Endogenous First-Possession Property Rights in Open-Access Resources

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ABSTRACT: This Essay examines the emergence of spontaneous claims to inframarginal rents in open-access resources. Although early models of open-access in economics predicted full rent dissipation as homogeneous agents exploited the resource, later theory and empirical observations indicated persistence of inframarginal rents. The existence of inframarginal rents under open-access has been recognized in the literature, but agents' incentives to invest in de facto institutions to protect rental streams from competitors has not been explored. These institutions include local property rights, specialized production, and restricted information sharing. Moreover, there has been no recognition of how these informal arrangements might contribute to observed resistance by inframarginal-rent earners to externally imposed schemes in order to reduce aggregate rent dissipation. Proponents are high-cost agents, who earn low or zero rents. High-cost agents ought to be able to compensate low-cost agents for a shift to a new property regime if the shift makes them better off than they were under open-access. Empirically, however, this appears not to happen and formal open-access persists. This Essay develops a simple framework to show why "willingness to pay" and "willingness to accept" do not overlap and that institutional change is not Pareto-improving for those who have adjusted well to open-access. If agents are heterogeneous in search and production costs, and the resource is large and heterogeneous in quality, then low-cost parties search for the most productive locations and apply their superior skills and develop human and physical capital to earn inframarginal rents. The Essay then applies this framework to historical experiences in oil and gas and fisheries.

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I. INTRODUCTION

Losses of competitive entry and production in open-access resources have long been recognized.[1] In the absence of formal property rights, there are no restrictions on entry, and agents do not bear the full costs of their production decisions. Classic externalities arise with the use of excessive capital, other inputs, short-time horizons, races to produce, congestion, reduced investment in the resource stock, and lower output value. To mitigate these externalities, governments implement various regulatory and rights-based instruments to constrain entry, limit output, and internalize external costs. We are interested in a particular set of institutions that establish a total resource extraction cap and then distribute shares of the resource or resource rents to individual

1. *See* H. Scott Gordon, *The Economic Theory of a Common-Property Resource: The Fishery*, 62 J. POL. ECON. 124, 130–32 (1954) (outlining the situation in fisheries as iconic open-access resources); Garrett Hardin, *The Tragedy of the Commons*, 162 SCIENCE 1243, 1244–48 (1968) (describing the problem more broadly).

users. These institutions are termed rationalization, which is how we will refer to them in this Essay. The potential for open-access exists for many natural resources. Here, we examine attempted rationalization of fisheries and U.S. hydrocarbon deposits in the presence of informal property rights to streams of rents under open-access resource use.

Rationalization can create large gains by internalizing externalities in use decisions and instituting extraction levels consistent with maximizing long-term rents from the resource stock. The existence of net surplus from mitigating aggregate open-access losses suggests beneficiaries of rationalization ought to be willing and able to pay opposing parties for their consent whenever rationalizing creates a surplus. In such settings, willingness to pay for transfers exceeds the willingness to accept transfers, and institutional responses to address open-access dissipation should be observed. Empirically, the process is far more complex, with certain parties systematically holding out.

The existence of heterogeneity, both in users' costs and in the resource itself, has important implications for the emergence of informal institutions to protect inframarginal rents. Informal institutions are locally devised and may not be recognized in formal statutes, regulatory actions, or court rulings. These institutions emerge due to low-cost users' ability to discover and invest in more productive resource deposits and those users' desire to protect their claims. In settings where individuals interact with the resource in particular locations with differential information about the overall stock and invest in protecting their rent-generating skills, rationalization imposed by governments at the behest of less-productive users may strand investments in the resource made by more productive agents, their claims to it, and any associated human capital. In this case, rationalization effectively expropriates the informal property rights of low-cost users. Unless compensated, this expropriation is a basis for opposing otherwise socially beneficial institutional change.

The view that inframarginal rents—positive economic profits earned by low-cost producers in competitive settings—exist in open-access settings has been explored in the fishery-economics literature.[2] Johnson and Libecap show how differential production costs generate inframarginal rents captured by highly skilled agents that are vulnerable to redistribution or loss if uniform quotas or shares in a total allowable output are installed.[3] Anderson et al. and Johnson argue that Pigouvian taxes or the auctioning of production shares

2. *See generally, e.g.*, Colin W. Clark, *Towards a Predictive Model for the Economic Regulation of Commercial Fisheries*, 37 CAN. J. FISHERIES & AQUATIC SCIS. 1111 (1980); Terry Heaps, *The Effects on Welfare of the Imposition of Individual Transferable Quotas on a Heterogeneous Fishing Fleet*, 46 J. ENVTL. ECON. & MGMT. 557 (2003).

3. Ronald N. Johnson & Gary D. Libecap, *Contracting Problems and Regulation: The Case of the Fishery*, 72 AM. ECON. REV. 1005, 1012–14 (1982).

transfer rents from low-cost agents.[4] Despite the recognition that inframarginal rents exist in open-access resources, the economics literature has not explored the connection between sustained open-access and the establishment of endogenous, informal institutions to protect these rents.[5]

Long-term expectations regarding the profits to be earned from resource exploitation under open-access are different for inframarginal-rent earners. If users with low expected rents view the resource stock as at risk, they may organize for new institutional arrangements implemented by the state that undermine the practices of those who have adapted to open-access, earn inframarginal rents, and view the stock's condition more favorably. This differential assessment creates a bargaining situation whereby some parties seek to implement new access and production rules whereas others seek to defend their incumbent advantages. If the former anticipate sufficient net gains from institutional change, they ought to be able to compensate the latter for any individual losses. Bargaining involves agreeing on the value of inframarginal rental streams—willingness to accept—and matching it with the value of the net benefits gained—willingness to pay. If these do not coincide, then there is no voluntary agreement and open-access persists; distributional conflicts can have efficiency implications. We examine and discuss empirically observed opposition to theoretically Pareto-improving rationalization attempts. We present a framework of search and exploitation and formation of informal claims to stochastic and heterogeneous resource rents by users who are heterogeneous in search and production cost.

II. ANALYTICAL FRAMEWORK

A. SOURCES OF INFRAMARGINAL RENTS IN OPEN-ACCESS

Understanding how informal institutions can emerge within open-access regimes requires studying the factors that allow users to earn rents in the absence of formal, legal property rights to resources. The most common explanation of inframarginal rents assumes some users have lower costs than others and are able to earn rents even when individuals on the margin earn zero profit.[6] Although this way of thinking about heterogeneity is analytically tractable, it is problematic because it does not account for how cost advantages persist over time. Open-access settings are characterized by a lack of formal rules or restrictions, so all users are free to adopt similar

4. Terry Anderson, Ragnar Arnason & Gary D. Libecap, *Efficiency Advantages of Grandfathering in Rights-Based Fisheries Management*, 3 ANN. REV. RESOURCE ECON. 159, 162 (2011); Ronald N. Johnson, *Implications of Taxing Quota Value in an Individual Transferable Quota Fishery*, 10 MARINE RESOURCE ECON. 327, 330–31 (1995).

5. *See generally* Dean Lueck, *The Rule of First Possession and the Design of the Law*, 38 J.L. & ECON. 393 (1995) (exploring open-access resources in the limited context of first possession establishment of property rights).

6. Johnson & Libecap, *supra* note 3, at 1013.

technologies and production practices as they become aware of them. Rent-generating cost advantages can persist only through differences in knowledge either about the resource or about production techniques. If that knowledge were common or costless to obtain, costs would converge and inframarginal-rent earners would cease to exist. Differences in search and production knowledge that are difficult to copy or convey to others must drive users' ability to sustain inframarginal rents over time.

Differences in knowledge about a resource will arise in settings where the resource is spatially heterogeneous and large and where extraction is site-specific. If search is costly and users are heterogeneous, those with lower search costs will find more productive locations and potentially earn inframarginal rents because they can access the most valuable part of the resource sooner than those who ultimately extract from less-productive locations. If these users also invest in specialized knowledge about how to produce the resource from particular locations, their production costs are also lower, further increasing their rents. Rents derive from asymmetric information—over the resource and over techniques—so settings where information is less stratified will be more subject to rent dissipation. Acquiring site-specific production knowledge increases the expected gains from searching for a productive location if site-specific resource abundance and user productivity are complements.

Where the resource is small and homogeneous in quality and users are also similar in search and production costs, the full-dissipation competitive setting described by Gordon occurs.[7] Resource homogeneity reduces the incentive to search because all locations are equally abundant and, if coupled with user homogeneity, prevents users from exploiting asymmetric information to earn rents. In this setting, users keep entering the resource as long as positive rents exist. Since all users are homogeneous, the equilibrium level of resource extraction corresponds to zero rents for all users. Resource and user homogeneity is also, paradoxically, the setting outlined by Ostrom for successful communal management of a local common-pool resource ("CPR").[8] It cannot be the case that homogeneity in the resource and agents leads to both success and failure. Accordingly, we seek a more general characterization of open-access that reflects the asymmetric information problems that cause collective action for mitigation of rent dissipation to break down.

Table 1 shows how our setting compares to those considered by Gordon and Ostrom. We argue that the homogeneity and information assumptions of Gordon and Ostrom, as shown in the upper left quadrant, are not representative of resources where sustained open-access is observed. Our

7. Gordon, *supra* note 1, at 130.

8. ELINOR OSTROM, GOVERNING THE COMMONS: THE EVOLUTION OF INSTITUTIONS FOR COLLECTIVE ACTION 90–102 (1990) (outlining conditions for successful management).

focus is on exploring the implications of relaxing these assumptions. We argue that most of the world's sustained open-access settings are located where inframarginal rents are earned by some agents, but low or zero rents are earned by new entrants, and there are no local communal arrangements to manage relatively small resource stocks. These conditions arise in the bottom right quadrant of the Table.

Table 1. Open-Access Conditions and Collective Action

	Resource Characteristics	
User Characteristics	**Small, Homogeneous**	**Large, Heterogeneous**
Homogeneous	Ostrom (1990)/Gordon (1954). No Search or Production Advantages; Willingness to Pay = Willingness to Accept; Collective Action Agreement	No Search or Production Advantages; Willingness to Pay = Willingness to Accept; Collective Action Agreement
Heterogeneous	No Search Advantages; Production Differences Observed; Willingness to Pay = Willingness to Accept; Collective Action Agreement	Our Framework: Search and Production Advantages; Willingness to Pay ≠ Willingness to Accept; No Collective Action Agreement

B. STRATEGIES TO DEFEND INFRAMARGINAL RENTS—THE SPONTANEOUS EMERGENCE OF DE FACTO PROPERTY ARRANGEMENTS

Productive locations and specialized search and extraction techniques can be thought of as rent-generating factors of production. Low-cost users are able to sustain their rents to the extent that they can maintain exclusive use of these factors of production. Despite their advantages, low-cost users' rents may be dissipated by high-cost users' actions in two ways. First, if high-cost users attempt to directly access specialized factors of production by imitating low-cost users (either following them to productive locations or adopting what they are able to observe about extraction techniques), they may reduce inframarginal rents.[9] Second, entry by high-cost users—though it generates little to no rents—may deplete the aggregate stock in a way that reduces rents for inframarginal users.[10]

9. This scenario assumes that it is less costly for high-cost users to imitate low-cost users than for low-cost users to initially discover the rent-generating factors of production.

10. *See* David Levhari & Leonard J. Mirman, *The Great Fish War: An Example Using a Dynamic Cournot-Nash Solution*, 11 BELL J. ECON. 322, 324 (1980) (providing an example of a resource harvesting problem with a Nash Equilibrium in harvest strategies that may correspond to a declining resource stock).

Rent earners stand to lose if others are able to dissipate their rents through entry or imitation. The benefits of establishing informal claims under open-access derive from streams of inframarginal rents that users seek to protect. There are a variety of ways in which rent earners might defend rental streams, and the method chosen depends on the characteristics of the resource, characteristics of the rent earners, informal norms, and broad underlying political institutions. Where users can profitably invest to defend rents, informal property rights spontaneously emerge. We define an informal property right as the de facto ability to earn a stream of rents over time—to the exclusion of others—due to search and production advantages or actions taken to exclude other individuals from one's stream of rents. These informal rights may cause open-access to persist longer than would otherwise be expected if the spontaneously emerged rights do not easily convert to de jure property rights. In this case, low-cost users would resist institutional change. Hence, the type of informal property rights that emerges has important implications for whether users will be willing to transition to a formal rights regime or some other joint-management institution.

Depending on inframarginal-rent sources and other users' attempts to compete those rents away, inframarginal-rent earners may pursue numerous strategies to defend their claims. Spatial exclusion may effectively block competition in some settings. Threatened or actual force, fencing, and continued occupation are possible strategies for establishing exclusive access of a location. Spatially excluding other users produces greater returns when rents derive primarily from knowledge of productive locations and when the spatial distribution of the resource is stable over time. For example, informal spatial claims within a fishery for a stationary species like lobster have higher expected returns than spatial claims in the fishery for tuna, which migrate globally. If spatial exclusion and private information are costly or not effective, or if competitive entry continues, inframarginal users will capture more of the resource rents in the short-term, but in the long-term, Gordon's prediction of full rent dissipation prevails.[11] Accordingly, we expect rent earners to invest in natural capital—to save some of the resource stock for later—only if they successfully establish an informal, spontaneous property right.

Users may also use the existing legal framework to exert spatial claims. Many spatially heterogeneous resources are relatively fixed and so correspond closely with the location of land. Grazing lands, surface water flow, stationary marine species, and (to some extent) oil reservoirs are a few examples. In these settings staking de jure claims to land coinciding with productive resource locations allows de facto exclusion of outsiders from the resource. Such de jure provisions quickly transform open-access resources into limited-access resources because users must have a land right prior to occupation and production. Like informal exclusion, this approach is much less effective if

11. Gordon, *supra* note 1, at 130–32.

the spatial distribution of the resource is highly variable. For example, Lueck documents the challenges associated with managing highly migratory wild game with private property rights to land alone.[12] Users of a resource will prefer formal, de jure claims over informal spatial claims in settings where there is a low-cost and low-risk existing legal framework for asserting title to land. In this case, users rely on the state to keep outsiders from trespassing on land and extracting the resource in their valuable location.

Faced with the prospect of resource dissipation through knowledge dissemination, users invest in knowledge and processes that are inherently difficult to communicate or copy.[13] As with search, users with lower costs of investment in knowledge and greater capacity to pay up-front costs will earn differential rents from their investments. Therefore, choosing whether to invest in "cheap" or "costly" knowledge has important implications for users' ability to agree on compensation when faced with the prospect of joint management or rationalization by the state. The upshot is that asymmetric information is endogenous in spatially heterogeneous resources with heterogeneous users. This same asymmetric information, however, creates barriers in negotiations for rationalization because the claims of low-cost users will be difficult for others to verify. Hence, willingness to pay and willingness to accept will diverge.

Spontaneous property rights to open-access resources tend to emerge in settings where users and resources are both heterogeneous (large potential gains), the spatial distribution of the resource is relatively stable over time, production is not fully transparent, and there is potential for learning by experience (lowering costs of developing rights). The greater the gains from asymmetric information, the more users will invest in keeping their advantages private. As in any competitive setting, rents accrue from the exclusive use of a factor of production. In our case, that factor may be an especially productive location or a production technique. Either way, rents will dissipate if knowledge of the factor is not kept private.

For those users who earn positive rents, information is valuable precisely because it is asymmetric. Developing and protecting information advantages is costly, but incurring these costs can allow users to assert an informal, de facto right to more of the resource than others who do not possess these advantages. The value, strength, and extent of these informal rights will shape users' expectations about the future of the resource stock and their willingness to participate in any attempt at formal management of the resource.

12. Dean Lueck, *The Economic Nature of Wildlife Law*, 18 J. LEGAL STUD. 291, 308–11 (1989).

13. This up-front investment in highly specialized, private, and tacit knowledge reduces the costs of maintaining privacy later.

C. CHALLENGES IN TRANSITIONING TO DE JURE PROPERTY RIGHTS

The extent and character of spontaneously evolved, informal property rights in open-access resources determines whether collective action to create formal property rights will confront bargaining problems over rent distribution. Informal property rights emerge after costly investments in search, knowledge, and exclusion. Creating formal property rights may strand some of these investments by changing the way in which all users interact with the resource. A user's willingness to accept rationalization will depend on their expected stream of rents both under open-access and under the new regime. If the investments made to secure rents under open-access are not as productive after rationalization, then the value of formal rights is reduced and inframarginal-rent earners will demand compensation. Those investments, however, are likely difficult to value because of endogenous information asymmetries.

While recognizing informal rights is important in any transition from informal to formal property rights, rationalization of open-access resources presents unique challenges. Users' ability to earn rents in open-access derives from their ability to translate some particular realization of the stochastic resource stock into output more effectively than others. Because official rationalization by the state involves formally open-access natural resources with no legally recognized owners, it is understandable that offered shares are uniform. Uniform shares are, by definition, a direct translation of the aggregate resource stock into individual output that works in the same way for every user. Rationalization puts all users on equal footing with respect to aggregate resource variability in a given period, be it stream flow, fish stock, or rangeland. Rationalization harms low-cost users of the resource by reducing their competitive advantage. Whereas, previously, users could assert an informal right to more of the stock, rationalization makes that right conditional on the structure of formal property rights. Though low-cost users will still translate an open-access resource into output at an above-average rate, rationalization tends to reduce low-cost users' competitive advantage and artificially advantage high-cost users.

If low-cost users' informal rights to the resource exceed their formal rights assigned under rationalization, those users must formally acquire rights to the additional units of output that they previously achieved informally. This acquisition reduces the value of the information that generated rents under open-access. Users can no longer profit directly from their specialized knowledge and cannot easily convey this tacit, private knowledge to others to secure offsetting shares. The corollary to this loss is that users with higher search costs that face low probabilities of discovering productive spatial claims stand to gain from being granted the right to a given amount of output. High-cost users gain the right to the return on natural capital investments made by low-cost users, forcing these parties to buy back their own returns through additional shares. Thus, rationalization in certain settings may represent

expropriation of informal property rights and redistribution of the rents from investment in informal property rights. That expropriation requires side payments—made feasible by the aggregate gains from formal controls—to informal-property-rights holders to secure agreement over rationalization.

The aggregate gains from rationalizing open-access resources may be quite large, even in settings where inframarginal users are made worse off. Costs associated with declining stocks and externalities from overproduction in both renewable and nonrenewable resources can be substantial from competition on the margin. The benefits—both immediate and long run—of instituting sustainable resource management accrue especially to high-cost, marginal users of the resource because they are most affected by variation in the stock and have the least specialized knowledge. Therefore, high-cost users ought to be willing to pay low-cost users to agree to rationalize. This willingness to pay for transfers should exceed the low-cost users' minimum willingness to accept in any setting where aggregate net gains from rationalization exist, provided that users agree about the net gains from rationalization. Agreement will nonetheless fail in the presence of what appear to be large aggregate gains if users' knowledge about the resource and the source of differential returns from exploitation systematically differ.

Individuals form their beliefs about the aggregate resource stock based on observations from particular locations in the spatial distribution of the resource. If low-cost users defend the most productive claims, then the claims available for extraction by high-cost users will be systematically less productive and lead to a more pessimistic view of the resource. Holders of informal property rights learn more about the location-specific dynamics of the resource in their location than do other users, giving them a different estimate of the stream of rents associated with holding that informal right. Alternatively, high-cost users develop a different sense of the potential rents from resource use. Each type of user learns about the resource and responds to that knowledge in sometimes fundamentally different ways. This can lead to different views about the benefits of rationalization because, in spatially connected resources such as fisheries and oil reservoirs, the productivity of each location affects the productivity of the resource as a whole.

The key insight of our framework is that inframarginal rents in open-access resources ultimately derive from differences in highly specific knowledge. Users who develop spontaneous claims to the resource develop knowledge of the stock in their private location. That knowledge generates inframarginal rents, shapes expectations of future rents, and molds investment and production choices. High-cost users learn about the resource in a different way because they observe less productive and more vulnerable parts of the stock. Low-cost users invest to protect their rents by keeping their differential knowledge private. Through this process, informal de facto property rights emerge spontaneously with no central organization or demarcation. Accordingly, these informal rights are inherently difficult to

value because their basis is in asymmetric information, private, tacit knowledge and related production and investment decisions. Users seeking to negotiate over rationalization will find it difficult to credibly communicate their profitability under either regime because their differences in knowledge are the source of their differences in profitability.

Table 2 lists some hypotheses that structure our examination of the natural-resource cases. We use two cases, fisheries and oil and gas, to explore these hypotheses. However, we do not test these hypotheses because of limited data.

Table 2. Hypotheses

Differences in knowledge of specialized sites and/or production processes drive sustained inframarginal rents.
Settings where users earn inframarginal rents will be characterized by asymmetric information about the resource.
Inframarginal-rent earners are motivated to invest in strategies that generate private knowledge of the resource and/or techniques and block others from imitating.
Informal rights spontaneously emerge as spatial exclusion when the spatial distribution of the resource is not subject to high variation over time, generating durable productive locations.
Informal rights spontaneously emerge as spatial exclusion to adjacent land when bounding costs are lower than for the resource itself.
Informal spatial rights may complement valuable specialized knowledge when the spatial claim limits observation.
Informal spatial claims may be marked and defended by foregone inframarginal through under or overexploitation.
Inframarginal-rent earners have an incentive to support rationalization if it recognizes their informal claims.
Rationalization may not be Pareto-improving even when there are aggregate benefits. Distributional disputes result in delayed or blocked rationalization.

III. THE FRAMEWORK APPLIED

A. *OIL AND GAS*

1. Nature of the Resource and Potential for Open-Access

The size of oil and gas reservoirs generally is given in production potential.[14] In the United States, access to subterranean deposits is granted by surface landowners, thus surface acreage is a more useful measure for this Essay. Sizes for some prominent oil fields range from 213,543 acres for

14. See, for example, the list of the world's largest oil fields in *The List: Taking Oil Fields Offline*, FOREIGN POL'Y (Aug. 14, 2006), http://www.foreignpolicy.com/articles/2006/08/13/the_list_taking_oil_fields_offline.

Prudhoe Bay in Alaska to 140,000 acres for East Texas to 26,400 acres for Yates in West Texas to 13,770 acres for Oklahoma City.[15] Larger fields with more fragmented surface ownership raise the potential for open-access as greater opportunity exists for firms drilling from each parcel to compete to capture the resource. Hydrocarbon reservoirs are heterogeneous in terms of the production potential, amounts of oil versus natural gas, subsurface flows, porosity, and rock formations. Accordingly, there are more productive areas in the reservoir, often above the deepest portion, and less productive areas, often on the deposit's periphery. Moreover, natural gas tends to congregate in certain areas (the gas cap), whereas oil settles in other areas (the oil rim). This heterogeneity affects the value and productivity of those firms that hold productive leases to the reservoir.

The problem of open-access losses in oil and gas production has been recognized since they were first discovered in the United States in 1859.[16] Entry is limited based on the number of leases from surface landowners, but hydrocarbons migrate, thus creating the potential for competitive drilling and draining of the reservoir. Oil and natural gas deposits are under great pressure. When any part of the surrounding geologic formation is punctured by a well bore, a low-pressure area is created and natural gas and oil migrate toward the opening. Movement depends upon subsurface pressures, oil viscosity, amount of natural gas, and the porosity of the surrounding rock. In the United States, surface-land owners generally grant search and production leases to specialized firms. Both surface property owners and leaseholders have an incentive to produce rapidly, and most leases contain production timelines. Oil and natural gas cannot be left in the ground because property rights to the resource are secured only via the rule of capture. This, combined with the spatial connectivity of reservoirs, makes hydrocarbons a classic common-pool resource.

With fragmented surface ownership, multiple firms extract from the same reservoir. Firms are motivated to drill and drain competitively to increase their shares of oil field rents, even though these individual actions lead to aggregate losses. The rule of capture results in various forms of rent dissipation. First, capital costs increase by drilling wells beyond what geologic conditions or price and interest rate projections warrant. Additionally, firms invest in surface storage to protect against drainage by other firms, and

15. *See* Lloyd E. Gatewood, *Oklahoma City Field—Anatomy of a Giant*, *in* GEOLOGY OF GIANT PETROLEUM FIELDS, TULSA 223 (1970); BP PLC, FACT SHEET: PRUDHOE BAY 1–2 (2006), *available at* https://dec.alaska.gov/spar/perp/response/sum_fy06/060302301/factsheets/060302301_factsheet_PB.pdf; Julia Cauble Smith, *East Texas Oil Field*, TEX. STATE HISTORICAL ASS'N (June 12, 2010), http://www.tshaonline.org/handbook/online/articles/doe01; Julia Cauble Smith, *Yates Oilfield*, TEX. STATE HISTORICAL ASS'N (June 15, 2010), http://www.tshaonline.org/handbook/online/articles/doy01.

16. Gary D. Libecap & James L. Smith, *The Economic Evolution of Petroleum Property Rights in the United States*, 31 J. LEGAL STUD. S589, S591–92 (2002).

storage can lead to fire and other losses. Rents also dissipate by venting natural gas too rapidly. Natural gas is lighter than oil and is necessary to push oil across subsurface formations to the surface, necessitating early use of costly injection wells and reducing total recovery because heavy oil becomes trapped in formations as gas passes by. Finally, aggregate, long-term rent decreases because production patterns deviate from those that would maximize the value of output over time.

2. Characteristics of Claimants and Existence of Inframarginal Rents

Claimants invest in specialized search and production methods and have an incentive to drain neighboring properties secretly. Though surface-land rights are secure, because migratory hydrocarbons can be extracted from many parts of the field, and because of the uncertainty as to location and size of deposits, there is an important benefit from search. Certain small firms termed "wildcatters" specialize in search and risk taking, while larger firms with multiple leases across many fields are termed "majors." Majors may also have integrated refining and retail operations along the supply chain and are more likely to agree to constraints on production to reduce open-access losses because they capture more of the in situ rents, whereas smaller lease owners depend more on drainage or hold rights to particularly valuable locations less vulnerable to overall field conditions and hence, are more likely to resist those controls. For example, unconstrained output from the East Texas field in the early 1930s led the Governor of Texas to place the field under martial law, enforced by the National Guard. The production constraints' main problem was rampant violation by small firms.[17]

What is important for our purposes is that leaseholders all rely on private information to develop their understanding of the resource and that small and large leaseholders get different information about the reservoir based on the size and location of their claims. Some leases are far more productive than others, and holders of leases to small, very valuable portions of a reservoir are often favorably positioned to capture subterranean hydrocarbon flows and earn rents, even in the presence of competitive open-access drilling and production. These leaseholders have different assessments of the hydrocarbon stock's long-term viability and resist unitization or buyout as solutions.

3. Nature of Spontaneous Property Rights

Informal claims to hydrocarbons correspond to de jure property rights to surface land. In competitive oil and gas production, firms secure rights to search and produce through leases from land owners and property rights to oil via the rule of capture. Information on lease output from individual wells

17. Steven N. Wiggins & Gary D. Libecap, *Firm Heterogeneities and Cartelization Efforts in Domestic Crude Oil*, 3 J.L. ECON. & ORG. 1, 3–4 (1987).

is public, but it is descriptive only of the immediate vicinity of a well and does not necessarily reflect subterranean conditions.[18] This creates incentives for competitive waste. Through drilling individual leases, firms gain knowledge of their portion of the reservoir, though the full extent of the deposit and the other areas' production potential are revealed only through other firms' drilling activities. A lease's production potential and commercial value are a function of objective variables—such as the number of wells, current and past production, and lease acreage—as well as subjectively evaluated geological variables—including the amount of oil below lease lines, net oil migration, oil viscosity, permeability of the surrounding medium, bottom hole pressure, net-acre feet of pay (nonporous and non-oil-bearing rock are subtracted for estimates of gross acre feet of pay, which is the estimated size of the producing formation), and assessments of remaining reserves below lease lines and location of the lease above subsurface flows (some leases are well situated to capture hydrocarbon movement across the formation). Interpreting data gathered from well bores suggests the thickness of the formation, oil and gas migration, and surrounding medium conditions and allows for estimating how production techniques might fracture the formation and release more hydrocarbons. Company engineers translate these interpretations into long-term projections for production, revenues, and costs through subjective assessments.[19] Those assessments are private information and may differ importantly among engineers from different firms, but they are the basis for lease owners' individual value estimates.[20]

4. Formal and Informal Attempts to Rationalize

Local common-oil pool management occurs through unitization or by lease consolidation through buyout. In either case, the rule of capture is replaced by single-firm extraction or ownership of the subsurface hydrocarbon stock. But leases are not uniform in production potential or value and this heterogeneity blocks agreement on those options. When competitive extraction is eliminated, output timelines can maximize return, capital investment in wells and storage occurs only if it is profit enhancing; and overall recovery increases.

By the early 20th century, oil was valuable enough to raise concerns about open-access losses and engineering information developed sufficiently to understand potential remedies. Despite this, neither the option for joint management through unitization or lease buyout was widespread through the 20th century. Even where the numbers of lease owners are relatively small, a

18. Steven N. Wiggins & Gary D. Libecap, *Oil Field Unitization: Contractual Failure in the Presence of Imperfect Information*, 75 AM. ECON. REV. 368, 369–71 (1985).

19. *Id.*

20. The likelihood that there will be differing, and difficult to reconcile, valuations of particular leases increases with the complexity and depth of a formation as well as with the amount of oil and natural gas lodged within.

local complete solution generally did not occur.[21] As late as 1975, neither Oklahoma nor Texas had as much as 40% of production from fully-unitized fields, and even the huge Prudhoe Bay field, discovered in 1968, suffered from competitive production until buyout was completed in 1999.[22] In their analysis, Wiggins and Libecap and Libecap and Smith show that opposition has not merely been held up by lease owners to extract more of field rents, with lease owners defecting sequentially as purchase agreements are completed or as unit agreements are finalized.[23] Rather, certain lease owners systematically resist because they believe their leases are more valuable than do those seeking to purchase or unitize with them.

Wiggins and Libecap identify small leaseholders above the deepest and potentially longest-lived portion of the reservoir as the firms most likely to resist buyout or unitization.[24] Estimating long-term production patterns in these areas involves more subjective private information and more uncertainty than for leases located in shallower areas on the field periphery, where value assessments based on private and public information often converge. Firms with large leases covering more of the reservoir, or with many leases on the field, are also more likely to have value assessments agreed upon by others because differing value assessments across leases offset one another. Libecap and Smith also emphasize the bargaining problems raised when lease owners specialize in oil or natural gas due to the difficulty in valuing the two different hydrocarbons and in developing an agreeable conversion factor to translate natural gas into oil or vice versa.[25] This is a significant issue because 63% of the largest U.S. oil fields have significant volumes of natural gas along with oil; oil lease owners prefer to re-inject gas into the formation to expel the oil, whereas gas lease owners prefer to sell the gas.[26]

Another related asymmetric information problem that is not stressed by Wiggins and Libecap or Libecap and Smith is valuing locational advantages and investments that provide value under open-access but not under rationalization. Unitization changes field and production dynamics such that lease locations above past reservoir flows and related investment in resources knowledge and production may no longer have value. This is, in effect, stranded capital that affected firm owners would seek to recover in voluntary transactions as part of their willingness-to-accept calculations. At the same

21. Gary D. Libecap & Steven N. Wiggins, *Contractual Responses to the Common Pool: Prorationing of Crude Oil Production*, 74 AM. ECON. REV. 87, 92–93 (1984).

22. Gary D. Libecap, *Open-Access Losses and Delay in the Assignment of Property Rights*, 50 ARIZ. L. REV. 379, 396 (2008); Gary D. Libecap & Steven N. Wiggins, *The Influence of Private Contractual Failure on Regulation: The Case of Oil Field Unitization*, 93 J. POL. ECON. 690, 702 (1985).

23. *See generally* Gary D. Libecap & James L. Smith, *Regulatory Remedies to the Common Pool: The Limits to Oil Field Unitization*, 22 ENERGY J. 1 (2001); Wiggins & Libecap, *supra* note 18.

24. Libecap & Wiggins, *supra* note 22, at 697–98; Wiggins & Libecap, *supra* note 18, at 372–76.

25. Libecap & Smith, *supra* note 23, at 9.

26. *Id.* at 5.

time, other parties may disagree on the value claims made by those lease owners. Hence, willingness-to-pay calculations may be too low to support side payments.

In a detailed analysis of unitization efforts for seven reservoirs in Texas and New Mexico, Wiggins and Libecap found that negotiations took from four to nine years to complete.[27] Negotiations for one of the fields, Empire Abo in New Mexico, took six years and required 58 different votes on the distribution of shares.[28] The division of net revenue via shares is specified at unit agreement, and these are permanent; updates are not possible because once the unit is formed, production dynamics change and the lease loses its production role. Some wells are plugged and others are converted to natural gas injection to maintain subsurface pressure, changing subterranean hydrocarbon flows. The absence of contingent updates places particular pressure on long-lived leaseholders who have the most asymmetric information and uncertainty associated with calculating lease values. Moreover, in five of the seven cases, the final unit's acreage was far less than that involved in the early negotiations because not all parties would agree.[29] Subunits, however, are less complete solutions because they involve only part of the formation and because they require drilling costly boundary wells to block the migration of hydrocarbons to non-cooperating leases. Libecap and Smith examine 60 unit agreements and find that those with distinct oil and gas deposits are most apt to be incomplete. They detail the case of Prudhoe Bay where 31 years from discovery passed with competitive subunits until lease owners on the gas area (gas cap) and the oil area (oil rim) agreed to consolidate. In the meantime, there was substantial waste in lost oil production and excessive, competitive capital.[30]

Large firms, often majors, with multiple leases across many non-unitized oil fields bear disproportionate costs from the failure to cooperate to control rent dissipation. These leaseholders lobby state legislatures to impose field-wide unitization. This, however, produced opposition from the same small lease owners that resist voluntary private agreements.[31] Lease owners do not believe they would receive sufficient returns under the new arrangement, even with open-access, and forced unitization or rationalization does not offer compensation to align willingness to accept with willingness to pay. Similarly, the State of Alaska could not force complete unitization of Prudhoe Bay, and other states' forced-unitization statutes implement assigned net production shares to complete units only once a designated percent of the field acreage agrees to unitize. In Oklahoma, compulsory unitization legislation was

27. Wiggins & Libecap, *supra* note 18, at 377–84.

28. *Id.* at 378, 384.

29. *Id.* at 384.

30. Gary D. Libecap & James L. Smith, *The Self-Enforcing Provisions of Oil and Gas Unit Operating Agreements: Theory and Evidence*, 15 J.L. ECON. & ORG. 526, 543–45 (1999).

31. Libecap & Wiggins, *supra* note 22, at 706–12.

adopted in 1945, which required unitization once 85% of the leased acreage supported unitization. This percentage was gradually reduced to 63% by 1951 as production declined and information asymmetries dissipated. In Texas, however, opposition by small-lease owners continues to block a compulsory unitization law forcing lease owners to accept a share that they believed undervalued their leases.[32]

Oil and gas search and production under open-access has not led to smooth and quick responses to close the potential for rent dissipation. Rather, opposition of particular lease owners that do well under open-access delayed or limited possible institutional responses. Despite a general belief that gains are possible from defining more precise formal property rights, the parties cannot agree upon the sharing of those rents. As described in the framework above, distributional factors impede agreement on what otherwise would be efficiency-enhancing institutional change.

B. FISHERIES

1. Nature of the Resource and Potential for Open-Access

Depending on the species, fish stocks may be large and variable as to location in the sea and migration patterns. Shellfish, such as oysters, lobsters, mussels, crabs, and clams, tend to be located in specific sites with little movement, whereas demersal and pelagic fish move more broadly. Distribution is often imperfectly known, and uncertainty increases with range of movement and variation in currents and sea floor terrain. Accordingly, the sea is heterogeneous in the probability of harvest, and this condition creates returns to search and a race to locate the richest fishing areas. The potential areas involved are very large, even within U.S. waters.[33]

In 2013, the largest fisheries by landings in the United States were Pollock, Menhaden, Pacific Cod, Pink Salmon, and Pacific Hake.[34] Historical catch rates grew rapidly beginning in 1940 before slowing dramatically by 1970, drawing attention from the scientific community and from policymakers. That slowdown resulted in the passage of the Magnusson–Stevens Act—the United States' first national fishery legislation—which established the extent of U.S. territorial waters and outlined fisheries management goals.[35]

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32. *Id.* at 710–12.

33. The length of U.S. coasts is 12,383 miles with tidal shorelines comprising 88,633 miles. The exclusive economic zones ("EEZs") of the U.S., in turn, extend out 200 miles into the open sea except where constrained by the international boundaries of adjacent coastal states.

34. NAT'L OCEANIC & ATMOSPHERIC ADMIN., U.S. DEP'T OF COMMERCE, FISHERIES OF THE UNITED STATES 2013: STATISTICAL HIGHLIGHTS 2 (2013).

35. Warren G. Magnuson, *The Fishery Conservation and Management Act of 1976: First Step Toward Improved Management of Marine Fisheries*, 52 WASH. L. REV. 427, 434–38 (1977).

The Magnusson–Stevens Act sets few restrictions on entry, either because of the migratory nature of the species or due to legal requirements in the United States for open-access by the general population. For this reason, wild ocean fisheries are classic open-access resources. Fishers from many different ports can intercept migratory stocks, and rising fish prices encourages entry. But competitive access also means that fish stocks are depleted from over-harvest; firms over-capitalize and invest excessive labor inputs; catch-per-unit-of-effort and incomes decline; and product value decreases by the rush to harvest. Therefore, output is comprised of small or juvenile fish or frozen fish products rather than more valuable larger and fresher products, which are possible only with moderated fishing effort. Indeed, fish stocks are the focus of the most complete discussion of the theory and empirical evidence of the losses of open-access.[36]

2. Characteristics of Claimants and Existence of Inframarginal Rents

Fishers invest in specialized search and production skills and capital, and in concealment through limited information sharing. As a result, they are heterogeneous in their search and production skills, and differential harvests and incomes persist. In fishing communities, there is a hierarchy of fishers exploiting the resource, and more skilled fishers—termed "highliners"—consistently outperform others.[37] Scott notes: "Fisheries experts repeatedly speak of durable groupings of skippers, vessels, and crews according to the size of their catch or earnings, year in and year out."[38] These returns are primarily attributed to knowledge of how to set nets and regulate their spread, where to set lines and their depth, correct trawling speed, and identifying where to find fish.[39] Skills develop over time and are not easily duplicated. They cannot be readily conveyed or valued from fisher to fisher or from skipper to skipper. Long-lasting, higher-than-average catches translate into inframarginal rents that exist even when average fishers may earn no rents. Johnson and Libecap provide evidence of persistent differential harvest

36. *See generally, e.g.*, Jennifer A. Devine, Krista D. Baker & Richard L. Haedrich, *Deep-Sea Fishes Qualify as Endangered*, 439 NATURE 29 (2006); Gordon, *supra* note 1; R. Quentin Grafton, Dale Squires & Kevin J. Fox, *Private Property and Economic Efficiency: A Study of a Common-Pool Resource*, 43 J.L. & ECON. 679 (2000); Ransom A. Myers & Boris Worm, *Rapid Worldwide Depletion of Predatory Fish Communities*, 423 NATURE 280 (2003); Anthony Scott, *The Fishery: The Objectives of Sole Ownership*, 63 J. POL. ECON. 116 (1955); Vernon L. Smith, *On Models of Commercial Fishing*, 77 J. POL. ECON. 181 (1969).

37. Johnson & Libecap, *supra* note 3, at 1010–11.

38. Anthony Scott, *Development of Economic Theory on Fisheries Regulation*, 36 J. FISHERIES RES. BOARD CAN. 725, 733 (1979).

39. *See generally* Ray Hilborn, *Fleet Dynamics and Individual Variation: Why Some People Catch More Fish than Others*, 42 CAN. J. FISHERIES & AQUATIC SCIS. 2 (1985); James Kirkley, Dale Squires & Ivar E. Strand, *Characterizing Managerial Skill and Technical Efficiency in a Fishery*, 9 J. PRODUCTIVITY ANALYSIS 145 (1998) (discussing the relationship between sea captains' experience and education and fishing productivity).

returns among fishers using data from the fall 1978 bay shrimp season on the Texas Gulf Coast. Fishers with catches one standard deviation above the sample mean were termed "good," those at the mean, "average," and those one standard deviation below the mean, "poor." These differences across fishers persist through the fishing season.[40]

Similar to oil and gas lease valuation, public information on differential success includes past and current harvests, vessel size, equipment, crew size, and departure and arrival times at port. Private information includes the subjective interpretation of tides, water temperatures, ocean currents, floor terrain, historical migratory patterns of the stock, as well as the art of fishing itself.

3. Nature of Spontaneous Property Rights

Enforcing claims to fish stocks via land or other spatial claims is not feasible for highly migratory fish species. Instead, control arises from investment in specialized search and production skills and keeping information private or asymmetric. Because fishers for migratory fin fish cannot easily establish spontaneous, informal first-possession claims, they rely upon secrecy and limited information sharing about productive fishing locations and useful fishing techniques among vessels from their own community or fleet. There are complex, quid-pro-quo information sharing practices that favor long-term, local knowledge of the stock and of fishers. Other less-skilled, higher search-and-production-cost fishers have incentives to free ride as much as possible, so highliners limit information sharing.[41] As with hydrocarbons, secure property rights to open-access fish are granted only by the rule of capture. Hence, first arrival at a spot and secrecy (as well as superior skills and lower costs) form a type of spontaneous property right when more formal ownership rights, such as those called for by Scott, are not feasible.[42]

4. Formal and Informal Attempts to Rationalize

Widespread open-access losses in fisheries since the 1970s prompted state and federal governments in the U.S. to implement various regulations to constrain entry and harvest. These constraints include limited entry, limited fishing seasons, vessel, and equipment controls.[43] Fishers adapted around these regulations such that stock and rent depletion continued. Grafton, Squires, and Fox detail vessels and other capital increases in the Pacific Northwest halibut fishery as seasons tightened to protect the stock.

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40. Johnson & Libecap, *supra* note 3, at 1010–11.

41. James A. Wilson, *Fishing for Knowledge*, 66 LAND ECON. 12, 12–13 (1990).

42. Scott, *supra* note 36, at 116–17.

43. Frances R. Homans & James E. Wilen, *A Model of Regulated Open Access Resource Use*, 32 J. ENVTL. ECON. & MGMT. 1, 1–3 (1997).

Between 1980 and 1989, the number of vessels rose by 31% and as stock levels fell, regulators progressively reduced the fishing season from 65 days to six days a year by 1990. The shortened season increased investment by fishers in larger and more powerful vessels and created a competitive fishing derby to harvest as many fish as possible in the limited time available.[44]

Recent rationalization efforts involve assigning individual transferable quotas ("ITQs") and these arrangements increased fishery rents.[45] ITQs involve setting an annual total allowable catch ("TAC") and shares of that total allowable. Rationalization via ITQs was first proposed as a solution to open-access conditions in fisheries in 1972, but the United States has been slow to adopt individual transferrable rights in fisheries.[46] Our framework sheds light on why this might be the case, given the characteristics of the resource outlined above and the claimants themselves, which we describe below.

Johnson and Libecap describe how spontaneous property rights and inframarginal rents based on those rights, earned by highliners, are at risk from rationalization that imposes uniform quotas or in other ways undermine their skill and knowledge advantages and investments.[47] These advantages and related human and physical capital investments allow highliners to out-compete others under regulated open-access. Unless they are compensated, rationalization is not Pareto-improving for highliners, even though the overall fishery stock is better-conserved and total rents increase. Similarly, Abbott and Wilen discuss how catch limits to reduce bycatch result in races to harvest commercially valuable stocks before reaching the total allowable bycatch. These regulatory-imposed races change optimal fishing strategies, potentially reducing returns and inframarginal rents.[48]

There are few documented cases of highliner-opposed rationalization. Deacon, Parker, and Costello provide such a study of the short-lived Chignik Salmon Fishery Cooperative in Alaska.[49] In 2002, the Alaska Board of Fisheries approved a request from a group of fishers to create a voluntary cooperative to coordinate harvests and limit effort and vessels.[50] Eighteen highliners, whose catch histories exceeded those of members, chose not to join. The Alaska Board of Fisheries increased the share of the total annual allowable catch assigned to the cooperative as the number of cooperative

44. Grafton, Squires & Fox, *supra* note 36, at 684.

45. Christopher Costello, Steven D. Gaines & John Lynham, *Can Catch Shares Prevent Fisheries Collapse?*, 321 SCIENCE 1678, 1678–80 (2008).

46. *See* Libecap, *supra* note 22, at 389.

47. Johnson & Libecap, *supra* note 3, at 1012–17.

48. Joshua K. Abbott & James E. Wilen, *Dissecting the Tragedy: A Spatial Model of Behavior in the Commons*, 62 J. ENVTL. ECON. & MGMT. 386, 393–400 (2011).

49. Robert T. Deacon, Dominic P. Parker & Christopher Costello, *Reforming Fisheries: Lessons from a Self-Selected Cooperative*, 56 J.L. & ECON. 83, 89–114 (2013).

50. *Id.* at 87–88.

members grew from 77 to 87.[51] The cooperative retired the proportion of permits and vessels that otherwise would be used by its higher-cost members by 31%, reducing capital and labor costs per unit of harvest.[52] It also increased the fishing time or season for its members by about 48% by reducing the race to intercept fish in the open ocean.[53]

Highliners and members generally agreed that the cooperative improved overall rents by around 33%, but disagreed as to the division of the rents.[54] The cooperative was granted a growing share of the TAC as its membership expanded.[55] Hence, allowable harvests were not distributed according to historical catch shares, and the share granted by the regulators to independents declined in 2004 by 40%. Independents' share of the total allowable catch threatened their inframarginal advantages, which were most valuable under competitive conditions and entry controls. In the face of this, two of the most successful highliners successfully sued to block the Alaska Board of Fisheries' allocations to the cooperative in 2005, and the cooperative was dismantled by court order.[56]

One might ask why allocation did not use historical harvest. The cooperative changed fishing practices and location so that past practices reflecting fish interception in the open ocean and uncoordinated harvest were no longer relevant. Highliners who invested in those techniques demanded compensation or allocations based those techniques. Cooperative members, however, were earning rents based on new coordinated fishing practices, not historical ones, and apparently did not have willingness-to-pay commensurate with the willingness-to-accept demands of highliners. Although there is no information as to the source of any bargaining breakdown, such a breakdown is consistent with difficulties in valuing stranded capital and skills appropriate for open-access and a race to capture stock, but not relevant or valuable under rationalization. This bargaining breakdown in the presence of aggregate benefits is similar to outcomes observed in oil field unitization efforts, and likely undermines other efforts to rationalize.

51. *Id.* at 88.

52. *Id.* at 104.

53. *Id.* at 105.

54. *Id.* at 110, 112.

55. *Id.* at 88.

56. The Alaska Supreme Court ruled that the co-op was inconsistent with Alaska's Limited Entry Act of 1973, which requires "present active participation" of any permit-holder in a fishery. Robert T. Deacon, Dominic P. Parker & Christopher Costello, *Improving Efficiency by Assigning Harvest Rights to Fishery Cooperatives: Evidence from the Chignik Salmon Co-op*, 50 ARIZ. L. REV. 479, 504 (2008).

IV. CONCLUSION

This Essay outlines a framework for understanding how informal property rights emerge in open-access resource settings traditionally characterized as lacking any sort of property right. Our approach elucidates why sustained open-access is observed, even in the presence of apparently large aggregate benefits from transitioning to joint management of the resource. Heterogeneous users of spatially heterogeneous resources will invest in differential levels of search and learning, accumulating knowledge that generates inframarginal rents. In response to threats of continued entry, replication, and other forms of rent dissipation, inframarginal-rent earners invest in strategies to protect their expected rental streams. These strategies create and entrench asymmetric information about any particular institution's costs and benefits for managing the resource, making bargaining between parties costly, potentially to the exclusion of side payments for what otherwise appears to be a Pareto-improving transition to formal management of the resource.

Our framework describes heterogeneous users' behavior in settings lacking formal property rights, but our predictions are inherently difficult to test. We argue that the source of users' ability to earn and protect positive rents is tacit—private knowledge that is, by design, difficult to communicate. Our framework explains why some resources have proven less amenable to rationalization. We document differential skill in locating hydrocarbons and fishery resources. Differential search and learning in each setting resulted in users with differing knowledge about the resource. This differential knowledge stymies rationalization attempts.

Rationalization is the chosen policy tool for spatially connected resources because each user's behavior affects all other users by changing the aggregate stock available, even when the resource is spatially heterogeneous. Hydrocarbons and fishery resource both fit this pattern. In both cases, we show that users exhibit differing levels of search, investment, and knowledge, resulting in a heterogeneous distribution of rents that is correlated with users' knowledge of the resource itself. Both resources have seen repeated attempts at rationalizing. When unsuccessful, rationalization fails due to users' inability to reconcile their contradictory "knowledge of the particular circumstances of time and place" to form an agreement about characteristics of the aggregate resource.[57] The result is sustained open-access with competitive losses that are larger for high-cost users who tend to know less about the resource.

57. F.A. Hayek, *The Use of Knowledge in Society*, 35 AM. ECON. REV. 519, 521 (1945).