\frac{\sigma^T}{\alpha}\right)\right)\left(+(1-\gamma^{nr})\sigma^n - \gamma^{nr}\sigma'^r\right) + \gamma^{nr}\alpha \int_{\frac{\sigma^T}{\alpha}}^{1} vf(v)\,dv\right)p^{\sigma_r}q_r. \tag{7}$$

Note that rational bargainers are being given quite an advantage here. Two completely agreeable people ($\sigma^T = 0$) will divide the surplus without difficulty even when this surplus is unknown. We have:

$$\frac{\partial u}{\partial \sigma^n} = \sum_{r\in\Theta}\sum_{p^{\sigma_r}\in\tilde{E}_r}\left((1-\gamma^{nr})\left(1 - F\left(\frac{\sigma^T}{\alpha}\right)\right) - \frac{1}{\alpha}f\left(\frac{\sigma^T}{\alpha}\right)\sigma^n\right)p^{\sigma_r}q_r, \tag{8}$$

When $\sigma^T = 0$ agents always reach an agreement. When an agent increases his demand beyond this point he gets a larger fraction of the surplus when there is an agreement, but also reduces the probability of agreement.

**Proposition 2** *The probability of disagreement is always positive.*

**Proof.** There will be no disagreement when $\sigma^T = 0$. A necessary condition for this to be a Nash equilibrium is $\left.\frac{\partial u(\sigma,0)}{\partial\sigma}\right|_{\sigma=0^+} \leq 0$ for each agent. It is necessary to take the right hand derivative, because the density is continuous only on the support. But we have

$$\left.\frac{\partial u(\sigma^n, 0)}{\partial \sigma^n}\right|_{\sigma^n=0^+} = (1 - F(0))\sum_{r\in\Theta}\sum_{p^{\sigma_r}\in\tilde{E}_r}(1-\gamma^{nr})\,p^{\sigma_r}q_r \tag{9}$$

Since $\gamma^{nr} \in (0,1)$, this expression is positive, and $\sigma^T = 0$ cannot be a Nash equilibrium. Since it is always a Nash equilibrium for each agent to always demand $\alpha$, Nash equilibria exist and they exhibit some disagreement.

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By increasing her demand an agent does better in those bargains that are nonetheless completed, but risks some disagreements. For an increase of size $\varepsilon$ in the demand, starting at $\sigma = 0$, the probability of disagreement is of order $\varepsilon$ as is the loss in those matches where disagreements occur. Thus the expected losses due to this change in strategy are of order

[9] Bargaining ability must be bounded in this model, but only so that this ratio is well defined.

$\varepsilon^2$. The gains occur in those agreements that are nonetheless completed. These are of order $\varepsilon$. Thus it always pays to increase ones demand, and the no disagreement outcome is not a Nash equilibrium.

Of course it is always a Nash equilibrium, regardless of parameter values, to have every agent demand $\alpha$. What we have shown above is that even the most efficient Nash equilibrium will involve some disagreement so long as $\alpha$ is positive.

**Proposition 3** *If $sup_{v\in[0,1]} |f'(v)|$ is sufficiently small, then at the most efficient pure strategy Nash equilibrium higher ability individuals demand less.*[10]

**Proof.** At any pure strategy Nash equilibrium the first order condition for each agent is given by:

$$\frac{\partial u}{\partial \sigma^n} = \sum_{r\in\Theta} \left( (1-\gamma^{nr}) \left( 1 - F\left(\frac{\sigma^T}{\alpha}\right)\right) - \frac{1}{\alpha} f\left(\frac{\sigma^T}{\alpha}\right) \sigma^n \right) q_r \ = 0 \ . \tag{10}$$

Since there is a continuum of agents and $\gamma$ is discrete, when we consider this expression for a higher $\gamma$ the distribution of abilities in the population is the same. The result then follows by inspection.

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This result that the more able individuals take less extreme positions is consistent with Hirshleifer (1991)'s paradox of power. The following results are immediate.

**Proposition 4** *If $sup_{v\in[0,1]} |f'(v)|$ is sufficiently small, then when more able agents meet the probability of disagreement is lower.*

When two agents who are relatively good at rational bargaining meet, they will be more likely to reach agreement. However, if the whole society becomes better at communication and bargaining, the overall level of disagreement is not affected. What matters is one's ability relative to the average.

**Proposition 5** *If $sup_{v\in[0,1]} |f'(v)|$ is sufficiently small, then an increase in $\alpha$ will increase demands.*

[10] Given that we have placed no restrictions on the distribution $F()$ we cannot make any general statements on the efficiency of the pure strategy Nash equilibrium characterized by the first order conditions. However for the uniform distribution, the reaction functions are linear on the interior of the support, so that one may show that this is the most efficient Nash equilibrium.

Thus in a bargaining marketplace a dealer might refuse to sell to a rich tourist at a certain price, but be quite willing to sell the same object at a lower price to a local buyer. The behavior is not based on dislike (necessarily) but on an estimate of the potential gains from trade in the match.

## 3.2 Endowments

Consider now the case where each agent receives an endowment $e^i \geq 0$ at the beginning of each trading period. We will suppress from now on any differences in the ability of agents, and will denote agents as $i$ or $j$. We assume that the expected endowment is the same for all agents, so that evolution does not favor those with large endowments. The total surplus to be divided by the agents is: $S = e^i + e^j$. When choosing their level of commitment, agents cannot observe the endowment of the other agent. Suppose that the endowments take on a finite number of possible values, taken from the set $\mathcal{E} = \{e_1, e_2, ...., e_n\}$, each occurring with probability $p_k$. In this case the strategy of agent $i$ is a demand that is a function of her endowment, $\sigma^i(e)$. All else is the same as in the base case of the first section, and in particular each agent loses her endowment if agreement is not reached. The fitness of agent $i$ against agent $j$ is:

$$V^i(\sigma^i, \sigma^j) = \sum_{k=1}^{n} \sum_{l=1}^{n} u^i \left(\sigma^i(e_k), \sigma^j(e_l)\right) p_l p_k. \tag{11}$$

**Proposition 6** *At the unique stable equilibrium each agent demands her endowment, that is* $\sigma^i(e) = e$.

**Proof.** Suppose all agents demand $\sigma^i(e_k) = e_k$, then there is always agreement, and the outcome is efficient with an expected return given by:

$$u^* = \sum_{l=1}^{n} e_k p_k.$$

It is straightforward to verify that this is a Nash equilibrium, and clearly it is fully efficient.

It is also the unique efficient equilibrium. First observe that if for some endowment a positive fraction of agents play $\sigma^i(e_k) > e_k$, then there would be disagreement in equilibrium (when type $e_k$ plays $e_k$), and hence there would be an inefficient outcome. Now suppose that in equilibrium $\sigma^i(e_k) < e_k$. Given that all other agents are selecting $\sigma(e) \leq e$, it is possible for agent $i$ to increase her demand and therefore her return without decreasing the probability of agreement. Hence each agent at a stable equilibrium claims her endowment.

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Logically this result is straightforward, but it is important for understanding what follows. Notice that it depends very much on the information structure. If the endowments were common knowledge, then the 50/50 split would also be an efficient equilibrium (we would be back in the first case where agents observe $S = e^i + e^j$). As well, it is essential that there be no gains from trade. If there were a reason for any agent to demand strictly more than her endowment, other agents with large endowments might demand less in order to ensure they reach agreement.

## 3.3 A Trading Model

We now consider the standard textbook case where agents meet and have the opportunity to trade two goods. Agent $i$ enters the match with a strictly positive randomly drawn endowment given by $e^i = (e_1^i, e_2^i)$. This endowment is private knowledge – i.e. while an agent might know the amounts his partner has offered to trade, he will not know how much he has left over. The agent also has a fitness function defined over the two goods given by $u(x_1^i, x_2^i)$, where $x$ denotes consumption levels. This fitness function is increasing in both its arguments and its form is also private knowledge. The class of fitness functions for each agent is sufficiently rich that the contract curve for a given match could lie anywhere in the Edgeworth Box.

Note that in communicating with each other, the two agents must speak in terms of net trades from their endowment points. This does not require that each claim her endowment as part of her territory. In the text that follows, in order to use the intuition and results from earlier sections, we will continue to speak in terms of absolute consumption and endowment levels.

There is, as always, the potential for violence. As before, this is modelled with the assumption that agents who enter a match must agree to an outcome or else everything disappears, including their endowments. Thus, while we have called this a trading game, it is not clear *ex ante* that the agents will in fact trade one good for the other. In principal they can bargain over the entire Edgeworth Box, and the outcome could be anywhere.

Bargaining outcomes are determined in a way that is analogous to the one-dimensional case. Agent $i$ will claim a two dimensional territory $\Delta^i$, the outer boundary of which is denoted by $\overline{\Delta}^i$. We assume this boundary is continuous. This boundary defines the minimum acceptable consumption levels she will accept as the outcomes of any bargain. For consistency we also assume that if a point $x = (x_1, x_2)$ is claimed, then so are all points $y$ such that $y \leq x$. Otherwise there are no constraints on where this boundary may lie.

When two agents meet there may be a region in the Edgeworth Box that is unclaimed by either party. We will call outcomes in this region feasible. As before, we assume that the two agents will dicker agreeably within the feasible region, if it is unempty. Their bargaining abilities are assumed to be equal and the default is the worst outcome for each individual in the feasible set. Thus if there is any unclaimed region in the Edgeworth Box there will be no violence. Further, we assume the agents will find an efficient outcome within the feasible set that divides the gains from trade.

The general situation for one of the agents is illustrated in the diagram below.

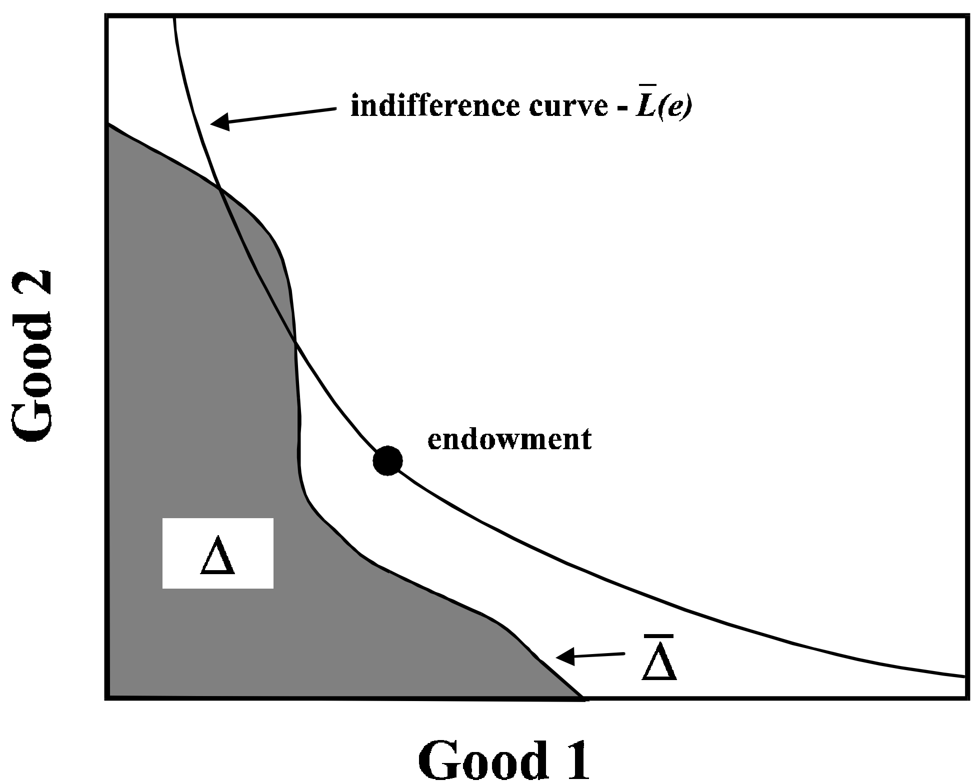


Figure 1:

We wish to determine the strategies of the two agents at the most efficient Nash equilibrium, where a strategy is simply a claimed region $\Delta$. We have not been able to solve the problem formally for general fitness functions. Thus in the text we will proceed in an intuitive fashion. In the appendix we work out an example with specific functional forms that illustrates the equilibrium.

We note first that it is a Nash equilibrium for each agent to claim the "no trade"region $\Delta^* = \{x \mid x_1 \leq e_1 \bigvee x_2 \leq e_2\}$ In this case each agent claims her endowment point, and will only accept those trades that provide more of both goods. In this case the only feasible outcome is the endowment point. There will be no trade, but at least there will be no violence, and each agent will be able to leave with her endowment. No other strategy can do strictly better against this population, and note that claiming strictly less than one's endowment makes one worse off.

The most efficient outcome, of course, would be achieved by a population where each agent claims the lower contour set through her endowment point, denoted by $L(e)$ with associated border denoted $\overline{L}(e)$. If each agent claims exactly this much then we are in the standard textbook case. It follows easily from the geometry of the Edgeworth Box that there will always be agreement, and whenever there are gains from trade these will be fully realized.

However, as we have seen in the one dimensional case an agent may be able to gain if he is willing to risk some disagreement. Suppose a new agent enters a population where all agents are claiming $L(e)$. All the incumbent agents are willing to respect the entrant's claim to his endowment. He will therefore do better in those bargains that are nonetheless completed if he behaves as if his endowment (which is the threat point in the bargain) is worth more to him than it really is. But if he claims strictly more of both goods than his endowment, he runs the risk of meeting someone with whom the feasible set is empty. This would be very costly, since it means the loss of his endowment.

In this two dimensional case there is a way to improve one's outcomes without risking disagreement and the loss of the endowment. In an efficient population, if two agents are bargaining over a region of the Edgeworth box that is distant from the endowment point, then there are gains from trade to be achieved. If the trade vector is very short, then these gains are small but still positive, and in the limit if there are no gains then each agent simply walks away with her endowment. This suggests that the amount by which this new agent overvalues his endowment should depend on the length of any offered trade vector.

Suppose an agent enters with a claimed territory as in the following diagram.

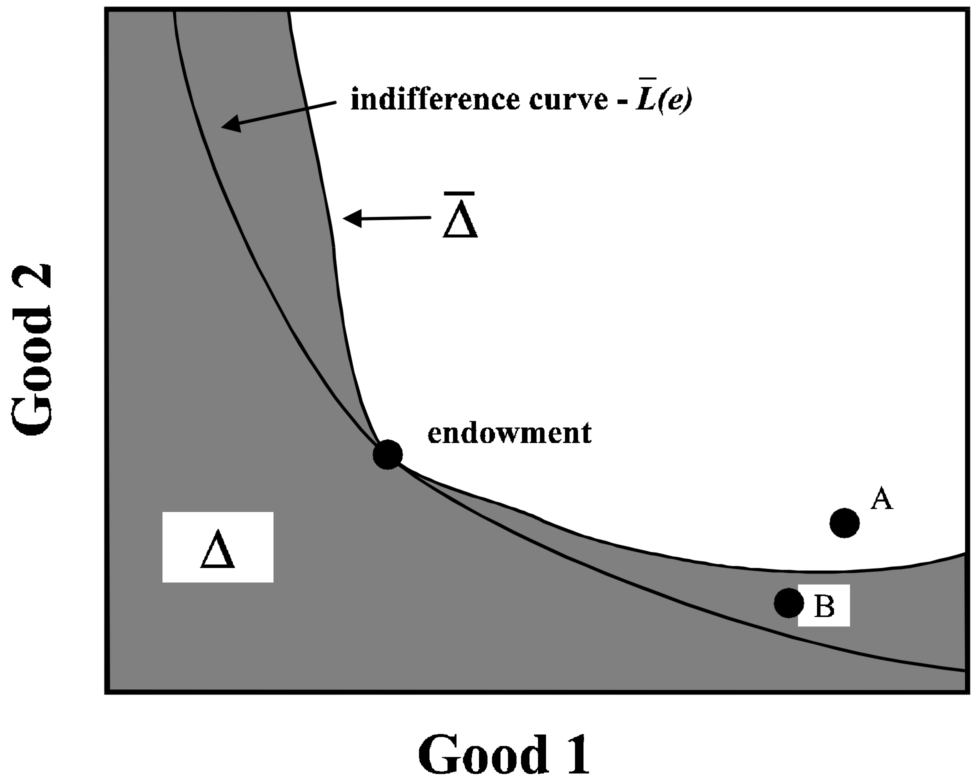


Figure 2:

This agent's territorial border includes his endowment point, but everywhere else $L(e)$ is strictly contained within $\Delta$. Since this agent does not claim any points that have more of both goods than his endowment, he will always reach agreement with incumbent members of the population and with other agents like himself. The worst he will ever do is walk away with his endowment. Suppose he is offered an outcome like point $B$. This outcome increases his fitness. However, since the offered trade vector has positive length and the offered outcome improves his fitness, there are gains from trade available. This agent will nonetheless refuse such a deal, saying he would prefer to keep his endowment.

So long as this behavior improves the expected outcomes in those bargains that are nonetheless completed, this can be a fitness improving strategy. Further, so long as $(e_1, e_2) \in \overline{\Delta}$, a very small increase in claimed territory is sure to be fitness improving. Such an increase causes a small increase in the probability that each side will forgo some gains to trade, but the forgone gains are themselves very small, since the endowment point is always available. Thus the gains from this strategy are first order and the losses second order, as in the one-dimensional case.

There are two ways that claiming more territory can improve outcomes. The first is analagous to the one dimensional case – believing that one's alternative is worth more than it really is may shift the bargaining outcome within the feasible set in one's favour. A second possibility occurs only in this two dimensional case. Here it is possible for an agent to meet a partner for whom the feasible set is so restricted that it no longer contains the contract curve as defined by the two agents' fitness contours. In this case the outcome is the most efficient point within the feasible set, and occurs at the intersection of the two territorial boundaries. Increasing one's demand then directly improves the outcome, although it shrinks the trade vector and reduces efficiency. In the appendix, for a particular parameterization of the problem, we exploit the second of these channels to prove the following proposition.

**Proposition 7** *There is a stable Nash equilibrium for the trading game characterized by individuals demanding territories with boundaries that include their endowment points, but which elsewhere strictly contain the associated lower contour sets.*

The claimed region for each agent in equilibrium therefore appears as in the diagram for our entrant above.

There are two aspect to this result that deserve emphasis. First, each agent enters the match willing to defend his endowment, and willing to respect his partner's claim to her endowment. This happens because each side can credibly threaten violence, endowments are private information and because in an Edgeworth Box there are never any gains from trade when the most efficient outcome is the endowment point. Under these conditions, property rights emerge as a part of the equilibrium. These rights respect endowments, and therefore the situation becomes a trading game rather than a fight over the entire Edgeworth Box.

Second, when engaging in trades that move her away from the endowment point, each agent behaves as if her endowment were worth more to her than it really is. Suppose we were to observe the behavior of an agent like this in a trading situation. In Figure 2, this agent would be seen to choose a point like $A$ over her endowment point. She would refuse to accept an allocation like point $B$. We would be forced to conclude that she has an indifference curve running through her endowment point and between points $A$ and $B$. In essence, the boundary $\overline{\Delta}$ of the agent's claimed territory is precisely what revealed preference analysis would identify as the indifference curve through her endowment point. Revealed preferences are intransitive, and exhibit the "endowment effect".

# 4 Discussion and Extensions

In this paper we have begun with the idea that the level of commitment that occurs before rational discussion is endogenous. The idea that emotional commitment has survival value is not new to us. Schelling (1980) was one of the the first to emphasize the importance of commitment, and Frank (1988) has developed this idea into a theory of signalling and emotion. The literature on property rights, beginning with Alchian (1965) and Demsetz (1967), has highlighted the importance of some system of enforcement of these rights. We have shown that under certain conditions a particular system of property rights will emerge on its own, enforced by emotional commitment. We have linked this result to the intransitivity of revealed preferences that has been observed in some experiments.

"Rationality" continues to have value in our context although it must take its place alongside the ability to make commitments. Of course intelligence will always have survival value as agents learn to exploit their physical environment. Emotional commitment arises in the interactions that members have with other members of their own group, who are products of the same evolutionary competition. This suggests that an understanding of commitment may be more important for the interactions studied in game theory than for the study of competitive markets.

There are many ways in which these results can be extended. In this section we very briefly outline the implications for conflict models, welfare economics, and "framing".

## 4.1 Conflict

Our assumption that each side in the match has the ability to force an outcome where each loses his endowment is meant to capture the fact that each partner, by "losing his temper" can impose costs on everyone. For the results of the last section, all that is required is that there be discrete costs to disagreement for both sides. As well, even if it is the State that enforces each person's claim to her endowment, the "endowment effect" will still arise.

Clearly the threat of violence can be modelled in a much richer fashion. In particular, there is no possibility in our model for an agent to invest in a weapon that would affect the outcomes in his favor, or for agents to band together for the purpose of conquest. For this reason our model is not an allegorical history of the emergence of order from chaos. The State in our model still plays an essential role, which is to enforce a prohibition on the excessive private use of force.

However, the concepts we develop here may find application in more realistic models of conflict, such as the one examined by Hirshleifer (1995). In such a model agents must choose how much effort to put into producing on their own land and how much to devote to obtaining land from their neighbors (or preventing it from being obtained by their neighbors). An implication is that there is always a positive level of conflict, since agents must always be putting some effort into fighting if they are to control any territory at all. As well, any change in the weaponry of an agent will lead to a change in her territory.

Suppose a group of agents enter this world with preferences that have a kink at an agreed-upon territorial boundary.[11] These agents are willing to defend their own territory, but are not so interested in expansion. So long as the boundaries are mutually consistent, these agents will peacefully coexist with each other while defending themselves from incumbents. They can put more effort into production, and should therefore successfully invade. Peaceful coexistence is possible in a conflict model, and not suprisingly it depends on respect for property.

Clearly there is the potential for an arms race, as in any model of conflict. The difference is that in ours, a small improvement by one side will not necessarily lead to changes in the allocation of territory. Since even a limited invasion will be met with an emotional and violent response, boundaries can be stable even as the race proceeds in discrete steps. The position of territorial boundaries will therefore have an historical component.

The technology of conflict is also critical. As Hirshleifer (1995) shows, there must be decreasing returns to conflict for there to exist a stable allocation of territory. An endogenous kink in preferences is one source of decreasing returns. However, even in our model it is essential that the surplus be divisible. Without this there are no no natural territorial boundaries other than the two endpoints, and bargaining (or fighting) ability is

[11] Tullock (1980) suggests that a kink in preferences leads to more realistic outcomes, but does not argue that a kink will in fact evolve.

all that matters.

## 4.2 Welfare

In a well known experiment, Knetch (1989) gave a series of subjects either a chocolate bar or a coffee mug, and then gave them the opportunity to trade one for the other. Far fewer subjects wished to trade than predicted by the standard model. This preference for the "status quo" survived even when subjects were offered positive inducements to trade. One has to conclude that for at least some of these subjects, having a coffee mug meant they preferred the mug to the bar, and having a chocolate bar meant they preferred the bar to the mug. When revealed preferences are this fickle, how can one use behavioral data to recover information about individual welfare? The whole concept of a stable individual preference ordering, on which so much of economic analysis is based, appears suspect.

The evolutionary approach gives reason for more optimism. If our model is correct, then underlying the behavior in this experiment is a meaningful welfare ordering. Underlying preferences (i.e. fitness) are stable. It is just that agents are being far more sophisticated in maximizing these preferences than is commonly assumed.

Revealed preferences in the Knetch experiment do not reflect the underlying welfare ordering since the choices offered mimic those that are made in a trading situation. But if we are truly interested in recovering information about underlying fitness, we are not restricted to a trading framework. If we want to learn which of these two objects gives the individual more fitness, we could just as well use a "free choice" framework – i.e. put both objects in front of him and see which one he picks up.

It is only when we insist on identifying revealed preferences *in all situations* with individual welfare that we run into trouble. The approach we provide here suggests that revealed preferences in some situations will be less indicative of individual welfare than in others. Further, it provides some guidance as to the frames that will produce the most accurate information.[12] A procedure based on the free choice framework might prove useful in contingent valuation studies.[13]

[12] More precisely, our model suggests no reason why the choices made in the "free choice" experiment should be distorted. There may be other arguments, evolutionary or otherwise, that would predict problems here but we can't think of any. This is an area that needs experimental examination.

[13] The endowment effect is not the only concern in interpreting the results of contingent valuation studies. See the symposium organized by Portney (1994)

### 4.3 Framing Effects in Bargaining

Practical textbooks on bargaining technique rely very little on the models of bargaining that appear in the economics literature. Our approach can provide some practical guidance, although this section is necessarily more speculative. Suppose that the environment is much more complicated than the succession of similar matches that is modelled here. In particular, the agent faces a series of bargains that may be of completely unanticipated character. In this case the agent, when he enters a bargain, will not be able to rely on his social knowledge to determine the appropriate territorial boundary (i.e. the frame) with which he should view the situation.

Persuasion in bargaining is attempt to convince one's opponent to reframe the situation in front of him.[14] It is the process that determines acceptable territorial boundaries. Once consistent boundaries are established agreement is relatively easy since the boundary determines not only where one begins to fight, but also what one will cede to the opponent without a fight.

One criterion that should be important in an evolutionary model is that of relative performance. A strategy that continually produces two successful offspring in a population of strategies that produce only one will be more successful in the long term than a strategy that produces ten offspring while its compatriots produce eleven. Further, in some contexts agents that do not allow themselve to be beaten will do better than those that always insist on winning, because they manage to coexist when they meet each other. This suggests that doing as well as one's peer group might be an important criterion in bargaining.

However, it may not always be obvious what the appropriate peer group should be, and this is where bargaining skill becomes important. A good example arises in the determination of faculty salaries. The first author of this paper is currently head of a department in Canada, where wages for academic economists are significantly below those in the US. He tells his disgruntled colleagues that they are in a Canadian university, they are doing well by Canadian standards, Canada is a low wage country given the current exchange rate, etc. But when talking with the dean, he says that it is outrageous the way

[14] The capacity to be persuaded may provide an advantage in some evolutionary situations. To *believe* a promise is to reframe the promise giver's future actions in such a way that if he does not do what he said, an emotional, destructive response is possible. Thus agents who believe promises, so long as they have the capacity to retaliate, can engage in a wider set of agreements than those who do not.

his colleagues are paid. They publish in the same journals, sit on the same editorial boards, and get the same number of citations as their peers at American universities, but are paid far less.[15]

## 5 Conclusions

Nature is surely capable of creating beings who, in their interactions with each other, exploit all the available gains from trade. However, such a society would be invaded by others who are willing to risk disagreement in order to do better in those bargains that are successfully concluded. These agents, once they are the majority in the society, cannot be displaced by gentler types even though resources are being wasted. When endowments are private knowledge, agents will respect each other's property and will have preferences that exhibit the "endowment effect", even though their underlying fitness function is well behaved.

The notion of private property – a social equilibrium where each agent is willing to defend his own property but respects the property of others – emerges spontaneously in this context. When endowments are publicly known, possession does not necessarily imply ownership. Egalitarian outcomes, where each member of society claims a share of the whole surplus, are stable. When endowments can be hidden, the model predicts that each agent will have ownership of his endowment[16].

Finally, there is a small irony in the history of the ideas presented here. In his work applying game theoretic techniques to biology, Maynard-Smith (1982) used the term "bourgeois" to describe a strategy where an animal is agressive on his own territory but meek on his opponent's territory.[17] The allusion is to bougeois people, who have acquired a social rank and a number of worldly possessions, and will fight hard to retain them. In this paper, in order to describe the behaviour of people with possessions we have alluded to the territorial behaviour of animals.

[15] Of course his colleagues (and the dean) are far too sophisticated for this to work.

[16] See Yellen (1990) for a fascinating account of the transformation of a Kalahari Desert society. Contact with the outside world introduced trade goods that were durable and could be concealed. Within decades a sharing society with very little privacy had become one where wealth was hidden and no longer belonged to the group.

[17] Dawkins (1976) also argues that territorial behavior is evolutionarily stable.

Of course the real connection is that human and animal species have each evolved on this planet in the context of finite resources, competing wants, and the potential for violence. Humans have discovered and exploited the gains from trade. But achieving these gains depends on territoriality – the recognition of every agent's right to his or her endowment.

## 5.1 Appendix

Suppose that agents have a representable monotonic fitness ordering over a two dimensional bundle of goods, $u^i(x,y)$, which for simplicity we take $u^i(x,y) = u(x,y) \equiv \sqrt{xy}$. To avoid potentially difficult measurability issues, let us assume that the set of possible endowments is a finite set of strictly positive allocations $E \subset \Re^2_{++}$, with the probability of an individual recieving $e \in E$ given by $P(e)$. Generically the game played each period is as follows:

1. Individuals are matched at the beginning of a period, with agent $i$ receiving an endowment $e^i \in E$, with probability $P(e)$.
2. Agent $i$ enters the match with a territorial demand in *net trades*, $T^i \subset \Re^2$.
3. The set of net trade demands are realized, resulting in sets $T^i$ and $T^j$.
4. If $T^i \cap -T^j = \emptyset$ then $U^i = U^j = 0$. Otherwise the agents bargain over the set of feasible trades $T^i \cap -T^j$.

The demanded territories may have a very complex structure. In order to make some progress we restrict analysis to the following parametric set of demands, or acceptable outcomes, defined using a constant elasticity of substitution (CES) utility function. We suppose that the strategy of individual $i$ after she learns her endowment is a pair $\omega = (d, \alpha) \in \Re_+ \times [0,1]$, corresponding to the demand:

$$T(\omega, e) = \left\{ t \in \Re^2 | U_\alpha \left( \frac{e_1 + t_1}{e_1}, \frac{e_2 + t_2}{e_2} \right) \geq d \right\}, \tag{12}$$

where

$$U_\alpha(x,y) = \left\{ x^{-\tan(\alpha\pi/2)} + y^{-\tan(\alpha\pi/2)} \right\}^{-1/\tan(\alpha\pi/2)}. \tag{13}$$

The function $U_\alpha$ represents a CES utility function re-normalized so that as $\alpha$ varies from 0 to 1, one goes from a Cobb-Douglas utility function ($U_0(x,y) = \sqrt{xy}$) that represents the agent's true preference, to a Leontief utility function ($U_1(x,y) = \min\{x,y\}$). The demands are normalized about the endowment in that the choice $d$ corresponds to a utility demand premium when $d > 1$, and an acceptance of lower utility when $d < 1$. Given that consumption is non-negative, then $d \geq 0$.

With these demands we can define the outcome of the process of bargaining once the territorial demands have been made. Observe that the set of net trades that yield as good or better utility than one's endowment $e$ is given by $T\left((1,0),e\right)$. We call this the set of *Paretian* trades, and denote it by $T^*\left(e\right)$

We shall examine the symmetric Nash equilibria for this game in pure strategies, given by the function $\sigma : E \rightarrow \Re_+ \times [0,1]$. Given a bargaining pair $i$ and $j$, the payoff given the endowments and strategies is given by the Nash bargaining solution over the set of feasible net trades:

$$v\left(e^i,\sigma^i,e^j,\sigma^j\right) = \begin{cases} 0, & \text{if } T^{ij} = \emptyset \\ u\left(e^i + t\left(e^i,e^j,T^{ij}\right)\right), & \text{if not.} \end{cases}, \tag{14}$$

where

$$T^{ij} = T\left(\sigma^i\left(e^i\right),e^i\right) \cap -T\left(\sigma^j\left(e^j\right),e^j\right), \text{ and} \tag{15}$$

$$t\left(e^i,e^j,T^{ij}\right) = \arg\max_{t\in T^{ij}} \left(u\left(e^i+t\right) - u\left(d\cdot e^i\right)\right)\left(u\left(e^j - t\right) - u\left(d \cdot e^j\right)\right). \tag{16}$$

We have assumed that the threat point for each player is the lowest payoff in the set of feasible trades. This ensures that the model is consistent with the one dimensional case where bargaining occurs over the gains to trade, given that each player receives their demand.

The expected payoff to agent $i$ with these strategies is formally given by:

$$V\left(\sigma^i,\sigma^j\right) = \sum_{(e^1,e^2)\in E^2} v\left(e^1,\sigma^i,e^2,\sigma^j\right) P\left(e^1\right) P\left(e^2\right).$$

Let $V^0 = \sum_{e\in E}\sqrt{e_x e_y} P\left(e^1\right)$ denote the expected payoff if each agent consumes her endowment. Our first observation is that this outcome is a Nash equilibrium.

**Proposition 8** *The strategy $\sigma^0\left(e\right) = (1,1)$ for all $e \in E$, consisting of demanding the only trades that are non-negative for both goods, forms a Nash equilibrium with a payoff of $V^0$ for each agent.*

**Proof.** Since $d = 1$ and $\alpha = 1$ then $T\left(\sigma^0\left(e^i\right),e^i\right) \cap -T\left(\sigma^0\left(e^j\right),e^j\right) = 0$ for all $e^i, e^j \in E$, therefore the equilibrium payoff is $V^0$. To see that this is a Nash equilibrium observe that for all $t \in -T\left(\sigma^0\left(e^j\right),e^j\right) \setminus \{0\}$ then $u\left(e^i+t\right) < u\left(e^i\right)$. There adjusting ones demand to include more potential net trades cannot increase ones payoff. Similarly, increasing ones utility demand only results in no trade at all, and a zero payoff. Thus $\sigma^0\left(e\right) = (1,1)$ forms a Nash equilibrium.

■

This result simply asserts that it is a Nash equilibrium to repect each other's property. If there are no gains to trade then this is also the most efficient equilibrium, as we see in the next proposition.

**Proposition 9** *Suppose that the endowment bundle* $e$ *satisfies* $supp\, P \subset \{\lambda e | \lambda \in \Re\}$, *and then all efficient equilibria are of the form* $\sigma(e) = (1, \alpha)$, $\alpha \in [0, 1]$.

**Proof.** Given that $u(\lambda e) = \lambda u(e)$, then it is efficient for each agent to consume their endowment. Thus there are no gains from trade, except the need to reach an agreement. Hence the proof for proposition (6) applies to demonstate that $d = 1$ is the unique efficient equilibrium, while the value of $\alpha$ is irrelevant.

∎

Given that preferences are homethetic, then if agents demand the Paretian net trades, $T^*$, this results in the most efficient payoff possible in this trading game, defined by

$$V^* = \sum_{(e^1, e^2) \in E^2} u\left(e^1, \sigma^*, e^2, \sigma^*\right) P\left(e^1\right) P\left(e^2\right) \tag{17}$$

where $\sigma^*(e) = (1, 0)$, for all $e \in E$. However this is not a Nash equilibrium when there are gains from trade. In that case some agent has an incentive to demand more to affect the outcome of bargaining.

There are gains to choosing a net trade different from zero whenever $e^i_x / e^j_x \neq e^i_y / e^j_y$. Let $\nu$ be the probability that this occurs[18]. When $\nu > 0$, then setting $\alpha = 1$ is no longer the most efficient Nash equilibrium.

**Proposition 10** *There is an* $\varepsilon > 0$ *such for* $\nu \in (0, \varepsilon)$ *the most efficient Nash equilibrium results in an agreement every period and payoffs strictly larger than* $V^{\mathbf{0}}$. *At the equilibrium agents claim net trades that are stictly within the set of Paretian trades,* $T^*(e)$.

**Proof.** First fix the demand level $d = 1$. Think of the game as one for which there is a player for each endowment level $e^i \in E$, $i = 1, ..., n$. Associate to each endowment the strategy $\alpha^i \in [0, 1]$. We already know that $\alpha^i = 1$ for each player forms a Nash equilibrium. However this is not the only equilibrium.

Observe that for $d = 1$, payoffs are continuous in $\alpha$. Furthermore, for $\alpha$ sufficiently close to 1, payoffs are strategic complements, with payoffs locally increasing as we decrease

[18] Let $E(e) = \{\lambda e | \lambda \in \Re\} \bigcap E$, then $\nu = \sum_{e^i \in E} P\left(e^i\right) \left\{\sum_{e^j \in E(e^i)} P\left(e^j\right)\right\}$.

$\alpha$. Thus there exists an $\bar{\alpha} < 1$, such that the strategies may be restricted to $[0, \bar{\alpha}]$. The continuity in $\alpha$ ensures the existence of at least one mixed strategy equilibrium with support strictly in $[0, \bar{\alpha}]$. The set of Nash equilibria is closed, thus we may select the most efficient equilibrium with the support of $\alpha$ in $[0, 1]$. Given that we have establish the existence of at least one equilibrium with payoff greater than $V^0$, then we know that $\alpha = 1$ cannot be a stable equilibrium.

Notice that a small increase in $d$ causes a discrete decrease in payoffs, and hence it is not locally optimal to do so. When the probability of the gains $\nu$ is sufficiently close to 0 then we approach the payoffs from the one dimensional demand game. In that case $d = 1$ is a unique best reply, hence for $\nu$ sufficiently close to 0, $d = 1$ is unique best reply. For similar reasons it much also be the most efficient Nash equilibrium, otherwise we could find a more efficient Nash equilibrium than $d = 1$ in the case $\nu = 0$, which we know is not possible.

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# References


**Alchian, Armen A.**, "Uncertainty, Evolution and Economic Theory," *Journal of Political Economy*, June 1950, *58* (3), 211–21.

____ , "Some Economics of Property Rights," *Il Politico*, 1965, *30* (4), 816–829.

**Binmore, Kenneth G.**, "Nash Bargaining and Incomplete Information," 1981. ICERD discussion paper.

**Boyd, Robert and Peter Richerson**, *Culture and the Evolutionary Process*, Chicago: University of Chicago Press, 1985.

**Carmichael, H. Lorne and W. Bentley MacLeod**, "Gift Giving and the Evolution of Cooperation," September 1994. Forthcoming *International Economic Review*.

**Conlisk, John**, "Why Bounded Rationality?," *Journal of Economic Literature*, June 1996, *34* (2), 669–700.

**Cosmides, Leda and John Tooby**, "Better than Rational: Evolutionary Psychology and the Invisible Hand," *American Economic Review, Papers and Proceedings*, May 1994, pp. 327–32.

**Dawkins, R.**, *The Selfish Gene*, Oxford: Oxford University Press, 1976.

**Demsetz, Harold**, "Toward a Theory of Property Rights," *American Economic Review*, May 1967, *57* (2), 347–59.

**Ellingsen, Tore**, "The Evolution of Bargaining Behavior," June 1995. mimeo Stockholm School of Economics.

**Frank, Robert H.**, *Passions within Reason*, New York, NY, U.S.A.: W. W. Norton & and Company, 1988.

**Hayek, F. A.**, *Law, Legislation and Liberty*, London, U.K.: Routledge and Keagan Paul, 1982.

**Hirshleifer, Jack**, "The Emotions as Guarantors of Threats and Promises," August 1984. UCLA, Department of Economics working paper.

____, "The Paradox of Power," *Economics and Politics*, November 1991, *3* (3), 177–200.

____, "Anarchy and its Breakdown," *Journal of Political Economy*, February 1995, *103* (1), 26–52.

**Kahneman, David and Amos Tversky**, "Prospect Theory: An Analysis of Decisions Under Risk," *Econometrica*, 1979, *47*, 262–91.

**Knetch, Jack L.**, "The Endowment Effect and Evidence of Nonreversible Indifference Curves," *American Economic Review*, 1989, *79*, 1277–84.

**MacLeod, W. Bentley**, "Decision, Contract and Emotion," *Canadian Journal of Economics*, November 1996, *28.*

**Maynard-Smith, John**, *Evolution and the Theory of Games*, Cambridge, UK.: Cambridge University Press, 1982.

**Osborne, Martin J. and Ariel Rubinstein**, *A Course in Game Theory*, Cambridge Mass.: The MIT Press, 1994.

**Portney, Paul R.**, "The Contingent Valuation Debate: Why Economists Should Care," *Journal of Economic Perspectives*, Fall 1994, *8* (4), 3–8.

**Schelling, Thomas C.**, *The Strategy of Conflict*, Cambridge, MA: Harvard University Press, 1980.

**Simon, Herbert A.**, *Models of Bounded Rationality, Volume 2*, Cambridge, Mass.: MIT Press, 1982.

**Tullock, Gordon**, "Efficient Rent Seeking," in J. M. Buchanan, R. D. Tollison, and G. Tullock, eds., *Toward a Theory of the Rent-Seeking Society*, College Station, TX: Texas A & M University Press, 1980.

**Umbeck, John R.**, "A Theory of Contractual Choice and the California Gold Rush," *Journal of Law and Economics*, 1978, *21*, 421–437.

**Weibull, Jürgen**, *Evolutionary Game Theory*, Cambridge MA: MIT Press, 1995.

**Wilson, E. O.**, *Sociobiology: The New Synthesis*, Cambridge, MA: Harvard University Press, 1975.

**Yellen, John E.**, "The Transformation of the Kalahari !Kung," *Scientific American*, April 1990, *262* (4), 96–105.

**Young, H. Peyton**, "The Economics of Convention," *Journal of Economic Perspectives*, Spring 1996, *10* (2), 105–122.