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The Technologies of Property Rights: Choice among Alternative Solutions to Tragedies of the Commons

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The Technologies of Property Rights: Choice Among Alternative Solutions to Tragedies of the Commons

Bruce Yandle* and Andrew P. Morriss**

The authors propose a framework for analyzing the broad class of problems that fall within the "tragedy of the commons," the dominant metaphor for understanding environmental problems. The Article applies industrial organization theory to the issue of how to solve tragedies of the commons, developing a conceptual analysis built around the various forms of property rights (common, public, private, regulatory) used. It then examines how technology affects the appropriateness of different solutions. Finally, the Article expands the notion of technology to include the legal institutions that implement the various forms of property, uncovering an important set of incentive effects.

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INTRODUCTION

Garrett Hardin's classic description of the tragedy of the commons¹ tells us that all environmental problems require a property rights solution. The property solution or rule may call for the definition and enforcement of common, public, or private property rights, but any escape from the tragedy requires some rationing mechanism that allocates a form of property rights to some entity. These solutions fall into one of two broad traditions within economics: the Pigouvian, or regulatory tradition,² and the Coasean,³ or market-based tradition.⁴ Any proposal for action in either tradition implies *some* definition of property rights.⁵ The difference lies in the type of property rights required. If the recommendation follows the Pigouvian tradition, it will call for government taxation or regulation, and the politically determined rules will form a public or regulatory property regime.⁶ A recommendation in the Coasean tradition, on the

1. Garrett Hardin, *The Tragedy of the Commons*, 162 *Sci.* 1243 (1968).

2. The Pigouvian tradition, which calls for the state to intervene by imposing taxes or regulation on pollution as a way to achieve some politically determined standard, comes from the seminal work of A. C. PIGOU, *THE ECONOMICS OF WELFARE* (1920).

3. The Coasean tradition is based on the seminal work by R. H. Coase, *The Problem of Social Cost*, 3 *J.L. & ECON.* 1 (1960). Coase's analysis is an attack on the Pigouvian position and calls for a greater reliance on private property rights and markets than does Pigou.

4. See generally Bruce Yandle, *Coase, Pigou, and Environmental Rights*, in *WHO OWNS THE ENVIRONMENT?* 119 (Peter J. Hill & Roger E. Meinert eds., 1998).

5. Of course, enduring a tragedy by doing nothing can be the low-cost solution. Doing so allocates the property rights to the polluter.

other hand, will rely on markets and a system of private property rights to solve the tragedy.⁷

Defining property rights is central to solving any tragedy of the commons. Thus, understanding the factors that influence how property rights are defined is critical to understanding the solutions to environmental problems. In this Article, we propose a framework for examining how technology influences the definition of property rights. This framework, depicted in Figure 1, clarifies the differences between Coasean and Pigouvian solutions to commons problems and assists with the choice between them.

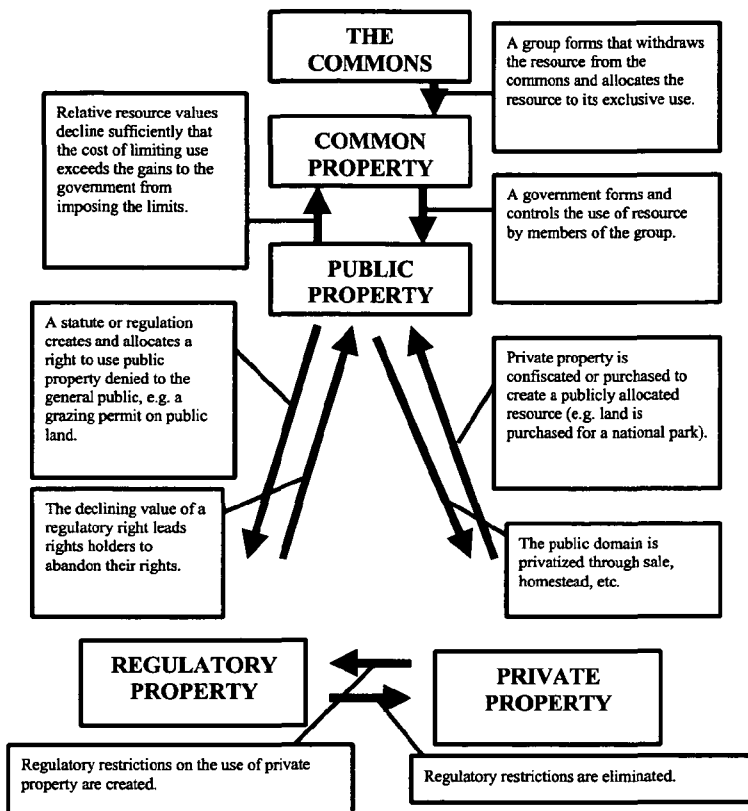
Technologies that reduce transaction costs allow individuals to engage in increased wealth-increasing trades. When such technologies allow the creation of private property rights, entrepreneurs facilitate the creation of new bundles of property rights to meet the demand for property. Such entrepreneurs can play an important role in delivering environmental goods.

At the same time, equally powerful incentives exist for individuals to use the power of government to capture property rights. Such rent-seeking disrupts the entrepreneurial process and prevents the development of new solutions to new problems. Our theory helps explain how these two conflicting impulses shape the provision of environmental goods.

6. The basic blueprint followed by the Clean Water Act and Clean Air Act calls for command-and-control regulation, implying government definition of public or regulatory property. The blueprint is consistent with the Pigouvian tradition. A more detailed description of regulatory property is given in Carol M. Rose, *The Several Futures of Property: Of Cyberspace and Folk Tales, Emission Trades and Ecosystems*, 83 MINN. L. REV. 129, 164-65 (1998). See also Jonathan Baert Wiener, *Global Environmental Regulation: Instrument Choice in Legal Context*, 108 YALE L.J. 677, 799 (1999).

7. Recent developments in the Clean Air Act that define allowable amounts of sulfur dioxide emissions from specified electricity generating plants and then allow for permit trading among plants begin to incorporate the Coasean idea. The definition of constrained and tradeable property rights to pollute encourages the polluter to find low-cost solutions to the pollution reduction problem. Another example of a Coasean solution to an environmental problem can be found by looking at how the United Kingdom protects fisheries by giving private fisherman the right to sue. Common law suits brought by angling clubs against polluters comes even closer to the property rights ideal described by Coase. See *Pride of Derby & Derbyshire Angling Assoc. v. British Celanese L.D.*, 1953 Ch. 149; see also Roger Bate, *Protecting English and Welsh Rivers: The Role of the Anglers' Conservation Association*, in *THE COMMON LAW AND THE ENVIRONMENT: RETHINKING THE STATUTORY BASIS FOR MODERN ENVIRONMENTAL LAW* 86 (Roger E. Meiners & Andrew P. Morriss eds., 2000).

FIGURE 1
EVOLVING PROPERTY RIGHTS



In Part I, we describe the role of technology in defining possible property rights solutions. Part II utilizes a theory from industrial organization to build a conceptual model of how property rights evolve.⁸ In Part II, we discuss various kinds of transaction costs that affect the evolutionary process and show how property rights technologies address these costs. In Part III, we discuss two competing legal frameworks for solving commons problems, the common law and statutory law. Finally, Part IV discusses certain aspects of the competition between providers of property rights institutions and explains how this competition affects the resulting definition and distribution of property rights.

8. See *infra* note 31 and associated text (developing parallels with the theory of the firm).

I

THE ROLE OF TECHNOLOGY IN PROPERTY RIGHTS SOLUTIONS

A. *Property Rights Technology*

Property, at least as taught in most American law schools, concerns itself with a great deal of historical detail on the origins of the basic concepts of Anglo-American property law arising out of the struggles between the landed aristocracy of England and assorted monarchs.⁹ Modern land law, for example, has its genesis in William the Conqueror's desire to keep the Norman overlords he installed in England loyal to him.¹⁰ To speak of "property rights technology" may, therefore, seem odd.

Yet William was a "technological" innovator, and many consequences of his innovations are still with us. Like any innovator, William created a new method of achieving his goals. Like many innovations, William's construction of the beginnings of Anglo-American property law had consequences that he could not foresee. Nonetheless, thinking about law as a technology has important conceptual advantages—it allows us to bring to bear the established body of economic analysis of technological change to help explain legal change and its consequences. The separation of the legal interests in property from the physical object possessed has enabled us to constantly modify the set of property rights that constitutes "ownership" of land (or anything else). Property rights are affected by a variety of technologies. They include physical world technologies of the type traditionally associated with technology such as barbed wire, which made private property rights cheaper to enforce across the Great Plains, property rights technologies such as those explored in this section, and legal technologies—namely common law and statutory law—considered in detail in Part IV.

The common metaphor for Anglo-American property rights is helpful here: generations of law students have wrestled with the notion that property interests are best represented by a bundle of sticks. Particular rights—the right to harvest timber or to cross a particular piece of land—represent individual sticks;

9. See, e.g., JESSE DUKEMINIER & JAMES E. KRIER, *PROPERTY* (4th ed. 1998), which begins its section on possessory estates with the following sentence: "In January 1066, Edward the Confessor, saintly and celibate, died childless." *Id.* at 187.

10. A. W. B. SIMPSON, *A HISTORY OF THE LAND LAW* 3 (2nd ed. 1986) ("The invasion of England by a band of military adventurers made it necessary to quarter this military aristocracy on the conquered land; William had to reward his followers and preserve his military strength for the future.").

various rights holders have bundles of varying composition with respect to particular parcels of land.

The technology of property rights can be understood by thinking about this bundle of sticks. Technology, either in law or in a more conventional sense, allows increasingly sophisticated definitions of property rights and allocation of particular sticks to either private property owners or public entities. Registration of deeds is a comparatively recent property rights technological innovation from 1640,¹¹ and it allows certainty of title—enabling complex financial dealings based on land as collateral. Once created, however, its use evolved in unanticipated ways as individuals sought to fulfill their own plans and projects. The technology of deed registries allows this to occur despite its origins in other needs of the society that created it. For example, patents and copyrights allow the creation of new forms of property. To take another example, changes in water law allowing water rights owners to leave water in streams instead of requiring out-of-stream use create new types of water rights.¹² Each of these innovations added sticks to the bundles of rights held by property owners. Conversely, zoning laws removed sticks from property owners' bundles by regulating previously unrestricted land. The invention of aircraft also led to the erosion of the traditional common law maxim *cujus est solum ejus est usque ad coelum*, which translates as *whose is the soil, his is to the sky or high heavens*.¹³ Thus, the ultimate impact of these innovations on property rights cannot be foreseen—the order that results is unplanned.

While the impact of particular technologies is generally unpredictable, the effects of technology on property rights can be classified into several different categories. First, technology can affect what rights can be placed into the bundles of sticks. Thus a legal change or scientific innovation may place something within the category of things that may be owned or may remove it from that category. For example, the invention of the harpoon made it possible to convert whales from unowned to owned property. The property right to dead whales might be lodged in the harpoon thrower, the town nearest where the whale washed ashore, or the public in general—the point being that ownership

11. See, e.g., DUKEMINIER & KRIER, *supra* note 9, at 651 ("Public recording of deeds, mortgages, leases, and other instruments affecting land title began in this country in the Plymouth and Massachusetts Bay Colonies around 1640. It was not an English custom.")

12. TERRY L. ANDERSON & DONALD R. LEAL, *ENVIRO-CAPITALISTS* 89-107 (1997).

13. RALPH E. BOYER, *SURVEY OF THE LAW OF PROPERTY* 258 (3rd ed. 1981).

of the whale could now be assigned. Live whales remained beyond the effective reach of the property rights bundle.¹⁴ Owning a whale therefore required killing it. Recent advances in GPS technology and DNA fingerprinting, however, may soon make it feasible to own live whales, substantially changing the feasible set of property rights in whales.¹⁵

Second, technology can make it possible to subdivide property rights within a particular bundle in new ways. The innovation of the fee tail estate, for example, made it possible to create a new temporal division of land ownership.¹⁶ Likewise, the development of the trust enabled the division of the legal and equitable interests in property, making it possible to “break” particular sticks into new pieces.¹⁷

Third, technology may make different forms of property possible. Generally, property falls into five broad categories:

1. The Commons: property which is available to all mankind: the atmosphere is an example of a commons;
2. Common Property: property which is available to a particular group but not to outsiders: a family’s living room is an example of common property;
3. Public Property: property controlled by government, such as a national park;
4. Private Property: property controlled by private entities, such as a fee simple absolute ownership in land; and
5. Regulatory Property: a property right created and allocated by a government entity, such as a right to emit specified pollutants into the atmosphere under the terms of a permit issued by a government regulator.¹⁸

Technology affects which of these kinds of property are possible with respect to any given stick from the bundle.

14. Of course, one can always assign a property right in theory. We could, for example, claim to own Mars, but such a claim is mere speculation without the ability to enforce it.

15. See Richard S. Cahoon & Ron Herring, *Biotechnology, Intellectual Property, ‘Bioproperty’ and Novel Schemes for Wild Biota Conservation*, in *THE TECHNOLOGY OF PROPERTY RIGHTS* (Terry L. Anderson & P. J. Hill eds., forthcoming 2001).

16. See SIMPSON, *supra* note 10, at 85.

17. See DUKEMINIER & KRIER, *supra* note 9, at 275 (“The trust, a brilliant invention of English jurisprudence, is an extremely flexible form of property management.”).

18. There is a long running debate over whether or not private property ultimately depends on the government’s enforcement mechanisms for its existence. We need not resolve that issue here; it suffices to note that regulatory property must be allocated by a government while private property need not be.

B. *The Paths out of the Commons*

Consider the archetype of the commons problem: Garrett Hardin's description of a pasture into which anyone may place as many cattle as she sees fit.¹⁹ Because no one can restrict others' rights to the commons, overstocking soon results from individually rational behavior. Each individual cattle owner bears only a portion of the costs her cattle impose on society, yet she reaps all the benefits of her cattle. The cattle owner's decisions thus do not take into account that adding cattle will reduce the productivity of the pasture for others.

Escape from this tragedy is possible by transforming the commons into any of the other four forms of property, although the route chosen has important consequences that we will explore shortly. The local village could convert the commons into common property, regulating the number of cattle by linking the right to own cattle to the amount of land owned in the community. (This was, in fact, how medieval English villages escaped the tragedy Hardin described.) The pasture could also be made public property in the form of a park, thus allowing cattle to be banned from the pasture. (The United States used this strategy in creating Yellowstone National Park.²⁰) The commons could also be privatized by granting or selling a portion to individual owners. (The Homestead Act did this with respect to large areas in the United States.²¹) Finally, the government could issue a limited number of grazing permits to control the number of cattle allowed into the pasture. (Public land grazing permits in the western United States fall into this category.²²) Many different property rights paths can resolve the problem of the commons.

In describing the private property rights route of escape from the commons, most accounts of the evolution of property rights

19. Hardin, *supra* note 1, at 1244. For a description of the modern version of the same practice, see ELINOR OSTROM, *GOVERNING THE COMMONS* 58-102 (1990). See also Andrew P. Morriss, *Miners, Vigilantes & Cattlemen: Overcoming Free Rider Problems in the Private Provision of Law*, 33 *LAND & WATER L. REV.* 581, 650-78 (1998) (describing the methods used to overcome commons problems among western cattlemen).

20. On the formation of Yellowstone National Park and the "national park idea," see AUBREY L. HAINES, *THE YELLOWSTONE STORY: A HISTORY OF OUR FIRST NATIONAL PARK* 156-73 (revised ed. 1996).

21. On homesteading, see Richard L. Stroup, *Buying Misery with Federal Land*, 57 *PUB. CHOICE* 69 (1988); Terry L. Anderson & Peter J. Hill, *The Race for Property Rights*, 33 *J.L. & ECON.* 177 (1990).

22. For a summary of the rules governing grazing on federal land in a property rights context, see Leigh Raymond, *Are Grazing Rights on Public Land a Form of Private Property?*, 50 *J. RANGE MGMT.* 431 (1997).

focus on “demand thresholds” or the points at which, with a given technology, it becomes profitable to define a new private property right. In these accounts, broadly described transaction costs are at issue and entrepreneurs claim, define, trade, and are held accountable for certain rights to a former common-access resource.²³ According to this model, the process begins when the common-access resource is made more valuable by growing demand. As demand increases, the potential profits from defining private property rights bring the common access resource to the threshold at which it is worth incurring the transaction costs necessary to define rights. But for the private property rights threshold to be approached, cost-effective technologies for measuring, monitoring, and enclosing private property must emerge so that identifiable units of the resource can be claimed and transferred. Once such technologies are in place, the threshold crossing may occur, provided the associated wealth distribution effects are successfully resolved.²⁴ Having sufficient gains from trade to cover market-related costs is necessary but not sufficient. Side payments may also be required to satisfy those interested in maintaining the status quo. Where either private property rights technology is lacking or the distributional cost hurdle is too high, private property rights cannot emerge because the transaction cost wedge is simply too large. Political or regulatory property rights will emerge instead.

Among environmental property rights historians, the free market environmentalism school focuses most on the importance of private property rights technologies.²⁵ The development of barbed wire dramatically demonstrates how technology affects the development of private property rights.²⁶ Consider the salient parts of the barbed wire story. With the introduction of barbed wire, it became possible to divide and enclose large amounts of open range grazing land at significantly

23. See, e.g., Terry L. Anderson & P. J. Hill, *The Evolution of Property Rights: A Study of the American West*, 18 J.L. & ECON. 163 (1975); YORAM BARZEL, *ECONOMIC ANALYSIS OF PROPERTY RIGHTS* (2nd ed. 1997); Steven N. S. Cheung, *The Structure of a Contract and the Theory of a Non-Exclusive Resource*, 13 J.L. & ECON. 49 (1970); Harold Demsetz, *Toward a Theory of Property Rights*, 17 AM. ECON. REV. 347 (1967); MICHAEL DE ALESSI, *FISHING FOR SOLUTIONS* (1998); GARY LIBECAP, *CONTRACTING FOR PROPERTY RIGHTS* (1989); OSTROM, *supra* note 19; Carol M. Rose, *Energy and Efficiency in the Realignment of Common-Law Water Rights*, 19 J. LEGAL STUD. 261 (1990).

24. LIBECAP, *supra* note 23, at 11-12.

25. See Anderson & Hill, *supra* note 23; TERRY L. ANDERSON & DONALD R. LEAL, *FREE MARKET ENVIRONMENTALISM* (1991); DE ALESSI, *supra* note 23; LIBECAP, *supra* note 23, at 10.

26. ANDERSON & LEAL, *supra* note 25, at 24-34.

lower costs than before barbed wire. Ranchers could enforce exclusive rights to vast sections of western territory, resulting in enhanced stress on the grazing land; as cattle production increased, grazing land became more valuable. At the same time, however, the prior technology for enforcing property rights in cattle—cowboys and horses—declined in value as demand for the “old technology” decreased. Just as rising demand for transportation allowed the automobile to replace the horse and carriage and so doomed buggy whip manufacturers and blacksmiths, so barbed wire reduced demand for horses and cowboys.

The economist’s reliable model of the firm operating within a competitive industry can explain this result: at the time barbed wire was introduced, there was a growing demand for the capability to enclose and exclude. The foregone gains from trade were large. As demand for private property rights grew and the cost of enforcing such rights remained constant, the potential for gain by reducing enforcement costs expanded. Creative people observed the opportunity for profit and barbed wire was born.

This stylized form of the story omits a critical element from the model—an institutional arrangement that accommodates the market process. The legal institutions that conditioned and affected the definition and enforcement of private property rights need to be explicitly considered. For the barbed wire story to hold, the cattlemen occupying western land must first be able to exercise the right to enclose the land.²⁷ This was not always the case for western cattlemen; indeed, their enthusiasm for barbed wire enclosures led them to fence off illegally at least thirty-six million acres of U.S. government land.²⁸

For land to be enclosed and alienated and barbed wire sold, a technology must exist for measuring and recording land, as well as for producing barbed wire. Then for the story to lead to full land-value maximization, the cattlemen must hold a recognized right to alienate the land. As residual claimants, owners of rights that can be defined, defended, and devised to others, the holders of private property rights in land have the incentive to search for and install barbed wire. If enforcement of these rights is lacking, however, the market for barbed wire will be severely limited; there will be little barbed wire, other than in museums or in engineering laboratories.

27. See LIBECAP, *supra* note 23, at 60-64.

28. *Id.* at 64.

Thus, the commons-to-private-property story is incomplete. Some means of allocating and recording rangeland was necessary to account for the technological development of barbed wire. Several competing providers of these institutional services were available. At one extreme, the resource in question could be controlled and managed by government. Statutory law and regulation administered by civil servants can develop a system of regulatory property rights that solves a problem of the commons. At the other end of the spectrum, fully alienable rights to the resource may be held exclusively by private parties, administered through common law, contracts, and voluntary exchange. Thus, the development and implementation of property rights technologies will be significantly determined by which institutional provider is dominant.²⁹

II

THE EVOLUTION OF PROPERTY RIGHTS

We can begin to unpack the black box of property rights by using the economic theory developed to explain the allocation of transactions between firms and markets. Economic theory has often treated the internal workings of firms as a "black box" impenetrable to the theory's insights. Similarly, legal scholars have often treated property rights institutions as equivalent black boxes. Economic theory requires more than knowledge of supply and demand to explain why some transactions occur within firms outside of the marketplace while others occur between firms in the marketplace.³⁰ Similarly, explaining how particular sticks in the bundle end up defined as private property, public property, or regulatory property requires examination of more than the demand thresholds considered in the usual evolution of property rights story.

To unpack the black box of the firms, George Stigler turned to one of Adam Smith's insights, rephrased as a theorem of industrial organization, to explain how specialized activities

29. See Andrew P. Morriss, *Law on Range* (unpublished working paper, 1999) (on file with author) (discussing differences in rangeland allocation practices between Texas, where cattlemen procured private property rights to land, and Wyoming, where cattlemen were unable to do so because of federal land policies).

30. Understanding why, for example, auto manufacturers purchase some parts in the marketplace but create others in house requires understanding more than the prices and quantities of the various parts. The industrial relations analysis of General Motors' relationship with Fisher Body is the classic in this field and is still provoking profitable analysis today. See, e.g., R. H. Coase, *The Acquisition of Fisher Body by General Motors* (2000).

within firms can sometimes become firms themselves and why they do not do so in all cases. Noting that the "division of labor is limited to the extent of the market," Stigler developed a theory of vertical integration and disintegration.³¹ This "division of labor" model is consistent with the demand threshold concept of property rights evolution discussed previously. By applying Stigler's model to property rights evolution, it is possible to find similar effects that can be termed a "division of property rights" model. Thinking of ownership as a bundle of potential rights, we can readily see that where demand for particular rights is weak, some specialized rights might not be unbundled and traded in the market, just as some functions within a firm awaiting growth in demand for a specialized service might remain integrated. For example, mineral rights might remain attached to the land package until the time that the expected value of the ore removed rises sufficiently to justify their unbundling. Similarly, the right to discharge particular waste materials in a river might go unmarketed until the benefits of unbundling those specialized rights exceeds the cost of building the related institution. Thus, we see that the division of property rights is limited to/by the extent of the market.

From at least John Locke on, property rights theorists have assumed that all of nature was initially a commons.³² At some point, however, parts of the commons became sufficiently scarce that it became economical to define, unbundle, and protect those parts of the commons as common property. Then, with further increases in demand and encounters with scarcity, efficient behavior dictated further unbundling of specialized rights. Eventually, the unbundling process led to private property rights. As Yoram Barzel argues, "property rights are *constantly* created and abandoned" as economic conditions change.³³

The notion of property rights specialization is illustrated in Figure 1, which gives a highly stylized property rights flow diagram for a generic resource.³⁴ The evolutionary path of property rights formation begins with a commons. The path then leads to common property as a group (tribe, clan, and nation), which defines itself and limits access to common property to its

31. GEORGE J. STIGLER, *THE ORGANIZATION OF INDUSTRY* 129-41 (1968).

32. JOHN LOCKE, *TWO TREATISES OF GOVERNMENT* 29 (Thomas J. Peardon ed., 1952) (1690) ("Thus in the beginning all the world was America.").

33. BARZEL, *supra* note 23, at 90 (emphasis in original).

34. Of course, particular resources may follow different paths out of the commons. The path illustrated here is intended largely as an example, not as a definitive description of how property rights develop for every resource.

members. As the group develops more formal government structures (a king), property is reallocated from the collective to the ruler(s) and becomes public property. At that point, a fork is encountered where either fully defined, protected, and alienable private property rights emerge, or some form of regulatory property is defined and maintained by government. The arrows in the figure indicate the general direction followed as economic and other social forces stimulate the evolutionary process. Understanding why particular forms of property rights arise in a particular case requires examining the components of the property rights definition process.

A. *Unbundling*

Unbundling is a vital component of the process of property rights evolution. All of the paths out of the tragedy of the commons require creating and allocating some new stick or sticks in a property rights bundle. Although the paths differ in what they require to create and allocate a stick, each path involves some combination of defining, defending, and enabling transferability of property rights. The costs associated with these paths vary and property rights may be redefined multiple times for the same piece of land as property rights evolve, for example from public to private property or from public to regulatory property. An examination of this evolution, as depicted in Figure 1, shows that the degree of openness in the property rights system first contracts as property is taken out of the commons, then expands and contracts again.³⁵

The unbundling process is thus made up of three activities: defining, defending, and enabling rights to be transferred or devised. These activities, in turn, contain elements of fixed and variable cost. Defining property has a high fixed cost element. For example, defining property rights in land may require that the land be surveyed and the dimensions marked and recorded; water flows and interactions with pollution be mapped using geographic information systems;³⁶ or stack emission monitors installed for measuring environmental uses. In contrast, costs

35. Property in a commons is "open access" to those able to use the commons—that is, the users are able to make decisions about using the property without regard to others. As property moves from the commons to private property, the degree of openness contracts; if it then shifts to regulatory property, the degree of openness expands again.

36. See Clay J. Landry, *The Role of Geographic Information Systems in Water Rights Management*, in *THE TECHNOLOGY OF PROPERTY RIGHTS*, *supra* note 15.

associated with defending or transferring property rights are variable. The interaction of fixed and variable costs generates a set of short-run cost curves much like those in any standard economic text. The result is an upward-sloping supply curve that represents the cost of property rights definition, transfer, and defense. Thus, different forms of property will present different mixes of fixed and variable costs in each of these areas, and the relative costs will dictate the form that property rights take. Technological change alters these relative costs and can change the form of property rights under conditions we explore in the next section.

The level of precision necessary for defining, defending, and enabling transferability of property rights varies with the form of property created; therefore, so does the relative cost associated with creating such rights. Creating fully alienable private property requires the most precision: a right must be created that can be measured and described with sufficient precision to allow its transfer. Public property generally requires the least precision, if only because it is by nature untransferable and so any precision required for transfer can be safely ignored. Regulatory property generally falls between the two, with the degree of precision dictated by the particulars of each case. Consider, for example, the choice of how to allocate a tract of land. If the land is to be given to private property owners, the boundaries of each tract must be defined, a means of defense of the boundaries provided (fences, trespass suits etc.), and the incidents of a market guaranteed (at a minimum, bans on force and fraud). If the land is to be made into public property, as a park, the overall boundaries must be delineated and rules for use of the park created and enforced. Providing private entities with a means of defense and guaranteeing the conditions necessary for a market are not necessary. If the land is to be made regulatory property, through grazing permits for example, the rights associated with the permits must be defined and defended.

History and tradition tell us that once a resource makes the transition from common access and becomes the exclusive property of a tribe, family, or political unit, the process is seldom totally reversed.³⁷ So long as the once common-access resource

37. This is not always the case, however. In the barbed wire story, horses that were a valuable property rights technology used in defining and defending property rights in pre-barbed wired days were displaced by wire and released to the wild to become public property. In some cases, the horses and their progeny became common-access resources; they were not worth the cost of protecting them. *See* Terry

has sufficient value to justify relatively low marginal cost border protection, the resource will at least remain in the public domain. However, Figure 1's double arrows, between common property and public property and between public and private or regulatory property, indicate that property rights previously defined and enforced at a rather detailed level can and do return to common property or public domain status.³⁸

There are distributional effects associated with a change in property rights status. Movement from common property to private or regulatory property simultaneously creates and destroys property rights. These rights can range from the classic "sole dominion" characteristic of single ownership in fee simple absolute to ownership vested in a closed group, which might be called voice.³⁹ For example, when rights to a resource are held in common by an identifiable group, membership is a prerequisite for sharing the common resource. Access to fisheries, grazing range, hunting territories, even swimming areas is frequently managed by club-like organizations having specified membership requirements.⁴⁰ Membership in the property system may be tightly closed,⁴¹ and, depending on the group decision rule, each member has some voice in determining the arrangement for sharing or transferring units of the resource. Even if direct voice is lacking, each member of the group has well-founded expectations for sharing in the benefits of the common property. Of course, the group's identity can be so elastic that the nominally closed system is really open for all practical purposes, such as agreements under which tribal lands may be available to all members of the Cherokee nation or all persons of Germanic descent. In either case, the number of parties is unknowable and the related property claims are practically unlimited.

All else being equal, the rising transaction costs that accompany the need to obtain agreement from an expanded or open-ended set of claimants to a property right diminish the prospects for gains from trade. Alienability and openness are

L. Anderson & Donald R. Leal, *From Free Grass to Fences*, in *MANAGING THE COMMONS* 119-34 (John A. Baden & Douglas S. Noonan eds., 2nd ed. 1998).

38. The common property and public property distinction is ancient. Bracton, or Henry of Bratton, used this characterization of water rights in the mid-thirteenth century, as did another English treatise of unknown authorship. See T. E. Lauer, *The Common Law Background of the Riparian Doctrine*, 28 *MO. L. REV.* 60 (1963).

39. See ALBERT O. HIRSCHMAN, *EXIT, VOICE, AND LOYALTY* (1970).

40. See generally James M. Buchanan, *An Economic Theory of Clubs*, 32 *ECONOMICA* 1 (1965).

41. Clifford G. Holderness, *A Legal Foundation for Exchange*, 14 *J. LEGAL STUD.* 321, 322 (1985).

inversely related. Fewer transactions will be observed in more open groups. If a private association or club formed for managing common property expands its membership beyond the limits that provide expected gains on average for each member, it is possible for a move to public property to be viewed by existing club members as wealth increasing. They may favor public sector management, hoping to obtain a meaningful output restriction or larger share at lower cost. At the same time, movement from common to public property can dilute the value of rights (or voice) held by a smaller defined group within the polity while expanding group membership to include all citizens. There are, again, distributional tradeoffs that follow from this.

Consider a person who is not a member of the common property group. If he can obtain citizenship at a lower cost than group membership, then movement to public property opens the system for that person, along with all other citizens. Rights (or voice) are created for that person as he participates in the shared use of the resource but shares are diminished for each member of the former common property group. We observe this with the demise of tribal fishing rights for Native Americans in the Pacific Northwest that accompanied the arrival of the new American citizens.⁴² For all parties taken together, new and old, the expected transaction costs for contracting increases; the previous Native American market process suffers. The incentive to conserve the resource is replaced by an incentive to exploit the resource. Thus, enforcement costs rise with openness.

Figure 1 implies that as property rights evolve, the degree of openness first contracts and then expands and contracts again. In the process, wealth is created, destroyed, and redistributed. Different types of property rights technology emerge along the way. A transition from public to private property rights by definition produces a closed system.⁴³ All rights are allocated; to participate in the use of the resource, an individual must obtain rights from some private right holder. There is one-to-one mapping between the number of rights and right holders. If the rights in question are fully alienable, any change in ownership requires unanimous agreement. In other words, any individual owner has unilateral powers to transfer his rights to another agreeing party. By comparison, movement from public property to regulatory property along the other path partially reopens the

42. See Robert Higgs, *Legally Induced Technical Regress in the Washington Salmon Fishery*, 7 RES. IN ECON. HIST. 55 (1982).

43. See Holderness, *supra* note 41.

system relative to private property, but does so by political means; to use the resource, the qualifying individual must be favored politically or satisfy regulatory requirements that ration use. The rule of unanimity is generally broken; voting rules of less than unanimity and competition among special interest groups for political favors affect outcomes.

B. *Transaction Costs and Property Rights Technologies*

Transaction costs provide a crucial piece of the explanation of why particular forms of property rights arise. In a world without such costs, the process of defining particular sticks in the property rights bundle would produce an optimal bundle regardless of the initial conditions. In a world like ours, however, where transactions costs play a significant role, the form of property rights that emerges may be heavily influenced by the magnitude and placement of such costs. Thus, factors affecting the magnitude of transaction costs have a large impact on the emergence of particular property rights. Changes in property rights technology can alter the mix of costs associated with defining, defending, and enabling transferability as well as the relative magnitudes of the various cost generators. The previous section illustrated that different forms of property will present different mixes of fixed and variable costs in each of these areas. The relative costs, based on a particular property rights technology, will then dictate the form property rights take. This section will show that technological change alters these relative costs and so can change the form of property rights.

Again, analogizing to Stigler's theory of industrial organization is useful. Stigler examines the case where two firms can achieve gains from trade but are prevented from doing so because the price of one firm's product is fixed by regulators.⁴⁴ He notes that by combining into one firm, thereby removing the transaction from the market and thus from the regulator's control, the firms can capture the gains from trade that are impossible in the marketplace.⁴⁵ The transaction costs of defining a property right may play an analogous role. Assume that we are considering the demand and supply for rights to in-stream flows in a particular river location. Assume also that if property rights are defined for in-stream flows, then market supply and demand analysis would produce trades at an

44. STIGLER, *supra* note 31, at 137.

45. *Id.*

equilibrium price defined by the intersection point of the supply and demand curves. But if the right to in-stream flows is not currently defined as an alienable "stick" in the water rights bundle, then some level of positive transaction costs associated with defining it will prevent the attainment of the zero transaction cost equilibrium. The payment or sharing of transaction costs by market participants (those with the right to in-stream flow and those who want to purchase the rights to such flows) will ration the available goods in the market and absorb part of the theoretical gains from trade. Obviously, if transaction costs are zero, the quantity transacted in the market will expand to the traditional equilibrium point. In the extreme, when transaction costs are sufficiently high, however, there will be no transactions. (We must keep in mind, however, that the asset may still be used in wealth-creating ways even though there are no observed transactions or trade.)

Several kinds of transaction costs affect the choice among types of property rights. One important class of transaction costs relates to measuring and monitoring the items transferred among trading parties. Where the ability to define, defend, and therefore, monitor such transfers is lacking, alienability and gains from trade cannot be obtained, and contracts cannot be enforced. Therefore, insufficient technology will result in a closed system where the bundle of private property rights still exists, but no transfers of certain sticks in the bundle will be observed.⁴⁶ In these cases, the desired right, which cannot be unbundled, can be obtained only by acquiring the entire bundle of rights to which it belongs.

A second important class of transaction costs is those associated with gaining agreement among those who share property rights. At one extreme, the sole owner of a fee simple absolute needs to "discuss" her actions only with herself. At the other, gaining the agreement of a large group of individuals who each possess a veto may make transactions costs prohibitively high.⁴⁷ Thus, while defining and defending may be feasible, the rising transaction costs associated with gaining agreement to move from an open to a closed system may eliminate the prospects for individual ownership and trade. For example, it is

46. Examples of this include rights to in-stream flows in some locations, riparian and some mineral rights that accompany land ownership, certain hunting, grazing, and fishing rights that cannot be transferred from the certified individual, and a multitude of informal arrangements for sharing common property.

47. See Michael A. Heller, *The Tragedy of the Anticommons: Property in the Transition from Marx to Markets*, 111 HARV. L. REV. 621 (1998).

possible to measure and monitor the withdrawal of oil from the Arctic National Wildlife Refuge, but, heretofore, gaining agreement on changes in the terms and conditions for withdrawal has been prohibitively costly.

Defining, defending, and gaining agreement involve three aspects of property rights technology. For any type of property right to exist, the resource itself must be identified and its amount and quality measured. To defend the defined rights to the resource, threats and harms must be identified and measured. For rationing and exchange to take place, resource activity must be monitored and recorded. These categories of technology can include basic scientific knowledge about the resource and threats to it, as well as meters, remote sensing and recording devices, fences, brands, and identifying marks. The third category, gaining agreement, generally involves the use of some kind of two-way communications technology that provides information, feedback, and recorded agreement or disagreement between and among people who would normally transact with each other. These technologies can be as simple and subtle as council meetings where senior community members discuss issues and reach agreement on resource use or a telephone call between a broker and client where an agreement is made and a contract formed. They can be as complex and costly as satellite sensors that emit signals to interested parties who, viewing the same data, make decisions in a virtual council meeting. Among the technologies are some that are best suited for private property protection and others that satisfy special regulatory requirements.

Our investigation into the "black box" of property rights technology thus reveals a second black box embedded within the first: what physical-world technologies are available will influence the availability of the different property rights technologies in particular cases. The relationship goes both ways, of course, as allowing those who can define a right to withdraw it from the commons will create an incentive to create the physical-world technology to claim the right.

C. *The Fork in the Property Rights Path*

The private/regulatory property fork in the path of property rights evolution shown in Figure 1 is the focal point of any discussion of evolving rights for environmental goods. This junction is also where incentives for the development and use of different categories of property rights technologies live or die.

One might assert with little fear of contradiction that government regulation of U.S. environmental goods is currently so pronounced that there is hardly any activity along the private property fork in the road. Is this the case because of technological inability to measure, monitor, and enclose the regulated property rights? Or, more cynically, has a regulatory system become dominant because politicians have seized opportunities to redistribute wealth?

There is evidence to support both cases. Quite possibly, the absence of property rights technology provides the initial nudge along the regulatory property route. Once regulatory property is the norm, rent seeking and redistribution take over, making it costly to deregulate and privatize.⁴⁸ Holding the potential gains from trade constant, there are currently few if any incentives to develop the physical-world technologies necessary to develop private property rights technologies once the regulatory path is chosen. Without the potential customers for a new rights technology offered by private property, entrepreneurs will not invest in creating such technologies. Just as the demand for a means to exclude others created the incentive for the invention of barbed wire, so opportunities for entrepreneurs would stimulate the production of new technologies to provide environmental goods. The regulatory property path forecloses such developments, however, by eliminating the opportunity to profit from developing such technologies. We have separate paths that generate path-specialized property rights technologies—a path-dependent story. We can assign cost in terms of foregone gains from trade to the degree of divergence between the regulatory and private property paths. Cost may be highest when regulation precludes totally the ability of resource managers to make efficiency-enhancing adjustments in the use and deployment of resources. That cost falls as flexibility enters the regulatory process.

Consider the U.S. pollution control experience. The regulatory/private property rights junction became meaningful in 1970 for air quality and 1972 for water quality with the passage of the fundamental national statutes.⁴⁹ The two statutes effectively nationalized the two environmental assets (air and

48. See THE MIT DICTIONARY OF MODERN ECONOMICS 373 (David W. Pearce, ed., 4th ed. 1992) (defining rent seeking as "the use of real resources in an attempt to appropriate a surplus in the form of a rent.").

49. See A. Myrick Freeman III, *Air and Water Pollution Policy*, in CURRENT ISSUES IN U.S. ENVIRONMENTAL POLICY 12 (Paul R. Portney ed., 1978); see also ALLEN V. KNEESE & CHARLES L. SCHULTZE, *POLLUTION, PRICES, AND PUBLIC POLICY* (1975).

water), embraced a technology-based command-and-control regime, and ended a period of property rights history that relied significantly on decentralized regulation, private property rights, and market forces.⁵⁰

Early U.S. environmental regulation recognized the magnitude of the regulatory task by using technology as the monitoring mechanism. In effect, the federal government became the new "landlord" of the nation's air and water resources, and polluters became "tenants," renting rights to emit specified pollutants. As landlord, the federal government did not measure and monitor environmental quality directly. Instead, the government established technology-based standards for broad categories of production processes within specific industries.⁵¹ If the standards were met, permits were issued. After issuing permits, the regulator would check each user and determine if the user was properly equipped. If so, it was assumed that the outcome would be in the interest of the landlord. Since by statute each discharge source had to be controlled by specified technologies, there was no possibility for trade, even within the confines of a particular plant. The incentive to discover private property rights technologies was practically non-existent.

Effective law enforcement protects the value of the regulatory rights and maintains output restrictions. While regulatory property rights holders desire to minimize their own costs even though they cannot trade, they want their competitors' activities effectively monitored. A variety of technologies accomplish this, including inspections, physical monitoring of locations where the resource is used, and requirements that all parties provide reports on the use of the resource being managed. Generally speaking, however, the technologies for monitoring regulatory compliance in a command-and-control regime are not suitable for private property rights' protection and trade enhancement.

50. See Karol Ceplo & Bruce Yandle, *Western States and Environmental Federalism: An Examination of Institutional Viability*, in ENVIRONMENTAL FEDERALISM 225 (Terry L. Anderson & Peter J. Hill eds., 1997) (discussing pre- and post-federal period environmental regulation).

51. There was a "one suit fits all" aspect of this that imposed costs on all but the "average" production process. The obvious economic hardship was the basis of *E.I. du Pont de Nemours and Co. v. Train*, 430 U.S. 112 (1977), a water pollution control case arguing that permits should be individualized. Siding with the U.S. EPA, the Court agreed that the transaction costs of dealing with more than 42,000 dischargers made it impossible for the agency to custom design permits and still meet the statutory deadline. See ROGER W. FINDLEY & DANIEL A. FARBER, CASES AND MATERIALS ON ENVIRONMENTAL LAW 286-87 (1995) (discussing *E.I. du Pont de Nemours and Co.*).

We must recognize here a fundamental difference in regulatory and private property rights. Regulatory property rights are valuable because a government imposes a restriction that must be satisfied. A permit to operate a plant is valuable. If regulation goes away, however, the permit value evaporates.⁵² Private property rights are valuable because of market forces, which are supplemented by rules of law. The private property rights enhance the value of an economic resource. If the marketplace closes, as when the New York Stock Exchange closes at the end of the day, the resource is still valuable.

Command-and-control regulation generates regulatory property rights in the form of nontransferable government-issued permits. Defining and defending such rights is the business of the government, which is assisted in its task by regulated firms, environmental organizations, and interested citizens.⁵³ Under the command-and-control regime, outcomes and environmental conditions play second fiddle to pollution control inputs and the appropriate use of technologies. With trade forbidden, no market incentives exist to discover and apply new techniques for monitoring, measuring, and legally packaging tradeable units of pollution rights. Instead, they are simply driven to meet the technological demands of regulators and to assure that these demands are imposed on their competitors.

Whether operating in a common law or regulatory regime, to obtain efficiency in environmental management, economic agents must be allowed to truck and barter as they juggle access to and use of environmental resources. Sometimes use of scarce environmental assets requires ownership of particular land parcels, membership in some specified community or tribe, or citizenship in some political unit. At other times, access and use is simply a matter of engaging in mutually beneficial exchange of fee simple rights with rights holders. The degree to which property rights can be alienated determines the wealth creation potential for the resource in question. The limits of efficiency are

52. Taxicab medallions are a classic example of this phenomenon. In cities where the taxicab business is regulated, only the owner of a taxi medallion is authorized to operate a cab. In New York City, these medallions sell for more than \$225,000. This value is entirely dependent on the continued artificial scarcity caused by the regulatory property regime. *New York Cabbies Allege Exploitation, Plan Lawsuit*, THE TIMES OF INDIA, Jan. 13, 2000, available at 2000 WL 2552516.

53. See Jonathan H. Adler, *Stand or Deliver: Do Liberalized Standing Rules Advance Environmental Protection?* (unpublished paper), available at <http://www.home.earthlink.net/~jhadler>.

found when defined and defended environmental rights can be completely alienated.

Holding constant the demand for a bundle of environmental rights, the supply of activities that define, defend, and divest various sticks in the bundle or the entire bundle depends on the technology of property rights definition and enforcement. Wealth depends on the transferability of property rights. When the ability to measure and subdivide parcels from a larger tract of land is lacking, the asset owners cannot maximize the potential value of the land. For example, if water flows cannot be metered and water users billed, then water will not be provided by private suppliers. Similarly, if particular emitters of harmful pollutants cannot be distinguished from a host of similarly situated potential emitters of the same pollutant, then the scope for bargaining and use of rules of liability will be reduced. Command-and-control will rule the day. Evolving property rights technologies enable movement along the path from the commons to private property.

D. Legal Technologies for Property Rights

At the time barbed wire was developing, there were two basic forms of law in the United States: common law and statutory law. The same is true today. These types of law differ in several important ways and represent different systems for producing innovations in property rights technology. The common law emerges on a case-by-case basis from real controversies adjudicated by common law judges.⁵⁴ Common law evolves in a small numbers setting. Through judges' use of precedent in deciding cases, the law is generalized to large numbers of parties. Statutory law, on the other hand, emerges in a large numbers setting, but can be specialized so as to apply in selected ways to smaller numbers of people and technically specific situations. Note that the process through which the common law generalizes rules to large numbers varies considerably from the way statutory law solves the large number problem. Statutory laws apply to a defined group from the beginning; common law rules must be applied through

54. See JAMES C. CARTER, *THE PROVINCES OF THE WRITTEN AND THE UNWRITTEN LAW* 28 (1889); F. A. HAYEK, *VOLUME 1: LAW, LEGISLATION, AND LIBERTY* 94-97 (1973); BRUNO LEONI, *FREEDOM AND THE LAW* 85-87 (3rd ed. 1991); Andrew P. Morriss, *Codification and Right Answers*, 74 *CHI-KENT L. REV.* 355, 376-79 (1999); Yandle, *supra* note 4; Todd J. Zywicki, *Environmental Externalities and Political Externalities: The Political Economy of Environmental Regulation and Reform*, 73 *TUL. L. REV.* 845 (1999).

individual lawsuits.⁵⁵ This represents both an important adaptive mechanism—new facts can modify the rule—and an important constraint on rent-seeking.⁵⁶ The common law process is continuous; an opportunity for the modification and introduction of new knowledge is afforded each time a common law judge writes an opinion. By contrast, the statutory law process is sporadic. Statutes are written when the legislative body is in session and when the political agenda calls for action. Finally, potential authorship differs significantly. Any person who writes a contract has written common law. Only politicians and bureaucrats, however, can write statutory laws or regulations.

Now consider the market entry of barbed wire under two distinct situations. Situation 1: If legal prohibitions are absent, and if common law judges will enforce property lines defined by barbed wire as well as by other methods, then cattlemen and barbed wire producers have an incentive to pursue gains from trade. Thus, the market process will be fully competitive. Situation 2: If the legislative body, by statute, outlaws the use of barbed wire, all bets are off. Or, if the legislative body establishes a land management commission with delegated authority to define and regulate the use of appropriate technologies for enclosing land, then another set of incentives enters the picture. In Situation 1, barbed wire sellers will expend resources in a competitive process to gain the patronage of interested cattlemen. In Situation 2, however, barbed wire entrepreneurs must leap two hurdles—the invention, production, and marketing of barbed wire and successful lobbying to obtain regulatory approval of the use of barbed wire. Indeed, the producers, or just one producer, may lobby successfully to have barbed wire, or one patented type of wire, specified as the only state-approved method for defining the borders of cattlemen's property rights to rangeland.

The two market entry situations generate different competitive and rent-seeking responses from barbed wire and other enclosure system producers. Barbed wire may become an approved enclosure device by way of custom or contract (Situation 1), or by statute (Situation 2). In Situation 1, there is no low cost way for individual barbed wire producers, or the barbed wire industry at large, to affect a change in custom or to

55. Of course, class action suits are sometimes possible, which can apply a rule of law to a large number of parties through a single decision.

56. If people must incur the costs of litigation each time they seek to enforce a rule, they will "purchase" less rules enforcement, and so pursue fewer rents, than if they are offered the economies of scale provided by legislation.

influence the content of all land use contracts. There is also no easy way for a special interest group to obtain favorable outcomes from common law judges in cases involving the use of barbed wire. The legislature and regulators provide low-cost opportunities for favor seeking by individual barbed wire producers, the barbed wire industry at large, and interest groups because a statutory law can govern the whole land enclosure system.

The barbed wire story illustrates several key distinctions between the common law and statutory law. First, the transactions costs are placed on different parties. Under the common law, individuals are free to adopt innovations, legal or otherwise, and anyone objecting to an innovation has the burden of challenging it. Further, the ability to challenge innovation is limited to those directly affected by the innovation—we cannot challenge your contract with a third party, nor can you challenge ours. Under the statutory law, however, the burden is on the party seeking to legitimize the innovation. For example, if boundaries may only be marked by approved fence types, the individual seeking to use barbed wire (or a new type of barb) must obtain an amendment to the statute (or administrative regulation). (If this seems fanciful, consider the process a coal-fired power plant must go through in order to adopt an innovative form of emissions control that fulfills the Clean Air Act's requirement of scrubbers.⁵⁷) Moreover, in the legislative and administrative processes, third parties not only can, but are encouraged to intervene.

Second, legal innovations are adopted through different processes. In the common law, legal innovations emerge from the facts of actual cases and the interactions of those facts with the established system of rules. Creating a "new" variant on a rule requires convincing not just one judge, but many judges that a particular fact pattern requires a different solution. Bad ideas must thus pass multiple hurdles. Statutory innovations, on the other hand, are produced solely by convincing a majority of legislators to act. The public choice literature amply documents the broad class of problems this entails and illustrative examples are legion.⁵⁸ To take just one—Hollywood stars are regular witnesses before legislative committees, but rarely appear in

57. See BRUCE A. ACKERMAN & WILLIAM T. HASSLER, CLEAN COAL/DIRTY AIR 15-21 (1981).

58. See generally *id.* (describing how eastern coal interests and environmental pressure groups combined to create air pollution regulations that worsened air quality).

court unless they are parties to a case.⁵⁹ The common law is also less likely to make large-scale errors because the pace of legal innovation is more deliberate than the pace in a statutory regime.

Third, statutory law carries with it a strong incentive for continual government involvement. Agencies must implement, monitor, and report back to legislatures. A “ratchet” effect occurs with one intervention leading to more as the legislature corrects unintended consequences and expands the scope of legislative solutions. In the common law, by contrast, courts rarely maintain an ongoing intervention into private litigants’ affairs after a decision has been made.

Fourth, Coasean bargaining around common law decisions is possible. If you prevail against us in a nuisance case, we can always purchase the contested right from you. If we persuade a legislature to outlaw your behavior, however, you can no longer buy us off as the “public interest” has now attached to the rule in question.

III

DEFINING AND DEFENDING ENVIRONMENTAL RIGHTS: BUILDING LEGAL FENCES

The path-dependent⁶⁰ story helps explain how the particular mix of property rights technologies that govern environmental problems today developed. The rent-seeking portion of the story explains why we are stuck there even in circumstances where the potential gains from trade are large relative to the transaction costs of a change. These stories do not, however, explain how we might reap the gains from trade possible from a shift to the private property rights fork in situations where gains from trade exceed the transaction costs. In this section, we use the evolution of water rights to explore how such a shift can occur.

59. For what it is worth, movie stars appear to seek opportunities to appear before Congress but shrink from appearing in lawsuits. To the extent we think being a successful movie star is a bad proxy for having good ideas for government, the common law process has an additional advantage.

60. Path dependence is an economic term meaning that the outcome depends on where you start. Stan Liebowitz & Stephen E. Margolis, *Policy and Path Dependence from Qwerty to Windows* 95, 18 REGULATION 33, 33 (1995), available at <http://www.cato.org/pubs/regulation/reg18n3d.html> (describing and exploring the concept of path dependency).

A. *Evolving Property Rules for Quantity and Quality*

Scientific discoveries play a crucial role in the definition and protection of private property rights in general, and forming markets for environmental rights in particular. Consider water quantity and water quality, two distinctly different commodity characteristics. If we start at the most basic level—for example, the flow of water through an irrigation ditch—we can imagine the relative ease with which early users could determine when and where water flowed. Measuring the rate of flow and total volume in a given time period is obviously more complex. For water quantity, we would expect that crude rules based on first occupancy would emerge initially. Then, as technological sophistication increases, appropriative rights with a “use it or lose it” condition might come next. Later, with improved metering, we would expect to see a more sophisticated rule of law that accommodates water transfer and markets. Indeed, this scenario approximates the development of water law in the United States.⁶¹

By comparison, developing institutions for managing water quality is far more daunting, if for no other reason than the scope of qualitative dimensions that might be rationed. Consider the problem of assuring the healthfulness of water for human consumption. The capability of certifying healthfulness makes it possible to expand the market for drinking water. This can be seen in the proliferation of bottled water sales in developing countries as well as in the United States. Other more costly ways of assuring quality would prevail if the ability to measure and certify were lacking. Consider the use of rivers for disposing of waste. Being able to measure levels of dissolved oxygen makes it possible to set related constraints and market consumption rights.

Each characteristic in the water quality bundle that might be scarce and valuable comes with a measurement challenge. Being able to measure and meter does not necessarily solve the control problem. In other words, the ability to measure the level of dissolved oxygen in a stream does not translate into technology for reducing the consumption of suspended oxygen. Without the ability to meter and monitor, it would be impossible to know when property rights were held, transferred, or taken. In the absence of scientific knowledge, it would be impossible to move beyond the stage where the mysterious nature of the

61. Rose, *supra* note 23, at 267-94.

environment causes people to avoid risky encounters with environmental use.

1. *The Evolution of U.S. Water Rights*

In her rich discussion of evolving U.S. water law, Carol M. Rose describes what at first seems to be a puzzle.⁶² In the earlier years of industrial development in both England and the eastern United States, water in streams was valuable primarily for providing motive power to mills. The issue was water quantity and the rules of law and property were clear. First, the property rights of ancient uses of streams were given priority at common law. After that came the rule of first occupancy.⁶³ Generally speaking, first occupancy meant the first owner to make a water-dependent capital investment. Newcomers to streams understood that they would have to bargain for water rights already held by established users. The world was Coasean.⁶⁴ The appropriative rights system in the western United States was similarly well grounded. In both cases, measuring and monitoring use was relatively easy.⁶⁵ An impartial observer could quickly determine if a stream was diverted away from a water wheel or if an irrigation ditch was opened or closed. No special legal machinery was needed to accommodate trades.

Rose's puzzle arises when accelerated economic development in the eastern United States led to a revision in water law. Leaving the relatively well-founded rule of first occupancy, the law moved, not to a rule of prior appropriation like that which developed in the arid West, but to a seemingly mushier doctrine of reasonable use within a riparian system. What previously looked a lot like a private property rights system became common property in a multiple-user setting. But, as Rose suggests, what appears to be a puzzle is really no puzzle at all. Accelerated economic development resulted in the need to simultaneously ration two attributes of water—physical supply

62. *Id.*

63. *Id.* at 273.

64. It is interesting to note that an identical system of water rights developed in Japan in what is called Japanese Common Law. See J. Mark Ramseyer, *Water Law in Imperial Japan: Public Goods, Private Claims, and Legal Convergence*, 18 J. LEGAL STUD. 51 (1989).

65. See Andrew P. Morriss, *Lessons from the Development of Western Water Law for Emerging Water Markets: Common Law vs. Control Planning* (2001) (manuscript on file with author).

and the quality of the water supplied.⁶⁶ Physical volume could be monitored and metered at low cost. Markets for rights to water flows came with relative ease.

While water quantity could be monitored and metered at low cost, water quality was another matter entirely, since each user's activity could affect the level of quality available to all future users. Use determined quality. When identifiable mines or farms consume an acre-foot of water, the metered water quantity is a private good. When an acre-foot of water receives waste discharge from multiple users, the resulting water quality is a collective good. Lacking private ownership of in-stream water quality, and lacking the technology to identify water quality consumption, reasonable use became the rule of law. The turning point came in the foundational water rights case, *Palmer v. Mulligan*.⁶⁷ Palmer, a downstream owner, complained about water pollution and the interruption of water flow caused by an upstream owner who had built a mill and dam that diverted logs that normally floated to Palmer's operation. This diversion created debris that affected Palmer's operation. In his complaint, Palmer claimed first possession and first use, citing the fact that he arrived first and was the first to build a dam. Historically, Palmer's claims were the type of private property rights claims that succeeded. The court, however, decided differently. The court concluded that all riparian owners had a right to correlative use of a stream, and that any one might impose costs on another so long as the costs were small. What had been a private right prescribed by use became common property.

Palmer influenced Justice Joseph Story's opinion in the 1827 federal case of *Tyler v. Wilkinson*,⁶⁸ a case concerning a large number of competing users of stream flow for motive power. In *Tyler*, a number of mill owners located along the Pawtucket River near Providence complained after an upstream diversion canal was built that reduced downstream flow. Taking note of *Palmer*, the *Tyler* court announced a new doctrine of reasonable use. The court held that rights to water flow were common property held

66. Rose, *supra* note 23, at 293-94. There are other issues as well. Exclusive riparian rights may not work effectively where there are interdependencies among users. The "mushier" reasonable use doctrine turns out to be more efficient. See Higgs, *supra* note 42, at 55 (giving details on how reasonable use maintained the economic value of salmon fisheries for American Indians prior to the arrival of the Europeans, who destroyed the fishery by using appropriative rights).

67. *Palmer v. Mulligan*, 3 Cai. R. 307 (N.Y. Sup. Ct. 1805).

68. *Tyler v. Wilkinson*, 24 F. Cas. 472, 474 (C.C.D.R.I. 1827) (No. 14,312).

by any and all riparians, entitling each user to make reasonable use of the flowing asset.⁶⁹

This account of evolving water law, technology, and rules of property tells us about demand for two fundamental traits of water supply—water quantity and water quality. The technology for rationing quantity is far simpler than that for quality, which itself is multidimensional. When water use involves common pools and large numbers of simultaneous users, the definition and enforcement of water quality rights becomes even more complicated. The evolving pattern of law that addresses these issues is described in Figure 2. Where the number of water quantity users is small, individualized private property rights seem to emerge without difficulty. When the number of users is large and the users draw from a common pool, common property with rules for sharing emerges. Community water systems with membership and user fees arise. When water quality is the trait under consideration, however, common property seems to develop, regardless of the size of the user group. River basin associations and other firm-like approaches emerge to “own” and manage the common property.

FIGURE 2
PROPERTY RULE VARIATIONS

	<i>Small Numbers</i>	<i>Large Numbers</i>
<i>Water Quantity</i>	Private Rights	Common Property
<i>Water Quality</i>	Common Property	Common Property

Figure 2 suggests that, for water property rights, two kinds of technologies are needed to reduce the cost of moving from common to private property arrangements. The first type of necessary technology relates to transaction costs in the large numbers case. If new technologies are developed that successfully reduce the cost of communicating and negotiating agreements, then private property rights can be defined for water quantity irrespective of group size. A different type of technology is needed to resolve the water quality problems. If the pattern of costs imposed by particular dischargers can be measured and monitored at low cost, then private rights and markets can evolve when both small numbers and large numbers of users are

69. *Id.*

involved. A review of some court decisions and regulatory actions will illustrate how science and technology assisted these changes.

2. *Science and the Cost of Defining and Defending*

As the pace of eastern industrial development quickened and the locations for water-driven mills became filled, pollution became a more serious problem than water supply. Theoretically, riparian rights⁷⁰ would protect downstream occupiers of property from having their water rights degraded by upstream dischargers.⁷¹ If an upstream discharger imposed costs on a downstream party, the damaged party had a cause of action at common law. The remedy was payment of damages and injunctive relief. To succeed in court, the plaintiff had to show evidence of harm caused by the defendant. The common law acted as a legal fence around the property rights of downstream landowners. This placed the burden of building a physical fence to protect riparian right holders on the upstream discharger. The polluter could either develop a technological fix, contract around the rule, or violate the property rights of downstream users and face the consequences. Scientific knowledge about pollution—its source, how to measure it, and how to fence it in—heavily influenced the economic calculus involved in selecting the logical option.

The discovery of germ theory in the 1890s led to the rise of an early U.S. environmental movement calling for the use of science to manage water quality.⁷² Before this breakthrough, there was a vague recognition that human health was related to water quality, but the exact linkages were not understood. With germ theory established, the Massachusetts Board of Health

70. "Riparian rights" are water rights that are allocated based on ownership of land adjacent to water bodies. The riparian system is the dominant system of water rights east of the Mississippi River. West of the Mississippi River, many states rely on the "prior appropriation" system, which allocates water according to the order on which users first claimed and used the water. See Rose, *supra* note 23, for a more detailed discussion.

71. See Roger Meiners & Bruce Yandle, *Common Law and the Conceit of Modern Environmental Policy*, 7 GEO. MASON L. REV. 923 (1999) (providing a survey of common law actions that reflect this legal theory); see also BRUCE YANDLE, *COMMON SENSE AND COMMON LAW FOR THE ENVIRONMENT* (1998). For a survey of relevant Canadian common law actions, see ELIZABETH BRUBAKER, *PROPERTY RIGHTS IN THE DEFENCE OF NATURE* (1995).

72. Roger E. Meiners, Stacie Thomas & Bruce Yandle, *Burning Rivers, Common Law, and Institutional Choice for Water Quality*, in *THE COMMON LAW AND THE ENVIRONMENT: RETHINKING THE STATUTORY BASIS FOR MODERN ENVIRONMENTAL LAW*, *supra* note 7, at 54, 66-67.

soon discovered the relationship between sewage in rivers and typhoid. Then, enhanced filtration technology developed to eliminate the germs,⁷³ making it possible for sewage producers to protect the water quality property rights of downstream users.

At the time germ theory was developing, new state regulations shielded industry from common law suits. In essence, such firms enjoyed the protection of regulatory property rights. The typical regulatory body in industrialized states wrote technology-based standards for firms that discharged in rivers and streams; these were applied to new sources.⁷⁴ Established industry continued to operate unabated. Downstream landowners could do little to protect themselves. Existing polluters enjoyed preemptive rights that could not be challenged. Thus, in the absence of scientific evidence of harm, downstream receivers of waste could not have their day in court. The new scientific knowledge changed this balance of power and emboldened citizens in protecting their common law rights. Using germ theory, they were able to provide evidence of harmful invasion of their riparian rights, and the new filtering technology lowered the cost for common law judges to enforce a strict property rule. With common law rights reestablished for downstream parties, water quality users became members of a closed system. To engage in activities that lowered the water quality, a discharger had to first negotiate with downstream holders of property rights. Scientific knowledge about the linkage between waste, germs, and disease set in motion economic forces that led to the development of improved pollution control machinery and the reinforcement of riparian property rights.

Justice Holmes' opinion in *Missouri v. Illinois*,⁷⁵ demonstrates how new scientific knowledge affected common law decisions and how this knowledge affected property rights protection.⁷⁶ The case concerned the City of Chicago's pumping of raw sewage into a canal, whose water eventually flowed into the Illinois River and, allegedly, the Mississippi River.

73. Stacie Thomas, *Water Quality Management and Property Rights: A Financial Markets Test of Institutional Stability* (unpublished working paper, Clemson Univ. Dept of Econ., 1999) (copy on file with authors).

74. For examples, see M. T. MALONEY & BRUCE YANDLE, BUILDING MARKETS FOR TRADABLE POLLUTION RIGHTS IN WATER RIGHTS 283, 293-300 (Terry L. Anderson ed., 1983).

75. *Missouri v. Illinois*, 200 U.S. 496 (1906).

76. *Id.*; see also Roger E. Meiners, *Elements of Property Rights: The Common Law Alternative*, in LAND RIGHTS: THE 1990S' PROPERTY RIGHTS REBELLION 269, 276-90 (Bruce Yandle ed., 1995).

The state of Missouri brought suit at common law against Chicago, asserting that Chicago's sewage was the cause of typhoid in St. Louis, where between 95 and 441 people died each year from 1890 to 1903.⁷⁷ In effect, the good people of Chicago were charged with "grazing" on water quality that belonged to St. Louis.

Among the difficult questions in the case was the matter of causation. Could Chicago's use of a river cause typhoid in St. Louis? Or was it possible that some other discharger of sewage, closer to St. Louis, caused the harm? The property rights question involved the status of downstream right holders, who at common law held superior claims to property in the face of upstream activities that caused water quality to deteriorate. The scientific issue concerned the newly developed scientific understanding of the typhoid bacillus. Could a Chicago bacillus survive the 357 mile trip from Chicago to St. Louis? In the end, the weight of scientific testimony and evidence supported Chicago's contention of no harm⁷⁸ and the case against Chicago was dismissed. The matter with respect to dischargers located closer to St. Louis remained open to investigation. Knowledge of biological science sharpened the definition of property rights.

Another example of the early interaction of the courts with science in generating pollution control technologies can be seen in *Georgia v. Tennessee Copper Co.*⁷⁹ This 1907 Supreme Court decision involved a public nuisance suit brought by the state of Georgia against a copper mine and smelter located just across the Georgia-Tennessee border. Georgia won its original suit claiming that the smelter's emissions imposed costs on people and property in Georgia, and the Court gave the smelter a reasonable time to find a solution to the problem.⁸⁰ In effect, the Court ordered the smelter to either fence in its pollution or shut down. Eight years later, the Georgia plaintiffs requested a permanent injunction against the plant.⁸¹ In response, the defendants reported that they had installed new pollution control equipment that reduced sulfur emissions by half.⁸² Instead of granting an immediate injunction, the Court required the copper company to cut back its production and secure the consulting

77. 200 U.S. at 523.

78. 200 U.S. at 522-23, 526.

79. *Georgia v. Tennessee Copper Co.*, 206 U.S. 230 (1907). For further discussion of this case see YANDLE, *supra* note 71, at 102-03.

80. 206 U.S. at 239.

81. *Georgia v. Tennessee Copper Co.*, 237 U.S. 474, 476 (1915).

82. *Id.*

services of a Vanderbilt University engineer who resolved the problem to the satisfaction of the Court and the plaintiff.⁸³ Note that the Court imposed no specific technology restrictions on the firm; any technology was allowed so long as it accomplished the goal. The common law process accommodated the discovery of a tailor-made approach for protecting Georgia property rights.

With the rise of the U.S. industrial economy, scientific knowledge of the linkage between human health and pollution combined with common law actions to make a compelling case for protection of environmental rights. By 1917, a number of industrial states—Connecticut, Ohio, and Pennsylvania—had state boards for controlling industrial wastes.⁸⁴ By 1923, the American Water Works Association could report that industrial pollution had damaged some 248 water supplies in the U.S. and Canada.⁸⁵ Phenol discharge from coke works topped the list of harmful pollutants.⁸⁶ The combination of scientific evidence, pressure from state health boards, and the very real threat of science-based common law suits encouraged firms along the Ohio River to join in a voluntary effort to reduce phenol discharge into the Ohio River. Subsequently, technology for removing phenol from wastewater was discovered and installed. By 1929, practically every phenol discharger had elimination devices at work. Fear of science-based common law suits partly motivated this clean-up.

Donald Dewees reports a similar outcome in 1969 regarding fifteen chlor-alkali plants that were discharging mercury to Canadian rivers:

In the span of only three years the discharge of this pollutant was reduced by 99 percent. Three public nuisance actions were filed, and while none of these cases resulted in a judgment, . . . the possibility of substantial liability, far in excess of any fines that could have been imposed, induced the firms to accelerate the abatement process beyond what could have been achieved by regulation alone.⁸⁷

Notice that the common law's threat of strict liability inspired a cooperative research effort to discover cost-effective pollution

83. See YANDLE, *supra* note 71, at 102-03.

84. Am. Water Works Ass'n, *Progress Report of Industrial Wastes in Relation to Water Supply*, 10 J. AM. WATER WORKS ASS'N. 415, 416 (1923).

85. *Id.*

86. *Id.*

87. Donald Dewees, *Tort Law and the Deterrence of Environmental Pollution*, in INNOVATION IN ENVIRONMENTAL POLICY: ECONOMIC AND LEGAL DEVELOPMENTS IN ENVIRONMENTAL ENFORCEMENT AND LIABILITY 139, 161 (T. H. Tietenberg ed., 1992).

control. The fact that damages could be proved and sources identified, even if only collectively, was enough to induce action.

Improvements in the science of hydrology made it possible for common law judges to identify polluters who poached on the property rights of downstream owners and made major modifications in common law rules involving groundwater pollution. In *Wood v. Picillo*,⁸⁸ neighbors brought suit against a farmer whose waste dump had allegedly contaminated their drinking water. In holding for the plaintiffs, the Rhode Island Supreme Court overturned a 1934 precedent that would have favored the defendant.⁸⁹ Noting improvements in the scientific understanding of groundwater since 1934, the court held that the flow of groundwater contaminants could now be predicted, making it possible to provide strong property rights protection to downstream parties.⁹⁰

Changes in measurement costs also affect water quantity rights. Transferability of water rights under New Mexico's prior appropriation doctrine requires the state engineer to certify that the transfer of consumptive use in terms of time or location does not impair existing rights.⁹¹ By statute, the state engineer is required to hold a public hearing prior to making a determination of transfer.⁹² As evidence of an open system, the hearing provides all that claim to have an interest in maintaining water flows an opportunity to state their concerns. When there are controversies, which implies a reasonable likelihood of third-party effects, the party receiving the transferred right to consume water may be required to install wellhead metering devices and report on usage.⁹³ Only after approval does the transfer become a private property rights matter between a willing buyer and seller. During the approval process, the water rights are common property waiting to be transformed by the proceeding. When metering devices were lacking or costly, the state engineer could rely only on records of the number of acres of land assigned particular water flows. Then, calculations of

88. *Wood v. Picillo*, 443 A.2d 1244 (R.I. 1982).

89. *Id.* at 1248-49 (overturning *Rose v. Socony-Vacuum Corp.*, 173 A. 627 (R.I. 1934)).

90. *Id.* at 1249 ("Since this court decided *Rose v. Socony-Vacuum Corp.* in 1934, the science of groundwater hydrology as well as societal concern for environmental protection has developed dramatically.").

91. Ronald N. Johnson, Micha Gisser & Michael Werner, *The Definition of a Surface Water Right and Transferability*, 24 J.L. & ECON. 273, 284 (1981).

92. See N.M. Stat. Ann. 72-5-23, 72-5-4, 72-5-5 (1997) (requiring hearing if requested by any party).

93. Johnson, Gisser & Werner, *supra* note 91, at 283-87.

acre-feet of stream flow could be compared with rough measurements of amounts allocated. The technological development of metering devices provided greater precision in measuring actual use, which in turn reduced transaction costs, thereby affecting quantity-based rights.

Indeed, technology can enable "new" property to be created. Colorado Springs created a sophisticated water monitoring system. By increasing the capabilities of its system, the city was able to capture ownership of return flows of water into ground water systems and then sell the rights to these flows to downstream users.⁹⁴ "Since these return flows would be almost impossible to capture, the exchange agreements allow for these rights to be fully utilized by exchanging them to a downstream user."⁹⁵ The city has also been able to economize on wastewater treatment costs by selling non-potable return flows.

3. *Property Rights Technology and Community Action*

The community involved relates directly to the complexity of property rights technology required and therefore to the transaction costs involved. The cases discussed above, with the exception of *Tennessee Copper*, involve a small number of parties, making the development of private property rights more likely. The transaction costs involved in such a development are relatively small, and the technical challenge posed by identifying cause, effect, and damages presented a low barrier for defining and defending private property rights. On the other hand, where the number of interested parties is large and the environmental outcome is collectively determined, the property rights technology problem becomes more complex and costly to resolve. Where that is the case, history tells us that communities organize around the resource in question, form a transaction cost-minimizing virtual firm, and treat the environmental resource as a managed asset. The firm's management then has the responsibility of defining, defending, and transferring property rights. Two well-known water quality stories illustrate the point.

Heavy pollution in the Ruhr, Emscher, and Wupper rivers and serious human health consequences in nineteenth century Prussia led the government to define, defend, and allocate public

94. Robert B. Naeser & Mark G. Smith, *Enforcing Property Rights in Western Water: Is It Better to Be Upstream with a Shovel or Downstream with a Model?*, in THE TECHNOLOGY OF PROPERTY RIGHTS, *supra* note 15.

95. *Id.*

property rights in water quality for those three river basins.⁹⁶ Today, the water management organizations act with owner-like concern as they build treatment plants, determine and collect fees, manage parks and recreational areas, and produce and sell drinking water. To the extent possible, the public sector managers charge prices and manage environmental assets as though they were private property.

Prior to building a facility that discharges into these waters, the plant owner must provide scientific data on the water quality effects of their discharge to the river basin association managers. Then, the river basin managers take representative samples of the discharge and run ecological tests using flora and fauna from the rivers. Finally, the river basin associations have geographic information systems that enable them to model the effects of discharge on water quality at different points in the system. Discharge fees are assessed on the basis of this technical information.⁹⁷

At this point, the German associations are a partially closed property rights system. The associations "own" certain specified rights to rivers, manage the rights, and sell access to them by collecting money and then granting access in various forms. The associations maintain water quality and quantity constraints; there is no apparent political meddling with respect to these. By contrast, the other rivers in Germany are managed as an open system and are controlled by statutes and regulation. Environmental organizations and other special interest groups have voice in determining outcomes, and polluters hold regulatory property rights that enable them to limit competitive entry.⁹⁸ Property rights technology has emerged in the association-run water quality systems, but has not emerged in the government regulated systems.

A similar story can be told about the Ohio River and the Ohio River Sanitation Commission (ORSANCO), the river association that resulted from a 1948 multi-state compact for

96. See BLAIR T. BOWER ET AL., *INCENTIVES IN WATER QUALITY MANAGEMENT: FRANCE AND THE RUHR AREA* (1981).

97. *Id.*

98. There are no formal property rights in the sense of pieces of paper and a registry, as there is for land. This is our point. Implicit property rights emerge when environmental groups are able to obtain restrictions, which they enforce through lawsuits, and industrialists gain revenue from the enforcement action's effects, and so indirectly support it. See Bruce Yandle, *Bootleggers, Baptists, and Global Warming* (PERC Policy Series Ps-14) (1998), available at <http://www.perc.org/ps14.pdf>.

the purpose of restoring water quality to safe levels.⁹⁹ The stimulus that shifted property rights for the Ohio River came when microbe carriers of gastroenteritis traveled upstream and imposed costs on Pittsburgh and other upstream cities that had routinely discharged untreated human waste into the river. In an interesting way, Cincinnati got revenge. With the compact in place, the Ohio River ceased being a commons and became subject to a system of public property rights managed by a multi-state river basin association, ORSANCO.¹⁰⁰ With many dischargers along the path of the Ohio, water quality at any given point was a collective result. To bring transaction costs to manageable proportions, the river had to be organized as a firm, and the firm had to develop the technology to define and defend its asset.

ORSANCO did this by developing a system of continuous water quality monitoring with data transmitted to its Cincinnati headquarters. This new technology could scan and measure a number of individual water quality parameters, and reduced the unit testing cost to 7.5 cents. In contrast, the older technique cost \$2.20 per test.¹⁰¹ With monitoring costs reduced, the association then imposed custom-tailored cleanup standards on dischargers in the basin. Water quality and public health improved. ORSANCO's primitive water quality monitoring system served as "barbed wire" in protecting water quality in the Ohio River.

B. Market-like Regulatory Property Rights

At times, prospects for gains from trade become so large that market-like regulatory approaches begin to emerge. Two of the best known examples are the lead and SO₂ tradeable permit systems created by the Clean Air Act. The lead program, designed to cut the cost of the phase out of leaded gasoline, is estimated to have saved regulated entities \$228 million,¹⁰² and

99. See EDWARD J. CLEARY, *THE ORSANCO STORY* (1967); M. T. Maloney & Bruce Yandle, *Building Markets for Tradable Pollution Rights*, in *WATER RIGHTS: SCARCE RESOURCE ALLOCATION, BUREAUCRACY, AND THE ENVIRONMENT* 283 (Terry L. Anderson ed., 1983). In fact, the Ohio and Ruhr Rivers share similar histories. Both are major industrial rivers located in coal and steel territories, and both experienced serious degradation from the discharge of human waste.

100. See generally Cleary, *supra* note 99. Note that Cleary does not refer to property rights directly in telling the ORSANCO story—that is our interpretation of the events that transpired.

101. CLEARY, *supra* note 99, at 210.

102. Robert W. Hahn, *Economic Prescriptions for Environmental Problems: How the Patient Followed the Doctor's Orders*, 3 J. ECON. PERSP. 95, 102 (1989).

the ongoing SO₂ tradeable permit program is estimated to save between \$1 billion and \$2 billion annually.¹⁰³ The U.S. experience with its regulation-induced air pollution permit markets illustrates a situation where regulatory property rights technology could be transferred to a private property rights regime if there were demand for the resources independent of the regulation itself.

In the development of federal air pollution control, command-and-control regulation supplemented and supplanted common law property rights protection. At common law, either a damaged owner or occupier of land or an entire community could bring a nuisance suit against a polluter or negotiate with the polluter to receive compensation for damages. The ability to define and defend property rights was driven by market forces and the law of private property rights. By contrast, a marketable permit regime imposes emission standards that require polluters to reduce either their own or someone else's equivalent emissions by a stipulated amount. Once the collective constraint is met, individual dischargers can generate a tradeable asset by reducing emissions beyond the amount stipulated. But while the regulatory property rights in the form of marketable emission allowances facilitate trade among certified members of the regulated community, the value of the permits is determined strictly by the opportunity cost of pollution control. Since the opportunity cost is determined by government imposed specification standards, it is regulation, and only regulation, that causes the right to emit one ton of sulfur dioxide or a milligram of phosphate loading to have value. Regulation induces scarcity and determines the potential for gains from trade, but the utilitarian basis for the value is uncertain at best. Nonetheless, these programs offer a path for privatization of regulatory property rights, which we contend is their primary importance rather than the potential for reducing the costs of regulation.

Consider, for example, California's south coast where the South Coast Air Quality Management District asserts that "15 million people breathe some of the dirtiest air in the U.S."¹⁰⁴ This region offers the most prominent example of the emergence of air pollution control markets. Under California law, participants in marketable permit markets must have continuous emission

103. Dallas Burtaw, *Trading Emissions to Clean the Air: Exchanges Few but Savings Many*, 122 RESOURCES 3, 5 (1996).

104. South Coast Air Quality Management District, available at <http://www.aqmd.gov>.

monitoring capability and report emissions data that can be audited.¹⁰⁵ If a firm reduces emissions by more than the required amount, the firm can record and "bank" its regulatory gains with the authorities and receive a "deed" for the reductions; the deed is a transferable asset.¹⁰⁶ California's regulatory property rights system has generated private property rights technologies for managing air quality. Moreover, it has created incentives to develop the physical world technologies needed to create private property rights solutions. All that remains is to generate the legal technology necessary for privatization. In spite of the heavy layer of regulatory property, the path to private property rights has become clearer.

The EPA's controversial Total Maximum Daily Load (TMDL)¹⁰⁷ program for water pollution also gives an example of how regulatory property programs can contain the seeds of private property solutions. As part of an initiative to clean up rivers nationwide, EPA proposes allowing pollutant credit trading programs.¹⁰⁸ EPA hopes that by focusing on water quality outcomes rather than pollution emissions, environmental fences will be erected and that rapid gains in monitoring technology will reduce the cost of building the proposed environmental fences. This plan is supplemented by EPA's improved system for simulating the effects of discharge on water quality, which now allows the property rights protector to estimate the marginal effects of individual polluters on ambient stream conditions. In spite of the heavy layer of regulatory property, the path to private property rights has become clearer.

IV

COMPETING PROPERTY RIGHTS PROVIDERS

There is still a missing piece to this story. Let us return to the impact legal technology has on the development of property rights to address the tragedy of the commons. In Anglo-American

105. See Matthew Polesetsky, *Will a Market in Air Pollution Clean the Nation's Dirtiest Air? A Study of the South Coast Air Quality Management District's Regional Clean Air Incentives Market*, 22 *ECOLOGY L.Q.* 359, 402-05 (1995).

106. See South Coast Air Quality Management District Rule 301, available at <http://www.aqmd.gov/rules/html/r301part1.html>.

107. See Oliver A. Houck, *TMDLs IV: The Final Frontier*, 29 *ENVTL. L. REP.* 10,469 (describing TMDL program); Andrew P. Morriss, Bruce Yandle & Roger E. Meiners, *The Failure of EPA's Water Quality Reforms: From Environment-Enhancing Competition to Uniformity and Pollution Profits* (2001) (unpublished manuscript on file with authors) (describing and criticizing TMDL program).

108. See Susan McInerney, *Environment: Clinton Unveils New Steps for Protecting U.S. Waterways*, *BNA WASH. INSIDER*, Aug. 16, 1999, at D2.

law there are two such technologies: common law and statute law.¹⁰⁹ These are not simply different sets of rules but different technologies for generating rules. Libertarian scholars such as Epstein,¹¹⁰ Hayek,¹¹¹ and Leoni¹¹² describe stark differences between statutes written by politicians and law discovered by common law judges.

The common law is a process based on the resolution of disputes between parties by a judge and jury. Rules arise from the classification of facts and in response to the nature of the problems parties bring to court. Particularly in a country like the United States with a multiplicity of jurisdictions, innovations spread relatively slowly and through a decentralized system of persuasive precedent. Judges are generally unable to seek particular types of cases to advance their own agendas.¹¹³ Even when a case arises that offers a judge the opportunity to advance her own political agenda, she must persuade her colleagues at the appellate level to follow her views.

Statutory law, on the other hand, results from a political process. Public choice theory has made clear the structural

109. Civil law countries have a third, the code system, which differs from statutory law by requiring consistency and generality of principles.

110. Richard Epstein describes the differences this way:

The allocative effects of choices between common law rules are, in any event, often small in comparison to what is accomplished by direct government action. Statutory controls can utilize a range of sanctions that are unavailable at common law: taxes, fines, inspections, filing requirements, and specific bans and orders with wide and dramatic effects. Even so simple a matter as placing limitation periods on private actions requires a statute; no common law principle explains why a cause of action valid on one day should be barred the next. Private law remedies are a limited arsenal in comparison; the private law of nuisance and the Clean Air Act are very different modes of social control.

Richard A. Epstein, *The Social Consequences of Common Law Rules*, 95 HARV. L. REV. 1717, 1721 (1982). Oddly enough, legal historian A. W. Brian Simpson does not see the difference between the rule of politics and the rule of law. He takes issue with Coase on this very point, saying that Coase's preference for common law over legislation reflects a controversial view. See A. W. Brian Simpson, *Coase v. Pigou Reexamined*, 25 J.L. & ECON. 53-101 (1996). Having made this point, Simpson proceeds to weaken his own case by noting that parties can contract around common law rules, but cannot contract around statutes.

111. HAYEK, *supra* note 54, at 141-43.

112. LEONI, *supra* note 54, at 110-11.

113. See Gregory C. Sisk, Michael Heise & Andrew P. Morriss, *Charting the Influences on the Judicial Mind: An Empirical Study of Judicial Reasoning*, 73 N.Y.U. L. REV. 1377, 1391-92 (1998) (summarizing literature on public choice and the judiciary); Richard A. Epstein, *The Independence of Judges: The Uses and Limitation of Public Choice Theory*, 1990 B.Y.U. L. REV. 827 (1990); Richard A. Posner, *What Do Judges and Justices Maximize? (The Same Thing Everybody Else Does)*, 3 SUP. CT. ECON. REV. 1 (1993).

reasons why the legislative process is frequently captured by special interests: the concentration of the benefits of controlling the creation of regulatory property rights and the diffuse nature of the costs of these rights.¹¹⁴ The record is clear that this phenomenon has been present in federal environmental legislation from the beginning.¹¹⁵

What is important for our purposes is how statutory and common law compete as property rights providers. After all, property rights generate appropriable wealth that property right providers may wish to share in. Ideally, common law courts will not be productive venues for industry cartelization and rent-seeking, ills that generally plague environmental regulatory efforts.¹¹⁶ However, we obviously do not live in an ideal world—we live in a world of competing institutions that seek the patronage of special interest groups. If common law protection of property rights becomes too rigid or burdensome, special interest groups can, and do, turn to legislative bodies for relief.¹¹⁷ This was the case even in the heyday of the English common law system, when common law judges dealt with environmental harms and property rights.¹¹⁸ The history of the landmark case *Rylands v. Fletcher*¹¹⁹ illustrates the point. In recounting the

114. See generally DENNIS C. MUELLER, *PUBLIC CHOICE II* (1989).

115. See ACKERMAN & HASSLER, *supra* note 57; E. Donald Elliott et al., *Toward a Theory of Statutory Evolution: The Federalization of Environmental Law*, 1 J.L. ECON. & ORG. 313 (1985); Andrew P. Morriss, *The Politics of the Clean Air Act*, in *POLITICAL ENVIRONMENTALISM* (Terry L. Anderson ed., 2000).

116. Yet while rent-seeking behavior may not rule the day successfully in common law courts, Horwitz and Friedman argue that those same courts, in some early version of conscious parallelism, systematically favored industry during periods of industrial development. See MORTON HORWITZ, *THE TRANSFORMATION OF AMERICAN LAW, 1780-1860* (1977); LAWRENCE FRIEDMAN, *A HISTORY OF AMERICAN LAW* (2d ed. 1985). But in an examination of every nineteenth century tort case recorded for California and New Hampshire, Gary Schwartz found no evidence of the Horowitz-Friedman effect. Gary T. Schwartz, *Tort Law and the Economy in Nineteenth-Century America: A Reinterpretation*, 8 YALE L.J. 1717 (1981). With the exception of employment law, Schwartz's findings go the other way: common law courts seemed to favor farmers, consumers, small businesses, and ordinary people as plaintiffs against large firm defendants. These findings, however, do not prove that there is no rent seeking in courts of law. Surely there is, since many if not all tort actions are motivated by efforts to recover or obtain some rents. But actions taken by a plaintiff or group of plaintiffs to seek rents by bringing suit is an entirely different social phenomenon from systematic efforts exerted by organized interest groups to raise rivals' costs or permanently cartelize a market through the legislative process.

117. See Jason Scott Johnston, *On the Commons and the Common Law*, in *THE COMMON LAW AND THE ENVIRONMENT: RETHINKING THE STATUTORY BASIS FOR MODERN ENVIRONMENTAL LAW*, *supra* note 7, at 211.

118. See A. W. B. Simpson, *Legal Liability for Bursting Reservoirs: The Historical Context of Rylands v. Fletcher*, 13 J. LEGAL STUD. 209 (1984).

119. *Rylands v. Fletcher*, L.R. 3 H.C. 330 (1868).

facts of the case, legal historian A. W. Brian Simpson explains that matters involving natural resources were routinely handled by special bills in Parliament, also referred to as Local and Personal Statutes. Simpson tells the rent-seeking story this way:

The industrial and agricultural revolution[s] of the eighteenth and nineteenth centuries were accompanied by the development of new bodies of law and the invention of new legal regimes; the typical instrument employed in this process was the private act of Parliament promoted by advocates of change and development, who hoped to profit by it. . . . The number of such acts passed was very considerable indeed, reaching a peak in 1846, when 402 were passed, in contrast to a mere 170 public acts; in the 1860s the annual figure fluctuated between 159 in 1869 and 372 in 1865.¹²⁰

Matters covered by this form of specialized legislation included tramways, tunnels, canals, harbors, docks, sanitation, burial grounds, waterworks, and water for consumption, industrial use, or water power.¹²¹ Simpson indicates there were two reasons for the private acts, one being “the need to override private property rights” and the other the “desire to produce conditions of monopoly.”¹²² Later, the same thing would be said about the rise of U.S. administrative law as indicated by the outpouring of new rules in the Federal Register.¹²³

Unlike competing providers of consumer goods, courts and legislatures do not offer alternative products on store shelves. These institutions compete nonetheless—legislators hold public hearings to signal their interest in solving problems through legislation, and attorneys, if not judges, advertise that they can resolve problems through the courts. Legislatures’ broad surveys, ability to act proactively, and greater resources gives statutory law a competitive advantage in defining solutions to common problems. Because legislatures can shift some or all of the costs of solutions onto underrepresented third parties, statutory solutions may also offer more attractive rent-seeking opportunities than do courts. We should not be surprised, therefore, to see statutory solutions dominate in areas where there are gains to be had from rent seeking and the creation of regulatory property rights. The interesting question will thus

120. Simpson, *supra* note 118, at 252.

121. *Id.* at 252-53.

122. *Id.* at 253.

123. Nancy G. Marzulla. *The Property Rights Movement: How it Began and Where it is Headed*, in LAND RIGHTS: THE 1990S’ PROPERTY RIGHTS REBELLION, *supra* note 76, at 1, 5-7.

often be whether the path to the creation of regulatory property rights is a one way street. Once sticks in the bundle have been created as regulatory property, can they be transformed into private property rights? This is not simply a matter of relabelling rights. Recall from our earlier discussion that a key distinction between regulatory and private property rights bundles is the incentive created to develop new legal and physical world technologies to permit trade of the rights within the bundle and to create new rights in the bundle.

The transformation is not impossible—our discussion of market-like regulatory property rights in Part III above shows that when sufficiently large gains from trade exist, regulatory property rights owners will seek to create means of capturing those gains. The use of market-like mechanisms will in turn create both incentives to privatize the resulting regulatory property rights and incentives to create the technologies necessary to do so. Saying something is possible if enough money is on the table is not particularly helpful, however. Can we say more?

Emphatically, yes. By focusing on getting the incentives right and setting distributional concerns aside, our analysis suggests that a clear path to procuring the potential gains from trade that private property rights make possible for society, if not for particular individuals is created. The key is to encourage entrepreneurs by offering them opportunities to profit by defining new property rights “sticks” and creating the ability to trade them. Allowing entrepreneurs to homestead bundles of such potential rights creates such incentives and can be accomplished within the statutory framework in many instances. The public choice theory concerns will now encourage the definition of such bundles through legislation, since special interests can grab first-mover advantages in the resulting “land rush” to stake claims.

The distribution of the new property rights will undoubtedly be more skewed toward the wealthy than it would be under the common law, because we will, in effect, be bribing special interest groups to rely on private property rather than regulatory property, and because money has always had greater influence in politics than in law. Nonetheless, this may be the price we have to pay to secure the benefits of private property technology. In addition, these distributional impacts are mitigated by the greater future wealth created by allowing appropriation. As David Schmidtz points out, contemporary Americans are far better off than were the original appropriators in the Jamestown

colony despite the colonists' appropriations out of the commons.¹²⁴

CONCLUSION

This analysis of how competing legal processes can accommodate and encourage flows of private property rights technology describes a long journey that began with a commons and ended with private property rights. Along the way, we developed a theory about the division of property rights and applied it to environmental resources. Building on the demand threshold model used by other property rights scholars, the model developed in this Article emphasized the development of property rights technology as a transaction cost reducing mechanism. After tracing the development of property rights to U.S. environmental resources through common law and regulation, we end with the conclusion that the gap between regulatory and private property rights enlarges and contracts as technologies enter and overwhelm rent-seeking forces that stand in the way of the development of new markets for environmental resources.

Analyzing the evolution of solutions to tragedies of the commons in terms of technological change offers the potential for a number of insights. Regulatory property solutions differ in their impact on future technological change. Some solutions, such as tying a right to emit to use of a specific technology, effectively eliminate the incentives necessary to produce the new technologies necessary for the evolution of private property solutions. Others, like tradeable emissions permits, offer a path into private property rights solution by creating incentives for technological innovation. In situations where private property rights solutions are unavailable or politically impossible, the form of regulatory property chosen may make the difference between a low-level equilibrium trap with large dead-weight losses and eventually being able to take advantage of the gains from trade private property rights make possible. Through appropriate institutional choices, we can unleash the creative power of countless individuals on tragedies of the commons, discovering solutions we cannot now imagine. Although we cannot predict the ultimate path of technological change, we can

124. David Schmitz, *The Institution of Property*, in *THE COMMON LAW AND THE ENVIRONMENT: RETHINKING THE STATUTORY BASIS FOR MODERN ENVIRONMENTAL LAW*, *supra* note 7, at 109, 112.

safely say that such a path is preferable to the dead end offered by some forms of regulatory property.

A second important insight concerns the institutions that implement the solutions to the tragedy. Evolutionary institutions are critical to capturing the potential gains from trade. Private property rights have a clear advantage over regulatory property in this regard, but steps can be taken to bring regulatory property solutions closer to the private property model. Avoiding fixed mandates and focusing on outcomes and adjudicatory procedures offer a way to make regulatory property solutions more adaptable. We must remember that legal institutions are themselves technology and can evolve in response to incentives.

A third conclusion developed in this Article is that solutions to the tragedy of the commons need not be fixed. Neither regulatory nor private property solutions are ultimate destinations but merely forms of institutions that can change in response to incentives and circumstances. An escape from the tragedy is never final, but always preliminary and tentative. In some respects, the difference between a common law nuisance rule and the Clean Water Act is only the degree of potential gains from trade necessary to produce change.

In sum, the technologies of property rights offers a framework for analysis of solutions to tragedies of the commons that clarifies institutional choices across a wide range of problems. Further work is necessary to identify the specific factors that lead to particular forms of property rights.