Incomplete Contracts and the Problem of Social Harm

Rohan Pitchford

Australian National University

Christopher M. Snyder

George Washington University

August 5, 1999

Abstract: We construct a model in which a first mover decides on its location before it knows the identity of the second mover; joint location results in a negative externality. Contracts are inherently incomplete since the first mover's initial decision cannot be specified. We analyze several kinds of rights, including damages, injunctions, and rights to exclude (arising from covenants or land ownership). There are cases in which allocating any of these basic rights to the first mover—i.e., first-party rights—is dominated by second-party rights, and cases in which the reverse is true. A Coasian result (efficiency regardless of the rights allocation) only holds under a limited set of conditions. As corollaries of a theorem ranking the basic rights regimes, a number of results emerge contradicting conventional wisdom, including the relative inefficiency of concentrated land ownership and the relevance of the generator's identity. We conclude with a mechanism and a new rights regime that each yield the first best in all cases.

JEL codes: K11, D23, C78, H23

Pitchford: Centre for Economic Policy Research, Research School of Social Sciences, Australian National University; email: `ropitch@coombs.anu.edu.au`. Snyder: Department of Economics, George Washington University; email: `csnyder@gwu.edu`. We are grateful for helpful discussions with John Asker; Dhammika Dharmapala; Simon Grant; Oliver Hart; Ilya Segal; Anthony Yezer; Martin Zelder; seminar participants at Berkeley, Harvard, Georgetown, and George Washington; and conference participants at the Australian Industry Economics, E.A.I.R.E., Econometric Society, and Southern Economic Association meetings. Theresa Alafita and Tony Salvage provided excellent research assistance. We retain responsibility for errors.

1 Introduction

Consider the case of a factory that emits pollution which soils the clothes at a nearby laundry. In the presence of such a negative externality, market equilibrium (with price-taking agents) will typically be inefficient. Coase (1960) argued that private bargaining between the factory and laundry can yield an efficient outcome as long as bargaining is frictionless and property rights are well defined. An important implication of the Coase Theorem is that the efficiency of the outcome does not depend on the specific allocation of property rights. The factory may have the right to pollute at will or the laundry may have the right to force the factory not to pollute at all—in either case, the outcome from private bargaining will be efficient.

We endogenize the investment decisions made by parties such as the factory and laundry, decisions which may result in their locating together despite the negative externality between them. We maintain the Coasian assumption that they engage in frictionless bargaining over the externality if they end up locating together. We add two new elements to the basic Coasian model: (a) parties make sequential investment decisions before any externality is generated and (b) the first party makes its initial decision before it knows the identity of the second. The latter element is labeled *ex ante anonymity*. Put simply, ex ante anonymity amounts to assuming that one does not always know one's future neighbors at the time when location-specific costs may be incurred. For example, the factory may face a location decision before it knows which of a large set of laundries will actually locate near it, and it is likely to be prohibitively expensive to negotiate with all of them (especially if the set is expanded to include all potential second parties such as restaurants, residences, etc.).

We maintain that ex ante anonymity is a pervasive aspect of externality problems and may be a leading cause of contractual incompleteness.[1] Our departure from Coase's assumption of complete contracting over all relevant variables is quite simple—contracting is impossible at the time of the first party's initial location decision but is frictionless once the two parties meet—yet the implications of this simple departure are significant and in some cases surprising:

[1] In the model, the first party has the option to delay its location decision until after the second party arrives on the scene. Allowing such delay effectively endogenizes the degree of contractual incompleteness since the factory is able to make its location decision contractible by delaying. To the best of our knowledge, this form of endogenous contractual incompleteness has not previously been analyzed.

- The "coming to the nuisance" doctrine asserts that property rights should be allocated to the first party, since the second party to arrive on the scene chooses to move into a situation where it is harmed. This logic is consistent with the incomplete-contracts literature, following the seminal papers by Grossman and Hart (1986) and Hart and Moore (1990) (hereafter, GHM). GHM's basic proposition is that to be protected from hold-up, the investing party should be granted rights in the form of asset ownership. Contrary to this proposition, we identify cases in which the first party is the only one to have sunk its locational investment at the time it bargains with the second party over the externality, yet granting property rights over the externality to the first party is inefficient, dominated by granting rights to the second party.

- In a seminal paper in law and economics, Calabresi and Melamud (1972) compare *damage rights*—the right to sue for harm caused by another party's negative externality—with *injunctive rights*—the right to stop the externality outright. They argue that, when transactions costs are high, damage rights are preferable to injunctive rights. We show that, despite the presence of transactions costs in the form of ex ante anonymity, the Calabresi-Melamud rule is equally likely to be reversed. In the construction of an efficient property-rights allocation, the distinction between damage and injunctive rights matters less than distinctions based on the timing of ownership (first- vs. second-party rights).

- Governments have tended to grant property rights only to parties that have an established interest in the land, perhaps reflecting an effort to deter speculators. For example, the Homestead Act of 1862 required the construction of a house and other improvements to gain rights to a parcel. We demonstrate that such requirements can be socially harmful: it may be better to grant property rights on the basis of the timing of ownership alone (*owner rights*) rather than additionally requiring investments sufficient to have a bona fide establishment on the land (*investor rights*).

- There is a conventional belief in economics that ownership of land by a single party will lead to the internalization of externalities. For example, Posner (1992, p. 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 paper 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, chapter 3; Starrett 1988, chapter 5; and Hardin 1993). We show that these arguments do not hold with ex ante anonymity. Ownership of all affected land by a single party is a special case of a more general rights regime we propose, *exclusion rights*, which allows the holder to exclude other parties from the general location in addition to setting the externality level. Exclusion rights turn out to be no better than standard (*non-exclusion*) rights, a result which has the immediate corollary that concentrated ownership is no better than separate ownership by the two parties. Indeed, under a small departure from our basic assumptions, concentrated ownership can be strictly worse than separate ownership.

[2] One of Coase's (1960) major insights was that the identity of the generator of the externality is not economically relevant: the central question is one of conflicting uses, rather than causation. We offer a definition of generator that is consistent with common usage and show that conditioning the allocation of property rights on the identity of the generator can improve social welfare. In the presence of ex ante anonymity, the identity of the generator may indeed be economically relevant.

As can be inferred from the previous discussion, the conclusions from the Coase Theorem no longer hold when ex ante anonymity is introduced: with ex ante anonymity, (a) outcomes can be inefficient and (b) the allocation of property rights can affect the level of social surplus. Concerning point (b), there is a rich set of multi-dimensional property rights (formed by taking various combinations of the alternatives first- vs. second-party rights, injunctive vs. damage rights, owner vs. investor rights, exclusion vs. non-exclusion rights), which differ in their relative efficiencies. One of the major contributions of the paper is to rank, according to social welfare, a number of common property-rights regimes drawn from this rich set. The results cited in the previous five bullet points are immediate corollaries of the ranking theorem.

To gain some intuition for the ranking theorem, note that all variables are contractible ex post except for the first party's initial investment decision; so it is the equilibrium value of this variable which determines the relative efficiency of regimes. Granting property rights (of any of the basic forms we consider) to the first party may lead to overinvestment; i.e., the first party initially locates in the area where the externality may arise rather than locating somewhere else or at least delaying location until the second party arrives. Granting property rights to the second mover may lead to underinvestment. One might think that strong rights regimes—strong in the sense of affording the rights holder power to extract surplus from the other party—exacerbate these inefficiencies. This intuition is not correct. What matters for the first party's investment decision is not its surplus *level* but rather its surplus *at the margin*—the difference between its surplus conditional on investing and its surplus conditional on not investing. Both surpluses rise the stronger are the first party's rights, but the margin between the two may increase or decrease. It turns out that the ranking of regimes is non-monotonic in the strength of property rights.

Since the model admits a rich set of alternative rights regimes, an obvious question is whether there are policies that can induce first-best equilibria in all cases. We construct a mechanism that does so using only the information courts would need to enforce standard contracts, and we discuss its practical applicability. We then derive a new type of damages regime that can also induce the first best in all cases.

To the best of our knowledge, ours is the first analysis of torts and social harm in an incomplete-contracting framework.[2] There are a number of recent papers in the context of incomplete contracts and the theory of the firm that show, as do we, that welfare may be reduced if property rights are granted to the investing party. De Meza and Lockwood (1998) show that GHM's conclusions can be reversed by changing the underlying bargaining game so that the threat points involve "outside" rather than "inside" options. Though our bargaining game superficially resembles De Meza and Lockwood's in that parties can pursue outside options in the event bargaining breaks down, our setup is actually closer to GHM's since outside options are never binding in equilibrium. The difference between our setup and GHM's is that the first party's investment may lead to a negative externality between it and the second party in our setup, whereas investment always has a neutral or positive effect on the other party in GHM's. Thus, granting rights to the investing party may lead to overinvestment, which never occurs in GHM.

The insight that granting property rights to the investing party may lead to overinvestment has been applied to various aspects of the internal organization of firms including transfer-pricing schemes among divisions (Holmström and Tirole 1990), exclusive-dealing contracts (Segal and Whinston 1998), and asset access and ownership (Rajan and Zingales 1998). There are three essential differences between our work and theirs. First, our underlying application is social harm and torts rather than the theory of the firm. Second, the related incomplete-contracts literature assumes that players set optimal rights regimes ex ante in private negotiations. Ex ante anonymity prevents such negotiations in our setup; our focus is instead on optimal government policy—and hence the application to torts rather than contracts. Third, we analyze a broad range of multi-dimensional rights allocations. One dimension we analyze, exclusion versus non-exclusion, is similar to exclusivity in Holmström and Tirole (1990) and Segal and Whinston (1998) and asset

[2]Previous work, including Rob (1989), Mailath and Postlewaite (1990), and Neeman (1999), analyzed the nuisance problem in the context of private information and complete contracting. In contrast, our model involves symmetric information and incomplete contracting. This literature's central focus (the design of optimal contracts between private parties) differs from ours (the imposition of property-rights regimes on private parties by an external authority); the source of the underlying the underlying inefficiency in this literature (suboptimal externality level and/or suboptimal investment decision by the second mover) also differs from ours (suboptimal date-0 investment decision by the first mover).

ownership in Rajan and Zingales (1998). We analyze a large number of other dimensions as well, including owner versus investor rights, damages versus injunctions, and first versus second-party rights, as well a providing a complete ordering of these regimes.[3,4]

2 Model

2.1 Setup

We model a situation where at different times, two players become aware of opportunities to purchase and invest in plots of land in some general location. Figure 1 is a schematic diagram of the model's timing. There are two dates, 0 and 1. At the beginning of date 0, the court chooses a property-rights regime, which becomes common knowledge. Party A then becomes aware of an opportunity to make an investment that is specific to a plot of land it can purchase on a competitive market. A also decides whether to sink this locational investment immediately or to delay the decision until date 1. Immediate investment costs $c_0 \geq 0$ and has the potential to generate flow returns at both date 0 and date 1, $\alpha \geq 0$ and $a(e)$, respectively, where e is an externality level discussed below. We allow for the possibility that A invests at date 0, paying c_0 and earning α, but then exits at date 1 before $a(e)$ is realized. (This might be a rational strategy, for example, if $a(e) < 0$.) If investment is delayed and then made at date 1, the cost is $c_1 \geq 0$ and the flow return $a(e)$ obtains at date 1, where all payoffs are in date-0 present value terms. Formally, $\ell_0^A = 1$ if A invests immediately and $\ell_0^A = 0$ if A delays; $\ell_1^A = 1$ if A is present in the market at date 1 and $\ell_1^A = 0$ if A is not.[5]

[3] Besides our paper, only Rajan and Zingales systematically analyze the welfare effects of moving from the traditionally-studied "blanket" rights (e.g., exclusive dealing, ownership) to more general regimes involving multi-dimensional rights. Rajan and Zingales allow for asset access as well as ownership. We consider regimes with four dimensions, each dimension having at least two possibilities, leading to at least $2^4 = 16$ possible rights regimes.

[4] An analogy can be drawn between our work and Bergstrom's (1989) analysis of Becker's (1974) "Rotten Kid Theorem." The "Rotten Kid Theorem" states that a selfish child in a family with a benevolent head will act in the family's best interest, similar to the Coase Theorem's statement that a selfish polluter's choosing the socially-optimal pollution level. Bergstrom's main result—the "Rotten Kid Theorem" only holds under restrictive conditions—can be easily understood within our framework: the rotten kid's actions can be interpreted as non-contractible ex ante investments; as such they will be chosen inefficiently in general, to maximize the kid's share of the family's surplus rather than the family's surplus itself.

[5] The full range of possibilities for location are open to A: it can invest immediately and remain in the market at date 1 ($\ell_0^A = \ell_1^A = 1$), invest immediately and exit at date 1 ($\ell_0^A = 1$, $\ell_1^A = 0$), delay and invest at date 1 ($\ell_0^A = 0$,

At the beginning of date 1, another party B becomes aware of an opportunity to invest in a location near A.[6] We assume *ex ante anonymity*: A is unaware of B's identity, and is thus prevented from contracting with B, at date 0.[7] However, A subsequently learns B's identity at date 1, and the two players bargain subject to the property rights that the court allocated at date 0. B can choose to sink a locational investment there ($\ell_1^A = 1$) or elsewhere ($\ell_1^A = 0$). We assume that a negative externality $e \in [0; \bar{e}]$ is generated between the parties if and only if they end up locating in the same general area (i.e., if and only if $\ell_1^A = \ell_1^B = 1$). For example, consider a factory that has moved to a certain location. If a laundry moves nearby, then an externality is created in that the pollution impregnates the clothing. If the laundry does not move close to the plant, then this externality is not created. The externality affects A's pre-bargaining payoff according to the function $a(e)$ and B's according to $b(e)$.[8] The assumption that e is a negative externality is captured as follows. Define $e^A = \arg\max a(e)$, and $e^B = \arg\max b(e)$. If A emits the externality (implying that B is harmed), then we assume $e^A > 0$, and $e^B = 0$; i.e, A's pre-bargaining optimum involves a positive level of the externality, whereas B's pre-bargaining optimum involves the lowest level possible (where the externality level in the "state of nature" with no party operating has been normalized to zero). Conversely, if B emits the externality, then we assume $e^A = 0$ and $e^B > 0$. To cover all possible cases, we make no restrictions on which party emits the externality.

The functions $a(e)$ and $b(e)$ can be regarded as payoffs net of what the parties could earn in the alternative location or, equivalently, can be regarded as gross payoffs with the return from the alternative location normalized to zero. Under either interpretation, it is important to allow

$\ell_1^A = 1$), or never invest ($\ell_0^A = \ell_1^A = 0$).

[6] Formally, B is chosen from large set of identical players B. The assumption of identical players in B serves to simplify the analysis and is analogous to the assumption made in the literature on incomplete contracts (e.g. Grossman and Hart 1986) that players have identical payoff functions in each of a number of different states of the world.

[7] One way to justify ex ante anonymity is to suppose that there is a discrete cost of contracting with each agent in B. If the surplus A earns in the game is bounded, ex ante contracting will be prohibitively expensive if the number of elements in B is large enough. Though discrete contracting costs have been criticized in the literature when they have been applied on a per-clause basis. (see Dye 1985 and the criticism by Hart 1987), in our case the discrete cost is incurred in contracting with separate individuals rather than clauses. Another way to justify ex ante anonymity is to suppose that A has to make its decision before the agents in B have incorporated, and incorporation is necessary for an agent to sign a valid contract.

[8] B's investment cost is incorporated in $b(e)$. A's is broken out separately since A can influence the cost by investing at date 0 or delaying.

for the possibility of negative values of $a(e)$ and $b(e)$. For conciseness, let $a^J \equiv a(e^J)$ and $b^J \equiv b(e^J)$ for $J = A, B$. It will prove useful to define joint-surplus function $s(e) \equiv a(e) + b(e)$. The joint-surplus maximizing externality level then is $e^* = \arg\max_e s(e)$. For conciseness, let $a^* \equiv a(e^*)$, $b^* \equiv b(e^*)$, and $s^* \equiv s(e^*)$.

The variables that are set in date-1 bargaining include A's and B's locational decisions, respectively ℓ_1^A and ℓ_1^B, and the externality, e. A's date-0 location decision ℓ_0^A affects the bargaining game by affecting the cost of choosing different values for ℓ_1^A. If $\ell_0^A = 1$, A can remain in the location at no additional cost (beyond the sunk cost c_0); if $\ell_0^A = 0$, A needs to expend c_1 to enter. After bargaining, the parties' payoffs are realized, and the game ends.

To focus on the effect of ex ante anonymity, we assume that date-1 bargaining is frictionless, always yielding the ex post efficient surplus (that is, the efficient surplus conditional on the investments sunk at date 0). Therefore, e, ℓ_1^A, and ℓ_1^B will always be set at their ex post efficient values; the only welfare-relevant decision that is made is A's date-0 invest-or-delay decision ℓ_0^A. This means that the efficiency of a particular rights regime is fully determined by the equilibrium value of ℓ_0^A.[9]

For concreteness, we adopt the form of Nash bargaining in which the default payoffs are parties' surpluses in the event bargaining breaks down.[10] Let U_1^I and U_1^D be A's date-1 continuation payoffs. We will maintain the notational convention that superscript I indicates the value of a variable conditional on $\ell_0^A = 1$ (i.e., conditional on A's having invested immediately) and superscript D conditional on $\ell_0^A = 0$ (i.e., conditional on A's having delayed investing). Our Nash bargaining assumption implies

$$U_1^I = d_A^I + \gamma_A(W_1^I - d_A^I - d_B^I) \tag{1}$$

$$U_1^D = d_A^D + \gamma_A(W_1^D - d_A^D - d_B^D). \tag{2}$$

[9] The "ex ante non-contractible, ex post contractible" structure of our analysis is standard in incomplete-contracting models.

[10] This is the second variant of Nash bargaining studied by Binmore, Rubinstein, and Wolinsky (1986), who show it is the limit of a subgame-perfect equilibrium of an alternating-offers bargaining game with an exogenous probability of a breakdown in bargaining as this probability approaches zero. The results are qualitatively similar using the first variant of Nash bargaining from Binmore, Rubinstein, and Wolinsky (1986), in which the default payoffs are the flows earned during the bargaining process, as long as parties are free to opt out of the bargaining process and pursue their outside options. Calculations are available from the authors upon request.

Conditional on $\ell_0^A = 1$, d_J^I is the default payoff (the payoff that results if bargaining breaks down) of party $J = A; B$ and W_1^I is the maximum date-1 continuation social surplus; d_J^D and W_1^D are their analogues conditioned on $\ell_0^A = 0$. A obtains share γ_A of the gains from successful bargaining and B gains share $\gamma_B = 1 - \gamma_A$.

2.2 A's Investment Decision

Let U_0^I denote A's date-0 continuation payoff conditional on $\ell_1^A = 1$ and U_0^D conditional on $\ell_0^A = 0$. If $\ell_0^A = 1$, A's date-0 continuation payoff is the sum of the date-0 flow $\alpha - c_0$ and the date-1 flow U_1^I, implying $U_0^I = \alpha - c_0 + U_1^I$.[11] If A delays investment, it obtains no date-0 flow payoff, so U_0^D simply equals the date-1 flow U_1^D. Using this and equations (1) and (2), we have

$$\Delta U_0 = \alpha - c_0 + \Delta d_A + \gamma_A(\Delta W_1 - \Delta d_A - \Delta d_B) \quad (3)$$

where Δ indicates the marginal effect of A's investing on a variable's value: i.e., $\Delta U_0 \equiv U_0^I - U_0^D$; $\Delta d_J \equiv d_J^I - d_J^D$ for $J = A; B$; and $\Delta W_1 \equiv W_1^I - W_1^D$. The sign of the expression in (3) determines A's privately-optimal decision rule regarding date-0 investment: A invests immediately if $\Delta U_0 > 0$ and delays if $\Delta U_0 < 0$.

The efficiency of various property rights regimes will depend crucially on whether A's privately-optimal investment rule matches the socially-optimal rule. Let W_0^I denote the maximum date-0 continuation social surplus conditional on $\ell_0^A = 1$ and W_0^D conditional on $\ell_0^A = 0$. If $\ell_0^A = 1$, the maximum date-0 continuation surplus is the sum of the date-0 flow $\alpha - c_0$ and the date-1 flow W_1^I; i.e., $W_0^I = \alpha - c_0 + W_1^I$. If $\ell_0^A = 0$, there is no social surplus realized at date 0; so $W_0^D = W_1^D$. Letting $\Delta W_0 \equiv W_0^I - W_0^D$, we have

$$\Delta W_0 = \alpha - c_0 + \Delta W_1. \quad (4)$$

The socially-optimal rule, therefore, is for A to invest immediately if $\Delta W_0 > 0$ and delay if $\Delta W_0 < 0$.

It can be seen by manipulating (3) and (4) that the gap between A's privately-optimal invest-

[11] Since all payoffs are expressed as present discounted values, they can simply be added.

ment incentives and the socially-optimal ones is given by

$$G \equiv -[\Delta d_B + \gamma_B(\Delta W_1 - \Delta d_A - \Delta d_B)]. \tag{5}$$

We have the following proposition:

Proposition 1 (Efficiency of A's Investment) *If* $G > 0$ *(respectively,* $G < 0$*), then equilibrium involves weak overinvestment (underinvestment), and there exists* $(\alpha, c_0) \in \mathbf{R}^2_+$ *such that overinvestment (underinvestment) is strict. As* $|G|$ *increases, the set of parameters* $(\alpha, c_0) \in \mathbf{R}^2_+$ *for which investment is inefficient strictly grows. A's date-0 investment is socially optimal for all* $(\alpha, c_0) \in \mathbf{R}^2_+$ *if and only if* $G = 0$*. Consequently, investment is socially optimal for all* $(\alpha, c_0) \in \mathbf{R}^2_+$ *and for* γ_A *in a nontrivial subinterval of* $(0, 1)$ *if and only if* $\Delta d_A = \Delta W_1$ *and* $\Delta d_B = 0$*.*

The proofs of Proposition 1 and subsequent propositions are in Appendix A. The results in Proposition 1 are intuitive. From (5), it can be seen that G equals the reduction in B's equilibrium surplus caused by A's ex ante investment, including the reduction in B's default payoff and the reduction in its share of the gains from successful bargaining. Investment incentives are excessive when $G > 0$ and inadequate when $G < 0$. If $G = 0$, then private and social incentives coincide, and investment is efficient. The last statement in the proposition gives necessary and sufficient conditions for the equilibrium to be efficient for all feasible values of α and c_0.[12] It is clear the conditions are sufficient: substituting them in (5) implies $G = 0$ and, by an earlier statement in the proposition, that investment is efficient. The conditions are necessary since, if they do not hold, we can produce a non-zero value of G by varying γ_A in the nontrivial subinterval.

2.3 Property-Rights Regimes

Social welfare depends on the property-rights regime since the regime affects the default payoffs in the date-1 bargaining game, which in turn affect the bargaining outcome, which in turn affects A's ex ante investment decision. Since property-rights regimes can differ in a number of dimensions, a rich set of alternative regimes is possible.[13]

[12] Any $(\alpha, c_0) \in \mathbf{R}^2_+$ is feasible. We focus on α and c_0 since these are date-0 variables, while G depends only on date-1 variables.

[13] Implicit in the discussion below is the fact that the rights regimes we specify have four dimensions: first vs. second mover, owner vs. investor, exclusion vs. non-exclusion, injunction vs. damages. Taking different

Our benchmark rights regimes give the holder an injunctive right to set the externality level, e. We suppose that the court can unambiguously identify A as the first mover and B as the second mover[14] and can allocate rights on the basis of the timing of moves.[15] *FBR* denotes the regime in which benchmark rights are given to the first mover, meaning that A has the right to set e. *SBR* is the second-party benchmark rights regime, defined analogously. A summary description of *FBR*, *SBR*, and the other regimes presented below is contained in Table 1. Comparing *FBR* and *SBR* (or indeed any of the variants of first-party regimes below to its second-party counterpart) will allow us to assess the merits of the "coming to the nuisance" doctrine, the policy of granting property rights to the first mover, a policy which has had some support in the legal tradition.

The benchmark regimes allocate property rights based only on the timing of ownership. An alternative is to require the potential rights holder (the party that would have obtained rights under an owner-rights regime) to make property-improving investments in order to maintain its rights; if the potential rights holder merely owns unimproved land, the rights go to the other party.[16] We call this alternative *investor rights* (as distinct from *owner rights* embodied in the benchmark). *FIR* denotes the regime in which investor rights are given to the first mover. Under *FIR* A can set e in *FIR* if and only if $\ell^A_1 = 1$; otherwise the right devolves to B. *SIR* is the second-party investor rights regime, defined analogously. As discussed in Section 3.6, there are several motives for studying investor rights. First, this regime has the intuitively appealing feature of preventing a party which has no bona fide interest in a location from affecting another party's operation. Second, the very nature of some applications may transform what the court intends to be an owner-rights regime into an investor-rights regime.

combinations produces $2^4 = 16$ different regimes (actually a continuum of different regimes can be produced by choosing different specifications for the damage rule). The subset of regimes we analyze will allow us to perform the comparative-statics exercise of changing the benchmark one dimension at a time.

[14] This assumption holds if the court can verify the timing of parties' land purchases and if A must buy the land on which it will operate at date 0 or lose the opportunity forever (e.g., because another party acquires the land, makes large sunk investments, and earns a return high enough to deter A's later purchase). This assumption also holds if the court can verify the date at which parties become aware of their investment opportunities.

[15] This assumption rules out the case in which A remains inactive until B arrives in an attempt to gain rights allocated to the second mover, possibly leading to a war of attrition between A and B to see who obtains the rights. Such a war of attrition would generate an outcome even less efficient that the one derived below. Thus, our central result on the inefficiency of the standard property-rights allocations would still hold. The assumption limits the bifurcation of cases which we analyze.

[16] Note first that there is no ambiguity about the level of investment needed to have a bona fide operation since it is a discrete decision. Note second that the court needs additional information to implement an investor-rights regime, information which may be impracticable to obtain in some cases.

Rights can cover more than just the externality level. The court may also assign the right to exclude the other party from the location entirely, called *exclusion rights* (as distinct from the *non-exclusion rights* embodied in the benchmark). Exclusion rights arise naturally if one party can buy all the land over which the externality extends or if one party obtains a covenant restricting the use of neighboring land. *FER* denotes the regime in which exclusion rights are given to the first mover, meaning that A has the power to set e and to require B not to locate in the area (formally, requiring $\ell_1^B = 0$). *SER* is the second-party exclusion rights regime, defined analogously.

The benchmark regimes involve *injunctive rights*, the power to set the externality at whatever level the holder chooses. The alternative traditionally studied in the law-and-economics literature is *damage rights*: a damage-rights regime forces the party that chooses the externality level to compensate the rights holder for harm. For example, if a laundry holds injunctive rights over air quality, it can force a factory not to pollute. If the laundry holds damage rights, the factory is free to pollute but must pay the laundry for the harm caused by its pollution.[17,18] *FDR* denotes the regime in which the first mover is allocated damage rights. There are a number of ways to formulate a damages regime; we adopt the most commonly-studied one, referred to as *perfect expectation damages*. This involves B's choosing e and paying A the difference between a^A (A's surplus in its private optimum) and $a(e)$ (A's surplus given the externality level e chosen by B).[19] *SDR* is the second-party damage rights regime, defined analogously.

Table 2 lists parties' default payoffs induced by each of the four basic rights regimes conditional on $\ell_0^A = 1$ and $\ell_0^A = 0$, respectively. (The last row of the table, included for reference, will be discussed in Section 5.) We use $\lceil \cdot \rceil$ to denote the maximum operator and $\lfloor \cdot \rfloor$ to denote the minimum operator; i.e., $\lceil x_1, \ldots, x_n \rceil \equiv \max\{x_1, \ldots, x_n\}$ and $\lfloor x_1, \ldots, x_n \rfloor \equiv \min\{x_1, \ldots, x_n\}$. The reader is referred to Appendix B for a derivation of the default payoffs in Table 2.

---

17 A damage regime requires more verifiable information on the part of the court than an injunctive regime, including the rights-holder's actual surplus and its surplus in the counterfactual case where the externality is set at its private optimum. The information requirement may be so great that it is impossible for the court to implement a damages regime.

18 Damages can be based on many forms of harm besides that stemming from the externality: a party may be harmed if it is excluded from a location or if other rights are exercised over it.

19 To best capture how damage regimes work in practice, we have implicitly specified *FDR* as an investor-rights rather than an owner-rights regime, implying that A has to have an bona fide operation on the land that can be harmed by B in order to collect damages $a^A - a(e)$.

3 Efficiency of Rights Regimes

3.1 First Best

Let W_0 be the first-best level of social welfare. Using our previous notation, $W_0 = \lceil W_0^I, W_0^D \rceil = \lceil \alpha - c_0 + W_1^I, W_1^D \rceil$. Both W_1^I or W_1^D can involve three sorts of outcomes: A's locating alone, A and B's locating together, or B's locating alone. Hence, $W_1^I = \lceil a^A - c_1, s^* - c_1, b^B \rceil$ and $W_1^D = \lceil a^A, s^*, b^B \rceil$. W_1^I and W_1^D only differ in that A's investment cost is sunk at date 0 if $\ell_0^A = 1$, so it does not enter the expression for date-1 flow surplus W_1^I; whereas A's investment cost is not sunk if $\ell_0^A = 0$, so c_1 appears in the terms in W_1^D which require A to have invested in the location, namely $a^A - c_1$ and $s^* - c_1$. To rule out the trivial case in which it is optimal for neither party to locate in the area under consideration, we assume $W_1^I > 0$ and $W_1^D > 0$.[20] Substituting,

$$W_0 = \lceil \alpha - c_0 + a^A, \alpha - c_0 + s^*, \alpha - c_0 + b^B, a^A - c_1, s^* - c_1, b^B \rceil. \tag{6}$$

Given the weak restrictions placed on parameters α, c_0, a^A, s^*, b^B, and c_1, it is straightforward to see that any of the six outcomes embedded in (6) can be the first best. Consider the first term, $\alpha - c_0 + a^A$. This is the payoff if A invests immediately, and is alone at the location. The second term is the maximum payoff from immediate investment and joint location. The third term is the payoff from immediate investment by A at date 0 and withdrawal of the investment and sole location by B at date 1. The fourth term, $a^A - c_1$, is delayed investment and sole location by A at date 1, the fifth is delayed investment and joint location at date 1, and the final payoff b^B is delayed investment and sole location by B at date 1.

3.2 Ranking Theorem

One of our key results is the ranking all of the eight standard regimes in terms of the social welfare each induces in equilibrium. If equilibrium under rights regime X is at least as efficient as under Y for all parameters, and for each $\gamma_A \in (0, 1)$ there exist feasible values of the other

[20] If $W_1^I < 0$ for example, the externality problem is trivially solved by having the parties locate in remote areas.

parameters such that equilibrium under X is strictly more efficient, then we write $X \succ Y$. That is, a social planner would prefer X to Y from an ex ante perspective if all cases are in the support of the planner's prior distribution. The definition of $\succ$ ensures that our ranking results do not depend on a particular distribution of bargaining power. If equilibrium under X is equally efficient as under Y for all feasible parameters, we write $X \sim Y$. That is, a social planner would be indifferent between the two regimes. In Proposition 2, the notation *1ST* denotes the first-best regime.

Proposition 2 (Ranking of Rights Regimes) *If* $W_0 = \alpha - c_0 + W_1^I$, *then*

$$\mathit{1ST} \sim \mathit{FBR} \sim \mathit{FER} \sim \mathit{FDR} \sim \mathit{FIR} \succ \mathit{SDR} \succ \mathit{SIR} \succ \mathit{SBR} \succ \mathit{SER}. \tag{7}$$

If $W_0 = \lceil a^A - c_1, s^* - c_1 \rceil$, *then*

$$\mathit{1ST} \sim \mathit{FBR} \sim \mathit{FER} \sim \mathit{FDR} \sim \mathit{FIR} \sim \mathit{SDR} \sim \mathit{SIR} \sim \mathit{SBR} \sim \mathit{SER}. \tag{8}$$

If $W_0 = b^B$, *then*

$$\mathit{1ST} \sim \mathit{SDR} \sim \mathit{SIR} \sim \mathit{SBR} \sim \mathit{SER} \succ \mathit{FBR} \sim \mathit{FER} \succ \mathit{FDR} \succ \mathit{FIR}. \tag{9}$$

If the parameters are such that A invests immediately at date 0 in the first best (i.e., if $W_0 = \alpha - c_0 + W_1^I$), all four first-party rights regimes *FBR*, *FER*, *FIR*, and *FDR* are efficient, while the second-party regimes *SBR*, *SER*, *SIR*, and *SDR* are all inefficient in at least some cases. (Indeed, for all γ_A, there exist cases in which these second-party regimes are inefficient.) The first-party regimes provide A with adequate incentives to choose β_0^A optimally; the second-party regimes lead to underinvestment. This set of results is in line with the intuition from Grossman and Hart (1986) and Hart and Moore (1990) (GHM) that granting an investing party stronger rights ameliorates the hold-up problem, thus leading to an improvement in investment incentives and an increase in welfare.

On the other hand, if the parameters are such that A should not invest in either dates 0 or 1 (i.e., if $W_0 = b^B$), all four second-party regimes are efficient, while all four first-party regimes are inefficient in at least some cases. This set of results runs counter to GHM's idea that the investing party should be protected with strong rights. The reason for the discrepancy is that investment only generates positive externalities in GHM's model of the firm, so there is no over-investment problem, only underinvestment. Here, by contrast, investment may generate negative externalities—indeed, this is the essence of the problem of social harm—so overinvestment is possible. The first-party regimes are inefficient precisely because they can lead to overinvestment, with A choosing $\ell_0^A = 1$ rather than $\ell_0^A = 0$ (the efficient value when $W_0 = b^B$).

In sum, the proposition shows that the allocation of property rights has real effects on social welfare in equilibrium. None of the eight standard rights regimes we have so far considered is efficient in all cases. Within any given class of regime (benchmark rights, investor rights, exclusion rights, damage rights), the first-party version sometimes dominates, and sometimes is dominated by, the second-party version. Our results therefore provide only limited support for the "coming to the nuisance" doctrine, a doctrine which allocates rights to the first mover even if it is the generator of the externality on the grounds that the second mover could have taken the externality into account before it moved, a doctrine which has been adopted by the courts in deciding a large number of cases.[21] True, this doctrine can protect the first mover's investment from hold-up, but it may induce the first mover to invest excessively.

In view of Proposition 1, to prove there is weak overinvestment with the first-party regimes *FBR*, *FER*, *FIR*, and *FDR*, one need only prove the efficiency gap G is non-negative for all $\gamma_A \in (0, 1)$; to prove there is weak underinvestment with the second-party regimes *SBR*, *SER*, *SIR*, and *SDR*, one need only prove $G \le 0$ for all $\gamma_A \in (0, 1)$. (One can further prove that investment is strictly inefficient in some cases by showing that the preceding inequalities involving G are strict for some parameters.)[22] To derive some intuition for Proposition 1, recall that G is equivalent to the reduction in B's equilibrium surplus caused by A's date-0 investment. It turns out that A's date-0 investment weakly reduces B's equilibrium surplus if A has the property rights, implying there is weak overinvestment. On the other hand, A's date-0 investment weakly increases B's equilibrium surplus if B has the property rights, implying there is weak underinvestment.

[21] For example, the concurring appellate opinion in Krueger v. Mitchell, 332 N.W.2d 733 (Wis. 1983), noted that it was the plaintiff who located near the defendant (an airport whose overflights impaired the operation of the plaintiff's lawn-and-garden store); and thus the jury instructions by the trial judge ruling out a "coming to the nuisance" defense were in error. See also the cases cited in Keeton, *et al.* (1984): McCarty v. Natural Carbonic Gas Co., 189 N.Y. 40, 81 N.E. 549 (1907); Peck v. Newburgh Light, Heat & Power Co., 132 App. Div. 82, 116 N.Y.S. 433 (1909); Staton v. Atlantic Coast Line Railroad, 147 N.C. 428, 61 S.E. 455, 17 LRA (N.S.) 149 (1908); Dill v. Excel Packing Co., 183 Kan. 513, 331 P.2d 539 (1958).

[22] In a model of complete contracts and asymmetric information, Neeman (1999) finds that a polluting firm overinvests if it has property rights and underinvests if victims have property rights. His result is due to a free-rider problem among victims, which hinders truthful revelation of their private harm.

It is clear that A's date-0 investment should not harm B if B has property rights: B is fully protected from hold up; if anything, B's surplus may rise since it may be able to extract a share of A's investment-cost savings (A can remain in the date-1 market without paying c_1 if it invested at date 0). It is less clear why A's date-0 investment may harm B when A has property rights. Rearranging the expression for the efficiency gap G in (5) slightly, we have

$$G = -\gamma_A \Delta d_B + \gamma_B(\Delta d_A - \Delta W_1). \qquad (10)$$

It follows that $G \geq 0$ for all $\gamma_A \in (0,1)$ if and only if two conditions hold: $\Delta d_B \leq 0$ and $\Delta d_A \geq \Delta W_1$. Intuitively, it must be the case that A's date-0 investment weakly decreases B's default payoff (reflected in the condition $\Delta d_B \leq 0$) and increases A's default payoff weakly more than it increases social surplus (reflected in the condition $\Delta d_A \geq \Delta W_1$).

We will separately argue that both conditions hold when A has property rights. With the first-party regimes, Table 2 shows that A's date-0 investment either has no effect on d_B (the case with *FBR* and *FER* since A controls the property rights whether or not it invests) or reduces d_B (the case with *FIR* and *FDR* since investment allows A to wrest the rights away from B). Hence $\Delta d_B \leq 0$ when A has property rights.

To prove $\Delta d_A \geq \Delta W_1$ when A has property rights, note the terms Δd_A and ΔW_1 both measure the date-1 benefit of A's date-0 investment—Δd_A measuring the increase in A's payoff when bargaining breaks down, ΔW_1 the increase in the joint payoff of A and B when bargaining is successful. The date-1 benefit of A's date-0 investment is that A can remain in the market without having to expend c_1. Given A has property rights, this benefit is realized more often if bargaining breaks down than if bargaining is successful: successful bargaining sometimes results in A's being compensated to leave the market at date 1 (in which case no date-1 benefit to date-0 investment is realized) though A would choose to stay in the market if bargaining were to break down and it did not receive compensation for leaving.

3.3 Necessary Conditions for the Coase Theorem

In this section, we analyze in more depth the relationship between our results and the Coase Theorem. To avoid confusion about semantic issues, we formalize the Coase Theorem in two ways. The Weak Coase Theorem states that, if bargaining over *all* choice variables is efficient, then the first best will be attained in equilibrium regardless of the allocation of property rights. The Strong Coase Theorem states that, if bargaining over *ex post* choice variables is efficient, then the first best will be attained in equilibrium regardless of the allocation of property rights. The two differ in that only a subset of the variables are subject to efficient bargaining in the Strong Coase Theorem. Proposition 2 does not contradict the Weak Coase Theorem. The assumption of ex ante anonymity implies that β_0^A is not subject to efficient bargaining, so the conditions in the antecedent of the Weak Coase Theorem are not met in our model.

Proposition 2 implies that the Strong Coase Theorem is not generally true. The inability to bargain over β_0^A due to ex ante anonymity can be regarded as a transaction cost. A natural question is whether there are *any* cases in which the Strong Coase Theorem holds despite this transaction cost.

Proposition 3 *The first best is obtained in equilibrium under any of the rights regimes considered (FBR, SBR, FIR, SIR, FER, SER, FDR, SDR) if* $W_0 = \lceil a^A - c_1; s^* - c_1 \rceil$ *or if* $\alpha > c_0$.

The condition $W_0 = \lceil a^A - c_1; s^* - c_1 \rceil$ implies $\beta_0^A = 0$ in the first best. The second-party regimes must be efficient since they lead to weakly less investment than in the first best; there remains the possibility that the first-party regimes lead to overinvestment. Since the efficiency gap G is zero if $W_0 = \lceil a^A - c_1; s^* - c_1 \rceil$, the first-party regimes in fact do not lead to overinvestment.

Suppose $W_0 > \lceil a^A - c_1; s^* - c_1 \rceil$ but that $\alpha > c_0$. Then $W_0 = \alpha - c_0 + W_1^I$, implying $\beta_0^A = 1$ in the first best. The first-party regimes must be efficient since they lead to weakly more investment than in the first best; there remains the possibility that the second-party regimes lead to underinvestment. A has an incentive to invest at date 0 even under the second-party regimes. Investing (weakly) increases A's default payoff since A can operate at date-0 without having to pay c_1. This helps A to gain more surplus in date-1 bargaining, a strategic benefit of date-0 investment. The only cost of date-0 investment, c_0, is outweighed by the date-0 flow benefit α.

3.4 Covenants and Land Ownership

Exclusion rights allow the holder to keep the other party out of the general location in which an externality would otherwise have been caused. Exclusion rights can be obtained either through land purchase or through covenants. For example, a factory may buy all the land in a given radius around its plant and refuse to allow laundries to trespass on its property. Alternatively, the factory may negotiate with neighboring landowners to have covenants placed on their lots restricting them and future owners from operating laundries. The two means of obtaining an exclusion right are clearly related, the difference being that the party obtains a whole bundle of rights with land purchase, one of which happens to be the right to exclude others, whereas a covenant can be narrowly designed to provide only the right to exclude certain operations.

For concreteness, in the subsequent discussion we will speak of obtaining exclusion rights through *concentrated ownership*—i.e., one party purchases all the land on which an externality could be caused—though covenants could serve as well. We will refer to the case in which the land is divided among several owners as *dispersed ownership*. As discussed in the Introduction, the propositions that (a) concentrated ownership is superior to dispersed ownership and (b) that it can achieve the first best have taken on the status of conventional wisdom. The conventional wisdom is incorrect on both points, however, as shown in Proposition 2. Recall that the exclusion-rights regime *FER* encompasses concentrated ownership and note that *FBR* is the benchmark (involving non-exclusion rights) regime, which encompasses dispersed ownership. From the ranking theorem, we see that concentrated ownership (*FER*) is no better than dispersed ownership (*FBR*). Among second-party regimes the case for concentrated ownership is even weaker: *SER* is dominated by all the others in terms of social welfare. It is also clear from the proposition that both *FER* and *SER* are inefficient in some cases.

What is the intuition behind the conventional wisdom that concentrated ownership is superior to dispersed ownership, and where does the intuition fail? Suppose A is a factory operating on one lot but owns a number of nearby fallow lots which it intends to sell to other users, say laundries. The intuition is that the expected price of land the factory intends to sell to the laundries falls as the externality which is generated by the factory's ex ante investments becomes more severe. The factory effectively internalizes the externality through the land price. It turns out that the intuition is valid if the factory owner is assumed to have all the bargaining power in negotiations with the laundries over the sale of the land (equivalent to assuming $\circ_A = 1$ in our notation.) Then, indeed, concentrated ownership leads to the first best.[23] *FER* is not special in this regard,

[23]This can be seen formally by computing the efficiency gap G for the *FER* case after substituting $\circ_A = 1$ and

however; with *FBR*, and in fact all the second-party regimes *SER*, *SBR*, *SIR*, and *SDR*, the first best is always obtained for $\gamma_A = 1$. The intuition fails when the factory has any less than 100 percent of the bargaining power, since then it does not fully internalize the externality through land prices.

In the context of our model, in which bargaining plays such an important role, what should surprise the reader is not that *FER* $\not\succ$ *FBR* but that *FBR* $\not\succ$ *FER*. After all, the problem with first-party regimes is one of overinvestment. Given that *FBR* is a weaker regime than *FER*—weaker in the sense that A earns less surplus with *FBR* than with *FER*—one might expect that *FBR* better mitigates the overinvestment problem. However, it is ΔU_0, the difference between two surpluses, not the level U_0^I on which A's investment decision rests. Though U_0^I is higher with *FER* than with *FBR*, U_0^D is also higher with *FER* by the exact amount so that the difference $\Delta U_0 \equiv U_0^I - U_0^D$ is the same under *FER* and *FBR*.[24]

The comparison of *FER* and *FBR* illustrates the more general point that there is a non-monotonic relationship between the strength of A's rights (measured by surplus *level* U_0^I) and A's incentive to invest (measured relative to the social optimum by $G = \Delta U_0 - \Delta W_0$, an increasing function of the surplus *difference* ΔU_0). Consider Figure 2, which arrays the eight standard rights regimes according to the implied strength of A's rights. For points above the horizontal axis, $G > 0$; and thus there is overinvestment; for points below the horizontal axis, $G < 0$; and thus there is underinvestment. While *FER* is stronger than *FBR*, they are of equal height above the axis and thus involve an equal incidence of overinvestment.

3.5 Injunctions Vs. Damages

Arguably the most influential paper in law and economics, aside from Coase (1960), is Calabresi and Melamud (1972). One of their basic contributions was to compare the efficiency of injunctions and damages (in their terms property and liability rules) under various assumptions about the level of transactions costs. They argue that injunctions dominate damanges when transactions

$\gamma_B = 0$, and noting that $G = 0$.

[24]The welfare equivalence of *FER* and *FBR* should not be overemphasized. In calculations available from the authors, we adopted the alternative form of Nash bargaining from Binmore, Rubinstein, and Wolinsky (1986). With this alternative involving a time cost of delay rather than an exogenous probability of breakdown, we show *FBR* $\succ$ *FER* in some cases.

costs are low since damages require measurement, whereas injunctions simply require enforcement. They argue that damages dominate injunctions when transactions 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 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 A, and asks whether it is better to have A pay damages to B or not. *FBR* corresponds to the injunctive regime in which A sets e and does not need to pay damages to B; *SDR* to the damages regime in which A sets the externality level but must pay damages. According to Proposition 2, if $W_0 = \alpha - c_0 + W_1^I$, then *FBR* $\succ$ *SDR*. That is, despite the presence of transactions costs at date 0, the injunctive regime is preferred. The now familiar explanation for this result is that A's ex ante investment incentives are too low with *SDR*. On the other hand, if $W_0 = b^B$, then the damages regime *SDR* is preferred. (One could similarly perform the comparison between *SBR* and *FDR* and show that *SDR* $\succ$ *FBR* when overinvestment is the chief concern and vice versa when underinvestment is the chief concern.) Our results are another manifestation of the conclusion that first-party rights lead to overinvestment, and second-party rights lead to underinvestment. For a given social optimum, the timing of parties' arrivals matters more than the type of remedy.

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 *FBR* and *FDR* if A is the rights holder or between *SBR* and *SDR* if B is the rights holder. In either case, the damages regime can be considered weaker than the injunctive regime, because in the latter case there is no penalty for the external effect at all. It might be conjectured that the weaker damage right will mitigate overinvestment in the case of first-party regimes, and mitigate underinvestment in the case of second-party regimes, thus dominating the benchmark injunctive-rights regimes. However, as discussed in the previous section and as shown in Figure 2, the relationship between strength of a rights regime and investment incentives is non-monotonic. Among second-party regimes, *SDR* does indeed dominate the benchmark *SBR*.

Among first-party regimes, *FDR* is dominated by the benchmark *FBR*.[25] Again, we do not have clear support for either injunctions or damages.

3.6 Investor Versus Owner Rights

It is often a condition of receiving rights that a party have an established interest in the property rather than simply owning an umimproved lot. For example, the Homestead Act of 1862 required the construction of a house and other improvements to gain rights to a parcel (see Cooter and Ulen (1996, p. 113) for a discussion). In our terms, this type of requirement is what differentiates an investor-rights regime (such as *FIR* and *SIR*) from an owner-rights regime (such as the benchmarks *FBR* and *SBR*). An intuitively appealing feature of investor-rights regimes is that they may deter speculation by parties without a bona fide interest in the area, whose only purpose is to expropriate surplus from productive enterprises. For instance, consider a variant of the factory/laundry example in which the laundry is granted investor rights. This forces the laundry to construct a facility if it is to claim the right to restrict a factory's pollution; if the laundry simply owns an open field, the factory is allowed to pollute at will. It would seem to be efficient to allow the factory to produce freely when its production exerts no negative externality on the laundry's (non-existent) facility.

Since investor rights place an additional requirement for a party to obtain them, they represent a weaker regime for the holder than owner rights. As we have seen, the fact that investor rights is weaker does not guarantee that investor rights dominate owner rights. In fact, investor rights are sometimes dominated by owner rights. While *SIR* dominates *SBR*, *FBR* dominates *FIR*. *FBR* dominates *FIR* because the overinvestment problem is more severe with *FIR*. Under *FIR*, A is able to wrest property rights from B by investing, thus reducing B's default payoff. This reduction in B's default payoff gives A the additional investment incentive.

A second reason for studying investor rights is that the nature of some applications may transform what the court intends to be an owner-rights regime into an investor-rights regime. To see this, consider an example in which the factory is granted an injunctive right over air quality.

[25] *FBR* Â *FDR* since there is more overinvestment with *FDR*. Intuition for this result is similar to the intuition behind *FBR* Â *FIR* (see Section 3.6). The intution is similar because both *FIR* and *FDR* involve investor rather than owner rights (see footnote 19.

The court may specify that that the factory has owner rights; i.e., it has the right to pollute at will regardless of whether it has constructed a facility. In practice, however, the factory may only be able to harm the laundry if it actually builds a facility that emits pollution, not if it simply owns an open field. Thus, even if the court-intended (*de jure*) regime involves owner rights, the operational (*de facto*) regime may involve investor rights. This issue is discussed further in the next section.

3.7 Identity of the Generator

Coase (1960) emphasized the reciprocal nature of externalities: while it is true that a factory can harm a laundry by emitting pollution, it is also true that the laundry can harm the factory by enjoining it not to pollute. According to this line of argument, the terms "generator" and "victim" are not economically meaningful. In this subsection, we show that the identities of the generator and victim indeed have economic meaning: in particular, the relative efficiency of various rights regimes can depend on whether or not the first mover is also the generator of the externality.

All that is required for this result is the additional assumption that the *generator* of the externality needs to invest in order for it to create a non-trivial externality; if it does not invest, it does not operate, and the externality level is the natural level, $e = 0$, which is also the *victim*'s preferred externality. Since the externality level preferred by the victim is the same as the natural level, it does not need to make an additional investment to enforce its injunctive right. For example, suppose the factory is the first to move and suppose the legal regime is *FBR*. While the factory may wish to threaten the laundry with polluted air in order to extract a large payment in negotiations, it cannot simply decree the air be polluted; it must actively pollute the air, an action requiring sufficient investment to build the polluting facility. On the other hand, it is possible in theory erstwhile laundry can ask the court to enjoin the factory's pollution even if it is not a bona fide operation.

Formally, we will consider adding the following assumption to the basic model:

Assumption 1 *A party can only generate* $e > 0$ *if it makes the discrete investment necessary for bona fide operation.*

There are situations in which Assumption 1 need not be true: for example, the factory may not need to build a full-blown plant to harm a laundry; it may only need to burn trash it finds on its property, producing a noxious smoke damaging to the laundry's operation, at very little expense to itself. More generally, a party might be able to generate $e > 0$ at lower investment levels than the discrete investment needed for bona fide operation, but the qualitative results will be unchanged as long as a positive investment level is necessary. Assumption 1 does not change the fact that the externality has a reciprocal nature; what it does is highlight the potential asymmetry between generator and victim: the generator has to invest to harm the victim; the victim can harm the generator without investing.

Under Assumption 1, the *de facto* rights regime may not correspond to the *de jure* regime. In the example from the previous paragraph, the *de jure* regime is *FBR*, ostensibly giving the factory an injunctive right simply if it owns the land. The *de facto* rights regime is *FIR*: the factory's threat to pollute is credible only if investing and operation would be a profitable undertaking in the default. The following proposition is immediate:

Proposition 4 *Suppose Assumption 1 holds and that* A *is the generator. Then the de jure regime under FIR is the same as the de facto regime. The same is true for SBR and SIR. If the de jure regime is FBR, however, the de facto regime is FIR. Suppose* B *is the generator. Then the de jure legal regime under FBR is the same as the de facto regime. The same is true for FIR and SIR. If the de jure regime is SBR, however, the de facto regime is SIR.*

To understand the proposition, if a generator happens to have owner rights *de jure*, *de facto* it will have investor rights. On the other hand, a victim's *de facto* rights are the same as its *de jure* rights. Since it is the *de facto* and not the *de jure* regime that matters for equilibrium, and these may differ, the identity of the generator may indeed matter for efficiency.

This point can be seen more concretely. By Proposition 4, if A is the victim, then *de jure* regimes *FBR*, *FDR*, and *FIR* are also the *de facto* regimes. By Proposition 2, *FBR* Â *FDR* Â *FIR*, so the court would be advised to adopt *FBR* in favor of *FDR*. If A is the generator, then *de jure FBR* is *de facto FIR*, which is dominated by *FDR*. The court would be advised to adopt *FDR* in favor of *FBR*. Putting these facts together, a rule conditioned on the identity of the generator, namely "give A damage rights (*FDR*) if it is a generator and injunctive rights (*FBR*) if it is a victim," would dominate either unconditional rule *FBR* or *FDR*.[26]

[26] Interestingly, similar reasoning does not hold for second-party rights. Since *SIR* dominates *SBR*, the court need not worry that the *de jure* regime it intends is an inferior regime *de facto*.

4 Endogenous Verifiability of Investment

The literature on incomplete contracts often assumes that certain variables are non-verifiable for exogenous reasons. We can construct an example in which verifiability is endogenized. In the example, A is allowed to transform a non-verifiable variable into a verifiable one without any loss of social surplus. Yet A chooses to keep the variable non-verifiable in order to extract more rent from B.

The example involves the following assumption on the parameters:[27]

Assumption 2 $\alpha = 0$, $0 < a^A < c_0 = c_1 < \gamma_B a^A + \gamma_A b^B$, *and* $\lceil a^A, s^* \rceil < b^B$.

Assumption 2 implies $W_0 = b^B$, so that there is no social gain from date-0 investment in equilibrium. Even stronger, Assumption 2 implies that there is no social gain from date-0 investment in any off-equilibrium-path subgame either. To see this, note that in any subgame involving $\theta_1^A = 1$, A's immediate investment involves date-0 flow surplus $\alpha - c_0$, but this is equal to the avoided date-1 investment cost c_1 under Assumption 2; so immediate investment would have no effect on social surplus. In any subgame involving $\theta_1^A = 0$, date-0 investment involves a loss of surplus ($\alpha - c_0$, which is negative under Assumption 2) relative to delaying investment.

A can choose to invest at date 0, in which case its investment is not subject to efficient bargaining with B because of ex ante anonymity. A can choose to delay investment until date 1, in which case its investment would be subject to efficient bargaining, along with θ_1^B and e. In this sense, A can choose to make its investment θ^A verifiable (by delaying) or not (by investing immediately at date 0). The previous paragraph showed that there is no social gain from keeping θ^A non-verifiable. Even so, there exists a rights regime in which A decides to invest at date 0 rather than waiting until investment is verifiable.

Proposition 5 *Suppose Assumption 2 holds. In equilibrium under FIR,* $\theta_0^A = 1$.

If A delays investment until it is verifiable, it obtains nothing in the date-1 negotiations with B. Since *FIR* is an investor-rights regime, A can only threaten to claim its rights in the default outcome if it is a credible investor. But $a^A - c_1 < 0$, so A is not a credible investor. If A

[27] It can be verified that Assumption 2 defines a non-empty set of parameters.

invests at date 0, it becomes a credible investor since the investment decision is sunk. Thus it can credibly claim its rights in the default outcome, allowing it to extract positive surplus from B in date-1 negotiations. In particular, it can be shown that A earns $\gamma_B a^A + \gamma_A b^B$ in its negotiations with B, greater than the net cost of immediate investment $\alpha - c_0$.

It is crucial that the rights regime specified in Proposition 5 is *FIR*. Under the other regimes (*FBR*, *FER*, *FDR*), it can be shown that A does not sink investment at date 0 if there is no social benefit from so doing. If A is the generator according to the definition in Section 3.7, however, we saw a *de jure FBR* regime is *de facto* a *FIR* regime; so endogenous verifiability can be an issue with the benchmark rights regime as well.

5 First-Best Policies

Proposition 2 indicates that none of the eight basic rights regimes studied so far is efficient in all cases. This begs the question of whether there exists *any* policy that always produces the first best. The question is approached in two ways. First, we construct an optimal mechanism that produces the first best in all cases. Second, we find a rights regime that also generates the first best in all cases. Throughout the discussion, we provide assessments of the relative merits of the mechanism and the rights regime.

5.1 Optimal Mechanism

Proposition 6 provides a mechanism that produces the first best for all feasible parameters.[28] The mechanism only requires a minimal amount of information be verifiable: announcements by the parties, the externality e, and transfers between A and B. The court must be able to verify e and transfers between the parties in any event: it must do so simply to enforce basic contracts between A and B that arise from ex post bargaining between them; if such basic contracts were not enforceable, ex post bargaining would not be efficient, contrary to the maintained assumptions.

[28]The use of subgame-perfect implementation in incomplete-contracting models is a topic of current debate. See Maskin and Tirole (forthcoming) and the reply by Hart and Moore (1998).

Proposition 6 *Suppose the court institutes the mechanism in Figure 3. In any subgame perfect equilibrium,* A*'s surplus is* $W_0 - \lceil b^B, 0 \rceil$*,* B*'s surplus is* $\lceil b^B, 0 \rceil$*, and the first best is attained.*

The mechanism in Figure 3 allows A to choose ℓ_0^A freely and then to announce a transfer and an externality level. A's announcement is disciplined by the fact that B can reject A's announcement and unilaterally set the externality level. Effectively, the mechanism creates an institution that gives all the bargaining power to A. A internalizes social surplus fully and so makes the socially-efficient decisions at each stage in the mechanism (and, with the offer to B implicit in its announcement, A induces B to make efficient decisions as well).

Though the mechanism requires minimal information on the part of the court, one drawback is that the court must administer the mechanism along the equilibrium path. In particular, the court must record A's announcements $\tilde{e}$ and $\tilde{T}$ for all externality problems that arise in the economy. If it is costly to record this announcements or otherwise administer the mechanism, the court may prefer a regime that only requires it to intervene out of equilibrium, say when ex post bargaining breaks down. As long as out-of-equilibrium intervention is credible, such a regime could be substantially less costly. We investigate such a rights regime in the next subsection.

5.2 Optimal Rights Regime

The first best can be obtained for all feasible parameters with the rights regime given in the last row of Table 1, *SOR*.[29] As with *SDR*, with *SOR* A still has the option to set e and pay the harm caused to B, $b^B - b(e)$. In addition, *SOR* allows A the option to exclude B entirely. If A excludes B, it must pay for the damages caused by this exclusion, equal to $\lceil b^B, 0 \rceil$ (what B could earn if it entered and the externality were set at e^B).

Proposition 7 *For all feasible parameters, SOR* $\sim$ *1ST.*

The substance of the proof verifies that *SOR* leads to the default payoffs given in the last row of Table 2. Given these default payoffs, it is immediate that the efficiency gap G is zero. Proposition 1 then implies that *SOR* $\sim$ *1ST*. In graphical terms, the proof establishes that the

[29] The "O" in the acronym *SOR* stands for "optimal." In our framework with two choices for each of four dimensions, *SOR* can be categorized as a second-owner-exclusion-damages rights regime.

point corresponding to *SOR* in Figure 2 lies directly on the horizontal axis, meaning that their is neither over- nor underinvestment.

SOR turns out to be most closely related to *FER*, and a comparison of the two regimes highlights why *SOR* is efficient while *FER* is not. Both *FER* and *SOR* allow A to control all relevant choice variables ℓ_0^A, ℓ_1^A, ℓ_1^B, and e. The difference between the regimes is that the damage payment with *SOR* forces A to internalize the effect of its choices on B. A therefore makes the efficient date-0 investment decision. There is no damage payment in *FER*, implying that A's does not internalize B's welfare and thus chooses ℓ_0^A inefficiently in some cases.

A drawback of the rights regime *SOR* relative to the optimal mechanism from Section 5.1 is that, out of equilibrium, *SOR* requires a great deal of information on the part of the court, perhaps a prohibitive amount in some cases. This was true for the standard damage regimes *FDR* and *SDR*, but the problem is more severe here since the court has to compute damages when a party is excluded. In the event that bargaining between A and B breaks down, A excludes B, and B sues for damages, the court would need to verify b^B. Given B has never actually operated, the court's determination of b^B would be highly speculative.

6 Conclusion

Starting with a standard model of externalities, we relaxed the assumption that all variables are contractible. In particular, we adopted the assumption of ex ante anonymity, where one party must make an investment decision before it knows the identity of the other. This simple departure from the standard model enabled a novel analysis of problems of social harm in the presence of contractual incompleteness, leading to a rich set of results, some of which run counter to conventional wisdom in the literature. We showed that first-party property rights (equivalent to a "coming to the nuisance" rule) may lead to overinvestment and may be dominated by second-party property rights. This is contrary to the standard result in the incomplete-contracting literature that rights should always be allocated to the party that makes the non-contractible specific investment. Contrary to conventional wisdom that having a single landowner will solve the problem of social harm, we showed that standard exclusion rights conveyed by land ownership or covenants not only fail to solve the problem of social harm, but may indeed exacerbate it. Contrary to Calabresi and Melamud's (1972) well-known rule that damages are better than injunctions in the presence of transactions costs, we showed the reverse may also be true. Contrary to the notion that—due to the reciprocal nature of the externality problem—the identity of "generator" and "victim" are irrelevant, we demonstrated a case in which social welfare can be improved by conditioning the rights allocation on the identity of the generator.

We constructed a mechanism, and found a rights regime, that both attain the first best in all cases. Both are simple enough to have some prospect of being implementable in practice. However, we noted possible obstacles to implementing these first-best policies in certain situations.

We provided an example in which A keeps its investment non-contractible even though it could choose to wait until investment is contractible without any social loss—indeed there would be a social benefit. A does so to gain a bargaining advantage. If A waits until the investment can be part of a contract, investment is not credible; to be credible, investment must be sunk prior to contracting, when by definition it is non-contractible. The example illustrates the general point that contracts are inherently incomplete any time there is a private cost to making variables contractible: the private cost itself is a primitive, non-contractible variable.

Our model is general in most respects—we make few functional form assumptions—but is stylized in one important respect—investment is a zero-one decision. Given that the results summarized above concern the demonstration of cases (i.e., we demonstrate cases in which one regime dominates another and cases in which the reverse holds), we do not view the discrete investment assumption as critically impairing the generality of our conclusions.

The present paper does not exhaust the applications of our analysis. For example, a pervasive problem with oil drilling is that firms compete for migratory oil in underground reservoirs. The common law "rule of capture" dictates that in order to obtain property rights over oil, it must first be extracted, analogous to *FIR* in our setup. An alternative solution to this problem, recognized since the 1930s, is *unitization*, where the first party owns the reservior and licenses production rights to other drillers, analogous to *FER* in our setup.[30] Our result that *FER* weakly dominates *FIR* lends formal support to unitization as a solution to the common-pool problem. Attention need not be restricted to the nine rights regimes we have considered. Other rights regimes might be important in specific applications; the simple rule for judging the efficiency of a rights regime

[30] See Libecap (1989, p. 93) for a discussion of the common-pool problem and unitization.

provided by Proposition 1 would be a useful tool in such applications. Indeed, attention need not even be restricted to negative externalities generated by neighboring facilities such as factories and laundries. The investments that each party makes can be interpreted much more broadly than simply location. For example, investments in research and development by one company can be affected by the outcomes of related investments by a future company. Suppose a company invests in developing a drug. A second firm, incorporated after the first's investment, develops a substitute that reduces the profitability of the first drug. Our analysis predicts the ways in which different property rights (including patents and more complex rules) will affect the investment decisions of these companies.

Appendix A: Proofs

For brevity, we introduce the operators $\Delta d_A(\cdot)$, $\Delta d_B(\cdot)$, $\beta_0^A(\cdot)$, and $G(\cdot)$ in the appendix to indicate the dependence of the variable on the underlying regime. For example, $\Delta d_A(\textit{FBR})$ equals the value of Δd_A in the *FBR* regime, etc. A series of lemmas is used in the proofs of the propositions.

Lemma A *Let* $x, y, z \in \mathbf{R}$ *with* $y, z \geq 0$. *Then* $\lceil x, y \rceil - \lceil x - z, y \rceil = \lceil \lfloor x - y, z \rfloor, 0 \rceil$.

Proof.

$$\begin{aligned} \lceil x, y \rceil - \lceil x - z, y \rceil &= \begin{cases} z & \text{if } x - y \geq z \\ x - y & \text{if } x - y \in (0, z) \\ 0 & \text{if } x - y \leq 0 \end{cases} \\ &= \lceil \lfloor x - y, z \rfloor, 0 \rceil. \end{aligned}$$

where the three cases in the first line are exhaustive if $y, z \geq 0$. *Q.E.D.*

Lemma B $\lceil a^A, 0 \rceil - \lceil a^A - c_1, 0 \rceil \geq \Delta W_1 \geq \lceil s^* - b^B, 0 \rceil - \lceil s^* - b^B - c_1, 0 \rceil$.

Proof. Substituting $a^A, 0, c_1$ for x, y, z, respectively, in the statement of Lemma A implies $\lceil a^A, 0 \rceil - \lceil a^A - c_1, 0 \rceil = \lceil \lfloor a^A, c_1 \rfloor, 0 \rceil$. Substituting $\lceil a^A, s^* \rceil$, $\lceil b^B, 0 \rceil$, c_1 for x, y, z, respectively, in the statement of Lemma A implies

$$\begin{aligned} \Delta W_1 &= \lceil \lceil a^A, s^* \rceil, \lceil b^B, 0 \rceil \rceil - \lceil \lceil a^A, s^* \rceil - c_1, \lceil b^B, 0 \rceil \rceil \\ &= \lceil \lfloor \lceil a^A, s^* \rceil - \lceil b^B, 0 \rceil, c_1 \rfloor, 0 \rceil. \end{aligned}$$

Substituting $s^* - b^B, 0, c_1$, for x, y, z in the statement of Lemma A implies $\lceil s^* - b^B, 0 \rceil - \lceil s^* - b^B - c_1, 0 \rceil = \lceil \lfloor s^* - b^B, c_1 \rfloor, 0 \rceil$. The first inequality in the statement of the lemma thus holds if $a^A \geq \lceil a^A, s^* \rceil - \lceil b^B, 0 \rceil$. But $s^* = a^* + b^* \leq a^A + b^B$ implies $a^A \geq s^* - b^B$, in turn implying $a^A \geq \lceil a^A, s^* - b^B \rceil \geq \lceil a^A - \lceil b^B, 0 \rceil, s^* - \lceil b^B, 0 \rceil \rceil = \lceil a^A, s^* \rceil - \lceil b^B, 0 \rceil$. The second inequality in the statement of the lemma holds if $\lceil a^A, s^* \rceil - \lceil b^B, 0 \rceil \geq s^* - b^B$. There are two cases to consider in verifying this inequality. First suppose $b^B < 0$. Then $\lceil a^A, s^* \rceil - \lceil b^B, 0 \rceil \geq a^A \geq s^* - b^B$, where $a^A \geq s^* - b^B$ was shown above. Second, suppose $b^B > 0$. Then $\lceil a^A, s^* \rceil - \lceil b^B, 0 \rceil = \lceil a^A, s^* \rceil - b^B \geq s^* - b^B$. *Q.E.D.*

Lemma C *If* $W_0 = W_1^D$, *then* $\alpha - c_0 + \Delta W_1 \leq 0$ *and* β_0^A*(1ST)* $= 0$. *If* $W_0 = \alpha - c_0 + W_1^I$, *then* $\alpha - c_0 + \Delta W_1 \geq 0$ *and* β_0^A*(1ST)* $= 1$.

Proof. If $W_0 = W_1^D$, then $\alpha - c_0 + W_1^I \leq W_0 = W_1^D$. A does not invest at date 0 in the first best. If $W_0 = \alpha - c_0 + W_1^I$, then $W_1^D \leq W_0 = \alpha - c_0 + W_1^I$. A invests immediately in the first best. *Q.E.D.*

Lemma D *If* $W_0 = \lceil a^A - c_1, s^* - c_1\rceil$, *then* $c_0 - \alpha \geq c_1$ *and* $a^A \geq c_1$.

Proof. Assume $W_0 = \lceil a^A - c_1, s^* - c_1\rceil$. Then $\lceil a^A, s^*\rceil - c_1 = W_0 \geq \alpha - c_0 + \lceil a^A, s^*\rceil$, implying $c_0 - \alpha \geq c_1$. Further, $\lceil a^A - c_1, s^* - c_1\rceil = W_1^D \geq \lceil b^B, 0\rceil$, implying $0 \leq \lceil a^A - c_1 - \lceil b^B, 0\rceil, s^* - c_1 - \lceil b^B, 0\rceil\rceil \leq \lceil a^A - c_1, a^* - c_1\rceil \leq a^A - c_1$. *Q.E.D.*

Lemma E *If* $b^B < 0$, *then* $W_1^I = a^A$, $W_1^D = a^A - c_1$, *and* $a^A > c_1$.

Proof. Suppose $b^B < 0$. The maintained assumption $W_1^I > 0$ implies $W_1^I = \lceil a^A, s^*\rceil$. But $s^* = a^* + b^* \leq a^A + b^B < a^A$. Thus $a^A = \lceil a^A, s^*\rceil = W_1^I$. The maintained assumption $W_1^D > 0$ implies $W_1^D = \lceil a^A - c_1, s^* - c_1\rceil$, in turn implying $W_1^D = a^A - c_1$ since, as was just shown, $s^* < a^A$. Finally, $0 < W_1^D = a^A - c_1$ implies $a^A > c_1$. *Q.E.D.*

Lemma F $0 \leq G(FBR) = G(FER) \leq G(FDR) \leq G(FIR)$. *For each of the preceding inequalities, and for all* $\gamma_A \in (0, 1)$, *there exist feasible values of the other parameters such that the inequality is strict.*

Proof. First, note $G(FBR) = \gamma_B(\lceil a^A, 0\rceil - \lceil a^A - c_1, 0\rceil - \Delta W_1) \geq 0$, where the inequality holds by Lemma B.

Further, Table 2 shows Δd_A is constant across the regimes *FBR*, *FER*, *FDR*, and *FIR*, and thus the first term of G—written as in (10), i.e., $G = \gamma_B(\Delta d_A - \Delta W_1) - \gamma_A \Delta d_B$—is constant across them. We proceed by showing $\Delta d_B(FBR) = \Delta d_B(FER) \geq \Delta d_B(FDR) \geq \Delta d_B(FIR)$. Referring to Table 2, $\Delta d_B(FBR) = 0$, $\Delta d_B(FER) = 0$,

$$\Delta d_B(FDR) = \begin{cases} 0 & \text{if } a^A > c_1 \\ \lceil s^* - a^A, 0\rceil - \lceil b^B, 0\rceil & \text{if } a^A \in (0, c_1) \\ 0 & \text{if } a^A < 0, \end{cases}$$

$$\Delta d_B(FIR) = \begin{cases} 0 & \text{if } a^A > c_1 \\ \lceil b^A, 0\rceil - \lceil b^B, 0\rceil & \text{if } a^A \in (0, c_1) \\ 0 & \text{if } a^A < 0. \end{cases}$$

If $a^A \in (0, c_1)$, $\Delta d_B(FDR) = \lceil s^* - a^A, 0\rceil - \lceil b^B, 0\rceil \leq 0$ since $s^* = a^* + b^* \leq a^A + b^B$, implying $s^* - a^A \leq b^B$. Further, $\Delta d_B(FIR) = \lceil b^A, 0\rceil - \lceil b^B, 0\rceil \leq \lceil s^* - a^A, 0\rceil - \lceil b^B, 0\rceil$ since $s^* = a^* + b^* \geq a^A + b^A$, implying $b^A \leq s^* - a^A$. If $a^A < 0$ or $a^A > c_1$, $\Delta d_B = 0$ in all four regimes.

This proves $0 \leq G(FBR) = G(FER) \leq G(FDR) \leq G(FIR)$. For each of the preceding inequalities, it is a straightforward exercise to demonstrate a case in which the inequality is strict for all $\gamma_A \in (0, 1)$. *Q.E.D.*

Lemma G $G(SER) \leq G(SBR) \leq G(SIR) \leq G(SDR) \leq 0$. *For each of the preceding inequalities, and for all* $\gamma_A \in (0, 1)$, *there exist feasible values of the other parameters such that the inequality is strict.*

Proof. We first show $G(SDR) \le 0$. Now $G(SDR) = \gamma_B[\Delta d_A(SDR) - \Delta W_1]$. There are two cases to consider. Suppose $b^B < 0$. By Lemma E, $\Delta W_1 = a^A - (a^A - c_1) = c_1$, $\lceil a^A, 0 \rceil = a^A$, and $\lceil a^A - c_1, 0 \rceil = a^A - c_1$. These three facts together imply $G(SDR) = \gamma_B(c_1 - c_1) = 0$. Second, suppose $b^B > 0$. Then $G(SDR) = \gamma_B(\lceil s^* - b^B, 0 \rceil - \lceil s^* - b^B - c_1, 0 \rceil - \Delta W_1) \le 0$ by Lemma B.

Table 2 shows $\Delta d_B = 0$ for all regimes *SER*, *SBR*, *SIR*, and *SDR* and thus $G = \gamma_B(\Delta d_A - \Delta W_1)$ for them. We proceed by showing $\Delta d_A(SER) \le \Delta d_A(SBR) \le \Delta d_A(SIR) \le \Delta d_A(SDR)$. Referring to Table 2, $\Delta d_A(SER) = 0$, $\Delta d_A(SBR) = \lceil a^B, 0 \rceil - \lceil a^B - c_1, 0 \rceil$,

$$\Delta d_A(SIR) = \begin{cases} \lceil a^B, 0 \rceil - \lceil a^B - c_1, 0 \rceil & \text{if } b^B > 0 \\ \lceil a^A, 0 \rceil - \lceil a^A - c_1, 0 \rceil & \text{if } b^B < 0; \end{cases}$$

$$\Delta d_A(SDR) = \begin{cases} \lceil s^* - b^B, 0 \rceil - \lceil s^* - b^B - c_1, 0 \rceil & \text{if } b^B > 0 \\ \lceil a^A, 0 \rceil - \lceil a^A - c_1, 0 \rceil & \text{if } b^B < 0. \end{cases}$$

Clearly, $0 \le \lceil a^B, 0 \rceil - \lceil a^B - c_1, 0 \rceil$, so $\Delta d_A(SER) \le \Delta d_A(SBR)$. If $b^B > 0$, $\Delta d_A(SBR) = \Delta d_A(SIR)$. If $b^B < 0$, $\Delta d_A(SIR) = \lceil a^A, 0 \rceil - \lceil a^A - c_1, 0 \rceil = \lceil \lfloor a^A, c_1 \rfloor, 0 \rceil \ge \lceil \lfloor a^B, c_1 \rfloor, 0 \rceil = \lceil a^B, 0 \rceil - \lceil a^B - c_1, 0 \rceil$, where the second and fourth steps hold by Lemma A. Thus, $\Delta d_A(SBR) \le \Delta d_A(SIR)$ in all cases. If $b^B < 0$, $\Delta d_A(SIR) = \Delta d_A(SDR)$. If $b^B > 0$, $\Delta d_A(SDR) = \lceil s^* - b^B, 0 \rceil - \lceil s^* - b^B - c_1, 0 \rceil = \lceil \lfloor s^* - b^B, c_1 \rfloor, 0 \rceil \ge \lceil \lfloor a^B, c_1 \rfloor, 0 \rceil = \lceil a^B, 0 \rceil - \lceil a^B - c_1, 0 \rceil = \Delta d_A(SIR)$, where the second and fourth steps hold by Lemma A and where the third step holds since $s^* = a^* + b^* \ge a^B + b^B$, implying $s^* - b^B \ge a^B$. Thus, $\Delta d_A(SIR) \le \Delta d_A(SDR)$ in all cases.

This proves $G(SER) \le G(SBR) \le G(SIR) \le G(SDR) \le 0$. For each of the preceding inequalities, it is a straightforward exercise to demonstrate a case in which the inequality is strict for all $\gamma_A \in (0, 1)$. *Q.E.D.*

Proof of Proposition 1: Assume $G > 0$. (The proof for $G < 0$ is similar.) If $\ell_0^A = 1$ in the first best, then the discussion preceding equation (4) shows $\Delta W_0 \equiv W_0^I - W_0^D > 0$, implying $\alpha - c_0 + \Delta W_1 > 0$. But $\Delta U_0 = \alpha - c_0 + \Delta W_1 + G > \alpha - c_0 + \Delta W_1 > 0$, so $\ell_0^A = 1$ in equilibrium as well. This proves equilibrium involves weak overinvestment. For a given $\Delta W_1 \in \mathbf{R}$, let

$$S \equiv \{(\alpha, c_0) \in \mathbf{R}^2_+ \mid -\Delta W_1 - G < \alpha - c_0 < -\Delta W_1\}.$$

(Note that ΔW_1 and G involve date-1 payoffs only and is thus independent of α and c_0.) S is nonempty: it contains the point $(0, G/2 + \Delta W_1)$ among others. For any $(\alpha', c_0') \in S$, $\ell_0^A = 0$ in the first best (i.e., $\alpha' - c_0' + \Delta W_1 < 0$) but $\ell_0^A = 1$ in equilibrium (i.e., $\alpha' - c_0' + \Delta W_1 + G > 0$). This proves the existence of parameters $(\alpha, c_0) \in \mathbf{R}^2_+$ such that investment is strictly inefficient. It can be shown that S contains all the parameters $(\alpha, c_0) \in \mathbf{R}^2_+$ such that ℓ_0^A is chosen inefficiently in equilibrium. Clearly, S grows as $|G|$ increases. This proves that the set of parameters $(\alpha, c_0) \in \mathbf{R}^2_+$ for which investment is inefficient grows as $|G|$ increases.

If $G = 0$, investment is obviously efficient for all $(\alpha, c_0) \in \mathbf{R}^2_+$. If $G \neq 0$, the arguments in the preceding paragraph establish that investment is inefficient for some $(\alpha, c_0) \in \mathbf{R}^2_+$. This proves the penultimate statement of the proposition.

To prove the last statement of the proposition, assume $\Delta d_A = \Delta W_1$ and $\Delta d_B = 0$. Then $G = 0$ for all $\gamma_a \in (0,1)$, and so by the preceding paragraph investment is efficient for all $\gamma_A \in (0,1)$. Assume investment is efficient for all $(\alpha, c_0) \in \mathbf{R}^2_+$ and for $\gamma_A \in \Gamma$, where Γ is a nontrivial subinterval of $(0,1)$. Then $G = 0$ and $\partial G/\partial \gamma_A = 0$ for all $\gamma_A \in \Gamma$, implying the following two equations must hold:

$$\Delta d_A - \Delta W_1 - \gamma_A(\Delta d_A - \Delta W_1 + \Delta d_B) = 0$$

$$-(\Delta d_A - \Delta W_1 + \Delta d_B) = 0.$$

These two equations imply $\Delta d_A = \Delta W_1$ and $\Delta d_B = 0$. *Q.E.D.*

Proof of Proposition 2: Considering the whole set of feasible parameters, Lemma F and Proposition 1 imply *1ST* $\succ$ *FBR* $\sim$ *FER* $\succ$ *FDR* $\succ$ *FIR*. Lemma G and Proposition 1 imply *1ST* $\succ$ *SDR* $\succ$ *SIR* $\succ$ *SBR* $\succ$ *SER*. The following three conditions will be used to establish the relative efficiency of regimes on various restricted sets of parameters:

$$W_0 = \alpha - c_0 + W_1^I \tag{11}$$

$$W_0 = W_1^D \tag{12}$$

$$W_0 = \lceil a^A - c_1, s^* - c_1 \rceil. \tag{13}$$

Assume (11) holds. Then $\ell_0^A(\mathit{1ST}) = 1$. By Lemma F, $G(\mathit{FBR})$, $G(\mathit{FER})$, $G(\mathit{FDR})$, and $G(\mathit{FIR})$ are non-negative. Thus, by Proposition 1, $\ell_0^A(\mathit{FBR}) = \ell_0^A(\mathit{FER}) = \ell_0^A(\mathit{FDR}) = \ell_0^A(\mathit{FIR}) = 1$. Nash bargaining ensures the rest of the choice variables are set at the optimal levels as well. Hence *1ST* $\sim$ *FBR* $\sim$ *FER* $\sim$ FDR $\sim$ *FIR* if (11) holds.

Assume (12) holds. Then $\ell_0^A(\mathit{1ST}) = 0$. By Lemma G, $G(\mathit{SDR})$, $G(\mathit{SIR})$, $G(\mathit{SBR})$, and $G(\mathit{SER})$ are non-positive. Thus, by Proposition 1, $\ell_0^A(\mathit{SDR}) = \ell_0^A(\mathit{SIR}) = \ell_0^A(\mathit{SBR}) = \ell_0^A(\mathit{SER}) = 0$. Nash bargaining ensures the rest of the choice variables are set at the optimal levels as well. Hence *1ST* $\sim$ *SDR* $\sim$ *SIR* $\sim$ SBR $\sim$ *SER* if (12) holds.

Assume (13) holds. Then $\ell_0^A(\mathit{1ST}) = 0$. Further, $\Delta U_0(\mathit{FIR}) = \gamma_B(\alpha - c_0 + c_1) + \gamma_A(\alpha - c_0 + \Delta W_1) \leq \gamma_B(\alpha - c_0 + c_1) \leq 0$, where the equality holds since $a^A \geq c_1$ by Lemma D, the first inequality holds by Lemma C, and the second inequality holds since $c_0 - \alpha \geq c_1$ by Lemma D. Thus $\ell_0^A(\mathit{FIR}) = 0$. Nash bargaining ensures that in equilibrium under *FIR*, the values of the rest of the choice variables are set at their optimal levels as well, implying *1ST* $\sim$ *FIR*. But then *1ST* $\sim$ *FBR* $\sim$ *FER* $\sim$ *FDR* if (13) holds since—as established in the first paragraph—*FBR*, *FER*, and *FDR* are at least as efficient as *FIR* for any feasible parameters.

We have shown *1ST* $\succ$ *FBR* $\sim$ *FER* $\succ$ *FDR* $\succ$ *FIR* on the unrestricted set of feasible parameters but that *1ST* $\sim$ *FBR* $\sim$ *FER* $\sim$ *FDR* $\sim$ *FIR* if either (11) or (13) holds. The only other case is for the parameters to satisfy $W_0 = b^B$. Therefore, *1ST* $\succ$ *FBR* $\sim$ *FER* $\succ$ *FDR* $\succ$ *FIR* if $W_0 = b^B$.

We have shown *1ST* $\succ$ *SDR* $\succ$ *SIR* $\succ$ *SBR* $\succ$ *SER* on the unrestricted set of feasible parameters but that *1ST* $\sim$ *SDR* $\sim$ *SIR* $\sim$ *SBR* $\sim$ *SER* if (12) holds. The only other case is for the parameters to satisfy (11). Therefore, *1ST* $\succ$ *SDR* $\succ$ *SIR* $\succ$ *SBR* $\succ$ *SER* if (11) holds.

Proof of Proposition 3: By statement (8) of Proposition 2, any of the rights regimes *FBR*, *SBR*, *FIR*, *SIR*, *FER*, *SER*, *FDR*, or *SDR* yield the first best if $W_0 = \lceil a^A - c_1, s^* - c_1 \rceil$. Throughout the remainder of the proof, maintain the assumptions $\alpha > c_0$ and $W_0 \neq \lceil a^A - c_1, s^* - c_1 \rceil$. Note $b^B + \alpha - c_0 > b^B$, so $W_0 = \alpha - c_0 + W_1^I$. *1ST* $\sim$ *FBR* $\sim$ *FER* $\sim$ *FDR* $\sim$ *FIR* by statement (7) of Proposition 2. It remains to be shown that *1ST* $\sim$ *SDR* $\sim$ *SIR* $\sim$ *SBR* $\sim$ *SER*. By Proposition 2, this is true if *1ST* $\sim$ *SER* since *SER* is dominated by the other second party rights regimes in terms of social efficiency. Now $\ell_0^A(\mathit{1ST}) = 1$. Further, $\Delta U_0(\mathit{SER}) = \alpha - c_0 + \gamma_A \Delta W_1 > 0$ since $\alpha > c_0$ and since $\Delta W_1 \geq 0$. Thus $\ell_0^A(\mathit{SER}) = 1$, and so *SER* is efficient. *Q.E.D.*

Proof of Proposition 6: The proof proceeds in three steps.

Step 1: We first construct strategies that form a subgame perfect equilibrium providing surpluses $W_0 - \lceil b^B, 0 \rceil$ for A and $\lceil b^B, 0 \rceil$ for B. In stage 1 of the mechanism in Figure 3, A's strategy is the following:

$$
\begin{array}{ll}
\text{if } W_0 = \alpha - c_0 + a^A, & \ell_0^A = 1,\ \tilde{e} = e^A,\ \tilde{T} = \lceil b^B, 0 \rceil; \\
\text{if } W_0 = \alpha - c_0 + s^*, & \ell_0^A = 1,\ \tilde{e} = e^*,\ \tilde{T} = b^B - b^*; \\
\text{if } W_0 = \alpha - c_0 + b^B, & \ell_0^A = 1,\ \tilde{e} = e^B,\ \tilde{T} = 0; \\
\text{if } W_0 = a^A - c_1, & \ell_0^A = 0,\ \tilde{e} = e^A,\ \tilde{T} = \lceil b^B, 0 \rceil; \\
\text{if } W_0 = s^* - c_1, & \ell_0^A = 0,\ \tilde{e} = e^*,\ \tilde{T} = b^B - b^*; \\
\text{if } W_0 = b^B, & \ell_0^A = 0,\ \tilde{e} = e^B,\ \tilde{T} = 0.
\end{array}
\tag{14}
$$

In stage 2 of the mechanism, B accepts if and only if $\lceil b(\tilde{e}), 0 \rceil + \tilde{T} \geq \lceil b^B, 0 \rceil$. In the stage-3 subgame following B's accepting, A sets $\ell_1^A = 1$ if $a(\tilde{e}) - (1 - \ell_0^A)c_1 - \tilde{T} \geq 0$ and $\ell_1^A = 0$ otherwise. B sets $\ell_1^B = 1$ if $b(\tilde{e}) \geq 0$ and $\ell_1^B = 0$ otherwise. In the stage-3 subgame following B's rejecting, B announces $\hat{e} = e^B$. A sets $\ell_1^A = 1$ if $a(\hat{e}) - (1 - \ell_0^A)c_1 > 0$ and $\ell_1^A = 0$ otherwise. B sets $\ell_1^B = 1$ if $b(\hat{e}) \geq 0$ and $\ell_1^B = 0$ otherwise.

It can be verfied that A earns $W_0 - \lceil b^B, 0 \rceil$ and B earns $\lceil b^B, 0 \rceil$ given these strategies. Since B can always guarantee itself $\lceil b^B, 0 \rceil$ by rejecting in stage 2 and since the parties' joint surplus is bounded above by W_0, A cannot earn more than $W_0 - \lceil b^B, 0 \rceil$ by deviating from its strategy. By design, the above strategies form a subgame perfect equilibrium on the subgames starting in stage 2. Thus the constructed strategies form a subgame perfect equilibrium.

Step 2: Prove B earns $\lceil b^B, 0 \rceil$ in any subgame perfect equilibrium. First note that B cannot earn less than $\lceil b^B, 0 \rceil$ in equilibrium since it can guarantee itself $\lceil b^B, 0 \rceil$ by rejecting. Suppose the parties' strategies are such that B earns $\lceil b^B, 0 \rceil + \varepsilon$ for some $\varepsilon > 0$. We will show that these strategies do not form a subgame perfect equilibrium. A's surplus given these strategies is bounded above by $W_0 - \lceil b^B, 0 \rceil - \varepsilon$. Assume that the strategies form a subgame perfect equilibrium on the continuation subgames starting in stage 2 (if not, we are done). It can be shown that the strategies must be identical on the subgames starting in stage 2 to those specified above in step 1 (technically, the choices made when parties are indifferent may differ, but this is immaterial for the subsequent analysis). Then A can ensure itself $W_0 - \max\{b^B, 0\} - \epsilon/2$ by deviating to a new strategy that is identical to (14) with the exception that $\epsilon/2$ is added to $\tilde{T}$ in all cases. A strictly prefers the deviation, proving that the original strategies do not form a Nash equilibrium and therefore cannot be subgame perfect.

Step 3: The fact that A earns $W_0 - \max\{b^B, 0\}$ in any subgame perfect equilibrium can be established by arguments paralleling those in step 2. *Q.E.D.*

Proof of Proposition 7: We will verify that the entries for $d^I_A(SOR)$ and $d^I_B(SOR)$ in Table 2 are correct and leave the verification for d^D_A and d^D_B for the reader. First, assume $b^B > 0$. Then B invests and obtains its damage rights in the default. A has three options: exclude B and earn a^A minus the damage payment b^B; allow B to enter, choose externality e^*, and earn a^* minus damage payment $b^B - b^*$; exit and earn zero. A's payoff is thus $\max\{a^A - b^B, a^* - (b^B - b^*), 0\} = \max\{a^A, s^*, b^B\} - b^B = W^I_1 - \max\{b^B, 0\}$ if $b^B > 0$.

Second, assume $b^B < 0$. Then B would not invest in the default; so A can earn $a^A = W^I_1 - 0 = W^I_1 - \max\{b^B, 0\}$. The last equality holds by Lemma E and by the fact that $0 = \max\{b^B, 0\}$ if $b^B < 0$.

Combining the two cases, $d^I_A(SOR) = W^I_1 - \max\{b^B, 0\}$. To show $d^I_B(SOR) = \max\{b^B, 0\}$, it is easy to see that B can earn at least $\max\{b^B, 0\}$ in the default outcome. But $d^I_B(SOR)$ is bounded above by the residual between W^I_1 and $d^I_A(SOR) = W^I_1 - \max\{b^B, 0\}$. Hence $\max\{b^B, 0\} \le d^I_B(SOR) \le \max\{b^B, 0\}$.

Given the parties' default payoffs are correct in the last row of Table 2, it is straightforward to show $G(SOR) = 0$. By Proposition 1, $SOR \sim$ *1ST*. *Q.E.D.*

Appendix B: Derivation of Default Payoffs

In this appendix, we derive parties' default payoffs listed in Table 2 for the case in which A has the rights and in which A has invested at date 0. The calculations for the case in which A delays investment at date 0 is similar, only differing in that the investment cost c_1 is not sunk. The calculations for the default surpluses when B has rights is essentially the mirror image of those below.

Consider the default payoffs associated with *FBR* given in the first row of Table 2. Recall *FBR* is the first-party variant of the benchmark rights regime, which gives an injunctive right over the externality to A. If bargaining breaks down, then A sets the externality at e^A provided this yields a positive payoff; otherwise it will not operate. This gives the default payoff from investing as $d^I_A = \lceil a^A, 0 \rceil$, where recall $a^A \equiv a(e^A)$. Note that date-0 flow return α and cost c_0 are regarded as sunk and do not figure into d^I_A. Party B must decide whether it will locate near A, and will do so on the basis of whether $b^A \equiv b(e^A)$ is positive. This yields default payoff $d^I_B = \lceil b^A, 0 \rceil$.

Consider the default payoffs associated with investor-rights regime *FIR* in Table 2. If A has invested at date 0 and it receives a positive payoff from operating, it will maintain its investment and choose e^A. If continuted operation would result in losses, then A would withdraw its investment in the area; and B would be given the right to choose e. This yields payoff $d^I_A = \lceil a^A, 0 \rceil$ to A. A maintains its investment if $a^A > 0$, in which case B either endures externality e^A chosen by A or B simply decides to locate elsewhere. Thus, B receive $d^D_A = \lceil b^A, 0 \rceil$ if bargaining breaks down. A withdraws its investment if $a^A < 0$, in which case B is allowed to choose externality level e^B and receives default payoff $d^D_B = b^B$.

Exclusion rights give default payoffs similar to benchmark rights, except that the party who does not hold the right gets a zero payoff in all cases. This is reflected in the entry for *FER* in Table 2.

To compute the default payoffs associated with damage rights *FDR*, first consider the continuation subgame following $\beta^A_0 = 1$. If B operates, it is free to set e. A earns a(e) plus damage payment $a^A - a(e)$ by maintaining its investment or zero by withdrawing its investment. If B does not operate, A can set the externality at e^A. Thus, A earns $d^I_A = \lceil a^A, 0 \rceil$ regardless of B's actions in the default. B's default payoff depends on whether A maintains its investment. If A maintains its investment, it can be harmed by—and extract a damage payment from—B. B earns $b(e) - [a^A - a(e)] = s(e) - a^A$ if it operates, and optimally sets externality e^* (the joint-surplus-maximizing level). B's payoff would thus be $d^I_B = s^* - a^A$. If A withdraws its investment, it cannot extract a damage payment from B, so B optimally sets the externality at e^B and earns $\lceil b^B, 0 \rceil$ (note B can guarantee itself a payoff of zero in any event by simply exiting the area). Whether or not A maintains its investment depends on the sign of a^A.

References

Baumol, William J. (1988) *The Theory of Environmental Policy*. Cambridge: Cambridge University Press.

Becker, Gary S. "A Theory of Social Interactions," *Journal of Political Economy* 82: 1063–1094.

Bergstrom, Theodore C. (1989) "A Fresh Look at the Rotten Kid Theorem—and Other Household Mysteries," *Journal of Political Economy* 97: 1138–1159.

Binmore, Ken, Ariel Rubinstein, and Asher Wolinsky. (1986) "The Nash Bargaining Solution in Economic Modelling," *Rand Journal of Economics* 17: 176–188.

Coase, Ronald H. (1960) "The Problem of Social Cost," *Journal of Law and Economics* 3: 1–44.

Cooter, Robert and Thomas Ulen. (1997) *Law and Economics* (second edition). New York: Addison-Wesley.

De Meza, David and Ben Lockwood. (1998) "Does Asset Ownership Always Motivate Managers? Outside Options and the Property Rights Theory of the Firm," *Quarterly Journal of Economics* 112: 361–386.

Dye, Ronald H. (1985) "Costly Contract Contingencies," *International Economic Review* 26: 233–250.

Grossman, Sanford J. and Oliver D. Hart. (1986). "The Costs and Benefits of Ownership: A Theory of Vertical and Lateral Integration," *Journal of Political Economy* 94: 691–791.

Hardin, Garrett. (1993) "The Tragedy of the Commons," in Herman E. Daly and Kenneth N. Townsend, eds., *Valuing the Earth.* Cambridge, MA: MIT Press.

Hart, Oliver D. (1987) "Incomplete Contracts," in John Eatwell, Murray Milgate, and Peter Newman, eds., *The New Palgrave: Allocation, Information, and Markets*. New York: Macmillan.

Hart, Oliver D. and John Moore. (1990) "Property Rights and the Nature of the Firm," *Journal of Political Economy* 98: 1119–1158.

Holmström, Bengt and Jean Tirole. (1990) "Transfer Pricing and Organizational Form," *Journal of Law, Economics, and Organization* 7: 201–228.

Keeton, W. Page, Dan Dobbs, Robert Keeton, and David Owen. (1984) *Prosser and Keeton on the Law of Torts*. St. Paul: West Publishing.

Libecap, Gary D. (1993) *Contracting for Property Rights*. Cambridge: Cambridge University Press.

Mailaith, George J. and Postlewaite, Andrew. (1990) "Asymetric Information Bargaining Problems With Many Agents," *Review of Economic Studies* 57: 351–367.

Maskin, Eric and Jean Tirole. (forthcoming) "Two Remarks on the Property-Rights Literature," *Review of Economic Studies*.

Neeman, Zvika. (1999) "Property Rights and Efficiency of Volntary Bargaining under Asymmetric Information," *Review of Economic Studies* forthcoming.

Posner, Richard. (1992) *Economic Analysis of Law* fourth ed. Boston: Little, Brown and Company.

Rajan, Raghuram G. and Luigi Zingales. (1998) "Power in a Theory of the Firm," *Quarterly Journal of Economics* 112: 387–432.

Rob, Rafael. (1989) "Pollution Claim Settlements under Private Information," *Journal of Economic Theory* 47: 307–333.

Rubinstein, Ariel. (1982) "Perfect Equilibrium in a Bargaining Model," *Econometrica* 50: 97–109.

Segal, Ilya and Michael D. Whinston. (1998) "Exclusive Contracts and the Protection of Investments," University of California at Berkeley mimeo.

Starrett, David A. (1988) *Foundations of Public Economics*. Cambridge: Cambridge University Press.

Stull, William. (1974) "Land Use and Zoning in an Urban Economy," *American Economic Review* 64: 337–347.

Williamson, Oliver. "Transaction-Cost Economics: The Governance of Contractural Relations," *Journal of Law and Economics* 22: 233-61.

Table 1: Basic Rights Regimes

Rights Regime	Description
Benchmark Rights	
FBR	A can specify e
SBR	B can specify e
Investor Rights	
FIR	A can specify e if and only if $\ell_1^A = 1$
SIR	B can specify e if and only if $\ell_1^B = 1$
Exclusion Rights	
FER	A can specify e and require $\ell_1^B = 0$
SER	B can specify e and require $\ell_1^A = 0$
Damage Rights	
FDR	B can specify e but must pay $a^A - a(e)$ to A if $\ell_1^A = 1$
SDR	A can specify e but must pay $b^B - b(e)$ to B if $\ell_1^B = 1$
Optimal Rights	
SOR	A can specify e and require $\ell_1^B = 0$ but must pay $b^B - b(e)$ to B if $\ell_1^B = 1$ and $\lceil b^B, 0\rceil$ to B if $\ell_1^B = 0$.

Table 2: Parties' Default Surpluses in the Rights Regimes

	A invests at date 0 ($\ell_0^A = 1$)		A delays investment ($\ell_0^A = 0$)	
Rights Regime	A's default payoff (d_A^I)	B's default payoff (d_B^I)	A's default payoff (d_A^D)	B's default payoff (d_B^D)
Benchmark Rights				
FBR	$\lceil a^A, 0 \rceil$	$\lceil b^A, 0 \rceil$	$\lceil a^A - c_1, 0 \rceil$	$\lceil b^A, 0 \rceil$
SBR	$\lceil a^B, 0 \rceil$	$\lceil b^B, 0 \rceil$	$\lceil a^B - c_1, 0 \rceil$	$\lceil b^B, 0 \rceil$
Investor Rights				
FIR	$\lceil a^A, 0 \rceil$	$\begin{cases} \lceil b^A, 0 \rceil & \text{if } a^A > 0 \\ \lceil b^B, 0 \rceil & \text{if } a^A < 0 \end{cases}$	$\lceil a^A - c_1, 0 \rceil$	$\begin{cases} \lceil b^A, 0 \rceil & \text{if } a^A > c_1 \\ \lceil b^B, 0 \rceil & \text{if } a^A < c_1 \end{cases}$
SIR	$\begin{cases} \lceil a^B, 0 \rceil & \text{if } b^B > 0 \\ \lceil a^A, 0 \rceil & \text{if } b^B < 0 \end{cases}$	$\lceil b^B, 0 \rceil$	$\begin{cases} \lceil a^B - c_1, 0 \rceil & \text{if } b^B > 0 \\ \lceil a^A - c_1, 0 \rceil & \text{if } b^B < 0 \end{cases}$	$\lceil b^B, 0 \rceil$
Exclusion Rights				
FER	$\lceil a^A, 0 \rceil$	0	$\lceil a^A - c_1, 0 \rceil$	0
SER	0	$\lceil b^B, 0 \rceil$	0	$\lceil b^B, 0 \rceil$
Damage Rights				
FDR	$\lceil a^A, 0 \rceil$	$\begin{cases} \lceil s^* - a^A, 0 \rceil & \text{if } a^A > 0 \\ \lceil b^B, 0 \rceil & \text{if } a^A < 0 \end{cases}$	$\lceil a^A - c_1, 0 \rceil$	$\begin{cases} \lceil s^* - a^A, 0 \rceil & \text{if } a^A > c_1 \\ \lceil b^B, 0 \rceil & \text{if } a^A < c_1 \end{cases}$
SDR	$\begin{cases} \lceil s^* - b^B, 0 \rceil & \text{if } b^B > 0 \\ \lceil a^A, 0 \rceil & \text{if } b^B < 0 \end{cases}$	$\lceil b^B, 0 \rceil$	$\begin{cases} \lceil s^* - b^B - c_1, 0 \rceil & \text{if } b^B > 0 \\ \lceil a^A - c_1, 0 \rceil & \text{if } b^B < 0 \end{cases}$	$\lceil b^B, 0 \rceil$
Optimal Rights				
SOR	$W_1^I - \lceil b^B, 0 \rceil$	$\lceil b^B, 0 \rceil$	$W_1^D - \lceil b^B, 0 \rceil$	$\lceil b^B, 0 \rceil$

Figure 1: Timing of the Model

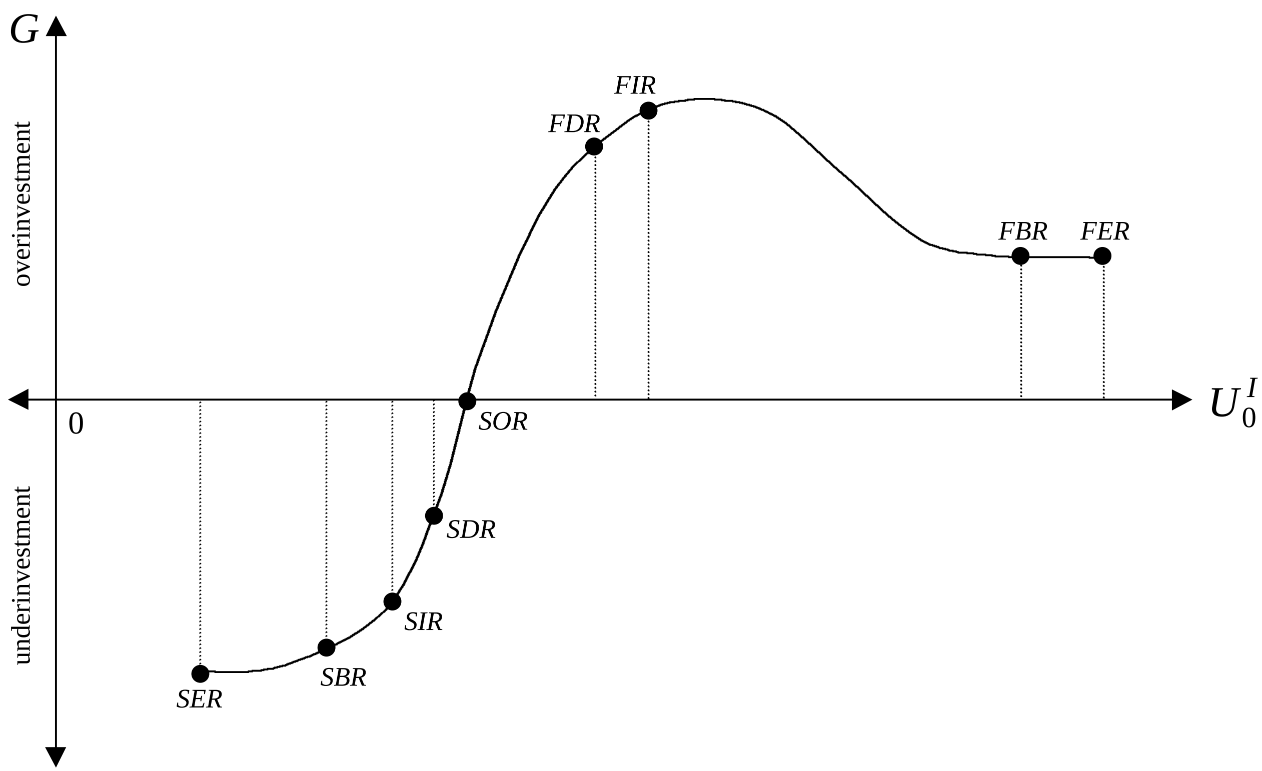

Figure 2: Strength of *A*'s Rights and Its Investment Incentives

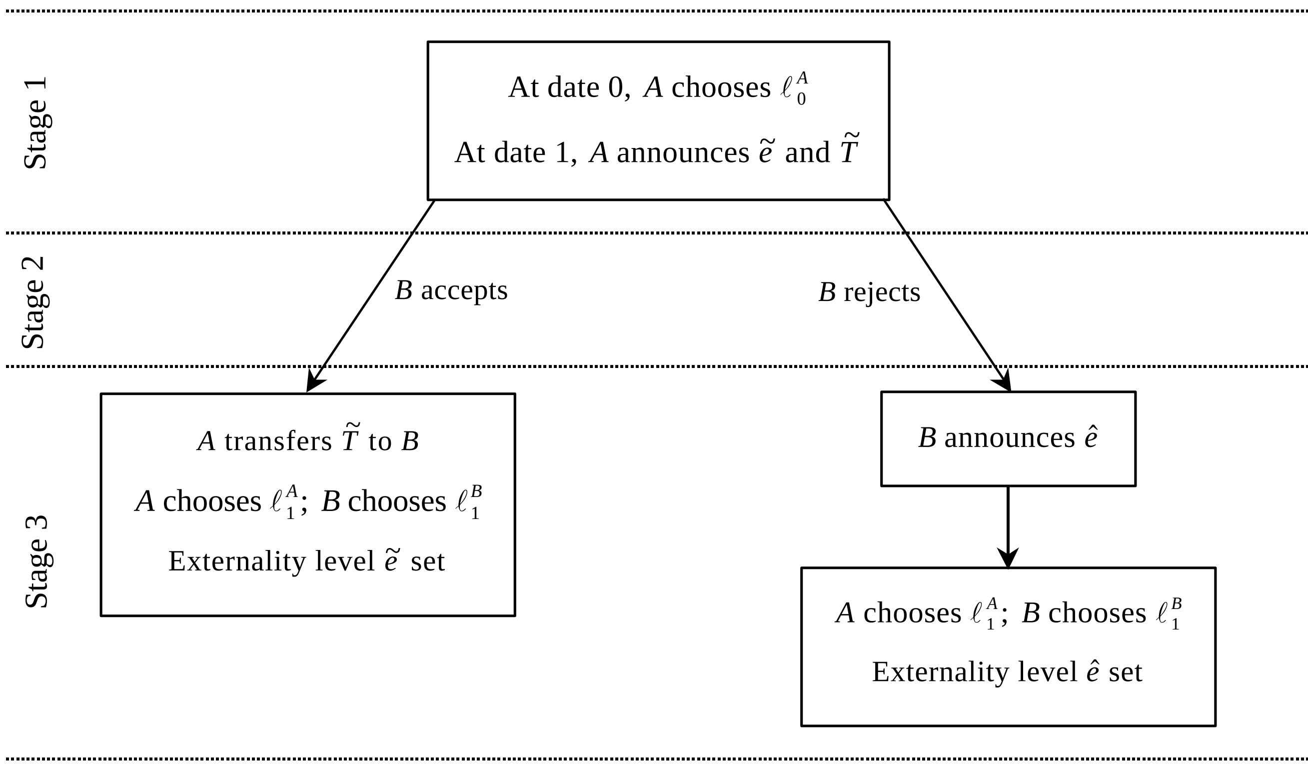

Figure 3: Optimal Mechanism