THE RHINO'S HORN: INCOMPLETE PROPERTY RIGHTS AND THE OPTIMAL VALUE OF AN ASSET

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Abstract

Under certain conditions, it is possible for the costs of enforcing property rights to exceed their benefit for assets with high first-best values. Under these conditions, previously privately held assets may revert to the public domain. This paper analyzes this prospect and considers attempts to lower the gross value of the asset as a possible method of maintaining the private property right. The paper examines several examples including built-in obsolescence and penal colonies to demonstrate the general idea.

Half a loaf is better than no bread. [Anonymous]

I. Introduction

Harold Demsetz's seminal paper on property rights contains several critical ideas that have stood the test of time and have become foundational in subsequent literatures. First, Demsetz stresses that the term "property rights" should not be restricted to the narrow legal notion of rights to property under the law but should be extended to include the ability to make all manner of choices. In his words, they are "expectations that [one] can reasonably hold in his dealings with others."[1] Second, Demsetz notes that prop-

[1] Harold Demsetz, Toward a Theory of Property Rights, in Ownership, Control, and the Firm: The Organization of Economic Activity 104 (Harold Demsetz ed. 1988). Although there are many economists (for example, Yoram Barzel, Economic Analysis of Property Rights (1997)) and lawyers (for example, Robert C. Ellickson, Order without Law: How Neighbors Settle Disputes (1991)) that appreciate the distinction, this critical point separates the understanding of many, if not most, economists and lawyers in the study of property rights. Some 35 years after Demsetz made this point, confusion still abounds in much property rights writing because of a failure to spell out whether one is discussing rights under law (legal property rights) or abilities to make choices (economic property rights). This important distinction allows property rights theory to be used in explaining behavior and organization.

erty rights emerge when the benefits of establishing those rights exceed the cost. Finally, Demsetz notes that different patterns of property rights lead to different patterns of behavior. All of these ideas have survived into the modern theory of property rights, whether in the law and economics or institutional literatures.

This paper considers an extension of the second point made by Demsetz. Most economists who have written on the evolution of property rights have essentially assumed that the costs of establishing them are linear. Although he does not explicitly consider all of the implications of nonlinear costs in the establishment of property rights, Yoram Barzel recognizes that increases in first-best values are not always followed by increased ownership—the major implication of linear costs.[2] In particular, he states, "A priori reasoning does not yield the outcome that policing expenditures should increase more slowly than the gains from more detailed pricing. Although owners control which methods to employ for protecting their rights, thieves are also free to use whatever methods they see fit. Thus, the claim that rights will be better delineated when the returns from more accurate pricing increase is not always true."[3]

In an earlier work, Barry Field also notes that "encroachment" may increase with increases in values.[4] He writes, "If the resource has no value, there would be little incentive to encroach, and thus it would be relatively easy to exclude, other things equal. So an increase in value of output could be expected to increase the incentive for encroachment, which implies that additional resources are required to achieve the same effective level of exclusion that pertained before."[5]

Both authors leave open the possibility of nonlinear costs without explicitly stating so. In this paper, I explicitly analyze the case of nonlinear costs in the establishment of property rights and derive an interesting implication that has many applications.

II. Establishing Property Rights: The Demsetz Way

A number of writers have picked up on the Demsetz theme that rights are established when the benefits of establishment exceed the cost.[6] Figure 1,

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[2] Barzel, *supra* note 1.

[3] *Id.* at 94.

[4] Barry C. Field, The Evolution of Property Rights, 42 Kyklos 319 (1989).

[5] *Id.* at 328.

[6] For example, see Terry Anderson & P. J. Hill, The Evolution of Property Rights: A Study of the American West, 18 J. Law & Econ. 163 (1975); John Umbeck, The California Gold Rush: A Study of Emerging Property Rights, 14 Explorations Econ. History 197 (1977); or Barzel, *supra* note 1. Thrainn Eggertsson, Economic Behavior and Institutions (1990), refers to this as the "naive theory" of property rights because it fails to model the institutional context. Many have also criticized the Demsetz hypothesis because there would appear to be many instances in which the predicted movement to private property is either reversed or incom-
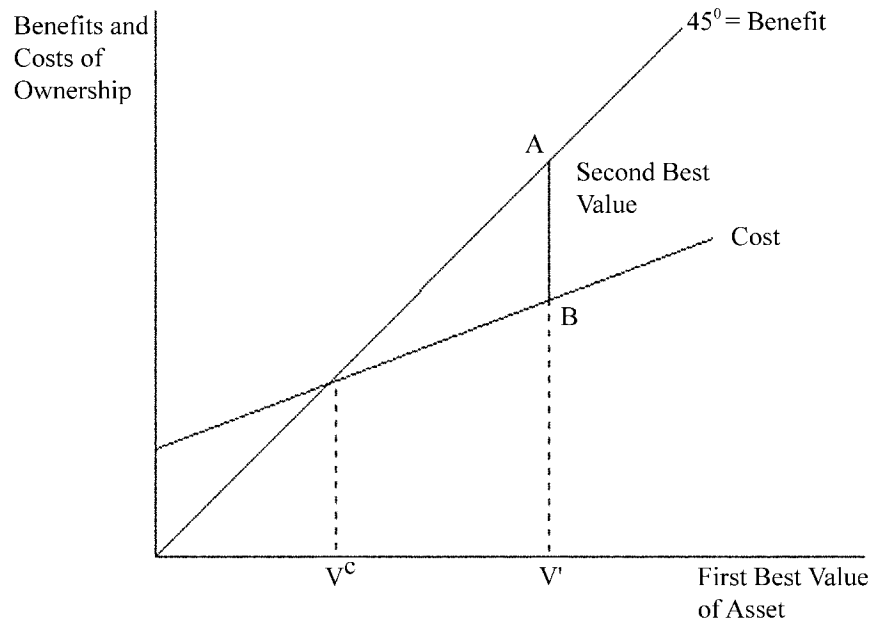
FIGURE 1.—Establishing property rights

taken from a work by John Umbeck,[7] captures this idea. On the horizontal axis is the first-best value of a single-attribute asset, determined by underlying demand and supply conditions. This gross value is independent of transaction costs and is set by a volunteer Walrasian auctioneer in a competitive market. On the vertical axis are the dollar benefits and costs of ownership of the asset. Assuming ownership is complete, meaning the owner of the asset receives all of its value, the benefit of property rights is simply the 45 degree line. The cost function in Figure 1 shows the cost of establishing and maintaining property rights over the asset. In other words, this is the transaction cost function.[8] This function incorporates all of the costs of ownership, whether they are enforcement, measurement, moral hazard, or other such costs. The vertical distance between the two lines represents the asset's second-best value. For example, if the first-best value of an asset is V', then

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plete. Many of these criticisms, however, are merely elaborating on the costs of establishing rights and are therefore quite consistent with the general hypothesis.

[7] Umbeck, *supra* note 6.

[8] See Douglas W. Allen, What Are Transaction Costs? 14 Res. L. & Econ. 1 (1991); and Douglas W. Allen, Transaction Costs, in 1 Encyclopedia of Law and Economics (Boudewijn Bouckaert & Gerrit De Geest eds. 2000), for a defense of the definition that transaction costs are the costs of establishing and protecting property rights. Most notably, I do not hold that transaction costs are just the "costs of exchange." A proper notion of the meaning of transaction costs eliminates or clarifies many of the arguments surrounding the evolution of property rights.
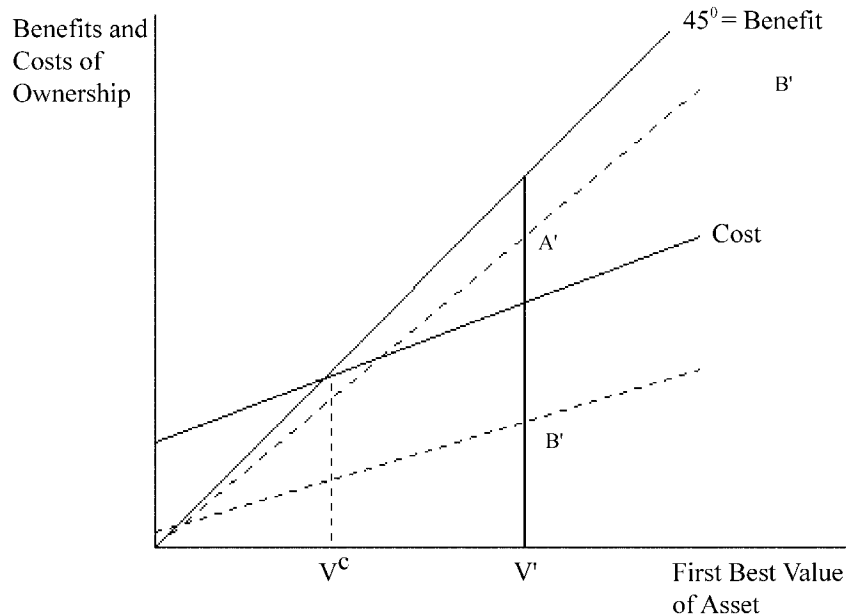
FIGURE 2.—Optimal asset values

the second-best value would be given by distance *AB*. The critical point made by Demsetz and others was that, assuming these functions had an intersection, a critical first-best value, V^C, determines whether property rights exist or not. To the left of V^C, the asset is in the public domain because the costs borne by those attempting to establish ownership exceed the benefits, and wealth maximizers exert no rights to the asset.[9] The asset remains in the public domain and has no value. To the right of V^C, some type of ownership exists.[10]

When all benefits to an asset are private, the benefits of ownership equal the first-best value of the asset, and the benefit line is the 45 degree line. This means that when the asset is owned, ownership is complete. To the extent that ownership, or property rights, is not perfect, then the benefit line falls below the 45 degree line. For example, in Figure 2, the benefit function

[9] Here I follow Barzel, *supra* note 1, in defining an asset in the public domain "when the resources needed to acquire it accrue to no one" (*id.* at 5). This is equivalent to having open access to the asset.

[10] The nature of the ownership—its structure or form—is not dealt with here; presumably the optimal type of ownership is chosen. Nor am I concerned with the temporal evolution of rights. Often in the empirical implementation of the Demsetz hypothesis, asset values are followed through time. This has given the impression that the Demsetz model is defined over time. However, this is false. The Demsetz prediction is based on the costs and benefits of ownership and, specifically, the movement of rights to assets from the public domain to private property as an asset's value increases.

B' represents a degree of property rights of, say, only 90 percent; that is, the individual expects to acquire only 90 percent of the first-best value of the asset. Of course, the costs of enforcing a 90 percent property right are lower than the costs of enforcing perfect rights, and so the cost function falls as well. It still remains true that the value of the asset is given by the vertical distance: in this case, $A'B'$. In Figure 2, the costs have fallen by more than the benefits, and the second-best value of the asset has increased. The optimal degree of property rights in the asset would be the one that maximized the second-best value.[11] In order to focus on the issue at hand, I assume that 100 percent of the benefits of ownership accrue to the owner. This does not mean that transaction costs are zero, nor does it mean that the public domain is empty. I am assuming, for ease of exposition, only that when an asset is privately owned, all of the benefits of ownership are captured by the owner.

III.   Nonlinear Transaction Costs

A modest alteration to the basic Demsetz model is to recognize that costs of enforcing property rights are unlikely to be linear in the first-best value of the asset. For the moment, ignore why this might occur and simply assume that as the asset becomes more valuable, it increasingly becomes more difficult to protect. Suppose an individual owns an asset with a first-best value of v but that a thief also exists who can steal this asset from the owner. Suppose that $e \in [0, 1]$ is the amount of effort used by the thief to steal and that this effort translates into the probability that the thief will be successful. Effort is costly and is given by $c(e)$, where c', $c'' > 0$. That is, the transaction costs are nonlinear.[12]

Assuming that the thief observes the value of the asset, the thief chooses the amount of effort according to

$$\max_e \pi^t(v) = ev - c(e). \tag{1}$$

The optimal level of effort e^* devoted to theft is given by $v \equiv c'(e^*)$. Clearly $e^* = g(v)$, where $g(v)$ is increasing in terms of v: the more valuable the asset, the more effort devoted to theft. The function $g(v)$ tells us the probability of a successful theft conditional on the value of the asset.

If the owner knows that the thief behaves this way, he chooses the value of the asset according to

$$\max_v \pi^o(v) = [1 - g(v)]v. \tag{2}$$

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[11] The issue of the optimal degree of property rights is yet another extension of Demsetz's original idea, but one that has been dealt with elsewhere (see, for example, Anderson & Hill, *supra* note 6).

[12] The term $c(e)$ is the transaction cost function because it is the cost necessary for the thief to establish property rights over the asset.
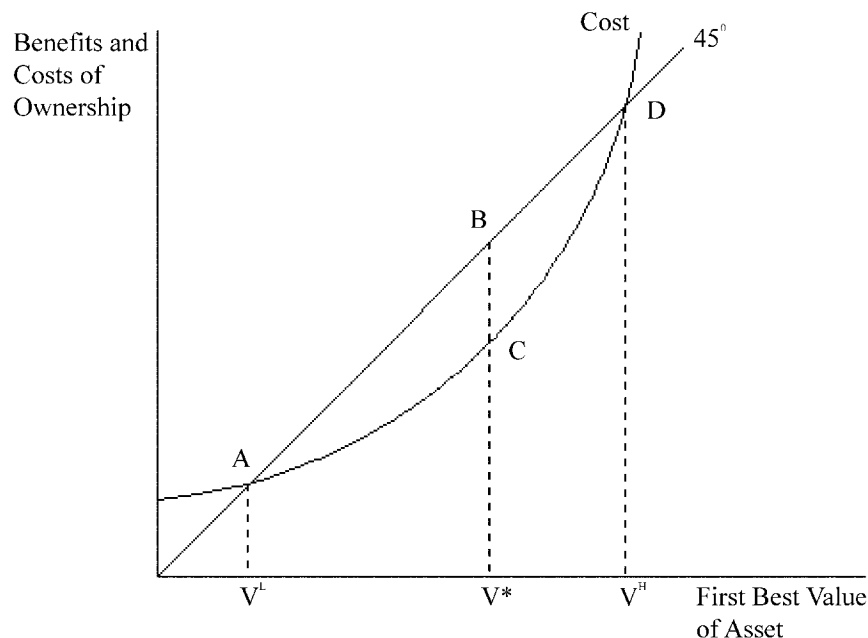
FIGURE 3.—Property rights with nonlinear costs

The wealth-maximizing level of v is given by

$$1 - g(v) = g'(v)v. \tag{3}$$

Equation (3) shows that the optimal second-best value of the asset is less than the first-best value.[13] Figure 3 shows a graphical interpretation of this in the context of Figure 1, where the costs and benefits of establishing rights are nonlinear. The model states that for a given technology of establishing and maintaining property rights (that is, for a given transaction cost function), the optimal value of the asset is the one that maximizes its net value.

Even in this modest extension of the naive model, several predictions immediately follow. First, it is still the case that low-valued assets are likely to move from the public domain to private ownership as their first-best value exogenously increases. In other words, in the neighborhood of V^L in Figure 3, the original Demsetz prediction still holds. For example, investigations into property rights to land or gold fields during the time of white settlement in North America or the California gold rush are correct to predict the emergence of private property as land values increased as a result of settlement and gold discoveries. A second observation is just as apparent. It is possible

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[13] For example, if $c(e) = e^2/2$, then $g(v) = v$ and $v = 1/2$ the first-best value.

that assets may have first-best values that are so high that the transaction costs of ownership again exceed the benefits, and the asset reverts back to the public domain. Hence, paradoxically, in principle the public domain may contain extremely valuable (in a first-best sense) and extremely low-valued assets.[14] A third implication of the model is that there exists a finite optimal second-best value of an asset, V^*. Under the traditional Demsetz approach, increases in the first-best values of assets always increase the second-best value as well. This is no longer the case. As assets increase in value, the cost of establishing and maintaining the property right can increase faster than the rise in value, leading to a decrease in the second-best value.

It is easy enough to draw a nonlinear transaction cost function; however, it is important to inquire why such a function might exist. Henry Smith notes that four conditions must hold for a high-valued asset to exist in the public domain.[15] First, a thief or encroacher must value the asset more at high values than the owner does. Second, trade between the thief and owner is not feasible. Third, protection by a third party is not economical. And fourth, the asset cannot be divided into smaller usable pieces that are worth protecting. In light of the discussion thus far where the asset is composed of a single attribute and where the costs of establishing and maintaining property rights have been left to a simple cost function of one variable, it is difficult to imagine how these conditions could exist since single-attribute assets should be trivial to trade, protect, and divide.

However, goods are never simple one-dimensional items. On the contrary, goods are complex and composed of multiple attributes that both vary in nature and are alterable by people. With multiattribute goods, changes in the relative valuation of the various attributes by the thief and the owner as the first-best value of the asset increases can lead to nonlinear transaction costs. Asset values increase when the values of the individual attributes increase, but the increase in the value of the asset may be due to increases in attribute values that the owner does not care much about for his particular use of the good. On the other hand, a thief may value those attributes more as the value of the good increases. This difference in valuation of different attributes lies behind the nonlinear transaction cost function because the thief is willing to spend more to capture the good than the "nominal" owner is willing to spend

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[14] Pebbles on the side of the road are low valued and in the public domain. For reasons discussed below, practical examples of high-valued assets in the public domain should be rare. An example, of the "urban legend" variety, is of an owner of a convertible who leaves his top down when parking on public streets because he does not want the top damaged by a thief. This would place the valuable interior of his car in the public domain. A historical example is dealt with in Dean Lueck, The Extermination and Conservation of the American Bison, in this issue, at S609. Bison values increased throughout the nineteenth century. However, property rights to bison were reduced over the period (from common property to open access) because the costs of establishing ownership increased over time as well.

[15] Henry E. Smith, Exclusion versus Governance: Two Strategies for Delineating Property Rights, in this issue, at S453.
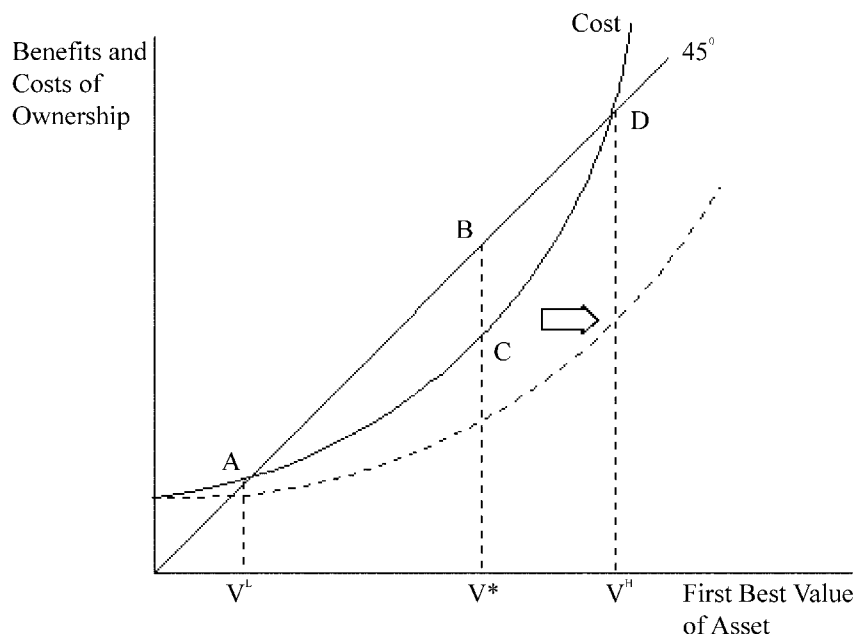
FIGURE 4.—Falling transaction costs

to protect it. When these attributes are inseparable and indivisible, they make trade, division, and third-party enforcement infeasible. The result, in principle, could mean that a valuable good (in a first-best sense) ends up in the public domain.[16]

IV. IMPLICATIONS AND APPLICATIONS

Implication 1: Lowering Transaction Costs

Wealth maximizers do not like assets in the public domain. When assets are in the public domain because they are too costly to protect given their high first-best value, two general solutions are available. The first is to innovate on the transaction cost margin. As shown in Figure 4, a decrease in transaction costs brought about by an innovation in policing technology allows the high-valued asset to be removed from the public domain. This type of innovation is common and has generally been discussed in the lit-

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[16] As I will argue below, high-valued assets are unlikely to remain in the public domain. However, a close example of valuable assets purposely not treated as private property are all of the cases of common property found in the literature. Common pastures, forests, and other resources, though not open access, are held in common because it is simply too costly to exclude all outsiders from the resource.

erature. Terry Anderson and P. J. Hill, for example, discuss how the innovation of barbed wire brought vast amounts of land in the arid West out of open grazing to enclosed pasture and how innovations in water law created a legal framework for trading water rights.[17] Declining transaction costs may result from institutional changes as well as physical ones. The U.S. government initially sold public lands at the turn of the nineteenth century, only to later give away one-quarter of it under the Homestead Act of 1862. Although economists have criticized the act for dissipating rents to the frontier, these costs were the result of the institutional innovation of homesteading. Homesteading created a rush of individuals on public domain land and thereby avoided the bloodshed of greater Indian wars that would have occurred had settlers arrived slowly and in smaller numbers.[18] History is full of examples of innovations that reduce transaction costs and, therefore, increase net wealth. However, innovation takes time, and its success is always uncertain. In the short run, another option may be more profitable.[19]

Implication 2: Lowering Gross Value

A second solution to removing assets from the high first-best-valued end of the public domain is to lower their gross value. Lowering the gross value makes the asset less attractive to theft, and given the nonlinear transaction costs, the costs of enforcing the property right decrease by more than the value of the property right. The net result is private ownership and a positive second-best value. The asset should be reduced in value to the level of V^* in Figure 4, where the second-best value is maximized.[20] It is critical to note that this type of behavior is different from efforts at protection that raise both gross and net values. For example, I am not referring to cases such as

[17] Anderson & Hill, *supra* note 6. A modern example of protection innovation is the new digital versatile disc (DVD) technology. Although DVD provides a higher-quality video and audio output, the driving force behind its development was the ability to prevent pirated copies of the contents through various encryption devices. The "regional lock" on DVDs is capable of a preventing a North American DVD from being used in any of five other world regions. Extra signals, called Macrovision, prevent the DVD contents from being copied to video tape. They also contain a "content scrambling system" that encrypts data and requires a reader decoding key. Ironically, all of these measures were "broken" rather quickly, and "patches" can easily be downloaded from the Web to avoid them.

[18] See Douglas W. Allen, Homesteading and Property Rights; or, "How the West was Really Won," 34 J. Law & Econ. 1 (1991), for a detailed discussion of this hypothesis.

[19] The entire institutional literature is about lowering transaction costs and increasing second-best values, and so it is difficult to summarize this literature here. However, tie-in sales, vertical integration, government intervention, and so on, could all play a role in lowering the transaction cost function.

[20] Here I focus on the dramatic case of actual wealth destruction, but a more common practice is simply hiding or disguising wealth. Wealth can be hidden through nonconspicuous consumption, trade secrets, and offshore holdings. Apparently it was not uncommon during the Renaissance, when public protection of private wealth was minimal, for elaborate palaces to be constructed behind a ghetto facade.

putting locks on doors, antitheft devices on car steering wheels, or security strips in currency. These are the "classic" examples of establishing property rights as described initially by Demsetz. Here I am referring to an action that actually reduces or destroys part of an asset such that its gross value is lowered.

To help understand this point, consider the case of a large well-known diamond, and assume that there are large fixed costs of splitting the diamond, that the costs of measuring a diamond as a fraction of its value decline as the diamond increases in value, and that the owner prefers the diamond whole rather than split. Further assume that the gross value of one large diamond is always higher than the joint value of the smaller split diamonds. Under these conditions, if the costs of protecting the diamond were zero, the diamond would never be split. Unfortunately for the owner, one of the attributes of a diamond is that it can be split into smaller diamonds. More critical, split diamonds are harder if not impossible to trace, and so this characteristic is more valuable to a thief than the legal owner. As a result, the diamond thief may be willing to spend more resources to capture the diamond than the legal owner is willing to spend to protect it as long as the diamond remains large. In this case, we end up beyond V^H, where the second-best value of the diamond is negative.[21] Of course, rather than leave the diamond in the public domain, the original owner may cut the diamond. Each smaller diamond is now worth protecting, and the second-best value of the diamond is maximized. However, the first-best value of the single diamond is greater than the sum of the first-best values of the smaller stones.

I now turn to several examples to point out how general this extension of the simple Demsetz prediction is. As will become clear, there are many examples in life where the costs of maintaining a property right are higher than a good's value because some of the underlying attributes of the good are valued more by others. However, it is difficult to find examples where individuals are not able to reduce the value of the good by systematically reducing the proportion of these attributes.

Application 1: The Rhino's Horn.   I begin with the example of the rhinoceros because it provides such a stark and simple example of the model. The wild rhinoceros is valued for many attributes, not the least of which is its horn. The horn is essentially made of compressed hair (keratin) and is similar in makeup to a human fingernail. The horn continually grows and achieves its shape from constant sharpening. Although the horn is used to decorate ceremonial dagger handles in the Middle East, its chief use is in Asian medicine, where it is ground into a powder for the relief of fevers.

Generally speaking, the governments of Africa manage rhinos as a

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[21] One might ask, Why does the thief not purchase the diamond? However, the thief is not the high-valued user of the diamond; he has only a comparative advantage in stealing it, which also rules out the notion of third-party enforcement.

common-property resource in conservation areas and on public lands.[22] Since the 1970s, there has been an international ban on the trade of rhino horn, making it costly to develop private ranges to farm the animal. In light of the ban, a black-market trade in horns has developed, which has encouraged poaching. As a consequence, rhinoceros populations fell considerably between 1970 and 1990 as poachers killed rhinos for the valuable horn. For example, black rhinos numbered between 65,000 and 100,000 in 1970; today, population estimates are between 3,000 and 4,000.[23] Similar reductions have occurred in other rhino species in both Africa and Asia.

To date, no one has developed a method or technology to lower the transaction cost function for rhinos. Given the nature of the beast, they require vast amounts of territory and are difficult to relocate to safe places.[24] However, a solution has been found that appears to be working—dehorning. Dehorning involves the drugging of the rhino and sawing off the horn just above the skin line. The horn eventually grows back, and the procedure is repeated every 18–24 months. Dehorning, like having fingernails cut, does not hurt the rhino, nor does it appear to seriously reduce the rhino's ability to forage, defend, or breed.[25]

There is no question that removing a rhino's horn lowers the value of the rhino. However, given that the poacher values only the horn and that the state values the rhino for other attributes (tourism, biodiversity, and so on), removal of the horn lowers the cost of enforcement by much more than the decrease in the gross value. The result is an increase in the net value of the rhino. Although it is still early in the program, it appears that the policy has reduced poaching. According to Sue Armstrong, dehorning essentially eliminated poaching in northwest Namibia when it was first introduced.[26] Ac-

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[22] In North America, where legal property rights to land are well developed and where state regulation is often enforced, many migratory and wild species attributes are owned by private landowners, conservation groups, or local, state, and federal governments (see Dean Lueck, The Economic Nature of Wildlife Law, 18 J. Legal Stud. 291 (1989)). In some parts of Africa, most notably South Africa, there are large private reserves for mammals such as rhinos. Over the entire continent, however, rhinos are generally managed as common property.

[23] See Mark Atkinson, Dehorning (1996) (http://www.rhinos-irf.org/programs/black.html, visited April 24, 2001; on file with the author).

[24] Rhinos require special bacteria to digest food, and relocation means that new bacteria must develop when there are small changes in diet. The time lag involved means that rhinos often "starve" to death when moved. Sue Armstrong, Nose Jobs Save Namibian Rhinos, 32 New Scientist 32 (1989), estimates that 15 percent of rhinos are lost this way as a result of relocation.

[25] See id. Apparently rhinos often lose their horns in the wild with no major side effects. This is quite different from detusking elephants, whose tusk is essentially a tooth and full of nerves. Although removal of tusks has been done to elephants to reduce poaching, because it destroys other attributes of the animal, it has been less successful.

[26] There is debate among conservation biologists on how effective dehorning has been. No definitive answer has been reached yet, in part because tracking dehorned rhinos is difficult, sample sizes are small, and nations have changed enforcement policies over time. See Janet Rachlow & Joel Berger, Conservation Implications of Patterns of Horn Regeneration in De-

cording to Mark Atkinson, in reference to a dehorning program in Zimbabwe, there was "growing evidence that dehorning was having a positive effect . . . and was helping to bring about the halt of poaching. Indeed, Zimbabwe has not had a rhino poached since early in 1994. This represents a dramatic change from the situation in 1992, when rhinos were being poached at a rate of at least one every five days."[27] Dehorning lowers the gross value of the rhino by systematically eliminating the attribute that the thief values highly.[28]

Application 2: Built-in Obsolescence.　　On March 3, 1998, the U.S. Department of Agriculture, in partnership with Delta and Pine Land, a small Louisiana cotton seed company, announced a new patent for the control of germination in seeds. Monsanto, the largest seller of genetically modified seeds in the world, later purchased Delta and Pine Land and acquired the patent. Called the "terminator gene," the modification essentially makes plants sterile and unable to germinate. Almost immediately, there was a massive public campaign against the use of such technology, and in 1999, Monsanto announced that it would not use the terminator gene commercially, although it reserved the right to use it in the future.

From a neoclassical perspective, the terminator gene presents itself as an economic puzzle: a case of built-in obsolescence if ever there was one. The gene itself does not increase output or change the plant in any way; its sole purpose is to prevent reproduction and the storage of seed. Forcing farmers to buy seed that lasts only one period instead of seed that can perpetuate itself lowers only the price of the seed. Since seed is costly to produce, destroying the reproduction capabilities of the plant can only reduce profits—at least in a first-best world.

The problem for producers of genetically modified seed is that the seeds become stolen and future crops are not captured by the current price. "Seed pirates" are a common problem in third-world countries, but the case of a Saskatchewan farmer, though trivial in terms of the revenue to Monsanto, demonstrates the magnitude of the problem. Percy Schmeiser, aged 68, lives in Bruno, a small town close to Saskatoon, where he has farmed all of his

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horned White Rhinos, 11 Conservation Biology 84 (1997); or Gardner Brown & David Layton, A Market Solution for Preserving Biodiversity: The Black Rhino, in Protecting Endangered Species in the United States (Jason F. Shogren & John Tschirhart eds. 2001), for a discussion of the facts and issues.

[27] Atkinson, *supra* note 23, at 2.

[28] Clyde Reed suggests another application along the lines of "poaching." Residential street intersections often have flower beds or other physical interruptions that slow down traffic. These interferences with traffic flow are targeted at interloping drivers looking for quick shortcuts off the main streets. The local residents do not value "speed" as much as the out-of-neighborhood commuters do. In fact, speed on the local street may have no value to the local residents at all. Commuters in effect "steal" the local peace and safety of the street by traveling too fast. The local community responds by lowering the gross value of the street, but lowering only those margins that the thief values more than they do. The result is a higher net value to the street.

life. He recently was found guilty by the Federal Court of Canada of stealing 320 acres worth of "Round-Up ready canola."[29] Schmeiser, despite having a field of Monsanto product, never paid Monsanto the $37/hectare annual fee for growing it and claimed the seeds floated onto his property from passing grain trucks. Most remarkable about the case was the extent to which Monsanto had gone to protect its property. Monsanto employees entered the farm without permission to take crop samples for genetic testing, they obtained permission from local flour mills to test Schmeiser's seeds that had been left at the mill for cleaning, and they tried to hire the flour mill owner to report on other local farmers who might be cheating. All of this for a farmer growing a half-section of canola.[30] Clearly, the problem with genetic crops is that they are "too valuable" and encourage theft.[31]

Contracts with farmers to forgo storage and private sales, along with the inspection of crops, and tours of flour mills are expensive. The lowering of the first-best value of the seed by introducing sterility is not a corporate trick to exploit farmers but a method to increase the second-best value of the crop by reducing the transaction costs of protection.[32] Although it is yet to be seen whether the strategy is feasible, by having a seed that cannot reproduce, problems of theft of future crops are eliminated.

The terminator gene provides an excellent example of attributes that are valuable to seed pirates but not the legitimate farmers that purchase the seed. Assuming there are some economies of scale in growing and storing seeds, an "honest" farmer who pays for his Monsanto seed would prefer to buy one-time seeds each year from Monsanto rather than produce and store seeds himself. On the other hand, seed pirates highly value a seed's germination qualities. Without the ability to replicate, stolen seeds are worth only the bread they can make. Monsanto did not randomly lower the value of its seed.

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[29] Round-Up is a Monsanto product that farmers use to kill weeds. The court ruled on March 27, 2001 (Monsanto Canada, Inc., v. Schmeiser, 2001 FCT 256).

[30] According to court testimony, none of this behavior was unusual for Monsanto: the company routinely went to great lengths to protect its seeds. The normal outcome is that the offending farmer pays Monsanto for the seeds used and signs a contract for future sales.

[31] In the $30 billion per year seed industry, there are many attempts to protect seeds. First, international government organizations (such as the Union for the Protection of New Varieties of Plants) exist to issue international patents on new grain developments. Second, there are trade associations (such as the International Association of Plant Breeders for the Protection of Plant Varieties) that attempt to enforce patent protection. Third, there are services such as Farmland Dedicated Grains, an on-line tracking service that monitors grain from the seed producer to the farmer to the processor in order to certify that the seed was paid for. The problem with these types of protection is that they are difficult to enforce. Indeed, Monsanto is having to sue in order to enforce its patent.

[32] Interestingly enough, outcries in the press against the use of the terminator gene have not come from farmers using Monsanto seeds but from farmers who do not use it (many in the third world). One wonders how many of these farmers, like Schmeiser, are actually using stolen seed.

Rather, it lowered the value by eliminating the attribute that was valued more by the thief than by the farmer.[33]

The general issue with the terminator gene is one of built-in obsolescence. Built-in obsolescence may not be as rare as neoclassical textbooks claim it is.[34] By lowering the value of a product, the benefits of theft are also reduced. Lowering the value in a way that targets the thief increases net value. Consider the case of computer software. A frequent complaint about such software is that there is "excessive upgrading"; that is, producers of software are inefficiently inventing upgrades that consumers would prefer not be invented given the cost. Glenn Ellison and Drew Fudenberg suggest that excessive upgrading results either because the computer company is not able to commit to its customers that it will not upgrade (in the same way that a textbook publisher cannot commit to students that it will not issue a new edition in the future) or because it is a form of price discrimination.[35]

Here I provide a different explanation. Computer software is extremely easy to steal, and the better the product, the more likely the chance that it will be pirated. One strategy to protect the investment of the firm is to continually issue upgrades or to postpone improvements, even if the improvements are currently known! Learning how to use a new upgrade without the company's support or being incompatible with other users are costs of not upgrading. By offering legal owners of the software easy and cheap upgrades, the software company lowers the value of theft of the early versions.

An interesting example comes from one of the most popular typesetting packages for scientific writing. TeX was released by Donald Knuth into the public domain virtually complete in the 1970s. At the time, TeX was capable of producing mathematical expressions, tables, and publisher-quality typesetting that privately owned word processor packages developed only in the 1990s. Word-processing packages that came later, and that have been notorious for failures and constant upgrades, cannot be explained by a lack of knowledge of how to program mathematical expressions, tables, or other features that were in the public domain. Rather, the inferior products and constant upgrades reduced the amount of stolen software revenue and increased profits. Software companies lowered the cost of upgrades to legitimate

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[33] David Friedman points out that this gene is similar to the use of a copyright. A copyright lowers the value of an asset to the user because it restricts unauthorized reproduction. It is thus a method of reducing theft by reducing the value of the attribute thieves want. A copyright, however, seems a complicated example since the copyright also creates a legal right to the author, while the legal rights to seed existed for Monsanto prior to the introduction of the new gene.

[34] Perhaps the earliest textbook statement to this effect is Armen A. Alchian & William R. Allen, Exchange and Production 119 (1983).

[35] Glenn Ellison & Drew Fudenberg, The Neo-Luddite's Lament: Excessive Upgrades in the Software Industry, 31 Rand J. Econ. 253 (2000).

users by offering lower prices for registered users, with manuals and phone support.[36]

Application 3: An Alternative Explanation of Penal Colonies. The first British Transportation Act was made law in 1717 and allowed for prisoners to be sent to the Americas as convict workers. Although this particular practice ceased with the American Revolution, the practice of establishing penal colonies and forced migration of workers continued well into the twentieth century and was conducted by virtually every colonial power. Britain sent convicts to Bermuda, West Africa, Mauritius, Singapore, Malaysia, and of course Australia. France, Spain, and even Germany established other penal colonies in Africa, South America, and Southeast Asia.

The standard historical explanation for penal colonies was that they provided cheap labor, cheap prisons, and cheap deterrence to crime at home. It is also the general historical consensus that penal colonies were a mistake, not cheap in terms of workers, prisons, or deterrence, and that this explains their falling out of favor. In terms of labor supply, penal colonies deterred the large immigration of free labor. David Meredith, speaking of Australia, states that it is generally agreed that "transportation [of convicts] itself was an obstacle to increasing free immigration. Tradesmen and upper class migrants were put off by the reputation Australia had for lawlessness."[37] In terms of cheap prisons, contemporary reports of the time deny this. The British Home Office, in 1837, estimated that the cost of the convict transportation system to Australia was £439,000 per year, while the cost of keeping the prisoners in Britain was only £435,000 per year. Likewise, in terms of deterrence, the transport of convicts to Australia was considered a failure. Within a few years of the first ships' leaving in 1787, it became clear that

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[36] When a software company is able to price discriminate between different groups of customers, one form of "theft" against the company arises from low-end consumers selling the product to high-end consumers. One way to protect the rents from price discrimination is to actually destroy part of the value of the product, even though it is costly to do so. This is referred to in Carl Shapiro & Hal R. Varian, Information Rules: A Strategic Guide to the Network Economy (1999), as "value-subtracted versions" of software. They cite several examples: "Think about delay. A financial service firm that offers real-time and delayed stock prices needs added storage capacity to offer the delayed service. Or resolution: the images have to be scanned using a high resolution and then degraded to produce the low resolution. Or speed: Wolfram Research had to build or purchase a floating-point emulation library in order to produce the student version of its software. With information you usually produce the high-quality version first, and then subtract value from it to get the low-quality version" (*id.* at 63). Raymond J. Deneckere & Randolph Preston McAfee, Damaged Goods, 5 J. Econ. & Mgmt. Strategy 149 (1996), provides another series of examples from the computer industry of firms incurring costs to reduce the value of a product in order to price discriminate. The most interesting example is Intel's creation of the 486SX computer chip, which was the regular 486DX chip with its math coprocessor disabled. The price discrimination case is a specific example of the general case. Some developers are reducing the gross value of some of their products in order to prevent customers from stealing rents in the high-end market.

[37] David Meredith, Full Circle? Contemporary Views on Transportation, in Convict Workers: Reinterpreting Australia's Past 16 (Stephen Nicholas ed. 1988).

options for the poor in Australia were no worse than options at home. Many saw it as an adventure, and anecdotes can be found of individuals committing crimes for free passage.[38]

If not to supply labor, prisons, or deterrence, why would colonial powers establish such colonies? An alternative explanation is that penal colonies lowered the value of the colony and made it less attractive to a foreign aggressive power. That is, although the penal colony deterred the immigration of free men, it was an even greater deterrence to the arrival of foreign powers. Free men could come knowing that the convicts were somewhat contained within the institutions of a penal system. A foreign power would know that capture of a colony would be followed by the release of prisoners: a form of a "human doomsday" device. Again, we see the example of the lowering of an asset through the specific targeting of attributes that hurt the thief more than the current owner.

History is full of examples of colonies being taken over by other powers. One method of preventing this is to establish a military presence and defend the territory through might. Depending on the location of the colony and its value, this may not be a viable option. A second option is to allow free citizens to populate the colony on the condition that they defend the territory. If the value of the territory is negative to free citizens, then they might be paid to go in terms of land grants, homesteading, or other payments.[39] If the colony is extremely remote, then the price of moving valuable free citizens may exceed the cost of convict settlement. A final option is the forced migration of nonfree citizens. Convicts, unlike homesteaders, may have no incentive to defend a territory upon an invasion; however, they have the benefit of lowering the gross value of a colony to an aggressive power by more than they lower it to the current owner since they are confined while under the colonial government and could be set free if the territory was conquered by another power.[40]

Several facts of colonial penal colony history seem consistent with this hypothesis. Consider the case of Australia. Britain was interested in the east coast of this country during the eighteenth century almost exclusively for

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[38] At an 1835 House of Lords Select Committee on prisons, W. Cope, governor of Newgate Gaol, stated that "nineteen out of twenty are glad to go" (Meredith, *supra* note 37, at 19). Meredith further states that "[t]he Molesworth Committee came to the same conclusions as its predecessors: transportation was not dreaded and it was not acting as a deterrent to crime in Britain" (*id.* at 19).

[39] I exploit this hypothesis in the context of the American West in Allen, *supra* note 18. There, homesteaders were required to stay on the land for 5 years and make improvements. Both rules provided an incentive to defend the land against non-American claimants.

[40] Hence, on the surface, convict settlement appears similar to homesteading as a form of establishing property rights. However, the model here suggests that they are quite different. Homesteading, in reference to Figure 3, is a movement from the public domain to private property in the neighborhood of V^L, while convict settlement is a movement from the public domain to private property in the neighborhood of V^H. Both accomplish the same thing, but one increases the first-best value of the land, while the other decreases it.

Sydney Harbor. The country had, ironically, been discovered and claimed first by the Dutch, who at the time were a significant force in the region. Starting in 1772, the French began their first claim to the territory. Although ignored by the British, the French sent expeditions in 1785 and 1792, making significant explorations of southern Australia and Tasmania. The French did not cease these efforts until the 1820s. At such a great distance, and with the United States accepting all immigrants, no free English were willing to move to Australia. Furthermore, it was extremely costly to maintain a constant naval presence to defend the territory. The solution was to send prisoners. The British system of transportation eventually led to around 60,000 convicts being sent to Australia. The presence of convicts lowered the first-best value of Australia to the French and other colonial powers.[41] In the case of Australia, the hypothesis might appear silly. How much reduction in the first-best value to a continent can come from 60,000 convicts? However, one must keep in mind that the only value of Australia at the end of the eighteenth century was from Sydney Harbor, Norfolk Island, and a few other strategic locations. On these margins, the convicts could lower the value considerably.

There is no question that transportation to Australia was intentional and that cheaper alternatives existed. Canada was much closer. However, Canada already had an established population of loyalists and a military presence to defend itself. Ironically, it was after the War of 1812 that Britain realized the strategic significance of Bermuda and subsequently established a penal colony there.[42] When transportation costs decreased and as the gross value of the colonies increased to the point where free men were willing to go, the use of penal colonies fell. Hence, these colonies were unlikely to be used as cheap prisons but rather as deterrence to foreign powers by lowering the value of the colony.[43]

Application 4: The Potlatch.   The potlatch was a ceremonial practice of the Kwakiutl and other Pacific Northwest Indians located on the coast of

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[41] On May 28, 1789, 1 month after the infamous mutiny on the *Bounty,* Captain Bligh landed on the east coast of Australia in a small launch loaded with loyal crew members. Bligh choose to continue westward to the Dutch settlement of Coupang on Timor rather than head to the British penal colony in Botany Bay, even though the latter was British and closer. In his diary, Bligh is explicitly fearful of the penal settlement and the possibility that the prisoners may have risen up against the guards. See Richard Alexander Hough, Captain Bligh and Mr. Christian; The Men and the Mutiny 171 (1973), for an excellent account.

[42] Residents of Bermuda were susceptible to disease, and this raised the cost of settlement through free citizens.

[43] C. H. Wilson (Convicts, Commerce and Sovereignty: The Forces behind the Early Settlement of Australia, in Business Life and Public Policy: Essays in Honour of D. C. Coleman (Neil McKendrick & R. B. Outhwaite eds. 1986)) is the only historian to my knowledge that acknowledges that convict transportation was done for sovereignty and not for prisons or naval supplies. In the context of Australia he states, "How, then, to explain this grotesque enterprise? . . . It is, quite simply, the validity of the English claim to the possession of Australian territory under 'international law' as it stood in the mid-1780s" (*id.* at 94). However, Wilson is unable to explain why convicts rather than free men were used to colonize Australia.

British Columbia and Washington. In general, the potlatch consisted of a gift exchange in which a wealthy tribe would invite a lesser neighboring tribe to a feast and supply them with goods. Historians and anthropologists have interpreted the potlatch as a mechanism for generating prestige. D. Bruce Johnsen disputes this claim and argues that the potlatch was an intentional redistribution of wealth in light of a violence constraint.[44] That is, given the fluctuations in salmon harvests, tribes that experienced abundant harvests shared with less fortunate tribes in order to avoid bloodshed. Johnsen also reported the anomalous practice of actually destroying wealth instead of transferring it: "Although potlatch property was most often transferred, there are a few accounts of destruction of property at potlatches. The goods destroyed were normally either canoes, coppers, or eulachen oil. The most significant account of destruction concerns a 'grease feast' in which eulachen oil was poured on the fire by the participants (from both groups) in such large quantities that flames shot up to the rafters and burnt the roof of the lodge. Other accounts of property destruction involve the burning of canoes or the breaking of coppers and their disposal at the bottom of the sea. . . . [A]ctual destruction at potlatches appears to have been fairly infrequent."[45]

John Baden, Richard Stroup, and Walter Thurman, in a discussion of resource use among natives, dismiss the destruction of wealth as an example of extreme wealth and attempts to acquire social rankings: "The natives of the Pacific Northwest may have been wealthy relative to other native groups at the time, but the wars over fishing grounds and territories suggest that the destruction of wealth was not the result of a lack of scarcity or a 'burden of surplus.'"[46]

The destruction of wealth, as argued, lowers the cost of protection and raises the second-best value of the remaining assets. Johnsen is no doubt correct that the potlatch was generally used to redistribute wealth. Redistribution improves the welfare of the poor tribe while at the same time reducing

[44] D. Bruce Johnsen, The Formation and Protection of Property Rights among the Southern Kwakiutl Indians, 15 J. Legal Stud. 41 (1986).

[45] *Id.* at 54–55. Johnsen indicates that the destruction of wealth was rare. I can find no evidence on the frequency of its occurrence. Some, like Peter Farb, suggest that it was not that rare.

[46] John Baden, Richard Stroup, & Walter Thurman, Myths, Admonitions, and Rationality: The American Indian as a Resource Manager, 19 Econ. Inquiry 132 (1981), seems to have been influenced heavily by Peter Farb (Man's Rise to Civilization, as Shown by the Indians of North America from Primeval Times to the Coming of the Industrial State (1968)), who wrote, "The wealth of these new rich seemed limitless, more than they could ever consume at a potlatch. So they instead destroyed vast amounts of wealth before the horrified eyes of the guests, as well as the other contenders, to dramatize the extent of their holdings" (Farb, *supra,* at 150). Also, "A person demonstrated his wealth by giving large portions of it away. But the infusion of white wealth into societies already burdened by surplus altered the character of the affair. . . . When goods were plentiful and cheap they were used lavishly rather than conserved. In some cases, goods became even more plentiful, the marginal utility of the goods declined to such a degree that instead of being given away to demonstrate wealth, the goods were burned" (Baden, Stroup, & Thurman, *supra,* at 135).

the chance of a raid to secure food. However, the exchange of goods has two problems. First, the wealthy tribe may not know to whom to transfer wealth. Salmon runs, according to Johnsen, contained a random element, and in a time of poor communication, it may not have been well known who had experienced a poor run. Hence, it may have been unknown who should be invited to a potlatch. Second, the recipient of a potlatch gift may be reluctant to tell others about such a gift in fear of being raided themselves. The destruction of wealth solves both of these problems. The burning of valuable oil and capital is a dramatic demonstration that would no doubt spread to all surrounding tribes and lower the incentive of all other tribes to raid. Also, guests at a potlatch have no disincentive to reveal the destruction of such wealth to others since it does not increase the chance of a raid on their own territory.

Application 5: Optimal Bundling.   All of the applications above are really detailed cases of product bundling. Here I briefly consider the problem of the optimal bundling of attributes into a commodity as a general application of choosing an asset value at V^*. All goods are made up of attributes, and the final value of the good depends on the extent and the quantity of attributes included. When a difficult-to-protect attribute is included in a good, the entire good may become subject to greater theft and hence protection—lowering the second-best value. It thus increases second-best values to unbundle these attributes and lower the total quantity of attributes to make them less attractive to others.

Examples of goods being supplied in low-quality bundles abound. Office furniture in public buildings, for example, is notorious for being uncomfortable and unattractive. It is not as though manufacturers do not know how to make a comfortable chair; rather, a public institution is simply willing to pay more net of costs for the poorer chair because they will spend less to protect the chair from theft. Toilet paper and soap dispensers in public washrooms make it costly to "use too much." Companies that supply employees with tools, cars, and other easily stolen capital will also supply goods that are of lower quality given that the employee has a reduced incentive to protect the good. Finally, children's skis, snowboards, bikes, baseball gloves, and the like, are of a lower average quality than adult equipment because the transaction cost function of Figure 3 is higher for children than for adults. That is, for a given first-best value of a good, the good is more likely to be in the public domain if "owned" by a child. This means that the optimal bundle will be of a lower first-best value.

V. Conclusion

This paper has shown how a simple extension of Demsetz's early work on property rights can lead to a number of interesting explanations of behavior that are unexplained by the standard neoclassical framework. In particular,

in a world with perfect property rights, there is no room for lowering the gross value of an asset. I have argued here that although lowering gross value makes no sense in such a world, it might make every sense in a world where property rights must be established and protected, that is, in a world of positive transaction costs. There, lower levels of gross wealth may lead to still lower levels of transaction costs such that the second-best value of the asset is higher. In effect, altering the level of attributes in an asset can act as a substitute for explicit enforcement of ownership.

In his original paper, Demsetz claimed that the establishment of property rights unambiguously increases with the value of a good. Several authors have noted apparent counterexamples to this claim. However, these are mostly examples of cases in which the transaction costs have changed with the changes in asset value. In this paper, I have modeled a specific type of transaction cost situation that occurs at high asset values to show that the Demsetz framework is robust to modifications. By articulating the actual nature of the transaction cost problems (that is, the divergence of value of different asset attributes held by the owner and a thief), I have shown how this framework can explain a great deal of puzzling behavior.