

Coming to the Nuisance: An Economic Analysis from an Incomplete Contracts Perspective

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We construct a model in which an investment opportunity arises for a first mover before it knows the identity of a second mover and in which joint location results in a negative externality. Contracts are inherently incomplete since the first mover cannot bargain over its ex ante investment decision with the anonymous second mover. Given this departure from the setting of the Coase theorem, the allocation of property rights over the externality has real effects on social welfare. We investigate the relative efficiency of property rights regimes used in practice: injunctions, damages, the ruling in the *Spur Industries* case, etc. The first best can be obtained by allocating property rights (in particular the right to sue for damages) to the second mover. Allocating property rights to the first mover, as a “coming to the nuisance” rule entails, leads to overinvestment. In contrast to conventional wisdom, this inefficiency persists even if a monopoly landowner controls all the land on which the parties may locate.

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1. Introduction

A recent case in Australia, *Peters and Ors v. S. Burstin*, Appeal no. 1993/19735 (City of Caulfield Tribunal, 1993), featured a complaint of nuisance between a legal brothel and a children's dance studio. Ironically the brothel was the plaintiff in the suit. Students were alleged to have persistently rung the brothel's doorbell and to have stolen candy from the front office, activities which, in addition to the mere presence of children in the area, allegedly drove clients away. The judge ruled in favor of the brothel, arguing that it was established long before the dance studio began operations and as the first mover should have its property rights protected from infringement by subsequent nuisances. A related example is the classic tort case, *Spur Industries, Inc. v. Del E. Webb Development Co.* 108 Ariz. 178, 494 P.2d 700 (1972). Spur operated a cattle feedlot for years in the countryside before Webb purchased nearby land to develop residential homes. After Webb began construction, it sued the feedlot, alleging that the odors and flies from the feedlot reduced residential property values. The judge ruled that Spur had to move away from the development, but since Spur had arrived in the area first and Webb had come to the nuisance, Webb would have to compensate Spur for any lost surplus due to the move.

In both cases, the fact that the parties' location decisions were made sequentially was crucial: the judge's ruling in both cases favored the first mover. The rulings raise the theoretical question of whether it is economically efficient to favor the first mover, applying what is termed a "coming to the nuisance" rule. It may be tempting to apply the insights of Coase (1960) to answer this theoretical question. As long as parties are able to bargain at low cost from clearly defined property rights, the externality should be internalized, and efficient production should take place. But were the transaction costs of bargaining over all relevant variables likely to be low in these cases? In the *Spur Industries* case, the feedlot was in operation for years before the developer appeared; and in the *Peters* case, the brothel was in operation long before the studio opened its doors. It seems unlikely that the feedlot's or the brothel's investments could have been the subject of efficient negotiations with firms locating nearby many years later, and so the Coase theorem would seem to have limited practical applicability in these cases.

In this article we analyze situations where a first mover, *A*, makes an investment decision before it knows the identity of the second mover, *B*. *A* may foresee that a second mover will locate nearby in the future, resulting in a negative externality between them; however, *A* does not know which of a large set of potential second movers will actually turn up, rendering it impossible for *A* to contract with *B* over investment variables prior to *B*'s identity being revealed. We use the term *ex ante* anonymity to denote this source of contractual incompleteness. Though *ex ante* anonymity is a simple and realistic departure from the setting of the Coase theorem, this single departure produces a rich set of new implications. The various property rights regimes that have commonly been studied no longer all

produce the first best and differ among each other in terms of social welfare.

We are able to provide a full ranking of property rights regimes in terms of social welfare, but perhaps a more fundamental contribution of our article is a new framework for thinking about the economics of property rights regimes, a framework which leads to a simple formula for determining the efficiency of arbitrary regimes. In our model, A makes an initial noncontractible investment x ex ante, before B arrives. Once B arrives, we assume bargaining costs are low, so parties can arrive at an efficient agreement over ex post variables (the externality level between them, subsequent investments) conditional on A 's initial investment. Thus social welfare in equilibrium is completely determined by A 's ex ante investment. A 's ex ante investment has a strategic effect on this ex post bargain, leading A 's investment incentives to differ from the first best. To see this point, suppose the parties engage in Nash bargaining ex post, splitting the gains from arriving at an efficient ex post agreement equally. That is, each party obtains its threat point surplus—denoted $t(x)$ for A and $\tilde{t}(x)$ for B —plus half of the gains from agreement $s^*(x) - t(x) - \tilde{t}(x)$, where $s^*(x)$ is the maximum ex post social surplus. Taking account of the investment expense x , A 's objective function from an ex ante perspective is

$$t(x) + \frac{1}{2}[s^*(x) - t(x) - \tilde{t}(x)] - x.$$

The associated first-order condition can be written, upon rearranging, as

$$\frac{1}{2} \left[\frac{ds^*(x)}{dx} \right] + \frac{1}{2} \left[\frac{dt(x)}{dx} \right] - \frac{1}{2} \left[\frac{d\tilde{t}(x)}{dx} \right] = 1. \quad (1)$$

The left-hand side of Equation (1) is the marginal benefit to A from investment. The right-hand side is the marginal cost. This first-order condition differs from the condition determining the first best, $ds^*(x)/dx = 1$, the difference reflecting the strategic effect of A 's investment on bargaining.

A property rights regime determines a pair of marginal threat-point payoffs $dt(x)/dx$, $d\tilde{t}(x)/dx$ and affects social welfare by changing A 's marginal benefit from investment. The value of our framework is that it is relatively straightforward to translate a legal regime into the formal threat points it implies, and insights into the efficiency of a regime can subsequently be made with reference to Equation (1). (The algebraic analysis following from Equation (1) can also be summarized in a simple graph; see Figure 2 below.) We focus on three basic forms of property rights: the right to choose the externality (injunctive rights), the right to sue for damages from the other party (damage rights), and the right to exclude the other party from the location (exclusion rights). Each of these rights can be given to either the first or second party, leading to a number of different multi-dimensional rights regimes.

We show that one of these multidimensional rights regimes, second-party damage rights, yields the first best. It is a standard result that such damage payments induce the payer to set the externality at the socially optimal level in our simple setting, much as would an optimal Pigouvian tax (see, e.g., Polinsky [1979]). Indeed, by leading *A* to internalize *B*'s surplus at the margin, the damage payment causes *A* to set all of its choice variables at their socially optimal levels in our setting, not just the externality but also *A*'s ex ante investment (which is the crucial determinant of social welfare in our model).

In practice, it may be difficult to implement the second-party damage rights regime since the informational burden it places on courts to set the appropriate damage payment may be unrealistically high. The other second-party rights regimes we analyze, which may place fewer informational demands on the court, are inefficient, leading *A* to underinvest. These other second-party rights weaken *A*'s marginal threat point compared to the marginal social benefit, $dt(x)/dx \leq ds^*(x)/dx$, and strengthen *B*'s marginal threat point, $d\tilde{t}(x)/dx \geq 0$. In Equation (1), this means the marginal benefit of investment falls below $ds^*(x)/dx$, the first-best level; so there is underinvestment. In essence, in these second-party rights regimes, the second mover is able to expropriate some of the returns from the first mover's investment, leading to suboptimal investment by the first mover. This is an instance of the holdup problem, familiar from the literature on incomplete contracts and the theory of the firm (e.g., Williamson, 1979; Grossman and Hart, 1986; Hart and Moore, 1990).

The fact that second-party rights regimes (besides second-party damage rights) lead to underinvestment might seem to lend support to a first-party rights regime, that is, a coming to the nuisance doctrine. We show that a coming to the nuisance rule is not generally efficient. Allocating property rights to the first mover eliminates the standard holdup problem and consequent underinvestment but introduces a new problem of overinvestment. First-party rights give too strong a marginal default to *A*, $dt(x)/dx > ds^*(x)/dx$, and too weak a marginal default to *B*, $d\tilde{t}(x)/dx \leq 0$. In Equation (1), these conditions ensure that *A*'s marginal benefit from investment exceeds $ds^*(x)/dx$, the social level. Combining the facts that (a) first-party regimes are strictly inefficient, whereas (b) second-party damage rights yields the first best, we obtain the striking result that coming to the nuisance rules are strictly dominated by other legal rules. Our theoretical results thus provide a rationale for the gradual decline in importance of the doctrine in court cases.¹

1. See Wittman (1980) for an overview of the case law. Charter (1983) provides examples suggesting that coming to the nuisance is still important in some jurisdictions. For example, in *Prah v. Maretti* (108 Wis. 2d 223, 321 N.W.2d 182 (1982)), the Wisconsin Supreme Court began to establish first-party property rights for solar access. "Right to farm" laws, which protect farmers from nuisance suits, represent a present-day codification of the coming to the nuisance doctrine in that farmers are typically the first movers and nuisance suit plaintiffs the

One might suspect that the overinvestment problem would disappear if there were a single landowner controlling all the land on which the first and second mover might locate. In contract negotiations between the first mover and the landowner regarding the use and/or purchase of the land, the landowner might serve as a sort of proxy for the absent second mover, with the landowner internalizing the surplus of the second mover through the price it anticipates receiving from it. This is the conventional wisdom in the literature. For example, Posner (1992:66) writes, "Attaining the efficient solution would have been much simpler if a single individual or firm had owned all of the affected land." Stull (1974), in his seminal article on land use and zoning, argues that ownership by a single developer produces a social optimum which may Pareto dominate decentralized ownership. Similar points have been raised in discussions of the problem of the commons (see, e.g., Baumol [1988:chap. 3], Starrett [1988:chap. 5], and Hardin [1993]). Surprisingly, the conventional wisdom is not true in our framework: having a single landowner does not always lead to a social optimum. We show that if A is a monopoly landowner but does not have 100% of the bargaining power, it will have an incentive to increase its investment for rent extraction purposes, leading to strict overinvestment.

Wittman (1980, 1981, 1998) was the first to provide an economic analysis of the efficiency of coming to the nuisance rules in a model of sequential investment. He studies the case in which the court has unlimited information about parties' surplus and cost functions. He shows that in implementing the first best, which the court can always do with the information it has, the timing of parties' investments may sometimes be a relevant consideration and the first and second movers may sometimes be treated asymmetrically. By contrast, we study the case in which the court has much more limited information: the court must set a general legal rule before it knows the surplus and cost functions particular to each case. Another difference is that Wittman focuses on the case in which high transaction costs prevent private bargaining, so that the final allocation is directly determined by the court's ruling. Wittman (1981) mentions that the case of low transaction costs is relevant in coming to the nuisance cases, conjecturing that arguments along the lines of the Coase theorem would render concerns about the timing of investment immaterial:

[C]oming to the nuisance cases typically involve much lower transaction costs than traffic accidents where it is virtually impossible to contract *ex ante* with all potential participants to the damage. Since trading in property rights is often possible in nuisance cases, the courts need only initially assign property rights without paying any attention to sequence, and then as the stages of the sequence occur the parties can trade in the property right.

second movers in rural areas covered by the laws (see Grossman and Fischer [1983] and Reinert [1998]).

We focus on the case in which transaction costs are high when the investment decision is made *ex ante* before the second mover arrives, but low thereafter, so that private bargaining is efficient *ex post*, and property rights only indirectly affect the final allocation through the effect on threat points in bargaining. In this setting, we show the Coase theorem in fact does not apply: social welfare depends on whether property rights are allocated to the first or the second mover, along with other dimensions of property rights regimes.

There are connections between our work and the broader law and economics literature. First, there are a number of articles that also examine the effect of legal rules on *ex ante* investment, using *ex ante* investment as an index of social welfare, most notably the literature on government takings (Blume and Rubinfeld, 1984; Blume, Rubinfeld, and Shapiro, 1984; Hermalin, 1995). The takings literature shows, for example, that when the government provides full compensation for takings, the private owner has an incentive to overinvest, since investment increases its compensation but not social welfare (presuming it is efficient for the government to exclude the private owner from the location), an overinvestment effect similar to the one we obtain with first-party rights. We discuss the connection to the takings literature in Section 5.5. Second, our setting, involving as it does property rights and sequential investment, is related to research on patent protection with sequential innovation (Chang, 1995; Green and Scotchmer, 1995; Scotchmer, 1996; O'Donoghue, Scotchmer, and Thisse, 1998). Third, our result that first-party rights leads to overinvestment is similar to the result in the literature on first possession rules (Ellickson, 1989; Lueck, 1995) that such rules lead to excessive possessory investment. We study a broader range of rights than this literature, rights beyond simple possession, and we study a different setting, a setting in which the second mover is not available to sign contracts with the first mover *ex ante*, and thus is not available to race with the first for property rights.

The structure of the article is as follows. In the next two sections we set up the model and formally define the property rights regimes we will study. In Section 4 we prove the main propositions. Proposition 1 ranks the property rights regimes in terms of the *ex ante* investment and social welfare they generate. Second-party damage rights yields the first best; there is strict underinvestment with the rest of the second-party rights regimes we consider and strict overinvestment with all first-party rights regimes we consider. Proposition 2 shows that a whole range of property rights regimes produce the first best in the special case in which *A* has all the bargaining power. In Section 5 we apply the results to a number of different policy questions, including the question of whether coming to the nuisance rules are generally efficient, whether monopoly land ownership yields the first best, and whether injunctions are more efficient than damages. We return to the *Spur* case and show that the ruling the appeals court issued in the case is in fact less efficient than any other first-party rights regime we consider. We also discuss how our results in a nuisance setting bear on the issue of government takings. Section 6 concludes.

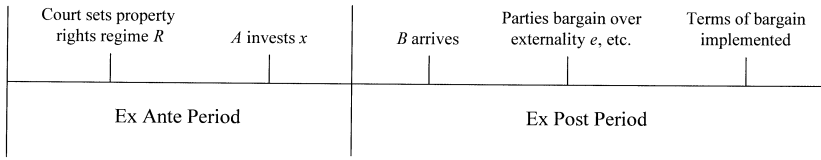


Figure 1. Timing of the model.

2. Model

The model has two periods, an ex ante and an ex post period, and two parties, A and B . Figure 1 depicts the timing of the model. Ex ante, the court specifies a property rights regime R , which is common knowledge. A becomes aware of an investment opportunity in a given location. It purchases land on a competitive market, the price of which is normalized to zero, and sinks investment expenditure $x \in [0, \infty)$. Ex post, B becomes aware of an opportunity that happens to be nearby A 's location. We will later allow for the possibility that A forecloses B 's entry by purchasing all the nearby land on which B might operate, but for now suppose B can purchase a plot of land at the competitive price and begin operations. The joint operation of A and B near each other leads to a negative externality $e \in [e, \bar{e}]$. In the *Spur* case, for example, the externality consisted of flies and odors emanating from the cattle feedlot (party A) suffered by the residential development (party B).

Our key assumption is that the first mover, A , is not aware of the identity of the second mover, B , ex ante, so that it is impossible for them to contract on x or any other variables ex ante. We refer to this assumption as “ex ante anonymity.” Ex ante anonymity can be justified on the grounds that there are many potential parties who could move nearby A , and it is too costly to negotiate with all of them. To focus on the pure effect of ex ante anonymity, we assume that once B arrives—that is, ex post—parties can bargain over any variables that were not sunk ex ante, including subsequent investment and the externality level. The only variable not subject to efficient bargaining is thus x . We will see that a comparison of the equilibrium value of x to the social optimum will be a sufficient statistic for the efficiency of a property rights regime.

For simplicity, assume there is no discounting across periods. Let $u(x, e)$ be A 's surplus function and $\tilde{u}(e)$ be B 's, both assumed to be positive, twice continuously differentiable, and strictly concave.² These surplus functions

2. The implicit assumption is that A has perfect foresight regarding B 's surplus function $\tilde{u}(e)$ but not B 's identity. This assumption simplifies the presentation of the results but is not crucial. The results would be identical if A were uncertain about B 's surplus function: that is, if B 's surplus function were written $\tilde{u}(e, \beta)$ where β is B 's type, a random variable with distribution function $F(\beta)$. An expectation over the support of β would have to be carried through the derivations, but the results and proofs would otherwise be identical.

should be thought of as ex post quasi rents in the sense that they do not subtract the investment expense x sunk ex ante but do subtract the ex post opportunity cost of operating in some other area. To conserve notation, and without loss of generality, we have suppressed the dependence of u and \tilde{u} on ex post investments that respective parties might make. Ex post bargaining will focus on setting e efficiently.

To formalize the notion that e is a negative externality, the following definitions will be useful.

Definition 1. A is the generator if $\partial u/\partial e > 0$ and $\partial^2 u/\partial x \partial e > 0$.

Definition 2. A is the victim if $\partial u/\partial e < 0$ and $\partial^2 u/\partial x \partial e < 0$.

Definition 3. B is the generator if $d\tilde{u}/de > 0$.

Definition 4. B is the victim if $d\tilde{u}/de < 0$.

Simply put, the generator of the externality prefers higher levels and the victim lower. In addition, with respect to party A , the definitions embody the standard assumption that the effect of the externality on total surplus has the same sign as its effect on the marginal benefit of investment. For example, letting A be a polluting factory of size x , the definitions imply that the larger A is, the higher its marginal benefit from pollution. In terms of the definitions, the assumption ensuring the parties have conflicting interests so that e is a negative externality can be stated:

Assumption 1. Either A is the generator and B is the victim, or vice versa.

Let $s(x, e) = u(x, e) + \tilde{u}(e)$ be joint surplus and $s^*(x) = \max_{e \in [\underline{e}, \bar{e}]}(x, e)$ be the associated value function. Let $e^*(x) = \operatorname{argmax}_{e \in [\underline{e}, \bar{e}]}(x, e)$, $e^A = \operatorname{argmax}_{e \in [\underline{e}, \bar{e}]} u(x, e)$, and $e^B = \operatorname{argmax}_{e \in [\underline{e}, \bar{e}]} \tilde{u}(e)$; that is, $e^*(x)$ is the joint surplus maximizing value of e , e^A is A 's private optimum, and e^B is B 's private optimum.³ We assume the socially optimal externality level is an interior solution:

Assumption 2. $e^*(x) \in (\underline{e}, \bar{e})$.

Assumption 2 is not crucial: it merely allows us to state subsequent propositions elegantly using strict inequalities rather than having to keep track of isolated cases where an inequality may be weak.

A and B bargain efficiently over all ex post variables, the list of which has been reduced here to the single variable, e . Parties agree on an efficient externality level $e^*(x)$ producing maximized joint surplus $s^*(x)$. The gains

3. Assumption 1 implies that the generator's private optimum is \bar{e} and the victim's is \underline{e} , independent of x . Hence e^A and e^B are not written as functions of x . Our subsequent results are qualitatively similar, and the proofs have a similar structure, in the case in which the generator's private optimum is an interior solution increasing in x rather than a corner solution. We will comment on the differences made if one were to assume an interior solution in the relevant sections below.

from agreement are split according to Nash bargaining. That is, A (respectively B) receives a threat point payoff $t_R(x)$ (respectively $\tilde{t}_R(x)$) plus a share $\alpha \in [0, 1]$ (respectively $1 - \alpha$) of the gains from trade. This bargaining game can be interpreted along the lines of Binmore, Rubinstein, and Wolinsky (1986), in which Nash bargaining is the limit of an extensive form game with alternating offers and with an exogenous probability bargaining breaks down each round. If bargaining breaks down, the outcome is determined by the property rights regime R specified by the court, yielding threat-point payoffs $t_R(x)$ and $\tilde{t}_R(x)$. This way of modeling property rights, namely through their effect on threat points to which parties default if bargaining breaks down, is a key element in what we refer to as our incomplete contracts approach. It is important to note that property rights affect the equilibrium indirectly by specifying what happens out of equilibrium: bargaining breaks down, and property rights are unilaterally exercised, only out of equilibrium.

3. Property Rights Definitions

In this section we define the property rights regimes, the efficiency of which we will go on to analyze in Section 4. Property rights R enter the model solely through threat points $t_R(x)$ and $\tilde{t}_R(x)$. Threat points in turn help determine surplus allocations, and so A 's choice of x .

Property rights are multidimensional, depending on the variables the holder is allowed to choose, the penalty for infringement, and the identity of the holder. Each dimension may have a number of alternatives, in some cases a continuum; so it is possible to conceive of a large number of regimes that could be analyzed theoretically. In this section we will define a handful of the most common, but, as will be seen, our framework can be used in a straightforward way to analyze other regimes.

An *injunction* right gives the holder the right to choose e . A *damage* right allows the holder to claim compensation for deviations from its preferred choice of e . Damage rights can be modeled by having the infringing party set e and pay the rights holder the difference between the rights-holder's surplus if e were set at its preferred level and its realized surplus. An *exclusion* right gives the holder the right to bar the other party from the location in addition to being able to choose e . Injunction and damage rights have been studied extensively in the law and economics literature beginning with Calabresi and Melamed (1972). Exclusion rights may seem less familiar, but in fact the regime arises naturally when a party is able to buy up the nearby land and refuse to sell land to the other party or force it to move if it has already invested. Analyzing exclusion rights will allow us to answer such questions as whether the externality problem is solved by having A be the monopoly landowner in the area.

Another dimension of property rights is the identity of the holder. In our model, an identifiable characteristic of the two parties on which property rights can be conditioned is the period in which they show up

Table 1. Threat Points Associated with Various Property Rights Regimes

Rights regime R	Acronym	A 's threat point $t_R(x)$	B 's threat point $\tilde{t}_R(x)$
First-party rights			
Injunction	<i>FIR</i>	$u(x, e^A)$	$\tilde{u}(e^A)$
Damage	<i>FDR</i>	$u(x, e^A)$	$s^*(x) - u(x, e^A)$
Exclusion	<i>FER</i>	$u(x, e^A)$	0
Second-party rights			
Injunction	<i>SIR</i>	$u(x, e^B)$	$\tilde{u}(e^B)$
Damage	<i>SDR</i>	$s^*(x) - \tilde{u}(e^B)$	$\tilde{u}(e^B)$
Exclusion	<i>SER</i>	0	$\tilde{u}(e^B)$

in the area: A is the first mover and B is the second. A coming to the nuisance rule is an allocation of property rights to the first mover; its opposite is an allocation to the second mover.

Granting property rights based on the timing of location raises the possibility of additional distortions if the timing of location is endogenous. First-mover rights may induce parties to engage in an inefficient racing/preemption game; second-mover rights may induce parties to engage in an inefficient delay game/war or attrition. Our model can be extended to allow for these possibilities, though space constraints prevent us from providing the details here. In brief, if one endogenizes the timing of location, property rights regimes are, if anything, less efficient than we find here: investment is made inefficiently early with first-mover rights and inefficiently late with second-mover rights; the inefficiency grows with the strength of the property rights for which the parties are competing. Our analysis of the simpler model with exogenous timing of location can be justified on several grounds. Regarding the race for first-party rights, we assume B does not exist as a party until the ex post period, so it cannot race with A . If it were assumed B could arrive ex ante, it would be natural in our model to assume A and B could negotiate efficiently, avoiding a preemption game and indeed achieving the first best.⁴ Regarding the war of attrition for second-party rights, for a broad range of parameters, delaying investment is too costly for A to engage in such a war. A would prefer to choose $x > 0$ ex ante and relinquish property rights to B . Our results would apply directly in this range of parameters.

Table 1 summarizes the threat points associated with the property rights regimes we will analyze. Consider the first-party rights regimes. First-party injunction rights (*FIR*) allow A to set the externality at its preferred level, e^A , yielding threat points $t_{FIR}(x) = u(x, e^A)$ and $\tilde{t}_{FIR}(x) = \tilde{u}(e^A)$. With first-party damage rights (*FDR*), B effectively sets e but pays A $u(x, e^A) - u(x, e)$.

4. One can conceive of a situation, however, in which A and B are aware of each other's existence ex ante yet cannot bargain efficiently. Using Ellickson's (1989) example, two whaling vessels in sight of each other may race toward the same whale, yet find it difficult to communicate, especially before the advent of the radio.

A 's threat-point surplus is $t_{FDR}(x) = u(x, e) + [u(x, e^A) - u(x, e)] = u(x, e^A)$. B 's surplus is $\tilde{u}(e) - [u(x, e^A) - u(x, e)] = s(x, e) - u(x, e)$, which is maximized for $e = e^*(x)$, yielding threat point $\tilde{t}_{FDR}(x) = s^*(x) - u(x, e^A)$. First-party exclusion rights (FER) let A set $e = e^A$, giving it threat point $t_{FER}(x) = u(x, e^A)$. A excludes B , reducing its threat point to $\tilde{t}_{FER}(x) = 0$. A consideration of the second-party rights regimes is analogous.

4. Analysis

As a benchmark, we characterize the first-best level of A 's ex ante investment, denoted x_{IST} : x_{IST} maximizes ex post joint surplus given e is set optimally, $s^*(x)$, minus ex ante investment expenditure x . Thus x_{IST} satisfies the first-order condition

$$\frac{ds^*(x)}{dx} = 1. \tag{2}$$

The left-hand side of Equation (2) is the marginal social benefit of investment, equal to the marginal social cost on the right-hand side.

Given property rights regime R , we can use backward induction to solve for the equilibrium value of A 's ex ante investment, denoted x_R . A 's ex post surplus from Nash bargaining is

$$t_R(x) + \alpha[s^*(x) - t_R(x) - \tilde{t}_R(x)]. \tag{3}$$

Ex ante, A maximizes Equation (3) minus investment expenditure x . Upon rearranging, x_R can be seen to satisfy first-order condition

$$\alpha \frac{ds^*(x)}{dx} + (1 - \alpha) \frac{dt_R(x)}{dx} - \alpha \frac{d\tilde{t}_R(x)}{dx} = 1. \tag{4}$$

The left-hand side of Equation (4) is A 's marginal private benefit of x resulting from Nash bargaining, equal to the marginal private cost on the right-hand side.

Equation (4) generally yields a different equilibrium value of x than the first-best level given by Equation (2). A 's marginal benefit, differs from the marginal social benefit, since A cares about how its investment affects parties' threat points $t_R(x)$ and $\tilde{t}_R(x)$ in addition to the effect on the total "pie" $s^*(x)$. Two property rights regimes will produce different equilibrium levels of investment to the extent their threat points differ at the margin.

The central proposition of the article ranks investment and social welfare for the property rights regimes defined in Section 3.

Proposition 1. Suppose $\alpha \in (0, 1)$ and $x_{SIR} > 0$. Equilibrium ex ante investment in the various property rights regimes can be ranked as follows:

$$x_{SER} < x_{SIR} < x_{SDR} = x_{IST} < x_{FIR} = x_{FER} < x_{FDR}. \tag{5}$$

Considering the first-party property rights regimes, social welfare is strictly lower in all (injunction, damage, exclusion) than in the first best; injunction and exclusion rights are equally efficient and are more efficient than damage rights. Considering the second-party property rights regimes, damage rights yields the first best; social welfare is strictly less in injunction and exclusion rights than the first best, with exclusion being less efficient than injunction.

We will sketch the structure of the proof here; a complete proof is provided in the appendix. To rank equilibrium investment in two property rights regimes, we take the threat points from Table 1, differentiate them, and substitute them into the first-order condition of Equation (4). The resulting expressions for marginal benefits on the left-hand side of Equation (4) can then be compared and monotone comparative statics results applied to draw general conclusions about the relative levels of investment. In particular, one can conclude that a regime in which the marginal benefit is strictly higher than another for each x will generate strictly more equilibrium investment by a theorem of Edlin and Shannon (1998). The last step of the proof is to establish social welfare $s^*(x) - x$ is strictly concave, implying the amount of overinvestment or underinvestment relative to the first best determines the relative efficiency of the property rights regimes.

To gain some intuition for the specific results in the proposition, consider the first-party rights regimes *FIR*, *FDR*, and *FER*. There is strict overinvestment in all three since the marginal effect of investment on A 's threat point exceeds the marginal effect on social welfare. To see this, note $dt_R(x)/dx = \partial u(x, e^A)/\partial x$ and, by the envelope theorem, $ds^*(x)/dx = \partial u(x, e^*(x))/\partial x$. But $\partial u(x, e^A)/\partial x > \partial u(x, e^*(x))/\partial x$, since the marginal effect of investment on A 's surplus function is highest at its privately optimal externality level e^A than any other, including $e^*(x)$. There is an additional effect with first-party damage rights in that increased investment by A worsens B 's threat point because it increases the losses for which B must compensate A . This can be seen mathematically by noting that the threat point $\tilde{t}_R(x)$ from Table 1 has a positive derivative. There is no effect of A 's investment on B 's threat point with injunction or exclusion rights.⁵ Therefore the overinvestment problem is worse with damage rights than the other first-party regimes.

Figure 2 presents the intuition graphically. The horizontal line of unit height is the marginal cost and the downward sloping curves marginal benefits of x . The third curve from the left is that associated with the first

5. We have assumed e^A is a corner solution. If $e^A(x)$ were assumed to be an interior solution, supposing A is the generator, A 's increased investment would increase $e^A(x)$ and worsen B 's threat point in *FIR*. B 's threat point in *FER*, zero, would remain unchanged, implying the overinvestment problem would be worse in *FIR* than in *FER*. On the other hand, one can construct alternative bargaining games in which *FER* is less efficient than *FIR*. We will not stress the equivalence of *FIR* and *FER* here, merely the robust result that both lead to inefficient overinvestment.

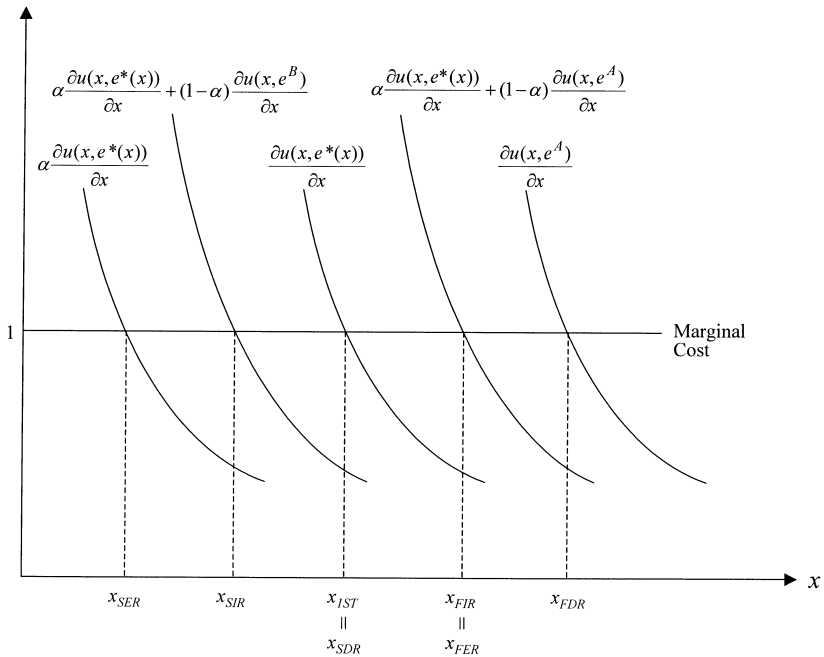


Figure 2. Investment in various property rights regimes.

best. First-party injunction and exclusion rights involve a higher marginal benefit function (fourth curve from the left), since it includes the effect of x on A 's threat point, which is greater than the effect on social welfare. The marginal benefit for first-party damage rights (last curve from the left) is even higher, since it includes the additional effect of x on B 's threat point. The equilibrium levels of investment, determined by the intersection of these marginal benefits with marginal cost, follow the same ranking as the marginal benefit functions.

Surprisingly, with first-party rights, stronger rights regimes (in the sense of giving more control over variables) do not necessarily translate into more overinvestment. Exclusion is a stronger right than injunction, which in turn is stronger than damages, yet a damage rights regime leads to the greatest investment. The reason is that it is marginal effects rather than level effects ("strength") associated with a regime which determine investment.

It turns out that with second-party rights, the efficiency of the property rights regime does follow the strength of the property rights regime. Second-party exclusion rights give B the greatest power to hold up A 's investment by excluding it from the location entirely. A 's threat point is zero, and does not contribute to A 's marginal benefit from investment (first curve from the left in Figure 2). Under injunctive rights, B can impose e^B on A but cannot have A removed. Thus A receives a positive marginal benefit from investment in the threat point and consequently invests

more than it would under exclusion rights (second curve from the left in Figure 2). Still, injunctive rights involve underinvestment relative to the first best: the marginal effect of investment on A 's surplus function in the threat point, $\partial u(x, e^B)/\partial x$, is less than in the first best, $\partial u(x, e^*(x))/\partial x$, since e^B is farther than $e^*(x)$ from A 's privately optimal externality level e^A .

Of all the second-party regimes, damage rights is best since it gives B even less holdup power than injunction. Indeed, damage rights achieves the first best because it forces A to internalize the cost that both the externality and its choice of investment impose on B . Formally, A 's ex post quasi rent—which is also its threat point $t_{SDR}(x)$, since there are no additional gains from bargaining in a damage rights regime—equals $u(x, e)$ minus the damage payment $\tilde{u}(e^B) - \tilde{u}(e)$, or $s(x, e) - \tilde{u}(e^B)$. The second term, $\tilde{u}(e^B)$, is independent of A 's decision variables x and e , so A 's marginal surplus equals social surplus. This result can also be seen in Figure 2, where A 's marginal benefit for second-party damage rights coincides with the marginal social benefit, the third curve from the left.

Proposition 1 left out a few isolated cases, the most interesting of which is the case of $\alpha = 1$, implying that A has all the bargaining power.⁶ We have the following proposition:

Proposition 2. Suppose $\alpha = 1$, so that A has all the bargaining power. First-party damage rights lead to strict overinvestment and provide strictly less social welfare than the first best. All other property rights regimes under consideration (*FIR*, *FER*, *SIR*, *SDR*, *SER*) yield the first-best level of investment and social welfare.

The proof can be seen immediately by letting α approach unity in the marginal benefit functions in Figure 2. All the marginal benefit functions converge to the one associated with the first best except for the marginal benefit for first-party damage rights, which does not vary with α . Intuitively, if $\alpha = 1$, A obtains all social surplus except B 's threat point. In all regimes but one, A 's investment does not affect B 's threat point, and so its marginal investment incentives are the same as in the first best.⁷ With first-party damage rights, even if A captures all the gains from trade, A overinvests, since this has the strategic effect of reducing B 's threat point.

6. The other omitted cases are $x_{SIR} = 0$ and $\alpha = 0$. The inequalities in Proposition 1 were strict because x_{SIR} and greater equilibrium investment levels were taken to be interior solutions (whether the lowest investment level x_{SER} is an interior solution is immaterial). If some of these equilibrium investment levels were corner solutions (zero), relevant inequalities would be weak rather than strict. If $\alpha = 0$, so that A has no bargaining power, the statement of Proposition 1 would be identical but for one change: social welfare would now be the same in all three first-party regimes—*FIR*, *FER*, and *FDR*—though all three would still involve overinvestment. This can be seen immediately in Figure 2 by setting $\alpha = 0$ in the marginal benefit functions.

7. If we assume e^A is an interior rather than a corner solution when A is the generator, then *FIR* may be inefficient even if $\alpha = 1$. See the discussion in footnote 5.

5. Policy Implications

The Coase theorem can be taken to imply that property rights do not matter in the sense that efficient bargaining between parties will obtain an efficient outcome for any well-defined property rights regime. We contend that the small-numbers environment in which bargaining may be assumed to be fairly efficient is unlikely to exist in practice, in particular at the stage in which a first mover sinks its initial investments. Potential bargaining partners are likely to be anonymous to the first mover at this *ex ante* stage; the transaction cost of bargaining over all relevant variables with all potential bargaining partners is likely to be prohibitive. In such an environment in which *ex ante* anonymity is an important bargaining friction, our main policy conclusions are that first-party rights generally lead to overinvestment and second-party rights generally lead to underinvestment, though second-party damage rights may generate the first best. Furthermore, we were able to rank different types of first property rights among each other and different types of second-party rights. Perhaps most important, our analysis provides a framework for analyzing other forms of property rights which a policy maker might devise.

These and subsequent policy conclusions should be taken as, to use Calabresi and Melamed's (1972) phrase, another "view of the cathedral." There are caveats to consider in applying the model. First, our results will apply most strongly to applications in which *ex ante* anonymity features prominently, so that parties do not have the opportunity to meet and bargain efficiently over *ex ante* investments. Second, the results to this point will apply most strongly to applications in which the relevant distortion is in the level of investment rather than in the timing. If the major concern is that first-party rights will lead to inefficient racing or second-party rights to inefficient delay, a framework in which the timing of location is endogenous (i.e., Ellickson [1989], Lueck [1995], or a dynamic extension of the present article) would be more useful. Third, different rights regimes place different informational burdens on the court. In some applications, certain regimes may simply require too much information to be feasible. Exclusion rights seem to pose the least informational burden, since all that the court needs to determine is whether the other party is present on the land over which the exclusion right holds. Damage rights pose the highest informational burden. The court must be able to calculate the holder's surplus in the hypothetical case of no harm and subtract from this a measure of its surplus as a result of the harm. If there is insufficient information to calculate damages, policy has to be restricted to less informationally burdensome rights. Thus, while second-party damage rights yield the first best in our model, it may or may not be a feasible rights regime in practice.

5.1 Coming to the Nuisance Rules

Proposition 1 does not generally enable us to rank first-versus second-party rights and thus whether it is efficient for the court to impose a coming

to the nuisance rule (first-party rights) or the opposite. First-party rights lead to a different direction of distortion than second-party—overinvestment rather than underinvestment—so to rank them we would require quantitative information on the sensitivity of social surplus to investment and the size of the associated over- or underinvestment.

If the court has sufficient information to implement a damage rights regime, we can be more concrete in our assessment of coming to the nuisance rules. All first-party regimes we studied result in strict overinvestment, while second-party damage rights yield the first best. Thus coming to the nuisance rules, in all forms we analyze, are strictly dominated by other legal rules.

If the court does not have sufficient information to implement a damage rights regime, and so must resort to one of the other sorts of rights we have studied (injunction and exclusion rights), cases can be constructed in which first-party rights dominate second-party rights, and cases can be constructed in which the reverse is true. Intuitively, as the importance of A 's surplus in the social welfare function grows, underinvestment becomes more of a concern, and first-party rights, because they prevent underinvestment, begin to dominate second-party rights. Conversely, as the importance of B 's surplus in the social welfare function grows, overinvestment becomes more of a concern, and second-party rights begin to dominate. In sum, if the court cannot implement a damage rights regime, our policy prescription would be for the court to favor the party whose contribution to social surplus dominates the other. A coming to the nuisance rule should be applied if this party is the first mover, but not if this party is the second mover. If the parties' contribution to social surplus is of the same order of magnitude, nothing concrete can be said about the optimality of a coming to the nuisance rule without further specific knowledge about functional forms involved.

5.2 Monopoly Landownership

A commonly cited solution to the externality problem (see the relevant references in the Introduction, for example) is to have one party own all of the land on which the externalities occur, a solution we will refer to as monopoly landownership. The intuition is that, when it bargains over the sale of land to A before B arrives, the monopoly landowner will internalize B 's surplus through the expected price it will receive from B . The monopoly landowner would thus have an incentive to require A to undertake the socially efficient amount of investment *ex ante*.

To assess the validity of this solution, we will take the simple case in which the first mover A is also the monopoly landowner. We have already introduced a property rights regime that captures this setting: first-party exclusion property rights, *FER*. *FER* allows A not only to set the externality level but to exclude B entirely from the relevant area, as A would be able to do if it were the monopoly landowner by refusing to sell land to B .

It turns out that having A be a monopoly landowner produces the first best if A is assumed to have all the bargaining power in negotiations over the sale of the land with B , equivalent to assuming $\alpha = 1$ in our notation. This is a result in Proposition 2, namely that *FER* leads to the first best if $\alpha = 1$. However, Proposition 2 further implies that *FER* is not special in this regard; *FIR*, and in fact all the second-party regimes, produce the first best if $\alpha = 1$.

Monopoly landownership fails to produce the first best when A has any less than 100% of the bargaining power. Even though A can exclude B from the area, B retains some bargaining surplus since B 's location in the area generates some quasi-rents. A distorts its ex ante investment to extract more of B 's surplus. As Proposition 1 shows, monopoly landownership by A (captured by *FER*) may be no better than dispersed landownership (captured, e.g., by *FIR*). Perhaps one reason for the popular belief that monopoly landownership solves the externality problem is a confusion between "monopoly landownership" and "having 100% of the bargaining power." As we have just argued, the two are distinct concepts that should not be confused.

Note that *FER* (and hence monopoly landownership) may strictly dominate *FIR* (and hence dispersed landownership) if the generator's externality were assumed to be an interior solution that increased with x rather than a corner solution as we have assumed here. Footnote 5 discusses the issue in more detail. This provides some justification for the popular regard for monopoly landownership. Still, *FER* (and hence monopoly landownership) would not produce the first best. Moreover, in certain modifications of the basic model, which space constraints prevent us from analyzing here—for example, extending the model to a dynamic setting with a possible race for first-party rights or adopting a different specification of Binmore, Rubinstein, and Wolinsky (1986) bargaining—*FER* may be strictly less efficient than *FIR*.

5.3 Injunctions Versus Damages

As noted in the introduction, there is a large body of work in law and economics comparing the efficiency of injunctions versus damages, beginning with Calabresi and Melamed (1972).⁸ Calabresi and Melamed (1972) argue that injunctions dominate damages when transaction costs are low, since damages require measurement, whereas injunctions simply require enforcement. They argue that damages dominate injunctions when transaction costs are high, since, with limited scope to bargain, the only way for parties to internalize the externality is for there to be some monetary penalty associated with it.

Our results add a new distinction between injunctions and damages that is absent from the large law-and-economics literature on this topic: the two

8. See also Ayres and Talley (1995), Kaplow and Shavell (1995, 1996), and the *Yale Law Journal* symposium (Sherwin, 1997).

rights regimes have different effects on the first party's ex ante investment incentives. There are two ways to perform the comparison between injunctions and damages. The first way fixes the identity of the party that can choose the externality level, say B , and asks whether it is better to have B pay damages to A or not. Second-party injunction rights (*SIR*) correspond to the injunction regime in which B sets e and does not need to pay damages to A ; first-party damage rights (*FDR*) corresponds to the damage regime in which B sets e but must pay damages. It is apparent from Proposition 1 that the ranking of these regimes is ambiguous: *SIR* produces underinvestment, *FDR* produces overinvestment, and the two cannot be ranked unless one has quantitative information about the relative severity of over- versus underinvestment problems. A similar exercise could be performed comparing *FIR* with *SDR*, regimes which let A choose e but differ in regard to whether A has to pay damages or not. In this case, the ranking is unambiguous: as Proposition 1 shows, *SDR* produces the first best and is strictly more efficient than *FIR*. In sum, if B is allowed to set the externality, it is unclear whether it should be forced to pay damages; if A is allowed to set the externality, forcing it to pay damages is efficient.

A second way to compare injunctions and damages is to fix the identity of the rights holder and ask whether it is better for it to have an injunctive or a damage right. This amounts to a comparison between *FIR* and *FDR* if A is the rights holder or between *SIR* and *SDR* if B is the rights holder. Consider first-party rights, that is, a coming to the nuisance rule of some form. An examination of Proposition 1 implies that *FIR* dominates *FDR*, so that first-party rights should be of the form of an injunction rather than damages. While *FDR* is a weaker regime than *FIR*, since the penalty for violating A 's chosen externality is finite rather than infinite, the effect on investment is higher at the margin with *FDR*, and thus there is greater overinvestment. Next consider second-party rights. *SDR* dominates *SIR*, and indeed produces the first best, so that second-party rights should be of the form of damages rather than an injunction.

In sum, we do not have clear support for either injunction or damages in terms of the effect on ex ante investment. We can say concretely that injunction is better than damages among first-party rights regimes, while damages is better than injunction among second-party rights regimes.

5.4 The *Spur Industries* Ruling

We have not analyzed an exhaustive list of property rights in this article; however, we have provided the tools with which to analyze the efficiency of any regime R , as long as it can be described in terms of default payoffs $t_R(x)$ and $\tilde{t}_R(x)$. The tools can be applied to the famous nuisance case cited in the introduction, *Spur Industries*. The legal remedy in *Spur* was somewhat unusual: the developer (party B) was given the right to exclusive use of the land, provided it paid the relocation costs of the cattle feedlot (party A). Note that the implied rights regime, which we will refer to as the *Spur*

rights regime, is a first-party rights regime in our taxonomy, and is hence a version of a coming to the nuisance rule, albeit a nonstandard one. The *Spur* rights regime is related to *FDR*, the difference being that the second mover is given the option to choose not just the externality level, but the presence of the first mover in the location.

The following proposition ranks the *Spur* rights regime among the other standard first-party rights we analyzed previously.

Proposition 3. Suppose $\alpha \in [0, 1)$ and $x_{IST} > 0$. The *Spur* rights regime generates greater ex ante overinvestment and less social welfare than any of the other first-party regimes studied so far (*FIR*, *FDR*, *FER*). Because it involves strictly more investment than the first best, the *Spur* rights regime is strictly inefficient.

The appendix contains a proof of the proposition. It also details the minor modifications to the model to accommodate the *Spur* case. The modifications include moving from the maintained assumption that it is ex post efficient for both parties to locate jointly to the assumption that it is ex post efficient for *B* to locate in the area alone.

Proposition 3 holds because marginal investment incentives are higher with the *Spur* rights regime than the other first-party regimes, which we already saw resulted in overinvestment. Marginal investment incentives are highest with the *Spur* rights regime because *A*'s ex ante investment has the strongest effect on *B*'s threat point: we have $\tilde{t}_R(x) = \tilde{u}(e^B) - u(x, e^A)$, so that an increase in x reduces *B*'s threat point—because of the nature of the damage payment *B* has to make—by a dollar for each dollar it increases *A*'s threat point.

Given that it is strictly worse than the other first-party rights regimes in our model, it is natural to ask why the judge ruled as he did in the case. We surmise that the judge had a different setting in mind than our model, namely one in which large transaction costs prevent ex post bargaining, in contrast to our setting in which ex post bargaining is efficient. If bargaining is assumed to be impossible, and it is further assumed that it is efficient for the feedlot to be excluded from the area, the only first-party regime among those studied so far that would accomplish the required exclusion is the *Spur* rights regime. Exclusion of *A* could also have been accomplished through second-party exclusion rights, but the judge may have thought that establishing second-party property rights as a precedent would lead to too much underinvestment in future cases.

Which assumption, high or low ex post bargaining costs, is more appropriate in the *Spur* case? The judge appears to have taken the view that the case involved high bargaining costs, emphasizing as he did the fact that the externality generated by the feedlot was a public nuisance, borne by a large number of small parties, namely the nearby residences. We would counter that nearby residences were not plaintiffs in the suit, the developer was. Given that the parties in the suit were two large businesses (*Spur*

Industries, the cattle feedlot, and Webb, the developer), and no mention was made about there being much uncertainty about parties' private values, it may be more reasonable to assume that bargaining costs were low.

5.5 Government Takings

The takings literature (e.g., Blume and Rubinfeld, 1984; Blume, Rubinfeld, and Shapiro, 1984; Hermalin, 1995) analyzes the problem in which the government uses its power of eminent domain to seize private property for its own direct productive use or damages a party's profitability through regulation. The typical model has one private party (A) and a government (B) that takes A 's land. The analysis focuses on whether B should take A 's land and if so, what compensation should be paid. Our setting is similar except A and B are both private. Furthermore, in our setting, the government's choice of property rights regime only indirectly affects A 's investment incentives through its effect on ex post bargaining between the parties; the government does not make direct payments itself. In the takings literature, by contrast, the government makes direct payments to A and this payment directly influences A 's investment incentives. Differences aside, for a given compensation rule in the takings setting, one can often construct a property rights regime in the nuisance setting that provides A with similar ex ante investment incentives, and vice versa.

Suppose, for example, that the compensation rule in the takings setting is to pay A an unbiased estimate of its value $u(x, e^A)$. This compensation rule can be related to the property rights regime implicit in the *Spur Industries* case, discussed in Section 5.4. In both settings, A is excluded from the area and receives compensation for its lost value. Since the government makes a must-take payment offer in the takings setting, to complete the isomorphism between the two settings, one needs to assume that A 's bargaining power is $\alpha = 0$ in the nuisance setting. Proposition 3 shows that there is strict overinvestment in the nuisance setting, analogous to the result in the takings literature that full compensation leads to strict overinvestment (Blume, Rubinfeld, and Shapiro, 1984). Intuitively, one effect of A 's investment is to increase its payment from the government, a transfer that has no social benefit.

Hermalin (1995) shows that a first-best takings policy is to have the private party pay the government an amount equal to the social benefit from taking to avoid having its land taken. This result is analogous to ours that having A pay damages to B (second-party damage rights) yields the first best.

6. Conclusion

Coming to the nuisance cases typically involve two important features: (1) sequential investment by a first and a second mover and (2) an inability of the parties to contract over the first mover's initial investment decision

because the second mover is not yet present. We derived a method for evaluating the efficiency of legal regimes in such a setting. The method involves calculating the first mover's marginal surplus from ex post bargaining between the two parties (which is a function of the threat points implied by the legal rule) and comparing this marginal benefit to the marginal cost of ex ante investment. We used this method to determine the efficiency of allocating property rights to the first versus the second mover, where we considered property rights of various forms (injunctions, damages, exclusion rights, monopoly landownership, the ruling in the *Spur Industries* case, and so forth).

We found that most regimes are inefficient, involving either overinvestment or underinvestment by the first mover. Allocating property rights to the first mover (i.e., following a coming to the nuisance rule) leads to overinvestment by the first mover. This is true whether the first mover is granted injunction or damage rights, whether the first party is a monopoly landowner from whom the second mover must purchase property, or whether the ruling in the *Spur Industries* case is followed so that the first mover is excluded from the area but receives compensation for the surplus lost in moving. In all these cases, the first mover strategically overinvests to improve its position in subsequent bargaining with the second mover. Allocating property rights to the second mover (the opposite of a coming to the nuisance rule) generally leads to underinvestment by the first mover. The one exception is second-party damage rights. Second-party damage rights always produce the first best since it forces the first mover to internalize the effect on the second mover of all its decisions (investment, externality, and so forth). A caveat is that second-party damage rights require the court to have a great deal of information about counterfactual surplus functions, perhaps too burdensome an informational requirement in some practical settings. If the court does have sufficient information to implement a damage regime, however, it should implement second-party damage rights; coming to the nuisance rules are then strictly dominated by other legal rules. In sum, our results suggest that policy choices need to be made by trading off the relative magnitudes of overinvestment and underinvestment inefficiencies, at the same time considering the informational demands of implementing various regimes.

We hope this article is a step toward showing that the incomplete contracts approach, as developed and used extensively in the analysis of the theory of the firm (e.g., Grossman and Hart, 1986; Hart and Moore, 1990), is potentially useful for the analysis of tort law. Future work might include application to other areas of the law, including property and criminal law.

Appendix

Proof of Proposition 1. We establish the ranking of property rights regimes from the lowest investment level to the highest, first proving $x_{SER} < x_{SIR}$, then $x_{SIR} < x_{SDR}$, then $x_{SDR} = x_{IST}$, then $x_{SDR} < x_{FIR}$,

then $x_{FIR} = x_{FER}$, then $x_{FIR} < x_{FDR}$. The proof concludes by showing that the social welfare function is strictly concave in x , so the investment ranking can be translated into a welfare ranking.

Step 1: Show $x_{SER} < x_{SIR}$. Differentiating the expressions for $t_{SER}(x)$ and $\tilde{t}_{SER}(x)$ from Table 1 with respect to x and substituting into Equation (4), the first-order condition for x_{SER} becomes $\alpha ds^*(x)/dx = 1$. By the envelope theorem, $ds^*(x)/dx = \partial u(x, e^*(x))/dx$. Hence the first-order condition for x_{SER} can be written

$$\alpha \frac{\partial u(x, e^*(x))}{\partial x} = 1. \tag{A1}$$

Similarly the first-order condition for x_{SIR} can be shown to be

$$\alpha \frac{\partial u(x, e^*(x))}{\partial x} + (1 - \alpha) \frac{\partial u(x, e^B)}{\partial x} = 1. \tag{A2}$$

Equations (A1) and (A2) can be nested as follows:

$$\alpha \frac{\partial u(x, e^*(x))}{\partial x} + \theta_R \frac{\partial u(x, e^B)}{\partial x} = 1, \tag{A3}$$

where $\theta_{SER} = 0$ and $\theta_{SIR} = 1 - \alpha$, so that $\theta_{SER} < \theta_{SIR}$ since $\alpha < 1$. By assumption, $\partial u(x, e)/\partial x > 0$, implying Equation (A3) is strictly increasing in θ_R . Further, $x_{SIR} > 0$ by maintained hypothesis. Thus the Strict Monotonicity Theorem 1 of Edlin and Shannon (1998) applies, implying $x_{SER} < x_{SIR}$.

Step 2: Show $x_{SIR} < x_{SDR}$. The first-order condition for x_{SDR} is

$$\frac{\partial u(x, e^*(x))}{\partial x} = 1. \tag{A4}$$

Nesting Equations (A2) and (A4),

$$\frac{\partial u(x, e^*(x))}{\partial x} + \theta_R \left[\frac{\partial u(x, e^*(x))}{\partial x} - \frac{\partial u(x, e^B)}{\partial x} \right] = 1, \tag{A5}$$

where $\theta_{SIR} = \alpha - 1$ and $\theta_{SDR} = 0$, so that $\theta_{SIR} < \theta_{SDR}$, since $\alpha < 1$. To show Equation (A5) is strictly increasing in θ_R , note that

$$\frac{\partial u(x, e^*(x))}{\partial x} - \frac{\partial u(x, e^B)}{\partial x} = \int_{e^B}^{e^*(x)} \frac{\partial^2 u(x, e)}{\partial x \partial e} de > 0. \tag{A6}$$

There are two cases to consider in proving the integral in Equation (A6) is positive. First, suppose A is the generator. Then $\partial^2 u/\partial x \partial e > 0$ by definition. By Assumption 1, B is the victim, so $e^B = \underline{e}$. But since $e^*(x) > \underline{e}$ by Assumption 2, $e^B < e^*(x)$. Thus the integral in Equation (A6) is positive if A is the generator. Next, suppose A is the victim. Analogous arguments to the preceding can be used to prove that the integral in Equation (A6) is

positive in this case as well. This establishes that Equation (A5) is increasing in θ_R . Thus $x_{SIR} < x_{SDR}$ by Strict Monotonicity Theorem 1.

Step 3: Show $x_{SDR} = x_{IST}$. This result is immediate since Equation (2), the first-order condition for x_{IST} , is identical to Equation (A4), the first-order condition for x_{SDR} .

Step 4: Show $x_{SDR} < x_{FIR}$. The first-order condition for x_{FIR} is

$$\alpha \frac{\partial u(x, e^*(x))}{\partial x} + (1 - \alpha) \frac{\partial u(x, e^A)}{\partial x} = 1. \quad (\text{A7})$$

Nesting Equations (A4) and (A7),

$$\frac{\partial u(x, e^*(x))}{\partial x} + \theta_R \left[\frac{\partial u(x, e^A)}{\partial x} - \frac{\partial u(x, e^*(x))}{\partial x} \right] = 1, \quad (\text{A8})$$

where $\theta_{SDR} = 0$ and $\theta_{FIR} = 1 - \alpha$, so that $\theta_{SDR} < \theta_{FIR}$ for $\alpha < 1$. To show Equation (A8) is strictly increasing in θ_R , note that

$$\frac{\partial u(x, e^A)}{\partial x} - \frac{\partial u(x, e^*(x))}{\partial x} = \int_{e^*(x)}^{e^A} \frac{\partial^2 u(x, e)}{\partial x \partial e} de > 0, \quad (\text{A9})$$

where the sign of the integral in Equation (A9) can be established using similar arguments to those following Equation (A6). Hence Equation (A8) is strictly increasing in θ_R . Thus $x_{SDR} < x_{FIR}$ by Strict Monotonicity Theorem 1.

Step 5: Show $x_{FIR} = x_{FER}$. This result is immediate since the first-order condition for x_{FER} is the same as for x_{FIR} , namely Equation (A7).

Step 6: Show $x_{FIR} < x_{FDR}$. The first-order condition for x_{FDR} is

$$\frac{\partial u(x, e^A)}{\partial x} = 1. \quad (\text{A10})$$

Nesting Equations (A7) and (A10),

$$\frac{\partial u(x, e^A)}{\partial x} + \theta_R \left[\frac{\partial u(x, e^A)}{\partial x} - \frac{\partial u(x, e^*(x))}{\partial x} \right] = 1, \quad (\text{A11})$$

where $\theta_{FIR} = -\alpha$ and $\theta_{FDR} = 0$, so that $\theta_{FIR} < \theta_{FDR}$ since $\alpha > 0$. By Equation (A9), Equation (A11) is strictly increasing in θ_R , so $x_{FIR} < x_{FDR}$ by Strict Monotonicity Theorem 1.

Step 7: To complete the proof we need to translate the ranking of investments into a welfare ranking. Now $s^*(x)$ is the value function associated with a strictly concave objective function $s(x, e)$ maximized over a convex set $e \in [\underline{e}, \bar{e}]$. By the Maximum Theorem under Convexity (see, e.g., Sundaram [1996], Theorem 9.17.3), $s^*(x)$ is strictly concave. Hence social welfare $s^*(x) - x$ is strictly concave. Therefore the second-party property rights regimes *SIR*, *SDR*, *SER*, which lead to weak underinvestment, can be ranked among themselves according to how close equilibrium investment comes to x_{IST} . Social welfare is strictly lower in *SER* than in *SIR*, which in turn is strictly lower than in *SDR*, which in turn yields the first best. First-party regimes *FIR*, *FDR*, *FER*, which lead to strict

overinvestment, can also be ranked among themselves according to how close equilibrium investment comes to x_{IST} . Social welfare in *FIR*, *FDR*, and *FER* is strictly less than the first best. Social welfare is the same in *FIR* and *FER*, and higher in both than in *FDR*. ■

Proof of Proposition 3. The basic model of Section 2 needs to be modified to accommodate the *Spur Industries* case. In particular, we assume that it is efficient for both parties to locate together ex post, generating maximum ex post social welfare $s^*(x)$. Presumably part of the motivation for the judge’s ruling in *Spur* was that it was ex post efficient for *B* to end up in the location alone. In our notation, this would generate maximum ex post social welfare $\tilde{u}(e^B)$. We will assume throughout the remainder of this proof that it is efficient for *B* to end up in the location alone.

A further modification, which is not essential for subsequent results, but is useful in understanding the *Spur* case formally, is that a term, denoted $v(x)$, needs to be added to capture *A*’s ex ante benefit from investing. Without this term, the social optimum would trivially involve zero investment, since there is no ex post social benefit from *A*’s investment, as it is now assumed that it is efficient for *A* to be excluded from the location ex post. If investment were zero in the social optimum, all of the second-party property rights regimes would lead to the first best, presumably not the case with *Spur*, since the judge did not choose to impose a second-party property rights regime. Assume $dv(x)/dx > 0$ and $d^2v(x)/dx^2 < 0$.

Finally, let *FSR* be the acronym for the rights regime implicit in the *Spur* ruling (where the leading “F” indicates that it is one of the first-party regimes).

Under these new assumptions, social surplus in the first best is

$$v(x) + \tilde{u}(e^B) - x. \tag{A12}$$

The associated first-order condition for the first-best investment level x_{IST} is thus

$$\frac{dv(x)}{dx} = 1. \tag{A13}$$

In equilibrium, *A* earns $v(x)$ less the cost of investment x ex ante, and its threat point plus α times the gains from trade through Nash bargaining ex post. *A*’s surplus hence is

$$t_R(x) + \alpha[\tilde{u}(e^B) - t_R(x) - \tilde{u}_R(x)] + v(x) - x. \tag{A14}$$

The first-order condition determining the equilibrium ex ante investment x_{FSR} is, upon differentiating Equation (A14) and rearranging,

$$(1 - \alpha)\frac{dt_R(x)}{dx} - \alpha\frac{d\tilde{t}_R(x)}{dx} + \frac{dv(x)}{dx} = 1. \tag{A15}$$

Threat points for the first-party regimes *FIR*, *FDR*, and *FER* are the same as in Table 1. The threat points associated with *Spur* rights are $t_{FSR}(x) = u(x, e^A)$ and $\tilde{t}_{FSR}(x) = \tilde{u}(e^B) - \tilde{u}(x, e^A)$.

The comparison of equilibrium investments across property rights regimes proceeds in a similar fashion as the proof of Proposition 1. First we will show $x_{IST} < x_{FIR}$. In view of Equations (A13) and (A15) and Table 1, the first-order conditions for x_{IST} and x_{FIR} can be nested as follows:

$$\theta_R \frac{\partial u(x, e^A)}{\partial x} + \frac{dv(x)}{dx} = 1, \quad (\text{A16})$$

where $\theta_{IST} = 0$ and $\theta_{FIR} = 1 - \alpha$, so that $\theta_{IST} < \theta_{FIR}$ since $\alpha < 1$. By assumption, $\partial u(x, e)/\partial x > 0$, implying Equation (A16) is strictly increasing in θ_R . Further, $x_{IST} > 0$ by maintained hypothesis. Thus the Strict Monotonicity Theorem 1 of Edlin and Shannon (1998) applies, implying $x_{IST} < x_{FIR}$.

The proof that $x_{FIR} = x_{FER} < x_{FDR}$ is similar to the proof in Proposition 1 and is omitted. We are left to prove $x_{FDR} < x_{FSR}$. The first-order condition for x_{FDR} is

$$\frac{\partial u(x, e^A)}{\partial x} - \alpha \frac{ds^*(x)}{dx} + \frac{dv(x)}{dx} = 1 \quad (\text{A17})$$

and for x_{FSR} is

$$\frac{\partial u(x, e^A)}{\partial x} + \frac{dv(x)}{dx} = 1, \quad (\text{A18})$$

since $d\tilde{u}(e^A)/dx = 0$. Equations (A17) and (A18) can be nested as follows:

$$\frac{\partial u(x, e^A)}{\partial x} - (\alpha - \theta_R) \frac{ds^*(x)}{dx} + \frac{dv(x)}{dx} = 1, \quad (\text{A19})$$

where $\theta_{FDR} = 0$ and $\theta_{FSR} = \alpha$. We proved in Proposition 1 that $ds^*(x)/dx = \partial u(x, e^*(x))/\partial x > 0$. Furthermore, $x_{FDR} > x_{IST} > 0$, where $x_{IST} > 0$ by maintained hypothesis. Thus $x_{FDR} < x_{FSR}$ by Strict Monotonicity Theorem 1.

It is obvious that the social welfare function of Equation (A12) is concave in x . Hence, by arguments similar to those in Step 7 of the proof of Proposition 1, the investment ranking we just derived determines the welfare ranking stated in the proposition. ■

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