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Settlement under the threat of conflict – The cost of asymmetric information

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Abstract

I study a situation where two players disagree on the division of a good. In the first of two stages, the players can divide the good peacefully between them by signing a contract. If either or both players reject the contract, they must engage in a costly contest over the good. One of the players' valuation is assumed to be private information. The feasibility of a contract that divides the good between the players prior to the contest is determined by the expected contest outcome and thus also by the distribution of the private valuation. The findings can be applied to environmental conflicts, for example to shed some light on how a valuation study of ecosystem services in Lofoten can affect the probability of opening up the area for oil and gas exploration, and also the appropriate level of compensation to negatively affected parties.

Keywords: Contest; Bargaining; Arctic; Environmental Conflicts;
JEL Classification: C72; C78; Q38;

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1 Introduction

Imagine two players trying to determine how to divide a good between them. What happens if the negotiations break down? Some issues that cannot be settled through bargaining might have to be settled in a more costly way similar to a conflict or a contest, such as court litigations or a third party decision where the third party can be lobbied. These are costly settlement procedures that could have been avoided. Hence, to better understand the mechanisms behind conflict resolutions, it is meaningful to study bargaining under the threat of a conflict.

One main driver for conflicts that has been emphasized is the "*combination of private information about resolve or capability and incentives to misrepresent these*" (Fearon 1995 p.409). In this

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paper, I aim at further exploring this mechanism and what it means for the possibility of avoiding conflicts. More specifically, I use a setting that combines bargaining and contests to study how private information affects the feasibility of a peaceful bargaining solution that would save the players from expending costly and wasteful effort in a contest.

I set up a two-stage game with two players, 1 (she) and 2 (he). Both players have an interest in acquiring a good. The good can be considered as, for example, a piece of land, a contract, or a favorable outcome in a parliamentary decision. Each player has an individual valuation of the good. Player 1's valuation is common knowledge but only the distribution of player 2's valuation is commonly known. The exact value, which determines player 2's type, is private information.

In the first stage of the game, an external party presents a contract that specifies how the good is to be divided between the players. If both players accept the contract, the game ends and the good is divided accordingly. Should either or both players reject the contract, a second stage contest ensues where the players invest in costly effort in order to obtain the good. I study how asymmetric information determines whether it is possible to divide the good so that player 1 and all types of player 2 prefer to settle rather than to engage in a contest, i.e., does a division exist that guarantees a peaceful outcome? A peaceful outcome is desirable from an efficiency perspective since the resources spent on effort in a contest only contribute to rent dissipation.

My paper primarily relates to settlement models; see Daughety and Reinganum (2008) for a survey. More specifically, my contribution to this literature is that I fully endogenize the second stage by introducing a contest that will determine the players' decision of whether or not to settle in the first stage. This set up enables me to study how asymmetric information on valuations have an impact on the expected contest outcome and, consequently, the settlement decision. Earlier litigation models commonly make exogenous assumptions about the trial stage, for example about the probability of winning (e.g., Bebchuk 1984, Reinganum and Wilde 1986 or Wärneryd 2010), or the cost of engaging in a contest (e.g., Daughety and Reinganum 1999, Friedman and Wittman 2006, or Spier 2007). While asymmetric information is included in these models, it does not have any direct impact on the cost of not settling or winning probabilities, which are variables that clearly affect settlement decisions. By introducing a contest, I am able to endogenize these variables and explore a new mechanism through which uncertainty affects the settlement decision, namely how asymmetric information affects the consequences of not settling. This has policy implications for how new information, such as valuation studies in environmental conflicts, can affect settlement possibilities.

I also make a small contribution to the contest literature by expanding the model in Hurley and Shogren (1998, HaS henceforth) by studying the effect of asymmetric information not only on equilibrium efforts, but also on equilibrium expected profits. Studies on contests commonly focus on equilibrium efforts since these determine the rent dissipation. In my study, the decision of whether or not to settle in the first stage is determined by expected profits, which are affected by both players' effort. Hence, I must explicitly study the effect on the expected profits.

The results from my study are the following. The feasibility of a peaceful solution depends on players' expected contest profits. If the contest implies low rent dissipation, players are inclined to reject peaceful solutions and try to grab the whole good in the second stage. The expected contest profits depend on the mean and the variance of the players' relative valuation. The only change that always makes a peaceful contract more feasible is a lower mean of the relative valuation, indicating that the informed player is likely to have a higher valuation, when the uninformed player believes herself to be the contest favorite. This would make the contest a worse alternative for both players. Increased uncertainty, represented by a higher variance in the distribution of the privately informed player's valuation, does not have any clear effect on the feasibility of a peaceful solution since it makes the uninformed player worse off in a contest and the informed player better off in a contest (more and less prone to settle in the bargaining phase, respectively).

Contests with one-sided asymmetric information are often used to study environmental conflicts, such as conflicts over land use between firms and the general public, i.e., resource extraction versus preservation (Moriath and Münster 2010, Hurley and Shogren 1997). This is motivated by the fact that the economic profitability of a resource is often well studied and publicly available while estimates of the value of the ecosystem and environmental services to the general public, such as the value of pristine nature, are unknown to firms. I will discuss the policy implications of the results in an Arctic context since land use conflicts are currently taking place in the Arctic and are also projected to become more common with increased accessibility to natural resources due to global warming (Dodds 2010).[1] A special mean for mitigating conflicts that is sometimes used in the Arctic already today is side payments. I will discuss the findings of my model in terms of how information affects the feasibility of using side payments as a mechanism to divide a good in practice and avoid conflicts.

Some Arctic examples where this model can apply are the conflicts between fishermen and petroleum companies in Lofoten Norway, between home owners and mining companies in Kiruna Sweden, and between reindeer herders and the Russian oil industry on the Yamal peninsula. New valuation studies that also incorporate non-market goods, e.g., environmental services and valuations of a pristine nature, may reduce disagreements over appropriate compensation, increase the likelihood of peaceful solutions and thus reduce costly lobbying, see e.g., St. Meld (2010) or Lemker and Karlsson (2012). In these examples, firms are likely to consider themselves contest favorites due to the relatively high economic valuation of their activities.[2] If non-market valuation studies provide new information that increases the expected value of fishermen's or homeowners' valuations, this would then fulfill the conditions for when new information increases the likeli-

[1]It should be clear, however, that the model is also applicable to other environmental conflicts in other regions of the world.

[2]For example in Lofoten, the value of oil extraction is estimated to be 105 billion Norwegian kroner and the present value of the fishing industry is estimated to be 25 billion kroner (St. Meld 2010).

hood of a peaceful solution. The policy implication is that to increase the likelihood of both sides accepting side payments in land use conflicts, compensation should not only focus on economic aspects, which often seems to be the practice (LKAB guidelines, St. Meld 2010), but also consider non-market values.

The rest of the paper is organized as follows. The model is developed and solved in section 2. The results are presented and discussed in section 3. To facilitate the interpretation of the results, I provide some specific examples in section 4 to show how new information can affect the feasibility of a peaceful solution. The empirical relevance of the model is discussed in section 5. Finally, section 6 wraps up the paper with some concluding comments.

2 The model

Players 1 and 2 (she and he), both risk neutral, desire a good. For expositional reasons, I assume the good to be divisible so that side payments between the players are made using parts of the good. Player 1 has a valuation of the good equal to v_1. To model private information, I define player 2's valuation of the good to be a random variable v distributed over an interval $[\underline{v}, \bar{v}]$. Only player 2 knows the realization v_2, which also specifies his type. The distribution of v is common knowledge. It has a cumulative distribution function $G(v)$ and an associated probability density function $g(v)$. It will prove to be beneficial to have a higher valuation. Therefore, I will sometimes call a player with a higher (lower) valuation a stronger (weaker) player.

The game is played over two stages. In the first stage, an external party formulates a contract that specifies a division of the good between the players. If both players sign the contract, the good is divided between them and the game ends. If either or both players reject the contract, stage two commences. In this stage, both players try to obtain the entire good in a contest through investment in costly effort that affects the winning probabilities. The resources spent on effort are a welfare loss due to the contest. Solving the conflict at an earlier stage is thus a more efficient outcome.

There are many ways of setting up a contest, see Corchón (2007) for a survey. In my paper, the contest stage is set up as the one-sided asymmetric information model by Hurley and Shogren (1998, HaS). In a contest, each player has a probability of winning determined by both the player's own effort and the other player's effort. To increase the own probability of winning, player 1 and 2 invest in efforts x_1 and x_2. The probability of winning and obtaining the entire good is specified by a contest success function $p(x_1, x_2(v_2))$. Consequently, the probability that player 2 obtains the entire good is $1 - p(x_1, x_2(v_2))$. It is natural to assume that $p(x_1, x_2(v_2))$ is increasing in x_1 and decreasing in x_2. Investing in effort is costly and comes at a marginal cost equal to unity.[3] In order to obtain analytically tractable solutions, the contest success function is specified to be the

[3]The exact specification of the cost function is not important for the main results of the model, see Allard (1988).

widely used[4] logit contest success function (see Tullock 1980 for origins) i.e.,

$$p(x_1, x_2(v_2)) = \frac{x_1}{x_1 + x_2(v_2)}$$

The game is solved by backward induction. Thus, I start by deriving the equilibrium outcome in the contest stage. The expected profits are needed in order to compare them to the profits the players can obtain by accepting the contract in the bargaining stage. Players 1 and 2 can thus choose either to divide the good peacefully or engage in a costly contest in order to obtain the entire good.

The Contest

Given the setup, the expected payoffs $E[\pi_i]$ for player 1 and for a given type of player 2 in the contest are the following.

$$E[\pi_1] = \int_{\underline{v}}^{\bar{v}} \frac{x_1}{x_1 + x_2(v)} v_1 dG(v) - x_1 \tag{1}$$

$$E[\pi_2 | v_2] = \frac{x_2}{x_1 + x_2} v_2 - x_2 \tag{2}$$

This is essentially the contest presented in HaS.[5] Before presenting my own contribution to this contest model, the effect of information on equilibrium profits, I summarize the main intuition and propositions of HaS over the next few pages. The following definitions from HaS will prove to be useful.

Definition 1. *Define the willingness to waste, β, to be the share of her valuation that player 1 is willing to spend on effort in equilibrium i.e., $\beta = \frac{x_1^*}{v_1}$.*

Definition 2. *Let $\rho(v_2) = (\frac{v_1}{v_2})^{1/2}$ define the relative resolve. Denote the expected value and variance of the relative resolve to be $E[\rho(v)] = \mu$ and $Var[\rho(v)] = \sigma^2$, respectively.*

The willingness to waste represents the share of her valuation that player 1 is willing to expend in order to obtain the good. The relative resolve shows the relationship between the two players' valuations. The larger the value of the relative resolve, the stronger player 1 is relative to player 2 on average.

Using definitions 1 and 2 and assuming an interior solution,[6] the equilibrium efforts of player

[4] See, for example, HaS, Schoonbeek and Winkel (2006) and Slantchev (2005). HaS also discuss the generalizability of the results to other contest success functions.

[5] HaS also study the effects of differences in ability to exert effort by introducing a player-specific coefficient to the efforts in the contest success function. While this could be an interesting extension, it does not affect my main results.

[6] As shown in HaS, given the functional form of the contest success function, the solutions to the first-order conditions of 1 and 2 are unique. Player 1 always exerts a positive effort. For all types of player 2 to exert a positive effort, the lowest valuation cannot be relatively much smaller than player 1's valuation. The exact condition can be derived from equation 4.

1 and all types of player 2 can be shown to be (see appendix), respectively,

$$x_1^* = \beta v_1 \tag{3}$$

$$x_2^*(v) = v_2 \left[\beta^{1/2}\rho(v_2) - \beta\rho^2(v_2)\right] \tag{4}$$

where the equilibrium expected value of the willingness to waste expressed in terms of mean and variance of the relative resolve is

$$\beta = \left(\frac{\mu}{1+\mu^2+\sigma^2}\right)^2. \tag{5}$$

For the rest of this section, I assume that $\mu > (1-\sigma^2)^{1/2}$ i.e., the probability that player 1 is much weaker than player 2 is low. This assumption will later facilitate the analysis of the effect of variance on equilibrium profits. This is also likely to be the case in the suggested empirical examples; the economic value of oil is vastly greater than the economic value of the fishery even with very low discount rates (St. Meld 2010). The following definitions from HaS will also prove to be important.

Definition 3. *Define player 1 to be the expected favorite (underdog) if her expected probability of winning is greater (smaller) than player 2's expected probability of winning, i.e., if* $E[p(x_1, x_2(v))] > (<)\frac{1}{2}$*. Define player 2 to be the true favorite (underdog) if his probability of winning is greater (smaller) than player 1's probability of winning, i.e., if* $p(x_1, x_2(v)) < (>)\frac{1}{2}$*.*

After simplifications, player 1 being the expected favorite is equivalent to (see the appendix)

$$\mu > [1+\sigma^2]^{1/2}. \tag{6}$$

Similarly, player 2 is the true favorite if

$$\mu[2\rho(v_2) - \mu] < 1+\sigma^2 \tag{7}$$

Some things are worth noting. First, player 1 can never be the expected favorite if the expectation of the relative resolve is less than 1. It is, however, possible for player 1 to be the expected underdog even if the expectation of the relative resolve is larger than 1 if the uncertainty (variance) is sufficiently large. Second, the more uncertainty in terms of variance, the higher is the likelihood that player 1 is the expected underdog. Third, player 1 being the expected favorite does *not* imply that player 2 is necessarily the true underdog. And finally, for a given type, player 2 is more likely to be the true favorite the more uncertainty there is in the form of variance in the relative resolve.

In order to study the effect of new information on profits, a good stepping stone is to study the effect of new information on equilibrium efforts. This is done in propositions 1 and 2 of HaS. The propositions can be proved by direct differentiation of equations 3 and 4. The proof can be divided into two parts: (i) the effect of changes in mean or variance of the relative resolve on the willingness to waste, β, and (ii) the effect of β on equilibrium efforts. The first part will be useful later and I state it below as a lemma:

Lemma 1. *An increase in the variance of the relative resolve always decreases the willingness to waste. An increase in the mean of the relative resolve increases (decreases) the willingness to waste if player 1 is the expected underdog (favorite).*

Proof. This can be proven by direct differentiation[7] of equation 5 with respect to μ and σ^2, and applying definition 3.

$$\frac{\partial \beta}{\partial \sigma^2} = -\frac{2\beta^2}{\mu^2} < 0 \tag{8}$$

$$\frac{\partial \beta}{\partial \mu} = 2\left[1 - \mu^2 + \sigma^2\right] \frac{\beta^{\frac{3}{2}}}{\mu^2} \tag{9}$$

□

I restate propositions 1 and 2 of HaS, where a full proof can also be found, below and give them a slightly different interpretation.

HaS 1. *A higher variance of the relative resolve decreases player 1's equilibrium effort. If player 2 is the true underdog (favorite), his equilibrium effort is increasing (decreasing) in the variance.*

HaS 2. *If player 1 considers herself to be an expected favorite, she lowers her equilibrium effort in response to a higher mean of the relative resolve. A player 2 who is the true favorite (underdog) in turn responds by decreasing (increasing) his optimal effort. If player 1 considers herself to be an expected underdog, she raises her equilibrium effort in response to a higher mean of the relative resolve. A player 2 who is the true favorite (underdog) in turn responds by increasing (decreasing) his optimal effort.*

The intuition behind the first proposition from HaS is the following. Interpreting variance as risk, increased variance makes player 1's effort a more risky input through decreasing her marginal utility of effort and thus also decreasing her equilibrium effort even though she is risk neutral (HaS). If the contest becomes closer due to this, i.e., player 2 is the true underdog, he responds by expending more effort. If player 2 is instead the true favorite, he decreases his effort since player 1 is now a weaker opponent; player 2 can still maintain the upper hand in the contest with less effort.

The second proposition from HaS has the following intuitive interpretation (see also table 2). If player 1 is the expected favorite and the mean of the relative resolve increases, she will expend less effort since she thinks she will face an on average weaker opponent. If player 2 is the true favorite, he will respond by decreasing his effort since he now faces weaker competition. As a

[7] Taking the derivative of an expression w.r.t. μ or σ^2 is done keeping the other variable constant throughout the paper.

favorite, player 2 can now *relax.* If player 2 is instead the true underdog, the contest becomes closer and he will increase his effort in order to *take his chance.* If player 1 is instead the expected underdog, for an increase in the mean of the relative resolve, she will increase her effort since she now thinks she has a better chance of winning being faced with an on average weaker opponent. If player 2 is a true favorite, he foresees this and increases his effort in order to *keep his lead.* If player 2 is instead a true underdog, he will respond by decreasing his effort since he now faces an even stronger opponent; he *gives up.*

Up to this point, the results have been a summary of HaS with some new interpretations. I will now expand their theory by also studying the effect of new information on equilibrium profits. Using the concepts of willingness to waste and relative resolve, the equilibrium profits can be rewritten in the following way

$$E[\pi_1] = v_1 \int_{\underline{v}}^{\bar{v}} \frac{x_1^*}{x_1^* + x_2^*(v)} dG(v) - x_1^* = v_1 \beta(\mu^2 + \sigma^2) \tag{10}$$

$$E[\pi_2|v_2] = v_2 \frac{x_2^*(v_2)}{x_1^* + x_2^*(v_2)} - x_2^*(v_2) = v_2 \left(1 - \beta^{\frac{1}{2}} \rho(v_2)\right)^2. \tag{11}$$

The effect of new information on equilibrium profits is summarized in proposition 1 below.

Proposition 1. *(i) An increase in the variance of the relative resolve always makes player 1 worse off and always makes player 2 better off, regardless of who is the expected and/or true favorite and who is the expected and/or true underdog. (ii) An increase in the mean of the relative resolve always makes player 1 better off and makes player 2 better off if player 1 is the expected favorite but worse off if player 1 is the expected underdog.*

Proof. (i) For player 1, direct differentiation of equation 10 yields

$$\frac{\partial E[\pi_1]}{\partial \sigma^2} = v_1 \beta \frac{1 - \mu^2 - \sigma^2}{1 + \mu^2 + \sigma^2} < 0. \tag{12}$$

For player 2, the sign of the effect is opposite to the sign of the effect of an increased variance on the willingness to waste. To see this, note that a direct differentiation of equation 11 yields

$$\frac{\partial E[\pi_2]}{\partial \sigma^2} = \frac{d\pi_2}{d\beta} \frac{d\beta}{d\sigma^2} = \left(\rho(v_2)^2 - \frac{\rho(v_2)}{\beta^{1/2}}\right) \frac{d\beta}{d\sigma^2} > 0 \text{ if } \frac{d\beta}{d\sigma^2} < 0$$

since multiplying both sides by β

$$\left(\rho(v_2)^2 \beta - \rho(v_2) \beta^{1/2}\right) \frac{d\beta}{d\sigma^2} = -\frac{x_2^*}{v_2} \frac{d\beta}{d\sigma^2} > 0 \text{ if } \frac{d\beta}{d\sigma^2} < 0.$$

The application of lemma 1 concludes the proof of proposition 1 part (i). The proof of part (ii) is analogous. Also for the effect of an increased mean on player 2's profit, the sole determinant of the sign is the sign of the effect of an increased mean on the willingness to waste. □

A higher variance of the relative resolve always decreases the expected profit for player 1. All types of player 2 are better off with more uncertainty. An increased mean, which indicates that player 1 becomes relatively stronger, is always beneficial for player 1. If player 1 is the expected underdog, player 2 is worse off. However, if player 1 is an expected favorite, all types of player 2 are actually better off if player 1 becomes relatively stronger on average. This implies that *both* players' expected profits may increase at the same time, i.e., for an increased mean of the relative resolve when player 1 is the expected favorite. The intuition is that player 1, who already is confident of winning, thinks that he faces an even weaker opponent and can relax some of his effort while still being better off in expectation. Player 2, whose type is fixed, thus faces a weaker opponent so regardless of being the true favorite or the underdog, he is also always better off.

From the proof of proposition 1 follows a convenient corollary to use when predicting the effect on player 2's profit of any type of new information.

Corollary 1. *For any type of player 2, the effect on the expected profit of an increased mean of the relative resolve goes in the opposite direction of the effect on player 1's equilibrium effort. The same holds for an increase in the variance of the relative resolve.*

Proof. Follows directly from the proof of proposition 1 □

Corollary 1 implies that player 2 is not necessarily better or worse off just because player 1 perceives him as stronger or weaker. The effect depends on the change in player 1's equilibrium effort and is thus solely determined by whether or not player 1 considers herself to be the expected favorite or underdog.

Table 2 summarizes the effect of new information on equilibrium efforts and expected profits for all combinations of expected and true favorites and underdogs.

Table 1: Effects of new information on efforts and profits

	Increased variance	
	P1 expected favorite	P1 expected underdog
P2 true favorite	$x_1^* \downarrow, x_2^* \downarrow, \pi_1^* \downarrow, \pi_2^* \uparrow$	$x_1^* \downarrow, x_2^* \downarrow, \pi_1^* \downarrow, \pi_2^* \uparrow$
P2 true underdog	$x_1^* \downarrow, x_2^* \uparrow, \pi_1^* \downarrow, \pi_2^* \uparrow$	$x_1^* \downarrow, x_2^* \uparrow, \pi_1^* \downarrow, \pi_2^* \uparrow$

	Increased mean	
	P1 expected favorite	P1 expected underdog
P2 true favorite	$x_1^* \downarrow, x_2^* \downarrow, \pi_1^* \uparrow, \pi_2^* \uparrow$	$x_1^* \uparrow, x_2^* \uparrow, \pi_1^* \uparrow, \pi_2^* \downarrow$
P2 true underdog	$x_1^* \downarrow, x_2^* \uparrow, \pi_1^* \uparrow, \pi_2^* \uparrow$	$x_1^* \uparrow, x_2^* \downarrow, \pi_1^* \uparrow, \pi_2^* \downarrow$

The relationship between efforts and expected profits varies. New information that implies a higher (lower) equilibrium effort does not necessarily imply higher (lower) profits. For example, player 1 is always better off with an increased mean. For an expected favorite, this is achieved through exerting lower effort while an expected underdog achieves it through increased effort. And player 2 is always better off with an increased variance but he can achieve this through either lower or higher effort depending on whether he is a true favorite or underdog.

Bargaining

In the first stage, the players are faced with the decision of whether or not to accept a contract, suggested by an external party, which specifies the division of the good between them without having to exert any effort.[8] This decision depends on the expected profits in the contest derived in the previous section. More specifically, the contract specifies θ, i.e., the share of the good received by player 2. I define a contract to be peaceful if it is accepted by all types of player 2 as well as player 1. The payoff to player 1 if both players accept the contract is then $(1-\theta)v_1$ and similarly for player 2, his payoff in case the contract is accepted by both players is θv_2. Note that since player 2 receives the same share of the good regardless of type, this implies that player 1 cannot infer any information about the type of player 2 by observing θ.

For a player to agree to a peaceful contract, a participation constraint needs to hold. If the participation constraints hold for all players, they imply that player 1 and each type of player 2 are better off by signing the contract than by rejecting the contract and thus engaging in a contest. The participation constraints for player 1 and 2, respectively, are

$$G(\hat{v})(1-\theta)v_1 + (1-G(\hat{v}))\pi_1^*(v|v>\hat{v}) \geq \pi_1 \tag{13}$$

$$\theta v_2 \geq \pi_2. \tag{14}$$

The left-hand sides of equations 13 and 14 are the expected payoffs for player 1 and 2 if they accept the contract. The right-hand sides are the expected payoff for each player in a contest. As long as the expected payoff in a peaceful solution is greater than or equal to the expected profit in a contest, the players will accept the suggested division of the good.

For player 1, the profit from accepting the contract depends on the share of player 2 types that accepts and rejects the contract. If, for example, all types with $v_2 > \hat{v}$ reject the contract, then player 1 faces a probability equal to $1-G(\hat{v})$ to have to enter a contest even though she accepted the contract. However, in this contest, she learns some information, namely that $v_2 > \hat{v}$ which she may use to update her optimal strategy in the second stage. If player 1 rejects the contract herself, she loses this source of information.[9]

Naturally, also player 2 knows that a rejection of the contract reveals some information of his type which would affect his expected profit. This is taken into account by him when calculating

[8]The contract is suggested by an external party. An interesting venue for further research would be to study different bargaining protocols such as Nash bargaining or the Kalai-Smorodinsky solution, alternatively let the players themselves propose the contract. However, my focus is on studying whether there is any possible division of the good that satisfies both players using the equilibria profits from the contest as threat points.

[9]This assumption can be relaxed without any important changes to the main result.

the optimal strategies in the contest stage. In the case of a peaceful contract $\hat{v} = \bar{v} \Rightarrow G(\bar{v}) = 1$ which means that conditions 13 and 14 become symmetric. In this case, player 1 runs no risk of having to enter a contest given that she accepts the contract herself.

3 Results

I focus on equilibria involving pure strategies. There are two types of equilibria involving pure strategies, pooling and separating equilibria. One pooling equilibrium occurs if player 1 accepts the contract and all types of player 2 accept the contract.[10] Since all types of player 2 choose the same strategy, player 1 cannot use the decision by player 2 to make an inference about player 2's type. This pooling equilibrium is equal to a peaceful contract since all players accept the contract and the contest stage never occurs.

The second type of equilibrium is a semi-separating equilibrium. In this type of equilibrium, all types of player 2 up to a type $\hat{v}$ accept the contract and all other types reject the contract. This strategy reveals some information about the type of player 2 which has consequences for the equilibrium profits in the contest stage. Since a semi-separating equilibrium leads to a contest with some probability, it is not a peaceful equilibrium but I will also comment on the conditions for the existence of this type of equilibrium.

An important determinant of any equilibrium are the beliefs player 1 is allowed to hold about player 2's type. Player 1's beliefs are determined by the distribution of v in the first stage since it is always reached. In a peaceful equilibrium, the second stage is never reached so Bayes' rule does not apply and player 1's out of equilibrium beliefs must be specified. I require player 1's out of equilibrium beliefs to be formed using passive conjectures (p.142ff Rasmussen 2001). This means that player 1 retains her prior after observing out of equilibrium actions. This limits the out of equilibrium beliefs that are specified in the Bayesian Perfect equilibrium later. Intuitively, player 1 believes that every type of player 2 has the same probability of making a mistake and playing his off equilibrium strategy. In an equilibrium where the second stage is reached with positive probability, player 1's beliefs are determined by Bayes' rule.

I start by studying the conditions under which a pooling equilibrium exists. In a contest, the player 2 type with the highest valuation gets the highest expected profit. Therefore, to confirm that the participation constraint holds for all types of player 2, it is sufficient to check that it holds for the strongest type. Hence, if a pooling equilibrium exists, using equations 10 and 11, the explicit versions of conditions 13 and 14 are

[10] Another trivial pooling equilibrium would be one where all players reject the proposed contract. However, this is clearly not a peaceful equilibrium.

$$(1-\theta)v_1 \geq \pi_1^* = v_1\beta\left(\mu^2+\sigma^2\right) \tag{15}$$

$$\theta\bar{v}_2 \geq \pi_2^* = \bar{v}_2\left(1-\beta^{\frac{1}{2}}\rho(\bar{v}_2)\right)^2. \tag{16}$$

The left-hand sides of equations 15 and 16 are the payoffs for player 1 and 2, respectively, if they accept the contract. This gives player 1 a share of the good equal to $1-\theta$ and player 2 a share equal to θ. The right-hand sides of the equations are the off-equilibrium contest profits if a player were to deviate from the peaceful equilibrium and reject the contract.

If there exists at least one θ that simultaneously makes both 15 and 16 hold, there exists a pooling equilibrium. The equations thus determine when a peaceful solution is feasible and the conditions can be summarized in a proposition.

Proposition 2. *A peaceful contract is feasible if player 1's and player 2's expected profits in the contest are not too large, or more specifically; if the sum of the expected profits for player 1 and the highest type of player 2 as a share of their respective valuations does not exceed 1.*

Proof. By dividing each condition in equations 15 and 16 by v_1 and $\bar{v}_2$, respectively, and then adding the left-hand and right-hand sides, the two equations together imply that a sufficient condition for a peaceful contract to exist is

$$1 \geq \frac{\pi_1^*}{v_1}+\frac{\pi_2^*}{\bar{v}_2} = \beta\left(\mu^2+\sigma^2\right)+\left(1-\beta^{\frac{1}{2}}\rho(\bar{v}_2)\right)^2. \tag{17}$$

□

If equation 17 does not hold, a peaceful contract is not feasible. This may occur if the players are overconfident, i.e., their combined expected profits are so large that it is not possible to divide the good to sufficiently compensate both players in the first stage. This could, for example, happen if player 2 is very likely to be weak, but is in fact strong. Then, player 1 wants a large share to settle peacefully since she thinks that she is likely to prevail in the contest. But player 2, who is in fact strong, also wants a large share since he knows that even though player 1 now expects to meet a weaker player, he is still the true favorite.

Given that equation 17 holds, the more slack there is, the more feasible I define a peaceful contract to be. This is motivated by the fact that the construction of such a contract might come at some fixed cost. By studying equation 17 and using the propositions from the previous sections, the effects of new information on the feasibility of a peaceful contract are summarized in proposition 3.

Proposition 3. *(i) The effect on the feasibility of a peaceful contract of increased variance of the relative resolve is ambiguous since it decreases player 1's profit and increases player 2's profit. (ii) If player 1 is the expected favorite, an increase in the mean of the relative resolve always makes a peaceful contract less feasible. If player 1 is the expected underdog, the effect is ambiguous.*

Proof. Follows directly from equation 17 and proposition 1. □

It is clear that anything that increases both players' profits makes a peaceful contract less feasible. Anything that decreases both players' profits makes a peaceful contract more feasible. Anything that has an asymmetric effect on player 1 and player 2's profits, respectively, will have an ambiguous effect on the feasibility of a peaceful contract and depend on further parameterization of the model.

In section 2, I found that an increase in the variance of the relative resolve always decreases player 1's profit and increases player 2's profit. Hence, the total effect of an increased variance of the relative resolve on the feasibility of a peaceful division of the good is ambiguous.

The effect of new information that increases the mean of the relative resolve is to some extent clearer. If player 1 is the expected favorite and new information indicates that player 1 is on average stronger, both player 1 and player 2's expected profits increase, which makes a peaceful solution less feasible. However, if player 1 is the expected underdog and new information indicates that she faces an on average weaker opponent, players 1's profit increases while player 2's profit decreases. This makes the effect on the feasibility of a peaceful solution ambiguous.

To summarize, the only type of new information that is guaranteed to make a peaceful contract more (less) feasible is new information that makes player 2 look stronger (weaker) when player 1 is the expected favorite.

The intuition is the following. Player 1 is always better off with a higher mean of the relative resolve. If player 1 is the expected favorite and she receives new information indicating that she on average faces a weaker opponent, she can relax some of her effort. Since she has a lower effort level but still keeps her (expected) advantage, it makes the contest less costly for her. Regardless of whether player 2 is the true favorite or underdog, he is also better off since he now faces an opponent who exerts less effort. Hence, for both players, a contest is no no longer as daunting which makes a feasible peaceful solution less likely. If, on the other hand, player 1 is the expected underdog, she will increase her effort and expected profit which makes player 2 worse off regardless of type. In this case, there is an ambiguous effect on the feasibility of the peaceful contract.

For a given θ that makes equation 17 hold, a Perfect Bayesian equilibrium with passive beliefs characterizing a peaceful solution would thus be the following. In the first stage, player 2 is fully informed of his own type and player 1 holds beliefs about player 2's type given by the commonly known distribution of v. Both player 1 and player 2 accept the contract where θ is defined so that both 15 and 16 hold. Player 1's beliefs about player 2's type if she observes the out of equilibrium stage 2 is determined by her prior. Player 1 would thus choose her optimal effort x_1^*, determined by equation 3, in the contest. The optimal response for each type of player 2 is to play his equilibrium strategy $x_2^*(v)$, determined by equation 4.

In a pooling equilibrium, there is in most instances an ambiguous effect on the feasibility of a peaceful contract of new information. A net analysis requires full parameterization of the model.

I provide such an example below. First, however, I comment on the conditions for the existence of semi-separating equilibria.

In a semi-separating equilibrium, all types of player 2 with $v \leq \hat{v}$ accept the contract and all other types reject the contract. A rejection of the contract by player 2 gives player 1 some information about player 2's type. If player 1 accepts the contract but is forced to compete in a contest, player 1 knows that player 2's type is greater than $\hat{v}$. Consequently, player 1 adjusts his optimal strategy in the contest stage according to this new information. Moreover, a player 2 type that rejects the contract knows that her rejection reveals some information to player 1 and takes this into account in the contest. Thus, player 1 solves the following updated problem in case of a contest

$$E[\pi_1] = \frac{\int_{\hat{v}}^{\bar{v}} \frac{x_1}{x_1+x_2(v)} v_1 dG(v)}{1-G(\hat{v}_2)} - x_1 = \int_{\hat{v}}^{\bar{v}} \frac{x_1}{x_1+x_2(v)} \tilde{v}_1 dG(v) - x_1 \tag{18}$$

with $\tilde{v}_1 = \frac{v_1}{1-G(\hat{v}_2)}$ and $1-G(\hat{v}_2)$ is the probability that player 1 will have to enter a contest even though she accepted the contract. This updated contest is then solved analogously to the original contest in section 2, resulting in equilibrium profits $\tilde{\pi}_1$ and $\tilde{\pi}_2$. In a semi-separating equilibrium, the participation constraints for player 1 and all types of player 2 must then be

$$G(\hat{v})(1-\theta)v_1 + (1-G(\hat{v}))\tilde{\pi}_1 \geq \pi_1^* \tag{19}$$

$$\theta v_2 \geq \pi_2^o \ \forall \ v \leq \hat{v} \tag{20}$$

$$\theta v_2 < \tilde{\pi}_2 \ \forall \ v > \hat{v} \tag{21}$$

where π_2^o is the contest profit for a player 2 of a type less than $\hat{v}$ who plays the off equilibrium strategy and engages in a contest.

It is not possible to determine the role of information without an exact parameterization of the distribution of valuations. An increase in the mean of the whole distribution does not necessarily affect the truncated distribution.[11] Hence, we have to remain agnostic on the effects of an increased mean and variation of the truncated distribution and the cumulative probability. This could be further studied using exact parameterization. However, the main focus of this study is peaceful contracts and I now return to them by studying explicit examples.

[11]Say, for example, that v_2 can take on the values 1, 2, 3 with the respective probability $\frac{1}{3}$, $\frac{1}{3}$ and $\frac{1}{3}$. If only the high value player rejects the contract in a semi-separating equilibrium, player 1 will only focus her attention on that player type if she is forced into a contest. However, decreasing the smallest valuation affects the mean for the whole distribution but not the truncated distribution. The same line of reasoning goes for the truncated probability. If the probability that player 2 is of type 1 and 2 changes to $\frac{1}{6}$ and $\frac{1}{2}$, respectively, this changes the mean but does not change the probability that player 1 will have to enter a contest if she accepts the contract.

4 An example

In this section, I present an analytical example to give some intuition for how the feasibility of a peaceful equilibrium may change with new information. I use a simple distribution where player 2's valuation can take two different values. Let player 2's valuation take the value $\underline{v}$ with probability q and the value $\bar{v}$ with probability $1-q$. I also relax the assumption $\mu > (1-\sigma^2)^{1/2}$ to analyze a broader set of outcomes.

Using the results from section 2, the equilibrium expected profits in contest are

$$\begin{aligned}
\pi_1^* &= v_1\beta(q\underline{\rho}^2 + (1-q)\bar{\rho}^2) \\
\underline{\pi}_2^* &= \underline{v}(1-\beta^{1/2}\underline{\rho})^2 \\
\bar{\pi}_2^* &= \bar{v}(1-\beta^{1/2}\bar{\rho})^2
\end{aligned}$$

with

$$\beta = \left(\frac{q\underline{\rho} + (1-q)\bar{\rho}}{1 + q\underline{\rho}^2 + (1-q)\bar{\rho}^2}\right)^2.$$

A feasible peaceful contract is available whenever the players do not claim shares of the good that sum to more than one i.e., whenever equation 17 holds which in this set up is equal to

$$1 \geq \frac{\pi_1^*}{v_1} + \frac{\bar{\pi}_2^*}{\bar{v}_2} = \beta(q\underline{\rho}^2 + (1-q)\bar{\rho}^2) + (1-\beta^{1/2}\bar{\rho})^2. \tag{22}$$

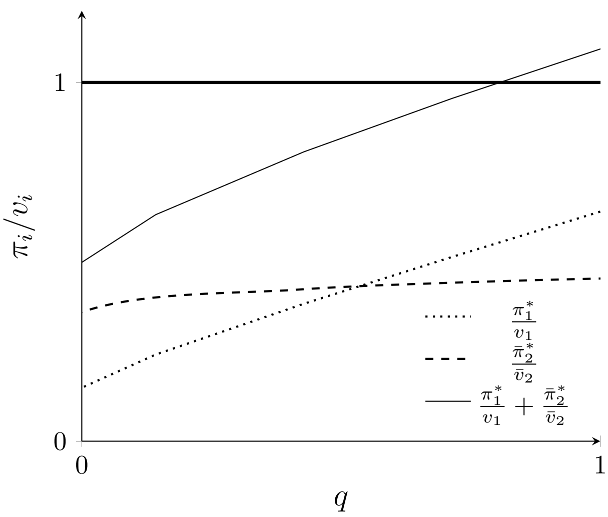
By varying the parameter values in equation 22, I can study the effect of new information on the feasibility of a peaceful contract. The importance of expected and true favorites and underdogs for effort and expected profits was made clear in the proposition from HaS and proposition 1. Therefore, I study three different settings, one where player 1 is sometimes the expected favorite, $\underline{v} < v_1 < \bar{v}$, one where player 1 is always the expected favorite $v_1 \leq \underline{v} < \bar{v}$ and finally, one where player 1 is always the expected underdog, $\underline{v} < \bar{v} \leq v_1$.

To study new information, I vary q. As for many distributions, changing a parameter has an effect on both the mean and the variance. Therefore, in these examples, it is the joint effect of a changed mean and a changed variance of the relative resolve that is studied to see if one effect dominates the other. For example, increasing q from zero increases the variance of the relative resolve which should have a negative effect on player 1's profit but it also increases the mean which should have a positive effect on player 1's profit.

For this distribution, the mean of the relative resolve will be increasing in q. The variance, however, has a maximum for $q = \frac{1}{2}$. Hence, an increased q affects player 1's expected profit negatively through a higher variance for $0 \leq q \leq \frac{1}{2}$, positively through a lower variance for $\frac{1}{2} \leq q \leq 1$ and positively through a higher mean of the relative resolve for all values of q. It affects player 2's profit positively through a higher variance for $0 \leq q \leq \frac{1}{2}$, and negatively through a lower variance for $\frac{1}{2} \leq q \leq 1$. However, the effect of a higher mean depends on player 1 being an expected favorite or underdog. A higher mean of the relative resolve is positive for player 2 if player 1 is the expected favorite and negative if she is the expected underdog.

In the first setting, player 1 can be both the expected favorite and the expected underdog depending on the values of q. Set $v_1 = 100$, $\underline{v} = 25$ and $\bar{v} = 150$. Thus, for small values of q, player 1 is the expected underdog while for high values of q, he is the expected favorite. How players' profits expressed as a share of their valuations and the feasibility of a peaceful solution depend on q is shown in figure 1.

Figure 1: Example 1



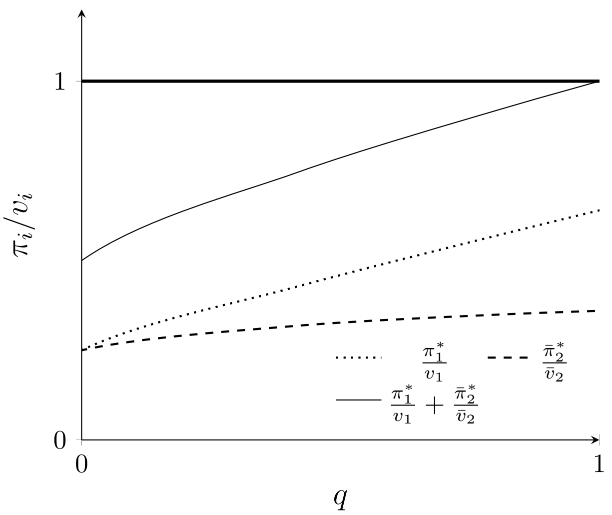
The dotted line is player 1's profit as a share of her valuation, the dashed line is the high type of player 2's profit as a share of his valuation and the solid line is the sum of these two. When the sum of the two players' profit shares is higher than 1, the thick line, a division of the good satisfying both players, becomes impossible (proposition 2). When this happens, one or both players would be better off deviating to the out of equilibrium path, rather than accepting the contract for any division of the good. The distance between the line measuring the sum of both players' profit shares and 1 is a measurement of the feasibility of a peaceful contract. The larger the distance between the line and 1, the more slack there is in equation 17. For values of q where the line is higher than 1, a peaceful contract is not feasible.

Both $\frac{\pi_1^*}{v_1}$ and $\frac{\bar{\pi}_2^*}{\bar{v}_2}$ are increasing in q. This means that for both players, the more probable it is that player 1 is facing a weaker opponent (the lower the q), the less costly a contest becomes. For sufficiently high values of q, there is no division of the good that simultaneously satisfies player 1 and both types of player 2. The variance of the relative resolve is increasing in q up to $q = \frac{1}{2}$, making player 1 worse off. However, the mean of the relative resolve is always increasing in q (player 1 faces a player 2 of the low type with higher probability) which makes player 1 better off. The positive effect of an increased mean of the relative resolve dominates the negative effect of an increased variance. For a high type of player 2, the effect of a higher mean goes in the same direction as a higher variance as long as player 1 is the expected favorite. Both affect player 2's expected profit positively. For $q > \frac{1}{2}$ i.e., when the variance is decreasing in q, the positive effect on player 2's expected profit of an increased mean dominates the negative effect of lower variance. For low values of q, when player 1 is the expected underdog, the positive effect of an increased variance dominates the negative effect of an increased mean.

So why is a peaceful contract not feasible for high values of q? Intuitively, when q is high, the likelihood that player 2 is of a low type is also high which means that player 1 will demand a large share of the good since going to a contest does not seem as intimidating. However, if the realization of player 2's type is high, he also wants a large share of the good. For sufficiently high values of q, the shares that player 1 and the high type of player 2 are demanding add up to a value above 1, which is impossible to distribute. Hence, a peaceful contract is not feasible.

In the next example, player 1 will be stronger than, or at least as strong as, player 2 in terms of valuations. Set $v_1 = 200$, $\underline{v} = 50$ and $\bar{v} = 200$. The result is displayed in figure 2.

Figure 2: Example 2



As in the first setting, a peaceful solution becomes less feasible when q increases. The only qualitative difference from the first example is that a peaceful solution is always feasible. It turns out that for this binary setting, a peaceful solution is always feasible when the high type of player 2 has a lower valuation than player 1. To see this, equation 22 can be reduced to

$$(2-q)\bar{\rho}^2 + q\underline{\rho}^2 \leq \frac{2}{\beta^{1/2}}\bar{\rho}. \tag{23}$$

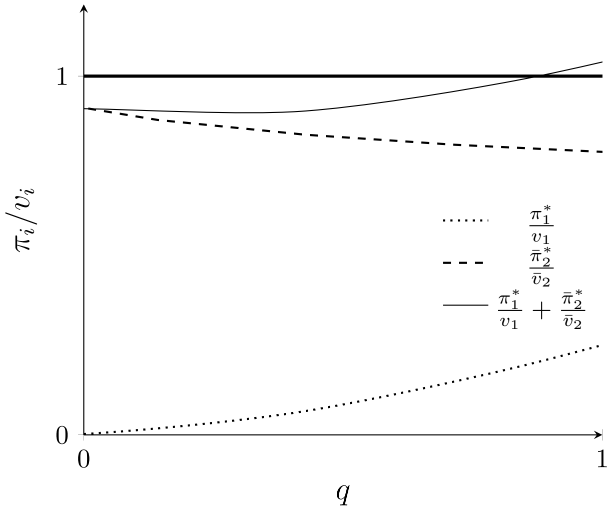
We know that $\underline{\rho} < \bar{\rho}$ so 23 holds if

$$(2-q)\bar{\rho}^2 + q\bar{\rho}^2 = 2\bar{\rho}^2 \leq \frac{2}{\beta^{1/2}}\bar{\rho}. \tag{24}$$

24 is guaranteed to hold since $\beta < 1$ ($\bar{\rho} < 1$ since $\bar{v} < v$ was assumed).

In the final example, player 1 is always the expected underdog. I let $v_1 = 100$, $\underline{v} = 100$ and $\bar{v} = 2000$. The results are displayed in figure 3

Figure 3: Example 3



As previously, Player 1's profit is increasing in q. For $q \leq \frac{1}{2}$, the negative effect on player 1's profit of an increased variance is dominated by the positive effect of an increased mean of the relative resolve. However, unlike the first two examples, the high type of player 2 has an expected profit that is decreasing in q. Player 1 is an expected underdog for all values of q. This means that player 2's profit is decreasing in the mean for all values of q. This effect dominates the positive effect on player 2's profit of an increased variance for $q \leq \frac{1}{2}$. Unlike the first two examples, the feasibility of a peaceful contract is actually decreasing in q for low values. The negative effect on the high type of player 2's profit dominates the positive effect on player 1's profit and the contest becomes more costly. However, the net effect switches as q increases and for sufficiently high values of q, a peaceful contract is not feasible.

It is clear from these examples that it is difficult to say anything in general about the feasibility of a peaceful contract. To be able to make predictions, accurate information about the contest structure and the players' relative valuations is needed. Moreover, comparative statics are dependent on player characteristics. Some findings are worth emphasizing:

- A peaceful contract is not always feasible. If both players are sufficiently confident to win the contest, their claimed shares of the good in the bargaining stage will sum to more than one, thus making a division of the good that satisfies all players impossible (example 1).

- If the valuation of the high type of player 2 is less than player 1's valuation, a peaceful contract is always feasible (example 2).

- A strong type of player 2 is not necessarily better off if player 1 believes that he faces a weaker opponent. If player 1 believes that he is the true underdog, player 2 can be worse off if player 1 believes that he is facing a weaker player. Moreover, even though this makes the contest closer, the net effect might be that a peaceful contract becomes more feasible (example 3).

It is straightforward to set up and theoretically analyze these models for different parameter values. However, due to the lack of general comparative statics results, it is difficult to make predictions about similar settings in the real world. It is, however, possible to discuss the different mechanisms in case studies. This is the aim of the next section.

5 Discussion

I assumed in the model that the division of the good could be represented by side payments between the players.[12] There is some empirical support for this assumption. The waters in the Norwegian Sea off Lofoten are rich in natural resources. There is, for example, a cod fishery dating back for centuries and a vibrant ecosystem. The waters also hold a lot of oil and gas, some of which is currently extracted. For new oil and gas fields, lobbying is done by petroleum companies arguing for extraction while fishermen are against extraction since they are afraid of the consequences for the marine resources. There is a system of payments to fishermen to compensate for economic losses due to petroleum activities (St. Meld 2010). Another example was the payments from a mining company in the Arctic part of Sweden to homeowners who run the risk of expropriation due to the expanded operations of the mine.

The conflict outside Lofoten is an interesting and appropriate case to discuss using the stylized framework presented in the paper. Define player 1 to be the petroleum companies and player 2 to be their organized opponents (fishermen, tourism). There are estimates of the economic values generated by both sides but there are large uncertainties about the potential effect of prospecting for, and extraction of, oil and gas on fisheries and tourism. The monetary valuation of the benefits from oil extraction is 105 billion Norwegian kroner while the present values of the profits generated by fisheries are about 25 billion Norwegian kroner (St. Meld 2010). But also non-market values give incentives to exert lobbying efforts. For example, ecosystem values or individual valuations are not quantified and there is also a great deal of uncertainty about these values. The social costs of petroleum extraction are discussed in the official management plan for the Lofoten area and it is stated that: "*[t]he figures on which the calculations are based are, however, both incomplete and uncertain. For example, there are no reliable figures on the economics damages on fisheries and aquaculture that a larger accidental discharge may cause*" (St. Meld 2010). Still, side payments are used to compensate fishermen to some extent for economic losses, but is it feasible to expand the usage?

It is not unreasonable to assume that due to their economic advantage, the petroleum companies consider themselves to be expected favorites when it comes to lobbying. But the opponents' valuation is difficult to determine. If the petroleum companies believe the opponents' valuation

[12] The results do not change qualitatively by using e.g., monetary side payments instead of a divisible good but some details change. For example, assume that side payments are made with a lump-sum transfer from player 1 to player 2. Equation 17 would then read $1 \geq \frac{\pi_1^*}{v_1} + \frac{\pi_2^*}{v_1}$, where π_2^* is the equilibrium profit for player 2 of type $\bar{v}$.

to be low with a high probability, they might not be willing to offer large side payments. But if the true value of the opponents' valuation is sufficiently large, the opponents will not accept a low compensation.

In this setting, consider the impact of a new valuation study trying to also quantify non-market values, such as oil spill risks and consequences. If a valuation study indicates that it is very likely that ecosystem services are of great value, and that fishermen's and tourists' valuation of a pristine nature is likely to be high, this would correspond to a decrease in the mean of the relative resolve (the ratio of player 1's valuation to player 2's expected valuation decreases). This has a negative effect on both players' expected profit and thus increases the feasibility of side payments.

The analogous line reasoning also holds for the mining company and homeowners. There are estimates on the value of the reserves of iron ore and the economic values of the homes. However, there are no studies on the sentimental or affective value of homes which homeowners could also demand to be compensated for in case of expropriation. Valuation studies indicating that these values are high could lead to lesser lobbying and a higher likelihood that both sides agree on the sufficient level of compensation.

Thus, if petroleum and mining companies underestimate their opponents' true valuation, this could be one explanation for why side payments have not been used more extensively and why the appropriate level seems difficult to agree upon. If future valuation studies indicate that the true valuation of the opponents is significantly higher than previously thought, side payments is a mechanism through which the probability of fishermen and homeowners being sufficiently compensated is increased and also the risk of inefficient and costly lobbying efforts is reduced.

How side payments are made in practice can differ. Payments are made directly from the mining company to the homeowners in Kiruna, while the state collects taxes and fees from petroleum companies and pays subsidies to fishermen in Lofoten. Compensating for expropriation and risk can thus be quite straightforward even though putting a value on these parameters is a complex process. Compensating for values that are provided to the general public, such as a pristine nature, is less straightforward. How this could be done in practice is debatable. Forcing firms to set aside resources for management of nearby similar areas, or the conservation of parts of prospected areas, could be one option. However, my main point is that these values need to be acknowledged in land use conflicts. The policy implication is that side payments should not only focus on compensation for economic damages but also on compensation for non-market values in order to reduce uncertainty and thus increase the acceptance for side payments as a mean to reduce conflicts over land use.

6 Conclusion

In this paper, I assumed two parties to be quarreling over the division of a good. I studied a mechanism which could prevent costly contests similar to settling out of court or the use of side payments between disputing parties. Using a one-sided private information setting, I studied the effect of new information on the feasibility of such a mechanism. I found that such a mechanism is only feasible if the sum of the expected contest profits as shares of the respective parties' valuations does not exceed one. The sum may exceed one if, for example, the uninformed player believes that the informed player has a valuation much lower than hers while the true valuation of the informed player is very high. Then, both players would want a large share of the good in order not to engage in a contest, since they would both be confident that they would prevail.

Further, increased uncertainty had an ambiguous effect on the feasibility of a peaceful solution since it made the contest option more attractive for the informed party and less attractive for the uninformed party. I also found that increased average strength of the uninformed player could increase the feasibility of a peaceful solution, if the informed player believes herself to be a true favorite since in this scenario, the change decreases both players' expected contest profit.

I discussed the model in relation to different contemporary Arctic developments. In northern Sweden, side payments are used to compensate homeowners that are, in practice, expropriated as the operations of a mine are expanded. However, the compensations are solely based on the economic value of the home and many homeowners feel that they are not sufficiently compensated. The other example was the potential use of side payments to fishermen to compensate for economics losses due to petroleum extraction in fishing waters outside Lofoten. This compensatory regime is also based on economic calculations, not involving risk, ecosystem services, or fishermen's cultural valuations. New non-market valuation studies might provide new information about the true valuations, thus increasing the probability of homeowners and fishermen being appropriately compensated, and hopefully reducing the amount of resources spent on lobbying.

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A Equilibrium efforts and expected favorites

The first-order condition of equation 1 implicitly defines the best response function for player 1. The first-order condition of equation 2 gives the best response functions for each type of player 2. The resulting equations are, respectively:

$$\frac{\partial E[\pi_1]}{\partial x_1} = \int_{\underline{v}}^{\bar{v}} \frac{x_2(v)}{(x_1 + x_2(v))^2} v_1 dG(v) - 1 = 0 \tag{25}$$

$$\frac{\partial E[\pi_2]}{\partial x_2} = \frac{x_1}{(x_1 + x_2)^2} v_2 - 1 = 0 \Rightarrow x_2^*(x_1, v_2) = (x_1 v_2)^{1/2} - x_1. \tag{26}$$

Using 26 in equation 25 shows the equilibrium efforts and the equilibrium value of β

$$\int_{\underline{v}}^{\bar{v}} \frac{(x_1 v)^{1/2} - x_1}{(x_1 + (x_1 v)^{1/2} - x_1)^2} dG(v) v_1 = 1$$

$$x_1^* = v_1 \left[\frac{\int_{\underline{v}}^{\bar{v}} \rho(v) dG(v)}{1 + \int_{\underline{v}}^{\bar{v}} \rho(v)^2 dG(v)} \right]^2 = v_1 \left(\frac{\mu}{1 + \mu^2 + \sigma^2} \right)^2$$

$$\Rightarrow \beta = \left(\frac{\mu}{1 + \mu^2 + \sigma^2} \right)^2.$$

Having determined the equilibrium efforts, player 1 is the expected favorite if his probability of winning is larger than $\frac{1}{2}$. Using the equilibrium efforts, we have that $p(x_1, x_2(v)) > \frac{1}{2}$ is equivalent to

$$\int_{\underline{v}}^{\bar{v}} \frac{v_1 \beta}{v_1 \beta + v(\beta^{1/2} \rho(v)) - \beta \rho^2(v))} dG(v) > \frac{1}{2}$$

$$\int_{\underline{v}}^{\bar{v}} \beta^{1/2} \rho(v) dG(v) > \frac{1}{2}$$

$$2\mu^2 > 1 + \mu^2 + \sigma^2 \Leftrightarrow \mu > (1 + \sigma^2)^{1/2}.$$