10-2009

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Boston University School of Law Working Paper No. 09-46
(October 16, 2009)

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Version 10/09

Abstract: In theory, property rights allow markets to achieve Pareto optimal allocations. But the literature on contracting largely ignores what happens when property rights are imperfectly defined and enforced. Although some models include weak enforcement or poorly defined rights or "anticommons," this paper develops a general model that includes all of these possibilities. I find that combinations matter: policy prescriptions to remedy individual imperfections are sometimes inappropriate under other conditions. For example, stronger penalties for violating rights can decrease Pareto efficiency, contrary to a common view. Also, collective rights organizations, such as patent pools, sometimes worsen problems of overlapping claims.

Keywords: property, markets, externalities, contract enforcement, regulation

JEL Codes: K11, K42, L14, L51

*Boston University School of Law. Thanks to Ben Depoorter, Mike Meurer, Ted Sichelman, Christopher Yoo and seminar participants at the American Law and Economics Association, BU, MIT and at the IP Scholars Conference.

I. Introduction

Property rights most often appear in microeconomics textbooks as an alternative form of regulation to Pigovian taxes/subsidies and to command-and-control policies. All these forms of regulation are seen as means to address externalities, which can be understood as instances of incomplete markets. Following Coase (1960) and Arrow (1970, 1971), the creation of new property rights can be used to overcome market failure and thus facilitate contracting. Optimal contracts "internalize" the externalities, allowing exchange to take place at socially optimal prices.

Based on this principle, property rights prevent overuse of natural resources (congestion externalities), they resolve pollution externalities with tradable permits, and they overcome free-rider externalities in inventions with patents. More generally, because property rights help get the incentives right, many economic historians and growth economists see property institutions as an essential factor, if not the essential factor, in economic growth (see Acemoglu et al. 2004 for a review of this literature).

However, this role for property rights comes with an important caveat: property rights must be "well-defined and enforceable." One textbook puts it this way:

> Note that the existence of both well-defined and enforceable property rights is essential for [Coasean] bargaining to occur....For this reason, proponents of this type of approach focus on the absence of these legal institutions as a central impediment to optimality.[1]

But even if the legal institutions of property are present, real world property rights are not always perfectly defined and perfectly enforced. For example, poorly defined land rights have given rise to squatters on Brazil's frontier (Alston et al. 1999) and problems defining patent rights have caused excessive litigation in some technologies (Bessen and Meurer 2008). What is the significance of imperfect definition and enforcement for the performance of property rights? It is hardly clear that real world property rights work the same as the idealized version found in textbooks. If most property rights

1 Mas-Colell et al. (1995, p. 357). Coase (1960, p. 19) states the qualification this way: "Of course, if market transactions were costless, all that matters (questions of equity apart) is that the rights of the various parties should be well-defined and the results of legal actions easy to forecast."

have at least somewhat less-than-perfect definition and enforcement, does this mean that markets usually fail to get prices right? Generally, what institutional features determine the effectiveness of property rights at getting prices right?

Surprisingly, the theoretical literature seems to lack a general model of property rights where those rights might be both imperfectly defined and/or imperfectly enforced.[2] There is a literature on regulatory compliance with uncertain enforcement,[3] however, that literature does not address specific issues related to property rights. There is also a literature on patents with uncertain enforcement,[4] but this literature also does not deal with imperfect definition of patents. Imperfectly defined property rights can generate overlapping claims on the same asset and overlapping claims can lead to an "anticommons" (Heller 1998, 2008). This has been modeled by Buchanan and Yoon (2000) and Schulz et al. (2002). Shapiro developed a similar model specifically for patents (2001). However, these models generally assume certain enforcement.

This paper sets out a general model of exclusionary property rights where those rights might be both imperfectly defined and imperfectly enforced. It turns out that different *combinations* of these two sorts of deficiencies generate very different patterns of behavior with very different policy implications.

For example, some commentators see overlapping patent rights giving rise to an anticommons in biomedicine, arguing that this has decreased innovation (Heller 2008). Others question this (Walsh et al. 2004), pointing to evidence that biomedical researchers generally ignore patents in deciding their research programs and investments. My model suggests that such behavior is *not* indicative of an anticommons (defined as overlapping rights that are relatively certain to be enforced). Instead,

2 Barzel (2003) describes problems of definition and enforcement as problems of transaction costs. Defining transaction costs broadly as "the resources used to establish and maintain economic rights," he states that (p. 52) "Without transaction costs, property rights are well-defined and enforced, which implies that all imposition of costs on one party by another result in full compensation." But this approach fails to identify concretely what happens when property rights might be poorly defined or enforced.

3 This literature includes Calfee and Craswell (1984), Craswell and Calfee (1986), Kaplow (1990), Kolstad et al. (1990), and Shavell (1984).

4 Models of patents with uncertain enforcement include Bessen (2003, 2005), Bessen and Meurer (2006), Crampes and Langinier (2002), Farrell and Shapiro (2008), Lemley and Shapiro (2005), Meurer (1989), and Shapiro (2001).

evidence that overlapping property rights are ignored suggests a different behavior and possibly a different sort of failure in the patent system (notice failure). This difference is significant to determining whether patents perform well in biomedicine and, if not, what sort of institutional remedy might improve their performance. For example, I find that collective rights organizations such as patent pools might help resolve a true anticommons problem (with well-defined rights), but might aggravate problems of overlapping rights when those rights are not well-defined.

In another example, some commentators see the primary failure of property systems arising from weak enforcement and therefore they argue for stronger penalties. For example, such views were raised in the recent Supreme Court decision in *Ebay*, concerning the automatic issuance of injunctions following findings of patent infringement. My model shows that stronger penalties such as injunctions might work well in some cases, but, if rights are not well defined, then stronger penalties might actually reduce Pareto efficiency.

Of course, applied economists are well aware that the institutional details of property rights matter. An empirical literature studies the importance of institutional features such as titling and public notice for the performance of property rights.[5] Also, economists have done detailed performance evaluation of some new property rights, most notably those involving tradable permits (see Tietenberg 2002 for a review). These evaluations have helped economists improve the institutional design of some of these rights. Yet the approaches that applied economists have used to evaluate and refine tradable permits do not seem to have been generalized for application to other sorts of property rights. Indeed, many new property rights have been created in recent years that have no similar empirical evaluation and no similar detailed refinement of institutional design.[6] A general model might help explain what

5 Bessen and Meurer (2008) on patents, De Soto (2000), Lanjouw and Levy (2002), Besley (1995), Alston et al. (1996), Alston et al. (1999), Clay (2006) on conflicting rights, Miceli et al. (2002) on titling, Miceli et al. (2001), Gerard (2001) on mining patents, Baker et al. (2001) on adverse possession, Lueck and Libecap (2008) on surveying and recording systems, Lueck (1995) on possession rules.

6 Some examples are new rights for databases in Europe, new property-like assets created by through securitization of financial instruments, and the extension of patent rights to cover genes, software, methods of doing business, and mental

institutions help property systems work well and how these systems sometimes fails.

Finally, this model might help clarify the role of property rights in contracting. There is a large economics literature on contracting, including a literature on self-enforcing contracts following Telser (1980), Klein and Leffler (1981) and Williamson (1983).[7] This literature, however, almost exclusively concerns only the parties to a contract, yet, as I argue below, the risk of expropriation by third parties affects contracting. Although there has been some treatment of the effects of state expropriation (see Greif 2005), the literature seems to have ignored the effects of third parties generally. In my model, parties can endogenously choose to expropriate or to contract depending on the nature and enforcement of rights. Moreover, although it is generally recognized that some level of ownership is necessary in order for contracts to be struck (e.g., "possession"), the specific role of *exclusionary* property rights has not been emphasized. As I develop below, exclusionary property rights can limit expropriation by third parties, but they might also introduce additional risks that affect contracting if those rights are not well-defined.

I begin by modeling the contracting of an externality without exclusionary property rights. Then I develop a model with exclusionary property rights. In Section IV, I use the model to explore some policy design issues and I conclude in Section V. In this paper I argue that institutional design depends critically on the specific difficulties faced by a property system, that is, the medicine depends on the malady. In a related paper (Bessen 2009), I consider the diagnosis and performance evaluation of property systems.

processes.

7 See MacLeod (2007) for a review of the theoretical literature and Greif (2005) for a review of the empirical and historical literature.

II. Base Model: Externality without Exclusionary Property Rights

Market exchange and property rights

Arrow (1971) argues that externalities can be understood as instances of market failure once the commodity space has been appropriately defined. If the effect of a polluter's activity on John Smith could be defined as a market commodity, then an efficient market would price this commodity so that the polluter would take the effect of his pollution into account.

Arrow identifies two reasons why markets for externalities might fail: the market might be too small (e.g, it might devolve into a bilateral monopoly) or the commodity might be insufficiently appropriable. In both cases, the market fails because exchange does not occur at a Pareto optimal price that fully reflects the costs and benefits to the parties. In the first case this is because of bargaining inefficiencies. In the second case, Arrow identifies the mis-pricing as a failure of Musgrave's (1959) exclusion principle,

> Exchange in the market depends on the property titles of the things that are to be exchanged. If a consumer wishes to satisfy his desire for any particular commodity, he must meet the terms of exchange set by those who happen to possess this particular commodity, and vice versa. That is to say, he is excluded from the enjoyment of any particular commodity or service unless he is willing to pay the stipulated price to the owner. This may be referred to as the *exclusion principle*. Where it applies, the consumer must bid for the commodities he wants. His offer reveals the value he assigns to them and tells the entrepreneur what to produce under given cost conditions.

When the exclusion principle applies, markets reveal the values agents place on the commodity exchanged. A Pareto optimal allocation is realized only if these values are reflected in market prices.

Property rights enter into the picture because they can provide a legally enforced exclusion when other means of exclusion fail. For example, a grant of patent rights can make inventions excludable even though they might be copied otherwise. In this way, externalities arising from such market failure can be internalized. That is, with property rights, markets can be used to realize Pareto-optimal allocations in the presence of erstwhile externalities, instead of using Pigovian taxes or command-and-

control policies. The ability of property rights to provide exclusion not only allows property rights to work as a form of regulation for inventions and pollution, but it also permits markets for bread-and-butter private goods to price efficiently as well.

But this highly stylized account abstracts away from the detailed workings of property rights. It is helpful to look a little closer. As is well recognized, this mechanism is not restricted to *literal* exclusion. Some forms of technological exclusion—walls, fences, etc.—literally prevent prospective consumers from enjoying the good or service by increasing the cost of expropriation. But legal rights such as patents do not literally exclude. That is, someone can use a patented invention, but the threat of legal enforcement provides disincentives for doing so.[8] What matters in order for market prices to reveal consumer value is not exclusion per se, but the cost of expropriation. As long as the expected penalty or other cost to the consumer for expropriating the good or service is sufficiently large, consumers will be willing to pay an amount equal to the value they privately place on the good or service. Literal exclusion is just the special case where the cost of overcoming the technological barrier is too large.

This more nuanced description has several implications for a model of property rights enforcement: a variety of different property rights and different institutions can provide such disincentives for expropriation. Musgrave is wrong when he states that exchange depends on property title. Legal title is a specific institutional feature of exclusionary property rights, but exchange can also take place with other rights, legal or extra-legal,[9] that do not involve title. Indeed, there is a very active market in illegal drugs that does not rely on property titles or other legal rights at all.

Economists often do not distinguish between different types of property rights, typically describing property rights as "bundles of use rights" that are exchanged in market transactions (see for

8 Ostrom (2003) notes that Olson (1965) attempted to identify some goods as inherently "excludable" but later scholars have identified that collective action problems arise from a broader set of goods.

9 What Barzel (2003) calls "economic rights." Social norms also provide a form of enforcement outside the law.

example Demsetz 1967 or Alchian and Demsetz 1973). However, as a number of legal scholars have pointed out, this can be confusing, especially for the analysis of legal property rights.[10] So it is helpful to review some of the differences among property rights. Below I also look at differences in the institutions that support these different rights.

First, I am concerned here with exchange between private agents, so I am concerned with privately owned property, not common property (owned by a group) or state property, although, with appropriate modification, the model can apply to these types of rights, too.

Second, some property rights are recognized legally and enforced by courts or administrative agencies; others are privately enforced by a variety of mechanisms including those involving reputation, repeated interaction, boycotts and threats of violence. Some of these private enforcement mechanisms are formal and others are implicit and informal. For ease of exposition, I will frame the discussion in terms of legal property rights, but the analysis applies more generally and, in practice, market participants often rely on combinations of private and legal enforcement mechanisms.

Third, not all property rights are use rights; some are rights of exclusion. Rights of exclusion are typically accompanied by residual use rights. For example, the right to clean air is a use right—potential polluters are not excluded from using the air, but they might face penalties if they pollute, depriving others of their rights to use clean air.[11] On the other hand, legal property rights in land are explicitly rights to exclude others from using or accessing the land; this implicitly includes residual rights to use the land in any way the landowner sees fit (within certain legal limits and limits on uses that affect others). Of course, rights can be mixed, e.g., ownership of land can include specific easements (use rights) granted to other parties. I will explore exchange both with and without legal exclusionary rights.

10 See, for example, Merrill and Smith (2001) or Posner (1992, p. 46-7) who writes, "Some economists, indeed, use the term property right to describe virtually every device—public or private, common law or regulatory, contractual or governmental, formal or informal—by which divergences between private and social costs or benefits are reduced."

11 For example, the rights in Coase's 1960 paper on social cost are use rights, not exclusionary rights.

A related distinction is whether legal enforcement uses a "property rule," where the owner obtains an injunction, or a "liability rule," where the owner is compensated for damages (Calabresi and Melamed 1972). Exclusionary rights often receive injunctive relief because courts might find it difficult to calculate the value of residual rights that have been lost. In what follows, I initially assume that contracts specify damages equal to the value of an injunction. Later, I look specifically at the effect of changing the penalties for violating property rights.

Market exchange does not depend on exclusion per se nor does it depend on exclusionary property rights. For example, in the United States there is no formal property right that covers databases.[12] Nevertheless, if I possess a database, I can contract to sell it to you. My possession (a more limited notion of property) of the database might be sufficient to induce you to pay for the database, for example, if I keep it hidden. However, without an exclusionary right, I have no protection if a third party gains access to the database because you lose it or because they are able to steal it from you (unless the theft can be proven). Nevertheless, while it is true that market exchange does not *require* exclusionary property rights, I show below that exclusionary rights might be essential to achieving *efficient* exchange when there is a risk of expropriation by third parties.

Once we understand that exchange depends on expropriation disincentives rather than exclusion per se, then it becomes clear that pricing might be imperfect. That is, if the disincentives are weak, an asset holder might only be able to charge a price that is less than the Pareto optimal price. This might seem to be a worrisome problem because one might expect that the enforcement of *most* rights is at least somewhat imperfect, so this might suggest that markets usually fail to price correctly.

As we shall see below, such a conclusion is not necessarily warranted. To explore the efficiency of exchange I develop formal models for contracts with and without exclusionary property rights.

12 In *Feist v. Rural Telephone* the Supreme Court ruled that copyright only protects the particular creative expression of a published database(e.g., the original selection of data and the arrangement by which it is displayed), not the data itself. Europe has a database right based on the effort invested in developing the database.

Externality

I begin with a simple model of a congestion externality of the sort that has been used to model natural resources.[13] Since the focus of this paper is on the effect of property rights on the pricing of assets, this same analysis can be done easily with a positive externality instead, including positive externalities with non-rival goods. I choose to model a congestion externality because that is the sort of externality that Garret Hardin (1976) and others have used to discuss property rights.

Let x designate the extent of an activity undertaken using a scarce resource. This variable could represent the number of cattle grazing on a pasture (Hardin 1976), or the number of fishing boats on a particular fishing ground (Gordon 1954), or the number of cars in a parking lot (Buchanan and Yoon 2000). Let c be the unit cost of this activity, for example, the cost of a head of cattle or of a fishing boat rental (in the parking lot example, $c = 0$).

Let $v(x)$ be the average consumer value derived from the activity for each unit of x, where v is positive and twice differentiable. Thus v represents the value of each head of cattle after grazing, or the average catch per boat on the fishing ground or the value of parking a car. The congestion externality implies that $v'(x) < 0$. I further assume that the marginal effect of the externality is non-decreasing, that is, $v''(x) \leq 0$.[14]

Note that v implicitly includes both technological factors, such as the the weight gain of each head of cattle, and market factors, such as the price per pound of beef. Because of the latter, v reflects the relative scarcity of the asset; that is, for example, if there is a lot of pasture land, then the price of beef will be relatively low and so the value derived from grazing on this particular pasture will be lower than if pasture land were less plentiful. Finally, note that v also reflects investments made in improving the asset. In some contexts, for example patents on inventions, the emphasis of analysis has

13 See, for example, Gordon (1954). For an early model of road congestion externalities see Knight (1924).

14 My results will hold with a less restrictive assumption, however, this assumption seems reasonable enough and it simplifies the exposition. This restriction is needed to ensure stability of the equilibria.

been on investment incentives.

Social Optimum

Assume that there are N prospective users of the asset and that both the users and the social planner are risk neutral. The net social surplus is

(1) $S(x) = v(x)\,x - c\,x.$

To assure a well-behaved social optimum with $x > 0$, I assume further that

(2) $v(0) > c$ and $\epsilon \equiv -v'(x)\,\dfrac{x}{v} < 1$

where $\epsilon(x)$ is the elasticity of v with respect to x. Then the first order condition for the social optimum and the corresponding net surplus are

(3) $x^S = x$ such that $v(x^S) = \dfrac{c}{1-\epsilon(x^S)}, \qquad S = (v(x^S) - c)\,x^S$

This first order condition provides our benchmark of Pareto optimality. Below I will derive first order conditions that can be compared to the one in (3).

Open Access

Now consider what happens under open access, that is, each of the N users independently chooses an activity level x_i, i=1,2,...,N. The profit of the ith user is then

(4) $\pi_i = v(\Sigma x_i)\,x_i - c\,x_i$

so that under Cournot assumptions, the symmetric Nash equilibrium yields a first order condition and a corresponding joint activity level, x^O,

(5) $x^O = \Sigma x_i$ such that $v(x^O) = \dfrac{c}{1-\epsilon/N}$

Taking the implicit derivative of x^O with respect to N, it is straightforward to show (see Appendix) that $x^O > x^S$ for $N > 1$, yielding the standard result that open access generates overuse.

Contract

There are many well-known ways to overcome this common pool problem (e.g., Ostrom 1990 or Wright 1983), one being through contracting and property rights. Since I wish to develop the specific institutional features of legal exclusionary property rights, I will first develop a contracting model where there are no rights of this type, although there are other property rights. Specifically, I initially assume that the asset is possessed by one party (implying some level of ownership), the rights of ownership can be enforced against the non-owning party to the contract (perhaps imperfectly), but these rights do not fully protect against expropriation by third parties. In this scenario, which is typical of many types of property rights, exchange is possible because the threat of enforcement provides some impetus to contract, although there is also some degree of expropriation by third parties.

Suppose that party A possesses the resource in the above model. For example, landowner A possesses the pasture. I assume that it is advantageous for another party to manage ranching, so party A seeks to lease or sell the pasture to one or more ranchers for grazing. A contract might then specify a price, p, that A charges ranchers per head of cattle using the pasture.

Since I am interested in exploring the effect of property rights on markets (as opposed to bilateral monopoly bargaining), I assume perfect competition between ranchers. That is, there are many prospective ranchers willing to contract for the pasture, so the landowner has all the bargaining power. The landowner can continue selling rights to use the pasture until ranchers can no longer make a profit. With perfect enforcement of property rights, this zero profit condition determines a level of usage,

$$\hat{x}(p) = x \quad \text{such that} \quad v(x) - p - c = 0. \tag{6}$$

The landowner then chooses a price to maximize rents,

$$p^* = \arg\max_p R, \qquad R(p) \equiv p\,\hat{x}(p) \tag{7}$$

which solves to (see Appendix)

(8) $$x^* = x \text{ such that } \quad v(x^*) = \frac{c}{1-\epsilon}, \quad p^* = v(x^*) - c$$

By comparison with (3), it can be seen that this price generates a socially optimal allocation and the landowner's rent, *R*, equals the net social surplus.

By contracting with one or more ranchers, the landowner internalizes the congestion externality. However, implementing this contract depends on the effectiveness of enforcement. There are two sorts of failures that might limit the ability of the landowner to collect rent *R*. First, contract enforcement might fail. For example, suppose that rancher B uses the pasture but does not pay the rent. The landowner can then take enforcement action—either private enforcement or legal enforcement through a breach of contract lawsuit. However, if contract enforcement is not perfect, then sometimes rancher B might succeed in getting away without paying. I model this by assuming that an enforcement action costs each side *L*, but the asset owner only wins with probability $1 - q$. If q is positive, then enforcement is imperfect.

Second, possession of the pasture might be also imperfect, allowing third parties to expropriate some part of the benefits. For example, with imperfect fencing, neighboring ranchers might be able to graze their cattle on the pasture at times. This reduces the benefit that rancher B can derive from the pasture and thus reduces the amount of rent he can afford to pay to A.[15] This notion of possession can be modeled as follows: let c_T be the additional marginal cost to a user who lacks permission to use the asset from the asset owner so that it costs that user $c + c_T$. In other words, c_T is the marginal cost imposed by technological means of exclusion. Possession is imperfect if $c_T < p^*$, so that a user might choose to expropriate rather than to pay the owner's optimal price.

The effect of these imperfections on Pareto efficiency can be analyzed in a simple game. To keep things simple, I assume that the asset owner prefers to contract with a single user, B_1, e.g., a single

15 A related problem is that landowner A might not be able to credibly commit to not expropriating some of the value himself, e.g., by grazing some of his own cattle on the pasture. (See Lanjouw and Levy 2002). This concern does not materially affect the results of interest here, so I do not consider it explicitly.

rancher who uses the entire pasture. This would be the case, for example, if monitoring costs increased with the number of contracts. Then the game has the following stages (see Figure 1):

1. Party A declares a price p.

2. Parties B_i, i =1,2,...N decide whether to expropriate or not.

3. If party B_1 decides not to expropriate, then A contracts with B_1 to use the asset at activity level x. The contract also specifies the rights of the parties and liquidated damages, that is, the level of damages that apply when the contract is found to be breached. I assume that the cost of writing and negotiating the contract is zero because I am concerned with contrasting simple contract with exclusionary property rights, where the costs of definition and notice are substantially greater. Because B_1 could be replaced by any other prospective asset user, B_1 has no bargaining power and thus makes zero profit.

4. Party B_1 sinks cx into the use of the asset. For ease of exposition, I model this as an investment that is sunk before B_1 chooses to pay A. Obviously the game could be modeled in other ways, e.g., A might require payment before B_1 can access the asset (in which case the relevant breach of contract would be A reneging on the promise of access). Such alternatives are irrelevant to the general results I wish to draw, so this choice does not affect the generality of my results. It is significant that I have assumed a positive sunk cost and below I explore cases where sunk costs approach zero.

5. Expropriators choose to enter or not, paying $c + c_T$ for each unit of use. If B_1's use of the asset is sufficiently large, then expropriation will not be profitable. If B_1 has contracted with A, then at this stage B_1 chooses whether to pay A or not.

6. A can costlessly detect if any party is using the asset. If B_1 does not pay, A and B_1 renegotiate the contract. I assume that the negotiation, if successful, realizes a Nash bargaining solution with equal shares of the net surplus.

7. If negotiations breakdown, then A initiates enforcement action (a lawsuit) against B_1 at a cost L to each party. Party A wins the suit with probability $1 - q$. If party A wins, it receives liquidated damages. For concreteness and for comparability with the exposition of property rights below, I assume that liquidated damages are set at the gross benefit, $v(x)\,x$. This is the effective penalty on B_1 if A were to obtain an injunction against B_1 (with full bargaining power). Below I explore the effect of different enforcement penalties.

The solution regions depend on the values of q and c_T (see Figure 2). First, consider the solutions when technological exclusion works perfectly, namely, when $c_T > p^*$. If q is small enough—that is, when contract enforcement is sufficiently certain—then the landowner can choose the optimal price, p^*. Specifically, if[16]

16 $\in$ is evaluated at x^*.

$$q \leq \underline{q}, \quad \underline{q} \equiv 1 - \epsilon ,$$

then the landowner will choose the optimal allocation in (8). This is zone I. In this region, contract enforcement is relatively certain so that the outcome is the same as it would be if contract enforcement were perfect (that is, if $q = 0$). If q is larger than this threshold, contract enforcement is relatively uncertain. In this case, the rancher can do better by forcing the landowner to renegotiate or go to court.

Specifically, as long as L is not too great,[17] there are four equilibrium regions (see Appendix):

I. $q \leq \underline{q}$ and $c_T > p^*$

In this region of relatively certain contract enforcement, party A charges p^* and B_1 pays this amount. Here, q is small enough so that B_1 earns less from renegotiating than from paying up front.

II. $\underline{q} < q < q^F$ and $c_T > (1\text{-}q)\ c/q$ (where q^F is defined below)

In this region of relatively uncertain contract enforcement, it is advantageous for B_1 to renegotiate. On renegotiation under the threat of enforcement, B_1 agrees to pay A

$$R = (1 - q)\, v(x)\, x$$

where x is the activity level specified in the contract. Party A chooses this level so as to maximize rent R subject to the zero profit constraint, specifically,

$$x^w = x \ \text{such that} \quad v(x) = \frac{c}{q}$$

Alternatively, A could charge B_1 this rent R upfront; then the parties would be indifferent whether B pays or renegotiates.

17 The specific conditions are $L < cx$ and $L < R$. These conditions ensure that the threat of enforcement is credible for both parties when $q=\underline{q}$.

III. $q^F \leq q, \qquad q^F \equiv 1 - \frac{L\,q}{c\,x^w}$

In this region, party A cannot credibly enforce the contract because its cost of enforcement exceeds what it expects to earn through enforcement. If there are even small transaction costs, then A will not enter into the contract in the first place, thus this is a region of contract failure.

IV. Here c_T is sufficiently small so that A charges a price equal to (infinitesimally smaller than) c_T. If A sets a higher price, than all users will choose to expropriate, paying A nothing.

From these equilibria, two propositions can be readily derived:

Proposition 1. Passively enforced contracts. If $q < \underline{q}$ and $c_T > p^*$, then the contract is followed without resort to renegotiation or the threat of litigation. Moreover, $x^* = x^S$ so that a Pareto optimal allocation is achieved.

Proposition 2. Inefficiency of expropriation. If $c_T < p^*$, then the level of resource use, x, is greater than the Pareto optimal level.

This first proposition says, in effect, that under a range of conditions, as long as exclusion is effective, minor imperfections in contract enforcement do not matter. When enforcement is sufficiently likely to occur, contracts are passively enforced in the sense that they are not renegotiated nor is active enforcement required—only the threat of enforcement is needed. Pretty good enforcement is often good enough.

The intuition driving this result is that sunk costs drive a wedge between the amount the buyer will receive if he pays and the amount he can expect from renegotiation. Because sunk costs do not affect the buyer's threat point, the buyer risks losing the gross value in a lawsuit (not the net value). In effect, sunk costs mean that the buyer has more at risk from losing a lawsuit than he can gain from winning. This means that the buyer makes out better by avoiding renegotiation if q is not too large.

A similar intuition drives a similar result by Williamson (1983), who shows that relationship-specific investments prior to exchange might be sufficient to achieve contract compliance even without legally enforceable rights. Here, in contrast, the sunk investment occurs after (partial) exchange. More generally, holdup is often seen as a scourge of contracting; my model suggests that some forms of holdup might help make contracting and markets generally more efficient because with holdup, actual recourse to enforcement is not usually required.

Of course, not all markets involve sunk costs. Spot or cash markets do not. These markets exhibit features suggesting alternative means for ensuring compliance. Noncompliance in these markets is often subject to criminal sanctions. Cash markets are often limited to simple standardized commodities so that questions of possession and definition can be resolved accurately and efficiently, allowing harsher sanctions to be effective (I explore this relationship below). Also, with valuable spot commodities, agents are sometimes required to post bond before they can participate in the market.

Thus overall, modest imperfections in contract enforcement might not pose much of an impediment to achieving Pareto efficient market exchange. On the other hand, from Proposition 2 it is clear that a risk of expropriation causes the price and the extent of activity, x, to diverge from Pareto efficient levels. This means that effective contract enforcing institutions alone are not sufficient to realize efficient markets—a point that has not been well addressed in the contracting literature. Institutions are also needed to curtail the risks of expropriation by third parties; these are the institutions of exclusionary property rights.

This provides a rationale for exclusionary property rights. Other types of property rights do not provide sufficient protection against third party expropriation. Usually, the need for exclusionary property rights is expressed as a need to provide secure incentives for investment. That rationale is not essentially different from the one I propose here. My model can easily be extended to include a stage where party A invests in the quality of its asset prior to exchange. Then the investment incentive

depends directly on the rents received and so any mis-pricing distorts investment incentives. Additionally, the model could accommodate a "null trade" to include those situations where party A is the preferred user of the asset.

III. Private Exclusionary Property Rights

Institutional comparison

This critical role in reducing expropriation by third parties defines the essential difference between contract and exclusionary property rights. This can be seen by comparing the features of the institutions associated with each (see Table 1). Contracts define the rights and duties of the two contracting parties. In contrast, legal exclusionary property rights grant residual use rights (not specifically defined) to the owner and they impose duties on the world, including parties both known and unknown, to avoid using or accessing the property.

Property rights institutions do this by providing clear public notice of the boundaries of the rights combined with strong penalties for trespass or infringement. An essential aspect of private exclusionary property is that the boundary information is designed so that third parties can be put on notice and can conduct clearance searches at low cost. Boundaries are described in standardized forms (there are legal restrictions on the forms that property rights can take called *numerus clausus*; see Merrill and Smith 2000), this information is made publicly available, third parties can interpret this information and insurance can be obtained against errors in interpretation. In addition, the enforcement of property rights sometimes involves stronger measures than does contract enforcement; typically, property owners can more readily obtain injunctions against infringing activities and some property rights are protected with police monitoring and criminal sanctions. Below I explore the relationship between clarity of notice and strength of enforcement.

Note that not all exclusionary rights have all of these institutional features. For example, low

value personal property does not have formal filing and recording of title (Baird and Jackson 1984).[18] However, in this case, simple possession typically provides relatively clear notice without the costs of titling, etc. For example, there is little question over the ownership of the shirt on one's back. Nevertheless, the critical difference with contract is that exclusionary property rights have to give third parties notice of ownership.

Finally, note that my focus here is on legal exclusionary property rights. There are private exclusionary property rights, including rights maintained by technological barriers (walls, forts) and also rights maintained by private organizations such as guilds[19] or mining camps (see Libecap 1989). In principle, the advanced legal institutions providing public notice, etc., can provide for more effective exclusion (perhaps at higher cost) than private forms of exclusionary property. However, the institutions of legal property rights are quite sophisticated, they involve some significant infrastructure and their effectiveness of exclusion depends on their implementation.

Modeling exclusionary rights

Because of this, clearly these institutions might fail to work perfectly. While exclusionary property rights have the potential to limit the dissipation of rents to third parties, they can, in some circumstances, also *cause* dissipation of rents to third parties. This is because rights sometimes overlap, meaning that multiple parties have rights that effectively make claims on a single usable asset. How do overlapping rights occur? There are generally two sorts of reasons:

1. Technological indivisibilities. This occurs when there are well-defined assets, but they are sub-divided below the optimal size of their best economic use. For example, a shopping mall needs a minimum amount of land. If a shopping mall is the best use for some land, but that land has been divided into smaller residential plots, then the owners of those plots hold overlapping

18 Higher value types of personal property, such as automobiles or boats, often do have title registries.
19 See *Fashion Originator's Guild v. FTC* (1941) for a modern example.

claims to the best use of the combined asset. This situation can arise because of the nature of the initial granting process (e.g., the Soviet transition to market economy as noted in Heller 1998), because of transfers (e.g., inheritance by multiple siblings), or because of changing economic opportunities (e.g., a shopping mall becomes more profitable than it was previously).[20]

2. Institutional failures in the specification, notice and interpretation of rights. An exclusionary property right requires public specification of property boundaries and title, efficient access of this information by both property owners and third parties, and predictable interpretation and enforcement. To the extent that these institutions fail to perform, there will be "Type I" errors (false positives), where multiple claims to the same asset are recognized. These institutional failures can happen in two general ways. Corruption, political influence and the general breakdown of the rule of law can give rise to overlapping claims. Or there might be specific flaws in the design of the institutions (e.g., unpredictable legal doctrine or excessive search costs) or specific technological difficulties (e.g., the difficulties defining boundaries for copper veins or software patents).[21]

In general, the different types of overlapping claims give rise to different patterns of enforcement. As in the contract model, the behavior in this model of exclusionary rights depends on the relative certainty of enforcement of the rights. As before, relatively certain rights are those where[22]

$$q \leq \underline{q}, \quad \underline{q} \equiv 1 - \epsilon \tag{9}$$

and uncertain rights are those with $q > \underline{q}$. In the case of technological indivisibilities, the rights are well defined and therefore the rights should be relatively certain in regimes where the rule of law is

20 Parisi et al. (2005) frame this issue as one of an asset being broken into complementary components.

21 The notion of overlapping rights in the latter case can be generalized to include cases where unpredictable legal doctrines (such as the doctrine of equivalents in patent law or fair use in copyright law) might allow rights holders to make claims on works of other parties who might only have informal ownership.

22 And ϵ is evaluated at the optimal x for the asset owner.

effective. Institutional failures, on the other hand, give rise to claims that have relatively uncertain rights. When institutions fail because of corruption, political influence or the breakdown of rule of law, then *most* claims (not held by the elite) might have a low probability of enforcement. In this case, as we saw in the simple contracting model above, contracts, if they are formed at all, are Pareto inefficient. On the other hand, when the institutions merely have flaws, then a mixed regime might be expected, where some rights are relatively certain and other rights are relatively uncertain.

With this in mind, I explore the exclusionary property model with three different assumptions about the distribution of rights on the relevant asset:

1. Single owner.

2. Overlapping Certain Rights (Anticommons). There are *N* owners, each with a relatively certain right. This has been described by Heller (1998) as an "anticommons."

3. Overlapping Mixed Rights (Notice failure). One owner has a relatively certain right and *N* other owners have relatively uncertain claims. As noted, mixed rights can arise from failure of the notice function of property.

I do not explicitly consider the case where multiple parties have claims that both overlap and are uncertain because it is similar to the case of a single owner with an uncertain right.

I seek to model the public notice function of property institutions in a very simple way (for a richer model see Meurer 2008). This function involves a variety of informational activities by both asset owners and asset users. Asset owners can take actions to improve the clarity of information provided to the public or to reduce the third party costs of obtaining boundary information. For example, mining claims can be patented and land boundaries can be posted with no trespassing signs. Asset users search for boundary information and attempt to clear rights.

To capture an essential aspect of these activities, I assume that asset owners can choose to spend u to improve the notice of their rights and I assume, further, that this cost is not so large as to deter formal acquisition of rights.[23] I assume that prospective users of an asset know the number of rights that claim the asset but they do not know the identities of those rights holders.[24] They search costlessly for these identities and find only the identities of those rights holders who have spent u to improve their notice. They then contract with those rights holders. As we shall see, an important feature of the model is that it does not pay all rights holders to spend u, and, consequently, some rights are not contracted over ex ante.

For this model, I assume that there is no effective technological exclusion, that is, $c_T = 0$. This means that exclusionary property rights are the only means of preventing expropriation. In Bessen (2009), I consider a model that includes both technological exclusion and legal exclusionary rights, giving rise to some situations where asset owners choose not to obtain title. Since this is not the focus of this paper, I abstract away from those concerns here.

As in the contracting model, I assume that asset owners prefers to contract with only one user, B, from among many and that competition among prospective users ensures that asset owners have all the bargaining power, leaving the one contracting user with zero profits. To keep things simple, in the case where users find expropriation preferable to contracting, I model enforcement against a single expropriator. Situations with multiple expropriators are equivalent to this if enforcement costs have constant returns to scale, that is, if each enforcement action against one of m expropriators costs each party L/m. Clearly, non-constant returns to scale can give rise to size-based strategies, but such refinements are beyond the scope of what I wish to consider here.

Another difference with the simple contract model concerns monitoring. The parties to a contract

23 For an example of cases where the costs are excessive see De Soto 2000.

24 This is a strong assumption and it could be modeled more realistically as a game of Bayesian inference where the asset users have priors about the number of rights holders and in a perfect Bayesian equilibrium the actual number of rights holders correspond to their (possibly) updated priors.

know each other and therefore the asset owner knows whose activity needs to be monitored for compliance with the contract. With exclusive property rights, anonymous third parties must be monitored for trespass or infringement. All else equal, monitoring would seem to be a more significant problem for exclusive property rights than it is for a simple contract. A richer model would want to include the costs of monitoring and the probability of discovering trespassers or infringers. However, it turns out that the effect of monitoring failure is similar to the effect of other failures of enforcement, so I simply treat monitoring by interpreting the variable q to reflect the combined probability that the asset user escapes monitoring *or*, in the case that monitoring is effective, enforcement fails.

Finally, I assume that each of the asset owners makes Cournot assumptions, that is, each owner maximizes his profit while taking the actions of other property owners as given. Where there are multiple property owners of the same type, I assume a symmetric Nash equilibrium. And I assume that the asset owners act independently, not forming coalitions. Below I explore the incentives for pooling or aggregating property rights.

Given these assumptions, the stages of the game are (see Figure 3):

1. Asset owners A_i, $i = 1,..., N$, each decide whether to spend u on improving notice or not.

2. Party B searches for the identities of asset owners and finds those who have spent u. Each ith such owner declares a price, p_i, and they bargain with B to a contract that specifies these prices and the maximum activity level x consistent with B's zero profit condition (competitive market) given these prices.

3. B sinks cx into the use of the asset.[25]

4. B chooses whether to pay each asset owner or not, including asset owners who did not put B on notice in stage 1 (they assert their rights at this stage).

5. If B does not pay asset owner A_i, then A_i and B renegotiate.

6. If negotiations breakdown, then A_i initiates enforcement action against B at a cost L to each party. Party A_i wins the suit with probability $1 - q_i$, independently of actions taken by other asset owners. If party A_i wins, it receives an injunction preventing B from selling the product.

25 I assume that B chooses to invest the required level of activity because if A detects a lower value of x, then A can threaten to let additional users access the asset.

Equilibria

The equilibria for each of the three distributions of rights are derived in the Appendix and summarized here:[26]

1. Single Owner

In the case of a single owner holding a relatively certain right, the owner spends u to notify asset users, the asset user follows the contract, and the resulting activity level is socially optimal:

(10) $$x^* = x \text{ such that } \quad v(x^*) = \frac{c}{1-\epsilon}, \quad p^* = v(x^*) - c \cdot$$

By comparison with (3), clearly $x^* = x^S$ and the equilibrium is Pareto efficient. Note that if A did not spend u to establish notice, then B, knowing that an unidentified property holder existed and anticipating a dispute, would use the resource at a level less than x^* to reduce exposure in that dispute (see Appendix). As a result, A would earn less. So in this case, A instead puts B on notice and B passively follows the contract.

If, on the other hand, the property owner has a relatively uncertain claim, $\underline{q} < q < q^F$, then the owner will not spend u, the asset user will not contract ex ante, and the parties will negotiate ex post under the threat of a lawsuit. In this case, neither party can gain anything by contracting ex ante, so A has nothing to gain by spending u to put B on notice. In this case, the activity level will be set at

(11) $$x^U = x \text{ such that } \; v(x^U) = \frac{c}{q}$$

Since by (9), $q > 1 - \varepsilon$, comparing this with (3),

$$v(x^U) < v^S, \quad x^U > x^S$$

In other words, with a single relatively uncertain property right, the resource is overused.

26 As above, I assume that enforcement costs, L, are sufficiently small so that both parties have credible threats of going to enforcement in Stage 6 when $q=\underline{q}$. The cases with larger enforcement costs generate different solution regions, but are less interesting to the analysis here. Specifically, these conditions are $L < cx$ and $L < (1-q)vx$.

Finally, if the right is so uncertain that $q > q^F$, then the property owner neither spends u nor enforces the right. This is equivalent to open access.

2. Overlapping Certain Rights (Anticommons)

With N relatively certain property claims on a single asset, the equilibrium is equivalent to Buchanan and Yoon's (2000) model of an anticommons and, with slight modifications, to Cournot's complements model (1838) and to Shapiro's (2001) model of patent thickets. Subject to the condition that $N\epsilon < 1$, the symmetric Nash equilibrium level of use is

$$(12) \qquad x^A = x \text{ such that } v(x^A) = \frac{c}{1 - N\epsilon}$$

and the corresponding sum of prices paid to asset owners is

$$\Sigma\, p_i^A = v(x^A) - c = \frac{N\, c\, \epsilon}{1 - N\epsilon} > p^* .$$

Comparing (12) to (3) I show in the Appendix that

$$v(x^A) > v^S, \qquad x^A < x^S$$

3. Overlapping Mixed Rights (Notice failure)

In this case, a single property owner, A_0 holds a relatively certain right ($q_0 < \underline{q}$) and N other parties hold relatively uncertain claims on the asset ($q^F > q_i > \underline{q}$, $i = 1,...,N$). For simplicity, assume that all of these N parties hold rights with the same certainty, $q_i \equiv q_w$.

Following the same logic as in the case of the single owner, A_0 spends u to put parties on notice, but the other property owners do not. Instead, they negotiate ex post.

These choices lead A_0 to contract the level of activity at:

$$(13) \qquad x^N = x \text{ such that } v(x^N) = \frac{c}{1 - \epsilon - N\,(1 - q_w)}$$

By comparison with (3), I show (see Appendix) that this outcome is also suboptimal,

$$v(x^N) > v^{S,} \quad x^N < x^S$$

Note that the effect of enforcement uncertainty here is the opposite of the effect in the single owner case. Here there is underuse, while the single owner with uncertain rights experiences overuse. The difference is the coordinating role played by A_0. This owner anticipates the losses that the user will experience as a result of the uncertain claims held by others. Effectively, these "tax" the output, reducing the level of use in the optimal contract. Of course, A_0 could indemnify user B against other conflicting property claims, but the result would be the same because the amount of the indemnity would equal the amount of loss that A_0 anticipates in this equilibrium.

* * *

The Pareto optimal ideal is realized only when there are single owners with relatively certain rights. Enforcing institutions can make Type I errors—false positives, when claims that should not be recognized are—and Type II errors—when valid claims are not enforced. This gives rise to at least three ways that property rights can fail:[27]

1. All or most property rights can have insufficient certainty of enforcement, such as some countries where the rule of law has broken down.

2. Property rights can have relatively certain enforcement, but overlap. Such was the difficulty of newly privatized Moscow stores where, for a period of time, there were too many owners to coordinate the operation or sale of the stores (Heller 1998).

3. Some property rights are relatively certain to be enforced, but they often face competing claims that are less certain. This is often the situation with squatters around the world, such as squatters in California during the 1850s and 1860s after the transition from Mexican rule (Clay

27 There are other ways property can fail as well, but these three seem to occur with some frequency, e.g., it is estimated that 35% of the of the total urban population of developing countries lives in squatter settlements (Hoy and Jimenez 1991). Neuworth (2006) estimates that there are about one billion squatters worldwide.

2006) or squatters on remote sections of large Brazilian estates today (Alston et al. 1999). This is arguably the case with software patents in the US (Bessen and Meurer 2008).

The model suggests that these different patterns of rights should be associated with different patterns of behavior. This means that these patterns can be used to evaluate the performance of rights institutions. Of course, an ineffective or corrupt judiciary, low damage awards and a low value of property (compared to intrinsic worth) provide evidence of weak enforcement.

But evidence can also be gleaned from the performance of other institutions of the property system such as those that provide public notice. For example, do rights holders obtain title and is it easy for them to do so? Do third parties conduct thorough clearance search or do they, instead, tend to ignore many rights? And can they search at low cost and high reliability? For example, do low-cost third party services exist to assist in rights clearance such as surveyors and title insurance? Are there many costly disputes that arise after asset users sink substantial costs?

All of these details reflect on the particular pattern of performance of property institutions. For example, squatting in both California and Brazil is associated with a high level of disputes, both in the courts and government agencies and also occasional violent conflict between private parties. As the model suggests, this is suggestive of a pattern of mixed rights possibly arising from inadequate institutions of public notice.[28]

Understanding the particular pattern of strengths and weaknesses of a property system is particularly important because, as the next section develops, the remedies for failure in property institutions depend on the specific nature of the failure.

28 In California there was uncertainty over the validity of land grants made under Spanish rule. In Brazil, there is uncertainty because of a constitutional provision that land owners must actively use land in order to continue owning it.

IV. Remedies

"Stronger" rights

In many circumstances where property rights are uncertain, increased deterrence seems to be a logical remedy. Increase the penalties for non-compliance and asset users will be more likely to respect property rights, making those rights passively enforced. Thus, for example, there are calls to criminalize intellectual property infringement in both the US and Europe. More generally, "stronger" property rights—often meaning stronger penalties—are commonly seen as more effective property rights. This approach seems natural when the enforcement of property rights fails to sufficiently deter trespass, theft or infringement.

However, this logic does not seem completely reasonable when pushed to the extreme. Imposing a mandatory death penalty for patent infringement might not improve the effectiveness of patent protection for inventions; it might, instead, prevent people from introducing new technologies. This suggests that there might be circumstances where stronger penalties do not improve the effectiveness of property rights. These issues appeared in the recent Supreme Court case of *Ebay v. MercExchange* over the question of whether an infringed patent holder could expect to get an injunction against the infringer more or less automatically. The court held that an injunction should not be automatic, considerations of equity should play a role, and Justice Kennedy, in particular, argued that, "The potential vagueness and suspect validity of some of these patents may affect the calculus" of this determination. Critics, on the other hand, argued that this decision undermined the strength of patents and made them less "property-like."

Justice Kennedy's notion receives partial support from my model. In this model, a property holder who wins a lawsuit and obtains an injunction expects to earn $v\,x$ (assuming the property holder has all the bargaining power at this point). Loosely speaking, a rule where the property holder does not

always obtain an injunction might lead to an expected transfer from the defendant of $s\ v\ x$ where $s < 1$. On the other hand, if a property holder receives an injunction plus enhanced damages or some other enhanced penalty, then the transfer might be $s\ v\ x$ where $s > 1$. The variable s is thus a measure of the "strength" of enforcement.

Then the following proposition can be shown to hold (see Appendix):

> Proposition 3. Suppose that the value a property owner obtains from winning a lawsuit is $s\ v\ x$. Then an increase in s:
>
> a.) increases $\underline{q}$,
>
> b.) increases q^F, and,
>
> c.) increases the amount that a property owner can expect to earn from pre-lawsuit negotiations, $(1 - q)\ s\ v\ x$. Owners will earn this amount in the range $\underline{q} < q < q^F$.

The effect of a change in s depends on the distribution of rights:

> a.) if there are one or more owners with relatively certain rights, $q < \underline{q}$ (both before and after the change), then these changes have no effect on the outcome,
>
> b.) if a single owner has a relatively uncertain claim, $\underline{q} < q < q^F$ (both before and after the change), then x will decrease and rents will increase to a *more* Pareto efficient level, and,
>
> c.) if there is one property owner with a relatively certain claim, $q_0 < \underline{q}$, and multiple property owners with relatively uncertain claims, $\underline{q} < q_w < q^F$ (both before and after the change), then x will decrease and joint rents will decrease to a *less* Pareto efficient level.

In other words, the effect of stronger penalties depends very much on the circumstances. If property rights are uncertain, but also overlapping—as might be the case, for example, if patent boundaries are vague, as Justice Kennedy contends—then *weaker* penalties might actually improve Pareto efficiency.[29] On the other hand, if property rights are uncertain yet well-defined so that they do not overlap, then stronger penalties might improve Pareto efficiency.[30]

This distinction might also help explain why criminal sanctions are applied only to some forms of

29 Of course, this does not mean that weaker penalties are necessarily the best policy; it might be possible to directly fix the problem of vague boundaries.

30 This result is similar to Kaplow's (1990) finding regarding regulatory compliance and Parisi et al. (2005) regarding the choice of property versus liability rules for situations with anticommons.

property.[31] Criminal sanctions improve Pareto efficiency when Type I errors are unlikely, for instance, when the property consists of simple commodities sold in a marketplace. The monitoring and enforcement of simple property in a marketplace is relatively straightforward. A policeman or a court can readily and accurately surmise that an apple was stolen from a fruit vendor. A policeman cannot be expected to readily and accurately determine patent infringement or who is the true inventor. For this reason, criminal sanctions on intellectual property might be welfare decreasing.

Aggregation

To the extent that overlapping claims cause problems, aggregation of rights seems a natural solution. By "aggregation" I mean that rights holders can merge or one holder can buy out the rights of others or rights holders can form collective rights organizations such as patent pools. If multiple rights holders can be aggregated into one collective entity through such "private ordering," then the inefficiencies associated with overlapping claims disappear, all else equal.

For example, problems of overlapping claims with patents—"patent thickets"—are held to be significant in some technologies. Economists and legal scholars have argued that patent pools might solve these problems (Carlson 1999, Lerner and Tirole 2004, Shapiro 2001, Merges 1996). Taking a similar view, the U.S Department of Justice and Federal Trade Commission issued antitrust guidelines that explicitly set forth the conditions under which patent pools would be approved (US Department of Justice and Federal Trade Commission 1995).

But here, too, the efficacy of this remedy depends on the particular circumstances. If rights are uncertain, aggregation also changes the nature of the litigation game in ways that can be socially detrimental. In general, the litigation threat posed by a group of uncertain property rights is greater than

31 Criminal sanctions are not exactly what I have modeled here because they do not directly increase the reward to the property holder. Nevertheless, because the threat of criminal sanctions improves the property holder's bargaining position, the effect is similar.

the threat posed by a single such right. This is because the joint probability of winning a lawsuit over multiple rights typically exceeds the probability of winning a lawsuit over a single right.

However, most of the analysis of collective rights organizations and patent pools in particular assumes certain enforcement. Yet it is widely recognized, for example, that firms take uncertain enforcement into account regarding patents.[32] Choi (2003) and Gilbert (2004) suggest that aggregating uncertain patents into pools can reduce incentives to challenge invalid patents. Since eliminating invalid patents is a sort of public good that is likely under-supplied, this aspect of patent pools can reduce social welfare. However, my model suggests another effect of aggregation that applies more generally even when the invalidation of property rights is not a public good:[33] when some property owners cannot credibly threaten litigation because their rights are so uncertain, they can gain credibility with aggregation, worsening problems of overlapping rights.

To see how this works, I assume that the probabilities of winning a lawsuit are statistically independent:

> Assumption of statistical independence: If two property owners each have a probability of $1 - q$ of winning a lawsuit against an asset user, then the property owners have a probability of winning a joint lawsuit over both rights of $1-q^2$.[34]

Then aggregation of uncertain rights increases the probability of winning. It is possible that some rights might be so weak that their owners cannot credibly threaten litigation, that is, $q > q^F$. In this case, because the threat of litigation is not credible, these rights do not affect the equilibrium allocation, hence they do not affect the Pareto efficiency. However, if two such rights holders aggregate their rights in a patent pool or other collective rights organization, then the probability of winning a joint lawsuit would be credible if $q^F > q^2$. Then the rights jointly operate as a single, more certain right that

32 See Bessen (2003), Choi (2003), Gilbert (2004), Lemley and Shapiro (2005), and Wagner and Parchomovsky (2005).

33 Patent invalidation is a public good only because the same property right affects multiple users of a technology thanks to the non-rivaly of inventions. For rivalrous goods, invalidation might not affect other parties.

34 I also assume implicitly that the costs of a lawsuit over multiple rights is the same to both parties as a lawsuit over a single right. This is probably strictly not true, but it serves as a reasonable first order approximation.

does affect Pareto efficiency.

This intuition can be formalized as (proof in the Appendix):

> Proposition 4. Consider a single property owner with a relatively certain claim, $q_0 < \underline{q}$, and two property owners with relatively uncertain claims, $\underline{q} < q_w$. Assuming these probabilities are statistically independent,
>
> a.) If $q_w < q^F$, then any aggregation of two or three rights will be Pareto improving, but,
>
> b.) If $q_w > q^F > q_w^2$, aggregating all three rights will leave Pareto efficiency unchanged and aggregating only the two less certain rights will decrease Pareto efficiency. Moreover, the firms holding the less certain rights will have private incentives to aggregate their rights.

The latter behavior does seem to have some empirical relevance. There are large numbers of low value patents that are unlikely to be worth litigating—the median value of a US patent is estimated to be about $7,000 in 1992 dollars (Bessen 2008). And in recent years, a class of patent aggregators has emerged who buy up large numbers of low value patents and successfully use them to extract large payments from technology companies. One such aggregator, Intellectual Ventures, reportedly threatens firms with lawsuits over a thousand patents at one time. My analysis suggests that this behavior might not be socially beneficial.

Moreover, this type of behavior is quite different from the socially beneficial behavior described in the first part of the proposition and in the academic literature more generally. In contrast, it appears that relatively few patent pools of the beneficial sort have been formed in recent years and almost all of these have been for standard-setting organizations, which are a special case.[35] So it appears that antitrust authorities need to evaluate the nature of the property failure before prescribing patent pools.

35 Of the 8 pools formed since 1990 and reported in Lerner et al. (2003), only one was not for a standard-setting organization and that one, for laser eye surgery, was the object of an FTC antitrust suit. This stands in contrast to the nineteenth and early twentieth centuries when patent pools were more common. Despite the DOJ-FTC Guidelines, Lerner and Tirole (p. 691) suggest that the low number of pools might be because of "ambiguities surrounding the manner in which proposed pools will be evaluated."

Other

A wide variety of institutional remedies can be observed with various types of property that are keyed to different sorts of property problems. For instance, Heller (1999) notes that various rules work against anticommons in land including primogeniture, limits on future interests and property taxes. Other sorts of remedies limit claims that are relatively uncertain, including adverse possession (which acts like a statute of limitations on claims where the asset is actively used by another party) and fee shifting in lawsuits.

One option that is used for some types of property is the null option: defining asset boundaries is so difficult for some types of assets that exclusionary property rights are not used, at least not until the asset is captured in a different form such as with a "rule of capture." For example, exclusionary property rights are not granted for oil and natural gas in the ground nor for wildlife until it is captured (Lueck 1995). Prior to then, these assets are simply too mobile to have cost effective property boundaries. Similarly, patent law excludes abstract ideas and mathematical principles from patent coverage. Exclusionary property rights are simply not an effective form of regulation in all instances.

V. Conclusion

Real world property rights are neither perfectly defined nor perfectly enforced. This has strong implications for the ability of markets to realize Pareto efficient allocations. The good news is that contract enforcement is robust to moderate imperfections in property rights in the common situation where buyers sink investments after the exchange. Contracts are passively followed even though enforcement is not perfect.

But transacting parties also have another problem: the risk of expropriation by third parties affects their willingness to transact at the Pareto efficient price. The problem of expropriation has been largely ignored in the contracting literature, yet it affects the Pareto efficiency of contracts.

Exclusionary property rights, which are rights against the world, work to limit such expropriation. However, imperfectly defined exclusionary rights generate another problem: the same asset can be claimed by more than one rights holder. Even when the additional claims are relatively unlikely to be enforced, these overlapping claims affect the Pareto efficiency of market transactions.

This added dimension means that property rights exhibit richly varied patterns of behavior and these different patterns have different strengths and weaknesses. One size does not fit all in the design of property rights institutions. For example, I show that stronger penalties improve Pareto efficiency in some situations, but decrease it in other common situations. Similarly, collective rights organizations work to reduce problems of overlapping claims in some situations, but aggravate these problems in others.

In short, property rights are a form of regulation like any other, their performance cannot be adequately evaluated using any single index of property "strength," and the appropriate medicine depends on the particular malady. In addition to looking at the likelihood that any claim will be enforced, empirical evaluation of property systems requires looking at matters of institutional performance, such as the costs of obtaining title and conducting search, the availability of low-cost third party services to determine property boundaries and to insure against errors, determining whether asset holders obtain title and whether asset users conduct clearance search or, instead, whether they ignore many rights. Although property systems function on private information about values and quantities, they require significant public information about boundaries in order to regulate efficiently.

Appendix

Contract model

I will find the equilibrium solution with imperfect enforcement and expropriation risk; the case with perfect enforcement is an instance of the more general model.

The payoff from enforcement in stage 7 is $\{(1-q)\,v\,x - L,\quad q\,v\,x - L\}$ for the property owner and asset user respectively. These quantities must be positive in order for both parties to have credible threats of proceeding to enforcement. The relevant thresholds for positive expected profits are

(A1a) $q < 1 - \frac{L}{v\,x}$ and (A1b) $q > \frac{L}{v\,x}$

for the rights holder and asset user respectively. As long as these conditions are met, it will be advantageous to settle in stage 6 and the Nash bargaining solution with equal bargaining power is

$\{(1-q)\,v\,x,\ \ q\,v\,x\}$.

In stage 5, B_1 will choose to pay if B_1 makes out better by paying,

(A2) $v\,x - p\,x \geq q\,v\,x$ or $q \leq 1 - \frac{p}{v}$.

An additional constraint on A's price comes in stage 1. If $p > c_T$, then no party B will choose to pay the price because they can always make out better by expropriating. So A is better off charging a price that is infinitesimally less than c_T, so that

(A3) $p \leq c_T$

A's optimal contract will depend on whether (A1) – (A3) hold or not. If these conditions are met at A's rent maximizing price and if this price is also less than c_T, then A can charge that price.

Zone I.

First, consider A's contract when all three conditions hold. Owner A seeks to choose p and x so as to

maximize $R = p\,x$ subject to the zero profit constraint on B_1,

(A4) $\quad v(x) - p - c = 0$.

Note that if B_1 makes no profits, no expropriator can profitably enter given (A3). Solving the Lagrangean, $\mathcal{L} = p\,x + \lambda\,(v(x) - p - c)$, yields a first order condition,

(A5) $\quad \dfrac{p}{v} = \epsilon$

and it is straightforward to show that constraint (A4) is met. Combining (A4) and (A5), the optimal level of activity is

$$x^* = x \;\text{ such that }\; v(x^*) = \frac{c}{1-\epsilon}$$

and constraint (A2) can be rewritten $q \le \underline{q}, \quad \underline{q} \equiv 1 - \epsilon$. Note also that by the assumption in footnote 14, constraint (A1b) will be met in the region where (A2) is also met, so B_1 will choose to pay in stage 5.

Zone II

Now consider the zone where (A2) is not met but where (A1a) and (A3) is met. In this case, B_1 does not pay and the contract is renegotiated. Here, the expected rents (from the renegotiated contract) are $(1\text{-}q)\,v\,x$. Since A's rents increase with x, A chooses the greatest x compatible with the zero profit condition, yielding

$$x^w = x \;\text{ such that }\; v(x) = \frac{c}{q}.$$

Given this, (A1a) can be rewritten

$$q < q^F, \qquad q^F \equiv 1 - \frac{L\,q}{c\,x^w}$$

Zone III

In this zone, (A1a) is not met, so owner A cannot credibly threaten to enforce its property claim.

Zone IV

Here (A3) is not met, so A can only charge $p = c_T$.

Property Model

Given the similarity between this and the contract model, I will only highlight those steps of the analysis that are different. Working backwards, the payoffs in Stage 6 are

$\{(1-q_i)\,v\,x - L, \quad q_i\,v\,x - L\}$ and renegotiation, subject to credibility constraints by both parties, yields a settlement of $\{(1-q_i)\,v\,x, \quad q_i\,v\,x\}$ to the asset owner and user, respectively.

Party B will choose to pay the *i*th asset owner (rather than renegotiate) in Stage 4 as long as

$v\,x - p_i x - \sum_{j \neq i} p_j x \geq q_i\,v\,x - \sum_{j \neq i} p_j x$ where the p_j are the prices B expects to pay to the other owners (either in stage 4 or 5). Alternatively, this condition can be rewritten

(A6) $$q_i \leq 1 - \frac{p_i}{v}.$$

If this condition is met, then the *i*th owner will seek to maximize rents, $p_i x$, taking the prices paid other owner fixed (Cournot assumptions), subject to the zero profit condition

$$v - p_i - \sum_{j \neq i} p_j - c = 0.$$

The first order maximizing condition is

(A7) $$\epsilon = \frac{p_i}{v}$$

If, on the other hand, (A6) is not met, then the property owner gets the amount from renegotiation, $(1-q_i)\,v\,x$. The property owner, in this case, could alternatively charge price $p_i = (1-q_i)\,v$ in stage 2, but since this would entail a cost of u to put the world on notice, the property owner does not do this.

Instead, the asset user ignores (or does not know about) the *i*th claim, and the matter comes up as a dispute that gets resolved at stage 5.

Single Owner

This case is equivalent to the contract model with $z = 0$. If $q < \underline{q}$, then

$$x^* = x \text{ such that } \quad v(x^*) = \frac{c}{1-\epsilon} \text{ , otherwise, } \quad x^U = x \text{ such that } \; v(x^U) = \frac{c}{q}$$

Note that if $q > \underline{q}$, then A has nothing to gain by negotiating the contract in stage 3 because B will only accept a rent equal to that derived from renegotiating the contract. Hence in this case, A has no incentive to spend *u*. If, however, $q < \underline{q}$, then A will spend *u* as long as *u* is not too large. To see this, note that if A does not spend *u*, then B knows that there is an unidentified property holder out there who will threaten a lawsuit at stage 5. Considering this, B will choose *x* so as to maximize profits from the renegotiated settlement, $q\, v\, x - c\, x$. This turns out to be

$$x^0 = x \text{ such that } v(x^0) = \frac{c}{q(1-\epsilon)}$$

It is straightforward to show that A makes out better at x^* than at x^0. Hence A chooses to pay *u* when A's claim is relatively certain. A similar calculation produces a similar result in the cases below.

Overlapping Certain Rights (Anticommons)

Summing (A7) over all *N* property holders

$$N\epsilon = \frac{\Sigma\, p_i}{v} = \frac{v-c}{v}$$

the last step by substituting the zero profit condition in the numerator. Rearranging, the first order condition becomes

$$x^A = x \text{ such that } \; v(x^A) = \frac{c}{1-N\epsilon}$$

Mixed rights (Notice failure)

Let p_0 be the price charged by the property owner with the relatively certain claim. Then using (A7) and substituting in the zero profit condition,

$$\epsilon = \frac{p_0}{v} = \frac{v - \sum p_j - c}{v} = \frac{v - N(1-q_w)v - c}{v}$$

which, rearranged, gives

$$x^N = x \text{ such that } v(x^N) = \frac{c}{1 - \epsilon - N(1-q_w)} .$$

Comparisons

Comparisons of the equilibrium level of activity, x, can be obtained by taking implicit derivatives using the equilibrium conditions. For example, (5) can be rewritten

$$G = v(x)(1 - \epsilon(x)/N) - c = 0$$

Taking partial derivatives, treating N as a continuous variable, and signing the terms (using primes to designate derivatives),

$$\frac{\partial G}{\partial x} = v'(1 - \epsilon/N) - \frac{v\epsilon'}{N} < 0 \text{ where } \epsilon' = -\frac{v''x + v'(1+\epsilon)}{v} > 0$$

$$\frac{\partial G}{\partial N} = \frac{v\epsilon}{N^2} > 0$$

so that $\frac{dx^O}{dN} = -\frac{\partial G}{\partial N} \Big/ \frac{\partial G}{\partial x} > 0$ and therefore $x^O > x^S$ for $N>1$.

By similar calculations,

$$\text{(A8)} \quad \frac{dx^A}{dN} = \frac{v\epsilon}{v'(1 - N\epsilon) - vN\epsilon'} < 0, \quad \frac{dx^N}{dN} = \frac{v(1-q_w)}{v'(1 - \epsilon - N(1-q_w)) - v\epsilon'} < 0$$

Proposition 3. Enforcement strength model

Now suppose that the payoff from winning a lawsuit is $s\,v\,x$. Then the expected outcomes from a lawsuit are $\{(1-q_i)\,s\,v\,x - L, \quad (1-(1-q_i)\,s)\,v\,x - L\}$ for the ith asset owner and the asset user,

respectively. The first term must be positive for the asset owner to have a credible threat of enforcement, so

$$q^F = 1 - \frac{L}{s\,v\,x}$$

The Nash bargaining payoffs prior to a lawsuit are $\{(1-q_i)\,s\,v\,x,\quad (1-(1-q_i)\,s)\,v\,x\}$, so B will choose to pay when $v\,x - p_i x - \sum_{j\neq i} p_j x \geq (1-(1-q_i)\,s)\,v\,x - \sum_{j\neq i} p_j x$ or, alternatively,

$$\underline{q} = 1 - \frac{p_i}{s\,v}\,.$$

It is straightforward to see that increases in s increase $\underline{q}$ and q^F and also the payoff to the asset owner from renegotiation. Thus a change in s has two sorts of effects: it changes the solution zones, affecting asset owners at the various margins, and it changes payoffs in the zone where $\underline{q} < q_w < q^F$, but not in the other zones. Within this zone, given (A8), an increase in s decreases the equilibrium level of activity, x. But the effect of this decrease will vary depending on the distribution of rights. If there is a single owner with a relatively uncertain claim, then at equilibrium,

$$v = \frac{c}{1-(1-q)\,s} = \frac{c}{q-(s-1)\,(1-q)}$$

Comparing this to (11), an increase in s will increase v and decrease x. Since x is overused in this region, such a decrease will improve Pareto efficiency. A similar result can be shown with multiple owners all holding relatively uncertain claims.

If on the other hand, there are mixed rights (one owner with a relatively certain claim and other owners with uncertain claims), then the equilibrium condition is

$$v = \frac{c}{1-\epsilon-N\,(1-q_w)\,s}$$

and increases in s decrease x here, too. However, since the activity level is below the Pareto optimal

level, x^*, in this case, further decreases reduce Pareto efficiency.

Proposition 4. Aggregation

Proposition 4 a.

In this case, the initial equilibrium is either a case of anticommons or notice failure. If an anticommons, the effect of aggregation is simply to reduce N and by (A8), this increases x^A, moving it closer to the Pareto optimal level.

If the initial equilibrium is notice failure (that is, $1 - \varepsilon < q_w < q^F$) then the initial x^N satisfies

$$v^0 = \frac{c}{1-\epsilon-2(1-q_w)}$$

(using the superscript 0 to denote "before aggregation" and 1 "after") and after aggregation it satisfies either

(A9) $$v^1 = \frac{c}{1-\epsilon-(1-q_w^2)} \qquad \text{or} \qquad v^1 = \frac{c}{1-2\epsilon}$$

depending on whether $1 - \varepsilon < q_w^2$ or not, respectively. It is straightforward to show that in either case, $v^1 < v^0$ from which it follows (by the implicit derivative) that $x^1 > x^0$. In other words, aggregation increases the level of x closer to the Pareto optimal level.

Proposition 4 b.

In this case, the initial equilibrium is Pareto optimal because the two holders of uncertain rights have no credible litigation threat,

$$v^0 = \frac{c}{1-\epsilon}$$

Similarly, if all three owners aggregate their rights to act as one, then the equilibrium will be the same. If, instead, the two weaker rights holders aggregate, then the equilibrium is one of the ones in (A9). It is straightforward to show then that $v^1 > v^0$ and $x^1 < x^0$, reducing x below the Pareto optimal

level.

In the initial equilibrium, the weaker rights holders earn zero profits. If they aggregate, then they jointly earn $(1-q_w^2)v^1 x^1 > 0$. Hence aggregation is privately profitable to them.

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Table 1. Institutional Comparison of Contract and Exclusionary Property

Institutional feature	Contract	Exclusionary property	Property example
Affected parties	Two signers	The world	
Definition / specification	Any form that can be interpreted by a court	Standardized forms (*numerus clausus*)	Standard land deed
Access to specification	Private	Public	Deed registry
Rights clearance	Seller representations	Clearance search	Title search
Interpretation	By court	By court and third parties	Surveyors
Boundary risk management	--	Insurance	Title insurance
Use rights	As specified for the two parties	Any use not restricted by law	Residual rights
Exclusionary rights	As specified for the two parties	Excludes the world with limited exceptions	
Monitoring	Private	Private and public (police)	"riding the fences"
Enforcement	Public (court)	Public (court)	
Remedies / penalties	Damages and injunctions	Damages, injunctions, and criminal penalties	

Figure 1. Contract Model

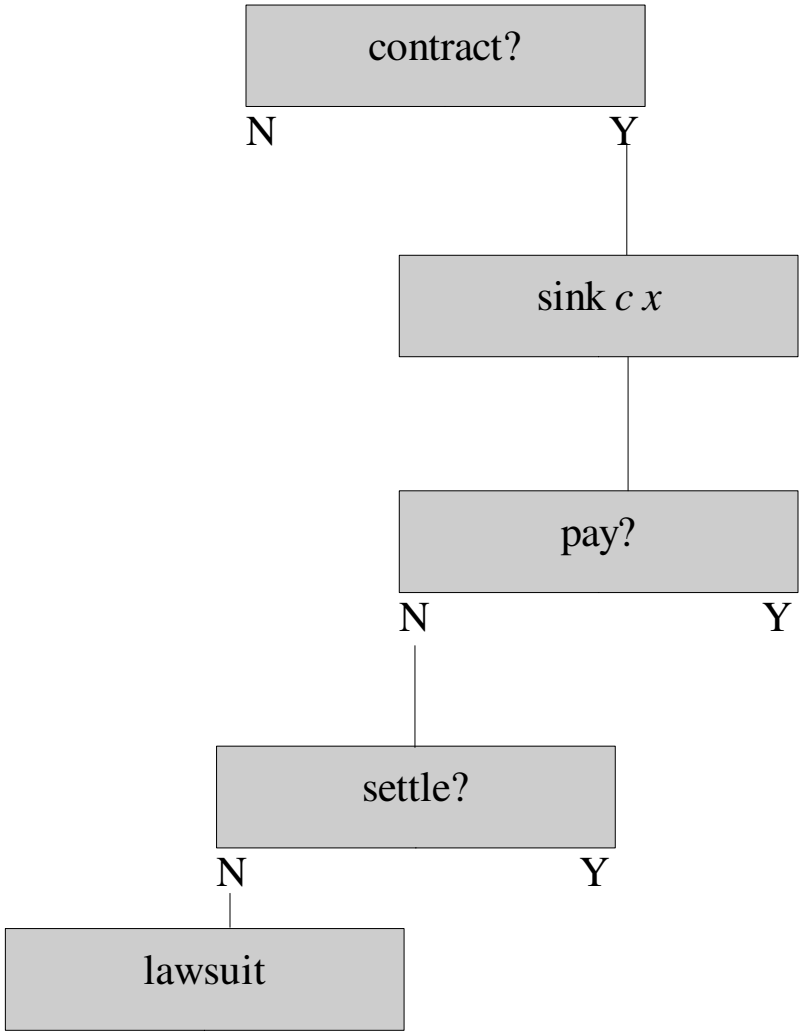

Figure 2. Contract Model Solution Regions

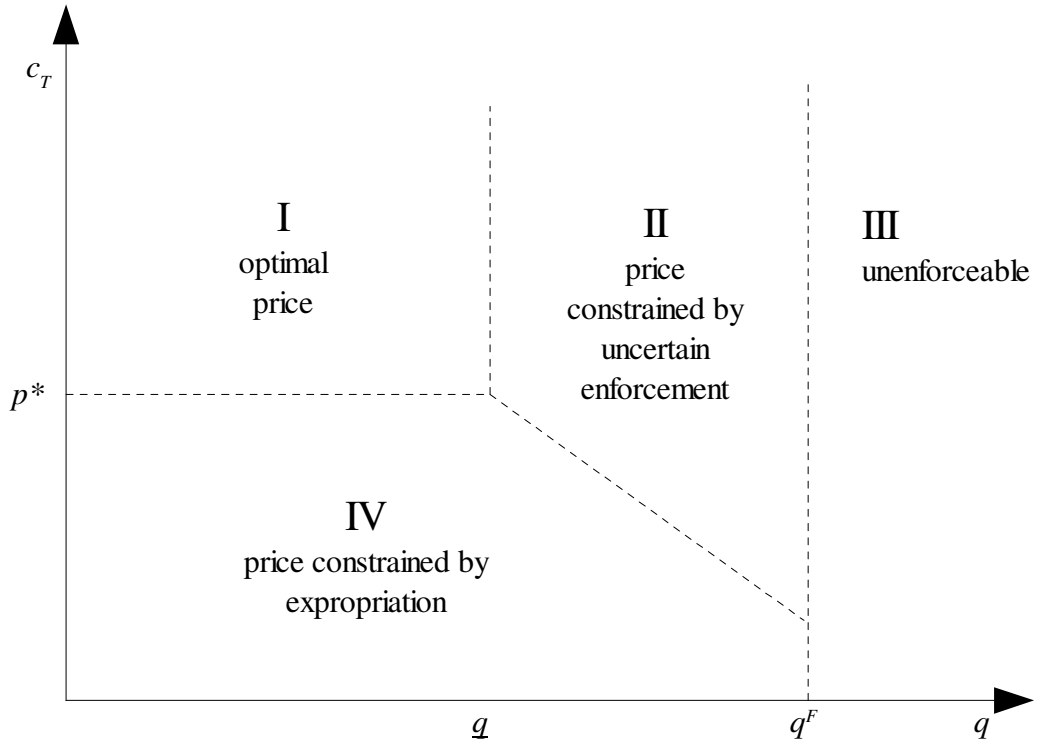

Figure 3. Exclusionary Property Rights Model