The First Property Rights Revolution

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Abstract

The eclipse of collectivist institutions by more individual-based systems is a recurring historical episode, as occurred with the enclosure of common land in 18th century England (Allen (1992)) and the triumph of individual-cum-state-based systems of contract enforcement over collectivist approaches in early modern Europe and the Mediterranean region (Greif (1994), Greif (2002)). We seek to illuminate an earlier instance, the emergence of individual property rights and the displacement of the collectivist and egalitarian social structures typical of mobile foraging bands that typified early human social structure during the 30,000 or more years prior to the development of agriculture beginning around 11,000 years ago. With the domestication of plants and animals, individual claims on property became more extensive, particularly in land, livestock and their products. Drawing on the existing archeological, ethnographic and other evidence, we present a cultural group-selection model and agent-based simulation of this process. Our simulations suggest that the very long term persistence of the collectivist hunter gatherer social order could have been sustained by frequent intergroup conflict, significant levels of conformist cultural transmission and second-order punishment (of those who did not punish norm transgressors). We also find that individual property rights provided a better system of coordination among members of groups only after the ambiguity of possession endemic to the hunter gatherer economy was attenuated with the domestication of crops and livestock. Thus it was by clarifying possession that the advent of agriculture may have permitted what we call the first property rights revolution.

JEL Codes: B54, D23, N20

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1. Introduction

The emergence of states, property rights and complex institutions from an institution-free “state of nature” was grist for the classical philosophers' mill and has recently been taken up by economists.[1] In the state of nature, wrote Thomas Hobbes, “every thing is his that getteth it and keepeth it by force: which is neither property nor community; but uncertainty” (Hobbes (1651/1968):296). As a result, there is “no place for Industry; because the fruit thereof is uncertain, and consequently no culture of the earth.. and the life of man, solitary, poor, nasty, brutish, and short." (p186) Hobbes used his parable to justify the citizens' obedience to a state capable of securing private property and personal safety.

Hobbes' state of nature is a valuable thought experiment, but taken as history (which Hobbes did not) it is deficient, for three reasons. First, individually-held property rights in land, its produce, and other sources of people's livelihood emerged with the domestication of plants and animals starting around 11,000 years ago, while in most cases states developed many millennia afterwards. Recognizably modern property rights existed in these newly agrarian societies without the assistance of states. Among fishing people and other sedentary foragers, individual or family-based property rights appear to have existed even before the advent of domestication. Indeed, humans are not unique in this respect; many species of spiders (Hammerstein and Reichert (1988)), male Hamadryas baboons (Sigg and Falett (1985), Kummer (1995)) and other animals respect prior possession of sites and objects by conspecific individuals. Beginning with the biologists' Hawk-Dove-Bourgeois game (Smith and Price (1973)) economists have modeled the asymmetries arising from possession to develop a theory of the emergence of property rights in a stateless environment. The underlying idea – that respecting prior possession may be a mutual best response – is not new. David Hume (1964):263, writing less than a century after Hobbes, used it as the basis for his evolutionary account of property rights emerging spontaneously in a non-state environment: “I observe, that it will be for my interest to leave another in the possession of his goods, provided he act in the same manner with regard to me. ... And this may properly be call'd a convention... ”

The second historical shortcoming of the Hobbesian account is that it is quite unlikely that Hobbes' state of nature ever existed. For most of our history as biologically modern humans – roughly the100,000 years prior to the advent of agriculture – social interactions were organized without the aid of institutions even remotely resembling contemporary states or private property in land or the other sources of people's livelihoods.[2] They apparently did not,

[1] Important early contributions are Eaton and White (1991), Hirshleifer (1988), Schotter (1981), and Sugden (1986).

[2] In addition to the sources cited below, we have relied on Foley (1996). See also footnote 4.

however, suffer the chaos of the Hobbesean state of nature. Rather, in all likelihood, beginning as early as 100,000 years ago in Africa and later in other parts of the world, these groups were organized in a manner similar to a subset of the modern mobile hunter-gatherers described in historical and ethnographic accounts, their lives regulated by social norms enforced by collective punishment of miscreants. Christopher Boehm (1982):421 writes:

> In these ... communities, group sanction emerged as the most powerful instrument for regulation of individually assertive behaviors, particularly those which obviously disrupted cooperation or disturbed social equilibrium needed for group stability.

Sharing norms must have applied especially to those items, like large game, that were available only sporadically and in large packages, as is observed in many hunter gatherer groups in the ethnographic record for example (Kaplan and Gurven (2003)). Thus, with early hominid transition to a meat-intensive diet, it seems likely that our ancestors shared food resources among unrelated members of their groups (Stanford (1999), Stanford and Bunn (2001), Stiner (2002)). Recent behavioral experiments among hunter gatherers such as the Ache, the Hadza and the Lamalera (some of them recently settled) suggest that sharing norms concerning meat were generalized to other realms of behavior (Henrich, Bowles, Boyd, Camerer, Fehr, Gintis, and McElreath (2001)).

Social interactions among foragers were thus far from institution-free. In Ronald Coase's view of property rights as " the rights to perform certain actions" (Coase (1992):717) foraging bands had a well developed system of property rights. Nor were these arrangements unstable or short lived: they endured far longer than the ten or fewer millennia that have elapsed since the emergence of private property rights.

Third, both the Hobbesian state-based account and Hume's evolutionary interpretation explain the emergence of private property rights as an effective way to minimize the waste occasioned by conflicts among rival claimants for resources. But if private property rights are simply a better way of organizing social interactions, and if spiders and baboons have the capacity to recognize rights of possession, one wonders why these rights did not become common among humans 100,000 years earlier than they did.

We seek to illuminate the eclipse of the collectivist and egalitarian property rights systems typical of mobile foraging bands by systems of individual property rights. With the domestication of plants and animals, individual claims on property became more extensive, particularly in land, livestock, and their products. These new property rights emerged and for many millennia proliferated without the assistance of states or other centralized enforcement agencies. This is without a doubt one of the most important cases of institutional innovation on record. We call it *the first property rights revolution*. The key questions to be addressed are:

How could the hunter gatherer social order have persisted so long? And, why was it displaced by individual property rights with the advent of agriculture?

For the reasons above we do not pursue the state of nature modeling strategy. Instead of deriving the evolution of property rights from the blank slate of a rights-free environment, we seek to understand the dynamics of the particular collectivist social order from which individual property rights systems emerged. In this respect our approach is similar to the account of the enclosure of common lands in England given by Allen (1992) and the demise of the community responsibility system of contractual enforcement in favor an individual-based system in early modern Europe described by Greif (2002). Our methods differ from theirs, however, in using an agent-based simulation of a evolutionary game theoretic model to generate histories of artificial societies modeled to reflect what is known about late Pleistocene foragers and the first farmers. Like Hirshleifer (1995), we model the population frequency of individuals engaging in predatory as opposed to property-rights-respecting behaviors. Our model shares with Grossman and Kim (1995) the idea that resources may be defended individually, but that collective defense is also possible in the form of collective punishment of predators. But unlike these and the subsequent contributions that they stimulated, we do not study equilibrium outcomes among utility-maximizing agents. Rather, we investigate the explicit out-of-equilibrium dynamics and long term average characteristics of populations in which individual behaviors are governed by norms that are culturally transmitted inter-generationally and subject to stochastic variation. In addition, we seek to understand a particular historical transition from one well-defined system of property rights to another rather than the more abstract problem of the emergence of property rights from an anarchic property-less environment. Another difference between our approach and both the historical and theoretical studies mentioned above is that between-group conflicts play a critical role in our model.

We begin with a survey of the relevant empirical knowledge of the first property rights revolution. We then model the strategic interactions of members of a small group with a strategy set representing actions open to our ancestors, identifying two states that are stationary in the underlying dynamic, a Hobbesian state of nature and a collectivist hunter-gatherer equilibrium. We then introduce idiosyncratic behaviors analogous to mutations and describe the joint effects of two selection processes, one operating within groups and the other between groups. The penultimate section presents an agent based-model of a population composed of such groups. In the conclusion we reflect on the causal mechanisms underlying this process and other property rights transitions, and especially the role of technical change. .

2. Modeling The First Property Rights Revolution

Because we are attempting to shed light on a real historical process rather than to use a stylized history to motivate a general model, some attention to relevant empirical information is in order.

Little is known about the relevant late Pleistocene social structures, and the difficulty in making inferences about the social organization of human groups during this period on the basis of contemporary or recent simple societies is well-known.[3] We can say with some confidence, however, that small mobile foraging bands composed of both kin and non-kin, characterized by limited status differentials among adult males, and lacking centralized political systems were a common form of social organization. Lacking specialized enforcement structures it is likely that order was maintained through multi-lateral monitoring and sanctioning. Bruce Knauft (1991) writes that "[i]n simple societies...the violence that does occur ..is based on consensually approved status leveling among men." Boehm (1993) also refers to "a moral determination on the part of a local group's main political actors that no one of its members should be allowed to dominate the others." (p.228) Population was extremely sparse, with a typical density of one person per square kilometer or less in the populated areas. However, as a result of extraordinary climate variations in the late Pleistocene, it is probable that groups survived by migrating over long distances, in the process often encountering and conflicting with other groups. (Boehm (2000), Richerson, Boyd, and Bettinger (2001)).

Recent enthographies also suggest that substantial differences in social organization and livelihood existed among these groups, there being no single model of a mobile foraging band. Where rich stationary sources of livelihood could be exploited – fisheries for example – well defined individual property rights in sites and goods and high levels of inequality between families probably existed well before domestication (for example, Hayden (1997)). Moreover individual property rights were probably not entirely absent even among very early foraging bands. Individual or family rights to ornaments and tools apparently existed, (Kuhn, Stiner, Reese, and Gulec (2001), Klima (1962)). But the bulk of the nutritional intake of the members of a mobile foraging band came from resources that were not individually owned prior to capture which was then divided among group members including those who did not participate

[3] See especially Foley (1987).On the basis of the pronounced sexual dimorphism evident in their skeletal remains, Foley (1988):219 suggests that late Pleistocene foragers may have relied more heavily than recent hunter gatherers on the acquisition of meat and other large nutritional packages by males. Direct archeological evidence (animal remains at sites of habitation) for this is also given by Braidwood and Willey (1962):332, who reach the same conclusion. Because nutrients acquired in large packages are generally shared, it seems likely that food sharing was even more common among our ancestors than among recent foragers. See also Kelly (1995) and the encyclopedic Binford (2001), which provides comparable data on various aspects of social interactions for 339 extant or recent hunter gather groups. Boehm (2002) has identified 154 of these groups whose economic and cultural practices may typify the range of late Pleistocene societies, characterizing these as "mobile foragers, who seem almost always to be politically egalitarian, emphasize hunting, and share their meat.." (p.19). Others advancing the view that a subset of contemporary foragers are likely to be indicative of social human social structure before the advent of agriculture are Knauft (1991) and Winterhalder (2001).

in its acquisition.

Richerson, Boyd, and Bettinger (2001) show that a dramatic amelioration of climatic variability about 11 millennia ago transformed the domestication of plants and animals from a livelihood that was previously "impossible" to one that in the long run became "mandatory." While climate amelioration was a necessary condition, it was hardly sufficient for the flourishing of agriculture, however, as is suggested by the fact that domestication did not develop in a number of regions until many millennia following the climate change (e.g. Australia and currently agriculture-rich California). One obstacle to domestication was institutional. The new technology could not readily be deployed in the institutional environment of the typical foraging band. A particular impediment was the lack of individual property rights in meat and other large food resources and land, and the principle of egalitarian division. An example from the recent past of a group of foragers in Malaysia illustrates the problem:

> The traditional Batek notions that all natural resources are unowned until collected and that any food obtained in excess of the needs of the procurer's family must be shared with other families seem well suited to a nomadic foraging life, but wholly unsuited to ... peasant farming... giving up that set of ideas and practices would be psychologically very difficult for them to do as the obligation to share food is one of the fundamental components of Batek self-identity and one of the main bonds that link Batek families together as a society. (Endicott (1988):127)

Endicott reports that some of the Batek planted rice but that others (still foragers) simply harvested it (and, of course, felt obliged to share the harvest with those foragers who arrived too late). The farming Batek eventually left the area.

Because agriculture developed from an intensification of gathering rather than from hunting, its emergence had impacts on the division of labor between the sexes. In the American South West, groups whose social order remained oriented exclusively towards male activities such as hunting were displaced by groups that adapted their institutions better able to exploit the greater productive potential of what had historically been "women's work" (Bettinger and Baumhauf (1982)).

The transition from a mobile foraging to a sedentary way of life appears to have taken place both by farmers displacing foragers and by foragers converting to farming for their livelihood.[4] The relevant facts are the following. The process of transition was gradual, with

[4] This is the subject of a vast literature. In addition to the works we cite elsewhere, we have relied principally on Reed (1977), Price and Berbauer (1994), Rindos (1980), Price (2000), Rindos (1984), Marcus and Flannery (1996), Ammerman and Cavalli-Sforza (1984), and

intensified local foraging first reducing the mobility of the band and eventually leading to domestication proper. Reversals occurred, as with hunter gathers in Sweden who adopted farming around 5,000 years before the present (B.P.) and abandoned it after some 300 years, resuming foraging for their livelihood for another four centuries before again taking up farming. Groups with different livelihoods probably co-existed over long periods, as the with millennium-long intermingling of the Mashubian mobile foragers and the sedentary Natufians (possibly the first farmers) in the Levant beginning around 12,000 B.P. (Henry (1989) and in recent years with the Mbuti pygmies and their farming neighbors (Cavalli-Sforza (1986)) and among the Hill Pandaram, the Paliyans and others in Southern India (Bird-David (1988), Gardner (1988)). Initially agriculture appears to have reduced the productivity of labor (calories per hour of labor), while increasing the productivity of land.[5].

The diffusion of agriculture gradually eclipsed the social orders of all but a few foraging bands, and over a period of many millennia the latter came to occupy marginal ecological niches. With the exception of the Nile Valley, where state formation followed within a millennium of the development of agriculture, the centralized enforcement of property rights emerged much later. Eventually, however, the greater precision with which possession could be defined in agrarian societies, along with the reduced ability of agrarian community members to simply move to evade punishment, allowed a more effective codification and third party enforcement of property rights. (The Nile Valley is instructive in this respect, as its circumscription by arid lands deterred flight, and appears to have facilitated the early formation of an effective state (Allen (1997)).) At the same time, the heightening of inequality among community members (aided by the ability to accumulate wealth) gave rise to more differentiated economic interests among families and may have made the multilateral forms of norm enforcement more difficult. The resulting growth of centralized enforcement bodies (chiefdoms and other proto-states, then states) eventually reduced the role of mutual monitoring and peer-based enforcement, ushering in the third party enforcement that characterizes contemporary private property rights.[6]

Our model of the displacement of communal rights by individual ownership captures

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Zvelebil (1986) An alternative economic model of the rise of agriculture is Smith (1975).

[5] The dietary shift associated with agriculture replaced nutrients characterized by high calorie per unit of labor time (e.g. meat) by relatively more labor intensive goods (e.g. cereals, or foraged plants). See Kramer and Boone (2002) and the works cited there. Health status appears to have declined with domestication. Cohen and Armelagos (1984) conclude that "The ...expansion of early farming populations was accomplished in spite of general diminution of both child and adult life expectancy..."(p.594)

[6] Wright (1978) surveys a number of theories of state formation.

the above facts and conjectures. First, because, like Hume, we represent these property rights systems as conventions (that is, symmetric mutual best responses), distinct systems may well coexist over long periods in adjacent groups. Second, the foraging equilibrium is characterized by sharing enforced by collective punishment of self-aggrandizing members. Third, two processes of displacement are modeled. Stochastic events may cause a group to "drift" from the neighborhood of one convention into the basin of attraction of the other, and adjacent groups may engage in conflict or differentially survive environmental crises, with the weaker group's members being dispersed and assimilated by the stronger groups. Finally, agriculture did not predate the emergence of individual property rights, for successful agriculture required these rights. Where they did not exist, agriculture did not flourish because, according to two leading archeologists of the period, Robert. Braidwood and Gordon Willey. "culture was not ready" (Braidwood and Willey (1962):343). Thus, the eventual superior productivity of agriculture required the introduction of individual property rights and cannot account for the initial success of these rights.

In this model, the exogenous shock explaining the first property rights revolution is the amelioration and stabilization of climate occurring about 11,000 B.P. which greatly favored domestication as a strategy. The connection between agriculture and the emergence of individual property rights is the fact that possession of land and livestock is relatively unambiguous, especially by comparison to food resources that are hunted or gathered. The key characteristic of agriculture in this model was thus not that some of its products – grains for example – were easily stored as in the conventional account, but rather that the ownership of its main inputs was not easily mistaken. The fact that in contrast to the productivity of labor, the productivity of land was enhanced by early agriculture meant that smaller, richer patches became the essential means to a livelihood, facilitating the defense of individual claims.[7]

As the emergence of individual property rights and the elimination of the foragers' communal based property system occurred literally thousands of times in quite different ecologies and political circumstances. Talcott Parsons (1964) called these "evolutionary universals" namely "any organizational development sufficiently important...that rather than emerging only once, it is likely to be hit upon by various systems operating under different conditions." (p. 339). Parsons provides no causal account of why the institutions he identifies as evolutionary universals might have succeeded. But Frederich Hayek (1988) offers a suggestive explanation, which we will model below: the norms supporting these institutions have "spread by means of an evolutionary selection – the comparative increase of population

[7] Thus in our model the change in the nature of the goods making up the livelihood of our ancestors plays a role analogous to changes in the "technology of conflict" (due to Hirshleifer (1991)) in the model of Skaperdas (1992), changes in the "enforcement mechanism" in Eaton and White (1991) or changes in the relative effectiveness of defensive as opposed to predatory activities in Grossman and Kim (1995) and Baker (2003).

and wealth – of those groups that happened to follow them." (p. 6).

We thus propose a model of cultural group selection in which members of groups making up a larger population update their behaviors in response to payoffs and other information, and occasionally engage in contests with other groups, the losers of which sustain economic losses and are subjected to cultural assimilation by the winning groups. The approach is novel in that cultural transmission is explicitly represented as a process whereby individuals meet cultural "models" (e.g., elders, teachers), where these models may be chosen non-randomly from the group. The non-random selection of models may reflect either conformism in the socialization institutions (models are disproportionately likely to be selected from the more numerous types within a group) or the subjugated status of assimilated loser populations (models are selected from winning groups). The strategy set includes both the collective punishment of norm transgression, and a Bourgeois strategy under conditions of imperfect information concerning possession.[8]

3. Hobbesian and Rousseauian Equilibria

Suppose the n members of a foraging band are paired randomly to divide a good whose value is v. They may adopt three strategies: *grabbing*, *sharing*, and *punishing*.[9] An individual's type is not directly observable, and hence is not known prior to an interaction. When Sharers meet they divide the good equally. When Grabbers meet Sharers they take the good; when they meet one another they fight, gaining the good or bearing the costs of defeat, $c > v$, with equal probability. Punishers meeting either Sharers or other Punishers divide the good equally. However, when a Punisher is paired with a Grabber, all of the Punishers attempt to punish the Grabber. If they are successful, the good is distributed in equal shares to all punishers, while if unsuccessful the punisher bears the cost of defeat c.

The punishment strategy is collective in the sense that other punishers assist any punisher paired with a grabber, the result being that the probability of successfully punishing a grabber depends on the fraction of punishers in the population. To simplify the presentation below we will assume that the probability of successfully punishing a Grabber is the population frequency of punishers, β. In the simulation we adopt a less simplified assumption. Thus given

[8] The model, an adaptation of Bowles (2001), is an extension of the original cultural group selection model of Boyd and Richerson (1990). See also Vega-Redondo (1996) (section 4.9). Mistaken possession was first modeled in a similar setting by Hammerstein and Parker (1982). Gintis, Boyd, Bowles, and Richerson (2002) provide related model of punishment of norm violations.

[9] This will be recognized as a modification of the familiar Hawk-Dove game, the innovation being the punish strategy.

that the Punisher retains $v/\beta n$ if successful, which happens with probability β, the expected payoff to a Punisher paired with a Grabber is:

$$\pi\,(p,g) = v/n - (1-\beta)c$$

(We will consider the distribution of gains from other successful Punishers presently.) Thus, the payoffs are as in Figure 2. If α is the population frequency of Sharers, the (βn-1) other punishers successful in an interaction with a Grabber will number $(\beta n-1)(1-\alpha-\beta)\beta$. Each Punisher will receive $v/\beta n$ from each of these, so punishers will receive an expected amount in redistribution from other fellow Punishers of

$$(\beta n-1)(1-\alpha-\beta)\beta v/\beta n = (1-\alpha-\beta)v(\beta-1/n\,)$$

Figure 2 Payoffs in the punishment game
(Row player's payoff)

	Grab	Share	Punish
Grab	$\frac{1}{2}(v-c)$	v	$(1-\beta)v - \beta c$
Share	0	$\frac{1}{2}v$	$\frac{1}{2}v$
Punish	$v/n-(1-\beta)c$	$\frac{1}{2}v$	$\frac{1}{2}v$

The expected payoffs to the three strategies are thus:

(1) $\pi^s = (\alpha+\beta)\frac{1}{2}v$

(2) $\pi^p = (\alpha+\beta)\frac{1}{2}v + (1-\alpha-\beta)(\beta v - (1-\beta)c)$

(3) $\pi^g = \alpha v + \beta\{(1-\beta)v - \beta c\} + (1-\alpha-\beta)\frac{1}{2}(v-c)$

A convenient graphical representation of the state space for this system is the simplex in Figure 3, the dimensions of which are normalized so that the length of a line perpendicular to the edge gives the fraction in the population who are of the type indicted at the opposing vertex.

Suppose that the three strategies are cultural traits, learned from others, and that the cultural transmission process based on these payoffs according to a payoff monotonic updating process. Assume that n is sufficiently large that realized payoffs are approximated by expected payoffs. Thus we have

(4) $d\alpha/dt = \alpha(\pi^s - \underline{\pi})$

(5) $d\beta/dt = \beta(\pi^p - \underline{\pi})$

where the average payoff, $\underline{\pi}$, is

$$\underline{\pi} \equiv \alpha\,\pi^s + \beta\,\pi^p + (1-\alpha-\beta)\pi^g$$

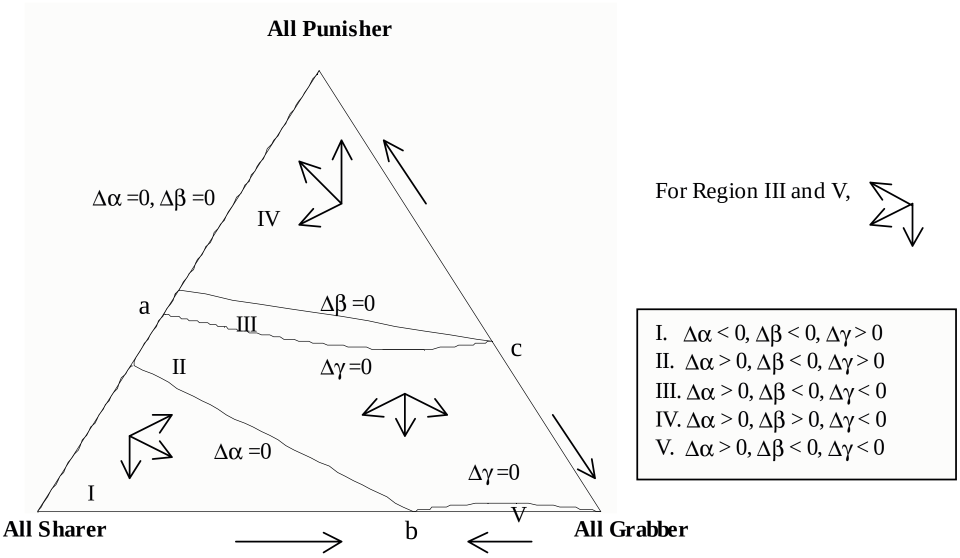

Figure 3. Within-group dynamics. The vectors indicate the direction of movement in the regions defined by the loci along which α, β and γ are stationary. To generate this and the next figure we used $v/c = 2/3$.

What can we say about the outcomes likely to be generated by this dynamical system? The dynamics implied by the above equations are presented in Figure 3. The vectors indicate the direction of movement for a population composed by the frequencies given by the point at the base of the arrows. Two types of stationary outcome are of substantive interest. In the first, $\beta=0$, $\alpha = 1\text{-}v/c$ (and $\gamma \equiv (1\text{-}\alpha\text{-}\beta) = v/c$). This outcome, point **b** in the figure, is analogous to the familiar equilibrium of the Hawk Dove game, and is asymptotically stable. Punishers cannot invade this population. Punishers do no better than Sharers interacting with them, and fare worse than Grabbers when interacting with them (they always fight and almost always lose).We will call this the *Hobbesian* equilibrium, as it is characterized by incessant fighting over property, with, as Hobbes suggested, consequently low level of average payoffs.

The second stationary outcome is the set of outcomes in which $\alpha+\beta = 1$, that is, the left edge of the simplex in Figure 3. Of particular interest are the states on the upper portion of this edge, that is, those for which for $\alpha<\alpha^{max}$, the point indicated by **a** in the figure. Each of these points is a Lyapunov (neutrally) stable equilibrium, that is, it is stationary but perturbations are not self-correcting. Every outcome in this set is uninvadeable by Grabbers (or any mixed strategy with Grabbing in its support). This is because, for $\alpha<\alpha^{max}$ and $\alpha+\beta=1$, $\pi^g < \pi^s = \pi^p$. But if non-best response behavior sometimes occurs, these equilibria are subject to drift along the edge of the simplex because Sharers and Punishers are behaviorally indistinguishable in the absence of Grabbers. This equilibrium combines the unconditional sharing and collective upholding of social norms admired by Jean-Jacques Rousseau, so, we will call it *Rousseauian.*

4. Equilibrium Selection (Hunter-Gatherer Style)

Which of these equilibria would we expect to obtain? All that can be said in the absence of non-best-response play is that initial conditions will determine which of the stationary outcomes will obtain.However, in a more realistic setting in which chance events occur we can say considerably more. Such stochastic events could be either mutations (if we considered the behavioral traits to be expressions of genetic inheritance) or some other kind of non-best-response play, that is, actions undertaken for reasons not accounted for in the model, including experimentation and errors. As the three strategies in this model are cultural traits, non-best response actions take the form of switching one's strategy for reasons not given in the model. Thus chance events may induce a shift from the neighborhood of one equilibrium into the basin of attraction of the other. Having taken account of out-of-equilibrium dynamics the question then becomes: in the long run will the population spend most of its time in the neighborhood of the Hobbesian or the Rousseauian equilibrium?

Given chance events, in the model thus far developed, the Rousseauian equilibrium will not persist over long periods. Suppose β=1, so only Punishers are present. Due to non-best-response play, both Grabbers and Sharers will be introduced into the population. The Grabbers will lose virtually all of their contests with the numerically predominant Punishers and will be eliminated. But in a population composed of just Sharers and Punishers, all will share, and except for the chance occurrence of a Grabber, they will receive the same payoffs. Depending on the rate at which chance events occur, it will take more or less time for sufficiently many Sharers to accumulate so that Grabbers can now invade, the Punishers being too few to impose sufficient punishment on them. In other words, the population will have drifted along the left hand edge of the simplex in Figure 3, past point **a**, that is, into the basin of attraction of the Hobbesian equilibrium. By contrast to the Rousseauian equilibrium, the Hobbesian equilibrium is asymptotically stable, and thus will not be subject to the chance-induced drift that unravels the former. Of course, the Hobbesian equilibrium will itself be displaced: sooner or later a bunching of chance events will displace the population into the basin of attraction of the Rousseauian equilibrium. But the fact that the Hobbesian equilibrium is asymptotically stable means that its displacement will be infrequent. The population would spend most of its time in the neighborhood of the Hobbesian equilibrium. Why, then, did most of human history apparently witness social arrangements more akin to the Rousseauian equilibrium? What is missing from the model? Three factors might contribute to the evolutionary success of the hunter-gatherer way of life.

First, if groups are subject to periodic encounters with adversity, either environmental or conflicts with other groups, the groups with higher average returns are more likely to survive. Average returns at the Rousseauian equilibrium are v/2, and at the Hobbesian equilibrium $v(1-v/c)/2$, so groups without Grabbers would be favored (and those with Grabbers will be disadvantaged in proportion to the fraction of Grabbers (v/c) in the population). Figure 4 gives the expected average payoff of every group composition in the simplex, the contours indicating iso-average-payoff loci. If higher payoff groups expand at the expense of lower payoff groups, the direction of change is given by the arrows, namely not toward the All Punisher state but rather towards the left-hand edge where Grabbers are absent and average payoffs are maximized.

Second, conformist cultural transmission will work against drift, making the All Punish outcome asymptotically stable. If virtually all members are Punishers even weak conformism will be enough for Sharers to be eliminated because the payoffs to Sharing and Punishing are equal in the absence of Grabbers.

Finally, *near* the Rousseauian equilibrium Sharers and Punishers *are* distinguishable because the occasional Grabber who occurs by chance will provide Punishers with an opportunity for collective punishment. The (also rare) Sharer will abstain from the collective punishment, free riding on the civic mindedness of the Punishers. But given human capacities to devise and enforce codes of moral conduct (already practiced by the Punishers against the Grabbers), it is likely that non-punishing Sharers would also be punished. Once this so called *second-order punishment* is added, the Rouseauian equilibrium will be asymptotically stable even if the punisher incurs a cost and the cost imposed on free riding Sharers is small, perhaps nothing but a brief period of shunning or a bit less of a shared food resource. The reason, as in the case of conformism, is that second-order punishment need not counteract selection *against* punishers; it need only prevent drift.[10]

[10] There are other reasons why the Rousseauian equilibrium might persist. It is unrealistic to assume the benefits of the prize are linear rather than concave in the amount acquired. This is particularly so where hunting of large game is concerned, as a single prize – an antelope, say – may represent food enough for the entire membership of the band in a form which is not easily stored. This is the basis of Blurton-Jones (1987) "tolerated theft" interpretation of sharing of large food packages in simple societies. Taking account of the concavity of returns would reduce the returns to Grabbing and enhance the returns to dividing the prize (that is Sharing, or Punishing).

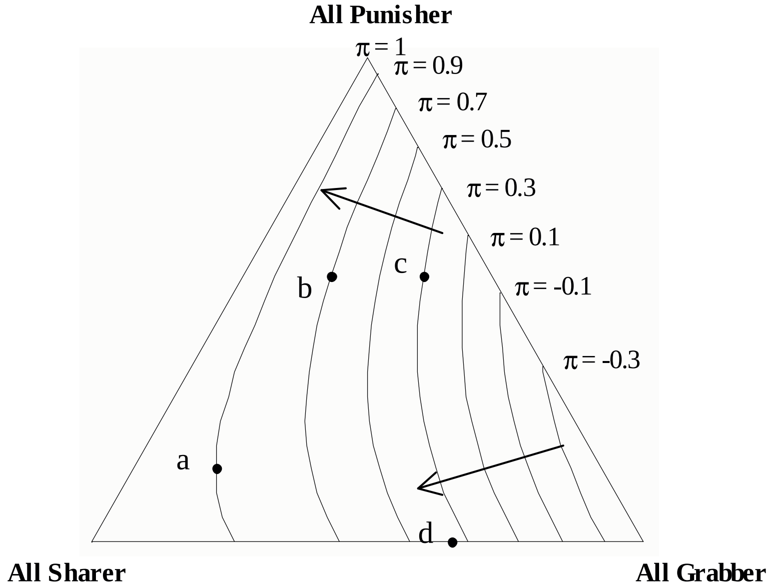

Figure 4 Average payoffs and between-group dynamics. The contours indicate distributions of the three strategies in the population for which the group level average payoff is the same. The arrows indicate the direction of ascent. The highest group average payoff=1 occurs when Grabbers are absent (the left edge). Thus a group with composition (**a**) (many Sharers, few Grabbers or Punishers) will have higher payoffs than a group (**b**) with many Punishers, few Grabbers and few Sharers. Note (i) that a group with a majority of Punishers such as (**c)** will have lower payoffs than a group at the Grabber-Sharer equilibrium (**d**); (ii) the surface is virtually flat in the neighborhood of the all Sharer distribution. The coordinates of the points indicate are [(1-α), α, β]: [**a**=(0.15, 0.70, 0.15), **b**=(0.16, 0.29, 0.55), **c**=(0.33, 0.12, 0.55), **d**=(0.66, 0.34, 0)]

Second-order punishment, the shared fates of group members when faced with adversity, and conformist cultural transmission make it plausible that Rouseauian equilibria might have persisted over very long periods of time, even millennia. That is, until climate change made agriculture possible. The Batek case mentioned above suggests that the development of agriculture depended on the emergence of rights of individual ownership in such things as crops, domesticated animals and land. It seems likely that if the Batek case were repeated numerous times, a new strategy might emerge and proliferate: act like a Grabber if one is a possessor, and like a Sharer if not. This is of course the Bourgeois strategy in the Hawk-Dove game: the Bourgeois strategy is evolutionarily stable and can invade the Hobbesian equilibrium, creating a new asymptotically stable equilibrium (with no Punishers, Grabbers, or Sharers present) which we will call *Bourgeois.* As long as possession is unambiguous, at this equilibrium no fights occur, so average payoffs are the same as at the Rousseauian equilibrium, namely $v/2$.

But if the Bourgeois equilibrium is so good, one may wonder, why did it not emerge long prior to the advent of agriculture? A possible answer is that agriculture made possession unambiguous: it is much simpler to determine if this plot of cultivated land or this store of harvested grain is in my possession or not than to know who "possesses" the prey we are stalking but have not yet seen. Ownership of large foraging territory with sparse human population would be equally difficult to define and enforce. Where property rights become unambiguous, individuals can use the asymmetries associated with possession to support correlated equilibria that eliminate conflict.[11]

We model this as follows. Some fraction of the time $\mu \in [0,1]$ Bourgeois players mistakenly believe they are possessors, or in any case act that way, playing Grabber, while in the role of possessor they always play Grabber.[12] Does the Bourgeois equilibrium exist if possession is subject to error? To answer this, we need to consider the expected payoffs to this strategy, when played against itself, to determine if Bourgeois can be a mutual best response (and hence an evolutionarily stable strategy), or

$$\tfrac{1}{2}[(1-\mu)v + \mu\tfrac{1}{2}(v - c)] + \tfrac{1}{2}\,\mu\tfrac{1}{2}(v - c) = \tfrac{1}{2}(v - \mu c)$$

The first term on the left hand side expresses the fact that with probability one-half the individual is a possessor, playing Hawk, and facing an intruder who as a Bourgeois "correctly" plays Sharer $(1-\mu)$ of the time, granting v to the possessor, but μ of the time "mistakenly" plays Grabber, leading to the conflict payoff $\tfrac{1}{2}(v-c)$. The second term on the left repeats this mistaken conflict payoff for the cases when the individual is an intruder. As expected, the payoff is declining in the degree of property rights ambiguity, μ, and reproduces the Grabber-to-Grabber

[11] The nature of agricultural property may also have favored possessors over intruders in conflicts as has been observed in spiders' defense of their webs and many other animals. The result would have been a reduced level of conflict, favoring Bourgeois individuals in the within group selection process and groups near the Bourgeois equilibrium in between group selection. The model is readily extended in this way, but for simplicity we model only the reduced ambiguity of possession.

[12] Alternatively, assume that possession is never ambiguous but that the diet consists of two types of goods, meat for which sharing norms exist and seeds which are typically consumed by the family of the individual who acquired them. Then μ is the fraction of the diet made up of meat, and the Bourgeois strategy is if intruder respect rights of possession of the "owned" (non-meat) goods, but not of meat, if possessor, defend all goods. This formulation reproduces the model of property rights ambiguity that we simulated.

payoff ($\frac{1}{2}(v - c)$) when μ=1, and is $v/2$ when $\mu = 0$.

The expected payoff to a mutant Grabber in a homogeneous population of Bourgeois players is $\frac{1}{2}v(1-\mu) + \frac{1}{4}(v-c)(1+\mu)$. For $\mu < 1$, this expression is clearly less than the payoff to Bourgeois when played against itself (above). Thus the mutant Grabber will not proliferate. (The same can easily be shown for Punishers.) But the expected payoff to a mutant Sharer in a Bourgeois population is $(1-\mu)V/4$ so there clearly exist values of $\mu < 1$ such that Share is a best response to Bourgeois. If contestation over property rights is sufficiently likely due to the ambiguity of possession, the Sharer mutants will thus proliferate, and the Bourgeois equilibrium is not stable. Thus, a foraging way of life would be unlikely to support a Bourgeois equilibrium, while in an economy based on domesticated plants and animals, a Bourgeois equilibrium might persist over long periods.[13]

5. An Agent-Based Model of the First Property Rights Revolution

The account we have just given, while consistent with what is known about the relevant facts, is incomplete in an important respect: we have not shown that the Rousseauian equilibrium could have persisted under environmental and other conditions approximating early human existence. Nor have we shown that the causal model we have just outlined would have brought about a revolution in property rights under these empirical conditions.

We know that as long as possession is somewhat ambiguous, the Rousseauian equilibrium will allow higher average payoffs but will be more susceptible to displacement by chance events (drift) than the less efficient but more robust (because it is asymptotically stable) Hobbesian equilibrium. If the groups interact, with the homogeneous and higher payoff groups replacing the more conflict ridden and poorer groups, will the payoff advantages of the Rousseauian equilibrium result in enough victories over Hobbesian groups so that the robustness advantages of the Hobbesian equilibrium are more than offset, and Rousseauian groups predominate? How will migration among groups affect the outcome? And will the perfection of property rights associated with the rise of agriculture eventually doom the Rousseauian communities?

Analytical answers to these questions are not possible due to the complexity of the

[13] Agriculture favored the Bourgeois equilibrium in another way. First, unlike meat and many gathered foods, grains and some other crops could be stored with relatively little loss, reducing the concavity of the relationship between productive success on the one hand and living standards on the other. Grain production allowed one to self-insure against adverse future events by storage, rather than relying on mutual sharing to smooth out the vagaries of the foraging economy. This linearization of benefits thus raised the opportunity cost of sharing, and reduced the risk pooling advantages of sharing.

interactions under investigation. These arise because selection both within and between groups takes place, small group size heightens the importance of matching noise, idiosyncratic non-best response play, migration, and chance events involved in the fissioning of groups. We therefore use agent-based simulations to reveal the underlying dynamic, presenting long-term behavior of the population averaged over many runs of many thousands of generations each. The two main tasks of the simulation are to see if something like the Rousseauian equilibrium could have persisted over many millennia prior to 11,000 years before the present, and to explore the effects of increasing certainty of possession on this social order.

Our artificial society is made up of individuals -- Sharers, Grabbers, and Punishers – living in groups.[14] (Bourgeois types will be introduced presently.) Within groups, individuals interact according to the above game (with slight modifications to be described); and they also interact with members of other groups when groups come into conflict over resources or for some other reason. They interact as follows. During each period (a biological generation), each of the 20 members of a group is randomly paired with another member to play the Grabber-Sharer-Punisher game. Each member plays the game (with a newly selected partner each time) a number of times in a generation (in most simulations, five). If a Punisher and a Grabber meet, the probability that the Punisher will win the fight depends on m, the number of Punishers in the group (who join in punishing the grabber) and the number of grabbers, g, with the probability that the Punishers win being $m/(m+g) - \omega$ where $\omega \in [0,½]$ is the advantage that the single Grabber has in resisting collective punishment. (Note that if $\omega = 0$ a single Punisher fighting with a single Grabber would stand an even chance of winning. This and other minor amendments of the theoretical model have been introduced because some of the assumptions adopted to keep the theoretical model analytically tractable are unrealistic. More plausible assumptions are easily accommodated in the simulation model.) As before, if the Punishers win, they share the prize, v.

The agent-based model can accommodate a considerably more detailed account of the process of inter-generational cultural transmission. Technically, our group members live forever; the passage of generations is marked by the occasional occurrence of a period (call it adolescence) during which they may adopt new behaviors. Once each generation – after all games have been played -- each member is paired with a cultural model, possibly a teacher, religious leader, successful hunter, or competitor. This pairing process reflects the way the group socializes its members. If the model and the member are of the same type, the member simply retains his trait. If the two have different traits, then the member compares his total payoffs this period to the model's payoffs, and switches to the model's trait if the model's payoff is higher. Thus behavioral diversity “turns on” the updating mode, which if, activated, is monotonic in realized payoffs.

[14] We executed the simulation using C++. A detailed description of our simulation algorithm is available at http://www.santafe.edu/~bowles/artificial_histories.

The pairing rule will introduce conformism to the transmission process if each member of the more numerous type within a group is more likely than others to be drawn to be a cultural model. To allow for this, we let the probability that a Sharer will be drawn a cultural model be

$$\alpha^{\eta} / (\alpha^{\eta} + \beta^{\eta} + \gamma^{\eta})$$

where $\eta > 0$ is a measure of biased cultural transmission. The probability that a Grabber or a Punisher is drawn for the cultural model pool is calculated in similar fashion. Figure 5 illustrates the biased assignment of models to members if there are just two types in the population; for $\eta > 1$, the bias is conformist, with larger groups contributing proportionally more to the pool of cultural models. For $\eta = 1$ the pairing of members and cultural models is random. (For $\eta < 1$ the bias is anti-conformist, larger groups contributing proportionally fewer to the pool;we do not consider this case).

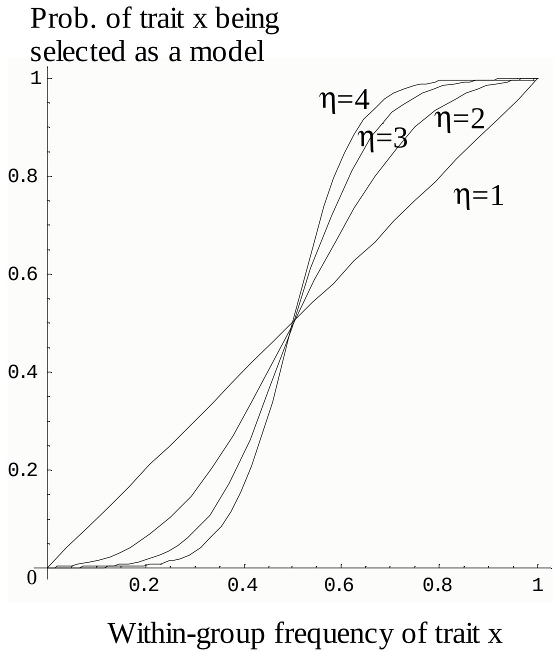

Figure 5 Biased cultural transmission. The parameter η determines the extent to which cultural models are drawn disproportionately from the more common types. The figure shows the degree of bias in a group with two types.

Groups were placed on a torus (a donut-shaped graph with no edges, insuring that every group had the same number of neighbors). Each generation the group engages in a conflict with a randomly chosen neighbor. (Warfare was probably much more common than this;we consider the evidence on the frequency of conflicts in Bowles, Choi, and Hopfensitz (2002)). The group with the higher average payoff wins the conflict and the losing group suffers cultural extinction, its members being assimilated into the winning group.[15] As a result, members of the winning group play a pre-eminent role in the socialization of the next generation of the losers. We model this as follows. The cultural models for the losing group are all drawn from the winning group according to a pairing rule given by some value of $\eta > 1$. Thus if the winning group is mostly Punishers and the losing group is composed of Grabbers and Sharers, virtually all of the cultural models to which the losers will be exposed will be

[15] This model conflict and assimilation is based on the study of historical processes, as for example took place among the Dinka conquered by the Nuer during the early 20th century and the assimilation of local European cultures into the nation states that displaced them between 1500 and 1900 (Weber (1976), Gellner (1983), Kelly (1985)).

Punishers. This experience will activate the updating mode of most of the next generation among the losers inducing them to compare payoffs. The winners of a conflict also seize some of the resources of the losing group, perhaps occupying favored habitats. We model this by a reduction in payoffs to all members of the losing group. The losers thus suffer two effects of their loss, both increase the likelihood that they will switch to a trait that was common among the winners: they are assigned models from the winning group, and their payoffs are reduced.

We simulated the above dynamic. To explore the viability of the Rousseauian equilibrium, we systematically compared the distribution of types in the total population under the six distinct structures of within- and between-group social interaction listed in Table 1. Migration takes place among neighboring groups (the so called stepping stone model of migration) while keeping group size constant at 20. We initiated each simulation with a random distribution of types in each of the groups. To be confident that we had captured the long term average behavior of the system, we executed twenty or thirty simulations of 10,000 generations for the results reported (this insured that the initial conditions or occasional long term lock-in to a particular equilibrium did not bias our results. Figure 6 presents a sample of the main results.

Interaction structure	α	β	γ	$\underline{\pi}$
(a) group conflict, biased transmission, 2nd order pun.	18.8	72.0	9.2	0.72
(b) none of the above	31.5	8.6	60.0	0.30
(c) biased transmission and 2nd order punishment	12.9	7.1	79.9	-0.19
(d) group conflict	39.0	27.6	33.4	0.62
(e) group conflict and biased transmission	37.7	41.5	20.8	0.74
(f) group conflict and 2nd order punishment	24.7	57.0	18.3	0.59

Table 1 Equilibrium selection: mean distribution of strategies and payoffs The columns headed α, β and γ give the average composition of the total population, that is the percent Sharers, Punishers, and Grabbers, respectively, in 10 runs totaling 300,000 generations (for each entry). The six interaction structures are the same as in Figure 6 The average payoff per game is $\underline{\pi}$. The parameter set for these runs is as follows: there are 25 groups with 20 members, the rates of migration and idiosyncratic play are both 0.2 per generation, group conflict occurs every generation, five games are played per generation, η = 2, v=2, c=3 ω=0.2. Following a conflict between Punishers and a Grabber, any Sharers present suffer a second-order punishment of 0.3 while the Punishers bear a cost of carrying out this punishment of 0.15 shared amongst all of them. The post-conflict resource transfer from loser to winner groups is 3 (which when compared to a maximum difference in payoffs per generation of 25 may understate the economic losses in warfare.)

Panels **a** and **b**, represent specifications for which most groups were in the neighborhood of the Rousseauian and Hobbesian equilibrium, respectively. What accounts for the difference in panels **a** and **b** is that the former is a simulation representing the structure of social interactions which we consider typical of the mobile foraging band: intergroup conflicts, second-order punishment, and conformist cultural transmission. By contrast, the simulation in panel **b** included none of these aspects of hunter gatherer society. Table 1, reporting the average of 300,000 generations for each entry, confirms the visual impression given by the sample of data points in Figure 6. When all three aspects of hunter gatherer society are present, Punishers constitute almost three quarters of the population on the average, and when all three are absent, Grabbers make up 60 percent of the population. Average payoffs are more than twice as great under the first condition. Comparison of **a** and **b** suggests that these three aspects of social interaction (or some of them in combination) played a central role in the remarkable persistence of the foraging way of life.

To identify the contribution of each, we ran simulations with all the possible combinations. For example when biased cultural transmission and 2^{nd} order punishment are operative, but there are no group conflicts (panel **c**) an even greater fraction of the population are Grabbers, and Sharers are correspondingly fewer. The reason is that conformist transmission favors the Grabbers in the neighborhood of the Hobbesian equilibrium where they are in a majority. By contrast, 2^{nd} order punishment of Sharers by the few Punishers present reduces the payoffs of both types. When group conflict and 2^{nd} order punishment are combined without conformist transmission, (**f**), the population oscillates between the neighborhood of the Rousseauian and Hobbesian equilibria.

Notice (Table 1) that when the population is in the neighborhood of the Rousseauian equilibrium, a substantial number of Sharers are typically present. This is in part the result of drift along the left edge of the simplex, as anticipated. But in addition, group conflict strongly favors groups with many Sharers (recall the group average payoff contours in Figure 4). A surprising result of this is that group selection *per se* tends to *de*stabilize the Rousseauian equilibrium by accelerating movement downwards along the left edge of the simplex, augmenting the influence of drift, and thus propelling groups into the basin of attraction of the Hobbesian equilibrium.

By contrast, in simulations in which second-order punishment and conformist transmission combined with group conflict, most groups remained close enough to the Rousseauian equilibrium to avoid the unraveling of its social order. The occasional groups near the Hobbesian equilibrium were then readily eliminated by group conflict (recall the substantial difference in payoffs). When group conflict alone is operative, the population is about evenly divided, with a slight preponderance of Sharers, Punishers being the smallest of the three sub-populations (Table 1 and panel **d**). Simulations not shown indicate that if group conflicts are less frequent (once every two or three generations) the Rousseauian equilibrium is sustained most of the time, as long as second-order punishment and conformist cultural transmission (η

= 2) are operative. The results are not very sensitive to variations in group size, and the rates of non-bst response play and migration.

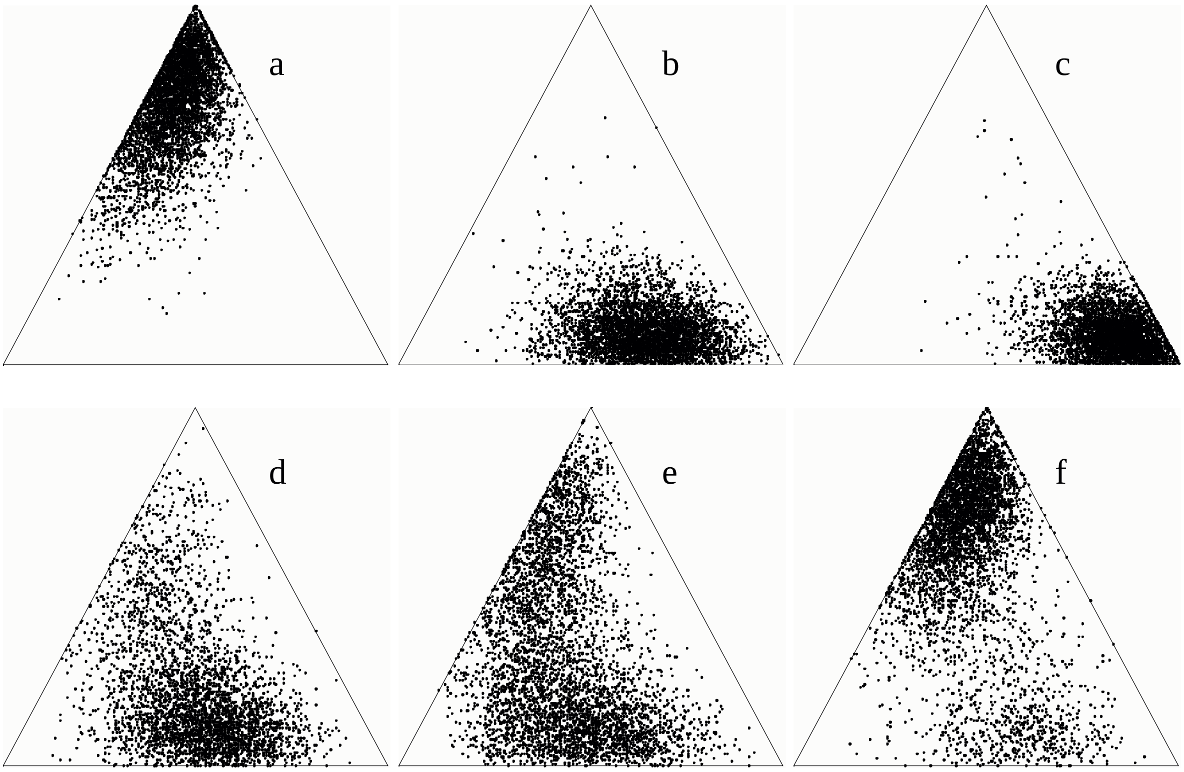

Figure 6 Equilibrium selection: simulation results. Each simplex represents a distinct structure of within and between group interactions. The dots in each simplex indicate the composition of one group in one generation. The interaction structures represented in each panel are: (a) group conflict, biased cultural transmission, second-order punishment; (b) none of the above; (c) biased cultural transmission and second-order punishment; (d) group conflict; (e) group conflict and biased cultural transmission; (f) group conflict and second-order punishment. The 5000 observations shown here represent the composition of all 25 groups in 200 consecutive generations selected to correspond closely to the average compositions over the 300,000 generations simulated for each treatment shown in Table 1.

How does the reduction in the ambiguity of property rights associated with the introduction of agriculture and the coincident appearance of Bourgeois players change the picture? As one would suspect, the answer depends on how good the property rights are. To model this new situation, we eliminate the Grabbers (we know that Bourgeois mimics Grabber when property rights are always mistaken, and will do better than Grabber as long as property rights are *ever* correctly identified, so they would be eliminated by the evolutionary forces we

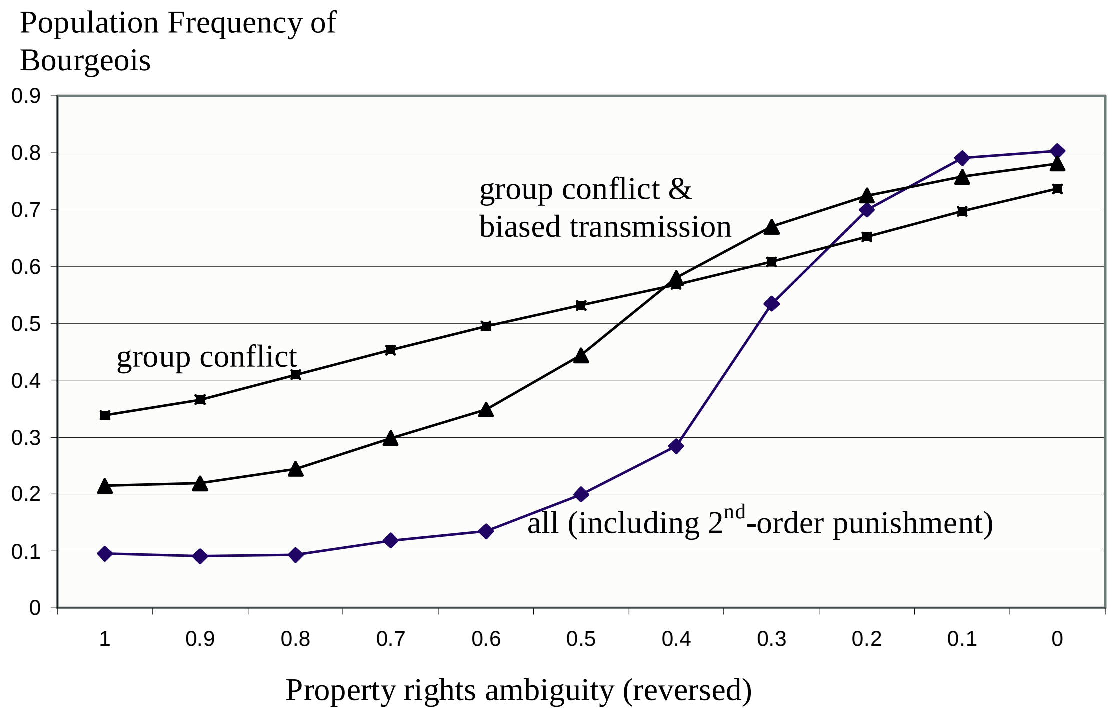

Figure 7 The first property rights revolution. Each point is the average frequency in 20 simulations of 10,000 generations each. Simulations combingin group conflict and second-order punishment were virtually identical to that shown that combine group conflict and biased transmission.

are modeling in any case). But we retain the Sharers, because their role in unraveling the Rousseauian equilibrium is an essential part of the evolutionary process under investigation.

One way to explore the effect of the decline in property rights ambiguity is to simulate the population for the various combinations of structures of between- and within-group interaction, for values of μ from 1 (complete ambiguity) to 0 (complete certainty). Figure 7 presents these results. Because the Bourgeois strategy is identical to the Grabber complete property rights ambiguity, the Bourgeois fraction in the simulations with $\mu=1$ replicates the results for the Grabber column in Table 1. When group conflict, biased cultural transmission and 2^{nd} order punishment are all operative, the Bourgeois fraction of the population remains low until μ falls to one-half or less. But with additional improvements in the definition of property rights, the Bourgeois fraction rises steeply. By contrast, when only group conflict is operative, even small reductions in the ambiguity of property rights result in significant increases in the Bourgeois fraction.

6. Conclusion

What can one conclude from these simulations? We have learned that for the parameter values and model specification implemented, the Rousseauian equilibrium is sustainable against either the Hobbesian or Bourgeois invasion if property rights are ambiguous and second-order punishment, conformist transmission or group conflict is operative. However, as property rights become more certain, these mechanisms cannot sustain the Rousseauian equilibrium even when all of its supporting mechanisms are operating simultaneously. Both the historical relevance of the hunter-gatherer social order modeled as the Rousseauian equilibrium and the critical role of the emergence of agriculture and the increasing certainty of possession are strongly suggested by these simulations. Of course this does not mean that the first property rights revolution happened for the reasons given above. All that this or any other simulation can show is that it could have.[16]

Our model has stressed the importance of an exogenous technology shock in the emergence of individual property rights. But the commonly-held view that a *prior* domestication of animals and plants created the environment in which individual rights could subsequently develop is surely incorrect. As the case of the hapless Batek rice growers suggests, had something like collectivist and egalitarian property rights of the typical foraging band not given way to individual property rights, it is unlikely that agriculture would have proven such a successful alternative to the foraging way of life. The early transformation of the human diet to include more meat provides another example. Winterhalder and Smith (1992):60 write:

> ...only with the evolution of reciprocity or exchange-based food transfers did it become economical for individual hunters to target large game. The effective value of a large mammal to a lone forager ...probably was not great enough to justify the cost of attempting to pursue and capture it, ... However, once effective systems of reciprocity or exchange augment the effective value of very

[16] Our interpretation will be more persuasive if it proves difficult to model and simulate alternative scenarios that generate the relevant historical transitions for historically plausible parameter sets.

large packages to the hunter, such prey items would be more likely to enter the optimal diet.

As in the case of domestication, the technological change – targeting big game – apparently does not predate and cause of the cultural change; rather it appears that that the two developed in tandem. An account of the first property rights revolution recognizing the role of culture in shaping technological evolution as well as the converse, would identify the climate change as the exogenous shock, with technology (domestication) and culture (new property rights) co-evolving in the newly ameliorated ecological settings.[17]

This model thus may provide the causal underpinnings for the claim that individual property rights may be counted among Parsons's list of evolutionary universals, while vindicating Hayek's suggestion that market institutions may have evolved through cultural group selection.[18] Ironically, the causal mechanism itself is Marxian in origin, for he was the first to articulate the view that revolutions in social structure are driven by advances in technology. "Social revolution" occurs, he wrote, when "the material forces of production [technologies]...come into conflict with ... the property relations within which they had been at work before. From forms of development of the forces of production these relations turn into their fetters." (Marx (1904):11-12) The same mechanism (albeit with less revolutionary consequences) appears to have been at work in a number of property rights transitions. Examples include the introduction of barbed wire fencing and its impact on property rights in the U.S. South West (Anderson and Hill (1975)), and the impact of water-driven mills in 19th century New England on riparian rights (Horwitz (1977)). Oliver (1962) gives a related account of the transformation of the social structure of the U.S. Plains Indians resulting from the introduction of horses. Of course, if this general approach to the evolution of property rights is correct, there is no to doubt that future changes in technology may lead to further property rights transformations, suggesting that the teleological implications sometimes read into Parsons, Hayek and Marx may be misguided.

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[17] Richerson and Boyd (2001) advance a similar co-evolutionary interpretation of the evolution of social complexity.

[18] The model may also give a causal basis for the otherwise functionalist explanation of the emergence of individual property rights offered by Alchian and Demsetz (1973) and other seminal works of the property rights paradigm. Many historical and ethnographic studies inspired by the property rights school, however, provide persuasive causal accounts of changes in property rights regimes. Among these not cited elsewhere are Davis and North (1971), Firmin-Sellers (1996), Ensminger (1996), Umbeck (1977) and Libecap (1978)

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