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Opacity in Bargaining over Public Good Provision

Abstract

We consider ultimatum bargaining over the provision of a public good. Offer-maker and responder can delegate their decisions to agents, whose actual decision rules are opaque. We show that the responder will benefit from strategic opacity, even with bilateral delegation. The incomplete information created by strategic opacity choices does not lead to inefficient negotiation failure in equilibrium. Inefficiencies arise from an inefficient provision level. While an agreement will always be reached, the public good provision will, however, fall short of the socially desirable level. Compared to unilateral delegation, bilateral delegation is never worse from a welfare perspective.

JEL-Codes: C780, H400.

Keywords: public good provision, transparency, opacity, bargaining, incomplete information, delegation.

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1 Introduction and Literature Review

Standard bargaining models suggest that with complete information, bargaining will succeed with certainty and efficient allocation will be achieved. While this result is fairly general, the distribution of the surplus generated by successful negotiations will rely on the particular setting. Depending on the players' costs or preferences, as well as the bargaining protocol itself, bargaining power may differ considerably. In the extreme case of an ultimatum game, the proposing player will have all the bargaining power. By making a take-it-or-leave-it offer, she can harvest the complete surplus of successful negotiations, leaving the responder only with her fallback payoff.

There are various strategies for modifying bargaining power at a pre-negotiation stage. The main idea of opacity, as introduced by Konrad and Thum (2020), is that a favorable redistribution of cooperative gains can be achieved by appointing a delegate whose costs or preferences are on average the same as the principal's but may diverge in both directions due to imperfectly observable characteristics. From the responding player's point of view, opacity is beneficial, as a proposer may pursue a less aggressive strategy in order not to put the success of negotiations at risk. While Konrad and Thum (2020) consider bargaining over a fixed rent, we look at a non-cooperative game of public good provision with the cooperative rent being determined endogenously. This way we bring together the strands of literature on strategic opacity choice and the private provision of public goods. The idea of strategic opacity is also closely related to the literature on information design.[1] As actions will depend on the information available, a player who is able to reveal or obscure information can manipulate the other players' optimal strategies. Unrelated to delegation, the approach by Condorelli and Szentes (2020) is closely linked to Konrad and Thum (2020). Condorelli and Szentes (2020) consider randomness of the buyer's true valuation in a buyer-seller interaction, where the buyer can actively modify the distribution from which her valuation for an asset will be drawn.

Usually, incomplete information in bargaining over the division of a rent or over the provision of a public good is assumed to be exogenously given. The basic messages of Chatterjee and Samuelson (1983) and Myerson and Satterthwaite (1983) carry over to bargaining over the provision of a public good. With incomplete information, negotiations may lead to inefficient outcomes. Incomplete information furthermore entails the risk of failed negotiations. Bargaining over a public good under incomplete information has explicitly been considered e.g. by Harstad (2007) and Konrad and Thum (2014, 2018). In the offer-counteroffer game of Harstad (2007), proposed contracts may be rejected and inefficiencies of incomplete information arise from delays in reaching an agreement. The parties have an incentive to signal a low valuation for the public good by delaying their offers and counteroffers. Side-payments between the parties involved may actually worsen the bargaining outcome. Konrad and Thum (2014, 2018) consider bilateral bargaining over mitigation efforts in a one shot game. In both papers, negotiations fail with a positive probability when there is asymmetric information about abatement costs. Pre-commitment to high abatement levels (Konrad & Thum, 2014) as well as the possibility of cost efficient trans-border mitigation in the non-cooperative game (Konrad & Thum, 2018) lead to an increase in the probability of failed negotiations. Helm and Wirl (2014) consider ultimatum offer bargaining in the presence of a public bad with uncertainty regarding the willingness to pay for abatement. The proposing player offers a menu of incentive compatible contracts. An agreement will be reached with certainty achieving cost effectiveness, yet the first-best emission levels of both proposer and responder are missed.

In our framework, incomplete information results from a decision maker's individual acceptance costs, which emerge beyond the physical cost of public good provision. A decision maker's acceptance costs may stem from moral views and political beliefs, as well as career concerns. For example, a politician might fear not getting reelected or damaging her inner-party career options when signing an agreement which runs counter to her constituents' interests. There might also be a warm glow (Andreoni, 1990) from supporting a climate-friendly project due to ethical and altruistic motives such as genuinely caring for the environment or the well-being of future generations. While the actual costs of production are easily observable, the political and personal costs are private information to the decision maker. This notion of political costs has already been used as source for uncertainty in Fingleton and Raith (2005) and Konrad and Thum (2014, 2018). These political costs may gradually be revealed in the course of a politician's career. Depending on her standpoint in previous negotiations or her active participation in certain projects, the decision maker's motives and values eventually become apparent.

[1] A survey of the literature on information design can be found in Bergemann and Morris (2019).

If the negotiators are well-known public figures or know each other from earlier negotiations, their behavior and values are predictable to a certain extent. Choosing a delegate lacking such a track record can become a strategic advantage. With the delegate still being a blank page, her actual political cost will be unknown to her counterpart in negotiations.

With delegation being the source of opacity, our work is also related to the literature on strategic delegation in bargaining over a public good. Delegation is usually considered in the form of a tough agent, who will reject the least favorable proposals that would have been accepted by the principal and in this way secure a better deal. The notion of a delegate's toughness introduced by Schelling (1960/1980) and developed by Jones (1989a, 1989b) and Burtraw (1992) has also been applied to bargaining over public goods or bads, e.g. considering the case of international environmental agreements (IEA). In a Nash bargaining framework, Segendorff (1998) and Buchholz, Haupt, and Peters (2005) have shown that if the principal decides to delegate, she will appoint an agent who has a strictly lower preference for the environmental good than herself. This way bargaining power can be increased. Segendorff (1998) finds that in equilibrium at least one player will be worse off under delegation than if self-representation had been chosen. If the delegates were to decide on contribution levels in the case of failed negotiations, the other player's fallback utility can be lowered by appointing a tougher delegate. In equilibrium the principals' payoffs may even be lower than in the non-cooperative game without delegation. Buchholz et al. (2005), who consider elections as a form of delegation, show that in the case of complete spillovers there are no gains from bargaining as the elected governments will not value the environment at all. The delegate could be greener and the median voter's payoff higher if bargaining were not to take place. There is a strong link to the literature on strategic commitment at a pre-negotiation stage, e.g. regarding technology choice (Buchholz & Konrad, 1994; Urpelainen, 2012) or investment in green equipment (Beccherle & Tirole, 2011). In those papers, commitment can be used to shift the burden of public good provision towards the other player, thus achieving a favorable movement of the threat point (Beccherle & Tirole, 2011; Buchholz & Konrad, 1994). Even if there is no crowding-out, Beccherle and Tirole (2011) and Urpelainen (2012) find that committing to high emissions by low investment lowers the fallback utility of the other player. Simultaneously, in Beccherle and Tirole (2011) the fallback position becomes more attractive as low levels of investment lead to a higher marginal utility of emissions.

Delegation in the context of uncertainty is considered by Harstad (2008). Heterogenous principals, who have to unanimously decide over the realization of a project, face uncertainty regarding their resulting utility. By appointing a delegate with a lower valuation for the project, they can increase their bargaining power if side payments are applied. On the other hand, projects that may have been favorable from the principal's point of view may be rejected by the delegate.

Applying the concept of opacity (Konrad & Thum, 2020) to bargaining over a public good, the rent from bargaining will become endogenous. The setup allows us to discuss whether an agreement is reached at all and which size of the public good will be realized if negotiations succeed. As do Konrad and Thum (2020), we use a model of ultimatum bargaining where one or both parties can appoint delegates whose preferences may be imperfectly observable. From the offer maker's point of view, bargaining will be a game of incomplete information. For the unilateral case, we can determine a unique equilibrium with delegation by the responder. Through delegation, the responder can achieve a favorable redistribution of bargaining surplus. However, opacity will lead to an inefficiently low level of public good provision and thus a welfare loss. Considering the bilateral case, multiple equilibria arise where, except for corner solutions, both principals' opacity choices are strategic substitutes. Yet, in any subgame perfect equilibrium, an agreement will be reached with certainty. This is in contrast to Konrad and Thum (2020), who found a set of equilibria entailing the risk of failed negotiations in bargaining over a fixed rent. Bilateral delegation will never lead to lower welfare than unilateral delegation.

The paper is structured as follows. In chapter 2, the framework is introduced. Chapter 3 establishes the results of the bargaining game without delegation as a baseline scenario. We consider one-sided delegation in chapter 4. In chapter 5, we analyze the equilibria for bilateral delegation. Chapter 6 concludes.

2 The Setup of the Model

We consider a standard setup for the private provision of public goods. There are two players ($i = 1, 2$), who both derive benefit $B(G)$ from the provision level G of a public good. Each player's benefit is strictly increasing and is strictly quasi-concave in G, i. e. $B^{'}(G) > 0$, $B^{''}(G) \leq 0$. The size of the public good is determined through the non-negative contributions ($g_i \geq 0$) of the two players: $G = g_1 + g_2$. A linear technology generates constant marginal costs c_i of production. Player 1 is assumed to have the lower costs of production ($c_1 < c_2$); let the cost difference of the two players be denoted by $\beta \equiv c_2 - c_1$. Technologies as well as preferences are common knowledge. Player $i's$ payoff can be written as:

$$\Pi_i(G, g_i) = B(G) - c_i \cdot g_i. \tag{1}$$

Before we turn to our bargaining model with weak delegation, we first briefly describe the socially optimal provision and the Nash equilibrium with decentralized decisions as reference points for the subsequent analysis. Welfare is measured by the sum of both players' payoffs:

$$W = \sum_{i=1}^{2} \Pi_i(G, g_i). \tag{2}$$

Maximizing welfare over the (non-negative) contributions of the two players yields the provision level according to the Samuelson rule:

$$2 \cdot B^{'}(G^C) = c_1, \tag{3}$$

where low-cost player 1 is in charge of the entire production ($g_1^C = G^C, g_2^C = 0$).[2]

If the players provide the public good non-cooperatively, the Nash equilibrium can be described as:

$$(g_1^{NC} = G^{NC}, g_2^{NC} = 0) \text{ with } B^{'}(G^{NC}) = c_1. \tag{4}$$

Again only low-cost player 1 will make positive contributions. The public good is provided in a quantity so that the marginal benefit of player 1 equals her marginal cost. Technically speaking, the reaction curves of both players have a slope of -1, i.e. each unit of provision by the other player crowds out one unit of their own contributions. Due to the lower marginal cost, the reaction curve of player 1 will lie farther to the right than player 2's. Hence, the reaction curves only intersect once with $g_2^{NC} = 0$. In the Nash equilibrium, the two players earn payoffs:

$$\Pi_1(g_1^{NC}) = B(g_1^{NC}) - c_1 \cdot g_1^{NC} \text{ and} \tag{5}$$

$$\Pi_2(g_1^{NC}) = B(g_1^{NC}) \tag{6}$$

This simple variant of the standard model illustrates nicely the well-known property of underprovision of public goods in a non-cooperative setting: $G^{NC} < G^C$. Welfare with non-cooperative private provision remains below the social optimum:

$$\sum_{i=1}^{2} \Pi_i(g_1^{NC}) < \sum_{i=1}^{2} \Pi_i(g_1^{C}). \tag{7}$$

3 Ultimatum-offer Bargaining

As we want to analyze weak delegation to a representative with opaque preferences, we need a tractable model of negotiations. We use a simple ultimatum offer game where the high-cost player offers a contract that contains provision levels and a transfer. This is the simplest way to implement bargaining that helps to exploit efficiency gains by increasing public good provision beyond the non-cooperative level. As total rents are maximized with the Samuelson rule, the offer maker has an incentive to propose the socially efficient provision level. The proposed transfer is used to appropriate the rents from enhanced efficiency. Ultimatum-offer bargaining takes place within a three-stage game:

1. Player 2 proposes a contract stating the contribution levels g_1^{bar}, g_2^{bar} and a monetary transfer T to player 1.

[2] As the results of this and the subsequent section are standard, we do not provide proof. The formal derivations are available upon request from the authors.

2. Player 1 can either accept or reject the offer.

3. In the case of successful negotiations, public good provision and transfer happen according to the proposed contract. If negotiations fail, the non-cooperative game will be played.

With failed negotiations, players 1 and 2 receive payoffs $\Pi_1(g_1^{NC})$ and $\Pi_2(g_1^{NC})$ in stage 3. These payoffs are both players' fallback positions. For player 1 to accept a proposal in stage 2, she must receive a payoff that is at least as high as her fallback position $\Pi_1(g_1^{NC})$. Hence, her participation constraint can be written as:

$$B(g_1 + g_2) - c_1 \cdot g_1 + T - \Pi_1(g_1^{NC}) \geq 0. \tag{8}$$

In stage 1, player 2 makes an offer that maximizes her own payoff subject to player 1's participation constraint. The optimal contract proposed by player 2 can be obtained by solving the following maximization problem:

$$\max_{g_1, g_2, T} B(g_1 + g_2) - c_2 \cdot g_2 - T \tag{9}$$

$$\text{s.t.} \quad B(g_1 + g_2) - c_1 \cdot g_1 + T - \Pi_1(g_1^{NC}) \geq 0$$

$$g_1, g_2 \geq 0$$

Player 2 proposes contract P:

$$P = \left\{ g_1^{bar} = g_1^C, g_2^{bar} = 0, T = \Pi_1(g_1^{NC}) - B(g_1^{bar}) + c_1 \cdot g_1^{bar} \right\}, \tag{10}$$

where the provision level g_1^{bar} fulfills the Samuelson condition, i.e. $2 \cdot B^{'}(g_1^{bar}) - c_1 = 0$. The "pie" is maximized by letting the low-cost producer (player 1) provide the public good so that the sum of marginal benefits equals the marginal cost. Player 1 is compensated for her efforts by transfer T. Her participation constraint will be binding, i.e. player 2 will propose the lowest transfer possible, making player 1 indifferent between accepting and refusing the offer. All rents that are created by the transition to the socially optimal provision level accrue to the offer maker (player 2). Player 2 is strictly better off in the bargaining solution compared to the Nash equilibrium: $\sum_{i=1}^{2} \Pi_i(g_1^{NC}) - \Pi_1(g_1^{NC}) > \Pi_2(g_1^{NC})$. This framework of ultimatum bargaining serves as the baseline scenario for our model of weak delegation to a representative with opaque preferences.

4 Bargaining with Unilateral Delegation and Opacity

As shown in the basic model, ultimatum bargaining can ensure the welfare maximizing provision of the public good; the problem of under-provision is solved. Although the welfare loss has disappeared, it is only player 2 who benefits from the bargaining solution. She is able to harvest the total surplus of successful negotiations. It is well known (Schelling, 1960/1980) that player 1 can partially shield herself from being exploited by sending a delegate who has higher acceptance costs. These acceptance costs emerge beyond the costs of physical production. They may be grounded in the political sphere. For instance, a delegate may face reputational costs. A delegate who is known for pro-environmental positions may damage her future political career when striking a deal for a nature-consuming transnational infrastructure project. The larger the project the bigger the political damage. Hence, such a delegate will only accept a deal when these private political costs are compensated.

Such private costs are much harder to observe than the actual costs of production. The costs of infrastructure or climate mitigation are more or less quantifiable, also for offer-making player 2. However, the career concerns, political attitudes, and personal views of a delegate or even an entire delegation are quite opaque. This may not only be true for the counterparty (player 2) but also for delegating player 1. The delegate's precise political costs for accepting an offer may remain her private information. This opacity of a delegate's preferences can help to secure rents in ultimatum bargaining has been shown by Konrad and Thum (2020) in a game with fixed rents. Here we analyze how the strategic use of opaque preferences affects bargaining over public good provision, i.e. in a setting where rents are endogenous.

To separate the toughness (Schelling, 1960/1980) from the opacity dimension, we assume that player 1 can only choose a delegate whose preferences are opaque but who is not tougher on average. By focusing on a delegate with opaque preferences, we create a variant of the model just a one-step deviation from the basic ultimatum-offer model of the previous chapter. This allows us to clearly identify the effects of opacity. To be more specific, we assume that the delegate has either political costs of α_1 or political benefits of α_1 from each unit of the public good negotiated in the contract. The probability of a delegate with political costs is $\pi = 0.5$. In expectation, the preferences of the delegate do not diverge from the preferences of player 1 as the expected political costs are zero $[\pi \cdot \alpha_1 + (1-\pi) \cdot (-\alpha_1) = 0]$. The delegate's political costs or benefits are relevant in the bargaining process as the delegate decides on acceptance or rejection. The public good, however, is always provided by player i at cost c_i – either according to the negotiated contract or in a non-cooperative game. Following the definition of weak delegation according to Segendorff (1998), in the case of failed negotiations, the delegate reports back to player 1, who sets the non-cooperative level of public good provision. The delegate is not involved and, therefore, cannot be held accountable. Hence, we additionally assume (deviating from Segendorff (1998)) that the fallback position of player 1 and the delegate are the same and identical to the ultimatum-offer game in the previous section: $\Pi_{del}(g_1^{NC}) = \Pi_1(g_1^{NC})$.

From the perspective of player 2, who has to make an offer, the opaque preferences of the delegate generate a mean preserving spread of marginal costs around c_1. With probability $\pi = 0.5$, the delegate has marginal costs of public good provision of $c_1^h = c_1 + \alpha_1$. With probability $(1-\pi) = 0.5$, the delegate draws political benefits from successful negotiations; her marginal costs are $c_1^l = c_1 - \alpha_1$.[3] We assume that the degree of opacity α_1 is a choice variable of player 1. As discussed in the introduction, player 1 may choose a delegate, who is not well known in public, or she can create opacity by designing a decision mechanism for a group of delegates. The value α_1 is common knowledge. But neither player 1 nor player 2 know the actual type of the delegate.

The game is structured as before, the only differences being the new stage 0 (choice of opacity) and a slightly modified stage 2 (decision of the delegate):

0. Player 1 chooses α_1, i.e. appoints a delegate who is defined by her level of opacity.
1. Player 2 proposes a contract stating the contribution levels g_1^{del}, g_2^{del} and a monetary transfer T to player 1.
2. The delegate of player 1 can either accept or reject the offer.
3. In the case of successful negotiations, the public good is provided at marginal cost c_1 and the transfer made according to the contract. If negotiations fail, the non-cooperative game will be played.

We solve the game backwards. First, we establish that there are only two candidates of payoff-maximizing offers for player 2. Then, we show that there is a critical value for the degree of opacity α_1 where player 2 finds it optimal to switch between the two candidate offers. Finally, we determine the payoff maximizing degree of opacity for player 1 in stage 0. For clarity of exposition, we now focus on the case where the marginal costs of player 2 exceed those of the high-cost delegate ($c_1^h < c_2$); at the end of this section, we briefly discuss the alternative case.

Stage 1: Contract Offer

Lemma 1. *There are only two offers that can maximize player 2's expected payoff. Player 2 either offers a safe contract P^S, which will be accepted by both types of delegates, or a risky contract P^R, which will only be accepted by the low-cost delegate.*

Proof. We simply sketch the proof as the formal derivation is straightforward. In stage 2, the delegate accepts an offer from player 1, if $B(g_1 + g_2) - c_1^k \cdot g_1 + T \geq \Pi_1(g_1^{NC})$ with $k = l, h$. For a given level of contributions, the minimum transfer required for acceptance is always higher for the h-type by $2 \cdot \alpha_1$ per unit of the public good compared to the l-delegate. Hence, if the h-type is willing to accept an offer, the l-type will accept the offer *a fortiori*. The different acceptance thresholds have to be taken into account by player 2 when making her offer. Player 2 has the choice of offering a contract that is accepted by both types with probability 1, which we call the safe strategy, or a contract that is only accepted with probability 0.5 (by the low-cost type l, risky strategy). For any provision level, it cannot be profitable for player 2 to offer $T < \Pi_1(g_1^{NC}) - [B(g_1 + g_2) - c_1^l \cdot g_1]$ as such an offer will be rejected by both types and all potential gains from bargaining will be lost. Also a transfer offer

[3] Without loss of generality, it is assumed that c_1 is sufficiently large so that the private marginal costs c_1^l cannot become negative.

$\Pi_1(g_1^{NC}) - [B(g_1+g_2) - c_1^l \cdot g_1] < T < \Pi_1(g_1^{NC}) - [B(g_1+g_2) - c_1^h \cdot g_1]$ can never be optimal as the acceptance probability is only 0.5 but the transfer is higher than necessary to make the l-type accept the offer. Finally, $T > \Pi_1(g_1^{NC}) - [B(g_1+g_2) - c_1^h \cdot g_1]$ is not optimal as the acceptance probability is always unity but the transfer to player 1 is higher than necessary. Therefore, there are only two candidates for payoff-maximizing transfers: $\underline{T} = \Pi_1(g_1^{NC}) - [B(g_1+g_2) - c_1^l \cdot g_1]$ to win the l-type only and $\overline{T} = \Pi_1(g_1^{NC}) - [B(g_1+g_2) - c_1^h \cdot g_1]$ to make both types accept. □

We can now describe the payoff-maximizing offers in stage 1 under the safe and the risky strategy. The best safe contract can be found by maximizing:

$$\max_{g_1,g_2,T} B(g_1+g_2) - c_2 \cdot g_2 - T \tag{11}$$

$$\text{s.t.} \quad B(g_1+g_2) - c_1^h \cdot g_1 + T - \Pi_1(g_1^{NC}) \geq 0$$

$$g_1, g_2 \geq 0.$$

The relevant constraint is the participation constraint of the high-cost delegate. The best safe contract can be written as:

$$P^S = \left\{ g_1^{bar,S} = g_1^{C,h}, g_2^{bar,S} = 0, \overline{T} = \Pi_1(g_1^{NC}) - [B(g_1^{C,h}) - c_1^h \cdot g_1^{C,h}] \right\}, \tag{12}$$

where $g_1^{bar,S} = g_1^{C,h}$ is implicitly determined by the Samuelson rule: $2 \cdot B^{'}(g_1^{C,h}) - c_1^h = 0$. As player 2's cost exceeds the cost of the h-type delegate, the total payoff is maximized when the entire public good is provided by player 1. Player 2's (expected) payoff under the safe strategy can be written as:

$$\Pi_2^S = 2 \cdot B(g_1^{C,h}) - c_1^h \cdot g_1^{C,h} - \Pi_1(g_1^{NC}). \tag{13}$$

Player 2 reaps both parties' benefits of a public good of size $g_1^{C,h}$ but has to compensate player 1 for the cost of provision (including the political costs) and the opportunity cost of a bargaining solution.
To find the best risky contract we use the participation constraint of the l-type and take into account that this strategy is only successful with a probability of 0.5:

$$\max_{g_1,g_2,T} \frac{1}{2} \cdot [B(g_1+g_2) - c_2 \cdot g_2 - T] + \frac{1}{2} \cdot [\Pi_2(g_1^{NC})] \tag{14}$$

$$\text{s.t.} \quad B(g_1+g_2) - c_1^l \cdot g_1 + T - \Pi_1(g_1^{NC}) \geq 0$$

$$g_1, g_2 \geq 0.$$

Again, the public good is entirely provided by player 1 ($g_1^{bar} = g_1^{C,l}$) as she has the lower marginal costs. The size of the public good is implicitly given by the Samuelson rule, where the marginal costs of the l-type matter: $2 \cdot B^{'}(g_1^{C,l}) - c_1^l = 0$. As best risky contract, we get:

$$P^R = \{g_1^{bar,R} = g_1^{C,l}, g_2^{bar,R} = 0, \underline{T} = \Pi_1(g_1^{NC}) - [B(g_1^{C,l}) - c_1^l \cdot g_1^{C,l}]\}. \tag{15}$$

The risky strategy yields:

$$E\Pi_2^R = \frac{1}{2} \cdot [2 \cdot B(g_1^{C,l}) - c_1^l \cdot g_1^{C,l} - \Pi_1(g_1^{NC})] + \frac{1}{2} \cdot \Pi_2(g_1^{NC}) \tag{16}$$

as an expected payoff for player 2.

Lemma 2. *There is a unique value $\alpha_1^{indiff} \in [0, c_1)$ that makes player 2 indifferent between the risky and the safe strategy. For $\alpha_1 < \alpha_1^{indiff}$, she prefers the safe strategy; for $\alpha_1 > \alpha_1^{indiff}$, she prefers the risky strategy.*

Proof. Player 2 compares the payoffs under the two strategies:

$$\Pi_2^S \gtreqless E\Pi_2^R \tag{17}$$

At $\alpha_1 \to 0$, the comparison boils down to $2 \cdot B(g_1^{C,l}) - c_1^l \cdot g_1^{C,l} > \Pi_2(g_1^{NC})$, which holds due to $g_1^C = g_1^{C,l} = g_1^{C,h}$ for α_1 close to zero. As the cooperative solution generates higher rents (left-hand side) than the non-cooperative game (right-hand side), player 2 is always better off choosing the safe strategy with very small opacity. If α_1 increases, the left-hand side of (17) decreases, while the right-hand side increases:

$$\begin{aligned}\frac{\partial \Pi_2^S}{\partial \alpha_1} &= [2 \cdot B'(g_1^{C,h}) - c_1^h] \cdot \frac{\partial g_1^{C,h}}{\partial c_1^h} \cdot \frac{\partial c_1^h}{\partial \alpha_1} - \frac{\partial c_1^h}{\partial \alpha_1} \cdot g_1^{C,h} = -g_1^{C,h} < 0 \\ \frac{\partial E\Pi_2^R}{\partial \alpha_1} &= \frac{1}{2} \cdot \{[2 \cdot B'(g_1^{C,l}) - c_1^l] \cdot \frac{\partial g_1^{C,l}}{\partial c_1^l} \cdot \frac{\partial c_1^l}{\partial \alpha_1} - \frac{\partial c_1^l}{\partial \alpha_1} \cdot g_1^{C,l}\} = \frac{1}{2} \cdot g_1^{C,l} > 0.\end{aligned} \tag{18}$$

The safe strategy becomes less attractive, since aggregate payoffs are falling when the marginal cost c_1^h is increasing. The risky strategy becomes more attractive as c_1^l falls in α_1. With α_1 close to c_1, the marginal costs c_1^l converge to zero and the expected payoff $E\Pi_2^R$ to infinity. This way the existence of a unique point of intersection between Π_2^S and $E\Pi_2^R$ within the range $\alpha_1 \in (0, c_1)$ is ensured. Note that the fallback position is not affected by the degree of opacity. Hence, there is a unique value α_1^{indiff} making player 2 indifferent between the safe and the risky proposal:

$$\Pi_2^S \gtreqless E\Pi_2^R \Leftrightarrow \alpha_1^{indiff} \gtreqless \alpha_1. \tag{19}$$

□

Stage 0: Choice of Opacity

We can now turn to player 1's choice of opacity. Player 1 knows that the degree of opacity will influence player 2's offer. To what extent can player 1 secure some of the rents from extended public good provision for herself by sending an opaque delegate to the negotiations?

Proposition 1. *For player 1, it is always optimal to generate some opacity about the delegate's preferences* ($\alpha_1^{opt} > 0$)*.*

Proof. For player 1 the payoff if player 2 chooses the safe strategy, and the expected payoff if player 2 chooses the risky strategy can be written as:

$$\Pi_1^S = \Pi_1(g_1^{NC}) + (c_1^h - c_1) \cdot g_1^{C,h} \text{ and} \tag{20}$$

$$E\Pi_1^R = \Pi_1(g_1^{NC}) + \frac{1}{2} \cdot (c_1^l - c_1) \cdot g_1^{C,l} \tag{21}$$

respectively. Since $(c_1^h - c_1) \cdot g_1^{C,h} > 0 > \frac{1}{2} \cdot (c_1^l - c_1) \cdot g_1^{C,l}$, player 1 prefers the safe contract over the risky contract. Therefore, α_1^{indiff} is the upper limit to her opacity choice, i.e. $\alpha_1^{opt} \leq \alpha_1^{indiff}$. Taking the first derivative of Π_1^S with respect to α_1 yields:

$$\frac{\partial \Pi_1^S}{\partial \alpha_1} = (c_1^h - c_1) \cdot \frac{\partial g_1^{C,h}}{\partial \alpha_1} + \frac{\partial c_1^h}{\partial \alpha_1} \cdot g_1^{C,h} = \alpha_1 \cdot \frac{\partial g_1^{C,h}}{\partial \alpha_1} + g_1^{C,h}. \tag{22}$$

At $\alpha_1 = 0$, the derivative is strictly positive: $\frac{\partial \Pi_1^S}{\partial \alpha_1}(\alpha_1 = 0) = g_1^{C,h} > 0$. Hence, it always pays off for player 1 to create some opacity. □

This is where a difference emerges from Konrad and Thum (2020), who analyze the division of a fixed rent. In our model with endogenous rents, an increase in opacity comes at a cost. Opacity forces player 2 to target a delegate with high (political) costs. With rising α_1, the contribution level $g_1^{C,h}$ falls. In the opacity equilibrium, this mechanism reduces the provision level below the first-best level. The strategy of sending a delegate with opaque preferences entails a welfare loss. The compensation of player 1 for each unit provided is simply a transfer and is irrelevant from a welfare perspective. However, this compensation goes along with a downward distortion in the provision level ($g_1^{C,h} < g_1^C$), which makes aggregate payoffs of player 1 and player 2 ($\sum_{i=1}^{2} \Pi_i(g_1^{C,h})$) suboptimally low.

The Case of Small Cost Differences

So far, we have considered large cost differences between player 1 and player 2. Even the high-cost delegate still had lower costs than player 2. The cost to player 2 was never a binding constraint for the opacity choice of player 1. What happens if the cost difference β between the two players is small, so that the high-cost delegate would have a higher cost than player 2 when applying the previously optimal opacity choice?

Lemma 3. *If $\beta < \alpha_1^{opt}$, player 1's payoff-maximizing degree of opacity is $\alpha_1^{opt,2} = \beta$.*

We simply provide an intuition for this result; the formal proof is available upon request. How is player 2's offer in stage 1 affected if $c_1^h = c_1 + \alpha_1 > c_2$? Obviously, nothing changes for the risky contract as it aims at the low-cost delegate $c_1^l = c_1 - \alpha_1$. However, the safe contract is affected. Due to $c_1^h > c_2$, player 2 is now better off providing the public good herself and charging player 1 for this provision (negative transfer). This negative transfer pushes player 1 down to the reservation payoff. When increasing the degree of opacity beyond the threshold of $\alpha_1 = \beta$, player 1's payoff drops to the reservation level. Hence, player 1's best choice of opacity is $\alpha_1^{opt,2} = \beta$. This just prevents player 2 from providing the good, ensures a safe offer, and allows player 1 to secure some rents.[4]

5 Bilateral Delegation

We now consider the case where players 1 and 2 can simultaneously hand over negotiations to opaque delegates. The opacity choice is denoted as α_1 and α_2 respectively. The realizations of the players' types are mutually stochastically independent.

Player 2 chooses α_2; her delegate's costs are either $c_2^h = c_2 + \alpha_2$ or $c_2^l = c_2 - \alpha_2$ with equal probability. The payoff functions of player 2 and her delegate only differ in the marginal cost of public good provision. Therefore, the payoffs of player 2 and a delegate of type $m \in (h, l)$ are identical, if $g_2 = 0$. In the case of weak delegation, the fallback position of player 2's delegate will be $\Pi_{del2,m}(g_1^{NC}) = \Pi_2(g_1^{NC}) = B(g_1^{NC})$. With bilateral opacity there are minor changes to the overall structure of the game. In stage 0, there is now a simultaneous opacity choice by both players. In stage 1, it is now the delegate of player 2 (rather than player 2 herself) who makes a take-it-or-leave-it offer.

0. Player 1 chooses α_1 and player 2 chooses α_2, i.e. both players appoint a delegate who is defined by her level of opacity.
1. The delegate of player 2 proposes a contract stating the contribution levels g_1^{del}, g_2^{del} and a monetary transfer T to player 1.
2. The delegate of player 1 can either accept or reject the offer.
3. In the case of successful negotiations, the public good is provided at marginal cost c_1 or c_2 and the transfer is realized according to the contract. If negotiations fail, the non-cooperative game will be played.

The game is solved backwards.

Stage 2: Acceptance and Refusal

A delegate of type $m \in (h, l)$ either proposes a safe or risky contract. A safe offer is accepted with certainty; a safe offer may stipulate the provision of the public good by player 1 or player 2. In the case of a risky offer, bargaining is successful with probability 50%, i.e. when the delegate of player 1 is of the low-cost type. If she is of the high-cost type, the outcome of the non-cooperative game will be realized.

[4] We have focused on the case $c_1 < c_2$. If $c_1 \geq c_2$, player 1 cannot gain from opacity. The only way for player 1 to profit from delegation is achieving overcompensation for the cost of public good provision. This is only possible, if the high-cost delegate has lower marginal cost than player 2, i.e. $c_1^h < c_2$, which is not possible if $c_1 \geq c_2$. Another scenario is that player 2 considers delegation. Since player 2 has already all the bargaining power, she can harvest the complete rent from cooperation and there is no possibility for further redistribution towards player 2. Yet, by delegation the efficient provision level will be missed with certainty.

Stage 1: Contract Offer

There are three types of contracts that may be optimal for a delegate of type m. The optimal contract offer depends on the previous choices of α_1 and α_2. The delegate can either propose a safe contract with player 1 contributing to the public good (P^{S1}), a safe contract with player 2 contributing to the public good (P^{S2}), or a risky contract with player 1 contributing to the public good (P^R):

$$P^{S1} = \{g_1^{del} = g_1^{C,h}, g_2^{del} = 0, T^{S1} = \Pi_1(g_1^{NC}) - [B(g_1^{C,h}) - c_1^h \cdot g_1^{C,h}]\} \tag{23}$$

$$P^{S2} = \{g_1^{del} = 0, g_2^{del} = g_2^{C,m}, T^{S2} = \Pi_1(g_1^{NC}) - B(g_2^{C,m})\} \tag{24}$$

$$P^{R} = \{g_1^{del} = g_1^{C,l}, g_2^{del} = 0, T^{R} = \Pi_1(g_1^{NC}) - [B(g_1^{C,l}) - c_1^l \cdot g_1^{C,l}]\} \tag{25}$$

There is a single value $\alpha_1^{indiff,I}$ making a delegate of type m indifferent between proposing P^{S1} and P^R:[5]

$$\Pi_{del2,m}^{S1}(g_1^{C,h}) \gtreqless E\Pi_{del2,m}^{R}(g_1^{C,l}) \Leftrightarrow \alpha_1^{indiff,I} \gtreqless \alpha_1 \tag{26}$$

For any $\alpha_1 \leq \alpha_1^{indiff,I}$, a delegate of type m prefers P^{S1} over P^R. This value is independent of α_2. However, whether or not a delegate of type m considers P^{S2} depends on c_2^m and, therefore, on α_2.

In the following, we analyze whether the provision of the public good by player 2 (P^{S2}) can be part of an optimal offer by player 2's delegate. Whether this is the case, depends on the delegate's marginal costs $c_2^m = c_2 \pm \alpha_2$.

Lemma 4. *(a) For marginal costs $c_2^m \geq c_1 + \alpha_1^{indiff,I}$, P^{S2} can never be an optimal contract. A delegate of type m chooses either P^{S1} or P^R; therefore, player 1 always contributes to the public good. For $\alpha_1 \leq \alpha_1^{indiff,I}$, the safe contract P^{S1} will be proposed, otherwise the risky contract P^R.*
(b) For $c_1 < c_2^m < c_1 + \alpha_1^{indiff,I}$, the delegate's best offers are: P^{S1} for $\alpha_1 \leq \alpha_1^{indiff,IIa}$, P^{S2} for $\alpha_1^{indiff,IIa} < \alpha_1 \leq \alpha_1^{indiff,IIb}$ and P^R for $\alpha_1 > \alpha_1^{indiff,IIb}$. The critical value $\alpha_1^{indiff,IIa}$ is implicitly given by $\Pi_{del2,m}^{S2}(g_2^{C,m}) = \Pi_{del2,m}^{S1}(g_1^{C,h}(\alpha_1^{indiff,IIa}))$, and $\alpha_1^{indiff,IIb}$ is given by $\Pi_{del2,m}^{S2}(g_2^{C,m}) = E\Pi_{del2,m}^{R}(g_1^{C,l}(\alpha_1^{indiff,IIb}))$.
(c) For $c_2^m < c_1$, the delegate's best offers are: P^{S2} for $\alpha_1 \leq \alpha_1^{indiff,IIb}$ and P^R for $\alpha_1 > \alpha_1^{indiff,IIb}$.

The formal proof for Lemma 4 can be found in Appendix A. The configuration of best offers is illustrated in Figure 1a and Figure 1b:
(a) Figure 1a depicts the (expected) payoffs of a delegate of type m for the different contract choices as a function of α_1 for the case $c_2^m = c_1 + \alpha_1^{indiff,I}$. The blue lines are the (expected) payoffs if player 1 contributes and the red line visualizes the payoff from the contract with player 2 contributing. By construction, all three lines intersect once in $\alpha_1^{indiff,I}$. One of the contracts, P^{S1} or P^R, is always preferred over P^{S2}. This is *a fortiori* the case when $c_2^m > c_1 + \alpha_1^{indiff,I}$, i.e. when the red line shifts downwards. For $\alpha_1 \leq \alpha_1^{indiff,I}$, the delegate prefers the safe strategy P^{S1}; for $\alpha_1 > \alpha_1^{indiff,I}$, she prefers the risky strategy P^R.
(b) Figure 1b illustrates the case $c_2^m < c_1 + \alpha_1^{indiff,I}$. The blue lines depict again $\Pi_{del2,m}^{S1}(g_1^{C,h})$ and $E\Pi_{del2,m}^{R}(g_1^{C,l})$; the horizontal red line describes $\Pi_{del2,m}^{S2}(g_2^{C,m})$. At $\alpha_1^{indiff,I}$, the red line now lies above the intersecting point of both blue lines. As the blue line $\Pi_{del2,m}^{S1}(g_1^{C,h})$ starts above the red line – due to the lower cost of player 1 at $\alpha_1 = 0$ ($c_1 < c_2^m$) – and is downward sloping, there will be a unique value $\alpha_1^{indiff,IIa}$ that will make the delegate of type m indifferent between the safe contracts where player 1 (P^{S1}) or player 2 (P^{S2}) contribute. A similar threshold can be established for the comparison of P^{S2} and P^R. The expected payoff of the risky strategy is increasing in α_1 and goes to infinity as $\alpha_1 \to c_1$. Hence, there must be a unique critical value $\alpha_1^{indiff,IIb}$ where the risky strategy becomes more attractive for player 2's delegate than providing the public good herself.
(c) The mechanism is basically the same as under (b). When the red curve for P^{S2} shifts upward beyond $c_2^m < c_1$, the critical value $\alpha_1^{indiff,IIa}$ vanishes as player 2's delegate can always provide the good at lower costs than player 1. Hence, player 2's delegate offers P^{S2} for $\alpha_1 < \alpha_1^{indiff,IIb}$ and P^R otherwise.

Using these results, we can establish, which combinations of offers are possible given the opacity choice from the previous stage.

[5] Since $\Pi_2 = \Pi_{del2,m}$ for $g_2 = 0$, the proof is analogous to the previous chapter.

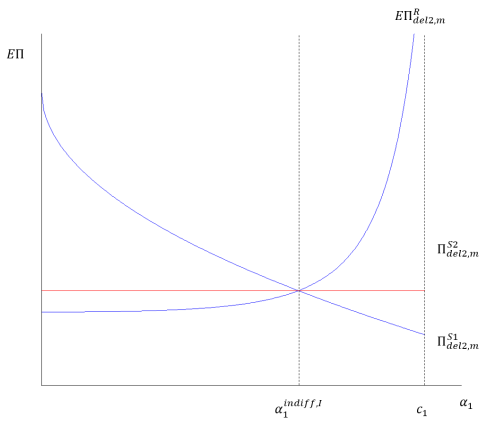

Figure 1a: Contract offers at $c_2^m \geq c_1 + \alpha_1^{indiff,I}$

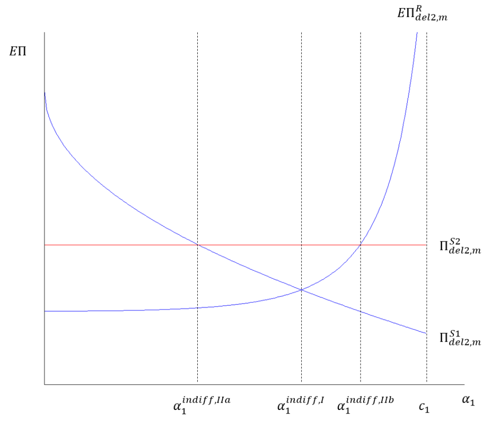

Figure 1b: Contract offers at $c_2^m < c_1 + \alpha_1^{indiff,I}$

Lemma 5. *If player 1 chooses $\alpha_1 > \alpha_1^{indiff,I}$, she will either receive an offer P^{S2} or P^R depending on α_2. As these offers are not profitable for her, player 1 will never choose $\alpha_1 > \alpha_1^{indiff,I}$.*

Proof. For $\alpha_1 > \alpha_1^{indiff,I}$, it holds that $\Pi^R_{del2,m} > \Pi^{S1}_{del2,m}$ irrespective of the proposing delegate's type m. Depending on α_2, an offer of P^{S2} or P^R will be made. There are three subcases to consider:

1. Both types of the proposing delegate will make a safe offer P^{S2}.
   Player 1's (expected) payoff is $E\Pi_1 = \Pi_1^{NC}$.
2. The delegate of the h-type proposes P^R while the delegate of the l-type proposes P^{S2}.
   Player 1's (expected) payoff is $E\Pi_1 = \Pi_1^{NC} - \frac{1}{2} \cdot (\alpha_1 \cdot g_1^{C,l}) < \Pi_1^{NC}$.
3. Both types of delegates propose the risky offer P^{R2}
   Player 1's (expected) payoff is $E\Pi_1 = \Pi_1^{NC} - \alpha_1 \cdot g_1^{C,l} < \Pi_1^{NC}$.

Hence, by choosing $\alpha_1 > \alpha_1^{indiff,I}$, player 1 cannot benefit compared to the situation without delegation.[6] □

Lemma 6. *For $\alpha_1 \leq \alpha_1^{indiff,I}$, a delegate of player 2 will either propose P^{S1} or P^{S2}. By choosing $\alpha_1 \leq \alpha_1^{indiff,I}$ player 1 will never be worse off than in the situation with no delegation.*

Proof. For $\alpha_1 \leq \alpha_1^{indiff,I}$, it holds that $\Pi^{S1}_{del2,m} \geq \Pi^R_{del2,m}$ irrespective of the proposing delegate's type m. The risky offer P^R therefore can be ruled out. Depending on α_2, either an offer of P^{S1} or P^{S2} will be made.

For a given value α_1, there are three possible combinations of offers depending on α_2.

1. Both types of delegates offer a contract P^{S1}.
   Player 1 will receive the (expected) payoff $E\Pi_1 = \Pi_1^{NC} + \alpha_1 \cdot g_1^{C,h}$.
2. The l-type delegate offers a contract P^{S2} and the h-type delegate offers a contract P^{S1}.
   The expected payoff of player 1 will be $E\Pi_1 = \frac{1}{2} \cdot (\Pi_1^{NC} + \alpha_1 \cdot g_1^{C,h}) + \frac{1}{2} \cdot \Pi_1^{NC}$.
3. Both types of delegates offer a contract P^{S2}.
   The (expected) payoff of player 1 will be $E\Pi_1 = \Pi_1^{NC}$.

For any $\alpha_1 \in (0, \alpha_1^{indiff,I})$, it holds that $E\Pi_1(\alpha_1) \geq \Pi_1^{NC}$. □

With the possible combinations of proposals established, we now look at stage 0 of the game. The opacity choices at stage 0 determine, which of these combinations is realized.

[6]A combination of P^{S2} from the delegate of the h-type and P^R from the l-type will never occur. If the h-type finds it profitable to provide the good, the l- type will do so *a fortiori*.

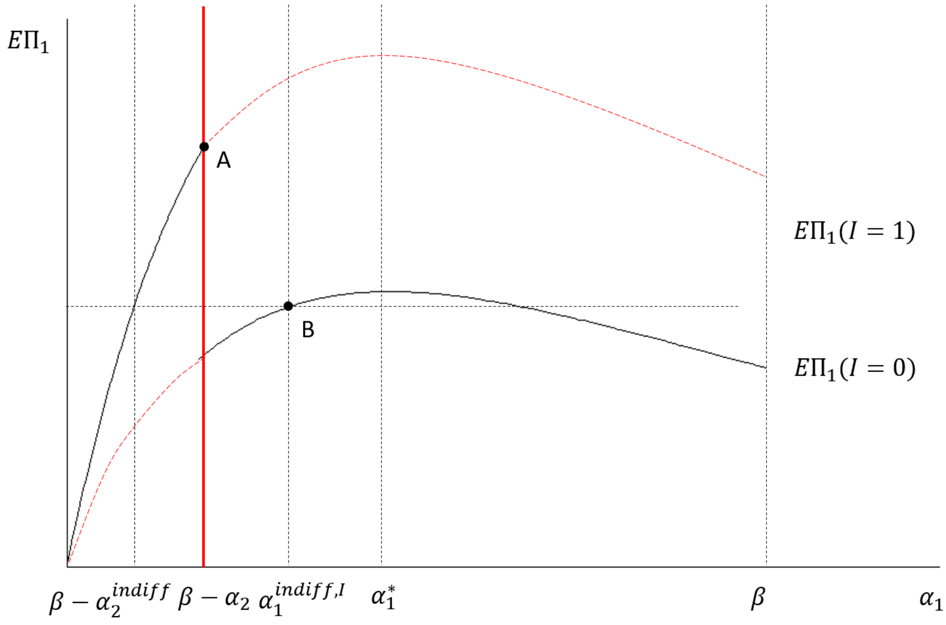

Figure 2: Player 1's maximization problem

Stage 0: Opacity Choice

Player 1:

For clarity of exposition, we again assume that the cost differential β is sufficiently large. This way we only have to consider the l-type among player 2's delegates. Since we have already established that player 1 will always choose a degree of opacity $\alpha_1 \leq \alpha_1^{indiff,I}$, the additional assumption $\alpha_1^{indiff,I} < \beta$ ensures that $c_2^h \geq c_1^h$, i.e. player 1 will always receive the safe offer P^{S1} from a h-type delegate irrespective of α_2. To establish the reaction function we only have to determine, whether player 1 will induce the l-type to offer P^{S1} or P^{S2} for a given α_2.

To determine the optimal reply to a given value α_2, player 1 solves the following maximization problem:

$$\max_{\alpha_1} E\Pi(\alpha_1,\alpha_2) = \frac{1}{2}\cdot[\Pi_1^{NC} + \alpha_1 \cdot g_1^{C,h}(c_1+\alpha_1)] + \frac{1}{2}\cdot[\Pi_1^{NC} + I(\alpha_1,\alpha_2)\cdot(\alpha_1 \cdot g_1^{C,h}(c_1+\alpha_1))] \tag{27}$$

$$\text{s.t. } 0 \leq \alpha_1 \leq \alpha_1^{indiff,I}$$

$$I(\alpha_1,\alpha_2) = \begin{cases} 1, & \text{if } \alpha_1 \leq \beta-\alpha_2 \\ 0, & \text{if } \alpha_1 > \beta-\alpha_2 \end{cases}$$

The first term in square brackets is player 1's payoff if the proposing delegate is of the h-type, who will always propose P^{S1}. The second term in square brackets is the payoff from delegation if the proposing delegate is of the l-type. The l-type will propose P^{S2} if $c_1^h > c_2^l$, which can be rewritten as $\alpha_1 > \beta - \alpha_2$. In this case, the indicator function $I(\alpha_1,\alpha_2)$ takes on the value 0. For $\alpha_1 \leq \beta-\alpha_2$, the indicator function $I(\alpha_1,\alpha_2)$ takes on the value 1, meaning that a delegate of the h-type will propose P^{S1}.

Lemma 7. *There is a discontinuity in the expected payoff function of player 1 at the threshold $\alpha_1 = \beta - \alpha_2$. A local maximum exists both to the left and the right of this threshold. Player 1's expected payoff $E\Pi_1$ is maximized at $min(\alpha_1^*, \alpha_1^{indiff,I}, \beta-\alpha_2)$ for $I(\alpha_1,\alpha_2)=1$ and at $max(min(\alpha_1^*, \alpha_1^{indiff,I}), \beta-\alpha_2)$ for $I(\alpha_1,\alpha_2)=0$.*

Proof. The formal proof for Lemma 7 can be found in Appendix B. □

The maximization problem is visualized in Figure 2. The threshold $\beta-\alpha_2$ is depicted by the vertical red line. The upper payoff function describes player 1's expected payoff if both types of delegates propose the contract P^{S1}, i.e. $E\Pi(I=1)$. The non feasible values to the right of the threshold are indicated by the dashed red line. In our example, the local maximum of $E\Pi_1(I=1)$ can be found at point A, i.e. by choosing $\alpha_1 = \beta-\alpha_2$ at the threshold. The lower curve describes player 1's expected payoff if only a delegate of the h-type is proposing the contract P^{S1}. Non-feasible values of the expected payoff function below the threshold are again indicated by a dashed red line. In Figure 2, $min(\alpha_1^*, \alpha_1^{indiff,I})$ lies to the right of the threshold. Therefore the local maximum for $E\Pi(I=0)$ can be found in point B, i.e. a choice of $\alpha_1 = \alpha_1^{indiff,I}$. We have established the existence of two local maxima for the two cases $I(\alpha_1, \alpha_2) = 0$ (point B) and $I(\alpha_1, \alpha_2) = 1$ (point A). By comparing the two local maxima, the best response of player 1 to a given value α_2 is found. In our example, this is $\alpha_1 = \beta - \alpha_2$. We now have to determine, how player 1's choice depends on α_2.

Lemma 8. *There is a critical value α_2^{indiff}, making player 1 indifferent between receiving the safe offer P^{S1} from both types of delegates or only from the l-type.*

Proof. The formal proof for Lemma 8 can be found in Appendix C. □

Player 1 is facing a trade-off between higher degrees of opacity α_1 and a higher probability of receiving the beneficial offer P^{S1}. Using Figure 2, the comparative statics with respect to α_2 can easily be understood. When α_2 increases, the vertical line shifts to the left. This will lead to a falling value of the local maximum $E\Pi_1^{opt}(I=1)$, while there will be no change in the local maximum $E\Pi_1^{opt}(I=0)$.[7] If the threshold is below but close to $min(\alpha_1^*, \alpha_1^{indiff,I})$, player 1 loses very little by choosing $\alpha_1 = \beta - \alpha_2$ and receiving the offer P^{S1} with certainty. Choosing the unrestricted opacity value instead puts the gains from delegation at risk with a probability of 50%. However, if $\beta - \alpha_2$ is close to zero, there are only small gains from delegation if player 1 wants to make sure to receive the offer P^{S1}. By an opacity choice to the right of the threshold, the rent from delegation will be achieved with a probability of 50%. There is a value α_2^{indiff}, making player 1 indifferent between a choice of α_1 that will guarantee offer P^{S1} with a low payoff and a choice of α_1 with a maximum degree of opacity $min(\alpha_1^*, \alpha_1^{indiff,I})$ that will lead to offer P^{S1} only with 50% probability. Player 1 receives a high payoff if player 2's delegate is of the h-type, and there will be no gains from delegation if the proposer's delegate is of the l-type.

Lemma 9. *Player 1's reaction function $\alpha_1(\alpha_2)$ is:*

$$\alpha_1(\alpha_2) = \begin{cases} min(\alpha_1^*, \alpha_1^{indiff,I}, \beta - \alpha_2), & \text{if } \alpha_2 \leq \alpha_2^{indiff} \\ min(\alpha_1^*, \alpha_1^{indiff,I}), & \text{if } \alpha_2 > \alpha_2^{indiff} \end{cases} \tag{28}$$

Proof. The reaction curve is directly obtained by taking together Lemma 7 and Lemma 8. □

The blue line in Figure 3 illustrates player 1's reaction function $\alpha_1(\alpha_2)$. For the diagrammatic exposition, we assume that $\alpha_1^* \geq \alpha_1^{indiff,I}$. Along the segment $\overline{AB}$, player 1 chooses $\alpha_1 = \alpha_1^{indiff,I}$ and receives the offer P^{S1} with certainty. Along the segment $\overline{BC}$, player 1 chooses $\alpha_1 = \beta - \alpha_2$. Increasing degrees of opacity of player 2 will lead to a decrease in α_1. In order to receive the offer P^{S1} with certainty, player 1 has to deviate from her unrestricted opacity choice $\alpha_1 = \alpha_1^{indiff,I}$. Along the segment $\overline{DE}$, player 1 chooses $\alpha_1 = \alpha_1^{indiff,I}$ and receives the offer P^{S1} only with 50% probability. The horizontal segments of the reaction curve are shifted downwards for $\alpha_1^* < \alpha_1^{indiff,I}$.

Player 2:

To derive the best reply correspondence of player 2, we have to distinguish between the cases $\alpha_1 \leq \alpha_1^{indiff,I}$ and $\alpha_1 > \alpha_1^{indiff,I}$.

$\alpha_1 \leq \alpha_1^{indiff,I}$: It has already been established that for $\alpha_1 \leq \alpha_1^{indiff,I}$ player 2, as well as any of her delegates, choose between P^{S1} and P^{S2}. Recall that we have assumed a sufficiently large β, i.e. $\beta > \alpha_1^{indiff,I}$. This way, player 2, as well as her delegate of the h-type, always proposes P^{S1} irrespective of the α_2 level, as $c_1^h > c_2^h$ for all α_2. The proposal of the l-type delegate, however, depends on α_2. The delegate proposes P^{S2} if $c_2^l < c_1^h$, i.e.

[7] For $\beta - \alpha_2 > min(\alpha_1^*, \alpha_1^{indiff,I})$ the threshold is not binding. Player 1 receives P^{S1} with certainty, choosing her maximum level of opacity $min(\alpha_1^*, \alpha_1^{indiff,I})$. A marginal shift of the threshold to the left will not affect player 1's choice of opacity.

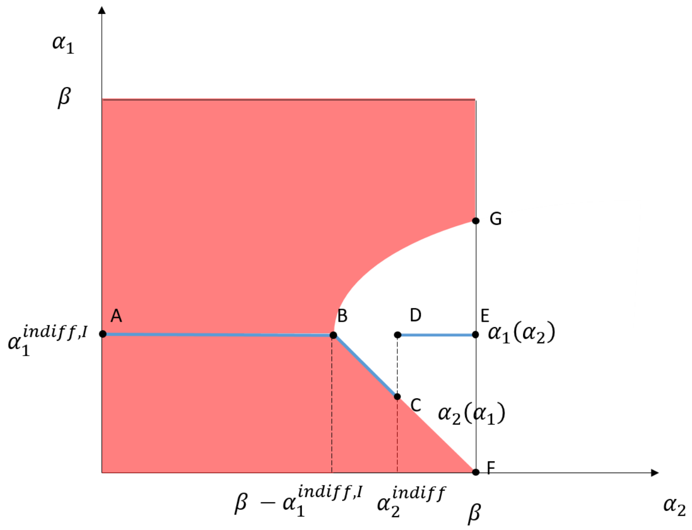

Figure 3: Reaction function $\alpha_1(\alpha_2)$ of player 1 and best response correspondence of player 2 for the case $\alpha_1^* > \alpha_1^{indiff,I}$

$\alpha_2 > \beta - \alpha_1$, and P^{S1} otherwise. Player 2 solves the following maximization problem to determine the optimal choice of α_2 for a given $\alpha_1 \leq \alpha_1^{indiff,I}$:

$$\max_{\alpha_2} E\Pi_2 = \frac{1}{2} \cdot [2 \cdot B(g_1^{C,h}) - c_1^h \cdot g_1^{C,h} - \Pi_1^{NC}] + \frac{1}{2} \cdot [2 \cdot B(\hat{g}_1(\alpha_2) + \hat{g}_2(\alpha_2)) - c_1^l \cdot \hat{g}_1(\alpha_2) - c_2 \cdot \hat{g}_2(\alpha_2) - \Pi_1^{NC}] \quad (29)$$

$$\hat{g}_1 = \begin{cases} g_1^{C,h}, & \text{if } \alpha_2 \leq \beta - \alpha_1 \\ 0, & \text{if } \alpha_2 > \beta - \alpha_1 \end{cases}$$

$$\hat{g}_2 = \begin{cases} 0, & \text{if } \alpha_2 \leq \beta - \alpha_1 \\ g_2^{C,l}(\alpha_2), & \text{if } \alpha_2 > \beta - \alpha_1 \end{cases}$$

The first expression in square brackets is player 2's payoff if her delegate is of the h-type, who always proposes P^{S1} with $g_1 = g_1^{C,h}$ and $g_2 = 0$. The second term in square brackets is player 2's payoff if her delegate is of the l-type. The contribution levels to the public good – $\hat{g}_1(\alpha_2)$ and $\hat{g}_2(\alpha_2)$ – are functions of α_2. As long as $\alpha_2 \leq \beta - \alpha_1$ (i.e. $c_1^h \leq c_2^l$), the l-type delegate proposes P^{S1} with $\hat{g}_1 = g_1^{C,h}$ and $\hat{g}_2 = 0$. Otherwise, the l-type delegate proposes P^{S2} with $\hat{g}_1 = 0$ and $\hat{g}_2 = g_2^{C,l}$.

Lemma 10. *For $\alpha_1 \leq \alpha_1^{indiff,I}$, the best response of player 2 is set valued with $\alpha_2 \in [0, \beta - \alpha_1]$, so that P^{S1} is proposed.*

Proof. The formal proof for Lemma 10 can be found in Appendix D. □

For $\alpha_1 \leq \alpha_1^{indiff,I}$, player 2 prefers P^{S1} over P^{S2} at $\alpha_2 = 0$. For $\alpha_2 > 0$, player 2 never wants any of her delegates whose marginal costs deviate from her own to propose P^{S2}. Hence, she has to make sure that P^{S1} is offered with certainty. As we assume a sufficiently large cost differential β, only the l-type is relevant, who will propose P^{S1} as long as $c_2^l > c_1^h$. This is the case for $\alpha_2 \leq \beta - \alpha_1$.

$\alpha_1 > \alpha_1^{indiff,I}$: Player 2 as well as both of her delegates prefer P^R over P^{S1}. Recall that we have considered a sufficiently large cost differential β, so that player 2 and her delegate of the h-type prefer P^R over P^{S2} irrespective of α_2. The proposal of the l-type delegate depends on α_2.

Lemma 11. *For $\alpha_1 > \alpha_1^{indiff,I}$, a delegate of the l-type chooses between P^R and P^{S2}. She is indifferent between these contracts at $\tilde{\alpha}_2(\alpha_1)$. The value $\tilde{\alpha}_2(\alpha_1)$ is strictly increasing in α_1.*

Proof. The formal proof for Lemma 11 can be found in Appendix E. □

Having described the l-type's trade-off between P^{S2} and P^R for given levels of α_1 and α_2, we now look at player 2's opacity choice. Player 2 solves the following maximization problem to determine the optimal level α_2 as a best response to a given $\alpha_1 > \alpha_1^{indiff,I}$:

$$\max_{\alpha_2} E\Pi_2 = \frac{1}{2} \cdot \{\frac{1}{2} \cdot [2 \cdot B(g_1^{C,l}) - c_1^l \cdot g_1^{C,l} - \Pi_1^{NC}] + \frac{1}{2} \cdot \Pi_2^{NC}\}$$
$$+\frac{1}{2} \cdot I_1(\alpha_1, \alpha_2) \cdot \{\frac{1}{2} \cdot [2 \cdot B(g_1^{C,l}) - c_1^l \cdot g_1^{C,l} - \Pi_1^{NC}] + \frac{1}{2} \cdot \Pi_2^{NC}\} + \frac{1}{2} \cdot I_2(\alpha_1, \alpha_2) \cdot [2 \cdot B(g_2^{C,l}(\alpha_2)) - c_2 \cdot g_2^{C,l}(\alpha_2) - \Pi_1^{NC}] \quad (30)$$

$$I_1(\alpha_1, \alpha_2) = \begin{cases} 0, & \text{if } \alpha_2 > \tilde{\alpha}_2 \\ 1, & \text{if } \alpha_2 \leq \tilde{\alpha}_2 \end{cases}$$

$$I_2(\alpha_1, \alpha_2) = \begin{cases} 0, & \text{if } \alpha_2 \leq \tilde{\alpha}_2 \\ 1, & \text{if } \alpha_2 > \tilde{\alpha}_2 \end{cases}$$

The first summand describes player 2's expected payoff if her delegate is of the h-type proposing P^R with certainty. The second summand is player 2's expected payoff if her delegate is of the l-type proposing P^R. This is the case for $\alpha_2 \leq \tilde{\alpha}_2$ and the indicator function I_1 taking on the value 1. A delegate of the l-type proposes P^{S2} for $\alpha_2 > \tilde{\alpha_2}$, which is described in the third summand. Here, I_2 takes on the value 1.

Lemma 12. *For $\alpha_1 > \alpha_1^{indiff,I}$, player 2's optimal level of opacity α_2 avoids her own contributions to the public good. The best response of player 2 is set valued with $\alpha_2 \in [0, \tilde{\alpha}_2(\alpha_1)]$.*

Proof. The formal proof for Lemma 12 can be found in Appendix F. □

At $\alpha_2 = 0$, player 2 prefers P^R over P^{S2}. For $\alpha_2 > 0$, player 2 wants to avoid any of her delegates, whose marginal costs deviate from her own, proposing P^{S2}. Again, we only have to consider the delegate of the l-type, who chooses between P^R and P^{S2} depending on α_2. For $\alpha_2 = \tilde{\alpha_2}(\alpha_1)$, the delegate is indifferent between these two options. As long as $\alpha_2 \leq \tilde{\alpha_2}(\alpha_1)$, the l-type prefers P^R.

Lemma 13. *The best response correspondence to player 1's opacity choice is described by $\alpha_2 \in [0, \beta - \alpha_1]$ for $\alpha_1 \leq \alpha_1^{indiff,I}$ – both delegates propose P^{S1} – and $\alpha_2 \in [0, \tilde{\alpha}_2(\alpha_1)]$ for $\alpha_1 > \alpha_1^{indiff,I}$ – both delegates propose P^R. $\tilde{\alpha}_2(\alpha_1)$ is the maximum level of opacity making a delegate of the l-type indifferent between P^R and P^{S2}.*

Proof. Taking Lemma 11 and Lemma 12 together, we obtain the optimal reply correspondence of player 2. □

It is never optimal for player 2 to provide the public good in the game with bilateral opacity. Opacity α_2 is chosen in a way that none of her delegates is tempted to propose P^{S2}.

In Figure 3, player 2's best reply correspondence $\alpha_2(\alpha_1)$ is illustrated by the red area. Within the range $\alpha_1 \in [0, \alpha_1^{indiff,I}]$, player 2 chooses $\alpha_2 \leq \beta - \alpha_1$. The maximum degree of opacity, which can be found along the segment $\overline{FB}$, is decreasing in α_1. For any α_2 below this maximum value, i.e. $\alpha_2 \leq \beta - \alpha_1$, $c_1^h \leq c_2^l$ is maintained. Any delegate of player 2 proposes P^{S1} and negotiations succeed with certainty. The realized allocation only depends on α_1 and not on the α_2 chosen. For $\alpha_1 > \alpha_1^{indiff,I}$, player 2 wants both her delegates to propose P^R. Therefore, player 2 has to choose $\alpha_2 \leq \tilde{\alpha_2}(\alpha_1)$. The maximum level of opacity $\tilde{\alpha_2}$ – illustrated by the curved segment $\overline{BG}$ – is increasing in α_1. With α_1 given, any $\alpha_2 \leq \tilde{\alpha_2}(\alpha_1)$ will lead to the same allocation. Negotiations fail if the delegate of player 1 is of the h-type.

Proposition 2. *In the case of bilateral delegation, negotiations succeed with certainty. Two sets of subgame-perfect equilibria arise: $(\alpha_1, \alpha_2) = (min(\alpha_1^*, \alpha_1^{indiff,I}), \alpha_2)$ in the range $\alpha_2 \in [0, \beta - min(\alpha_1^*, \alpha_1^{indiff,I})]$ and $(\alpha_1, \alpha_2) = (\beta - \alpha_2, \alpha_2)$ in the range $\alpha_2 \in [\beta - min(\alpha_1^*, \alpha_1^{indiff,I}), \alpha_2^{indiff}]$.*

Proof. The equilibrium combinations of α_1 and α_2 in pure strategies are the intersections of the best response function $\alpha_1(\alpha_2)$ of player 1 with the optimal reply correspondence of player 2. □

In any subgame-perfect equilibrium in pure strategies, negotiations succeed with certainty. Along the segment $\overline{BC}$, both players' opacity choices are substitutes. In these equilibria, a higher level of α_2 corresponds to a lower level of α_1. Any proposing delegate offers contract P^{S1}, which will be accepted by any responding delegate. Also in the second set of equilibria along the segment $\overline{AB}$, P^{S1} is proposed and accepted with certainty.[8]

We turn to the welfare evaluation of our findings. Aggregate welfare according to Kaldor-Hicks is maximized, if the public good is provided at marginal costs c_1 and the quantity is chosen according to the Samuelson Rule. As player 1 is the only contributor to the public good in any subgame-perfect equilibrium, welfare is increasing, if α_1 is decreasing. As player 1 chooses $\alpha_1 > 0$, the efficient provision of the public good is never achieved.

Proposition 3. *The set of subgame-perfect equilibria with bilateral delegation contains the equilibrium with unilateral delegation. According to the Kaldor-Hicks welfare measure, each equilibrium with bilateral opacity is at least as good as the unilateral equilibrium.*

Proof. The unique equilibrium in the game of unilateral delegation is $\alpha_1 = min(\alpha_1^*, \alpha_1^{indiff})$. Player 1's unrestricted opacity choice $\alpha_1^* = arg \max_{\alpha_1}[\Pi_1^{NC} + \alpha_1 \cdot g_1^{C,h}(\alpha_1)]$ is the same in the unilateral and the bilateral game.

In the unilateral game the level of opacity making player 2 indifferent between the safe and the risky proposal is denoted by α_1^{indiff}. This value is identical to $\alpha_1^{indiff,I}$ in the bilateral game since the critical value $\alpha_1^{indiff,I}$ is independent of player 2's choice of opacity α_2. The unilateral equilibrium $\alpha_1 = min(\alpha_1^*, \alpha_1^{indiff})$ therefore corresponds to the bilateral equilibrium $(\alpha_1, \alpha_2) = (min(\alpha_1^*, \alpha_1^{indiff}), 0)$. From both an efficiency and a distribution perspective, the whole set of bilateral equilibria $(\alpha_1, \alpha_2) = (min(\alpha_1^*, \alpha_1^{indiff,I}, \alpha_2)$ in the range $\alpha_2 \in [0, \beta - min(\alpha_1^*, \alpha_1^{indiff,I})]$ generates the same outcome as the unilateral game.
For $\alpha_2 \in [\beta - min(\alpha_1^*, \alpha_1^{indiff,I}), \alpha_2^{indiff,I}]$, α_1 and α_2 are strategic substitutes. Here, aggregate welfare is increasing in α_2:

$$\frac{dW}{d\alpha_2} = [2 \cdot B(g_1^{C,h}) \cdot \frac{\partial g_1^{C,h}}{\partial \alpha_1} - g_1^{C,h} - c_1^h \cdot \frac{\partial g_1^{C,h}}{\partial \alpha_1}] \cdot \frac{d\alpha_1}{d\alpha_2} = -g_1^{C,h} \cdot \frac{d\alpha_1}{d\alpha_2} > 0 \tag{31}$$

Hence, the equilibria along $\overline{BC}$ dominate all equilibria on $\overline{AB}$, where the outcome is the same as in the case of unilateral delegation. □

Comparing our results to Konrad and Thum (2020), the following differences emerge. In Konrad and Thum (2020) a positive rent is generated, if the buyer of an asset values it higher than the seller. The rent is determined by both players' valuation and therefore fixed. The rent is split among both players by negotiating the asset's price. In such a framework, inefficiencies only arise if negotiations fail. Opacity is used as a strategic tool to achieve a favorable redistribution of the rent. In our framework, the provision level of the public good is determined endogenously. The motives for delegation are identical to Konrad and Thum (2020). Yet, achieving a favorable redistribution of the surplus comes at the cost of social welfare. In any subgame-perfect-equilibrium, the proposed contract aims at the h-type delegate of player 1, who values the public good less than her principal. To avoid negotiation failure, proposals have to be formulated cautiously. A suboptimally low level of public good provision is proposed by any delegate of player 2. As in Konrad and Thum (2020), we find a set of equilibria where both players' opacity choices are strategic substitutes. The more opaque the delegate of player 2, the less opaque is the delegate chosen as a best response by player 1 in the equilibrium. This is not only relevant regarding the distribution of the generated surplus, but also from a welfare perspective. As the public good is provided by player 1 in any equilibrium, lower degrees of α_1 lead to an increase in public good provision and thus in aggregate welfare. Yet, the welfare optimal allocation cannot be attained in an equilibrium of bilateral opacity as this would require $\alpha_1 = 0$.

We find negotiations to succeed with certainty in any equilibrium; in Konrad and Thum (2020), there exists a set of equilibria where negotiations fail with a positive probability. In these equilibria, the players' opacity choices become strategic complements. This is the case because different types of proposing delegates follow different strategies: a proposing delegate with a high valuation for the asset pursues the risky strategy, i.e. proposes a high price, while the delegate with a low valuation pursues the safe strategy, i.e. proposes a low price. These types of equilibria can be ruled out in our model framework. There is no risk of failed negotiations. As it is never attractive for player 1 to choose $\alpha_1 > \alpha_1^{indiff,I}$, a delegate of player 2 will only choose among safe contracts with player 1 or player 2 being the contributor. The risk of failed negotiations due to an offer P^R can be ruled out.

[8] The results of the bilateral game hold for all cost structures. For small cost differences, $\min(\alpha_1^*, \alpha_1^{indiff,I}) \leq \beta$, there is only one set of equilibria with α_1 and α_2 being substitutes. Considering the case $c_1 > c_2$, there is no delegation on behalf of player 1. Player 2 may choose $\alpha_2 \in [0, \beta]$, yet delegation neither impacts the distribution nor the allocation of the game. The formal proofs for the different cost structures are available upon request.

6 Conclusion

This paper combines the idea of equilibrium opacity through delegation, introduced by Konrad and Thum (2020), with the private provision of a public good. If both, offer-maker and responder can delegate their decisions to agents, whose actual decision rules are opaque, the responder will benefit from opacity. Considering the private provision of a public good in contrast to a fixed rent, we find two main differences to Konrad and Thum (2020). In our model framework negotiations succeed with certainty. With the bargaining surplus being endogenous, inefficiencies do not only arise from negotiation failure but also from an inefficient provision level. We show that the first type of inefficiency vanishes with bilateral delegation; an agreement will always be reached. However, the public good provision falls short of the socially desirable level. Compared to unilateral delegation, bilateral delegation is never worse from a welfare perspective.

With the political costs being private information to the delegates, contract offers have to be formulated less aggressively. This way, the responding player can achieve a markup on the actual per unit cost of public good provision similar to a monopolist. This paper abstracts from the role experience plays in the bargaining process. By appointing a political newcomer as a delegate, the principal may face a trade-off between opacity and experience in negotiations.

The model can be extended in various dimensions. It may be interesting to see how players choose opacity if it is be randomly assigned, which side proposes and which side responds, after opacity has been chosen. Another interesting point to consider is how the opacity choice is affected by several rounds of bargaining. This entails the possibility of the delegate's type being revealed over time.

A Proof of Lemma 4

Lemma 4. (a) For marginal costs $c_2^m \geq c_1 + \alpha_1^{indiff,I}$, P^{S2} can never be an optimal contract. A delegate of type m chooses either P^{S1} or P^R; therefore, player 1 is always contributing to the public good. For $\alpha_1 \leq \alpha_1^{indiff,I}$, the safe contract P^{S1} will be proposed, otherwise the risky contract P^R.
(b) For $c_1 < c_2^m < c_1 + \alpha_1^{indiff,I}$, the delegate's best offers are: P^{S1} for $\alpha_1 \leq \alpha_1^{indiff,IIa}$, P^{S2} for $\alpha_1^{indiff,IIa} < \alpha_1 \leq \alpha_1^{indiff,IIb}$ and P^R for $\alpha_1 > \alpha_1^{indiff,IIb}$. The critical value $\alpha_1^{indiff,IIa}$ is implicitly given by $\Pi^{S2}_{del2,m}(g_2^{C,m}) = \Pi^{S1}_{del2,m}(g_1^{C,h}(\alpha_1^{indiff,IIa}))$, and $\alpha_1^{indiff,IIb}$ is given by $\Pi^{S2}_{del2,m}(g_2^{C,m}) = E\Pi^{R}_{del2,m}(g_1^{C,l}(\alpha_1^{indiff,IIb}))$.
(c) For $c_2^m < c_1$, the delegate's best offers are: P^{S2} for $\alpha_1 \leq \alpha_1^{indiff,IIb}$ and P^R for $\alpha_1 > \alpha_1^{indiff,IIb}$

Proof. (a) It has been established that for any $\alpha_1 \leq \alpha_1^{indiff,I}$, a delegate of type m will prefer the safe contract P^{S1} over the risky contract P^R and *vice versa* for $\alpha_1 > \alpha_1^{indiff,I}$. Now we rule out that the delegate would like to propose a contract P^{S2} with player 2 contributing to the public good. Suppose for the moment that $c_2^m = c_1 + \alpha_1^{indiff,I}$, i.e. the delegate's marginal cost c_2^m, is at the lower end of the restricted domain. For $\alpha_1 = \alpha_1^{indiff,I}$, it will hold, that:

$$\Pi^{S2}_{del2,m}(g_2^{C,m}) = \Pi^{S1}_{del2,m}(g_1^{C,h}(\alpha_1^{indiff,I})) = E\Pi^{R}_{del2,m}(g_1^{C,l}(\alpha_1^{indiff,I})). \tag{32}$$

Hence, for the special case $c_2^m = c_1 + \alpha_1^{indiff,I}$, all three options – P^{S1}, P^{S2} and P^R – yield the same expected payoff for the delegate. As $\frac{\partial \Pi^{S2}_{del2,m}(g_2^{C,m})}{\partial \alpha_1} = 0$, $\frac{\partial \Pi^{S1}_{del2,m}(g_1^{C,h})}{\partial \alpha_1} < 0$ and $\frac{\partial E\Pi^{R}_{del2,m}(g_1^{C,l})}{\partial \alpha_1} > 0$, the safe strategy P^{S1} is strictly preferred for any $\alpha_1 < \alpha_1^{indiff,I}$. And the risky strategy P^R is preferred for any $\alpha_1 > \alpha_1^{indiff,I}$. P^{S1} and P^R being preferred over P^{S2} holds *a fortiori* for $c_2^m > c_1 + \alpha_1^{indiff,I}$.
(b) Due to $c_2^m < c_1 + \alpha_1^{indiff,I}$, player 2's delegate prefers P^{S2} at $\alpha_1 = \alpha_1^{indiff,I}$: $\Pi^{S2}_{del2,m}(g_2^{C,m}) > \Pi^{S1}_{del2,m}(g_1^{C,h}) = E\Pi^{R}_{del2,m}(g_1^{C,l})$. At $\alpha_1 = 0$, both types of delegates have lower costs than player 2's delegate ($c_1 < c_2^m$), who therefore prefers P^{S1} $[\Pi^{S2}_{del2,m}(g_2^{C,m}) < \Pi^{S1}_{del2,m}(g_1^{C,h})]$. Due to $\frac{\partial \Pi^{S1}_{del2,m}(g_1^{C,h})}{\partial \alpha_1} < 0$, there must be a unique critical value $\alpha_1^{indiff,IIa}$ so that we obtain $\alpha_1 \gtreqless \alpha_1^{indiff,IIa} \Leftrightarrow \Pi^{S2}_{del2,m}(g_2^{C,m}) \gtreqless \Pi^{S1}_{del2,m}(g_1^{C,h})$. The expected profit from the risky strategy increases in α_1 and goes to infinity for $\alpha_1 \to c_1$, as the marginal costs of the low-type delegate of player 1 go to zero. Hence, there must be a unique critical value $\alpha_1^{indiff,IIb}$ so that we obtain $\alpha_1 \gtreqless \alpha_1^{indiff,IIb} \Leftrightarrow E\Pi^{R}_{del2,m}(g_1^{C,l}(\alpha_1) \gtreqless \Pi^{S2}_{del2,m}(g_2^{C,m})$.
(c) The proof is the same as for (b). The only difference is that P^{S2} can never be optimal as even for $\alpha_1 = 0$, player 2's delegate has lower cost than the high-cost delegate of player 1. □

B Proof of Lemma 7

Lemma 7. There is a discontinuity in the expected payoff function of player 1 at the threshold $\alpha_1 = \beta - \alpha_2$. A local maximum exists both to the left and the right of this threshold. Player 1's expected payoff $E\Pi_1$ is maximized at $min(\alpha_1^*, \alpha_1^{indiff,I}, \beta - \alpha_2)$ for $I(\alpha_1, \alpha_2) = 1$ and at $max(min(\alpha_1^*, \alpha_1^{indiff,I}), \beta - \alpha_2)$ for $I(\alpha_1, \alpha_2) = 0$.

Proof. We have to consider the existence of two local maxima, one for $I(\alpha_1, \alpha_2) = 1$ and one for $I(\alpha_1, \alpha_2) = 0$. These two maxima are determined separately.

1. $I(\alpha_1, \alpha_2) = 1$
   The maximization problem (27) can be reduced to:

$$\max_{\alpha_1} E\Pi_1(I = 1) = \Pi_1^{NC} + \alpha_1 \cdot g_1^{C,h}(c_1 + \alpha_1) \tag{33}$$

$$\text{s.t.} \quad \alpha_1 \leq \alpha_1^{indiff,I}$$

$$\alpha_1 \leq \beta - \alpha_2$$

$$\text{FOC: } \frac{\partial E\Pi_1(I = 1)}{\partial \alpha_1} = \alpha_1 \frac{\partial g_1^{C,h}}{\partial \alpha_1} + g_1^{C,h} = 0 \tag{34}$$

The first-order condition holds with equality at $\alpha_1 = \alpha_1^*$. To receive the safe offer with certainty, player 1 has to ensure that $\alpha_1 \leq \alpha_1^{indiff,I}$ (otherwise the h-type delegate would propose P^R) and $\alpha_1 \leq \beta - \alpha_2$ (otherwise the l-type would propose P^{S2}). The local maximum is at $min(\alpha_1^*, \alpha_1^{indiff,I}, \beta - \alpha_2)$.

2. $I(\alpha_1, \alpha_2) = 0$

   The maximization problem (27) can be reduced to:

$$\max_{\alpha_1} E\Pi_1(I=0) = \Pi_1^{NC} + \frac{1}{2} \cdot \alpha_1 \cdot g_1^{C,h}(c_1 + \alpha_1) \tag{35}$$

$$\text{s.t.} \quad \alpha_1 \leq \alpha_1^{indiff,I}$$

$$\text{FOC: } \frac{\partial E\Pi_1(I=0)}{\partial \alpha_1} = \frac{1}{2} \cdot (\alpha_1 \frac{\partial g_1^{C,h}}{\partial \alpha_1} + g_1^{C,h}) = 0 \tag{36}$$

   The first-order condition holds at the same value $\alpha_1 = \alpha_1^*$ as for the case $I(\alpha_1, \alpha_2) = 1$. Whether this value is feasible depends on the restriction $\alpha_1 \leq \alpha_1^{indiff,I}$. Two subcases have to be considered:

   (a) $min(\alpha_1^*, \alpha_1^{indiff,I}) > \beta - \alpha_2$
       The local maximum of $E\Pi_1(I=0)$ is at $\alpha_1 = min(\alpha_1^*, \alpha_1^{indiff,I})$.

   (b) $min(\alpha_1^*, \alpha_1^{indiff,I}) \leq \beta - \alpha_2$
       The local maximum of $E\Pi_1(I=0)$ is at $\alpha_1 = \beta - \alpha_2$.

   For $I(\alpha_1, \alpha_2) = 0$ the local maximum is described by $max(min(\alpha_1^*, \alpha_1^{indiff,I}), \beta - \alpha_2)$.

By comparing these two local maxima and choosing the one yielding the higher expected payoff, the best response of player 1 for a given α_2 can be determined. □

C Proof of Lemma 8

Lemma 8. There is a critical value α_2^{indiff} making player 1 indifferent between receiving the safe offer P^{S1} from both types of delegates or only from the l-type.

Proof. We have to consider the following two cases:

1. $min(\alpha_1^*, \alpha_1^{indiff,I}) < \beta - \alpha_2$:
   Player 1 can realize her unrestricted opacity choice $min(\alpha_1^{indiff,I}, \alpha_1^*)$. She receives the offer P^{S1} irrespective of the proposing delegate's type. The local maximum of $E\Pi_1(I=1)$ unambiguously dominates the local maximum in $E\Pi_1(I=0)$.

2. $min(\alpha_1^*, \alpha_1^{indiff,I}) > \beta - \alpha_2$:
   Player 1 cannot realize her preferred unrestricted degree of opacity $\alpha_1 = min(\alpha_1^*, \alpha_1^{indiff,I}$. The restriction $\alpha_1 = \beta - \alpha_2$ is binding for $E\Pi_1(I=1)$. The function $E\Pi_1(I=0)$ is maximized by choosing $min(\alpha_1^*, \alpha_1^{indiff,I})$. For $min(\alpha_1^*, \alpha_1^{indiff,I}) > \beta - \alpha_2$, player 1's opacity selection between the two possible local maxima is ambiguous:

$$\Pi^{NC} + (\beta - \alpha_2) \cdot g_1^{C,h}(\beta - \alpha_2) \gtrless \Pi^{NC} + \frac{1}{2} \cdot min(\alpha_1^*, \alpha_1^{indiff,I}) \cdot g_1^{C,h}(min(\alpha_1^*, \alpha_1^{indiff,I})) \tag{37}$$

   The right-hand side (RHS) is unaffected by player 2's choice of opacity:

$$\frac{\partial RHS}{\partial \alpha_2} = 0 \tag{38}$$

   Since $\alpha_1 = \beta - \alpha_2 < \alpha_1^*$, the left-hand side (LHS) is decreasing in α_2:

$$\frac{\partial LHS}{\partial \alpha_2} = -g_1^{C,h} - \frac{\partial g_1^{C,h}}{\partial c_1} < 0. \tag{39}$$

In case 1, player 1's expected payoff reaches its maximum value. Moving to case 2, as $\beta - \alpha_2$ becomes marginally lower than $min(\alpha_1^*, \alpha_1^{indiff,I})$, player 1 will at first prefer the lower level of opacity over the risk of failed negotiations. Furthermore, $\lim_{\alpha_2 \to \beta} = \Pi_1^{NC}$, i.e. player 1's gains from delegation disappear with α_2. The higher level of opacity $min(\alpha_1^*, \alpha_1^{indiff,I})$ leading to the offer P^{S1} with probability 50% will be preferred. We can conclude that both (expected) payoff functions will cross once for $\beta - \alpha_2 \in [0, min(\alpha_1^*, \alpha_1^{indiff,I}]$. Hence, there is the value α_2^{indiff}, making player 1 indifferent between choosing $\alpha_1 = \beta - \alpha_2$ and $\alpha_1 = min(\alpha_1^*, \alpha_1^{indiff,I})$. In the former case, the safe offer P^{S1} is proposed with certainty. In the latter case, player 1 can realize her unrestricted opacity choice receiving the offer P^{S1} with probability 50%.

□

D Proof of Lemma 10

Lemma 10. For $\alpha_1 \leq \alpha_1^{indiff,I}$, the best response of player 2 is set valued with $\alpha_2 \in [0, \beta - \alpha_1]$, so that P^{S1} is proposed.

Proof. The maximization problem (29) has to be evaluated for both cases $\alpha_2 \leq \beta - \alpha_2$ and $\alpha_2 > \beta - \alpha_2$:

1. $\alpha_2 \leq \beta - \alpha_1$:

$$\frac{\partial E\Pi_2}{\partial \alpha_2} = 0 \tag{40}$$

The delegate of the l-type proposes P^{S1}. Changes in α_2 do not affect player 2's expected payoff, since both delegates propose P^{S1} with $\hat{g}_2 = 0$. Player 1's contribution level $\hat{g}_1 = g_1^{C,h}$ is determined by her opacity choice α_1.

2. $\alpha_2 > \beta - \alpha_1$:

$$\frac{\partial E\Pi_2}{\partial \alpha_2} = \frac{1}{2}[2 \cdot B^{'}(g_2^{C,l}) \cdot \frac{\partial g_2^{C,l}}{\partial \alpha_2} - c_2 \cdot \frac{\partial g_2^{C,l}}{\partial \alpha_2}] < 0 \tag{41}$$

$$\text{with } 2 \cdot B^{'}(g_2^{C,l}) < c_2 \text{ and } \frac{\partial g_2^{C,l}}{\partial \alpha_2} > 0$$

The delegate of the l-type proposes P^{S2}. A marginal increase in α_2 lowers player 2's expected payoff because the delegate of the l-type proposes an excessive amount of the public good given player 2's actual marginal cost c_2.

The h-type delegate will propose P^{S1} irrespective of α_2. Therefore, we only have to show that player 2 prefers her l-type delegate to propose P^{S1} over P^{S2} for any $\alpha_2 > 0$. We do so by comparing the respective payoffs with the hypothetical payoff from P^{S2} under self-representation:

$$2 \cdot B(g_1^{C,h}) - c_1^h \cdot g_1^{C,h} - \Pi_1^{NC} > 2 \cdot B(g_2^C) - c_2 \cdot g_2^C - \Pi_1^{NC} > 2 \cdot B(g_2^{C,l}(\alpha_2 > 0)) - c_2^l(\alpha_2 > 0) \cdot g_2^{C,l}(\alpha_2 > 0) - \Pi_1^{NC} \tag{42}$$

We have established in (41) that player 2's payoff from her l-type delegate proposing P^{S2} is strictly decreasing in α_2. Therefore, player 2's payoff from the proposal P^{S2} with $\alpha_2 > 0$ is lower than from the contract P^{S2} under self-representation ($\alpha_2 = 0$). This is the second inequality in (42). For $\alpha_1 \leq \alpha_1^{indiff,I}$, player 2 prefers the offer P^{S1} over P^{S2} at $\alpha_2 = 0$. This is the first inequality in (42).

Player 2 maximizes her (expected) payoff at $\alpha_1 \leq \alpha_1^{indiff,I}$ if both her delegates propose P^{S1}. This is the case for $\alpha_2 \leq \beta - \alpha_1$.

We can conclude that the best response correspondence of player 2 for a given $\alpha_1 \leq \alpha_1^{indiff,I}$ is $\alpha_2 \in [0, \beta - \alpha_1]$. For any $\alpha_2 \leq \beta - \alpha_1$, the expected payoff $E\Pi_2$ is the same for every opacity choice of player 2. Both delegates or player 2 propose the safe offer P^{S1}, where player 1 contributes. □

E Proof of Lemma 11

Lemma 11. For $\alpha_1 > \alpha_1^{indiff,I}$, a delegate of the l-type chooses between P^R and P^{S2}. She is indifferent between these contracts at $\tilde{\alpha}_2(\alpha_1)$. The value $\tilde{\alpha}_2(\alpha_1)$ is strictly increasing in α_1.

Proof. For every $\alpha_1 > \alpha_1^{indiff,I}$, there is a value $\tilde{\alpha}_2(\alpha_1)$, so that the l-type delegate is indifferent between P^R and P^{S2}:

$$\tilde{\alpha}_2 \Leftrightarrow \frac{1}{2} \cdot [2 \cdot B(g_1^{C,l}(\alpha_1)) - c_1^l(\alpha_1) \cdot g_1^{C,l}(\alpha_1) - \Pi_1^{NC}] + \frac{1}{2} \cdot \Pi_2^{NC} = 2 \cdot B(g_2^{C,l}(\tilde{\alpha}_2) - c_2^l(\tilde{\alpha}_2) \cdot g_2^{C,l}(\tilde{\alpha}_2) - \Pi_1^{NC} \quad (43)$$

Due to the assumption of a sufficiently large cost differential, player 2 proposes P^R under self-representation if $\alpha_1 > \alpha_1^{indiff,I}$. For values α_2 close to zero, an l-type delegate also prefers P^R over P^{S2}. The right-hand side of (43) is strictly increasing in α_2 while the left-hand side does not react to changes in α_2. If for a given α_1 player 2 chooses opacity in a way that $c_1^l = c_2^l$, a delegate of the l-type clearly prefers P^{S2} over P^R. The l-type's payoffs are identical in the case of successful negotiations, but an offer P^R fails with probability 50%. The existence of a unique crossing point $\tilde{\alpha}_2$ can be concluded. By implicitly differentiating (43) it can be shown that $\tilde{\alpha}_2$ is increasing in α_1:

$$\frac{d\tilde{\alpha}_2}{d\alpha_1} = \frac{\frac{1}{2} \cdot g_1^{C,l}}{g_2^{C,l}} > 0 \quad (44)$$

□

F Proof of Lemma 12

Lemma 12. For $\alpha_1 > \alpha_1^{indiff,I}$, player 2's optimal level of opacity α_2 avoids her own contributions to the public good. The best response of player 2 is set valued with $\alpha_2 \in [0, \tilde{\alpha}_2(\alpha_1)]$.

Proof. Player 2's maximization problem (30) has to be evaluated for $\alpha_2 \leq \tilde{\alpha}_2$ and $\alpha_2 > \tilde{\alpha}_2$:

1. $\alpha_2 \leq \tilde{\alpha}_2$:
$$\frac{\partial E\Pi_2}{\partial \alpha_2} = 0 \quad (45)$$
If the delegate of the l-type proposes P^R, a marginal change in α_2 will not affect the expected payoff of player 2.
2. $\alpha_2 > \tilde{\alpha}_2$:
$$\frac{\partial E\Pi_2}{\partial \alpha_2} = \frac{1}{2} \cdot [2 \cdot B'(g_2^{C,l}) \cdot \frac{\partial g_2^{C,l}}{\partial \alpha_2} - c_2 \cdot \frac{\partial g_2^{C,l}}{\partial \alpha_2}] < 0 \quad (46)$$
If the delegate of the l-type proposes P^{S2}, a marginal increase in α_2 will lower the expected payoff $E\Pi_2$.

The h-type delegate proposes P^R irrespective of player 2's opacity choice α_2. Therefore, we have to show that player 2 prefers her l-type delegate to propose P^R over P^{S2} for any $\alpha_2 > 0$. We do so by comparing the respective payoffs with the hypothetical payoff from P^{S2} under self-representation:

$$\begin{aligned} 2 \cdot B(g_2^{C,l}(\alpha_2 > 0)) - c_2^l(\alpha_2 > 0) \cdot g_2^{C,l}(\alpha_2 > 0) - \Pi_1^{NC} &< 2 \cdot B(g_2^C) - c_2 \cdot g_2^C - \Pi_1^{NC} \\ &< \frac{1}{2} \cdot [2 \cdot B(g_1^{C,l}(\alpha_1)) - c_1^l(\alpha_1) \cdot g_1^{C,l}(\alpha_1) - \Pi_1^{NC}] + \frac{1}{2} \cdot \Pi_2^{NC} \end{aligned} \quad (47)$$

We know from (46), that player 2's payoff if her l-type delegate proposes P^{S2} is decreasing in α_2 if her delegate of the l-type proposes P^{S2}. Therefore, player 2's payoff from proposal P^{S2} with $\alpha_2 > 0$ is lower than from the hypothetical contract P^{S2} under self-representation ($\alpha_2 = 0$). This is the first inequality in (47). For $\alpha_1 > \alpha_1^{indiff,I}$, player 2 prefers the offer P^R over P^{S2} at $\alpha_2 = 0$, which can be seen from the second inequality in (47).

Player 2's payoff is maximized if both her delegates propose P^R. This can be guaranteed if she chooses $\alpha_2 \leq \tilde{\alpha}_2(\alpha_1)$ for a given $\alpha_1 > \alpha_1^{indiff,I}$. The best response is set valued with $\alpha_2 \in [0, \tilde{\alpha}_2(\alpha_1)]$. The maximum level of opacity $\tilde{\alpha}_2$ by player 2 is increasing in α_1: $\frac{d\tilde{\alpha}_2}{d\alpha_1} = \frac{\frac{1}{2} \cdot g_1^{C,l}}{g_2^{C,l}} > 0$. □

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Competing interests

The authors have no competing interests to declare.

References

Andreoni, J. (1990). Impure Altruism and Donations to Public Goods: A Theory of Warm-Glow Giving. *The Economic Journal*, *100*(401), 464–477. DOI: 10.2307/2234133

Beccherle, J., & Tirole, J. (2011). Regional Initiatives and the Cost of Delaying Binding Climate Change Agreements. *Journal of Public Economics*, *95*(11-12), 1339-1348. DOI: 10.1007/s10784-011-9165-7

Bergemann, D., & Morris, S. (2019). Information Design: A Unified Perspective. *Journal of Economic Literature*, *57*(1), 44-95. DOI: 10.1257/jel.20181489

Buchholz, W., Haupt, A., & Peters, W. (2005). International Environmental Agreements and Strategic Voting. *The Scandinavian Journal of Economics*, *107*(1), 175–195. DOI: 10.1111/j.1467-9442.2005.00401.x

Buchholz, W., & Konrad, K. (1994). Global Environmental Problems and the Strategic Coice of Technology. *Journal of Economics*, *60*(3), 299–321. DOI: 10.1007/BF01227484

Burtraw, D. (1992). Strategic Delegation in Bargaining. *Economic Letters*, *38*(2), 181-185. DOI: 10.1016/0165-1765(92)90051-Y

Chatterjee, K., & Samuelson, W. (1983). Bargaining under Incomplete Information. *Operations Research*, *31*(5), 835-851. DOI: 10.1287/opre.31.5.835

Condorelli, D., & Szentes, B. (2020). Information Design in the Hold-Up Problem. *Journal of Political Economy*, *128*(2), 710-739. DOI: 10.1086/704574

Fingleton, J., & Raith, M. (2005). Career Concerns of Bargainers. *The Journal of Law, Economics, and Organization*, *21*(1), 179-204. DOI: 10.1093/jleo/ewi008

Harstad, B. (2007). Harmonization and Side Payments in Political Cooperation. *American Economic Review*, *97*(3), 871-889. DOI: 10.1257/aer.97.3.871

Harstad, B. (2008). Do Side Payments Help? Collective Decisions and Strategic Delegation. *Journal of the European Economic Association*, *6*(2-3), 468-477. DOI: 10.1162/JEEA.2008.6.2-3.468

Helm, C., & Wirl, F. (2014). The Principal-Agent Model with Multilateral Externalities: An Application to Climate Agreements. *Journal of Environmental Economics and Management*, *67*(2), 141-154. DOI: 10.1016/j.jeem.2013.11.006

Jones, S. R. G. (1989a). The Role of Negotiators in Union-Firm Bargaining. *The Canadian Journal of Economics*, *22*(3), 630-642. DOI: 10.2307/135545

Jones, S. R. G. (1989b). Have your Lawyer Call my Lawyer: Bilateral Delegation in Bargaining Situations. *Journal of Economic Behavior & Organization*, *11*(2), 159-174. DOI: 10.1016/0167-2681(89)90011-5

Konrad, K. A., & Thum, M. (2014). Climate Policy Negotiations with Incomplete Information. *Economica*, *81*(322), 244-256. DOI: 10.1111/ecca.12065

Konrad, K. A., & Thum, M. (2018). Does a Clean Development Mechanism Facilitate International Environmental Agreements? *Environmental and Resource Economics*, *69*(4), 837-851. DOI: 10.1007/s10640-016-0107-2

Konrad, K. A., & Thum, M. (2020). Equilibrium Opacity in Ultimatum-Offer Bargaining. *Journal of Public Economic Theory*, *22*(5), 1515-1529. DOI: 10.1111/jpet.12471

Myerson, R. B., & Satterthwaite, M. A. (1983). Efficient Mechanisms for Bilateral Trading. *Journal of Economic Theory*, *29*(2), 265-281. DOI: 10.1016/0022-0531(83)90048-0

Schelling, T. C. (1960/1980). *The strategy of conflict.* Cambridge Mass: Harvard University Press.

Segendorff, B. (1998). Delegation and Threat in Bargaining. *Games and Economic Behavior*, *23*(2), 266-283. DOI: 10.1006/game.1997.0611

Urpelainen, J. (2012). Technology Investment, Bargaining, and International Environmental Agreements. *International Environmental Agreements*, *12*(2), 145-163. DOI: 10.1007/s10784-011-9165-7