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Restricted Coasean bargaining

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Abstract

We investigate the efficiency of Coasean bargaining when restrictions are placed on the set of feasible bargaining outcomes. When property rights are costly to (defend) appropriate, we find bargaining restrictions may be Pareto superior to unconstrained voluntary exchange. Under cost uncertainty over the externality, we show an efficient configuration of restrictions must balance the potential reduction in appropriation costs with the possibility of allocatively inefficient bargaining restrictions. For cases where the restrictions are contested, we show conditions for the continuing existence of welfare improvements.

Keywords: Coase theorem; bargaining restrictions; appropriation
JEL *classification numbers*: D62; D72; K1

1 Introduction

The Coase 'theorem' predicts that two agents arrive at a bargaining solution where an efficient level of harmful activity is realized and gains from trade are fully exploited (Coase, 1960). Yet, in many Coasean-style applications it is common to observe restrictions placed on the set of feasible bargaining outcomes. Restrictions may establish upper (and lower) bounds on permissible externality levels, i.e., *a priori* restrictions on the use of the property right. For example, two neighbors, before attempting to bargain over noise limits, may be aware of existing laws (or social norms) that prohibit excessive noise levels. A similar situation arises in litigation. When bringing a case to court, claimant and defendant have knowledge of existing legal provisions, stipulating basic rights and obligations. These are taken into account by both legal parties prior to any (out-of-court) settlement.[1] In such cases, when are restrictions on the set of feasible bargaining outcomes—the delineation of upper and lower bounds on the level of externality—Pareto improving? We attempt to answer this question.

Restrictions on Coasean bargaining outcomes may create efficiency losses. As the unalienability of such restrictions reduces the potential bargaining surplus, the existence of even low levels of transaction costs may make Coasean bargaining unattractive. For example, a neighbor may decide not to participate in Coasean bargaining if restrictions to the bargaining game result in costs negating all potential gains. Furthermore, in a world of uncertainty, bargaining restrictions stipulated *a priori* could even preclude the existence of an efficient Coasean equilibrium by being set 'too high' or 'too low.'

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[1] See Calabresi and Melamed (1972) for the seminal work on entitlements with respect to property rules, liability rules, and inalienability.

In addition to the potential efficiency losses from bargaining restrictions, property rights may also be costly to (defend) appropriate, such as the use of lobbying, litigation, or violent conflict to determine property ownership (e.g., Demsetz, 1964; Bush and Mayer, 1974; de Meza and Gould, 1992; Skaperdas, 1992; Grossman and Kim, 1995; Skaperdas and Syropoulos, 2002; Kolmar, 2008). The need to defend or appropriate property is a direct result of property ownership being costly to enforce, ambiguously defined within a contract, or even *de jure* non-existent.[2] Given property rights command value, both actors within the Coasean set-up have an incentive to secure initial ownership over these rights. Hence, if the additional costs from defensive and appropriation effort are also considered, allowing for Coasean bargaining may reduce *overall* efficiency.

Given the co-existence of unalienable bargaining restrictions and costly (defensive) appropriative activity, it would suggest that, *prima facie*, overall efficiency is not maximized. However, this conclusion does not take into account the potential interplay between these two elements. On the one hand, bargaining restrictions reduce the gains from trade (and, at the extreme, precludes the existence of an efficient equilibrium). On the other hand, rents from effective property ownership decrease, reducing costly appropriation effort and increasing overall efficiency.

To investigate this trade-off, we model a game between two agents where property rights are costly to appropriate and agents can voluntarily exchange part of their property rights after being initially endowed. In particular, our main framework consists of an all-pay auction for property rights followed by restricted bargaining. The all-pay auction stage represents the appropriation of property rights. The restrictions placed on the feasible set of bargaining outcomes provides a maximum (and minimum) guaranteed cost to agents.[3] We provide a general bargaining framework which can accommodate conventional surplus-splitting bargaining games. Under the presence of cost uncertainty over the externality, we show that the existence of *ex ante* bargaining restrictions, i.e., upper and lower bounds of specified externality levels may result in overall Pareto improvements compared to unconstrained bargaining. Provided the bargaining power of the property right holder is large enough, this result continues to hold even if there exists a probability of the efficient Coasean equilibrium not being attained due to binding bargaining restrictions. When bargaining restrictions are, themselves, initially contested, which engenders additional costs, we show the introduction of bargaining restrictions usually improves welfare.

Exploring efficiency problems in the Coase theorem is not new (see, for example, discussions by de Meza (1988) and Usher (1998)). Obviously, the presence of transaction costs is a key explanation for inefficiency. In particular, Dixit and Olson (2000) and Anderlini and Felli (2001, 2006) show when agents have a costly *ex ante* choice to participate in voluntary exchange, inefficiencies may occur. These transaction costs can be interpreted as 'preparation' costs prior to bargaining. Yet other forms of preparation costs exist: most notably, the effort used to appropriate property rights prior to any potential bargaining.

It is clear that, even in a contemporary society, many property rights are subject to costly appropriation effort. Either property rights are ambiguously defined, or the underlying activity has just emerged and no initial property right allocation presently exists. In the latter case, a currently observed trend is the formation of new property rights for externalities, such as tradable pollution permits and the attribution of liability in cyberspace. Robson and Skaperdas (2008) consider appropriation activities over a property right and show the associated costs are possibly

[2]This appropriative effort is likely to further increase with the prospect of future bargaining, as an agent's valuation of a property right increases due to gains from trade.

[3]Bargaining restrictions, which provide maximum (and minimum) levels of guaranteed costs, can also be interpreted as minimum consumption guarantees within an exchange economy, see Serizawa and Weymark (2003).

so large that it may be *ex ante* Pareto efficient to abstain from property right exchange. That is, the gains from trade are sufficiently large to warrant substantial investment in appropriation activity, which results in lower utility than what would be observed if the property right was not resold. Thus, to reduce appropriation costs, it is possible to delimit the gains from trade and improve efficiency (Anbarci et al., 2002; Skaperdas and Syropoulos, 2002).[4] Surprisingly, however, given the significance of appropriation activities and externalities, no analysis considers the delineation of restrictions within Coasean bargaining. Our analysis provides such a comparison. We analyze the efficiency of Coasean bargaining when restrictions to the set of bargaining outcomes are delineated by: a benevolent authority, agents under the veil of uncertainty, and agents contesting bargaining restrictions by investing in appropriation effort.[5] The bargaining restrictions analyzed here delimit the feasible externality levels, thus limiting the liberty of agents.

Arguments in favor of limiting liberty are voluminous. Most prominently, from classical liberalism, Mill (1991)[1859] advocates restrictions to individual liberty in terms of the harm principle: individual actions are to be restricted only if they produce harm to others. The criticisms against this thesis have been numerous (Gray, 1996). In particular, the requirement of limits on liberty is a necessary but not sufficient condition. Although individuals' actions may cause harm, the 'general interest'—i.e., the social optimum in terms of aggregated welfare—might require the limits to be removed. It follows, then, that it is not *a priori* known whether limits should be set, and even if they are set, it is not known at what level. Clearly, the harm to others and its reciprocal nature is a central issue within the Coase theorem. In our analysis, we argue that restrictions on liberty can not only produce welfare improvements, but in addition, we show that for many cases they turn out to be Pareto efficient in its narrow sense. Hence, in cases where bargaining restrictions provide expected Pareto improvements, they are in principle *a priori* acceptable to all players. As unanimous acceptability represents a less restrictive ethical stance than the existence of Kaldor-Hicks efficiency, our findings are also interesting from a normative perspective.

In the approach presented here, bargaining restrictions are defined as delimitations on the use of property rights, i.e., the former are of a higher legal order than the latter. The underlying institutional framework is hence three-tiered, where bargaining restrictions (situated at the highest level) can be assumed to be a set of general rules precluding aspects of property right use. The property right allocation represents the mid-level of the institutional cascade. The lowest institutional level represents the result of the (subsequent) Coasean bargaining, which is usually stipulated through a (fully enforceable) contract, an out-of-court settlement, or court order.

Note that this framework might reflect the creation of property rights via simple laws or jurisprudence, while bargaining restrictions can be viewed as being stipulated on a 'constitutional' level. In this interpretation, our approach is close to the field of constitutional economics pioneered by James Buchanan, which analyses the efficiency and feasibility of constitutional provisions. In particular, Buchanan (1975) develops a model where appropriation effort creates a distribution of property ownership, setting the stage for gains from trade. In the approach presented here, however, we explicitly differentiate between a 'constitutional' level and a 'legal'

[4]Discussing the efficiency of exchange, Skaperdas and Syropoulos (2002) provide an analysis where the existence of insecure property rights (and the associated enforcement costs) may result in Pareto improvements when restrictive exchange settlements are implemented. For the case of private contracts, Aghion and Hermalin (1990) show that legal restrictions can improve efficiency under a case of asymmetric information between two parties. Legal restrictions reduce the amount of signaling agents can do under the terms of contract, which reduces distortions. Additional arguments have also been made by Hermalin and Katz (1993) and Anderlini et al. (2011).

[5]As North (1990) argues, the creation of institutions to define and limit rights and behavior may not necessarily be efficient: institutions may be created due to private well-being rather than social well-being.

level of lower order where specific (enforceable) property rights are stipulated. This allows for representation of newly arising property rights issues, such as the ones associated with the arrival of the internet, which are purely post-constitutional. Hence, in the following, we start with a situation where the establishment of bargaining restrictions is initially given *a priori* and then we extend our model to include the contestability of bargaining restrictions. As Coasean bargaining can be interpreted as an efficient *ex post* balancing of interest between private parties, our framework is applicable to a multitude of different situations, where restrictions on the use of property rights lead to a favorable outcome. We therefore provide an additional rationale for the existence of *ex ante* restrictions on the set of bargaining outcomes such as basic rights, laws, and social norms.

Most relevant to our paper are the works by Dixit and Olson (2000), Anderlini and Felli (2006), and Robson and Skaperdas (2008). As already mentioned, Dixit and Olson (2000) and Anderlini and Felli (2006) show that Coase bargaining may be inefficient when *ex ante* transaction costs are incorporated. However, both papers omit the possibility of appropriation activity and the existence of bargaining restrictions—something we show has a counterbalancing (and possibly beneficial) effect. With respect to modeling the appropriation effort for property rights, Robson and Skaperdas (2008) use a contest structure to determine property ownership with the potential for bargaining, however they do not consider restrictions on the set of Coasean bargaining outcomes. Our main contribution, therefore, is the analysis of Coase bargaining when there exist *ex ante* transaction costs (appropriation costs) *and* restrictions on the set of bargaining outcomes. In particular, we provide a framework that investigates an all-pay auction over property rights with *ex ante* restricted bargaining.[6] The generality of our framework allows us to compare the relative advantage of delineated bargaining restrictions for traditional surplus-splitting bargaining games, such as Nash bargaining, alternating-offer bargaining, and ultimatum games.

The paper is organized as follows. In Section 2, we outline our model first without bargaining restrictions and second with the delineation of bargaining restrictions. Section 3 compares aggregate welfare under the establishment of bargaining restrictions, and Section 4 uses an all-pay auction for the endowment of property rights. Section 5 considers bargaining restrictions that are contested, while Section 6 provides further extensions. Section 7 presents a discussion about our analysis and possible applications. Section 8 provides some concluding remarks.

2 The model

2.1 A model without bargaining restrictions

Consider two agents, denoted by X and Y. Agent X participates in an activity that generates an external cost on agent Y. Agent X has the ability to reduce the level of external cost by investing in preventive measures, which we denote as $a \in [0,\bar{a}] \subset \mathbb{R}_+$, and $\bar{a}$ eliminates the externality. Preventive measures include either a reduction in activity or the use of externality-reducing technologies, which are independent of activity. The investment in preventive measures is associated with private costs to agent X denoted by $C(a)$ with $C(0) = 0 = C'(0)$, $C(\bar{a}) = \bar{C}$, $C'(a) > 0$, and $C''(a) \geq 0$. The external cost experienced by agent Y, henceforth damage, is given by $D(a)$ where $D(0) = \bar{D}$, $D'(\bar{a}) = 0 = D(\bar{a})$, $-D'(a) > 0$, and $D''(a) \leq 0$. Note that without voluntary exchange over the externality, $\bar{C}$ and $\bar{D}$ are the (mutually exclusive) costs and damages incurred by agents X

[6] For standard auctions with (unrestricted) resale see, for example, Hafalir and Krishna (2008) and references therein.

and Y, respectively. Following the logic of Coase (1960), we focus on the efficiency of voluntary exchange over an initial endowment of property rights.

Agents participate in appropriation and defensive activity for property rights over the externality. We assume the property rights over the externality to be either non-existent or highly insecure.[7] The former would apply to common-pool resources without initial endowments, where at an initial stage there exists ambiguity over the distribution of property rights. Insecure property rights arise, for example, if a resource has prior initial endowments, yet contractual incompleteness exists (Grossman and Hart, 1986; Hart and Moore, 1988). The latter interpretation is identical to the former when initial ownership has no influence on agents' defensive ability to secure property rights, e.g., through a lack of enforceability. Both interpretations are similar to that analyzed in common-pool models by de Meza and Gould (1992), Skaperdas (1992), Hirshleifer (1995), and Grossman (2001).[8]

To obtain (enforceable) control over the initial ownership of property rights, agents invest in appropriation activities denoted by $x, y \in \mathbb{R}_+$, for agents X and Y, respectively.[9] In order to reflect the standard Coasean framework, we define the game as a winner-takes-all contest, where the probability of agent X winning the initial endowment is given by $p_X(x,y)$ with the following properties $\frac{\partial p_X(x,y)}{\partial x} > 0$, $\frac{\partial^2 p_X(x,y)}{\partial x^2} \leq 0$, $\frac{\partial p_X(x,y)}{\partial y} < 0$, $-\frac{\partial^2 p_X(x,y)}{\partial y^2} \leq 0$, and ties in appropriation activities are decided randomly. For agent Y, the probability of winning is given by $p_Y(x,y) = 1 - p_X(x,y)$. Note that we allow contests with either pure or mixed strategy equilibria, for which the sum of expected equilibrium expenditures $E[x+y]$ increases in the gross value at stake. The costs of appropriation to each agent, $\kappa_X(x)$, $\kappa_Y(y)$, are assumed to be increasing, quasi-convex, continuous and twice-differentiable.

In terms of a timeline, we begin with Stage 1 where initial endowments of property rights are determined in dependence of appropriation activity. In Stage 2, voluntary exchange along the lines of Coasean bargaining occurs. Given an endowment of property rights for the externality in Stage 1, we assume agents have the ability to costlessly exchange and reach an efficient outcome (Coase, 1960). We later relax this assumption. Let us define a^* as the (*ex post*) efficient Coasean bargaining solution, so that $a^* = \min_a\{C(a) + D(a)\}$. Note that, given our assumptions on the cost curves, the allocative Coasean outcome always represents an interior solution. Obviously, this is a prerequisite for the existence of two-sided gains from trade.

We assume that prior to appropriation of the property right, both agents anticipate the outcome of the subsequent bargaining game. Following the logic of Coasean bargaining, the agent that fails to secure ownership will have to compensate the winner for the cost incurred to reach (accept) the optimal level a^*. Hence, as the loser also bears his own cost, he will incur costs corresponding to at least $C(a^*) + D(a^*)$. Additionally, the loser concedes an internalization rent R_j^u to the winner $j \in \{X, Y\}$, where superscript u designates the case without restrictions to property rights in the appropriation game. Hence, agents' expected pay-offs are as follows:

[7] Alternatively, when property rights are perfectly secure, there exists no appropriation activities and the model reduces to traditional Coasean bargaining. With the introduction of bargaining restrictions, transfers between agents are reduced, which may reduce the attractiveness for agents to participate in Coasean bargaining when there exists even small levels of transaction costs. If basic rights are established *a priori*, the efficient Coasean equilibrium may be unattainable.

[8] Our focus is on non-violent conflict. However, the emergence of property rights from anarchy has also been considered (Bush and Mayer, 1974; Buchanan, 1975; Skaperdas, 1992; Hirshleifer, 1995). See Vahabi (2011) for a survey on the political Coase theorem.

[9] Similar to Skaperdas and Syropoulos (2002), we assume contractual incompleteness at the stage of appropriation so that efforts are non-cooperatively chosen.

$$U_X^u(x) = p_X(x,y)R_X^u - [1-p_X(x,y)][C(a^*)+D(a^*)+R_Y^u] - \kappa_X(x), \tag{1}$$
$$U_Y^u(y) = p_Y(x,y)R_Y^u - [1-p_Y(x,y)][C(a^*)+D(a^*)+R_X^u] - \kappa_Y(y), \tag{2}$$

where R_j^u denotes the surplus attributed to the respective winner. Note that the overall gains from trade are calculated by subtracting the aggregated cost from activity level a^* (arising after bargaining) from the cost of the loser in a situation without Coasean bargaining, i.e. either $\bar{C}$ or $\bar{D}$. Hence, the winner's absolute share in gains from trade is given by:

$$R_X^u \equiv \bar{D} - [C(a^*)+D(a^*)] - z_Y^u \geq 0, \tag{3}$$
$$R_Y^u \equiv \bar{C} - [C(a^*)+D(a^*)] - z_X^u \geq 0, \tag{4}$$

where z_X^u and z_Y^u represents the *absolute* share of internalization rent captured by the loser, which reflects the bargaining power of agents X and Y, respectively. For example, in a Nash bargaining game, the surplus split between both agents is $z_Y^u = 1/2\,(\bar{D} - [C(a^*)+D(a^*)])$ and $z_X^u = 1/2\left(\bar{C} - [C(a^*)+D(a^*)]\right)$. Clearly, z_j^u for $j \in \{X,Y\}$ can represent a host of alternative surplus-splitting bargaining games. Further, by construct, we know that the loser's internalization of the rent, is, for example, $z_Y^u \leq \bar{D} - [C(a^*)+D(a^*)]$. Note that as the right hand side of the inequality increases, so does the (potential) absolute internalization rent of the loser.

By use of the the parameter z_j^u, we can consider cases where bargaining power is not only exogenously set prior to the contest, but, alternatively, dependent on the endogenous formation of initial endowments. For example, in many cases it is intuitive that the winning agent has a stronger bargaining position than the rival, i.e., z_X^u and z_Y^u are small. Note, however, that we can consider all intermediate cases of bargaining power and, at the extreme, model the case where the losing agent captures the entire rent, i.e., $R_X^u = 0 = R_Y^u$.

From (1) and (2), both agents always participate in voluntary exchange, as it directly follows from the assumptions placed on the convexity and concavity of cost and damages, respectively, i.e., $C(a^*)+D(a^*)+R_Y^u \leq \bar{C}$ and $C(a^*)+D(a^*)+R_X^u \leq \bar{D}$. Except for the extreme case where the loser holds full bargaining power, costless bargaining will always result in a transfer of surplus from trade to the winner.

2.2 The inclusion of bargaining restrictions

Define bargaining restrictions $[\eta,\varepsilon] \subseteq [0,\bar{a}]$ as *a priori* minimum and maximum allowed levels of the externality.[10] Note that we assume bargaining restrictions to be fully enforceable and known before Coasean bargaining commences. Hence, the winner of the appropriation game is effectively committed to concede to the loser a level of activity reduction (externality abatement), which corresponds at least to the loser's protected activity level. Furthermore, for the sake of simplicity, we abstract from potential income-effect feedbacks. With the establishment of bargaining restrictions, each agent maximizes their expected pay-off, which we denote with a superscript b:

$$U_X^b(x) = p_X[W_X] - [1-p_X][L_X], \tag{5}$$
$$U_Y^b(y) = p_Y[W_Y] - [1-p_Y][L_Y], \tag{6}$$

[10] For one-sided restrictions, the analysis directly follows by setting one bargaining restriction to a corner solution.

where W_j and L_j are the associated payoffs if agent $j \in \{X,Y\}$ wins or loses the appropriation game, respectively.

Given this set-up, three sets of situations are possible. The simplest case arises if bargaining restrictions are lax enough not to influence the allocative outcome of Coasean bargaining. The two remaining cases arise if either η or ε are set to levels precluding the first-best allocative outcome. As shown in Fig. 1, the first case arises for $[\eta,\varepsilon]$ with $0 < \eta < a^* < \varepsilon < \bar{a}$.

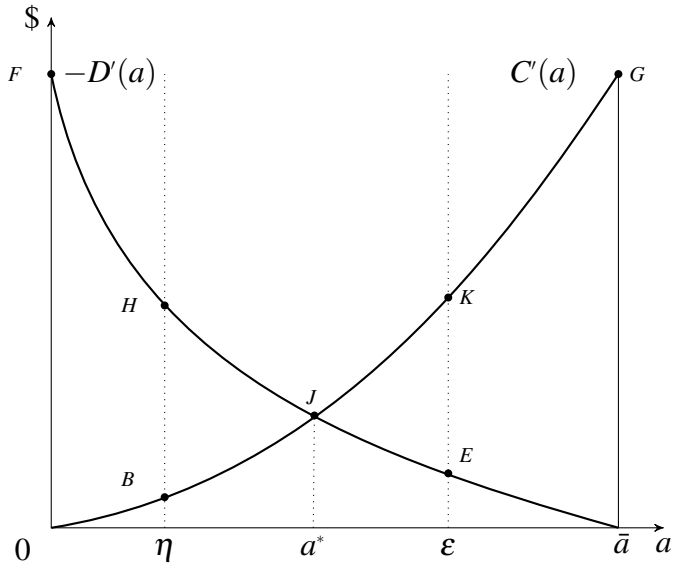

Figure 1: The delineation of bargaining restrictions η and ε.

In this case, bargaining restrictions represent a non-binding constraint on the efficient equilibrium a^*. However, although the efficient equilibrium is still feasible, bargaining restrictions alter the feasible benefits of voluntary exchange. As a consequence, while the allocative efficiency with respect to a remains unaltered, bargaining restrictions have an impact on the distribution of rents achievable through bargaining. In Fig. 1, the feasible rents are given by areas HJB and JKE for agents X and Y, respectively. Note that these rents are smaller than those achievable without bargaining restrictions, which would correspond to $FJ0$ and $JG\bar{a}$. We assume that both players anticipate this restriction on gains from trade when choosing their levels of appropriation activity x and y.

For this first case, agent X's achievable rent, in case of winning the appropriation game W_X^m, is

$$W_X^m = \underbrace{D(\eta) - D(a^*) + C(\eta) - C(a^*) - z_Y^m}_{\text{received transfer}} \quad \underbrace{-C(\eta)}_{\text{non-compensable costs}} = D(\eta) - C(a^*) - D(a^*) - z_Y^m. \qquad (7)$$

Note that compared to the case of unrestricted property rights, the transfer from Y is reduced by area $0FHB$, as agent Y is guaranteed a minimum level of preventive measure $a = \eta$. As a consequence, agent X's cost, up to this level of a, i.e., $C(\eta)$, is no longer compensable. These costs are hence incurred by agent X, even after having been granted the property right. Again, agent Y does not necessarily have to transfer the entire gains from Coasean bargaining. The gross gains from trade are deducted by a parameter z_Y^m, which is assumed to increase in the bargaining power of Y.

Correspondingly, if agent X loses the appropriation game in the first set of situations, his loss is $-L_X^m$, where

$$L_X^m = \underbrace{D(\varepsilon) - D(a^*) + C(\varepsilon) - C(a^*) - z_X^m}_{\text{transferred rent}} + \underbrace{D(a^*) - D(\varepsilon)}_{\text{compensation}} + \underbrace{C(a^*)}_{\text{costs at stake}} = C(\varepsilon) - z_X^m. \tag{8}$$

While agent X has to bear all the costs associated with the optimal level of prevention, i.e., $C(a^*)$, the compensation for Y for enduring the corresponding level of externality is reduced relative to the case of unrestricted property rights by area $\bar{a}EKG$, as agent X has a right to a minimum amount of externality, specified via $a = \varepsilon$. Obviously, this reduces gains from trade. Here, agent X retains an amount of z_X^m from the gross rent from trade achieved. The level of z_X^m is, again, dependent on agent X's bargaining power.

Given the reciprocal nature of Coasean bargaining, the same reasoning applies to the pay-offs of agent Y. The corresponding pay-off components for agent Y for the first set of situations are hence:

$$W_Y^m = \underbrace{D(\varepsilon) - D(a^*) + C(\varepsilon) - C(a^*) - z_X^m}_{\text{received transfer}} \quad \underbrace{-D(\varepsilon)}_{\text{non-compensable damages}} \quad = C(\varepsilon) - C(a^*) - D(a^*) - z_X^m, \tag{9}$$

$$L_Y^m = \underbrace{D(\eta) - D(a^*) + C(\eta) - C(a^*) - z_Y^m}_{\text{transferred rent}} + \underbrace{C(a^*) - C(\eta)}_{\text{compensation}} + \underbrace{D(a^*)}_{\text{costs at stake}} = D(\eta) - z_Y^m. \tag{10}$$

It is reasonable to assume $z_j^u \geq z_j^m$ for $j \in \{X, Y\}$, as even if the existence of bargaining restrictions were to alter a player's bargaining power, it is unlikely that rent retained in the bargaining game increases in *absolute* terms. Under this assumption, the introduction of bargaining restrictions unambiguously reduces bargaining surpluses. This is easily observed by comparing (7)-(8) with the corresponding terms in (1)-(2) and noting $\bar{C} > C(\varepsilon) + D(\varepsilon)$ and $\bar{D} > C(\eta) + D(\eta)$. Accordingly, the sum of expected *ex ante* appropriation costs is reduced.[11] Although the *absolute* size of the rent increases, this still allows for cases where the loser's *relative* bargaining power increases. Thus we can also model cases where a loser's protection provided by bargaining restrictions may increase their relative bargaining power.

Concluding our discussion of bargaining restrictions as a non-binding constraint, note that each party is required, irrespective of winning or losing initial ownership rights, to incur part of its cost, i.e., either $C(\eta)$ or $D(\varepsilon)$ is borne by respective agents without being compensated. This has two effects. First, the surplus won is lowered by the amount of the cost that must be incurred. Second, the loser has a lower transfer: the winner must privately incur some of the cost determined by bargaining restrictions.

The second class of situations that may arise under the existence of bargaining restrictions occurs if the upper restriction ε on a is restrictive enough to preclude the first-best optimal level, i.e., if $\eta < \varepsilon < a^*$. This is shown in Fig. 2.

Obviously, under this case, bargaining only arises if the property right is attributed to agent X, as there are no gains from trade possible in the opposite case. In Fig. 2, the potential gains from trade, if agent X is attributed the property right, is given by area $HKEB$. Under this case, expected gross rents for agent X in case of winning W_X^r, respectively losing L_X^r, are given by:

[11] Either the level of appropriation is lowered or, for mixed-strategy games, the support on which appropriation activity is chosen will be reduced, therefore expected appropriation activity decreases.

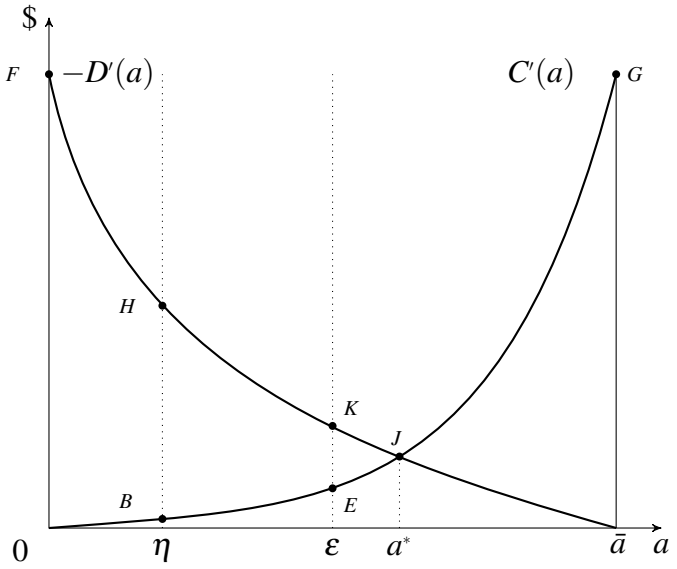

Figure 2: Bargaining restrictions η and ε below a^*.

$$W_X^r = D(\eta) - D(\varepsilon) - C(\varepsilon) + C(\eta) - z_y^r - C(\eta) = D(\eta) - D(\varepsilon) - C(\varepsilon) - z_y^r, \tag{11}$$
$$L_X^r = C(\varepsilon), \tag{12}$$

where z_Y^r is ultimately determined by the bargaining power of agent Y for $\varepsilon < a^*$. The logic for pay-offs, in case of agent X winning, is similar to the one with non-binding constraints. However, the restriction of the bargaining space renders gains from trade impossible in case the property right is assigned to agent Y: the allocative inefficiency is measured by area KJE. Here, agent X's costs are constrained by the binding restriction ε, i.e., $C(\varepsilon)$.

The corresponding levels W_Y^r and L_Y^r for agent Y are analogously:

$$W_Y^r = -D(\varepsilon), \tag{13}$$
$$L_Y^r = C(\varepsilon) - C(\eta) + D(\eta) - D(\varepsilon) - C(\varepsilon) + C(\eta) - z_y^r + D(\varepsilon) = D(\eta) - z_y^r. \tag{14}$$

When agent Y wins the endowment, she still has to incur $D(\varepsilon)$, without any Coasean bargaining. Furthermore, in case of agent Y losing the contest, the compensation required to incentivize agent X to change the level of a reduces to $C(\varepsilon) - C(\eta)$, as agent X is committed to at least incur $C(\eta)$ in all cases. Similar to the previous case, we assume throughout that $z_j^u \geq z_j^r$ for $j \in \{X, Y\}$.

As shown in Fig. 3, the third class of situations arises if the lower restriction η on a is restrictive enough to preclude the first-best optimal level, i.e., if $\eta > a^*$.

In this case, it is the protection of agent Y that represents a binding constraint on the optimization over a. This case is the opposite of the second class of situations discussed above. Yet, due to the reciprocal nature of the Coasean bargaining game, an analogous reasoning applies as above. Denoting this third class of situations with index l the corresponding pay-off components are:

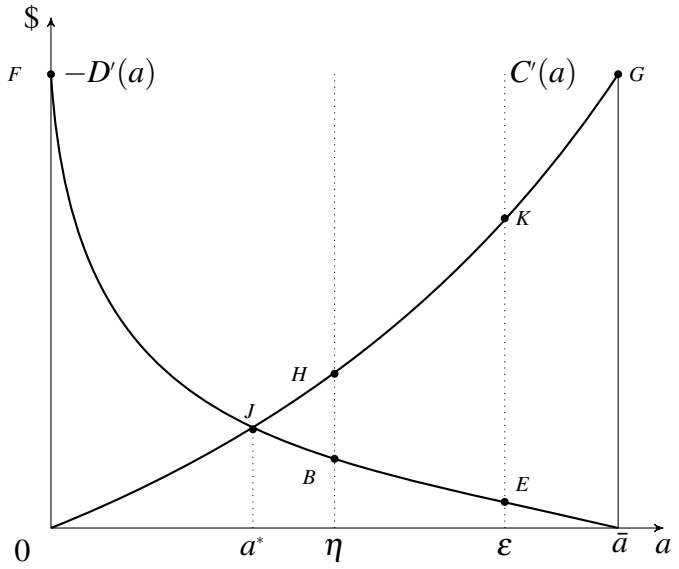

Figure 3: Bargaining restrictions η and ε above a^*.

$$W_X^l = -C(\eta), \tag{15}$$
$$L_X^l = D(\eta) - D(\varepsilon) + C(\varepsilon) - C(\eta) - D(\eta) + D(\varepsilon) - z_x^l + C(\eta) = C(\varepsilon) - z_x^l, \tag{16}$$
$$W_Y^l = C(\varepsilon) - C(\eta) - D(\eta) + D(\varepsilon) - z_x^l - D(\varepsilon) = C(\varepsilon) - C(\eta) - D(\eta) - z_x^l, \tag{17}$$
$$L_Y^l = -D(\eta), \tag{18}$$

and z_X^l is determined by the bargaining power of agent X for $\eta > a^*$. Similar to the second case, we assume $z_j^u \geq z_j^l$ for $j \in \{X,Y\}$.

Under the two latter cases, where reaching the Coasean equilibrium is precluded by bargaining restrictions, an interesting trade-off arises. Given that in these cases aggregate costs associated with the chosen level of prevention exceed the minimum, i.e., $C(\eta)+D(\eta) > C(a^*)+D(a^*)$ and $C(\varepsilon)+D(\varepsilon) > C(a^*)+D(a^*)$, bargaining restrictions are associated with allocative inefficiency. On the other hand, the bargaining surplus for both agents is reduced, which reduces the associated appropriation costs. It is, therefore, *a priori* not clear whether, in these cases, bargaining restrictions are Pareto or welfare improving.

Using (5) and (6), summing over the pay-off components presented in (7)-(18), and taking the appropriation costs $\kappa_j(\cdot)$ into account, the expected pay-off functions for agents X and Y are:

$$U_X^b(x) = p_X[D(\eta) - C(a^*) - D(a^*) - z_Y^m] - [1-p_X][C(\varepsilon) - z_X^m] - \kappa_X(x), \tag{19}$$
$$U_Y^b(y) = p_Y[D(\eta) - C(a^*) - D(a^*) - z_Y^m] - [1-p_Y][D(\eta) - z_Y^m] - \kappa_Y(y), \tag{20}$$

where $0 < \eta < a^* < \varepsilon < \bar{a}$. When $\eta < \varepsilon < a^*$, we have:

$$U_X^b(x) = p_X[D(\eta) - D(\varepsilon) - C(\varepsilon) - z_y^r] - [1-p_X][C(\varepsilon)] - \kappa_X(x), \tag{21}$$
$$U_Y^b(y) = p_Y[-D(\varepsilon)] - [1-p_Y][D(\eta) - z_Y^r] - \kappa_Y(y), \tag{22}$$

and finally, for the case $\eta > a^*$, we have:

$$U_X^b(x) = p_X[-C(\eta)] - [1-p_X][C(\varepsilon) - z_X^l] - \kappa_X(x), \tag{23}$$
$$U_Y^b(y) = p_Y[C(\varepsilon) - C(\eta) - D(\eta) - z_X^l] - [1-p_Y][D(\eta)] - \kappa_Y(y). \tag{24}$$

It is evident that Pareto- and welfare-improving aspects of bargaining restrictions depend on where they are set. We now turn our attention to the optimal configuration of bargaining restrictions.

3 The configuration of bargaining restrictions

It is clear from above that given full information, the results from the delineation of bargaining restrictions are trivial. Bargaining restrictions are set to minimize aggregate appropriation effort. Therefore, under full information, a welfare-maximizing authority would set the bargaining restrictions such that $\eta = \varepsilon = a^*$. Obviously, this would result in the same level of welfare as the efficient Coasean equilibrium, while appropriation effort of both players is reduced to zero. Yet, in most situations where bargaining restrictions or other superordinated rules are set, the authorities cannot anticipate all potential situations to which these rules will be applied in the future. To reflect the situation of an authority setting general rules without perfect foresight, we assume in the following that the authority is uncertain about the actual costs necessary for internalization and has the power to *ex ante* delineate bargaining restrictions. The authority is *a priori* uncertain about the costs and damages associated with both agents. For simplicity, we assume that uncertainty is only associated with agent X's cost structure. Note that all results derived below also hold if we were to additionally introduce uncertainty about agent Y's damages, because the actual variable of interest is the *ex post* efficient level of prevention a^*.

The authority's uncertainty is given by the random variable θ, which is on the support $[\underline{\theta}, \overline{\theta}]$. The pdf is given by $f(\theta)$, and the corresponding cdf is $F(\theta)$. The corresponding cost function is hence $C(a(\theta), \theta)$ with $\frac{\partial C(a,\theta)}{\partial \theta} < 0$ over $[\underline{\theta}, \overline{\theta}]$. We plausibly assume that maximum possible costs are subject to uncertainty and hence denoted $\bar{C}(\theta)$, while the costs of the first unit of a remain unaffected, i.e., $C(0,\theta) = 0 = C'(0,\theta)$.

Note that the uncertainty is resolved at the time of the Coasean bargaining situation. Hence, for any realization of θ the *ex post* first-best optimal level of a is implicitly determined by

$$-D'(a^*(\theta)) = C'(a^*(\theta), \theta). \tag{25}$$

The authority has to set bargaining restrictions levels η and ε, that are *ex ante* optimal. To reflect the authority's optimization problem, it is useful to define θ_ε, as the level of θ for which $a^*(\theta_\varepsilon) = \varepsilon$, where $a^*(\theta_\varepsilon)$ is implicitly defined by

$$-D'(a^*(\theta_\varepsilon)) = C'(a^*(\theta_\varepsilon), \theta_\varepsilon) \equiv -D'(\varepsilon) = C'(\varepsilon, \theta_\varepsilon). \tag{26}$$

Analogously, we define θ_η, as the level of θ for which $a^*(\theta_\eta) = \eta$, where $a^*(\theta_\eta)$ is implicitly defined by

$$-D'(a^*(\theta_\eta)) = C'(a^*(\theta_\eta), \theta_\eta) \equiv -D'(\eta) = C'(\eta, \theta_\eta). \tag{27}$$

With these definitions, and taking into account uncertainty as well as agents' expected pay-off functions (19)-(24), for any chosen level of η and ε, aggregate expected welfare is

$$
\begin{aligned}
W^b = &- \int_{\theta_\varepsilon}^{\theta_\eta} [C(a^*(\theta),\theta) + D(a^*(\theta),\theta) + \kappa_X(E[x_b(\theta)]) + \kappa_Y(E[y_b(\theta)])] f(\theta)\,\mathrm{d}\theta \qquad (28)\\
&- \int_{\theta_\eta}^{\bar{\theta}} [C(\eta,\theta) + D(\eta,\theta) + \kappa_X(E[x_b(\theta)]) + \kappa_Y(E[y_b(\theta)])] f(\theta)\,\mathrm{d}\theta\\
&- \int_{\underline{\theta}}^{\theta_\varepsilon} [C(\varepsilon,\theta) + D(\varepsilon,\theta) + \kappa_X(E[x_b(\theta)]) + \kappa_Y(E[y_b(\theta)])] f(\theta)\,\mathrm{d}\theta
\end{aligned}
$$

where $(x_b(\theta), y_b(\theta))$ denote the level of the respective appropriation activities optimally chosen by both agents dependent on the realization of θ. By use of the expectation operator in (28), we take into account the possibility of a mixed-strategy Nash equilibrium.

The upper integral shows aggregate welfare when bargaining restrictions are chosen so that, under the realization of uncertainty, the efficient externality level a^* lies between the two bounds, $\eta \leq a^* \leq \varepsilon$. The remaining integrals represent cases where realization of the efficient equilibrium solution to the Coasean bargaining lies beyond one of the bargaining restrictions. That is, for these cases bargaining restrictions are a binding constraint and the efficient level of a is unattainable. For a benevolent dictator maximizing aggregate welfare, bargaining restrictions are set so that $\eta^*, \varepsilon^* \in \arg\min\{W^b\}$, where W^b is given in (28). Hence, the welfare maximizing bargaining restrictions are chosen to balance the marginal change in expected aggregate appropriation costs (i.e., $E[\kappa_X + \kappa_Y]$) with the marginal change in expected costs and damages.

3.1 Comparison

To observe how the inclusion of bargaining restrictions over an externality may improve welfare, first note that by introducing uncertainty into the pay-off functions (1) and (2), their aggregation yields the expected welfare

$$
W^u = - \int_{\underline{\theta}}^{\bar{\theta}} [C(a^*(\theta),\theta) + D(a^*(\theta),\theta) + \kappa_X(E[x^*(\theta)]) + \kappa_Y(E[y^*(\theta)])] f(\theta)\,\mathrm{d}\theta. \qquad (29)
$$

By defining Δ as the difference in welfare between Coasean bargaining with and without bargaining restrictions, relative welfare can be expressed as

$$
\begin{aligned}
\Delta &= W^b - W^u \qquad (30)\\
&= \int_{\underline{\theta}}^{\bar{\theta}} [\kappa_X(E[x^*(\theta)]) - \kappa_X(E[x_b(\theta)]) + \kappa_Y(E[y^*(\theta)]) - \kappa_Y(E[y_b(\theta)])] f(\theta)\,\mathrm{d}\theta\\
&+ \int_{\underline{\theta}}^{\theta_\varepsilon} [C(a^*(\theta),\theta) + D(a^*(\theta)) - C(\varepsilon,\theta) - D(\varepsilon)] f(\theta)\ \mathrm{d}\theta\\
&+ \int_{\theta_\eta}^{\bar{\theta}} [C(a^*(\theta),\theta) + D(a^*(\theta)) - C(\eta,\theta) - D(\eta)] f(\theta)\,\mathrm{d}\theta.
\end{aligned}
$$

The upper integral is the difference in appropriation costs when bargaining restrictions are established. Note that this integral is positive for most standard bargaining positions. As mentioned earlier, it is, however, possible for this integral to be negative due to specific, and possibly unrealistic, bargaining positions. The second and third integrals, which are always negative, represent the allocative inefficiency in case the realized first-best optimum lies beyond the boundaries set by the bargaining restrictions due to the *ex ante* setting of bargaining restrictions by the author-

ity. Therefore, whether bargaining restrictions improve welfare or not depends on the trade-off between lower appropriation costs and the potential to create allocative inefficiencies.

It follows that the preferability of bargaining restrictions also depends on the support and the form of pdf $f(\theta)$. For example, if $C'(a,\underline{\theta}) < \infty$ it is always advantageous to grant a positive level of bargaining restrictions to the victim, as in this case $a^*(\theta) = 0$ is precluded for any realization of θ. As a consequence, setting $\eta = a^*(\underline{\theta})$ always improves welfare compared to bargaining without bargaining restrictions. Analogously, if $C'(a,\overline{\theta}) > 0$ it is always advantageous to at least grant protection corresponding to $\varepsilon = a^*(\overline{\theta})$ to the externality generator. Obviously, further predictions can be made with additional assumptions on the form of the pdf. For example, if we assume $f(\theta)$ to be unimodal, bargaining restrictions can increase in stringency and still remain preferable, given relatively small tails in the density functions.

4 Appropriation through an all-pay auction

In this section, we add further structure to our model by allowing the endowment of property rights to be determined by a first-price all-pay auction. Generally, this would reflect appropriation of property rights within a 'war of attrition.' A structured game could hence reflect appropriation via corruption, a law suit, or political influence (Konrad, 2009). Later in the paper, we provide alternative allocation mechanisms and compare our results.

In the first-price all-pay auction with complete information, the party with the largest appropriation effort obtains the property right with probability 1 with costs $\kappa_X(x) = x$ and $\kappa_Y(y) = y$. That is, for agent X, the probability of winning is

$$p_X(x,y) = \begin{cases} 1 & \text{if } x > y \\ \frac{1}{2} & \text{if } x = y \\ 0 & \text{if } x < y \end{cases} \tag{31}$$

with $p_Y(x,y) = 1 - p_X(x,y)$. The characterization of equilibria is well known (Hillman and Riley, 1989; Baye et al., 1996; Konrad, 2009). In particular, for this class of games, the Nash equilibrium is in mixed strategies which are determined by each agents' cumulative bid distribution function. Under these assumptions expected pay-offs of $p_i W_i + (1-p_i)L_i$, with $i \in \{X,Y\}$, can be re-arranged to:

$$p_X v_X - L_X - x, \tag{32}$$

$$p_Y v_Y - L_Y - y, \tag{33}$$

where $v_i = W_i + L_i$ denotes the gross value to agent i of winning relative to not participating in the contest. Assuming $v_X \geq v_Y$, the equilibrium mixed strategies are described by

$$G_X(x) = \begin{cases} \frac{x}{v_Y} & \text{for } x \in [0, v_Y] \\ 1 & \text{for } x > v_Y \end{cases} \tag{34}$$

and

$$G_Y(y) = \begin{cases} \left[1 - \frac{v_Y}{v_X}\right] + \frac{y}{v_X} & \text{for } x \in [0, v_Y] \\ 1 & \text{for } y > v_Y. \end{cases} \tag{35}$$

The expected pay-offs of both players are hence:

$$E[U_X] = -L_X + G_Y(x)v_X - x = -L_X + v_X - v_Y, \tag{36}$$
$$E[U_Y] = -L_Y + G_X(y)v_Y - y = -L_Y. \tag{37}$$

Note that in the set-up presented here, θ only realizes after appropriation. Hence, for appropriation unrestricted by bargaining restrictions with pay-off functions (1) and (2) with uncertain $C(a)$, we have

$$\begin{aligned} v_X^u = v_Y^u &= E\left[D(a^*) + C(a^*) + R_X^u + R_Y^u\right] \\ &= E\left[\bar{D} + \bar{C} - D(a^*) - C(a^*) - z_X^u - z_Y^u\right]. \end{aligned} \tag{38}$$

Introducing cost uncertainty into equations (7) to (18), we calculate the corresponding values for $v_X^b = v_Y^b$ for the case of appropriation being restricted by bargaining restrictions $[\eta, \varepsilon]$, which is

$$\begin{aligned} v_X^b = v_Y^b = &\int_{\theta_\varepsilon}^{\theta_\eta} \left[C(\varepsilon,\theta) + D(\eta) - D(a^*(\theta),\theta) - C(a^*(\theta),\theta) - z_x^m - z_y^m\right] f(\theta)\,\mathrm{d}\theta \\ &+ \int_{\theta_\eta}^{\bar{\theta}} \left[C(\varepsilon,\theta) - C(\eta,\theta) - z_x^l(\theta)\right] f(\theta)\,\mathrm{d}\theta + \int_{\underline{\theta}}^{\theta_\varepsilon} \left[D(\eta) - D(\varepsilon) - z_y^r(\theta)\right] f(\theta)\,\mathrm{d}\theta. \end{aligned} \tag{39}$$

Interestingly, for both cases, symmetry in valuations is a direct result of Coasean bargaining: the creation of an equilibrium price for the optimal level of prevention must, by definition, be identical for both parties. Therefore, the expected pay-offs for the unrestricted case are:

$$E[U_X^u(x)] = -L_X^u = E\left[-\bar{C} + z_X^u\right], \tag{40}$$
$$E[U_Y^u(y)] = -L_Y^u = E\left[-\bar{D} + z_Y^u\right]. \tag{41}$$

Analogously, expected pay-offs for the restricted case are:

$$E[U_X^b(x)] = -L_X^b = -E[C(\varepsilon)] + \int_{\theta_\varepsilon}^{\theta_\eta} z_X^m(\theta) f(\theta)\,\mathrm{d}\theta + \int_{\theta_\eta}^{\bar{\theta}} z_X^l(\theta) f(\theta)\,\mathrm{d}\theta, \tag{42}$$
$$E[U_Y^b(y)] = -L_Y^b = -D(\eta) + \int_{\theta_\varepsilon}^{\theta_\eta} z_Y^m(\theta) f(\theta)\,\mathrm{d}\theta + \int_{\underline{\theta}}^{\theta_\varepsilon} z_Y^r(\theta) f(\theta)\,\mathrm{d}\theta. \tag{43}$$

Note that, for generality, we allow the rent captured by the loser, i.e., the respective z_j, to vary with cost uncertainty: as the bargaining surplus is uncertain, it is possible agents' bargaining positions are also inherently uncertain. For example, a realistic bargaining position is influenced by both the initial ownership of property rights *and* size of the surplus. Clearly, it is easy to show cases where the bargaining positions are independent of cost uncertainty.

4.1 Welfare comparisons under an all-pay auction

Expected welfare for the unrestricted case is given by the summation over (40) and (41). For the case under bargaining restrictions, welfare is determined by the sum of pay-offs given by (42)

and (43). The difference of expected aggregate welfare with and without bargaining restrictions is

$$\begin{aligned}\Delta &= E[U_X^b(x) + U_Y^b(y) - U_X^u(x) - U_Y^u(y)] \\ &= \bar{D} - D(\eta) + E\left[\bar{C} - C(\varepsilon)\right] \\ &- E\left[z_X^u + z_Y^u\right] + \int_{\underline{\theta}}^{\theta_\varepsilon} z_Y^r(\theta) f(\theta)\,\mathrm{d}\theta + \int_{\theta_\varepsilon}^{\theta_\eta} [z_X^m(\theta) + z_Y^m(\theta)] f(\theta)\,\mathrm{d}\theta + \int_{\theta_\eta}^{\bar{\theta}} z_X^l(\theta) f(\theta)\,\mathrm{d}\theta.\end{aligned} \tag{44}$$

The above Δ helps to illustrate a main finding of our paper. The relative gain from establishing bargaining restrictions increases in the expected maximum costs and damages experienced by both agents, and decreases in the expected cost (damage) at the level of the respective bargaining restriction. Obviously, these costs are always smaller than the maximum costs. When the surplus is split via Nash bargaining, it is easily shown that Δ is non-negative, so that bargaining restrictions result in welfare improvements. In fact, bargaining restrictions only perform worse if $E\left[z_X^u + z_Y^u\right]$ is particularly large, i.e., if the loser's bargaining power in the unconstrained case is particularly large. In the often-discussed simple case where the winner of the property rights holds all the bargaining power, i.e., $z_j^u = 0$, Δ is unambiguously positive.

The possible levels of z_j^u are delimited by:

$$z_X^u(\theta) \leq \bar{D} - C(a^*(\theta), \theta) - D(a^*(\theta)), \tag{45a}$$
$$z_Y^u(\theta) \leq \bar{C}(\theta) - C(a^*(\theta), \theta) - D(a^*(\theta)). \tag{45b}$$

Similarly, with bargaining restrictions, the upper limits in rent captured by the loser are given by:

$$z_X^m(\theta) \leq C(\varepsilon, \theta) - C(a^*(\theta), \theta) - D(a^*(\theta)) + D(\varepsilon), \tag{46a}$$
$$z_Y^m(\theta) \leq D(\eta) - C(a^*(\theta), \theta) - D(a^*(\theta)) + C(\eta, \theta), \tag{46b}$$
$$z_Y^r(\theta) \leq D(\eta) - D(\varepsilon) - C(\varepsilon, \theta) + C(\eta, \theta), \tag{46c}$$
$$z_X^l(\theta) \leq C(\varepsilon, \theta) - C(\eta, \theta) - D(\eta) + D(\varepsilon). \tag{46d}$$

Maximum levels of rent attributed to the loser arise if (45)-(46) each hold with equality. In this latter case, the argument for implementing bargaining restrictions appears weak: bargaining restrictions help restrict the contestable bargain surpluses, which are reduced to zero. Yet, in this case, setting bargaining restrictions to a level where $E[C(\eta)] = E[C(\varepsilon)] = E[C(a^*)]$ and $D(\eta) = D(\varepsilon) = E[D(a^*)]$ leads to

$$\Delta = E[C(a^*) + D(a^*)] + \int_{\theta_\varepsilon}^{\theta_\eta} [z_X^m(\theta) + z_Y^m(\theta)] f(\theta)\,\mathrm{d}\theta > 0. \tag{47}$$

Hence, even if all the rent is captured by the loser, setting both bargaining restrictions to the expected optimal level of prevention (i.e., $\eta = \varepsilon = a^*$) is, *ex ante*, more efficient than not restricting property rights at all. Hence, entirely precluding bargaining via bargaining restrictions can be unambiguously welfare improving compared to a situation without restrictions on property rights.

Note that under specific conditions bargaining restrictions not only increase aggregated welfare, but can also lead to actual Pareto improvements for each actor. By comparing (40) with (42) and (41) with (43), we can state the conditions under which the delineation of bargaining

restrictions results in *ex ante* Pareto improvements. Bargaining restrictions are associated with Pareto improvements if:

$$E[\bar{C} - z_X^u] \geq E[C(\varepsilon)] - \int_{\theta_\varepsilon}^{\theta_\eta} z_X^m(\theta) f(\theta)\,\mathrm{d}\theta - \int_{\theta_\eta}^{\bar{\theta}} z_X^l(\theta) f(\theta)\,\mathrm{d}\theta, \tag{48}$$

$$\bar{D} - E[z_Y^u] \geq D(\eta) - \int_{\theta_\varepsilon}^{\theta_\eta} z_Y^m(\theta) f(\theta)\,\mathrm{d}\theta - \int_{\underline{\theta}}^{\theta_\eta} z_Y^r(\theta) f(\theta)\,\mathrm{d}\theta. \tag{49}$$

From (48) and (49), it is clear that the slopes of the cost and damage function, as well as the bargaining powers, determines the existence of Pareto improvements. Intuitively, bargaining restrictions Pareto dominate when the costs of implementing the rights ($C(\varepsilon,\theta)$, $D(\eta)$) are relatively small and expected bargaining power of the loser is larger under bargaining restrictions. In particular, for all realizations of θ on the support $[\underline{\theta},\bar{\theta}]$, the delineation of bargaining restrictions Pareto dominates the exclusion of bargaining restrictions when $E[\bar{C} - z_X^u] \geq E[C(\varepsilon)]$ and $\bar{D} - E[z_Y^u] \geq D(\eta)$. Given that $E[\bar{C}] \geq E[C(\varepsilon)]$ and $\bar{D} \geq D(\eta)$, Pareto dominance depends on relatively small z_j^u for $j \in \{X,Y\}$. As discussed earlier, for the traditional Coasean argumentation, both z_X^u and z_Y^u, would be set to zero, resulting in unambiguous Pareto dominance.

4.2 Optimal bargaining restrictions and the veil of uncertainty

Given that there exist a large set of situations where bargaining restrictions increase welfare, the authority constituting such restrictions might also aim for setting these restrictions at their *ex ante* optimal level. This would be the case if the authority acted from the normative stance of a benevolent dictator. Obviously, in order to derive optimal bargaining restrictions the authority would then need to have a clear notion over the specifications of expected cost and damage functions. In the following we showcase such an optimization for the prominent case of linear marginal costs and damages.

The slope of the linear marginal costs of prevention incurred by agent X is assumed to be of the form $m+\theta$, with $m > 0$, and the error term θ ranging in the interval $[-h,h]$ with $h < m$. We assume θ to be uniformly distributed such that $E[\theta] = 0$ and $f(\theta) = \frac{1}{2h}$. We continue to assume $E[C(0)] = 0 = E[C'(0)]$, $E[C'(a)] > 0]$, and $E[C''(a)] \geq 0$. The specification of the external cost experienced by agent Y is to fulfill $D(0) = \bar{D}$, $D'(\bar{a}) = 0 = D(\bar{a})$, $-D'(a) > 0$, and $D''(a) \leq 0$.

These conditions are met by the following functional forms:

$$D(a) = \frac{(b - n\cdot a)^2}{2n},$$
$$C(a) = \frac{1}{2}(m+\theta)a^2,$$

Given these specifications, the *ex post* and *ex ante* optimal levels of activity a are

$$a^* = \frac{b}{m+n+\theta}\ , \text{ and } E[a^*] = \frac{b}{m+n}.$$

Given these specifications, the authority *ex ante* maximizes the sum of expected payoffs of both actors, i.e. $E[U_X^b(x) + U_Y^b(y)]$, as given by (42) and (43). Assuming Nash bargaining after

stipulation of property rights, the losers' respective shares of internalization rent are:

$$
\begin{aligned}
z_X^m(\theta) &= \frac{1}{2}\left(C(\varepsilon,\theta) - C(a^*(\theta),\theta) - D(a^*(\theta)) + D(\varepsilon)\right),\\
z_Y^m(\theta) &= \frac{1}{2}\left(D(\eta) - C(a^*(\theta),\theta) - D(a^*(\theta)) + C(\eta,\theta)\right),\\
z_Y^r(\theta) &= \frac{1}{2}\left(D(\eta) - D(\varepsilon) - C(\varepsilon,\theta) + C(\eta,\theta)\right),\\
z_X^l(\theta) &= \frac{1}{2}\left(C(\varepsilon,\theta) - C(\eta,\theta) - D(\eta) + D(\varepsilon)\right),
\end{aligned}
$$

Hence, the rent is shared equally between both actors. Using the specifications above to specify (26) and (27) yields

$$
\begin{aligned}
\theta_\varepsilon &= \frac{b-(m+n)\varepsilon}{\varepsilon},\\
\theta_\eta &= \frac{b-(m+n)\eta}{\eta}.
\end{aligned}
$$

Substitution of the specifications above into (42) and (43) and taking the partial derivatives yields

$$
\begin{aligned}
\frac{\partial W}{\partial \varepsilon} &= \frac{b^2 - 2b(m+n)\varepsilon + \left(h^2 - 4hm + (m+n)^2\right)\varepsilon^2}{4h\varepsilon},\\
\frac{\partial W}{\partial \eta} &= -\frac{b^2 - 2b(2h+m+n)\eta + \left(h^2 + 4hn + (m+n)^2\right)\eta^2}{4h\eta}.
\end{aligned}
$$

Note that, as expected, the derivative of each restriction is completely independent of the other. Hence, by taking the first order conditions it is easy to identify the optimal levels of both restrictions ε^* and η^*, given by

$$
\begin{aligned}
\varepsilon^* &= \frac{b}{m+n-\sqrt{h(4m-h)}},\\
\eta^* &= \frac{b}{m+n+2h-\sqrt{h(3h+4m)}}.
\end{aligned}
$$

Note that the case of certain costs of prevention presented is reflected when setting h equal to zero, i.e. $\theta = 0$. In this case, both restrictions coincide with the (certain) allocatively efficient level a^*, i.e. $\varepsilon^* = \eta^* = a^* = \frac{b}{m+n}$, which again exemplifies our considerations on optimal restrictions under certainty laid out in Section 3.

Note that such *ex ante* optimal levels of bargaining restrictions can arise without the assumption of a benevolent dictator. Optimal bargaining restrictions will also be chosen if decided upon unanimously by actors acting under a veil of uncertainty (Buchanan and Tullock, 1962). In this case, at the stage of bargaining restriction formation all actors are *a priori* uncertain with respect to the position they will ultimately occupy within society. In the context of the framework presented here, it would hence be unclear whether an agent will ultimately be the originator of an externality or the damaged party. As under the veil of uncertainty, ending up in either of these

positions is equiprobable, all constituting agents will agree to levels of bargaining restrictions that minimize the costs incurred within both of these positions. As the conditions for Pareto improvements for each of these positions also yield the maximum in aggregated welfare, bargaining restrictions devised under the veil of uncertainty yield the same levels of bargaining restrictions as if conceived by a benevolent dictator.

5 Contestable bargaining restrictions

The assumptions that bargaining restrictions are set exogenously or chosen by a benevolent authority (decentralized agents under a veil of uncertainty) are reasonable when one considers that appropriation effort is, more often than not, chosen within a society that has historical *ex ante* restrictions. As such, agents take the 'rules of the game' as given, for example, customs or social mores: they may change throughout time, but from the perspective of the agent attempting to appropriate property rights, social norms simply limit the gains from trade.

It is, however, entirely possible that agents contest both the delineation of bargaining restrictions and initial property rights allocation. To this end, we now consider contestable bargaining restrictions. As we show below, contestable bargaining restrictions continue to improve aggregate welfare, however, Pareto improvements do not exist.

Consider the following sequential model. In stage -1, agents choose effort to determine whether or not η is formed. In stage 0, a similar struggle occurs for ε.[12] After bargaining restrictions have (not) been delineated, agents attempt to appropriate property rights and then participate in Coasean bargaining, as previously outlined. Allowing the order of bargaining restrictions to be reversed provides similar, but opposite, results from what is presented here.[13] We solve the game as a subgame-perfect Nash equilibrium. Therefore, as we know the general structure of payoffs from $t = 1$ onwards, we start with the competition over ε.

First note the expected utilities of agents when *only* η is delineated:

$$E[U_X^{\eta}] = -E[\overline{C}] + \int_{\underline{\theta}}^{\theta_\eta} z_X^{u}(\theta) f(\theta)\,\mathrm{d}\theta + \int_{\theta_\eta}^{\overline{\theta}} \hat{z}_X(\theta) f(\theta)\,\mathrm{d}\theta, \tag{50}$$

$$E[U_Y^{\eta}] = -D(\eta) + \int_{\underline{\theta}}^{\theta_\eta} z_Y^{m}(\theta) f(\theta)\,\mathrm{d}\theta. \tag{51}$$

Note that a new bargaining power for agent X has been denoted by $\hat{z}_x(\theta)$, which is the bargaining power of the losing agent X when the associated η makes it impossible to achieve the efficient equilibrium solution. This bargaining power differs from the previous non-attainment bargaining powers as now there is only one bargaining restriction. Similarly, expected utilities are calculated for agents when *only* ε is delineated:

[12] The sequential game here assumes a discrete choice between the delineation of bargaining restrictions. A relatively simple extension incorporates bargaining restrictions determined over a continuum, similar to endogenous public policy contests derived in Epstein and Nitzan (2007).

[13] Instead of contestability over both bargaining restrictions, it is also possible to envisage a case where a single bargaining restriction is established by agents' appropriation effort. We find a similar result to that presented here: even when bargaining restrictions are contestable, aggregate welfare improves. In this case, the establishment of one bargaining restriction—either η or ε— will result in improvements in welfare.

$$E[U_X^{\varepsilon}] = -E[C(\varepsilon)] + \int_{\theta_\varepsilon}^{\overline{\theta}} z_X^m(\theta) f(\theta)\,\mathrm{d}\theta, \tag{52}$$

$$E[U_Y^{\varepsilon}] = -\overline{D} + \int_{\theta_\varepsilon}^{\overline{\theta}} z_Y^u(\theta) f(\theta) + \int_{\underline{\theta}}^{\theta_\varepsilon} \hat{z}_Y(\theta) f(\theta)\,\mathrm{d}\theta. \tag{53}$$

where, similarly, $\hat{z}_Y(\theta)$ represents the losing agent Y's bargaining power when ε is established and the efficient equilibrium outcome is non-attainable.

We must compare these two possible outcomes, denoted above, with the expected utilities associated with the delineation of both bargaining restrictions (42)-(43), as well as the case without any bargaining restrictions (40)-(41). Clearly, we want to focus on the cases where agents prefer their delineated bargaining restriction over no bargaining restriction as well as attempting to avoid the delineation of a rival's bargaining restriction. The former is clear: a bargaining restriction for each agent will reduce their expected costs. The latter is beneficial to each agent as their potential compensation when winning will be larger without a rival's bargaining restriction. Comparison of the associated expected utilities reveals a number of intuitive assumptions that need to be met for this game to be rational, which are similar to those placed in the previous analysis. As before, we require $E[\overline{C} - C(\varepsilon)]$ to be sufficiently large. The cost function can either be 'sufficiently convex' or the delineated ε is sufficiently small. It is clear that this measures the simple benefits of a bargaining restriction and if this is sufficiently low, agents will not contest bargaining restrictions. Also assumed throughout the paper, we would expect the loser's bargaining power to be increasing in the size of the winner's bargaining space. Recall that the bargaining power is in terms of absolute rent and not a relative or proportional gain. For a sufficiently large $E[\overline{C} - C(\varepsilon)]$ it is relatively simple to show, but left out for sake of brevity, that agent X will always place a higher valuation on winning a bargaining restriction and have the greatest incentive to obtain a bargaining restriction in *every* stage of this game. Note that this is due to the sequential nature of the game. If the timing was reversed, so that the bargaining restriction ε was contested first and η second, we would observe the opposite results and the associated assumption needed would require a sufficiently large $\overline{D} - D(\eta)$. In this respect a second-mover advantage exists over the contestability of bargaining restrictions.

Let us begin with the Nash-subgame where η has already be delineated and ε is contested. The contest, then, is over the delineation (or not) of ε. Formally, the game is as follows:

$$E[\tilde{U}_X] = p_X E\left[U_X^b(x)\right] + (1 - p_X) E\left[U_X^{\eta}\right], \tag{54}$$

$$E[\tilde{U}_Y] = p_Y E\left[U_Y^{\eta}\right] + (1 - p_Y) E\left[U_Y^b(y)\right], \tag{55}$$

where $E[U_X^b(x)]$ and $E[U_Y^b(y)]$ are given by (42) and (43), and $E[U_X^{\eta}]$ and $E[U_Y^{\eta}]$ are given by (50) and (51), respectively. Clearly, agent X's payoff is increasing with the introduction of ε whereas agent Y's payoff is decreasing. Given our initial assumptions, expected utilities are given by:

$$E[\tilde{U}_X] = -E[C(\varepsilon)] + \int_{\theta_\varepsilon}^{\theta_\eta} z_X^m(\theta) f(\theta)\,\mathrm{d}\theta + \int_{\theta_\eta}^{\overline{\theta}} z_X^l(\theta) f(\theta)\,\mathrm{d}\theta - \int_{\underline{\theta}}^{\theta_\varepsilon} [z_Y^m(\theta) - z_Y^r(\theta)] f(\theta)\,\mathrm{d}\theta, \tag{56}$$

$$E[\tilde{U}_Y] = -D(\eta) + \int_{\theta_\varepsilon}^{\theta_\eta} z_Y^m(\theta) f(\theta)\,\mathrm{d}\theta + \int_{\underline{\theta}}^{\theta_\varepsilon} z_Y^r(\theta) f(\theta)\,\mathrm{d}\theta. \tag{57}$$

Let us now consider the alternative case, where η was not delineated. Just as above, agent X prefers the introduction of ε, while this is opposed by agent Y. Expected utilities are then:

$$E[\ddot{U}_X] = p_X E[U_X^{\varepsilon}] + (1-p_X)E[U_X^{u}] \tag{58}$$
$$E[\ddot{U}_Y] = p_Y E[U_Y^{u}] + (1-p_Y)E[U_Y^{\varepsilon}] \tag{59}$$

where $E[U_X^u]$ and $E[U_Y^u]$ are given by (40) and (41), and $E[U_X^{\varepsilon}]$ and $E[U_Y^{\varepsilon}]$ are given by (52) and (53), respectively, with expected payoffs:

$$E[\ddot{U}_X] = -E[C(\varepsilon)] + \int_{\theta_\varepsilon}^{\overline{\theta}} z_X^m(\theta) f(\theta)\,\mathrm{d}\theta - \int_{\underline{\theta}}^{\theta_\varepsilon} [z_Y^u(\theta) - \hat{z}_Y(\theta)] f(\theta)\,\mathrm{d}\theta \tag{60}$$
$$E[\ddot{U}_Y] = -\overline{D} + \int_{\theta_\varepsilon}^{\overline{\theta}} z_Y^u(\theta) f(\theta)\,\mathrm{d}\theta + \int_{\underline{\theta}}^{\theta_\varepsilon} \hat{z}_Y(\theta) f(\theta)\,\mathrm{d}\theta \tag{61}$$

Clearly, as agent Y has lower valuation of bargaining restrictions their payoff function includes the maximum damage $\bar{D}$ when η is not established.

5.1 Expected payoffs for contestable bargaining restrictions

Given the optimal strategies for the delineation of ε, we now turn to the preceding stage: the delineation of η, and, thus, the resulting expected payoff for the Nash-subgame perfect equilibrium. From (56)-(57) and (60)-(61), each agent maximizes:

$$E[U_X^*] = p_X E[\ddot{U}_X] + (1-p_X)E[\tilde{U}_X] \tag{62}$$
$$E[U_Y^*] = p_Y E[\tilde{U}_Y] + (1-p_Y)E[\ddot{U}_Y]. \tag{63}$$

where agent Y competes for the establishment of η whereas agent X competes against the delineation. Solving yields the following expected payoff when both bargaining restrictions are contestable.

$$\begin{aligned} E[U_X^*] = -E[C(\varepsilon)] &+ \int_{\theta_\eta}^{\overline{\theta}} z_X^m(\theta) f(\theta)\,\mathrm{d}\theta + \int_{\underline{\theta}}^{\theta_\varepsilon} [\hat{z}_Y(\theta) - z_Y^u(\theta)] f(\theta)\,\mathrm{d}\theta \\ &+ \int_{\theta_\varepsilon}^{\overline{\theta}} z_Y^u(\theta) f(\theta)\,\mathrm{d}\theta + \int_{\theta_\varepsilon}^{\theta_\eta} [z_X^m(\theta) - z_Y^m(\theta)] f(\theta)\,\mathrm{d}\theta \end{aligned} \tag{64}$$

$$E[U_Y^*] = -\overline{D} + \int_{\underline{\theta}}^{\theta_\varepsilon} \hat{z}_Y(\theta) f(\theta)\,\mathrm{d}\theta + \int_{\theta_\varepsilon}^{\overline{\theta}} z_Y^u(\theta) f(\theta)\,\mathrm{d}\theta \tag{65}$$

Comparing (64)-(65) with the expected payoffs under no bargaining restrictions (40)-(41) shows that agent Y has unambiguously lower utility when bargaining restrictions are contested. Given $E[\overline{C} - C(\varepsilon)]$ is sufficiently large, agent X benefits from the bargaining restriction compared to the unconstrained case. Solving for the relative advantage of bargaining restrictions in aggregate welfare, Φ, we have:

$$\begin{aligned} \Phi = E[\overline{C} - C(\varepsilon) - z_X^u - z_Y^u] &+ \int_{\underline{\theta}}^{\theta_\varepsilon} [\hat{z}_Y(\theta) - z_Y^u(\theta) - z_Y^r(\theta)] f(\theta)\,\mathrm{d}\theta \\ &+ \int_{\theta_\varepsilon}^{\overline{\theta}} z_X^m(\theta) f(\theta)\,\mathrm{d}\theta - \int_{\theta_\varepsilon}^{\theta_\eta} z_Y^m(\theta) f(\theta)\,\mathrm{d}\theta, \end{aligned} \tag{66}$$

which shows that for sufficiently large $E[\overline{C} - C(\varepsilon)]$, aggregate welfare will improve if bargaining restrictions are established, even when the bargaining restrictions are contestable.

It is useful to compare (66) with (44): cases in which bargaining restrictions are either contested or not. A common theme among both contested and non-contested bargaining restrictions is the degree to which the costs to the agent of the bargaining restriction are smaller than the full cost under no Coasean bargaining. What is clear from the analysis is, independent of whether bargaining restrictions are contested or not, bargaining restrictions are welfare improving given a sufficiently large difference between agents' costs of the bargaining restriction and the cost associated with a breakdown of Coasean bargaining. We return to the issue of bargaining breakdown in the following section.

6 Extensions

6.1 Costly bargaining

Previously, the assumption of costless bargaining meant that both agents always had an incentive to participate in voluntary exchange. Naturally, high transactions costs may result in agents deciding not to participate in bargaining.

These payoffs are to be compared with a situation where no trade occurs after appropriation of bargaining restrictions, i.e. either $\overline{D}$ or $\overline{C}$ are incurred by the losing agent. Note that in absence of trading, gross values v_j^n are no longer symmetric. Let us assume that $\overline{D} > \overline{C}$. In this case substitution of $v_X^n = L_X^n = \overline{C}$ and $v_Y^n = L_Y^n = \overline{D}$ into (36) and (37) yields payoffs:

$$U_X^n(x) = U_Y^n(y) = -\overline{C} \tag{67}$$

Adjusting the basic model with lump-sum participation costs, results in expected payoffs given by:

$$E[-C(a^*) - D(a^*) - R_Y^u] - t_X^u \tag{68}$$
$$E[-C(a^*) - D(a^*) - R_X^u] - t_Y^u. \tag{69}$$

Comparison with (68) and (69) and simplifying, yields the following conditions for voluntary exchange to occur given transaction costs t_j^u:

$$t_X^u \leq E[z_X^u], \tag{70}$$
$$t_Y^u \leq \overline{D} - E[\overline{C} - z_Y^u]. \tag{71}$$

Transaction costs may also be present when bargaining restrictions are set. To keep the analysis general, we allow for different transaction costs under the presence of bargaining restrictions. The expected payoffs for agents when they trade (under the delineation of bargaining restrictions) is:

$$-E[C(\varepsilon)] + \int_{\theta_\varepsilon}^{\theta_\eta} z_X^m(\theta) f(\theta)\,\mathrm{d}\theta + \int_{\theta_\eta}^{\overline{\theta}} z_X^l(\theta) f(\theta)\,\mathrm{d}\theta - t_X^{br}, \tag{72}$$
$$-D(\eta) + \int_{\theta_\varepsilon}^{\theta_\eta} z_Y^m(\theta) f(\theta)\,\mathrm{d}\theta + \int_{\underline{\theta}}^{\theta_\varepsilon} z_Y^r(\theta) f(\theta)\,\mathrm{d}\theta - t_Y^{br}. \tag{73}$$

Analogously to the case of with no restrictions, voluntary exchange occurs when the following inequalities hold:

$$t_X^{br} \leq \int_{\theta_\varepsilon}^{\theta_\eta} z_X^m(\theta) f(\theta)\,\mathrm{d}\theta + \int_{\theta_\eta}^{\overline{\theta}} z_X^l(\theta) f(\theta)\,\mathrm{d}\theta + D(\varepsilon) - E[C(\eta)], \tag{74}$$

$$t_Y^{br} \leq \int_{\theta_\varepsilon}^{\theta_\eta} z_Y^m(\theta) f(\theta)\,\mathrm{d}\theta + \int_{\underline{\theta}}^{\theta_\varepsilon} z_Y^r(\theta) f(\theta)\,\mathrm{d}\theta + E[C(\varepsilon)] - D(\eta). \tag{75}$$

Comparison of (68) with (72), and (69) with (73), we find a similar result to that discussed in Section 4. Given property rights are allocated using an all-pay auction and transaction costs are small enough for voluntary exchange to occur with and without bargaining restrictions, the delineation of bargaining restrictions results in *ex ante* Pareto improvements when:

$$E[\overline{C} - z_X^u] - t_X^u \geq E[C(\varepsilon)] - \int_{\theta_\varepsilon}^{\theta_\eta} z_X^m(\theta) f(\theta)\,\mathrm{d}\theta - \int_{\theta_\eta}^{\overline{\theta}} z_X^m(\theta) f(\theta)\,\mathrm{d}\theta - t_X^{br}, \tag{76}$$

$$E[\overline{D} - z_Y^u] - t_Y^u \geq D(\eta) - \int_{\theta_\varepsilon}^{\theta_\eta} z_Y^m f(\theta)\,\mathrm{d}\theta - \int_{\underline{\theta}}^{\theta_\eta} z_Y^r(\theta) f(\theta)\,\mathrm{d}\theta - t_Y^{br}. \tag{77}$$

For identical transaction cost between the case of (no) bargaining restrictions, (76) and (77) reduce to the inequalities (48) and (49). Further, it could be argued that with bargaining restrictions, as the bargaining surplus is reduced, lump-sum transaction costs may actually reduce in size. If so, this strengthens the argument for the establishment of bargaining restrictions.

Let us now consider the case where transaction costs are sufficiently large to eliminate any possible gains from trade. This reduces our game to a simple game of appropriation. This can be seen by comparing the expected payoffs defined in (67) with a case where bargaining restrictions exist, i.e.,

$$U_x^b = -D(\varepsilon) - E[C(\varepsilon) - C(\eta)], \tag{78}$$

$$U_y^b = -E[C(\varepsilon)]. \tag{79}$$

It is obvious that, under an all-pay auction, the delineation of bargaining restrictions Pareto-dominates the case without rights. As participation in voluntary exchange is not rational, the effect from the implementation of bargaining restrictions, is to only reduce appropriation costs. For intermediate cases, where trading may occur in either the case with or without bargaining restrictions, additional signs of support for the establishment of bargaining restrictions exist. It can be easily shown that Pareto improvements exists for the implementation of bargaining restrictions when transaction costs for the trading case are set to the threshold inequalities above.

6.2 Alternative property right allocation

In Section 4 appropriation over a property right was modeled with an all-pay auction, where the agent with the highest level of appropriation was endowed with the property right. We can consider alternative mechanisms, in particular a 'lottery' contest, where the probability of obtaining the property rights is based on a logit function (Konrad, 2009). To illustrate how a 'lottery' contest alters our results, consider the probability of agent X obtaining the initial property is given by $p_X(x,y) = \frac{x}{x+y}$ for $\max\{x,y\} > 0$, otherwise, $p_X(x,y) = \frac{1}{2}$. Using a 'lottery' contest suc-

cess function throughout, the relative welfare benefit of implementing bargaining restrictions, denoted here by Γ, is given by

$$\Gamma = \frac{1}{2}\Delta + \frac{1}{2}\int_{\theta_\eta}^{\bar{\theta}} [C(a^*(\theta),\theta) + D(a^*(\theta)) - D(\eta) - C(\eta,\theta)] f(\theta)\,\mathrm{d}\theta \qquad (80)$$
$$+ \frac{1}{2}\int_{\underline{\theta}}^{\theta_\varepsilon} [C(a^*(\theta),\theta) + D(a^*(\theta)) - C(\varepsilon,\theta) - D(\varepsilon)] f(\theta)\,\mathrm{d}\theta$$

where Δ is the relative welfare gain under the implementation of an all-pay auction in (44). Comparison of the 'lottery' contest to an all-pay auction shows qualitatively similar results, however, the relative gain from the delineation of bargaining restrictions is smaller. As expected, the lottery contest results in exactly half the expected appropriation costs compared to the all-pay auction, and consequently, the relative gains are smaller. The second and third terms in (80) show the additional allocative inefficiencies associated with the use of the 'lottery' contest.

7 Discussion

Our analysis has shown the Pareto- and welfare-improving aspects of bargaining restrictions. Applications abound, it is clear that in many Coasean-style scenarios, with externalities and insecure property rights, the delineation of bargaining restrictions can provide Pareto improvements.

In a traditional Coasean set-up, allocative efficiency is independent of property right allocation, yet it obviously matters for the distributive outcome of the bargaining game. This distributional non-neutrality is a key factor in determining whether bargaining restrictions increase overall efficiency. In direct contrast to traditional Coasean set-ups, the potential Pareto improvements of bargaining restrictions are increasing in the level of total damages $\bar{D}$ and costs $\bar{C}$. It follows that bargaining restrictions increase efficiency when property rights are initially insecure and the potential losses to agents in absence of Coasean bargaining are relatively large.

In the context of the above-depicted framework, bargaining restrictions are interpreted as restrictions to harmful activities that are determined prior to the allocation of specific property rights. These restrictions can also be viewed as "general regulations of economic activity which can be laid down in the form of general rules specifying conditions which everybody who engages in a certain activity must satisfy" (Hayek, 1960, p224). Hence, bargaining restrictions are to be interpreted in a broad sense as general rules on an upper level of the institutional cascade. Such rules can—but do not necessarily need to—be specified on the level of a country's constitution. Other sources of such restrictions might be principles and doctrines codified within substantive laws—like restrictions of commensurability—or procedural provisions that are to ensure 'fundamental justice.' Harmful activities might also be *a priori*-restricted by informal institutions like social norms. Such norms might, for example, define and restrict the group of persons that are to be generally granted access to a resource (Ostrom, 2000).

Note that, in the above interpretation, bargaining restrictions only preclude very high levels (and guarantee the lawfulness of very low levels) of potentially harmful activities, but will leave enough freedom of choice for intermediate levels of such actions. Bargaining restrictions are hence not provisions that fully attribute property rights to one party or the other, but represent *a priori*-restrictions on their use. It is quite intuitive to think of such restrictions being conceived without particular cases in mind, as they apply in principle to a large set of situations.[14]

[14] See Hayek (1960) for a normative justification of the independence of general rules from their particular appli-

Given the interpretation of bargaining restrictions to—but not full attribution of—property rights, the latter are stipulated on an institutional level of lower order. We assume these property rights to be allocated via a contest. With newly arising property rights, such a contest could for example reflect rent seeking within the political process. Another important interpretation arises if the contest is not over the *de jure* allocation of property rights but their actual enforcement. In this case the contest would represent a court procedure, with the injured party claiming also a *de facto* attribution of a property right. Indeed, in the context of litigation, all parties generally invest in legal proceedings to influence the legal rulings to their advantage. As laid out in Baye et al. (2005), the underlying contest can be reflected as an all-pay auction, very similar to the one specified in Section 4.

Disputes over property rights often arise with the introduction of new technologies. A prominent example is the rise of the internet and new media in the last decades, engendering a multitude of property rights issues. There exist, for example, privacy concerns with respect to image-based location tools, like Google Earth and Google Street View (Banerjee, 2010). Yet, another important case in this context is the protection of intellectual property rights over media content, exemplified by the rise and fall of file sharing networks. In the US, property right restrictions in the realm of the internet were specified within the Digital Millennium Copyright Act (DMCA) of 1998. In principle, the DMCA attributes the entitlement to the holder of the intellectual property right, but also creates safe havens from prosecution under specific circumstances, acting as restrictions to property right claims (Brown, 2008). Still, intellectual property rights were subject to a multitude of legal disputes (e.g., Google vs. Viacom). Most important to our argument is the fact that once property rights are established, negotiations over the licensing fees—as for example remunerations for the use of music by specific performers over webcasts—can be interpreted as a form of collective Coasean bargaining (Holland, 2010).

Note that the transferred rents resulting from the bargaining game—and hence both agents' appropriation effort—depends on the loser's share of the gains from trade z_j. In order to cover a large set of situations, the different z_j were not specified in the above-presented model, but surely deserve further discussion. We have shown that if the entire bargaining power is always with the winner, $z_j = 0$ having some restrictions over the harmful activity is always efficient under the examined contest structures. At the other extreme, where the winner does not have any bargaining power, efficiency gains from bargaining restrictions are less likely. However, such cases are probably rather rare, as it seems plausible that ownership of property rights is always associated with positive bargaining power.[15] However, for these cases we have shown that for appropriation via an all-pay auction, very restrictive property rights (i.e., with η and ε close to $E[a^*]$) will—at least *ex ante*—be more efficient than having no bargaining restrictions at all.

An interesting special case arise if the loser's bargaining power increases with the establishment of a restriction in his favor. In this case bargaining restrictions are more likely to be efficient, as can be seen from (44). Such a positive relationship between the establishment of a restriction for a specific group and its bargaining power might be, for example, due to an increase in political power following the explicit recognition of the group via the establishment of a group-specific basic right. Our model results can hence also be interpreted to provide additional arguments to establish minority rights. This is applicable to, for example, common-pool resources where indigenous communities lose control rights over a resource.

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cation.

[15] An exception to this rule might arise if additional legal provisions exist restricting the level of rents achievable through bargaining by the winner. For example in a breach of contract settlement, the penalty doctrine in Anglo-Saxon contract law prohibits contract damages beyond compensation of the injured party (e.g., Chung, 1992).

8 Conclusion

The purpose of this paper is to analyze the efficiency of Coasean bargaining when there exists *ex ante* restrictions on the set of bargaining outcomes. When property rights are costly to appropriate and agents can voluntarily exchange their endowments, we show under uncertainty that the delineation of bargaining restrictions may result in *ex ante* Pareto improvements. When bargaining restrictions are contested, we show that the delineation of bargaining restrictions is usually welfare improving.

The results in this article provide an alternative rationale for the existence of basic rights, social norms and laws that restrict the upper (and lower) levels of externality generation. Bargaining restrictions are often advocated from a constitutional perspective under a veil of uncertainty, where an unanimous decision is usually *ex ante* Pareto efficient. Instead, we have provided an argument that advocates the delineation of bargaining restrictions within a Coasean context. Our analysis can be interpreted within the traditional applications of the Coase theorem as well as more contemporary issues, such as the property ownership in cyberspace.

Given we have shown the Pareto-improving aspect of bargaining restrictions, it is interesting to consider when the delineation of bargaining restrictions may actually result in inefficiency. Aside from the conditions shown in this paper, further work may consider investigating additional informational problems, different appropriation mechanisms, as well as enforcement issues of bargaining restrictions.

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Sequential Aggregation of Verifiable Information

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On the Public Economics of Annuities with Differential Mortality

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Comparative Risk Aversion: A Formal Approach with Applications to Saving Behaviors

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Risk Aversion and the Value of Risk to Life

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Endogenous Growth, Asymmetric Trade and Resource Taxation

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Default Risk in Stochastic Volatility Models

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Economics of Endogenous Technical Change in CGE Models - The Role of Gains from Specialization

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Resource Wealth, Innovation and Growth in the Global Economy

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Tax Contracts and Elections

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