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Coming to the Nuisance: Revisiting *Spur* in a Model of Location Choice*

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Abstract

Building on recent work of Pitchford and Snyder (PS, 2003), this paper models effects of alternative property rights regimes on sequential location decisions of two players. A new resident decides whether to "come to the nuisance" by locating next to an existing business, or to locate elsewhere where there are no negative externalities between occupants. Faced with a new resident, the existing business can relocate. Once situated, local residents bargain to address negative externalities. However, location decisions are non-contractible. In this setting – contrary to PS – the first best is achieved by allocating property rights to the first party, entitling the initial resident to full compensation for damages. This rule is consistent with the *Spur Industries* decision. Allocating property rights to second parties excessively encourages residents to "come to the nuisance," while stronger first party rights (injunctive or exclusion) excessively deter nuisances from moving to areas less prone to external harm.

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Often farmers, ranchers, airports or industrial producers will operate unencumbered for years until residential development approaches their business. With residents now exposed to the noise, fumes, and odors of normal operation, demands are made for the business to curtail its pollution or move altogether. From a societal perspective, what rights should the different parties have in such circumstances? And what effects do alternative rights regimes have on the decisions made by the different parties, and on resulting efficiency?

The classic case of *Spur Industries, Inc. v. Del. E. Webb Development Co.*, 108 Ariz. 178, 494 P. 2d 700 (1972) is illustrative. After operating a cattle feedlot for years undisturbed, Del Webb bought neighboring land for a residential development. Webb sued Spur, arguing that the odors and flies from the feedlot impaired his residential property. The courts ruled that Spur had to move but that, because Spur was first in the area and Webb had "come to the nuisance," Webb had to compensate Spur for lost surplus.

From an economic point of view, key choices in the Spur case, and other "coming to the nuisance" situations, concern location. Should a "Webb" locate next to a "Spur" and, if he does, should "Spur" move or stay? The purpose of this paper is to study the impact of alternative property rights regimes on these location decisions. For example, the *Spur* decision implies a first party damage right in which Webb (the second mover) must compensate Spur (the first mover) for damages, but makes all decisions that affect the externality between them – namely, whether Spur moves or not and, if he stays, how he operates to limit flies and odors. We find that this legal rule produces efficient location decisions, while other alternatives produce inefficient ones.

The analysis draws heavily on the recent contribution of Pitchford and Snyder (PS, 2003), who also study "coming to the nuisance" situations in which there are two players, a first mover (A, c.f., Spur) and a second mover (B, c.f., Webb).[1] PS examine six property rules and their effect on an ex-ante and non-contractible investment choice of the first mover (A). A key insight of PS (among many) is that the players can engage in Nash bargaining ex-post, with disagreement payoffs that depend upon the property rights regime and that determine the ultimate (post-bargaining) player utilities. It is these final utilities that determine A's incentives for ex-ante investment. All six of the PS rights regimes are generic in the sense that they define entitlements to first and second movers that do not depend upon specific circumstances (benefits and costs) and are thus applicable to any situation. The central policy conclusion is that efficient investment incentives are achieved with second party damage rights that, in striking contrast to the first party damage rights embraced in the *Spur* decision, entitle the second mover B (c.f., Webb) to full compensation for any costs to him as a result of the actions or presence of the first mover A (c.f., Spur). The rough intuition for this result is that the second party rights serve as a Pigovian tax on A, forcing A to internalize the cost of higher investments (to B). In contrast, first party rights fail to confront A with costs to B, and thereby prompt over-investment.

Our central departure from PS is to focus on non-contractible location decisions, rather than ex-ante investment choices (although we discuss investment incentives in Section 7). We consider the same six property rights regimes as PS, and model their effects in the same way, with impacts on disagreement payoffs in bargaining games driving ultimate location incentives.

In our model – in view of the insights of PS – the salutary effects of first party damage rights have an intuitive explanation. When the first party A moves away, he becomes a second mover at the new location. And when B selects a location, he is also a second mover wherever he sites. Hence, to elicit efficient location choices, second movers must be confronted with costs of their siting to extant first movers. A first party damage rule has precisely this effect, by forcing the moving (second) party to pay costs of the move to the existing (first party) residents. Stronger first party rights – whether giving first parties injunctive powers or the right to completely exclude a new (second party) resident – tend to over-tax new residents, thus inefficiently inhibiting both the movement of existing residents (like Spur) and the location of new residents (like Webb) at sites where there are potential externalities (next to Spur). Conversely, second party rights tend to under-tax new residents, thus inefficiently promoting moves to externality-prone sites.

There is a key caveat to the efficiency of first party damage rights. In this paper, the first party (A) is generally assumed to have a given (fixed) *initial location*; however, when A *chooses* his initial site ex-ante, first party rights need not produce an efficient choice. Indeed, we show that *no* ex-post liability or property rights regime can achieve efficient ex-ante location decisions in all circumstances. The reason is that liability and property rules do not come into play when potentially infringing parties (A and B) are spatially separated. For example, suppose that it is optimal for B to site somewhere other than adjacent to A, so that no externality is produced between them and ex-post liability-cum-property regimes impose no cost on A. For B, a particular location may be most advantageous, call it site X. If A initially sites at X, then B must site at a less advantageous location in order to (optimally) avoid the externality; hence, a cost is imposed on B. Because A does not face this cost, A may inefficiently site at X. This inherent problem with ex-post liability/property rules may motivate the use of zoning powers to regulate ex-ante location decisions. Arguably, it also motivates this paper's focus on ex-post location decisions to appraise the efficiency effects of property law.

Beyond PS, this paper relates to a number of literatures. Perhaps most relevant is Wittman's (1980; 1981) landmark work on "coming to the nuisance." The first to identify the importance of distinguishing the legal treatment of first and second movers, Wittman's work differs from the present treatment by assuming that there is no private bargaining (due to high transactions costs), and focusing on the optimal case-specific assignment of rights, as opposed to effects of generic legal rules. However, like us, Wittman (1980; 1981) views location decisions as the central economic outcome of "coming to the nuisance" jurisprudence. Hence, in a sense, the present paper bridges the work of Wittman and PS, respectively.[2]

Second is a fascinating literature on optimal spatial location when some actors are polluters (White and Wittman 1981; 1982).[3] This work characterizes the effects of alternative pollution liability and tax regimes on both pollution prevention and one-shot location decisions of either competing pollutees (with a fixed polluter) or competing polluters (with a fixed pollutee). Consonant with our interest in "coming to the nuisance," we focus instead on impacts of *property rights* regimes on *sequential* location decisions when bargaining implicitly regulates the post-location externality. In doing so – and in contrast to prescriptions from this earlier work – we show that a rule that neither taxes nor assigns liability to a first party polluter can be optimal.

Third is a literature on first possession rules (Elickson 1989; Lueck 1995), arguing that such rules promote excessive investments to obtain first possession rights. We abstract from any race for possession rights in this paper, and focus on incentive effects of legal rules when the order of play is given exogenously (but naturally). More generically, we draw on the incomplete contracts literature (e.g., Williamson 1979; Grossman and Hart 1986; Hart and Moore 1990), and studies of property law where injunctive and damage rights are compared (e.g., Calabresi and Melamed 1972; Ayers and Talley 1995; Kaplow and Shavell 1996).

1. The Model

There are two locations, 1 and 2, and three players, A, B, and C. In a prior (unmodeled) period, player A has located at 1, and player C has located at 2. When at the same location, there is a negative externality between A and C, or A and B, but no externality between B and C. For example, A may be thought of as the Spur feedlot, and B and C as residential developments, with the feedlot creating odors and gases that have a negative impact on proximate residents. In the current (modeled) period, B chooses whether to operate at either location 1 or 2, and A can move from location 1 to 2.

Of course, in the prior period, A and C will choose locations as well. We will return to this issue in Section 6. However, for the moment, note that the two locations can be ex-ante identical, so that it is a matter of social (and private) indifference whether A locates at 1 or 2 initially, and we assume location at 1 (without loss). Given the negative externality between them, A and C locate at different sites initially.

Let $e \geq 0$ denote the externality level. We assume that A is an externality generator in the sense that it benefits from some positive level of e. B and C are externality receivers in the sense that higher levels of e are harmful to them. Formally, A enjoys profits $\pi_{Ai}(e)$ at location $i \in \{1,2\}$, where $\pi_{Ai}(0) \geq 0$, $\pi_{Ai}'(0)$ is positive and arbitrarily large, $\pi_{Ai}'' < 0$ and π_{Ai} has a unique bounded maximum:

$$e_{Ai} = \text{argmax } \pi_{Ai}(e). \tag{1}$$

Consonant with A's initial location at 1, we assume $\pi_{A1}(e) \geq \pi_{A2}(e)$ for $e \geq 0$. If A moves from 1 to 2, it must bear the relocation cost M. C receives profit $\pi_C(e)$ if A moves to location 2, and $\pi_C(0)$ otherwise, where $\pi_C' < 0$ and $\pi_C'' \leq 0$ in a relevant range of e, $\pi_C'(0)$ is bounded, and $\pi_C(e) \geq 0$ for all $e \geq 0$ (C can walk away). B receives profit $\pi_B(0)$ if at location 2 (with C and not A) and $\theta\pi_B(e)$ at location 1, where e=0 if A moves to 2, $\theta > 0$, $\pi_B' < 0$ and $\pi_B'' \leq 0$ in a relevant range of e, $\pi_B'(0)$ is bounded, and $\pi_B(e) \geq 0$ for all $e \geq 0$.

θ is a parameter that determines the relative efficiency of alternative location choices. We envision θ as ex-ante random; hence, we will be interested in the efficiency of location decisions for the full range of possible θ values. For simplicity, we capture the heterogeneity of possible ex-post circumstances with only uncertainty in B's location 1 rents. More generally, there will be uncertainty in B's profits at both locations 1 and 2 (as well as in the profits of A and C). The arguments developed here apply to these more general environments, at the cost of analytical complexity.

The game proceeds in the following order. First, B locates at 1 or 2. If B locates at 2, there is no externality and the game ends. If B locates at 1, then: Next, A and B bargain over the allocation of rents and two decisions, (i) whether A moves to 2 or not, and (ii) if A stays, the externality level e. If A stays at 1 under the bargain, then the agreed externality is implemented and the game ends. If A moves to 2, then A and C bargain over the externality level. Figure 1 illustrates this structure.

<<COMP: Place Fig. 1 about here>>

At both locations, Nash bargaining splits the gains from agreement according to a known rule. In the A-B (location 1) bargaining game, B (respectively A) obtains the threat point payoff t_{B1} (respectively t_{A1}) plus $\alpha_1 \in [0,1]$ (respectively $1-\alpha_1$) of the gains from agreement. In the A-C (location 2) bargaining game, A (respectively C) obtains the threat payoff t_{A2} (respectively t_{C2}) plus $\alpha_2 \in [0.1]$ (respectively $1-\alpha_2$) of the agreement gains.[4] As in Pitchford and Snyder's (2003) key work, property rights regimes affect ultimate payoffs via their impact on threat payoffs, the profits that arise if no agreement is made (given court-defined property rights).

A few comments are in order before proceeding. First, we assume that B's location decision is not the object of bargaining; it is not contractible because B's identity is not known to A until B has located at site 1. Before this point, there are an infinity of "potential B's," each of whom could hold up A for ransom to avoid its location next to A. Under property rules that leave A indifferent to the prospect of an agent B locating at 1, any positive costs of bargaining will deter A from dealing with "potential B's." Under property rules that permit hold up, A will be bankrupted if it deals with "potential B's." Hence, it is natural to model bargaining only after B has made (a sunk) location choice, and explore the effects of legal rules on its location incentive in view of the resulting (post-location) bargaining equilibrium.

Second, we model the game as a sequence of bilateral bargains, rather than one of multi-lateral (A-B-C) bargaining. Again this structure seems the most plausible representation of locational decisions, in part because C faces an infinite number of "potential A's" and thus negotiates only after A has made its (sunk) decision to move next door. If multi-lateral bargaining were possible over all location decisions and externalities, then Nash bargaining would produce efficient outcomes regardless of property rules. Similarly, if multi-lateral bargains were possible, but only after B has made its location decision, then Nash bargaining would produce efficient outcomes given the B location decision.[5] Such conclusions are both trivial and, we believe, implausible. We thus focus instead on a more realistic sequential choice environment in order to understand the potential effects of property rules on location choices of both externality generators and receivers (A and B in our model), reflecting the reciprocal nature of location in the "coming to the nuisance" debate.

Third, at both locations, we assume that land is purchased in a competitive market where the marginal land use is neither a generator nor recipient of an externality. Hence, land price is independent of location decisions and property rights regimes, and is implicitly incorporated in the above profit functions (and moving costs M) without loss. For lands in rural areas and the urban fringe, this premise reflects the reality of "backstop" land uses in cultivated agriculture and/or fenced range.

2. The Collective Optimum

There are three relevant cases: (1) A and B locate at 1; (2) B locates at 1, and A moves to 2; and (3) B locates at 2 (and A stays at 1). Joint A-B-C profit in these cases are, respectively:

$$\Pi_{11}(\theta) = \Pi_1(\theta) + \pi_C(0), \tag{2}$$

where $\Pi_1(\theta) = \max_e (\pi_{A1}(e) + \theta\pi_B(e))$;

$$\Pi_{21}(\theta) = \Pi_2 + \theta\pi_B(0) - M, \tag{3}$$

where $\Pi_2 = \max_e (\pi_{A2}(e) + \pi_C(e))$; and

$$\Pi_{12} = \pi_{A1}(e_{A1}) + \pi_C(0) + \pi_B(0). \tag{4}$$

Profit functions Π have first subscripts that represent A's location (1 or 2) and second subscripts that represent B's location (1 or 2). Π_{11} thus equals maximal joint A-B profit at location 1 ($\Pi_1(\theta)$) plus C's unencumbered (zero externality) profit at location 2 ($\pi_C(0)$). Similarly, Π_{21} equals maximal A-C profit at location 2 (Π_2) plus B's unencumbered profit at location 1 ($\theta\pi_B(0)$), less A's cost of relocation (M). Finally, Π_{12} equals A's maximal profit at location 1 ($\pi_{A1}(e_{A1})$) plus the unencumbered (zero externality) profits of B and C at site 2.

Figure 2 graphs the three collective profits as functions of θ. Note that both Π_{11} and Π_{21} rise with θ, but Π_{21} rises more steeply:

$$d(\Pi_{21}-\Pi_{11})/d\theta = \pi_B(0) - \pi_B(e^*(\theta)) > 0,$$

where $e^*(\theta) = \text{argmax}\ (\pi_{A1}(e)+\theta\pi_B(e))>0$ (by our earlier assumptions), and the inequality is due to $\pi_B'<0$ and $e^*()>0$. The Figure implicitly defines two critical values:

$$\theta^{A*}: \Pi_{11}(\theta) = \Pi_{21}(\theta); \tag{5}$$

$$\theta^{B*}: \Pi_{11}(\theta) = \Pi_{12}; \tag{6}$$

θ^{A*} partitions θ values between those for which it is optimal for A to move to location 2 ($\theta>\theta^{A*}$) and those for which it is optimal for A to stay at location 1 ($\theta<\theta^{A*}$). θ^{B*} likewise partitions between θ values for which B optimally locates at 2 ($\theta<\theta^{B*}$) and 1 ($\theta>\theta^{B*}$).

<< COMP: Place Fig. 2 about here>>

In order to ensure interior partitions, as depicted in Figure 2, we make the following Assumption:

Assumption 1. $\pi_{A1}(e_{A1}) + \pi_C(0) > \Pi_2\text{-}M > \pi_{A1}(e^*(\theta^+)) + \pi_C(0)$ for a bounded θ^+.

The left-hand inequality requires that, absent B, it is not optimal for A to move, which rules out a case in which A moves when B locates at 2.[6] The right-hand inequality implies that, if θ is sufficiently high (so that the corresponding optimal externality at location 1, e*, is low), the joint rents to A and C are higher if A moves. Assumption 1 implies:

Lemma 1. Critical θ^{A*} and θ^{B*}, as defined in (5) and (6), exist and are positive and bounded.

As indicated in Figure 2, we also assume that $\theta^{B*}<\theta^{A*}$, so that there are some cases (θ values) for which A and B optimally locate together.[7]

Assumption 2. $\theta^{B*}<\theta^{A*}$.

More generally, when B profits depend on (ex-ante) random parameters at both locations, there will be parameter realizations (for location 2) that partition optimal locations as in Figure 1, and others that involve A moving to 2 whenever B locates at 1. In our simplified setting, we focus on the former outcome in order to allow for the complete range of possible location optima.

3. Legal Rules

Following Pitchford and Snyder (2003), there are six legal regimes, corresponding to three types of rights – injunctive, exclusion or damage – and two alternative rights-holders in each case, the first mover and the second mover. At location 2, the allocation of rights (to A and C) relates to choice of the remaining decision: the externality level e. At location 1, rights concern choices of both the externality level (if A stays at 1) and A's relocation decision. In all cases, rights define entitlements absent any bargains, thus giving rise to threat points for the bargaining game.

Injunctive rights entitle the rights holder to make all choices. *Damage* rights entitle the holder to compensation for deviations from its preferred choices; damage rights are modeled by allowing the infringing party to choose e (and A's location, when relevant) but compelling compensation to the rights holder equal to the difference between its profit under its preferred choices and its realized profit. *Exclusion* rights entitle the holder to exclude the rival from operating at the location.

Rights can be allocated to either the first mover – the agent that is first to operate at a given location (A at 1, C at 2) – or the second mover – the newest arrival at a given location (B at 1, A at 2).

Table 1 describes the location 2 threat points that result from the alternative rules. First party injunctive rights give the first mover (agent C) the right to set e at his preferred level (e=0), giving threat payoffs $\pi_{A2}(0)$ for agent A and $\pi_C(0)$ for agent C. With first party damage rights, the second mover (A) can set e, but must compensate C for deviations from its preferred choice (e=0), $\pi_C(0)-\pi_C(e)$. A's payoff is thus

$$\max_e \{\pi_{A2}(e)-[\pi_C(0)-\pi_C(e)]\} = \Pi_2-\pi_C(0),$$

while C's payoff is

$$\pi_C(e) +[\pi_C(0)-\pi_C(e)] = \pi_C(0).$$

First party exclusion rights permit C to shut A down (reducing its payoff to zero) and thus again enjoy his no-externality profit, $\pi_C(0)$. Symmetric logic gives the threat points that arise under second party rights.

<<COMP: Place Table 1 about here>>

4. Equilibrium Location for A

We now examine how players A and B choose locations in our sequential game, given alternative legal rules. We start with A's relocation decision, whether to stay at site 1 or move to 2, assuming that B has located at 1. We turn to B's location choice in Section 5.

If B locates at 1, then A and B will bargain to an outcome that maximizes their joint profit. If A stays at location 1, this joint profit is:

$$L^{A1} = \Pi_1(\theta). \tag{7}$$

However, if A moves to location 2, then B obtains profit $\theta\pi_B(0)$ at location 1, A bears the relocation cost M and bargains with C at location 2 to obtain the profit,

$$I_R = t_{A2} + \alpha_2(\Pi_2 - t_{A2} - t_{C2}), \tag{8}$$

namely, A's threat payoff plus A's share (α_2) of the net gain to bargaining, $\Pi_2 - t_{A2} - t_{C2}$. We thus have the joint (A-B) profit from A's move to location 2,

$$L^{A2} = \theta\pi_B(0) - M + I_R. \tag{9}$$

I_R is the portion of the location 2 payoff (L^{A2}) that varies with the rights regime R.

We can now define the critical θ^A that partitions θ values between those that prompt A to stay at location 1 ($\theta \leq \theta^A$) and those that prompt A to move ($\theta > \theta^A$) in the location 1 (A-B) bargaining equilibrium:

$$\theta^A(I_R) = \begin{cases} 0 & \text{if } L^{A1}(\theta) - L^{A2}(\theta, I_R) < 0 \ \forall\theta>0 \\ \infty & \text{if } L^{A1}(\theta) - L^{A2}(\theta, I_R) > 0 \ \forall\theta>0 \\ \theta^A \in (0,\theta^+): L^{A1}(\theta) - L^{A2}(\theta, I_R) = 0 & \text{otherwise} \end{cases} \tag{10}$$

for a bounded θ^+. Note that, because $\partial(L^{A1}-L^{A2})/\partial\theta=\pi_B(e^*(\theta))-\pi_B(0)<0$ (with $e^*>0$ and $\pi_B'<0$), θ^A is unique.

Using equations (2), (3) and (5) (defining θ^{A*}), the definition of I_{FD} (from equation (8) and Table 1), and equations (7) and (9) (defining L^{A1} and L^{A2}), we have:

$$L^{A1}(\theta^{A*})-L^{A2}(\theta^{A*},I_{FD}) = \Pi_I(\theta^{A*}) - \theta^{A*}\pi_B(0) + M - I_{FD} = 0. \tag{11}$$

From equation (10) (and uniqueness of $\theta^A(I_R)$), equation (11) implies that $\theta^A(I_{FD}) = \theta^{A*}$; that is, *the FD rule achieves the first-best location for A.*

Intuitively, society's objective is to confront the A-B coalition with the true costs and benefits of moving A to location 2. The coalition faces all costs and benefits of staying together at 1. At location 2, they need to be confronted with the costs of moving to agent C. This can be done by requiring compensation to C for damages suffered as a result of the move – that is, by giving damage rights to C (the first mover).

Effects of the other legal rules can be determined by ranking the location 2 bargained payoffs to A, I_R:

Lemma 2. If $\alpha_2 \in (0,1)$, then $I_{SE} \geq I_{SI} > I_{SD} > I_{FD} > I_{FI} \geq I_{FE}$, where the first inequality is strict if $\pi_C(e_{A1})>0$ and the last is strict if $\pi_{A2}(0)>0$. If $\alpha_2=1$, then $I_{SE} \geq I_{SI} > I_{SD} > I_{FD} = I_{FI} = I_{FE}$. If $\alpha_2=0$, then $I_{SE} = I_{SI} = I_{SD} > I_{FD} > I_{FI} \geq I_{FE}$.

Intuitively, second party rights advantage A, the second mover at location 2. Moreover, the bargaining advantage to the rights holder rises with the holder's power to limit the rival's rents. Hence, the rights holder's payoff is higher with injunctive rights than with damage rights, and highest with exclusion rights. A's bargained profit is thus highest with second party exclusion rights, while C's profit is highest (and A's is lowest) with first party exclusion rights. Because the profitability of A moving rises with the bargained location 2 rents I_R, we have, for interior θ^A,

$$d\theta^A/dI_R = [\partial(L^{A1}-L^{A2})/\partial\theta]^{-1} < 0. \tag{12}$$

Combining Lemma 2 and equation (12), we can conclude: Relative to the first-best FD rule, second party rights give the A-B coalition excessive rents from A's move, and thereby inefficiently encourage the move (lowering θ^A). Conversely, giving A weaker rights (by giving C first party injunctive or exclusion privileges) inefficiently deters A's move (raising θ^A), unless A has all the bargaining power (α_2=1) and thus faces all joint benefits at location 2, net of C's costs.

In summary, we have the first key result of the paper:

Proposition 1. (A) Suppose $\alpha_2 \in (0,1)$ and B has located at site 1. Then: $\theta^A(I_{SE}) \leq \theta^A(I_{SI}) < \theta^A(I_{SD}) < \theta^A(I_{FD}) = \theta^{A*} < \theta^A(I_{FI}) \leq \theta^A(I_{FE})$, where the first inequality is strict if $\theta^A(I_{SI})>0$ (and $\pi_C(e_{A2})>0$) and the last is strict if $\theta^A(I_{FI})$ is bounded (and $\pi_{A2}(0)>0$). Hence, first party damage rights yield an efficient location choice for A. Second party rights prompt A to move more often than is efficient. First party injunctive and exclusion rights prompt A to move less often than is efficient. (B) If α_2=1, then $\theta^A(I_{SE}) \leq \theta^A(I_{SI}) < \theta^A(I_{SD}) < \theta^A(I_{FD}) = \theta^{A*} = \theta^A(I_{FI}) = \theta^A(I_{FE})$.

5. Equilibrium Location for B

To decide whether to operate at location 1 or 2, B compares the payoff at 2,

$$L^{B2} = \pi_B(0), \tag{13}$$

to the bargained payoff if locating at 1,

$$L_R^{B1} = t_{B1} + \alpha_1(L^{A*} - t_{B1} - t_{A1}), \tag{14}$$

where t_{A1} and t_{B1} are the threat points for the location 1 A-B bargaining game, and

$$L^{A*} = \max\,(L^{A1}(),\, L^{A2}()) \tag{15}$$

is the collective (maximal) A-B profit when A and B are both located at 1 (with L^{A1} and L^{A2} as defined in equations (7)-(9) above).

Threat points are again determined by the legal rules. However, now A always has the "outside option" of moving to location 2, even without a bargaining agreement. This limits the extent to which A's disagreement payoff can be reduced. Formally, A's threat point must satisfy the constraint,[8]

$$t_{A1} \geq I_R - M = \text{A's profit if unilaterally moving to 2.} \tag{16}$$

<<COMP: Place Table 2 about here>>

In view of constraint (16), Table 2 describes threat points for the alternative legal rules. Recall that A is the first mover and B the second mover at location 1. Hence, first party injunctive rights give A the right to set e, and first party exclusion rights entitle A to shut B down. First party damage rights let B choose e and A's location, but require compensation so that A obtains the same profit as would be obtained without B present. Likewise with second party rights, except that constraint (16) binds in two cases:

Lemma 3. Constraint (16) binds with second party injunctive or exclusion rights, but not with second party damage or first party rights.

Because L^{A*} rises monotonically with θ, we can define a unique critical θ_R^B that partitions θ values between those that prompt B to locate at site 2 ($\theta<\theta_R^B$) and at site 1 ($\theta\geq\theta_R^B$):[9]

$$\theta_R^B = \begin{cases} 0 & \text{if} \quad L_R^{B1}(\theta) - L^{B2} > 0 \quad \forall\theta>0 \\ \theta^B \in (0,\theta^+): L_R^{B1}(\theta) - L^{B2} = 0 & \text{otherwise} \end{cases} \tag{17}$$

for a bounded θ^+.

To evaluate the effect of a first party damage (FD) rule on B's location decision, note that Assumption 2 ($\theta^{B*}<\theta^{A*}$) and Proposition 1 ($\theta^A(I_{FD})= \theta^{A*}$) imply that

$$L^{A*}(\theta^{B*}, I_{FD}) = L^{A1}(\theta^{B*}) = \Pi_1(\theta^{B*}). \tag{18}$$

Together, equation (18), Table 2, and equation (13) yield

$$L^{B1}_{FD}(\theta^{B*}) - L^{B2} = \Pi_1(\theta^{B*}) - \pi_{A1}(e_{A1}) - \pi_B(0) = 0, \tag{19}$$

where the last equality follows from the definition of θ^{B*} (in equations (2), (4) and (6)). Hence, by (17), $\theta^{B}_{FD} = \theta^{B*}$; that is, *the FD rule achieves the first-best location for B.*

First party damage rights present new (moving) residents with the costs of their move to existing residents; in essence, these rights act like Pigovian taxes, compelling agents to internalize the external costs of their moving / location decisions. As a result, A makes an efficient decision between remaining at site 1, and relocating to site 2 where the existing resident C (the first mover) enjoys damage rights. Likewise, B makes an efficient decision between locating at site 2, and at site 1 where the existing resident A (the first mover) enjoys damage rights. For B, benefits and costs of locating at site 1 depend upon A's resulting relocation decision; here, the sequence of first party damage rights confronts B not only with the costs of its location at 1 (to A), but with the benefits of this choice in view of an optimal subsequent location choice by A.

To determine the effect of the other property rights regimes on B's location choice, θ^{B}_{R}, we compare the benefits to a site 1 location L^{B1}_{R}, as described in Table 2. Doing so gives the second central proposition of this paper.

Proposition 2. Suppose $\alpha_1 \in (0,1)$. Then:

$$\theta^{B}_{SI} \le \theta^{B}_{SE} \le \theta^{B}_{SD} = 1 < \theta^{B*} = \theta^{B}_{FD} < \theta^{B}_{FI} < \theta^{B}_{FE} \ ,$$

where the second inequality is strict if and only if $\theta^{A}(I_{SE})>1$, and the first is strict if $\theta^{A}(I_{SI})>1\ge\theta^{A}(I_{SE})$ or $\theta^{A}(I_{SE})>1$, $\theta^{B}_{SE}>0$, $\alpha_2>0$ and $\pi_C(e_{A2})>0$. Hence, first party damage rights yield an efficient location choice for B. Second party rights prompt B to locate at site 1 (with A) more often than is efficient. First party injunctive and exclusion rights prompt B to locate at site 2 (with C) more often than is efficient.

First party injunctive and exclusion rights inefficiently deter B's location at site 1 for two reasons. First, they implicitly over-tax B for costs of its site 1 location to A (except when B obtains all bargaining rents, $\alpha_1=1$). Second, they over-deter A's move to site 2 by also over-taxing this move (except when A obtains all site 2 bargaining rents, $\alpha_2=1$); because B shares in this excessive punishment to A at site 2, by virtue of its share of A-B bargaining rents, its payoff to location at site 1 also suffers. For both reasons, B's location at site 1 yields B a profit that is less than (maximal) net social benefit. Moreover, because the punishment to second movers is greater when first movers have exclusion (vs. injunctive) rights, the excessive deterrent to B's site 1 location is greatest with the exclusion rights (FE).

Conversely, second party rights inefficiently encourage B's location at site 1, again for two reasons. First, the second mover rights implicitly under-tax B for the costs of its site 1 location to A. Second, second party rights also under-tax A for its relocation to site 2, which inefficiently promotes this move; because B shares in these gains, due to its share of site 1 bargaining rents ($\alpha_1>0$), they also promote B's location at site 1. Both effects yield B a profit from siting at 1 that is higher than corresponding net social benefit.

With second party rights, we find that injunctive rights are more powerful than exclusion rights when it comes to encouraging B's location at site 1, even though exclusion rights are more powerful when it comes to encouraging A's location at site 2

(Proposition 1). In both cases, the second party rights give A a disagreement payoff (in its bargaining with B) that is determined by its "outside option" of moving away from site 1, an option which is attractive because A is the second party at site 2. Moreover, the profitability of A's outside option is greater when it has the stronger exclusion rights at site 2. As a result, the second party exclusion rights give A a larger bargained profit at site 1, and B a lower bargained profit, which in turn leads to a lessened incentive for locating at site 1.

6. Initial Location of A

We have taken A's initial choice of site 1 (at time 0) as given in this analysis. However, property rules can affect this initial site selection. Consider the foregoing model with one natural generalization: At time 1, B obtains profit of $\theta_i\pi_B(e)$ at location $i\in\{1,2\}$, where θ_1 and θ_2 are ex-ante random, distributed according to the density $f(\theta_1,\theta_2)$ on the support $\Theta=[0,\theta^+]x[0,\theta^+]$.[10] As mentioned at the outset, the two sites can then be ex-ante identical; for example, if f is symmetric (so that $f(a,b)=f(b,a)$ for any $(a,b)\in\Theta$) and A profit functions are the same at the two sites, then it will be a matter of social and private indifference which site is chosen by A apriori.

More interesting are potential ex-ante asymmetries between the sites. Consider the first party damage rule FD (under which A obtains his maximal profit, $\pi_{Ai}(e_{Ai})$, when initially located at site i). Further, suppose that θ_2 has a "better" marginal distribution than θ_1 (in the sense of stochastic dominance and/or monotone likelihood ratio properties) and that site 1 yields A higher profits than site 2 (with $\pi_{A1}(e)> \pi_{A2}(e)$ and a similar condition for initial period A profit). Then initial private location incentives for A, under FD, coincide with ignored social benefits of siting decisions (to B), both favoring site 1. Hence, FD achieves efficient initial siting in some circumstances.

However, if B instead obtains generally higher profits at site 1, thus exposing him to higher external harm from A's location at site 1, then external costs favor an initial A location at site 2. If A has a relatively small private incentive to select site 1, and the external cost of this site choice to B is large (because the θ_1 distribution is substantially better than θ_2's), then FD will lead A to choose site 1 even though site 2 is more efficient.

Although FD does not lead to an efficient initial site selection in all cases, nor does any other ex-post property or liability rule. The reason is this: It is often efficient to maintain a spatial separation between externality generators and receivers. In our model, for example, B may often optimally site away from A so that no externality is created and potential moving costs for A (which may be substantial) are avoided. In these cases, it is socially beneficial for A to choose an initial site that has a poorer ex-post profit distribution for B, so that foregone profits to B from not locating next to A are smaller. However, with an ultimate spatial separation between A and B, neither property nor liability rules confront A with any costs or benefits to B. A will thus ignore the impact of his siting choice on foregone profits to B.[11]

Proposition 3. (A) No ex-post regime of property rights and liability can achieve optimal location decisions for A at the initial time 0, and A and B at the subsequent time 1, in all circumstances. (B) Consider an ex-post regime of property rights and liability that, for some realizations of (θ_1,θ_2), produces a spatial separation between A and B (A at 1 and B at 2, or vice versa) at time 1. There is no such regime that, in all circumstances, achieves a constrained efficient location decision for A at time 0, *given* the ex-post (A and B) location decisions produced by the property/liability rule.[12]

This result suggests that ex-post property/liability regimes may not be the preferred method of regulating ex-ante location decisions such as those of A in this paper. Their failure argues instead for use of governmental zoning powers to help achieve optimal initial spatial locations. Property rules can then be relied upon in subsequent disputes to elicit the ex-post location choices analyzed in this paper.

7. Extensions

7.1. Non-Contractible Ex-Ante Investments

When A locates at site 1 initially, it may choose how much to invest in its operation. Likewise, if and when B locates at site 1, it may choose the extent of initial investment before bargaining can take place. Higher A investments will increase the benefits of the externality e to A, while higher B investments will increase the costs of the externality e to B. How do property rules affect the efficiency of such ex ante investment decisions?

Consider B's investment. Because a first party damage rule confronts B with true social surplus, including costs of its site 1 location to A, this rule will elicit an efficient B investment level. Stronger first party rules (injunctive or exclusion) will over-tax B and thereby lead to under-investment (unless B obtains all bargaining rents, $\alpha_1=1$). Conversely, second party rules will under-tax B and thereby lead to over-investment. In sum, an investment choice by B reinforces the efficiency motives for the FD rule identified in this paper.

The same cannot be said for an initial investment choice by A. Due to the logic of Pitchford and Snyder (2003), a first party damage rule (FD) will prompt A to over-invest.

The reason is that FD guarantees A the same payoff whether B locates at site 1 or not; hence, A receives the same high marginal returns on ex-ante investment regardless. However, when B locates next to A, the investment may be entirely lost (and at least partially lost) if and when A moves; and, when A doesn't move, the social return to marginal investment is lower than received by A because the optimal externality level e is lowered due to B's presence, which in turn lowers benefits of the investment to A. For both reasons, the societal return to marginal investment is lower than A's private return under an FD rule.

This logic is akin to that for over-investment in land when the government compensates for a "taking" (Blume, Rubinfeld and Shapiro 1984). From the takings literature, there is a fix to the over-investment problem: base compensation on optimal investment, rather than actual investment (see Lueck and Miceli 2006). A similar fix is available here: Design compensation to A (the first mover) so that it gives A the same payoff as would be obtained absent B *and with an efficient investment level*. Formally, suppose x is A's investment, $\pi_{A1}(x,e)$ is A's location 1 profit, and x* is A's socially optimal investment. Then require that A be compensated to guarantee the profit $\pi_{A1}(x^*,e_{A1}(x^*))$, assuming A chooses $x=x^*$.[13] An FD rule so designed will be free of investment incentive distortions and thus achieve efficient choices in both location and investment domains.

7.2. Identity of the Generator

We have so far modeled location choice with the externality recipient (B) moving to the externality generator (A), as in the case of Spur. Are qualitative results robust to the alternative of an externality generator moving to the externality recipient?[14] Consider our model with A now defined as an externality recipient (with $\pi_{A1}(e)= \pi_{A2}(e)= \pi_A(e)$ for simplicity and $\pi_A'<0\ \forall e\geq 0$) and B as the externality generator (with $\pi_B'(0)>0$, $\pi_B''<0$, and the unique bounded profit maximum, $e_B = \text{argmax}\ \pi_B(e) > 0$).[15]

In this case, A's relocation decision does not depend on the legal rule, as there is no longer an externality between A and C. Hence, if B sites at location 1 (with A), A and B obtain the collective payoff,

$$L^{A*} = \max\left(\Pi_1(\theta), L^{A2}\right) \quad , \quad L^{A2} = \pi_A(0) + \theta\ \pi_B(e_B) - M, \tag{18}$$

where L^{A2} is the profit obtained when A moves to 2. Table 3 gives the disagreement payoffs in the site 1 A-B bargaining game under the alternative legal rules (following the logic of Table 2).[16] As before, the critical θ^{B*} is defined to partition θ values between those for which it is efficient for B to site at 1 ($\theta\geq\theta^{B*}$) and at 2 ($\theta<\theta^{B*}$), respectively:

$$\theta^{B*}:\ L^{A*}(\theta^{B*}) + \pi_C(0) = \pi_A(0) + \Pi_2, \tag{19}$$

where $\Pi_2 = \max_e \pi_B(e)+ \pi_C(e)$, the left (right) side of (19) gives the joint maximal A-B-C profit when B locates at site 1 (2), and we assume θ^{B*} is positive and bounded.

<<COMP: Place Table 3 about here>>

Proposition 4. When B is an externality generator, and A and C are externality receivers, first party damage rights lead to efficient location decisions for A and B.

Whether B is an externality receiver or generator is immaterial to the efficiency of the first party damage rule; this rule works in all cases because the moving agent is the second party and will thus site efficiently if confronted with costs of his choice to the extant first party.

However, it is hard to compare the other rules because B obtains similar benefits (or costs) of under (or over) taxation at the two sites. For example, first party injunctive or exclusion rights disadvantage B in negotiations with externality recipients at both locations (A at 1, C at 2). Hence, the direction of distortionary effect is unclear absent more structure. To gain a sense of these effects, suppose that an externality only arises at site 1 (with A, and not with C). Then B's benefit of siting at location 1 is L_R^{B1} as given in equation (14) (with L^{A*} from (18) and threat points from Table 3), and for location 2, $L^{B2} = \pi_B(e_B)$. Comparing these benefits under the alternative legal rules, we can derive the following relationships between the critical θ_R^B that partitions θ values between B's selection of site 1 ($\theta \geq \theta_R^B$) and 2 ($\theta < \theta_R^B$).

Proposition 5. Suppose $\alpha_1 \in (0,1)$, B is an externality generator, A is an externality receiver, and C is unaffected by B's "externality." Then:

$$\theta_{SI}^B = \theta_{SE}^B \leq \theta_{SD}^B < \theta^{B*} = \theta_{FD}^B < \theta_{FI}^B \leq \theta_{FE}^B .$$

Hence, second party rights prompt B to locate at site 1 (with A) more often than is efficient, while first party injunctive and exclusion rights prompt B to locate at site 1 less often than is efficient.

Whether B is an externality generator or receiver, second party rights under-tax its location at the "externality-prone" site 1, and first party injunctive or exclusion rights over-tax this location choice.

8. Conclusion

In the case of *Spur Industries v. Del Webb* (1972), the court ruled that the existing resident (Spur) was entitled to compensation for damages from optimally mitigating the harm that his feedlot caused the new resident (Webb). Pitchford and Snyder (2003, p. 509) interpret the court's ruling as a case of misunderstanding the potential for the parties to bargain with one another. With relatively low bargaining costs – as is realistic when there are just two complainants and high stakes – the first party damage rule implicitly implemented by the court would spur ex-ante over-investment by, in this case, Spur.

In this paper, we propose a different interpretation of the *Spur* decision. When bargaining is possible, but location (rather than investment) choices are the outcome of property rights, the first party damage rule promotes efficiency. Second party rights, whether they are entitlements to damages, injunctions, or complete exclusion of offending uses, excessively encourage residents to "come to the nuisance," and excessively encourage nuisances to move to new areas where they themselves benefit from the second party entitlements. On the other hand, stronger first party rights – powers of injunction or exclusion – excessively deter residents from "coming to the nuisance," and excessively deter nuisances from moving to other areas.

In judging the merits of competing legal rules in this paper, we have taken the sequencing of choices for granted. However, particularly in view of work arguing that first possession rules promote excessive possessory investments (e.g., Elickson 1989; Lueck 1995), one might ask: Does a first party damage rule create a race for property rights, with incentives for investments that are "too early" in order to acquire a right to compensation for damages? Wittman (1980) offers a poignant resolution to this question, suggesting that first party rights should attach only if the party *should be* first, not merely because the party *is* actually first. He writes (p. 560): "Because the polluter (or pollutee) is given extra consideration only when he *should* be first, the social cost of unnecessarily trying to be first is overcome." Such a rule is similar to providing damages only for efficient investment levels (as in Section 7.1 above) in order to avoid the incentives for over-investment identified by Pitchford and Snyder (2003).

Wittman's (1980) criterion may help to reconcile case law that often seems contradictory. For example, while the *Spur* decision promotes a first party damage right, prior case law supports second party rights.[17] The *Gau v. Ley* (1916) decision is illustrative; there, the court ruled that prior residents were not entitled to relief for costs created by a new industrial plant that chose to site nearby. The court concluded that the residents should have anticipated the plant's arrival because of their proximity to railroad tracks. Stated differently, the courts implicitly called into question whether the plaintiff *should* have been first.

To some extent, the seemingly contradictory case law may also reflect the courts' efforts to grapple with both ex-ante and ex-post location incentives. Indeed, we find that the scope for property law to promote efficient *ex-ante* location decisions – siting in anticipation of potential future neighbors (ex-ante) vs. siting in view of contemporaneous competing and/or infringing uses (ex-post) – is limited. However, for given ex-ante siting choices, first party damage rules of the type embraced in the *Spur* decision promote efficient ex-post location decisions.

Appendix

Proof of Lemma 1. θ^{A*}: By Assumption 1, $\Pi_{11}(0)>\Pi_{21}(0)$. For $\theta=\theta^{+}$ arbitrarily large,

$$\Pi_{11}(\theta^{+}) - \Pi_{21}(\theta^{+}) < \pi_{A1}(e^{*}(\theta^{+}))+\pi_{C}(0)-\Pi_{2}+M < 0,$$

where the first inequality is due to $\pi_{B}(e^{*}(\theta^{+}))< \pi_{B}(0)$, and second follows from Assumption 1. Hence, by the Intermediate Value Theorem, there is a $\theta^{A*}\in(0,\theta^{+})$: $\Pi_{11}(\theta)=\Pi_{21}(\theta)$.

θ^{B*}: At $\theta=0$,

$$\Pi_{11}(0) - \Pi_{12} = -\pi_{B}(0) < 0.$$

Because $\Pi_{11}(\theta)$ is increasing in θ with derivatives bounded away from zero for all θ, there is a $\theta^{+}>0$: $\Pi_{11}(\theta^{+})-\Pi_{12}>0$. Hence, by the Intermediate Value Theorem, there is a $\theta^{B*}\in(0,\theta^{+})$: $\Pi_{11}(\theta)=\Pi_{12}$. QED.

Proof of Lemma 2. From Table 1 and equation (9),

$$I_{SE} - I_{SI} = \alpha_{2}\pi_{C}(e_{A2}) \tag{A1a}$$

$$I_{SI} - I_{SD} = \alpha_{2} \{\Pi_{2}-(\pi_{A2}(e_{A2})+ \pi_{C}(e_{A2}))\} \tag{A1b}$$

$$I_{SD} - I_{FD} = [\pi_{A2}(e_{A2})+ \pi_{C}(0)] - \Pi_{2} > 0 \tag{A1c}$$

$$I_{FD} - I_{FI} = (1-\alpha_{2}) \{\Pi_{2}-(\pi_{A2}(0)+ \pi_{C}(0))\} \tag{A1d}$$

$$I_{FI} - I_{FE} = (1-\alpha_{2}) \pi_{A2}(0), \tag{A1e}$$

where $\Pi_{2} > \pi_{A2}(e)+ \pi_{C}(e)$ for $e\in\{0,e_{A2}\}$ by the definitions of Π_{2} and e_{A2}, and (by our assumptions) argmax $\pi_{A2}(e)+ \pi_{C}(e) > 0$. The Lemma follows directly from (A1). QED.

Proof of Proposition 1. (i) $\theta^{A}(I_{FD}) = \theta^{A*}$. Follows from equations (10)-(11).

(ii) $\theta^A(I_{SE}) \leq \theta^A(I_{SI}) < \theta^A(I_{SD}) < \theta^A(I_{FD})$. The last inequality follows from Lemma 2 and $\theta^A(I_{FD})>0$ (by Lemma 1 and $\theta^A(I_{FD})= \theta^{A*}$). The remaining inequalities follow from Lemma 2 and, due to the following, $\theta^A(I_{SD})>0$:

$$L^{A1}(0)-L^{A2}(0,I_{SD}) = M + \pi_{A1}(e_{A1})- \pi_{A2}(e_{A2}) > 0, \tag{A2}$$

where the inequality is due to $\pi_{A1}(e_{A1})\geq \pi_{A2}(e_{A2})\ \forall e\geq 0$, the definition of e_{A1} in (1), and $M>0$.

(iii) $\theta^A(I_{FD}) < \theta^A(I_{FI}) \leq \theta^A(I_{FE})$. Follows from Lemma 2, Lemma 1, $\theta^A(I_{FD})=\theta^{A*}$, and equation (12). QED.

Proof of Lemma 3. For FD, constraint (16) is (substituting for I_{FD}):

$$t_{A1} = \pi_{A1}(e_{A1}) \geq \Pi_2 - M - \pi_C(0), \tag{A3}$$

which holds by Assumption 1. Vis-à-vis FD, FI and FE have common A threat points and smaller values of I_R; hence, satisfaction of (16) for FD implies satisfaction for FI and FE. For SD, we have

$$L^{A*} = \max\,(L^{A1}(),\, L^{A2}()) \geq L^{A2} = \theta\pi_B(0) - M + I_{SD}, \tag{A4}$$

$$\leftrightarrow \quad L^{A*} - \theta\pi_B(0) = t_{A1} \geq I_{SD} - M,$$

where the inequality is an equality if $L^{A*} = L^{A2}$. (A4) implies satisfaction of (16) for SD.

For $\theta\geq\theta^A(I_{SD})$ (so that $L^{A*}(\theta, I_{SD})=L^{A2}(\theta, I_{SD})$):

$$0 \leq \pi_{A1}(0) < \Pi_1(\theta) - \theta\pi_B(0) \leq L^{A*}(\theta, I_{SD}) - \theta\pi_B(0) \tag{A5}$$

$$= I_{SD} - M \;\leq I_{SI} - M \;\leq I_{SE} - M,$$

where the second inequality follows from the definition of $\Pi_1(\theta)$ (and $e^*(\theta)>0$), the third inequality is due to the definition of $L^{A*} = \max\,(\Pi_1(\theta), L^{A2}())$, the equality follows from (A4) (with $L^{A*}=L^{A2}()$), and the remaining inequalities are due to Lemma 2. Without constraint (16), SI and SE regimes yield A threat points of $\pi_{A1}(0)$ and zero, respectively.

Hence, because the left-most and right-most terms in (A5) are invariant to θ, (A5) implies that (16) binds (for all θ) for SI and SE regimes. QED.

Proof of Proposition 2. (i) $\theta^{B}_{FD}=\theta^{B*}$. Follows from equation (19).

(ii) $\theta^{B*}> 1$. Follows from (19), $\partial\Pi_1(\theta)/\partial\theta>0$, and $\Pi_1(1) < \pi_{A1}(e_{A1}) + \pi_B(0)$.

(iii) $\theta^{B}_{FD} < \theta^{B}_{FI}$. Evaluate B's net incentive to site at 1, with R=FI and $\theta=\theta^{B}_{FD}$ ($< \theta^A(I_{FD}) < \theta^A(I_{FI})$ by Proposition 1):

$$L^{B1}_{FI}(\theta^{B}_{FD}) - L^{B2} = L^{B1}_{FI}(\theta^{B}_{FD}) - L^{B1}_{FD}(\theta^{B}_{FD}) \tag{A6}$$

$$= (1-\alpha_1)\{ \theta^{B}_{FD}\pi_B(e_{A1}) + \pi_{A1}(e_{A1}) - \Pi_1(\theta^{B}_{FD}) \} < 0,$$

where the first equality subtracts $L^{B1}_{FD}(\theta^{B}_{FD}) - L^{B2} = 0$, the second substitutes for $L^{A*}(\theta,I_{FI}) = L^{A*}(\theta,I_{FD}) = \Pi_1(\theta)$ at θ^{B}_{FD}, and the inequality follows from $\alpha_1<1$ and the definitions of Π_1 and $e_{A1} \neq e^*(\theta)$ for $\theta>0$. Hence, in order to solve (17) (with $\partial L^{B1}/\partial\theta>0$), we must have $\theta^{B}_{FI} >\theta^{B}_{FD}$.

(iv) $\theta^{B}_{FI} < \theta^{B}_{FE}$. Evaluate B's net incentive to site at 1, with R=FE and $\theta=\theta^{B}_{FI}$. Because $\theta^A(I_{FE}) \geq \theta^A(I_{FI})$ (Proposition 1), either (a) $L^{A*}(\theta,I_{FE}) = L^{A*}(\theta,I_{FI})$ or (b) $L^{A*}(\theta,I_{FE}) = \Pi_1(\theta)$ and $L^{A*}(\theta,I_{FI}) = L^{A2}(\theta,I_{FI}) > \Pi_1(\theta)$ at $\theta=\theta^{B}_{FI}$. Hence,

$$L^{B1}_{FE}(\theta^{B}_{FI})-L^{B2} = L^{B1}_{FE}(\theta^{B}_{FI}) - L^{B1}_{FI}(\theta^{B}_{FI}) \tag{A7}$$

$$= \alpha_1(L^{A*}(\theta^{B}_{FD},I_{FE}) - L^{A*}(\theta^{B}_{FD},I_{FI})) - (1-\alpha_1)\theta^{B}_{FD}\pi_B(e_{A1}) < 0.$$

(v) $\theta^{B}_{SD} = 1$. By (17) and Table 2, θ^{B}_{SD} solves:

$$L^{B1}_{SD}(\theta^{B}_{SD}) - L^{B2} = (\theta^{B}_{SD}-1)\,\pi_B(0) = 0 \;\rightarrow\; \theta^{B}_{SD}=1.$$

(vi) For SE/SI regimes, we have (using Lemma 3):

$$L_R^{B1} - L^{B2} = \alpha_1(L^{A*}(\theta, I_R) - L^{A2}(\theta, I_R)) + \pi_B(0)(\theta - 1) \quad \text{(A8a)}$$

$$> 0 \quad \text{for all } \theta > 1, \quad \text{(A8b)}$$

$$= \pi_B(0)(\theta - 1) \quad \text{when } \theta \geq \theta^A, \quad \text{(A8c)}$$

$$> \pi_B(0)(\theta - 1) \quad \text{when } \theta < \theta^A, \quad \text{(A8d)}$$

where (A8b) follows from $L^{A*} = \max(L^{A1}(), L^{A2}()) \geq L^{A2}()$ and $\alpha_1 > 0$, (A8c) follows from $L^{A*} = L^{A2}()$ when $\theta \geq \theta^A$, and (A8d) follows from $L^{A*} = L^{A1}() > L^{A2}()$ when $\theta < \theta^A$.

Now, with $\theta^A(I_{SE}) \leq \theta^A(I_{SI})$ by Proposition 1, there are three cases:

(1) $1 \geq \theta^A(I_{SI}) \geq \theta^A(I_{SE})$. By (A8c), $\theta_{SI}^B = \theta_{SE}^B = 1$ in this case.

(2) $\theta^A(I_{SI}) > 1 \geq \theta^A(I_{SE})$. By (A8c), $\theta_{SE}^B = 1$, and by (A8d), $\theta_{SI}^B < 1$ in this case.

(3) $\theta^A(I_{SI}) \geq \theta^A(I_{SE}) > 1$. In this case, (A8d) implies $\theta_R^B < 1$ for both SI and SE.

To compare the two, use (A8a) to evaluate B's net incentive to site at 1 with R=SI and $\theta = \theta_{SE}^B$ $(< 1 < \theta^A(I_{SE}) \leq \theta^A(I_{SI}))$, provided $\theta_{SE}^B > 0$:

$$L_{SI}^{B1}(\theta_{SE}^B) - L^{B2} = L_{SI}^{B1}(\theta_{SE}^B) - L_{SE}^{B1}(\theta_{SE}^B) \quad \text{(A9)}$$

$$= \alpha_1(L^{A2}(\theta_{SE}^B, I_{SE}) - L^{A2}(\theta_{SE}^B, I_{SI})) = \alpha_1(I_{SE} - I_{SI}) > 0,$$

where the inequality follows from Lemma 2, provided $\alpha_2 > 0$ and $\pi_C(e_{A2}) > 0$. (A9) implies $\theta_{SI}^B < \theta_{SE}^B$ when $\theta_{SE}^B > 0$ (and $\theta_{SI}^B = \theta_{SE}^B$ otherwise). QED.

Proof of Proposition 3. (A) It suffices to find circumstances under which no ex-post regime achieves optimal location decisions. Suppose $\pi_{A1}(e) = \pi_{A2}(e) = \pi_A(e)$, θ_i has the binary support $\{\theta_-, \theta_+\}$ where $\theta_+ > \theta_-$, M is sufficiently large that it is never optimal for A to move ex-post, and

(A10) $\pi_A(e_A) + \theta_- \pi_B(0) > \Pi_1(\theta_+)$, so that it is never ex-post optimal for A and B to locate together. Further suppose that initial period A profit is ε (>0) higher at site 1 than site 2. Then any ex-post regime that elicits ex-post optimal location decisions prompts A to site initially at location 1 (because A obtains ex-post profit of $\pi_A(e_A)$ at both sites). However, if the following condition holds, then the optimal initial location for A is site 2:

$$\varepsilon + \pi_A(e_A) + E_1(\theta_1)\,\pi_B(0) < \pi_A(e_A) + E_2(\theta_2)\,\pi_B(0) \tag{A11}$$

$$\leftrightarrow\ \varepsilon < [E_2(\theta_2) - E_1(\theta_1)]\,\pi_B(0) = \pi_B(0)\,[\theta_+ - \theta_-]\,[p_2 - p_1],$$

where $E_i(\theta_i) = p_i\theta_+ + (1-p_i)\,\theta_-$, and p_i is the probability of θ_+ at site i. (A11) implies societal rents to A siting at location 1 are less than at location 2 because site 2 has the better B profit distribution (with $\theta_+ > \theta_-$ and $p_2 > p_1$).

(B) Let Θ_i be the set of $\{\theta_1, \theta_2\}$ realizations that elicit spatial separation between A and B if A locates at site i, and $\Theta = \Theta_1 \cap \Theta_2$. By assumption Θ is non-degenerate. Now suppose that the probability of Θ is one and, as above, $\pi_{A1}(e) = \pi_{A2}(e) = \pi_A(e)$, A's initial period profit is ε (>0) higher at site 1, and (A11) holds with $E_i(\theta_i) = \int_{\Theta} \theta_i\, g_i(\theta_i)\, d\theta_i$ (where g_i is the marginal density of θ_i). Then A sites initially at 1, even though the constrained optimal initial location choice is 2 (by (A11)). QED.

Proof of Proposition 4. A: Follows directly from A-B bargaining. B: B's post-bargaining profit from locating at sites 1 and 2, respectively, are:

$$L_R^{B1} = t_{B1} + \alpha_1(L^{A*} - t_{A1} - t_{B1}),$$

$$L_R^{B2} = t_{B2} + \alpha_2(\Pi_2 - t_{C2} - t_{B2}),$$

where α_i is B's share of bargaining gains at location I, and (t_{B2}, t_{C2}) are the disagreement payoffs in the B-C bargaining game if B locates at 2. Under FD, we have

$$t_{B2} = \Pi_2 - \pi_C(0) \quad , \quad t_{C2} = \pi_C(0).$$

Hence, from Table 3, we have

$$L_{FD}^{B1}(\theta^{B*}) - L_{FD}^{B2} = L^{A*}(\theta^{B*}) - \pi_A(0) - \Pi_2 + \pi_C(0) = 0, \tag{A12}$$

where the equality follows from (18). With L_{FD}^{B1} rising with θ, (A12) implies Proposition 4. QED.

Proof of Proposition 5. First note that θ^{B*}, now defined to equate L^{A*} and $(\pi_B(e_B) + \pi_A(0))$, is unique, positive and bounded. Hence, with $\alpha_1 \in (0,1)$ (by assumption), $L_{SI}^{B1} = L_{SE}^{B1} = L_{SIE}^{B1}$ (from Table 3 and equation (13)), and L_{R}^{B1} increasing in θ, it suffices to show:

$$L_{FI}^{B1} - L_{FE}^{B1} = (1-\alpha_1)\,\theta\pi_B(0) > 0, \tag{A13a}$$

$$L_{FD}^{B1} - L_{FI}^{B1} = (1-\alpha_1)\,\{L^{A*} - (\theta\pi_B(0) + \pi_A(0))\} > 0, \tag{A13b}$$

$$L_{SD}^{B1} - L_{FD}^{B1} = \begin{cases} \theta\pi_B(e_B) + \pi_A(0) - \Pi_1(\theta) > 0 & \text{if} \quad L^{A*} = \Pi_1(\theta) \\ M > 0 & \text{if} \quad L^{A*} = L^{A2} \end{cases} \qquad \text{A13c)}$$

$$L_{SIE}^{B1} - L_{SD}^{B1} = \alpha_1(L^{A*} - L^{A2}) \geq 0, \tag{A13d}$$

where the inequality in (A13b) follows from the definitions of $\Pi_1(\theta)$ and $L^{A*} \geq \Pi_1(\theta)$, the top inequality in (A13c) follows from the definitions of $\Pi_1(\theta)$ and e_B, and the final inequality is due to the definition of $L^{A*} \geq L^{A2}$. QED.

Footnotes

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[1] See also Pitchford and Snyder (2007), who study how to optimally assign property rights depending upon whether the rights holder is an externality generator or receiver.

[2] See also recent legal discussions of right-to-farm laws, which protect farmers from agents who "come to the nuisance" (e.g., Reinert 1998).

[3] See also the burgeoning literature on optimal spatial structure with environmental amenities and externalities (e.g., Wu 2006).

[4] For expositional economy, we do not model the details of the bargaining games. However, note that, in each case, the posited outcome can represent the Nash solution, the outcome of a unanimity bargaining game with discounting penalties to delay and a known order of play (e.g., Chatterjee and Sabourian 2000), or an alternating offers game with an exogenous probability of breakdown (Binmore, Rubinstein, and Wolinsky 1986).

[5] In this case, the conclusion that we obtain on the efficiency of B's location decision (Proposition 2 below) will apply, but not those on A's relocation decision (Proposition 1).

[6] Because $\Pi_2+\pi_B(0) \geq \max\,(\pi_{A2}(e)+\pi_C(e)+\pi_B(e)) \equiv \Pi_{2+}$, Assumption 1 implies that $\pi_{A1}(e_{A1})+\pi_C(0)+\pi_B(0) > \Pi_{2+}$-M; hence, it is never efficient for A to move to 2 when B locates at 2.

[7] Assumption 1 places regularity restrictions on the sum, M+$\pi_C(0)$. One way to think about Assumption 2 is that it places an additional restriction on the scale of C's profit $\pi_C(e)$ (e.g., restrictions on a parameter $\varphi>0$ with $\pi_C(e)=\varphi\, \pi_{C0}(e)$). A higher scale of π_C has

no effect on θ^{B*}, but raises Π_{11} by more than Π_{21}, thus raising θ^{A*}; hence, Assumption 2 implicitly restricts C profit to be sufficiently large.

[8] In principle, B also has an "option to move." However, this option will always be exercised by B by choosing to locate at 2 apriori. Hence, for simplicity, we ignore this option here, implicitly assuming that once B's investment is sunk, costs of moving are prohibitive. However, the analysis is easily extended to account for a profitable post-location move option for B.

[9] Except for the case of first party exclusion (FE) rights with α_1=0, θ_R^B is easily shown to be bounded above.

[10] We assume, for simplicity, that agent C profits are the same at the two sites, and C selects a different site than A initially (to avoid external harm).

[11] One might ask whether the land market will address this problem. If the ex-ante profit distribution to B at a given site is better, then won't the land price be correspondingly higher, thus deterring A's location at that site? In general, the answer is "no." For land in a given area, there is often a marginal "backstop" use that determines land price in a competitive market. For example, land may be used for cultivated agriculture or fenced range that neither causes nor suffers any negative externality. So long as our "A-B-C" uses do not occupy all land at the alternate sites, land price will be determined by returns to the "backstop" use. For simplicity, this is what we assume in this paper. This logic is more general than it might seem. Suppose, for example, that there are two "sites" at one "location," and A's use of one site makes B's use of the other site unattractive (so that B locates elsewhere) even though foregone B profits at the site are high (without A present). Hence, if A locates at one of the two sites, the other site is placed in a

"backstop" use. If owners of the two sites cannot collude, then A can obtain a site for a price determined by the return to the "backstop" (plus ε). Each landowner, knowing the other will accept A's offer if he doesn't, accepts A's bid for his site.

[12] The "circumstances" of Proposition 3 concern the joint probability distribution of (θ_1,θ_2) and the set of profit functions of A (times 0 and 1), B, and C. The proof of Proposition 3 requires the identification of some circumstances ((θ_1,θ_2) distribution and profit functions) such that no liability/property regime achieves an efficient (Proposition 3(A)) or constrained efficient (Proposition 3(B)) initial site selection by A.

[13] If A stays at location 1, compensation would then equal $\pi_{A1}(x^*,e_{A1}(x^*))-\pi_{A1}(x^*,e)$. If A moves, compensation would equal $\pi_{A1}(x^*,e_{A1}(x^*))-(L^{A2}(x^*)-\theta\pi_B(0))$, where L^{A2} is invariant to x if the investment is lost when A moves, but can depend upon x if some of the investment is recouped despite A's move.

[14] There are many examples, including the well known case of *Gau v. Ley* (1916) discussed in Section 8.

[15] We assume that C remains an externality recipient. Alternatively, B and C could both be externality generators with no externality between them. Qualitative conclusions derived below extend to this case.

[16] The analog to constraint (16) (that t_{A1} be no lower than A's payoff with his "outside option" of unilaterally moving to 2),

$$t_{A1} \geq \pi_A(0) - M = L^{A2} - \theta\, \pi_B(e_B),$$

binds under SI and SE regimes, but not the others. Formally, we have (for θ sufficiently high that $L^{A*}=L^{A2}$),

$$0 \leq \pi_B(e_B) < \Pi_1(\theta) - \theta\,\pi_B(e_B) \leq L^{A*} - \theta\,\pi_B(e_B) = L^{A2} - \theta\,\pi_B(e_B).$$

[17] These cases date back at least to *Howard v. Lee*, 5 N.Y. Sup. Ct. (3Sandf) 281 (1849), and include the case of *Pendoley v. Ferriera*, 345 Mass. 309, 187 N.E. 2d 142 (1963) that provides the benchmark for Wittman (1980) (see Wittman 1981). In *Pendoley*, residential developments approached an established pig farm over time, and sued to enjoin the farm from operating. Here, the court ruled in favor of the residents, compelling the farmer to move and pay minor damages for nuisance.

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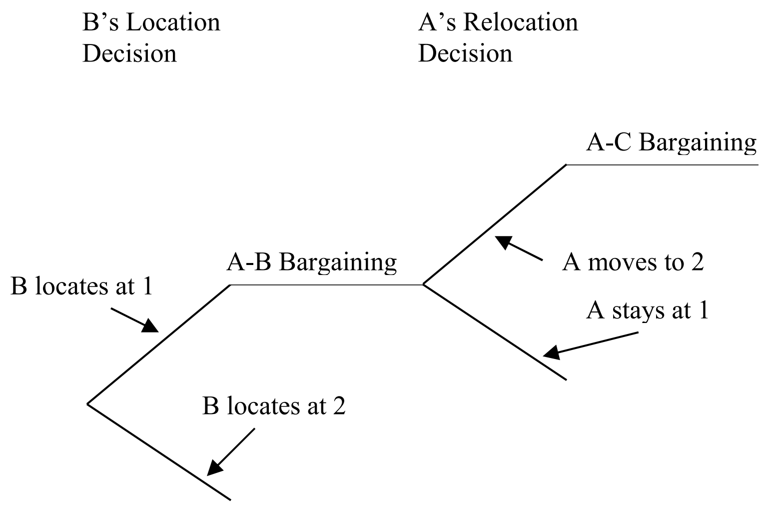

Figure 1. Model Sequence

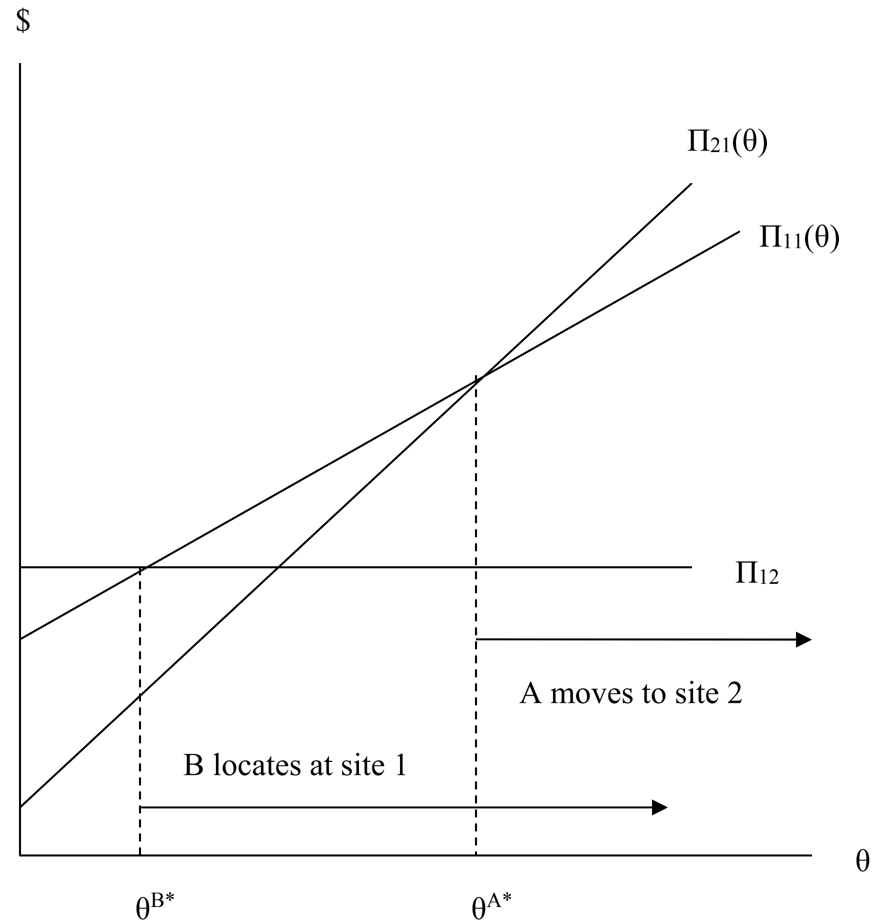

Figure 2. Collective Profit and Optimal Location

Table 1. Location 2 Threat Points Under Alternative Legal Rules

Legal Rule	A's Threat Point, t_{A2}	C's Threat Point, t_{C2}
First Party Rights		
Damage (FD)	$\Pi_2 - \pi_C(0)$	$\pi_C(0)$
Injunctive (FI)	$\pi_{A2}(0)$	$\pi_C(0)$
Exclusion (FE)	0	$\pi_C(0)$
Second Party Rights		
Damage (SD)	$\pi_{A2}(e_{A2})$	$\Pi_2 - \pi_{A2}(e_{A2})$
Injunctive (SI)	$\pi_{A2}(e_{A2})$	$\pi_C(e_{A2})$
Exclusion (SE)	$\pi_{A2}(e_{A2})$	0

Table 2. Location 1 Threat Points Under Alternative Legal Rules

Legal Rule	A's Threat Point, t_{A1}	B's Threat Point, t_{B1}	L_R^{B1}, B's Profit at Site 1
First Party Rights			
Damage (FD)	$\pi_{A1}(e_{A1})$	$L^{A*} - \pi_{A1}(e_{A1})$	$L^{A*} - \pi_{A1}(e_{A1})$
Injunctive (FI)	$\pi_{A1}(e_{A1})$	$\theta\pi_B(e_{A1})$	$\alpha_1(L^{A*} - \pi_{A1}(e_{A1})) + (1-\alpha_1)\theta\pi_B(e_{A1})$
Exclusion (FE)	$\pi_{A1}(e_{A1})$	0	$\alpha_1(L^{A*} - \pi_{A1}(e_{A1}))$
Second Party Rights			
Damage (SD)	$L^{A*}-\theta\pi_B(0)$	$\theta\pi_B(0)$	$\theta\pi_B(0)$
Injunctive (SI)	$L^{A2}-\theta\pi_B(0)$	$\theta\pi_B(0)$	$\alpha_1(L^{A*} - L^{A2})+\theta\pi_B(0)$
Exclusion (SE)	$L^{A2}-\theta\pi_B(0)$	$\theta\pi_B(0)$	$\alpha_1(L^{A*} - L^{A2})+\theta\pi_B(0)$

Note: (i) $L^{A*} = \max(L^{A1}(\theta), L^{A2}(\theta,I_R)) = \max(\Pi_1(\theta),\theta\pi_B(0) - M + \alpha_2\Pi_2 + I_R)$.
(ii) $L^{A2}-\theta\pi_B(0) = \alpha_2\Pi_2 - M + I_R$ (= right-hand-side of (15)).

Table 3. Location 1 Threat Points When B Is The Externality Generator

Legal Rule	A's Threat Point, t_{A1}	B's Threat Point, t_{B1}
First Party Rights		
Damage (FD)	$\pi_A(0)$	$L^{A*}- \pi_A(0)$
Injunctive (FI)	$\pi_A(0)$	$\theta\pi_B(0)$
Exclusion (FE)	$\pi_A(0)$	0
Second Party Rights		
Damage (SD)	$L^{A*}-\theta\pi_B(e_B)$	$\theta\pi_B(e_B)$
Injunctive (SI)	$L^{A2}-\theta\pi_B(e_B)$	$\theta\pi_B(e_B)$
Exclusion (SE)	$L^{A2}-\theta\pi_B(e_B)$	$\theta\pi_B(e_B)$