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Emergence and Evolution of Property Rights: an Agent Based Perspective

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Abstract In this paper we provide a critical assessment on how agent based models (ABMs) may improve and extend the traditional theoretical approaches on the origin and evolution of property rights, namely the economics of property rights and the evolutionary game models on contest behavior. We contend that ABMs, through their focus on adaptive complex systems, integrate and foster the analytical capacity of traditional approaches in several directions. First, they can add behavioral rules which go beyond simple utility maximization, such as those deriving from cultural traits. Second, they not only allow indentyfing stationary outcomes, but also the timing of evolutionary patterns. Third, ABMs highlight how the structure of interactions among agents will influence the outcome.

Keywords Property Rights, Agent Based Modeling,
JEL Codes C63, K11, P48, Q15

1 Introduction

The aim of the paper is to provide a critical assessment on how agent based models (ABMs) may improve and extend the findings of traditional theoretical approaches on the origin and evolution of property rights. As property rights are recognized as a key institutional component of societies and economies in shaping resource use and exchange (North, 1990), in the last decades there has been an increasing interest by several disciplines in understanding and explaining how property rights emerge, are defined and how their structure affect economic activities and agents' incentives.

As noted by Krier (2009), the several works addressing these issues can be classified into two main approaches, namely the economics of property rights and the evolutionary game models on contest behavior. The former applies a cost-benefit framework to investigate how changes in relative resource values and transaction costs affect the optimality of property regimes. In this case, the main advantage of this approach is to allow studying the creation and structure of property rights as a process whereby social costs and benefits are summed up to evaluate the relative efficiency of property

rights arrangements. However, its main limitation relates to a rather comparative static analysis of the evolutionary process.

By contrast, evolutionary game models on contest behavior seem more suited to address the dynamics of rights evolution emerging from the repeated interactions by agents. Indeed, in evolutionary game models property rights do not emerge as a result of intentional design, but as a stationary equilibrium based on the stable strategies of populations of agents, which can be eventually considered as emerging social norms. However, these models still remain grounded on the assumptions of rational choice theory to model agents behavior. Further, being based on the game theory framework, they often neglect the complexity of social systems and barely help explaining the development of complex property regimes.

Crucially, the two approaches have different strenghts and limitations in their capacity to explain the origin, structure and evolution of property regimes. Building on the intuition set forth by Krier, we contend that a further approach, namely ABMs, may integrate and foster the analytical capacity of the two traditional approaches in several directions. ABMs refer to the computational study of economic and social processes modeled as dynamic systems of interacting agents who do not necessarily possess perfect rationality and information. Agent-based simulation, through their focus on adaptive complex systems allows one to observe the system-wide outcomes that emerge from local interaction of individual strategies, and evolutionary processes provide a means of assessing and comparing the viability of various strategies and conventions over time (Axelrod, 1997).

Based on an discussion of existent approaches and a survey of works applying agent based simulations to the analysis of property rights, we argue ABMs may complement the existent approaches in several directions. First, agent based simulation may help testing the application of behavioral rules, such as those deriving from cultural traits, which go beyond rational choice theory. Second, agent based models not only allow identifying stationary outcomes such as in evolutionary game models, but also enable a better understanding of the timing of evolutionary patterns. Finally, not only ABMs enable to take into consideration the effect of the relative resource value and trasaction costs on property rights delineation, but they highlight how the structure of local interactions among agents influence the emergence and evolution of property rights.

The paper is organized as follows: Section 2 summarize the two main traditional approaches highlighting their strenghts and liminations; Section 3 present the Agent Based simulation approach and surveys the existent works applied to the study of property rights formation and evolution; Section 4 concludes by discussing to what extent ABMs may improve and extend the traditional approaches.

2 Theories on the origin and evolution of property rights

Research on the formation and evolution of property rights has been one of the most stimulating developments in the last decades in political economy and new institutional economics. As soon as the property rights approach came out as a response to extend the theory of production and exchange in economics in the sixties (Furubotn and Pejovich, 1972), the questions concerning how property rights originated and evolved have been of paramount relevance for scholars, who focused in particular on different types of land ownership by human societies or territoriality by animal species. Interestingly, two main approaches have taken ground to respond to such questions, both with distinctive theoretical and methodological features.

2.1 The Demsetzian legacy

The first approach originated by Demsetz (1967), who first applied economic analysis to address the issue of the origin and evolution of property rights. The basic intuition in Demsetz's seminal work is that property rights emerge when the benefits of establishing those rights, and thus internalizing land use externalities, exceed the cost. On the same line of reasoning Anderson and Hill (1975) propose a simple marginal cost and benefit model, where more definition and enforcement of property rights is expected if either the marginal benefit increases or the marginal cost decreases. Both Demsetz's and Anderson and Hill's works were mainly directed to explain the passage from open access regimes to private property over land.

Crucially, according to the naïve form of the model and examples provided, the greater the resource value or the lower the exclusion costs the higher the definition of private property. Such framework, focused on the dychotomy private property-open access, barely considered common property as an alternative system of property rights delineation. Increases in exclusion costs might explain for instance counterexamples to the Demsetz thesis in which private property leads to common property in the face of rising resource values. Field (1989) focuses on the optimal degree of parcelization between commons of different group size by developoing a model in which benefit is the savings in transaction costs among commoners by means of increased exclusion. In this case, an increase in the marginal costs of exclusion leads to more common property as less fine-grained parcelization.

Likewise, Lueck (1994) models common property as a joint wealth maximizing egalitarian share contract among an exclusive group of resource owners. Optimal group size is thus a tradeoff between increased resource use with a larger group and increased enforcement costs associated with a smaller group. Further, focusing on the interaction between resource value and exclusion costs, Allen (2002) suggests that when there is a nonlinear relation between the gross asset value and the costs in the establishment of property rights over the asset, this may explain why high valued resources remain in the public domain or there is an incentive to define property rights only if potential owners are able to reduce the gross value of the asset. Such kind of insight suggests that a more complex picture of the property regimes optimality arises when taking into account that resource may be comprised of a bundle of useful attributes, which can be put to various productive uses. In such cases, different property regimes may coexist to govern the simultaneous uses of the resource based on both exclusionary and governance rules (Smith, 2002).

This brief overview is useful to highlight the main characteristics and limitations of this approach in explaining the origin and the evolution of property rights. The models which express a Demsetzian legacy, regardless their sophistication, have a common denominator in applying a cost-benefit framework to investigate how changes in relative resource values and transaction costs affect the optimality of property regimes. In such a framework property rights emerge in response to the magnitude of the economic incentives to define and delineate those rights over the resources. The relative resource value is generally a function of the scarcity of the asset, while transactions costs in devising exclusionary and governance rules to enforce property rights are mainly due to technology and the size of the group at stake (Ellickson, 1993). Such models are particularly suited to explain the optimality of different types property regimes and how those affect the incentives of owners to exert their property rights (Lueck and Miceli, 2007). Several empirical works have been based on such approach to test the efficiency hypothesis of rights definition or differences across communities in property

regimes (Libecap, 1994; Anderson and Swimmer, 1997).

By contrast, concerning the evolutionary dynamics of property rights, Demsetzian models offer only a rather comparative static analysis of the institutional change. Indeed, Demsetz said little about the process by which the rights developed. He argued that they resulted from gradual changes in social norms and hit-and-miss procedures that selected in favor of cost-minimizing approaches. Crucially, the cost benefit framework developed in such models is able to capture the causal effects of the institutional change due to the modification of the key factors affecting property regimes' optimality. However, it lacks a micro-foundation of the evolutionary process addressing how agents' preferences, behavior and interaction lead to a new institutional equilibrium. Even when considering interest group explanations for the development of property rights (Levmore, 2002), these works add an institutional layer to the analysis of the causal effects of the institutional change but hardly provide a complete account of the evolutionary process.

2.2 Evolutionary responses to the Hobbesian state of nature

The second approach has its roots on the development of evolutionary game models to explain animals' territorial behavior. Biologists have long observed that members of many species – such as spiders, insects, birds, and mammals, for example – commonly resolve territorial disputes by a simple rule: "the resident always wins" (Maher and Lott, 2000; Kokko et al., 2006). Given such evidence, the basic intuition proposed by Maynard Smith (1974) is that, modeling contest behavior as an evolutionary hawk-dove game, if a contest shows some form of asymmetry (e.g. first possession of a site) then the assimmetry is used as a conventional cue to settle it. More formally, it can be shown that a behavior such that "if owner play Hawk, if intruder play dove" (generally labeled as Bourgeois strategy) is an evolutionary stable strategy (ESS) superior to the simple Hawk and Dove strategies.

Social scientists have soon incorporated the insights developed by biologists to explain animal behavior. For instance, using the same evolutionary game framework, Sugden (1989) proposes that property rights may spontaneously emerge as conventions (coordination on a single equilibrium when many exist) in the use and allocation of resources even without institutions of enforcement. He substitutes the Darwinian fitness and predetermined genetically behavior of animals considered in biologists' models with individuals having a subjective concept of utility who counsciously update their strategies through a process of imitation and learning. Several elaborations of this basic and elegant framework have been proposed adding some new insights to the original contribution. Hafer (2006) develops a dynamic model of the emergence of property rights where agents evolve through production and conflict of possession of factor goods. Her analysis shows over time a systematic bias in favor of incumbents as agent's possession of land credibly signals to the potential challengers that the agent is of a type that is difficult to defeat. Likewise, Gintis (2007) gives a behavioral explanation of "natural" property rights developing a model loosely based on the Hawk-Dove-Bourgeois game and the War of Attrition. He shows that the endowment effect implies that first possessors are willing to expend more effort to defend their possession than potential contestants in a war of attrition, creating an equilibrium in which contestants do not to attempt to seize and possessors fend off any such attempt. Further, Baker (2003) focuses on how ecological conditions affect the emergence and evolution of property rights. Modeling repeated games of conflict among hunter-gatherers, his findings suggest that the more plentiful and predictable the resources, the more secure

will be the rights to land containing those resources.

The main advantage of these models is that they conceive property rights formation as the elimination of costly conflict. Such theoretical treatments generally assume a Hobbesian "state of nature" and describe conditions under which cooperation (the absence of resource allocation toward conflict) is possible. With this perspective, these models are more effective in providing a theoretical explanation of the emergence and evolution of property rights based on the agents' evolving behavior.

However, as compared to Demsetzian models, one limitation of this approach is that it cannot account for anything beyond very simple property rules. Optimality of property regimens, such as the emergence of alternative property arrangements, cannot be generally analyzed because of its dependence on asymmetries that must be crude in order to be effective. More paradoxically, while the specification of the behavioral underpinnings of the Hawk, Dove, Bourgeois game allows us to determine the conditions under which a property equilibrium exist, asymmetric contest games may lead to an equal anti-property equilibrium where the agents' stable strategy is exactly the opposite (Maynard Smith, 1974; Gintis, 2007). Finally, although these models have proved to be consistent in taking into account how ecological conditions affect agents' behavior, the effects cannot be modeled at a micro level to analyse how the spatial heterogeneity of ecological conditions impact agents' local interactions.

3 Agent based models and property rights: a brief survey

Agent based models represent an increasingly adopted approach in social sciences to study economic and social processes understood as dynamic systems of interacting agents. Here "agent" refers to entities that are able to perform autonomous actions within their environment and to communicate with other agents. They may have a bounded representation of their environment and the decision making process may be based on satisfying goals and incoming information (Ferber, 1999).

The main features of agent based modeling compared to the two other analytical approaches relate to its abilities to i) linking social and environmental processes; ii) model individual decision-making entities, taking into account the interactions between them and incorporating social processes and nonmonetary influences; iii) integrate the influence of micro-level decision making into the system dynamics and iv) study the emergence of collective responses to changing environment and policies (Hare and Deadman, 2004; Matthews et al., 2007).

There exist already various examples of investigation on the emergence of property rights and access rules to resources using agent-based simulations.

Thebaud and Locatelli (2001) develop their work building on Sugden (1989). Sudgen is interested in the endogenous spontaneous process of this phenomenon, in situations without an external enforcement and without conscious design. He presents an example of a self-enforcing arrangement about the access to driftwood brought to the shore by storms on the coast of Yorkshire in England. The solution found by the considered community – the allocation of a stretch of the shoreline to the first who arrives in place - is efficient from an economic point of view in comparison to an open access scenario. However he argues that the efficiency properties are not sufficient to explain why and how this particular arrangement was established, among many other possibilities which would have been even more efficient. Therefore he raises two ques-

tions: (i) how a convention begins to attract more and more followers and (ii) what self-reinforcing mechanisms lead the convention to maintain itself in place for a whole community. Thebaud and Locatelli (2001) apply an agent-based framework to address the same questions. Simulation results show that the quantity of wood resource influences the stability of the system. Moreover peer pressure and imitation mechanisms strongly influence the degree of property rule observance.

Flentge et al. (2001) adopt agent-based models for exploring the emergence and the consequences of a "possession norm" in a simulated society. The authors extend the sugarscape model of Epstein and Axtell (1996) and give the individuals the possibility of claim ownership of a plot of land. They utilize the concept of memes as developed by Epstein and Axtell (1996). Memes carry particular attitudes among the agents and they determine the behaviour of every agent regarding the land claim of others. One result of their work is that when ownership claims of other are respected, the probability of survival of the population is higher. However agents respecting the property of others face short-term disadvantages. For this reason the authors conclude that a formal possession rule is needed. The presence of sanctions improve the norm enforcement as long it is not expensive for the sanctioning agents.

Bowles and Choi (2003) simulate the emergence of individual property rights during the establishment of the first agricultural societies. Around 11,000 years ago through agricultural and livestock activities individual claims on property became stronger with respect to the previous collectivist social order of hunters and gatherers. Through an agent-based model the authors develop a cultural group-selection model, informing the simulation with evidence from archeological and ethnographic research. Results suggest that the collectivist hunter gatherer society persisted for many thousands of years because of the frequent inter group conflicts, strong conformist cultural transmission and second-order punishment of those that did not punish rule violators. Only after that the plants and animals domestication became feasible and diffuse, individual property rights became a useful tool for coordination among group members, bringing the so called first property rights revolution.

In a similar vein, Kimbrough (2010) informs his agent-based simulations with details of a concrete and particular historical circumstance. He deals with the California Gold Rush of 1848/49, when articulated sets of property rights emerged in order to coordinate productive activities and reduce the likelihood of conflict among the miners. This happened without the intervention of a formal legal authority. Miners developed claims to land, established mechanisms of property transfer and compiled miners' codes. Through an evolutionary agent-based model the author tests the intuitions developed by Clay and Wright (2005) according to which fluid property rights emerge in case of high-variance and exhaustible resources. He finds that property rights structures adjust in response to ecological variables. The increase of the resource scarcity influences negatively the respect of property, and the contrary happens for low variance in resource distribution. These findings support the argument that the fluidity of property rights in the California Gold Rush was not caused by the absence of government structures, but rather by the nature and the specific feature of the resource. The author builds counterfactual examples confirming these findings.

Another stream of literature which is related to the effects of property rights is that of agent-based modeling applied to the study of socio-ecological systems. This application of ABM is included in the framework of the discipline of ecology, whose aim is to systematically study the behaviour of organisms in complex and spatially explicit environments (Grimm, 1999). As a result, while the first group of works presented above more properly deals with the emergence of individual property rights on non-

renewable resources, in this case the focus is rather on the emergence of governance rules for the exploitation of renewable natural commons at a sustainable rate.

One of the first agent-based models about socio-ecological systems is Bossel and Strobel (1978). In this model agents have cognitive capacity and base their decisions on the state of the global environment using indicators like livelihood needs, security and freedom of action. The state of the world determines the agent‘s priority, which in turns determines its decision about its behaviour. This process prevents a crisis of the system and leads to satisfactory policies.

Further, Bosquet et al. (1994) developed an agent-based model of management of fisheries in the central Niger delta. Based on field work, an artificial world was created where different scenarios of rules of when and where to fish in a wetland area were analyzed. The aim was to observe the impact on long term viability of the fish resources. Deadman and Gimblett (1994) constructed a model that simulates the behaviour of three types of visitors in a natural park: hikers, bikers, and visitors transported in tour vehicles. The results of hiker interactions with other users is useful for suggesting ideas about alternative recreation management planning. The work of Lansing and Kremer (1993) is one of the first simulations about collective natural resource management, even if it is not an agent-based simulation. This model is seminal since it provides a formal representation of self-governance. It is about traditional irrigation systems in Bali, Indonesia. It shows that simple bottom-up interactions of farmer groups at village level can lead to a good performance of a very complex large-scale irrigation system (Janssen, 2007). Probably the first work using agent-based models to investigate common pool resources situations was Deadman et al. (2000). They modelled agents that replicated most of the findings of experiments on the same topic, such as the strong effect of communication on cooperation and sustainable use of the resource. System behaviour was not specified in the model, but resulted from the interaction among individual agent choices. It is interesting to note the important role of a central authority in the communication routine, in order to inform agents of the strategy that best performed in past rounds. The central authority, although unable to enforce the proposed strategies, represented a rough sketch of an institution.

Janssen and Ostrom (2006) modeled the emergence of institutions in a population of heterogeneous agents. In this model agents play the common pool resources game and decide whether or not to implement an institution able to regulate the exploitation level to a fixed quantity. The decision mechanism of agents is based on two factors: the state of the resource and the amount of trust existing in the system. The level of trust depends on the outcome of trust games that agents played as a side activity that accompanied the main common pool resource game and on the heterogeneity of agents. The main finding of this model is that agents must experience one or more resource crises before being willing to create an institution. Nevertheless, in most conditions once the institution is in place is able to coordinate the agents' actions and to significantly improve the economical and ecological performance of the system.

4 Concluding remarks: advantages of agent based models on studying property rights

Considering the works analyzed, it is possible to highlight and summarize a number of potential advatages in applying the ABM approach in the study of the emergence and evolution of property rights. One important advantage of agent-based models is

the possibility to introduce various degrees of heterogeneity with regards to the attributes of the agents and of the biophysical world they are situated in (Epstein and Axtell, 1996; Squazzoni, 2010). Heterogeneity may be in terms of individual behaviour, budget constraints, features of the environment, renewability of resources. Such heterogeneous characteristics may evolve themselves over time (Janssen and Ostrom, 2006; Thebaud and Locatelli, 2001). The given flexibility for modeling heterogeneity and change allows to create credible counterfactuals to observe the impact of differences in resource and agents features on property rules (Kimbrough, 2010).

This allows to study the resilience of an institutional structure, which means observing whether and how a particular set of rules is able to absorb disturbances (Janssen and Ostrom, 2006). Indeed, while in game theory only strategies develop within a fixed set of rules, with ABM rules are able to evolve as well.

Through ABM it is possible to track the time-path towards an equilibrium state. Therefore one can observe the processes by which rules emerge, become established and enforced (Thebaud and Locatelli, 2001; Bowles and Choi, 2003; Janssen and Ostrom, 2006). It is possible to draw considerations on the timing of system's changes. In traditional analytical models there is the implicit assumption that each agent has an equal chance of interacting with every other agent. ABM are able to reproduce the fact that in reality agent interactions take place mainly within social networks. The structure of the social network may be crucial for the spread of behaviours of rules adoption or violation.

Moreover, it is possible to model the change of the social network as well or to make the payoff of one strategy dependent on the number of other agents choosing the same strategy, simulating in this way social comparison (Janssen and Jager, 2002). On the other hand, we recognize that in reality individuals may not know the preferences, the intentions or the strategies of other individuals there are interacting with. Simulated agents may have imperfect information and foresight about their neighbors (Moss, 2001; Janssen and Jager, 2002).

One of the most important gains offered by the ABM tool is introducing agents' behavioral rules which are more complex than simply utility maximization or random choice. Agents' may utilize social comparison, cultural norms which are intergenerationally transmitted, imitation, learning, or some other evidence that their previous behaviour is no longer functional or, at least, is less functional than other behaviours the agent can perform (Moss, 2001; Bowles and Choi, 2003; Thebaud and Locatelli, 2001). Moreover agents' preferences may be discrete rather than continuous. It is important to note that the rules that become actually in place may be suboptimal from a strictly economic point of view. Lock-in, path dependence, social influence, cascades effect may lead to the emergence of rules which are a second-best with respect to efficiency, but are socially more accepted by a community (Thebaud and Locatelli, 2001).

In the case that one investigates a specific real-world system, the emergent strategy composition of the population (which may converge to a single convention or consist of a mixture of types) can be said explicitly appropriate for that economic and social system. ABM allows to create an artificial laboratory to investigate how a set of relevant variables interacts while determining the emergence of a rule in a way that allows to track complexity better than any fully analytical technique (Janssen and Ostrom, 2006).

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