NBER WORKING PAPER SERIES

THE CREATION OF EFFECTIVE PROPERTY RIGHTS

Herschel I. Grossman

Working Paper 7897
http://www.nber.org/papers/w7897

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
September 2000

Prepared for presentation at a session on "Conflict and the Economy" at the annual meetings of the American Economic Association, January 2001. Minseong Kim has given me helpful comments. The views expressed herein are those of the author and not necessarily those of the National Bureau of Economic Research.

The Creation of Effective Property Rights
Herschel I. Grossman
NBER Working Paper No. 7897
September 2000
JEL No. D23, D74

ABSTRACT

Traditionally, general-equilibrium models have taken effective property rights to be given and have been concerned only with analysing the allocation of resources among productive uses and the distribution of the resulting product. But, this formulation of the economic problem is incomplete because it neglects that the appropriative activities by which people create the effective property rights that inform allocation and distribution are themselves an alternative use of scarce resources.This paper develops two canonical general-equilibrium models of resource allocation and income distribution that allow for the allocation of time and effort to the creation of effective property rights to valuable resources. In one model the valuable resources are initially in a common pool. In the other model agents initially have nonoverlapping claims to the valuable resources. For both models the analysis reveals how the amount of time and effort that agents allocate to the creation of effective property rights, rather than to production,depends on the environment for creating effective property rights, on the technology of production, and on the scale of the economy. The paper also analyses the security of initial claims to valuable resources and speculates about why initial claims sometimes are perfectly secure.

Herschel I. Grossman
Department of Economics
Box B
Brown University
Providence, RI 02912
and NBER
herschel_grossman@brown.edu

To say that an agent has an effective property right means that this agent controls the allocation of some valuable resources and the distribution of the fruits of this allocation.[1] Traditionally, general-equilibrium models have taken effective property rights to be given and have been concerned only with analysing the allocation of resources among productive uses and the distribution of the resulting product.[2] But, this formulation of the economic problem is incomplete because it neglects that the appropriative activities by which agents create the effective property rights that inform allocation and distribution are themselves an alternative use of scarce resources.

This paper develops two general-equilibrium models of resource allocation and income distribution in which agents allocate some of their scarce time and effort to creating effective property rights to valuable resources, rather than to production.[3] To keep the analy-

[1]Effective property rights are synonymous with what Dani Rodrik (2000) calls "control rights". Rodrik contrasts control rights with the formal property rights entailed in legal ownership. He stresses that control rights are the operational concept for economic analysis. Rodrik writes (page 5), "The key word is 'control' rather than 'ownership'. Formal property rights do not count for much if they do not confer control rights. By the same token, sufficiently strong control rights may do the trick even in the absence of formal property rights." For present purposes the definition of effective property rights is unambiguous. In the abstract models analysed in this paper subtle issues about the multiple dimensions of property rights and the nature of constraints, whether legal or social, on the exercise of property rights do not arise. See Thráinn Eggertsson (1990) and Eirik Furubotn and Rudolf Richter (1997) for overviews of the extensive literature that addresses these issues.

[2]An extensive literature examines the effects of property rights on resource allocation. This literature also takes the security or insecurity of property rights as given. For a recent example and further references, see Henning Bohn and Robert Deacon (2000).

[3]In a brief and long neglected contribution Trygve Haavelmo (1954, pages 91-98) provided a canonical general-equilibrium model of the allocation of resources between productive and appropriative activities. Over the years a number of authors have reinvented Haavelmo's formalization of this problem and have extended the analysis in a variety of ways. The present paper builds most directly on the analysis of Winston Bush and Lawrence Mayer (1974). Other related papers include Stergios Skaperdas (1992), Jack Hirshleifer (1995), and Herschel Grossman and Minseong Kim(1995). In contrast to the present paper, the

sis simple, both of these models assume that the valuable resources are nondurable and nonrenewable.[4] The two models differ in their specifications of the state of nature that exists prior to the creation of effective property rights.

In one model the valuable resources are initially in a common pool. Examples include wild animals, fish, or plants that agents want to harvest, minerals that agents want to extract, or land that agents want to cultivate or to use for grazing, but over which no agent has claimed as yet to have an effective property right. In this model agents create effective property rights by using time and effort to appropriate resources from a common pool.

In the other model agents initially have claims, which can be more or less secure, to the valuable resources. We can think of these claims as being natural in the sense that they arose in the process of discovery or creation of these resources. Examples include a person's claim to his own ideas or to things that he has produced with his own hands.[5] In this model agents create effective property rights, or, more precisely, convert initial claims into effective property rights, by using time and effort to defend their own initial claims and to challenge the initial claims of others. Relative success in challenging and defending initial claims determines the security of initial claims.

In contrast to much of the literature on property rights, the models in this paper study the

---

models in these papers abstract from time and effort and assume that agents use only a single resource both to appropriate resources and to produce consumables.

[4]Extending the analysis to allow for durable or renewable resources would require a dynamic model in which agents anticipate having to maintain the effective property rights that they create. The consideration of durable or renewable resources also would require a distinction between the stock of resources and the flow of resources or resource services units that are withdrawn from the stock.

[5]Claims to durable resources could be the result of prior appropriation of resources from a common pool. Examples include claims that agents staked out to public lands, as in the California Gold Rush of 1849. In this example the creation of effective property rights would involve two stages. In allocating time and effort to the competition to stake out claims to resources in the first stage, agents would anticipate having to defend these claims in the second stage. I leave the modeling of such a two-stage process for another time.

creation of effective property rights in an anarchic environment that abstracts from the state and the legal system. Although political theory typically views the state to be the enforcer of cooperative action to protect property rights, actual states sometimes either shirk this ostensible role or, even worse, act in such a way as to make property rights less secure rather than more secure. In these cases we can think of the state as being just another agent in an essentially anarchic environment.[6]

In any event the existence of a state and a legal system is neither necessary nor sufficient for the existence of effective property rights. In my view the existing literature on property rights focuses too much on the state and the legal system and does not give adequate attention to the appropriative activities of individual agents. The present paper redresses this imbalance.

1. The Creation of Property Rights from a Common Pool of Resources

Consider a group of $n+1$ identical unitary agents, $n \in \{1, 2, 3, ...\}$. These agents can be individuals, or they can be groups, such as families or tribes or other coalitions, who act as unitary agents. The agents can even be sovereign states, again as long as we can assume that they act as unitary agents. Each agent is endowed with one unit of inalienable time and effort.

Let there also be $(n+1)E$ divisible units of valuable resources. As mentioned above, the analysis assumes, for simplicity, that these resources are nondurable and nonrenewable. The resources are initially in a common pool. The appropriation of resources from the common pool requires time and effort. Also, both time and effort and resources are inputs into the production of consumables. Thus, the economic problem in this model is that appropriation

[6] Bush and Mayer (1974) augment their analysis of an anarchic equilibrium with a critical evaluation of the possible role of the state in enforcing cooperative action to protect property rights. Grossman (2000) derives conditions under which the existence of a state that protects property rights is or is not a Pareto improvement over anarchy. Mendoza (1999) derives conditions under which the state chooses to free ride on the efforts of private agents to protect property rights.

and production are alternative uses of time and effort. Each agent must choose how to allocate its endowment of time and effort between these activities.[7]

To model the creation of effective property rights by appropriation from a common pool, let $i, j = 1, 2, ..., n+1$, and assume that

$$e_i = \frac{r_i}{r_i + \sum_{j \neq i} r_j} \; (n+1)E, \tag{1}$$

where e_i denotes the amount of resources that agent i appropriates from the common pool, r_i denotes the amount of time and effort that agent i allocates to the appropriative competition, and r_j denotes the amount of time and effort that agent j allocates to the appropriative competition.[8]

Equation (1) is a black box that does not specify the process of appropriation. The appropriative competition modelled by equation (1) could involve such disparate processes as a nonviolent scramble, a division under the threat of force, or a violent struggle. In this respect equation (1) is like a standard generic production function, which does not specify the process of production. Equation (1) does not tell us how agents appropriate from the common pool any more than a production function tells us how to make cars.

Equation (1) simply says the following:

> Agent i creates an effective property right to a fraction of the resources in the common pool that equals the fraction that agent i contributes to the total time and effort that the $n+1$ agents allocate to the appropriative competition.[9]

[7] We could generalize this model without changing the main implications by assuming that the appropriation of resources requires both time and effort and weapons that are produced by combining time and effort with the resources.

[8] Hirshleifer (1995) suggests a generalization of equation (1) in which each agent's allocation of time and effort to the appropriative competition is raised to a positive power. Hirshleifer calls this exponent the "decisiveness parameter." In this context equation (1) is a special case in which the decisiveness parameter equals one. Grossman, Kim, and Juan Mendoza (2000) explore the importance of the decisiveness parameter.

[9] We could easily extend the analysis to allow the appropriative competition to despoil some of the

Accordingly, equation (1) exhibits two critical properties.

1. If, for all $j \neq i$, r_j equals zero, and if r_i is positive, then e_i equals $(n+1)E$. This property says that, if no other agent is allocating time and effort to the appropriative competition, then, by allocating any small amount of time and effort to the appropriative competition, agent i can appropriate the entire amount of resources in the common pool.

2. If, for any $j \neq i$, r_j is positive, then e_i is positive if and only if r_i is positive. This property says that, with at least one other agent allocating time and effort to the appropriative competition, agent i appropriates a positive amount of resources from the common pool if and only if it allocates time and effort to the appropriative competition.

Taken together, these two properties imply that the dominant strategy of each agent, taking as given the allocation decisions of other agents, is to allocate time and effort to the appropriative competition. Equation (1) precludes the possibility that the agents would choose to allow the valuable resources to remain in the common pool.[10]

---

resources by assuming that the amount of resources that the agents appropriate from the common pool is smaller than the amount of resources initially in the common pool by an amount of spoilage that depends on the amounts of time and effort that the agents allocate to the appropriative competition. Assuming that each agent takes the amount of spoilage as given, allowing for spoilage would not change the main implications of the analysis.

[10]In contrast to equation (1), the models in David de Meza and J. R. Gould (1992) and Aaron Tornell (1997) assume that appropriating resources from a common pool involves a fixed cost. These models also assume that agents can exploit valuable resources under conditions of open access without appropriating them from a common pool. Under these assumptions the agents might choose to allow resources to remain in a common pool. Another theoretical and empirical literature explores the possibility that, if agents interact repeatedly, then they can avoid appropriative competition by making credible commitments to share resources that are in a common pool. See, for example, Elinor Ostrom (1990) and Ostrom, et al.

Equation (1) also exhibits the following important properties.

• If, for any $j \neq i$, r_j is positive, then the partial derivative, $\partial e_i / \partial r_i$ is positive. This property says that, given the positive amount of time and effort that other agents are allocating to the appropriative competition, the amount of resources that agent i appropriates from the common pool is larger the more time and effort that agent i allocates to the appropriative competition.

• The partial derivative, $\partial e_i / \partial r_i$, evaluated with r_i equal to r_j for all i and j, is larger the larger is n. This property says that, if every agent is allocating the same amount of time and effort to the appropriative competition, then the larger is the scale of the economy the larger is the marginal effect of allocating time and effort to the appropriative competition on the amount of resources that agent i appropriates from the common pool. This result obtains because, the larger is n, the larger is the effect of r_i on the fraction that agent i contributes to the total time and effort that the $n+1$ agents allocate to the appropriative competition. Note that, given E, a larger value of n implies both a larger number of agents and an equiproportionately larger endowment of resources.

Turning to the technology of production, let ℓ_i denote the amount of time and effort that agent i allocates to the production of consumables, and let c_i denote agent $i's$ consumption. Assume that c_i depends on ℓ_i and on e_i according to a standard Cobb-Douglas technology,[11]

$$c_i = e_i^{\alpha} \, \ell_i^{1-\alpha}, \quad 0 < \alpha < 1. \tag{2}$$

The parameter α in equation (2) measures the importance of resources relative to

(1994). Presumably, such cooperative agreements are the basis for forming the unitary agents in the present model in cases in which these unitary agents comprise groups of people. We can regard the present analysis of the creation of effective property rights as complementary to the analysis of cooperation, with the present analysis becoming relevant when agents have exhausted opportunities for amicable sharing of resources.

[11] Grossman, Kim, and Mendoza (2000) extend this analysis to consider the class of constant-elasticity-of substitution technologies, of which the Cobb-Douglas technology is a special case.

time and effort for producing consumables. In the limit as α approaches one, the resources themselves are consumable, and the conversion of resources into consumables does not require time and effort. Smaller values of α represent production technologies in which resources are less important relative to the time and effort allocated to fabrication.

Agent i chooses r_i and ℓ_i to maximize its consumption subject to $r_i + \ell_i = 1$. Assume that in making these choices, agent i takes other agents' choices, r_j for all $j \neq i$, as given. Thus, the first-order condition for the solution to agent $i's$ choice problem is

(3)
$$\frac{dc_i}{dr_i} = \frac{\partial c_i}{\partial e_i}\frac{\partial e_i}{\partial r_i} - \frac{\partial c_i}{\partial \ell_i} = 0.$$

Equation (3) says that agent i chooses r_i such that the marginal benefit of r_i in increasing the amount of resources that agent i appropriates from the common pool equals the marginal cost of r_i in decreasing the amount of time and effort that agent i allocates to production.

Equation (3) implies a unique, symmetrical equilibrium in which r_i equals r_j for all pairs i and j. Using this equality and equations (1) and (2) to solve equation (3), we obtain for the equilibrium allocation of time and effort,

(4)
$$\frac{r_i}{\ell_i} = \frac{r_i}{1 - r_i} = \frac{n}{n+1}\,\frac{\alpha}{1-\alpha} \quad \text{for all } i.$$

See the Appendix for the derivation of equation (4).

Equation (4) confirms that each agent allocates time and effort to the appropriative competition. Equation (4) also implies that the amount of time and effort that each agent allocates to the appropriative competition is larger, and, hence, the amount of time and effort that each agent allocates to production is smaller, the larger is n, the scale of the economy, and the larger is α, the relative importance of resources for producing consumables.[12] The effect of n obtains because, as we have seen, in a symmetrical equilibrium the marginal

[12]We can view the positive relation between r_i and n as consistent with the common observation that life is more competitive in large cities than in small towns. I thank Harl Ryder for this observation.

effect of an agent's allocating more time and effort to the appropriative competition on the amount of resources that the agent appropriates from the common pool is increasing in n.

Also, in equation (4) the allocation of time and effort does not depend on E, the amount of resources in the common pool. This result obtains because in this model agents allocate time and effort either to appropriation or to production, and the return to both activities increases proportionately with the amount of resources in the common pool.[13]

2. The Conversion of Initial Claims to Resources into Effective Property Rights

As an alternative to resources being initially in a common pool, assume now that each agent has an initial nonoverlapping claim to E units of resources.[14] Agents convert initial claims into effective property rights by using time and effort both to challenge the initial claims of other agents and to defend initial claims from challenges by other agents.

Again each agent is endowed with one unit of inalienable time and effort. The economic problem in this model is that the defending of initial claims, the challenging of initial claims, and the production of consumables are alternative uses of time and effort. Each agent must choose how to allocate its endowment of time and effort among these activities.

For simplicity, assume that there are only two agents, agent 1 and agent 2. To model the challenging and defending of initial claims, let $i, j = 1, 2$, and let p_i denote the fraction of its initial claim that agent i successfully defends. Agent j, $j \neq i$, successfully challenges the fraction $1 - p_i$ of the initial claim of agent i.[15]

[13] If the marginal product of time and effort allocated to production were constant, rather than positively related to the amount of resources as in equation (2), then agents would allocate more time and effort to the appropriative competition the larger the amount of resources in the common pool. In contrast, in Grossman and Mendoza (2000) agents allocate more time and effort to the appropriative competition the smaller the amount of resources in the common pool. This result follows from the assumption that, if resources are scarce, then consumption and, hence, appropriated resources have a large effect on the probability of survival.

[14] A more complete analysis would allow for differences among individuals in their initial claims. The present analysis shows that interpersonal differences are not essential for rationalizing appropriative conflict.

[15] Generalizing the analysis to allow for many agents is not trivial because the appropriate specification

In this model p_i measures the security of initial claims. If p_i equals one, then initial claims are perfectly secure. If p_i is smaller than one, then initial claims are less than perfectly secure.

Using this notation, agent i creates an effective property right to e_i units of resources, where

$$e_i = p_i\ E\ + (1 - p_j)\ E, \quad j \neq i. \tag{5}$$

Equation (5) says that e_i equals the amount of its own initial claim that agent i successfully defends plus the amount of the initial claim of agent j that agent i successfully challenges.[16]

To determine the security of initial claims, assume that

$$p_i = \begin{cases} \dfrac{1}{1 + \theta g_j / h_i} & \text{for} \quad g_j > 0, \quad 0 < \theta < 1 \\ 1 & \text{for} \quad g_j = 0, \end{cases} \tag{6}$$

where g_j denotes the fraction of its time and effort that agent j, $j \neq i$, allocates to challenging the initial claim of agent i, and h_i denotes the fraction of its time and effort that agent i allocates to defending its own initial claim. Equation (6) says that, if g_j is positive, then p_i is smaller the larger is g_j relative to h_i.

The parameter θ in equation (6) measures the effectiveness of time and effort allocated to challenging initial claims relative to time and effort allocated to defending initial claims. This parameter quantifies the environment for the challenging and defending of initial claims. This environment can encompass technology as well as social arrangements that facilitate

depends on the nature of the matching process involved in agents' challenging the initial claims of other agents. One possibility would have every agent challenging the initial claim of every other agent and defending its initial claim from a challenge by every other agent. A more ambitious possibility would be introduce a fixed cost of challenging the initial claim of another agent. In this setup each agent would have to choose which subset of initial claims to challenge.

[16] In Grossman and Kim (1995) we saw how the analysis could easily incorporate possible destruction of resources as the result of the challenging and defending of claims.

either the challenging and or the defending of initial claims. The restriction that θ is smaller than one insures that agent i could not increase the equilibrium value of e_i by giving his initial claim to agent j and then challenging that claim.

Like equation (1), which described the creation of property rights from a common pool of resources, equation (6) is a black box. It does not specify the processes by which claims are challenged and defended. For example, the outcome modelled by equation (6) could involve either a division under the threat of force or a violent struggle.

Nevertheless, equations (5) and (6) exhibit the following important properties, which are analogous to the properties of equation (1).

- If both h_j and g_j equal zero, and if g_i is positive, then e_i equals $2E$. This property says that, if agent j were allocating no time and effort either to defending its own initial claim or to challenging the initial claim of agent i, then, by allocating a small amount of time and effort to challenging the initial claim of agent j, agent i would create an effective property right to the initial claims of both agents.
- If g_j is positive, then e_i is positive if and only if either h_i is positive or g_i is positive. This property says that, with agent j allocating time and effort to challenging the initial claim of agent i, agent i creates an effective property right to a positive amount of resources if and only if it allocates time and effort either to defending its own initial claim or to challenging the initial claim of agent j.
- If h_j and g_j are positive, then the partial derivatives, $\partial e_i/\partial h_i$ and $\partial e_i/\partial g_i$, are positive. This property says that, with agent j allocating time and effort both to defending its own initial claim and to challenging the initial claim of agent i, the amount of resources to which agent i creates an effective property right is an increasing function both of the amount of time and effort that it allocates to defending its own initial claim and of the amount of time and effort that it allocates to challenging the initial claim of agent j.

Assume again that agent $i's$ consumption, c_i, depends on e_i and on the amount of time and effort that agent i allocates to production, ℓ_i, according to the Cobb-Douglas technology specified in equation (2). Agent i chooses h_i, g_i, and ℓ_i to maximize its consumption subject to $h_i + g_i + \ell_i = 1$. Assume that in making these choices, agent i takes agent $j's$ choices of g_j and h_j as given. Thus, the first-order conditions for the solution to agent $i's$ choice problem are

$$\frac{\partial c_i}{\partial h_i} = \frac{\partial c_i}{\partial e_i}\frac{\partial e_i}{\partial h_i} - \frac{\partial c_i}{\partial \ell_i} = 0 \tag{7}$$

and

$$\frac{\partial c_i}{\partial g_i} = \frac{\partial c_i}{\partial e_i}\frac{\partial e_i}{\partial g_i} - \frac{\partial c_i}{\partial \ell_i} = 0. \tag{8}$$

Equation (7) says that agent i chooses h_i such that the marginal benefit of h_i in increasing the amount of its own initial claim that it successfully defends equals the marginal cost of h_i in decreasing the amount of time and effort that it allocates to production. Equation (8) says that agent i chooses g_i such that the marginal benefit of g_i in increasing the amount of the initial claim of agent j that agent i successfully challenges equals the marginal cost of g_i in decreasing the amount of time and effort that it allocates to production.

Equations (7) and (8) imply a unique, symmetrical equilibrium in which h_i equals h_j, and in which g_i equals g_j. Using these equalities and equations (2), (5), and (6) to solve equations (7) and (8), we obtain for the equilibrium allocation of time of effort,

$$h_i = g_i = \frac{\alpha}{1-\alpha}\,\frac{\theta}{(1+\theta)^2}\,\ell_i \quad \text{for all } i. \tag{9}$$

See the Appendix for the derivation of equation (9).

Equation (9) has the following implications for the allocation of time and effort:

• Over the range $0 < \theta < 1$, the equilibrium values of h_i and g_i are larger the larger is θ. In other words, the agents allocate more time and effort to challenging and defending initial claims as time and effort become equally effective at challenging and defending initial claims.

- The amount of time and effort that each agent allocates to defending and challenging initial claims is larger the larger is α, the relative importance of resources for producing consumables.
- The allocation of time and effort does not depend on E, the amount of resources to which each agent has an initial claim.

These results about α and E are analogous to results obtained in the preceding analysis of appropriation from a common pool.

Because g_j is positive, we see from equation (6) that p_i, the fraction of its initial claim that agent i successfully defends, is smaller than one. In this model initial claims to resources are less than perfectly secure. In addition, because h_i equals g_j, p_i equals $1/(1+\theta)$. In equilibrium the security of initial claims depends only on θ, the effectiveness of time and effort allocated to challenging initial claims relative to time and effort allocated to defending initial claims.

3. Secure Initial Claims

Although the preceding analysis implies that initial claims to resources are less than perfectly secure, casual observation suggests examples in which agents apparently do not challenge the initial claims of other agents and in which, as a result, initial claims to resources are perfectly secure. There are several ways to modify the model to allow the possibility of such an equilibrium.

1. A Fixed Cost of Challenging Initial Claims: An alternative to the specification in equation (6) would be to assume that challenging the initial claim of the other agent involves a fixed cost. Formally, we can introduce such a fixed cost, denoted by κ, by replacing g_j in equation (6) with $g_j - \kappa$. If κ were sufficiently large relative to E, then the dominant strategy of agent j, taking the allocation decisions of agent i as given, would be to set g_j equal to zero. (Analogously, if defending an initial claim

involved a sufficiently large fixed cost, then agents would surrender their initial claims without trying to defend them.) The main problem with appealing to a fixed cost to explain why initial claims sometimes are perfectly secure is that it is hard to imagine why this fixed cost is sufficiently large in some cases but not in other cases.

2. A Social Norm: Another alternative would be to assume that a social norm reinforces the ability of agents to defend their initial claims. Formally, we can introduce such a social norm, denoted by ρ, by replacing h_i in equation (6) with $h_i + \rho$. The analysis in Kai Konrad and Skaperdas (1998) shows that, if ρ were sufficiently large relative to E, then the dominant strategy of agent j, taking the allocation decisions of agent i as given, would be to set g_j equal to zero. The main problem with appealing to a social norm to explain why initial claims sometimes are perfectly secure is that it is difficult, if not impossible, to observe social norms independently of their consequences.

3. Repeated Interactions: The preceding analysis ignored the possibility that agents interact repeatedly. If the agents interact repeatedly, and if, among other things, agents are sufficiently foresighted, then each agent might be able to make a credible commitment not to challenge the initial claim of the other agent. For a recent example of a model of credible commitments, see Abhinay Muthoo (2000).[17] The main problem with appealing to credible commitments to explain why initial claims sometimes are perfectly secure is that examples in which initial claims are perfectly secure do not seem to be limited to cases in which agents interact repeatedly.

4. Deterrence: In the preceding analysis agent i took agent $j's$ choice of g_j as given. An alternative is to assume that agent i chooses h_i before agent j chooses g_j and that agent $i's$ choice of h_i is irreversible. Given these assumptions, agent i would

[17] This approach to modeling secure initial claims is related to the literature noted above on amicable sharing of resources in a common pool.

take into account the effect of h_i on agent $j's$ choice of g_j. For an example of such a model, see Grossman and Kim (1995). In this model, if the parameter θ is sufficiently small, then each agent allocates enough resources to defending its initial claim to deter challenges to its initial claim. This model suggests that differences in θ, which reflect differences in the environment for challenging and defending initial claims, account for why initial claims are perfectly secure in some cases but not in others. The main attraction of this explanation, which admittedly is my personal favorite, is that environmental determinants of θ are potentially observable.

4. Summary

This paper has developed two general-equilibrium models of resource allocation and income distribution that allow for the allocation of time and effort to the creation of effective property rights to valuable resources. In one model the valuable resources were initially in a common pool. In the other model agents initially had nonoverlapping claims to the valuable resources. For both models the analysis revealed how the amount of time and effort that agents allocate to the creation of effective property rights, rather than to production, depends on the environment for creating property rights, on the technology of production, and on the scale of the economy. The paper also analysed the security of initial claims to valuable resources and speculated about why initial claims sometimes are perfectly secure.

Appendix

Derivation of Equilibria

1. Derivation of Equation (4)

Equations (1) and (2) imply that we can expand equation (3) to

$$(A1) \qquad \frac{dc_i}{dr_i} = \frac{\partial c_i}{\partial e_i}\frac{\partial e_i}{\partial r_i} - \frac{\partial c_i}{\partial \ell_i} = \alpha \left(\frac{\ell_i}{e_i}\right)^{1-\alpha} \frac{\sum_{j\neq i} r_j}{(r_i + \sum_{j\neq i} r_j)^2}\ (n+1)\ E - (1-\alpha)\left(\frac{e_i}{\ell_i}\right)^{\alpha}.$$

From equation (A1) we can easily show that the second order condition for a maximum, $d^2c_i/dr_i^2 < 0$, is satisfied.

With each agent allocating the same amount of time and effort to the appropriative competition, equation (1) implies that e_i equals E for all i. Furthermore, with r_j, for all $j \neq i$, equal to r_i, $\sum_{j\neq i} r_j$ equals nr_i. Substituting these equalities into equation (A1), equation (3) becomes

$$(A2) \qquad \frac{dc_i}{dr_i} = \frac{\partial c_i}{\partial e_i}\frac{\partial e_i}{\partial r_i} - \frac{\partial c_i}{\partial \ell_i} = E^{\alpha}\ell_i^{1-\alpha}\left(\frac{n}{n+1}\ \frac{\alpha}{r_i} - \frac{1-\alpha}{\ell_i}\right) = 0.$$

Solving equation (A2) we obtain equation (4). The expression for dc_i/dr_i in equation (A2) implies that an equilibrium with r_i equal to zero, and $dc_i/dr_i \leq 0$, is not possible.

2. Derivation of Equation (9)

Equations (2), (5), and (6) imply that we can expand equations (7) and (8) to

$$(A3) \qquad \frac{\partial c_i}{\partial h_i} = \frac{\partial c_i}{\partial e_i}\frac{\partial e_i}{\partial h_i} - \frac{\partial c_i}{\partial \ell_i} = \alpha \left(\frac{\ell_i}{e_i}\right)^{1-\alpha} \frac{\theta g_j}{(h_i + \theta g_j)^2}\ E - (1-\alpha)\left(\frac{e_i}{\ell_i}\right)^{\alpha}$$

and

$$(A4) \qquad \frac{\partial c_i}{\partial g_i} = \frac{\partial c_i}{\partial e_i}\frac{\partial e_i}{\partial g_i} - \frac{\partial c_i}{\partial \ell_i} = \alpha \left(\frac{\ell_i}{e_i}\right)^{1-\alpha} \frac{\theta h_j}{(h_j + \theta g_i)^2}\ E - (1-\alpha)\left(\frac{e_i}{\ell_i}\right)^{\alpha}.$$

Again we can easily show that the second order condition for a maximum is satisfied.

Given that h_i equals h_j and that g_i equals g_j, equations (5) and (6) imply that e_i and

e_j equal E. Substituting these equalities into equations (A3) and (A4), equations (7) and (8) become

$$(A5) \qquad \frac{\partial c_i}{\partial h_i} = E^{\alpha}\ell_i^{1-\alpha}\left[\frac{\alpha\theta g_i}{(h_i+\theta g_i)^2} - \frac{1-\alpha}{\ell_i}\right] = 0$$

and

$$(A6) \qquad \frac{\partial c_i}{\partial g_i} = E^{\alpha}\ell_i^{1-\alpha}\left[\frac{\alpha\theta h_i}{(h_i+\theta g_i)^2} - \frac{1-\alpha}{\ell_i}\right] = 0.$$

Solving equations (A5) and (A6) we obtain equation (9).

References

Bohn, Henning and Deacon, Robert T. "Ownership Risk, Investment, and the Use of Natural Resources." *American Economic Review,* June 2000, *90,* pp. 720-739.

Bush, Winston C. and Mayer, Lawrence S. "Some Implications of Anarchy for the Distribution of Property." *Journal of Economic Theory,* 1974, *8,* pp. 401-412.

de Meza, David and Gould, J. R. "The Social Efficiency of Private Decisions to Enforce Property Rights." *Journal of Political Economy,* June 1992, *100,* pp. 561-580.

Eggertsson, Thráinn. *Economic Behavior and Institutions.* New York: Cambridge University Press, 1990.

Furubotn, Eirik G. and Richter, Rudolf. *Institutions and Economic Theory: The contribution of the New Institutional Economics.* Ann Arbor: University of Michigan Press, 1997.

Grossman, Herschel I. "'Make Us a King': Anarchy, Predation, and the State." unpublished, August 2000.

Grossman, Herschel I. and Kim, Minseong. "Swords or Plowshares? A Theory of the Security of Claims to Property." *Journal of Political Economy,* December 1995, *103,* pp. 1275-1288.

Grossman, Herschel I., Kim, Minseong, and Mendoza, Juan. "Decisiveness and the Viability of Anarchy." unpublished, January 2000.

Grossman, Herschel I. and Mendoza, Juan. "Scarcity and Conflict." unpublished, July 2000.

Haavelmo, Trygve. *A Study in the Theory of Economic Evolution.* Amsterdam: North-Holland Publishing Company, 1954.

Hirshleifer, Jack. "Anarchy and Its Breakdown." *Journal of Political Economy,* February 1995, *103,* pp. 26-52.

Konrad, Kai A. and Skaperdas, Stergios. "Extortion." *Economica,* November 1998, *65,* pp. 461-477.

Mendoza, Juan. "Private and Public Protection of Private Property: The Government as a Free-Rider," unpublished, October 1999.

Muthoo, Abhinay. "On the Foundations of Basic Property Rights, Part I: A Model of the State-of-Nature with Two Players." unpublished, July 2000.

Ostrom, Elinor. *Governing the Commons: The Evolution of Institutions for Collective Action.* New York: Cambridge University Press, 1990.

Ostrom, Elinor, Gardner, Roy, and Walker, James. *Rules, Games, and Common Pool Resources.* Ann Arbor: University of Michigan Press, 1994.

Rodrik, Dani. "Institutions and High Quality Growth: What They Are and How to Acquire Them." National Bureau of Economic Research Working Paper No. 7540, February 2000.

Skaperdas, Stergios. "Cooperation, Conflict, and Power in the Absence of Property Rights." *American Economic Review,* September 1992, *82,* pp. 720-739.

Tornell, Aaron. "Economic Growth and Decline with Endogenous Property Rights." *Journal of Economic Growth,* September 1997, *2,* pp. 219-250.