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Abstract: How should the economic performance of property systems be evaluated? Benefit-cost analysis is widely used to evaluate non-market based regulation when prices are not available. Market prices provide better information for property systems, but market prices are not necessarily socially optimal when property rights are imperfect. This paper discusses two practical approaches to evaluating the performance of property systems, one based on an analysis of institutional performance, the other based on measuring incentives. As an illustration, I show how these approaches might be used to evaluate the US patent system.

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Introduction

A well developed literature and practice evaluates the economic performance of government programs using non-market forms of regulation. Policy analysts use benefit-cost analysis to evaluate non-market resource allocations, following Kaldor (1939) and Hicks (1939). This provides a useful way of evaluating economic performance when prices are not available. For example, applied economists use this approach and related metrics to evaluate environmental regulation (Stavins 2008, Tietenberg 2002) or the regulation of common pool resources (Ostrom 1990).

However, following Coase (1960) and Arrow (1970, 1971), markets can be used as a form of regulation alternative to Pigovian taxes/subsidies and to command-and-control policies. If the government can create appropriate property rights, externalities can be internalized and markets can be used to achieve Pareto optimal regulation. Examples include tradable pollution permits overcoming pollution externalities and patents overcoming free-rider externalities.

But how can property systems be evaluated? It is sometimes argued, often implicitly, that there is no need to evaluate property systems. Indeed, many new rights have been created in recent years without any formal evaluation of their performance.[1] With property systems, in contrast to non-market regulatory systems, prices *are* usually available. With well-defined and enforceable property rights, these prices reveal the values placed on goods by market participants and, with competitive markets, these prices should theoretically lead to a Pareto optimal resource allocation.

However, property rights are not always perfectly defined and enforced. For example, poorly defined land rights have given rise to squatters on Brazil's frontier (Alston et al. 1999) and problems

1 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 processes.

defining patent rights have caused excessive litigation in some technologies (Bessen and Meurer 2008a). In these cases, prices do not necessarily lead to a Pareto optimal allocation nor do they necessarily reveal the intrinsic value placed on resources by market participants, as I show in a related paper (Bessen 2009). And 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.[2]

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.[3] There is a literature on regulatory compliance with uncertain enforcement,[4] however, that literature does not address specific issues related to property rights. There is also a literature on patents with uncertain enforcement,[5] but this literature also does not deal with imperfect definition of patents. Imperfectly defined property rights can generate overlapping claims on the same asset. One problem with overlapping claims, especially where property boundaries do not correspond to the optimal economic division, is that they 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).

2 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 (2009) on surveying and recording systems, Lueck (1995) on possession rules.

3 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 are poorly defined or enforced.

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

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

However, these models generally assume certain enforcement. In this paper I use a simple model of imperfect property rights where those rights might be both imperfectly defined and imperfectly enforced.

It is, of course, possible to evaluate property systems by conducting a full welfare analysis or a benefit-cost analysis. However, the data to make such evaluations appear difficult to obtain in many cases. This paper outlines two methods for obtaining limited evaluations of property systems that do not have such difficult data requirements. Using a model of exclusionary property rights, I show that there are several ways property systems can fail to achieve Pareto optimal allocations. These are each related to distinct institutional failures. This provides a first criterion for evaluating performance: whether property institutions do what they are supposed to do or not. Although this method of evaluation does not provide a quantitative measure of misallocation, it identifies specific institutional failures that correspond to market distortions.

Second, using the model, I show that estimates of the private value of assets and of the costs of disputes over rights—both of which can be estimated in some cases—provide a means for measuring performance in the case of one particular type of failures.

To illustrate the application of these methods, I show how they could be applied to evaluating the operation of the US patent system. In the next section I develop a simple but general model of property rights with possibly imperfect enforcement and imperfect definition. Following that, I describe how some aspects of economic performance can be evaluated using the model and I then perform that analysis using data on the US patent system.

A Model of Exclusionary Property Rights

To fix ideas, I model a congestion externality. With slight modification, the same model can be applied to other types of externalities, including positive externalities. The model considers two sorts of private, exclusionary property rights: simple possession and legal exclusionary rights. I assume that a single party "possesses" an asset. Possession gives that party limited, privately-enforced exclusionary rights.[6] Although there are many different sorts of private enforcement, including mechanisms involving reputation, repeated interaction, boycotts and threats of violence, I model these rights as enforced by a simple technological exclusion such as a wall or a fence. That is, possession means that other parties face an extra cost if they seek to expropriate the asset.

I also consider legal exclusionary rights where one or more owners obtain legal title that conveys a right of exclusion that can be enforced in court. Both obtaining title and legal enforcement involve costs to the owner and enforcement is not perfect. Note also that because the rights might not be perfectly defined, multiple parties might obtain legal claims to the same asset, including non-possessing parties (I assume that the possessing party can also obtain legal title).

Externality

I begin with a simple model of a congestion externality of the sort that has been used to model natural resources.[7] 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, e.g., patents on inventions. 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

6 This is a bit of an oversimplification because possession gives rise to legally enforceable claims as well in some cases. To the extent that this is true, possessory rights can be modeled as legally enforceable rights.

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

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 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, $v''(x) \leq 0$.[8]

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 been on investment incentives.

Social Optimum

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

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

8 My results will hold with a less restrictive assumption, however, this assumption seems reasonable enough and it simplifies the exposition.

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

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

where ϵ is the (negative) elasticity of v with respect to x.

Then the first order condition for the social optimum and the corresponding net surplus are

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

This first order condition provides our benchmark of Pareto optimality. Note that this allocation corresponds to a price. Suppose that a single agent had perfect control over the use of the asset. That agent could achieve this Pareto optimal allocation by charging each user a unit price

(4) $$p^S = \epsilon\, v(x^S).$$

Suppose there are M users and the jth user has activity level x_j. Since there is a competitive market, users would acquire rights to use the asset until the individual profit of the jth user is zero:

$$\pi_j = v(x)x_j - (c+p^S)x_j = 0, \qquad x \equiv \sum_{i=1}^{M} x_i$$

where summation is over all participating users. It is straightforward to show that the property owner realizes the rent maximizing allocation by charging the Pareto optimal price and the zero profit condition is solved when $\Sigma x_j = x^S$, or, in other words, the Pareto optimal allocation is realized. The property owner, in this case, receives the entire social surplus.

Possession

Now suppose that there are no legal property rights, however, the single agent who possesses the asset takes private measures to exclude users. Suppose that these measures impose an additional unit cost of c_0 on users. There are two sorts of allocations realized, depending on the value of c_0.

If $c_0 \geq p^S$, then the asset owner will maximize profits by charging a price $p^* = p^S$. The owner is able to charge the Pareto optimal price because the exclusionary measures are sufficiently costly to prospective users.

If, instead, $c_0 < p^S$, then the best that the owner can do is to charge $p^* = c_0$.[9] In this case, it is straightforward to show that $\Sigma x_j > x^S$, or, in other words, weak exclusion leads to overuse of the asset. In these situations, the addition of a legal property right can enhance social welfare.

Legal exclusionary rights

Now suppose that the party who possesses the asset can also obtain legal title by spending t. However, because the asset boundaries might not be perfectly defined for a variety of reasons (see Bessen 2009), a total of N parties can obtain legal claims on the asset. Note that I interpret this condition broadly to include cases where multiple parties have claims to a single *usable* asset at its socially optimal scale. For example, a shopping mall might be the best social use for some land, but the land might be subdivided into smaller, socially inefficient house-sized plots. In this case, the boundaries of the housing plots are technically well-defined, but technological indivisibilities make these plots sub-optimal.

Let the possessing agent be designated $i = 1$ and the remaining, non-possessing agents, $i = 2,...N$. I assume that possession is sufficient to provide notice, that is, prospective users know that owner 1 has

[9] In the unconstrained case, the owner makes out best with the unconstrained rent maximizing price. In the constrained case, the owner makes out best when the price equals the constraint (c_0) because the owner's rents decrease monotonically with price at any given x.

rights to the asset. The non-possessing owners, however, must choose to spend u in order to provide notice *ex ante*. I assume that this cost is not so large as to deter formal acquisition of rights and 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 ex ante.[10] 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. 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.

The combination of legal and privately enforced exclusion can be modeled as a game with the following stages (see Figure 1):

1. Asset owners A_i, $i = 1,..., N$, each decide whether to spend t to obtain title. Non-possessing owners, $i = 2,..., N$, decide whether to spend an additional u to provide notice. Each ith owner declares a price, p_i.
2. Prospective users search for the identities of asset owners and find those who have spent u in addition to user $i = 1$. Prospective users decide whether to pay the owners they have identified, to use the asset without paying *ex ante*, or to not use the asset at all.
3. Each of M users, B_j, who chooses to use the asset in amount x_j sinks $c\, x_j$ into its use.[11] Given the competitive nature of the market, users enter until the zero profit condition is met.
4. Asset owners can costlessly detect use of the asset. If B_j uses the asset but does not pay owner A_i, they bargain to reach a settlement prior to litigation. I assume that the negotiation, if successful, realizes a Nash bargaining solution with each party receiving equal shares of the net surplus.
5. If negotiations breakdown, then A_i initiates a lawsuit against B_j 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.[12] If

10 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.

11 Or $(c + c_0)\, x_j$ if using the asset without permission of the possessing owner.

12 A more complicated model might consider the possibility that a lawsuit with one party might influence the probability of winning for other parties. In this case, the variables q_i represent the probability of winning given the actions of other parties. However, since lawsuits don't occur in equilibrium under the other assumptions made, this interpretation should not affect the results.

party A_i wins, it receives an injunction against B_j. I assume that under these conditions, B_j will settle by paying $v\ x_j$.

To simplify the outcomes, I assume that there is a minimum efficient scale for users, $\underline{x}$, such that $x_j \geq \underline{x}$ and $c_0\ \underline{x} > L > 0$. This is sufficient to assure that when rights are relatively certain, both parties can credibly threaten to engage in a lawsuit and that such lawsuits will always be settled in stage 4. This simplifies the discussion, however, it obviously does not apply to those situations where the direct costs of litigation are excessive.

Solution Regions

I assume that property owners choose prices that maximize their rents subject to Cournot assumptions (taking other prices as given) and subject to the zero profit condition for asset users. An owner might not be able to realize the price that brings the greatest possible rent because that price might be so high that users will choose to ignore the property rights and take their chances in ex post negotiation or, possibly, litigation. This condition places a constraint on the maximum price that any owner can charge. Ignoring for the moment whether the *i*th owner can charge this price, the first order maximizing condition for the unconstrained rent-maximizing price is (see Appendix for calculations)

(5) $$p_i^* = \epsilon(x^*)\, v(x^*)$$

where x^* is level of total activity given the zero profit condition and the given prices.

The *i*th owner will be able to get this price as long as asset users make more by paying this amount than they could get from a Stage 4 negotiation. The per unit amount that the *i*th owner gets from a Stage 4 negotiation with activity level x is

(6) $$\underline{p_i}(x) \equiv \begin{cases} (1-q_1)\,v(x) + c_0, & i = 1 \\ (1-q_i)\,v(x), & i > 1 \end{cases}$$

If $p_i^* \leq \underline{p_i}(x^*)$, then asset users will choose to pay the unconstrained price, p_i*, and, because this is a rent-maximizing price, asset owner *i* will also make out best at this price. Otherwise, if $p_i^* > \underline{p_i}(x^*)$, asset users will make out better by not paying unless the owner charges a "constrained" price of $\underline{p_i}$ or less. In this case, it is straightforward to show that the asset owner makes out best by charging exactly $\underline{p_i}$, leaving the owner indifferent to getting paid or going to Stage 4 enforcement and leaving the asset users indifferent to paying or not.[13]

Non-possessing owners' decision to spend *u* to improve public notice of their rights depends on whether they are able to charge the unconstrained price or not. If so, then they will spend *u*, because they make out better by getting paid rather than by taking enforcement action. But if the price is constrained, then they are indifferent to whether they get paid up front or whether they take enforcement action. In this latter case, a non-possessing owner ($j > 1$) will not spend *u* to improve public notice and, as a result, it will not contract with users ex ante, but will, instead, pursue its claims ex post (Stage 4) where it will receive this amount from a negotiated settlement. This means that this scenario gives rise to ex post disputes and, possibly, to litigation. It is the only scenario in this model that does give rise to disputes.

Note also that the possessing property owner might not choose to obtain legal title. If $c_0 > p^*$, then the possessing property owner makes out better just by utilizing the degree of technological exclusion provided by possession. In this case, the owner can charge the rent-maximizing price without

[13] The intuition here is that owners' profits decrease monotonically with the activity level, *x*, once *x* exceeds rent-maximizing level. Under the zero profit condition, the lower the price, the greater the level of *x*, hence as prices fall below the rent-maximizing price, profits decline.

having to pay title cost, *t*, and without having to engage in enforcement activity.

Given these distinctions, I show in the Appendix that the efficiency performance of the different solutions falls into four zones, depending on whether there are multiple property owners with claims on the asset and whether one or more of those owners can charge their unconstrained rent maximizing price. These results are summarized by the chart in Figure 2.

{Figure 2 about here}

The top row includes cases where at least one owner is able to charge the unconstrained price. The Pareto optimal allocation is only realized when there is a single owner with a right that is relatively certain to be enforced (unconstrained price). In this case, property users obey the law and respect property rights. When a single owner owns a relatively *uncertain* right, then the price is constrained and there is too much use of the resource—"weak" property rights tend in the direction of the "tragedy of the commons." In addition, a single owner of a relatively uncertain right will not spend *u* to establish clear notice. This results in a dispute (at Stage 4) and, possibly, litigation.

On the other hand, when there are multiple owners, there will be too little use of the resource compared to the Pareto optimal level as long as one or more of the owners have rights that are relatively certain to be enforced. When there are multiple owners, all with relatively certain rights, this gives rise to an "anti-commons" where the failure of owners to coordinate gives rise to excessively high prices and a socially low level of resource use. When one owner has a strong right, but additional owners have rights that are relatively unlikely to be enforced, this situation might be better described as one of "notice failure" (see Bessen 2009). In this case, poorly defined rights give rise to disputes and litigation and the resource is also underutilized. When multiple owners all have relatively uncertain rights, the resource allocation could provide too little or too much use compared to the Pareto optimal level.

The economic performance of a property system thus depends on where that system falls on these two dimensions: whether the asset owner(s) can charge their rent maximizing price or not and whether there are multiple legal claims on the asset or not. These dimensions correspond loosely, but not exactly to the oft-cited requirement that property rights need to be "enforceable and well-defined." An insufficient probability of enforcement can constrain the price that the asset owner charges. However, if technological exclusion measures are sufficiently effective, then a Pareto optimal price can be realized even when the legal right has uncertain enforcement, but, in this case, asset owners will simply not obtain title to the property. Similarly, multiple claimants can arise when rights are not well-defined, but they can also arise when the rights are clearly defined, but are sub-optimally small. However, these two sub-cases can be distinguished because, according to the model, poorly defined rights give rise to disputes and litigation, while rights that are merely sub-optimally small do not.

Evaluation

Institutional Performance

This framework provides a means for categorizing the performance of a property system according to where that system falls on the chart in Figure 2. And, to some extent, this can be determined by examining the performance of the titling and notice institutions of that property system. If these institutions work as they are supposed to, then this indicates that the system likely falls into the "optimal" cell in the upper left; if the institutions don't work as they are supposed to, then this might mean the system falls into a sub-optimal cell. Several straightforward questions can be used to categorize institutional performance:

1. Do most property owners obtain title? For example, De Soto (2000) documents cases where

large numbers of property owners do not obtain title in less developed countries. Several factors might induce owners not to seek title: title might be too expensive to obtain, rights might be unreliably enforced, or private means of exclusion might work sufficiently well so as to make title superfluous.

2. Is there evidence that property owners have overlapping rights? One sort of such evidence is that property owners are aware of the benefits of coordination and attempt to coordinate, whether that effort is successful or not. For example, Libecap and Wiggins (Libecap and Wiggins 1985, Wiggins and Libecap 1985) document that owners of oil field leases understand the benefits of unitary control, even though they are often unable to contract to achieve such coordination.[14]

3. Do the property institutions provide effective public notice of boundaries? This involves several subsidiary inquiries. Is boundary information publicly available? Are access and search costs low? For example, is the information in standardized forms and are third parties available to conduct the search? Is the interpretation of the information predictable? For example, are district court or agency decisions often overturned? Are reliable third party interpretations available and insurable? Do users of the asset usually perform a thorough clearance search before investments are sunk? An example of notice failure in land occurs on the Brazilian frontier where conflicting laws give overlapping rights both to absentee owners of large estates and to settler squatters (Alston et al. 1999).

14 Heller (2008) suggests that property owners might not want their desire to coordinate to become public knowledge. Except in cases where the coordination is in blatant violation of antitrust statutes, there does not seem to be a clear economic motive to suppress such information. To the contrary, because parties can privately gain by coordinating, they have economic incentives to make their willingness to do so public knowledge.

A decision tree based on these inquiries is shown in Figure 3. If asset owners do not obtain title this might be because the property system is ineffective—e.g., title is too expensive or enforcement is too unreliable—or it might mean that private exclusion measures are simply effective enough. The other outcomes correspond to the various cells in Figure 2. Thus these inquiries into institutional performance shed some light on the qualitative nature of the economic performance of the property system. This helps identify the sources of institutional failure, if any, but it does not directly provide a quantitative measure of how bad any such failure might be.

Quantitative evaluation of patent notice

For one specific scenario—notice failure—it is possible to estimate a lower bound of the extent to which prices exceed the Pareto optimal level. Further, given an estimate of the elasticity of v, one can then estimate a lower bound on the associated loss of welfare.

In this scenario, one owner, A_1, has a right that is relatively likely to be enforced and can therefore charge the unconstrained price, p_1*. However, because property rights are not well-defined, other owners, A_j, j=2,...N, have rights that are relatively unlikely to be enforced and they can only charge their constrained prices, $\underline{p_j}$. The total actual price that a user pays to all asset owners is

(7) $$P^a \equiv p_1^* + \sum_{j=2}^{N} \underline{p_j} = \left(\epsilon(x^a) + \sum_{j=2}^{N} (1 - q_j) \right) v(x^a)$$

where x^a is the equilibrium level of use. The first term in parentheses corresponds to that portion of the total price going to the property owner with the relatively certain right while the second term corresponds to that portion going to the owners of "weaker" rights.[15] In this scenario, the optimal price

[15] Note that litigation cost, L, does not enter this expression because under the assumptions made, all disputes are settled in

would be realized if owner 1 held the only legal claim to the asset. In that case, the total price would be

(8) $$P^* = \epsilon(x^*)\, v(x^*) .$$

Define the share of actual rents going to the "weaker" property owners

(9) $$R \equiv \frac{P^a\, x^a - \epsilon(x^a)\, v(x^a)\, x^a}{P^a\, x^a} = \frac{Z}{\epsilon\,(x^a) + Z}, \qquad Z \equiv \sum_{j=2}^{N} (1 - q_j) .$$

As long as Z is not too large and v does not decrease too rapidly with small changes in x, then (see Appendix)

(10) $$\ln \frac{P^a}{P^*} \approx \frac{R}{2} .$$

This represents the extent to which poorly defined property rights inflate costs to asset users. These inflated prices make use of the asset suboptimal. The magnitude of this under-utilization depends on the elasticity, ϵ, but with an estimate in hand, the associated loss of social welfare can be calculated.

The ratio R can also be estimated. In this scenario, claimants with relatively uncertain rights (that is, $j = 2,...,N$) assert their rights after the users have sunk their investments. This means that the rents paid to "weak" property owners represents a risk of ex post disputes that asset users will take into account when they make their decisions to enter the market and invest. Alternatively, the asset owner with relatively certain rights (user 1) can indemnify her customers against these risks, as is typically done in many markets, and correspondingly increase the price charged. The result is the same, however, in that the risk inflates the effective price of asset use. The numerator of R thus represents the

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Stage 4 without going to trial (see Appendix). To the extent that disputes eventually do go to trial, the rents would be net of litigation cost in a more realistic model. However, this makes no difference in practice to the calculation I perform below. Also, if rights are so uncertain that an asset owner cannot credibly commit to spending L in Stage 5, then that expected dispute risk to asset users while the denominator represents the total rents realized from the asset by all users, making R the share of dispute risk in total rents. Where a lower bound on dispute risk can be estimated (as I show below for the case of patents), then these can be compared to measures of total rents received to obtain an estimate of the degree of excessive prices. My simple model does not consider other losses from disputes (e.g., lost business, management distraction costs) and it assumes that disputes settle before going to trial, thus avoiding direct litigation costs. To the extent that these costs add to the ex ante risk to asset users, they also increase the effective price of asset use and should thus also be included in this calculation. Note, finally, that this calculation only applies to the case of "notice failure," where a single party owns a relatively certain right and other parties have relatively uncertain rights.

Example: Patents

Patents are property rights in inventions intended to overcome the free-riding externality. How do patents perform at this task? Boldrin and Levine (2008) argue that patents are neither necessary nor helpful at promoting innovation. In this section, I apply the limited framework developed above to some empirical evidence about patents. I do this as a simple illustration of the approach developed here, rather than as an exhaustive final analysis of the US patent system. A complete analysis would need to go into greater depth and consider a wider range of evidence than I present here. Nevertheless, a brief consideration might help illustrate some of the main themes of my proposed approach to evaluating property rights systems.

Note that patents address a free-riding externality. This is a positive externality while the congestion externality I modeled above is a negative externality. Nevertheless, the model can be readily

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right is not enforced, that owner does not collect rents, and so does not appear in this equation.

adapted to the case of patents with only some minor differences.[16] Indeed, Shapiro (2001) creates a model that is an instance of my model, for the specific case where there are overlapping rights that are all relatively certain to be enforced.

Institutional performance

First, consider the three inquiries concerning institutional performance (for a more complete discussion of some of this evidence, see Bessen and Meurer 2008a):

1. Do most property owners obtain title? Table 1 shows the percentage of public firms in several high tech industries that applied for patents in 1999 or earlier that were granted by 2002. In almost all of these industries, most firms acquire patents. The exception is business services including software (these firms are mostly in the software industry). Software firms might obtain patents less frequently because historically the law significantly limited the degree to which software inventions could be patented. However, by 1999, case law affirming the validity of software patents had been well established. More important, the high degree of innovation during the decades when software patents were not routinely issued indicates that private means of exclusion (trade secrecy, first mover advantage, etc.) are highly effective in the software industry so that legal property rights might be frequently superfluous.

2. Is there evidence that property owners have overlapping rights? Industry participants contend that patent "thickets" exist in some industries such as information technology and electronics industries (Levin et al. 1987). Surveys find that among the main reasons to acquire patents are

16 The main difference is that v now represents the demand for the technology among heterogeneous users. In this setting, social welfare is calculated slightly differently: it now includes rents, as with the congestion externality, but it also includes infra-marginal consumers' surplus.

blocking competitors from developing their own technologies, preventing lawsuits (through threat of counter-suits) and for use in negotiations (Cohen et al. 2002). These uses only make sense if multiple firms have overlapping patent rights on each others' technologies. On the other hand, outside of standard setting organizations, which are a special case, there appears to be little effort to establish patent pools (see Lerner et al. 2003), even though antitrust authorities have set forth clear guidelines for doing so (US Department of Justice and Federal Trade Commission 1995). Furthermore, survey evidence among biomedical researchers and lawyers finds that overlapping patents rarely force researchers to abandon research paths; instead, they ignore patents in cases of possible conflict (Walsh et al. 2003). In summary, the evidence suggests that overlapping patent rights might be significant in some industries, but evidence of an "anticommons" is weak at best. The evidence might be more consistent with a "notice failure" scenario where many overlapping rights have relatively uncertain prospects of enforcement.

3. Do the property institutions provide effective public notice of boundaries? This involves several subsidiary inquiries:

    a) Is boundary information publicly available? Although patent documents are made public (in some cases only when the patents issue), it is possible for patent applicants to revise the claims in their patents over many years and by doing so, to effectively change the boundaries of their rights. One method of doing this is to maintain continuing applications, and by the late 1990s, nearly one third of all patent applications were continuing applications as opposed to original applications (Bessen and Meurer 2008a).

    b) Is the interpretation of the information predictable? Courts interpret patent boundaries through a process known as "claim construction." However, this process has become unpredictable so that nearly 40% of district court claim interpretations are overturned on appeal (Moore 2005). It is even more difficult to obtain a reliable determination of patent boundaries prior to a lawsuit. Although lawyers will provide interpretations of patent boundaries, these are expensive, they are not guaranteed and the market for insurance against misinterpretations hardly functions (Betterley 2006). This contrasts, say, with the predictable role of surveyors in interpreting land deeds and the availability of title insurance for land.

c) Do asset users usually perform thorough clearance searches before investments are sunk? According to a survey of patent counsel who are members of the Intellectual Property Owners Association, 65% do not always conduct clearance searches before introducing a product (Cockburn and Henderson 2003). In some industries such as computers and software, firms routinely do not conduct clearance searches because the numbers of overlapping patents they would have to search would make the cost of search prohibitively expensive, aside from the unpredictability of any determinations.

In sum, firms in most technology industries do acquire patents, indicating that these property rights do deliver positive private value. However, there is substantial evidence that some of the public notice functions of the patent system do not work well. Patent boundaries can be hidden for significant periods of time, interpretation of these boundaries is unpredictable and, not surprisingly, clearance searches are not conducted in many industries. For these reasons, the institutions of the patent system do not function as property systems are supposed to function. This inquiry does not, however, reveal how significant this failure is.

Quantitative evaluation of patent notice failure

Given the diagnosis of notice failure, the next step is to obtain a quantitative evaluation of this failure, specifically by estimating the extent to which prices exceed the Pareto optimal level as in equation (10). The variable R in (10) can be approximated as follows. First, the denominator represents the total rents received, in this case, the discounted expected future returns to R&D investment. In a competitive equilibrium with free entry, firms will invest in R&D until the total R&D investment equals the expected present value of future R&D rents from that investment. Beyond this point, further investment is no longer profitable. This means that under competitive equilibrium, the denominator equals the level of R&D spending. This will be true even when notice failure raises prices above their Pareto optimal level. Of course, barriers to entry in the performance of R&D might limit R&D spending, providing rents in excess of the R&D investment, but these barriers to entry are also likely to raise prices even further above the Pareto optimal level. Consequently, even without competitive markets, R&D spending is likely to serve as a first order approximation of R&D rents.

The numerator represents the rents going to the holders of relatively uncertain rights. As above, this corresponds to the risk of ex post disputes. This risk can be estimated from the loss of wealth that firms experience following the filing of a lawsuit against them using event study methods (see Bessen and Meurer 2008b).[17] Since some disputes are settled without a lawsuit being filed, this loss of wealth understates the total dispute risk and thus understates the rents to owners of uncertain rights.[18]

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17 In practice, lawsuits also involve deadweight loss in addition to a transfer. In the model above, I ignored such deadweight loss and included conditions so that litigation would not occur. It is straightforward to extend the model to scenarios where litigation occurs and where it creates deadweight losses. Deadweight losses increase the cost to users of the technology, thus driving up effective relative prices, so these should be included in the numerator of R. Note, moreover, that these estimates of lost wealth include the majority of cases where lawsuits are settled prior to trial.

18 Note that I am comparing the current litigation risk to current R&D spending. However, current R&D spending corresponds, in equilibrium, to *future* rents earned on innovations. Thus to the extent that R&D has been increasing, my

From the analysis of lawsuit filings for US public firms in 1999 (Bessen and Meurer 2008b), I obtain an estimate for loss of wealth of $29 billion (in 1999 dollars), after accounting for under-reporting and the stock market "bubble" (see the paper for details). This compares with $160 billion of non-Federal spending on industrial R&D in 1999. Inserting these values into (10) implies that patent notice problems increased the effective prices of technologies at least 9% above their optimal levels. The true value might be substantially greater, given that the estimate of R ignores disputes that are settled without litigation.

The effect of this mis-pricing on R&D spending and on social welfare depends on the price elasticity of technology. Nevertheless, it is clear that at reasonable values for this elasticity, notice failure reduced technology use and slowed R&D spending, although these reductions were not necessarily very large.

This price premium can also be compared to the "effective subsidy" that patents provide to R&D spending. Schankerman (1998) reviews the literature and concludes that this effective subsidy rate is only 10-15%, somewhat less than the increase in effective technology prices resulting from notice failure. Bessen and Meurer (2008a) compare litigation risk with private returns from patents among public companies and find that in the chemical and pharmaceutical industries, the private benefits substantially exceed the litigation risk, but that in other industries, the reverse is true. Thus the excessive user cost of technology arising from poorly defined patent boundaries might well eliminate the net incentives the patent system provides in overcoming free riding.

Conclusion

This paper provides a framework for evaluating the performance of property systems when rights

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estimate of R is understated.

might not be perfectly enforced and perfectly defined. I identify several distinct patterns of behavior associated with distinct institutional failures. The framework provides a simple set of inquiries to evaluate institutional performance and a quantitative means to measure the significance of one sort of institutional failure, specifically notice failure.

Applying this framework to the current US patent system as an illustration, I find evidence that patent institutions fail in several ways to provide clear notice of property boundaries and that this increases technology prices significantly above their Pareto optimal level.

This evidence, although strongly suggestive, is also limited. Although I identify specific institutional failings, this does not imply that patent reform can or cannot correct these failings. In contrast, Boldrin and Levine (2008) argue that patents are not necessary to encourage innovation and that society would be better off without them. My limited evaluation of the patent system cannot make such global judgments.

Appendix

Solution zones

First, consider the ith asset owner's rent maximizing problem. That owner seeks to choose a price, p_i, taking the prices of all other asset owners as given. The rents will also depend on the level of use, x, which is determined by the free entry zero profit condition,

$$v(x) - \sum_{j=1}^{N} p_j - c = 0 \tag{A1}$$

The Lagrangean for this constrained maximization problem is

$$\mathcal{L}(x, p_i) = p_i x + \lambda \left(v(x) - p_i - \sum_{j \neq i}^{N} p_j - c \right)$$

with a first order condition of

$$p_i^* = \epsilon(x)\, v(x) \tag{A2}$$

as in (5). Alternatively, the ith asset owner can pursue an enforcement action against the jth asset user. The payoffs to the asset owner and asset user in Stage 4 (under the assumptions, parties will always settle in Stage 4 rather than go to litigation in Stage 5) can easily be shown to be

$$\{ (1 - q_i)\, v(x)\, x_j, \quad q_i\, v(x)\, x_j \}$$

From this, the user will be indifferent between paying ex ante and going into Stage 4 negotiations when the price charge by owner i is(A3)

$$\underline{p_i}(x) \equiv \begin{cases} (1 - q_1)\, v(x) + c_0, & i = 1 \\ (1 - q_i)\, v(x), & i > 1 \end{cases}$$

In other words, this is the largest price that the asset owner can charge; when this is less that p_i*, this will be the "constrained" price. In this case, the asset owner makes the same profit by charging this price ex ante as by negotiating ex post, so there is no advantage to either party to forming an ex ante contract. This means that the asset owner has nothing to gain from spending u in order to establish notice in this case. The net result is that relatively uncertain enforcement, asset owners end up in disputes (or litigation) and they only expect to receive an amount equal to the constrained price.

On the other hand, when $\underline{p_i} > p_i$*, the asset owner has an incentive to charge p_i* ex ante and therefore to spend u to put prospective users on notice. If they did not do this, then prospective users—knowing that an asset owner with a relatively certain right exists, but not knowing who that asset owner is—would use the asset less than if they were charged p_i*. Although the ith asset owner would receive a higher price, the use of the asset and the total rents would be less than at the rent maximizing price. So, as long as u is not too large (as I have assumed), the asset owner would be better off spending u to establish notice and forming ex ante contracts.

To consider the solution zones, designate asset owners i = 1,...,n as charging their unconstrained prices and asset owners i = n+1,...,N as charging constrained prices. Then substituting (A2) and (A3) into (A1),

$$v(x) - n\epsilon(x)\,v(x) - v(x)\sum_{i=n+1}^{N}(1-q_i) - c = 0$$

or

$$v(x) = \frac{c}{1 - n\epsilon - \sum_{i=n+1}^{N}(1-q_i)} \quad \text{(A4)}$$

When N=1 and $\underline{p_i} > p_i$*, (A4) yields,

$$v^{1u}(x) = \frac{c}{1-\epsilon}$$

This is that same as (3), so, in other words, the unconstrained price yields the Pareto optimal allocation. When $\underline{p_i} < p_i^*$, then

$$v^{1c}(x) = \frac{c}{q} \quad \text{but, comparing (A3) and (A2),} \quad \frac{c}{q} < \frac{c}{1-\epsilon}.$$

Hence $v^{1u} > v^{1c}$. From this it is straightforward to show (see Bessen 2009 for use of the implicit derivative) that $x^{1u} < x^{1c}$, or, the asset is overused in this case.

When $N > 1$ and at least one asset owner can charge the unconstrained price, (A4) can be written in the form of

$$\text{(A5)} \quad v^{Nu}(x) = \frac{c}{1-\epsilon-Z}, \quad Z > 0$$

From this it follows that where an equilibrium exists, $v^{Nu} > v^{1u}$, and from this it is straightforward to show underuse by taking the implicit derivative of (A5) (see Bessen 2009 for details).

Derivation of (10)

Taking the implicit derivative of (A5),

$$\frac{dP}{dZ} = \frac{v \cdot v'}{v''\,x + v'(2-Z)}.$$

Then, as long as Z and v'' are not too large,

$$\frac{d\ln P}{dZ} \approx \frac{1}{2}\,\frac{1}{\epsilon+Z}.$$

Comparing a change in Z from 0 to the sum given in the text yields (10).

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Table 1. Share of Public Firms in Technology Industries with Patent Applications or Grants, 1999

Industry	SIC Code	Percent with Patents
Chemicals and pharmaceuticals	28	85%
Machinery, including computer equipment	35	87%
Electronics and electrical equipment, excluding computers	36	87%
Instruments	38	88%
Business services, including software	73	35%

Figure 1. Model decision Tree

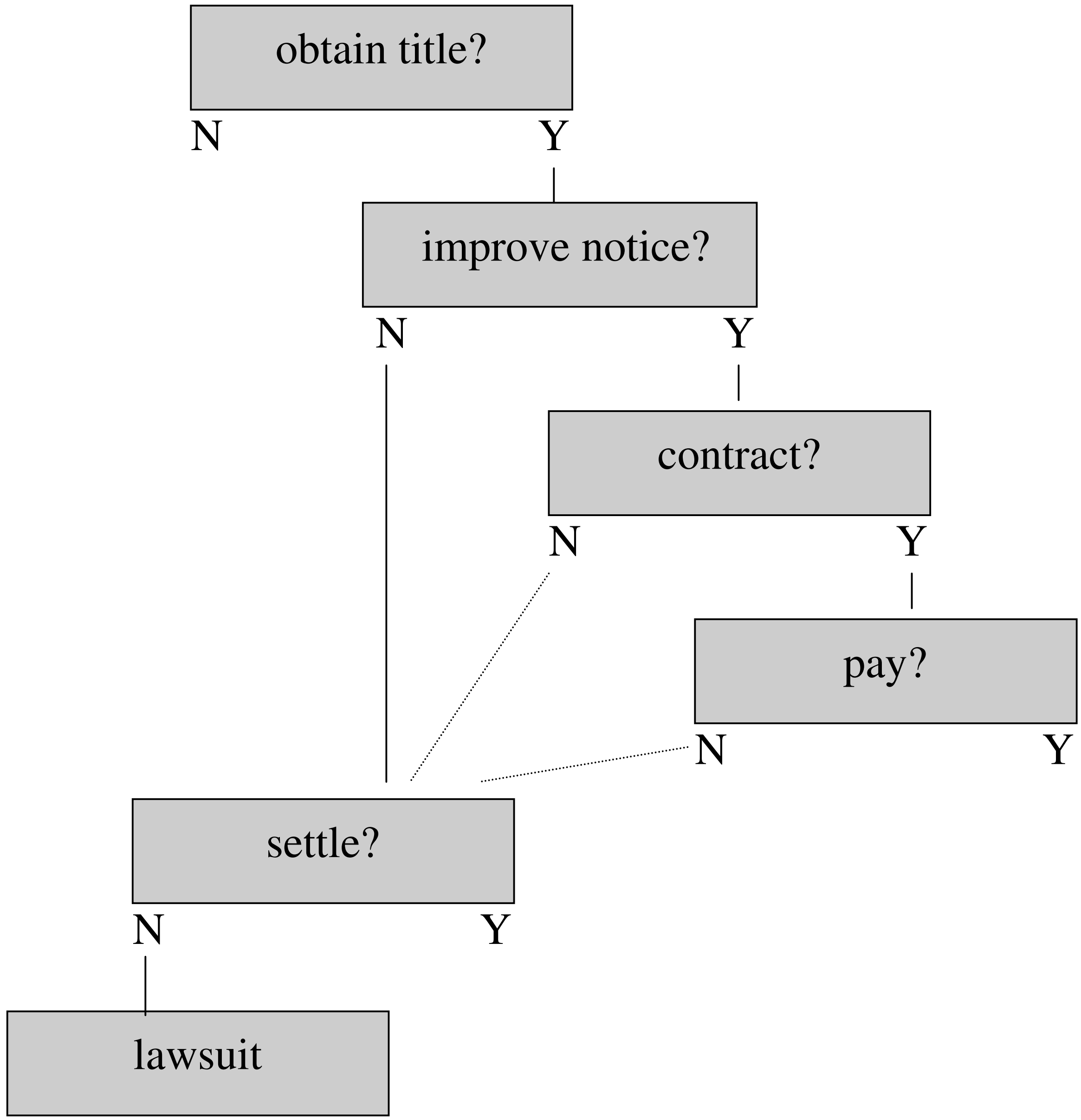

Figure 2. Solution regions

	Single Owner	Multiple Owners
Unconstrained price (one or more owners)	Pareto optimal allocation	Underuse
Only constrained prices	Overuse	Ambiguous

Figure 3. Decision tree for classifying institutional performance