The Diplomacy of Public Goods Problems: Why States with Common Goals Lie*

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Abstract

Uncertainty is pervasive in international public goods problems. Potential contributors to jointly beneficial projects often lack crucial information, such as how much the other participants are willing to contribute. According to existing theories of information transmission, states that have a common interest in a public good should be able to resolve mutual uncertainty through diplomatic talk. This paper, to the contrary, uses a formal model to show that there are broad conditions under which potential contributors to a public good cannot credibly reveal any information about how much they are willing to give. If a country reveals that it is highly willing to give, then other contributors will reduce their own contributions, knowing they can free-ride on its efforts. Therefore, states have an incentive to feign unwillingness so as to prevent their partners from free-riding. These findings illustrate why common interest, while necessary, is not a sufficient condition for political actors to reveal private information through cheap talk.

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1 Introduction

Relations among states are fraught with uncertainty, and a major question for international relations scholars is when diplomatic communication can help states transmit information. Conventional wisdom in the field holds that communication is effective at reducing uncertainty when states have common interests. When a group of states all want to achieve the same goal, each state involved should be willing to reveal information that would help the group succeed. As long as there is diplomatic contact, private information should not hinder states with a common goal from collaborating or cooperating. Uncertainty should prevail only when there is a severe conflict of interest, such as in a militarized crisis (see Fearon 1995). This paper argues, to the contrary, that common interest is not a sufficient condition for effective communication. States can hold similar preferences about international outcomes and nonetheless have incentives to be dishonest with one another. In fact, even states with strong joint interests may be unable to credibly reveal any information to each other through ordinary communication.

This paper highlights public goods provision as a political problem whose participants have a common interest (namely, in providing the public good) but may nonetheless prefer not to reveal information to each other. The main argument is that when states are unsure of each other's willingness to contribute, "cheap talk" diplomacy cannot reveal any information. Using a formal model of this scenario, I show that every state has an incentive to understate how much it is willing to give, so communication is ineffective. Therefore, if states have private information about their willingness to give to a public good, the amount provided will be no different if the states can communicate than if they cannot. The ineffectiveness of communication in these situations is not a mere theoretical curiosity—it has severe welfare consequences. Uncertainty exacerbates the well-known inefficiency problem in the private provision of public goods (Bergstrom, Blume and Varian 1986): total contributions end up even lower than if each state knew how much its partners were willing to give.

Why do potential contributors to a public good have an incentive to misrepresent their willingness to give? The impossibility of credible communication is a direct result of the free-rider problem. The best outcome for any potential contributor is for the public good to be fully supplied through the efforts of others—every state wants its partners to take up as much of the burden as possible. So if a state reveals that it can supply most of the necessary effort, its partners will jump on the opportunity to free-ride, contributing less than if they had been uncertain about the state's willingness. Therefore, even a highly willing state has an incentive to feign unwillingness, so as to induce its partners to contribute as much as possible. Honest information revelation is impossible because a state never wants to give its partners an excuse to free-ride.

My findings show that the current theoretical understanding of cheap talk diplomacy is incomplete. In the literature following Fearon's (1995) finding that communication is impossible in crisis bargaining, international relations scholars have claimed that whether diplomacy is effective boils down to whether states in a crisis have common interests (e.g., Sartori 2002; Trager 2010; Ramsay 2011). These arguments draw from Crawford and Sobel's (1982) workhorse model of information transmission, in which the amount of information that can be revealed in equilibrium shrinks with the distance between the informed and uninformed players' preferences. However, what works in a particular model of information transmission may not hold generally. In this paper, I show how the possibility of communication depends not only on common interests among the players, but also on whether different types of the informed player prefer different actions by the uninformed player. These two conditions coincide in Crawford and Sobel's model, but not necessarily in other contexts. To wit, in both crisis negotiations and public goods dilemmas, there are common interests (in avoiding war and in providing the good, respectively), but no variation in preferences over actions. Just as a state in crisis negotiations always wants a more favorable offer from its adversary, a state in a public goods dilemma always prefers greater contributions by its allies. This invariance of preference, not the lack of common interests, is what hampers information revelation in both settings.

Because public goods problems are prevalent in both international cooperation and conflict, this paper's findings have broad implications for international relations scholarship. In studies of international cooperation, it is widely accepted that public goods provision is the primary task of international organizations (Russett and Sullivan 1971; Keohane 1984). Can these institutions further their commonly valued goals by facilitating communication among their members? According to the conventional view of communication and common interest, the answer should be yes (e.g., Keohane 1982, p. 349). My results show why we should be skeptical that providing a forum for communication increases the chances of international cooperation. Because states have an incentive to misrepresent how much of the cost they are willing to bear to achieve an organizational goal, merely providing a forum to talk will not help bring this information to light. Therefore, insofar as international organizations do play a role in transmitting this kind of information, it is through their actions as independent actors (Barnett and Finnemore 1999) or because they send costly signals to domestic audiences (Thompson 2006; Fang 2008), not because they provide forums for diplomatic exchange. When uncertainty hinders public goods provision, an organization may be better served by collecting information independently than by trying to foster interstate communication.

Public goods problems also arise in the international security arena, most prominently in military alliances. When a group of states have a common adversary, their security is a public good to which each state's military preparation contributes (Olson Jr and Zeckhauser 1966). The literature on the informational role of alliances treats information sharing among allies as automatic, without considering whether it is actually in a country's interest to be honest with its allies (Bearce, Flanagan and Floros 2006; Konrad 2012). The main results of this paper cast doubt on the notion of alliances as vehicles for information transmission. Diplomatic talks between allies will reveal little if each ally simply wants its partners to contribute as much as possible. My findings call into question theoretical results that rely on the assumption that alliances reveal information about military preparedness or resolve, such as

Bearce, Flanagan and Floros's (2006) information-based explanation for why alliances reduce conflict among their members. On the other hand, my results are not entirely negative for the possibility of information exchange in security alliances—the possibility of communication depends on the kind of private information that allies hold. I consider an extension to the model in which there are multiple avenues of contributing to the public good (e.g., air power and ground forces in a military operation) and states have private information about their comparative advantage (Section 6.2). In this setting, there are broad conditions under which it is in a state's interest to honestly reveal which kind of contribution it can more easily undertake. Although diplomatic communication cannot help states learn about each other's overall willingness to contribute to joint security, it may be useful for the nuts and bolts of international military coordination.

The main result of this paper differs from analyses in the economics literature showing that cheap talk can affect contributions in public goods games when contributors have private information about how highly they value the good (Agastya, Menezes and Sengupta 2007; Barbieri 2012). These models assume the good is provided if and only if the total contribution meets or exceeds a commonly known, discrete threshold. This assumption is plausible in economic settings, such as a drive to raise money for a building project, but less so in international relations—or politics more generally. In international projects, it is often unclear exactly how much effort is required for success (e.g., joint military operations), or there is no strict success-failure dichotomy at all (e.g., global pollution reduction). To capture scenarios like these, I model the public good as continuous rather than discrete. In a continuous public goods game, a player always strictly benefits from greater contributions by its partners. By contrast, there is no additional benefit to "oversupplying" a discrete public good—either it is provided or it is not—meaning a player can sometimes be indifferent between potential levels of contribution by the other players. This potential for indifference accounts for why communication is possible in discrete public goods games, but not in the continuous setting that I examine.

In the next section of the paper, I provide an informal intuition for why states cannot reveal information to each other about how much they are willing to contribute to a public good. I then formalize the argument and prove the main result under both one-sided and two-sided uncertainty. Next, I extend the model to examine the possibility of communication under alternative sources of private information. A concluding section summarizes the findings and discusses their implications for the study of diplomacy.

2 Cheap Talk and Public Goods

Before delving into the formal model, I lay out a hypothetical example to illustrate the intuition behind the main argument. Imagine that India and China have a joint interest in reducing global carbon emissions. All else equal, both countries want total emissions to be as low as possible. Each country can contribute to the effort by cutting its own carbon usage. Emissions reduction is a public good, as any cut by India or China works to the benefit of both. A country pays a political cost for its own carbon-cutting efforts—due to, say, members of the winning coalition disapproving of commodity price increases—but not for its partner's. So while both India and China want to see low emissions overall, India would prefer that China do the bulk of the cutting, and vice versa. This hypothetical example is a standard public goods dilemma: the two parties have a common interest in the good being provided, but each individual participant wants to free-ride off its partner as much as possible. The countries agree about the goal but differ about how to divide the labor necessary to achieve it.

Now suppose that Indian leaders are unsure of exactly how politically costly it is for Chinese leaders to reduce carbon emissions. For simplicity's sake, suppose there are just two possibilities: either China is "willing" to cut carbon usage significantly due to low political costs, or it is "unwilling," only able to contribute a token amount to the joint effort. In addition, suppose the political cost of emissions abatement in India lies between these two extremes. In public goods problems like this, the participant with the lowest cost of contribution (relative to how highly it values the stakes) typically bears a disproportionate share of the burden (Olson Jr and Zeckhauser 1966). Therefore, the best course of action for Indian leaders depends on their beliefs about the political cost of carbon-cutting in China. If India knew China were willing, it could reduce its own emissions by relatively little, knowing that China would take up most of the effort itself. Conversely, India would do more carbon-cutting if it knew China had high costs and would thus be unable to contribute much on its own.

In this hypothetical example, can China credibly reveal through ordinary communication (i.e., cheap talk) its private information about the political price it must pay to reduce carbon emissions? To answer this question, we must first determine how India would respond if China revealed its willingness honestly, then analyze whether it would ever be in China's best interest to lie (Farrell and Rabin 1996). We have just worked through the first part: India will cut its own carbon emissions significantly if it learns that China says it is "unwilling," but only a bit if China claims to be "willing." Does the Indian response give either type of China an incentive to lie? Yes—it is always better for China to claim to be unwilling. Each country prefers low emissions and pays a political cost only for its own abatement efforts. Therefore, regardless of how much China is actually willing to contribute, it benefits from greater emissions reductions in India. Consider what would happen if the willing type of China claimed to be unwilling, and India believed it. China could still reduce its emissions by just as much, and thus pay the same political cost, as it would have if it had honestly revealed its willingness. Because India would cut emissions by more than if China had claimed to be willing, the result is even lower global emissions at the same political cost to China. Knowing that this incentive to feign unwillingness exists, Indian leaders will not believe China's statements about its own political costs when deciding how much to cut their own emissions.[1]

[1]The incentive to lie in this example is not an artifact of assuming that India reduces emissions more when China is unwilling. If the situation were reversed, and India contributed more when China claimed to

This example illustrates how it might be impossible for political actors to reveal information through cheap talk even when their interests overlap. Both of the actors in this example have the same main goal—namely, to reduce global carbon emissions. Moreover, they would be more likely to achieve this goal if India had full knowledge of China's political costs for emissions abatement. If India thought incorrectly that China was willing, and consequently cut its carbon usage only by a little, the result would be more emissions than if India had known the truth. Following the theoretical results of Crawford and Sobel (1982), political scientists often speak of interest similarity as a sufficient condition for cheap talk to be effective (e.g., Kydd 2003; Trager 2010). This hypothetical example, in which the countries have a common goal but China nevertheless cannot credibly reveal its private information, contradicts this conventional wisdom. What else must be true for communication to be possible?

This paper highlights a second condition for cheap talk to work: what an informed player wants the others to do must vary as a function of the private information she possesses. In other words, cheap talk statements are not credible if an actor's preferences over her partners' actions are unrelated to the private information she possess. This requirement follows from simple game-theoretic logic (see Farrell and Rabin 1996; Baliga and Morris 2002). In order for cheap talk to influence the outcome of a game, different types of a player must choose different messages. Since cheap talk by definition has no direct effect on the outcome of a game, a player will choose the message that results in the others taking the actions she most prefers. So if all types of a player have the same preferences over others' actions, then that player will always choose the same message—meaning the message is uninformative.[2] This line of logic is exactly what makes communication impossible in the current example. China wants India to cut its own carbon usage as much as possible, regardless of China's actual political costs for contributing. Since China would always prefer for India to view it

be willing, then the unwilling type would have an incentive to lie.

[2]There are exceptions to this logic if we allow for mixed strategies; see Example 1 in Baliga and Morris (2002).

as unwilling (and thus contribute more), its claims of unwillingness are not credible.

This line of reasoning is not specific to the example of emissions abatement—it extends to a wide class of public goods dilemmas. The main argument of this paper is that cheap talk cannot help potential public good providers learn about each other's willingness to contribute. No matter how much one participant may be willing to give, she benefits from her partners giving as much as possible. Given the opportunity to communicate through cheap talk, she has an incentive to make whatever statement would induce the other participants to contribute the most. Therefore, cheap-talk statements lack credibility. The barrier to communication here is not the absence of common interests, as the participants all want the public good to be provided, but instead the lack of variation in preferences. The incentive to free-ride precludes honest communication. If those who were most willing to contribute preferred that their partners contribute less, then it might be possible for cheap talk to convey information. However, as long as each participant benefits from free-riding, cheap talk diplomacy will not reveal useful information.

In the remainder of the article, I develop a formal model that captures this intuition. Formalization of the argument has a few important benefits. First, a formal model allows us to see what conditions are required (or not) for the argument to hold. I show that when there is one-sided uncertainty, the no-communication result holds under a wide range of assumptions about the uninformed state's prior beliefs and the functional relationship between contributions and provision of the public good (Section 4). A second, related benefit of formalization is that it allows us to extend the argument to settings that would be too difficult to reason through verbally. One such setting is when there is two-sided incomplete information (Section 5). Third, situating the analysis within a formal model makes it easy to compare alternative sources of uncertainty while holding fixed the other aspects of the theory. To this end, I adapt the main model to examine whether communication may be possible when states have private information about how much effort is required for the joint effort to succeed, or about their own comparative advantage among multiple means of contribution (Section 6).

3 The Model

This section introduces the model of public goods, uncertainty, and communication that forms the basis of the remainder of the paper.

3.1 Contribution Game

The core of the model is a public goods game, in which two countries individually choose how much effort to contribute to a joint project or goal.[3] The players are called country 1 and country 2. In the *contribution game*, each country chooses how much effort, denoted x_i, to devote to producing the public good.[4] Let $X_i = \Re_+$ denote the set of feasible contributions for country i. The public good may be any goal or accomplishment that benefits both states, and effort is any activity that increases the value of the project at a cost to the contributor. The maximal value of the public good is normalized to 1 for each country. The proportion of the good that is produced (or the proportion of its value that is realized) is $p(x_1 + x_2)$, a strictly increasing function of the total effort contributed. I assume throughout the analysis that the function $p : \Re_+ \to [0, 1]$ is twice differentiable and strictly concave.[5] The marginal cost of effort to each country is $c_i > 0$. A country's cost of effort is inversely related to its willingness to contribute to the public good. Although the good's realized value for both countries is determined by the total contribution, each country pays only for its own effort.

A country's payoff depends on its contribution and the proportion of the good that is

[3] Although I refer to the players as countries, the results apply to any continuous public goods problem that satisfies the assumptions below, not just in the international arena.

[4] Throughout the article, generic countries are labeled i and j, with the understanding that $i \neq j$.

[5] As in Bag and Roy (2011), these properties do not need to hold on the entire domain of p. It is sufficient that they hold on $[0, \frac{1}{\underline{c}_1} + \frac{1}{\underline{c}_2}]$, where the minimal types $\underline{c}_i$ are defined as below.

produced. Given its marginal cost of effort c_i, a country's utility function is

$$u_i(x_i, x_j \mid c_i) = p(x_i + x_j) - c_i x_i. \tag{3.1}$$

A country's payoff may be non-monotonic in its own effort, as higher values of x_i increase both the production of the good and the total cost to country i. However, a country always benefits from higher contributions by its partner.

A country's marginal cost of effort determines its *stand-alone contribution*—the amount it would contribute if it were the only player in the game or, equivalently, if it expected its ally to contribute $x_j = 0$. This is the amount at which the marginal benefit of contributing equals the marginal cost. Because p is strictly concave and continuously differentiable, the stand-alone contribution of a country with marginal cost c is given by the continuous, non-increasing function

$$x^*(c) = \begin{cases} (p')^{-1}(c) & c < p'(0), \\ 0 & c \geq p'(0). \end{cases} \tag{3.2}$$

It is immediate from this definition that $x^*(c) < \frac{1}{c}$ for all $c > 0$ and that any contribution $x_i > x^*(c_i)$ is strictly dominated (Bag and Roy 2011).

Under complete information, the stand-alone contributions determine the outcome of the game. A contribution scheme (x_1, x_2) is an equilibrium if and only if it meets two requirements. First, for any country that gives $x_i > 0$, the marginal benefit of contribution must equal the marginal cost. By definition, then, the total contribution must equal the stand-alone contribution of any country that gives. Countries with different marginal costs of effort cannot have the same stand-alone contribution (unless it is zero for both), so only one country can contribute in equilibrium when $c_1 \neq c_2$. The second requirement is that for any country that does not give, the marginal benefit of contribution cannot exceed the marginal cost. Therefore, in equilibrium, if the two countries have different marginal costs of effort, the one with the lower cost gives its stand-alone amount, while the other contributes nothing.

If they have the same marginal cost of effort, any scheme such that the total contribution equals their common stand-alone amount is an equilibrium. I state the complete-information equilibrium formally in the following proposition.

Proposition 3.1. *Suppose the marginal contribution costs c_1 and c_2 are common knowledge. Without loss of generality, let $c_1 \leq c_2$. If $c_1 < c_2$, the unique Nash equilibrium of the contribution game is $(x_1, x_2) = (x^*(c_1), 0)$. If $c_1 = c_2 = c$, then (x_1, x_2) is a Nash equilibrium of the contribution game if and only if $x_1 + x_2 = x^*(c)$.*

Proof. See the Appendix. □

3.2 Uncertainty and Communication

A fundamental problem of international relations is that states are uncertain of each other's capabilities and resolve (Schelling 1960; Jervis 1976; Fearon 1995). This observation applies to relations between countries with common goals as well as to adversaries. The primary goal of this article is to analyze whether ordinary communication, or cheap talk, can allow countries with common ends to resolve their mutual uncertainty and provide public goods more effectively. To this end, I introduce incomplete information and cheap talk communication to the public goods model described above.

Throughout the main portion of the article, I assume that one or both of the countries has private information about its marginal cost of contribution to the public good. As the marginal cost is inversely related to the maximal amount a country is willing to give, this can be interpreted as uncertainty about willingness to contribute to the project. To represent this asymmetric information formally, let each country's cost parameter c_i be a random variable drawn according to the cumulative distribution function F_i. I assume that each F_i is continuous,[6] has interval support, and is common knowledge; in addition, c_1 and c_2 are drawn independently from each other. Under the assumption of interval support, we

[6] An exception to the assumption of continuity is the case of one-sided incomplete information, in which c_2 has a degenerate distribution and F_2 is thereby a step function.

may write each country's type space as $T_i = [\underline{c}_i, \bar{c}_i]$. In the case of *one-sided incomplete information about costs*, only country 1's cost of contribution is private information: $\underline{c}_1 < \bar{c}_1$ and $\underline{c}_2 = \bar{c}_2 = c_2$, meaning F_2 is a degenerate distribution on c_2. On the other hand, under *two-sided incomplete information about costs*, we have both $\underline{c}_1 < \bar{c}_1$ and $\underline{c}_2 < \bar{c}_2$. I consider sources of incomplete information other than the marginal cost of effort in Section 6.

To model diplomatic communication, I introduce a *messaging stage* that occurs after the countries learn their types but prior to the contribution game. In the messaging stage, each country selects a message m_i from its message space M_i. For ease of exposition, I assume that each country's message space is identical to its type space, so $M_i = T_i$.[7] A *messaging strategy* is a function $\mu_i : T_i \to M_i$ that specifies the message sent by each type of country i. Messages are cheap talk, as in Crawford and Sobel (1982): each type of country i may send any message in M_i, and the chosen messages have no direct effect on either country's payoff. A country's message matters only insofar as it shapes its partner's beliefs, which in turn may affect the partner's contribution. Let $\lambda_j(m_i)$ denote country j's updated beliefs about c_i after receiving the message m_i, where each $\lambda_j(m_i)$ is a probability measure on T_i. For any real number r, let δ_r denote the probability measure that corresponds to a degenerate distribution on r.

Because the messaging stage occurs first, a country's choice in the contribution subgame may depend on which messages were sent. A country's *contribution strategy* is a function $s_i : T_i \times M_i \times M_j \to X_i$, where $s_i(c_i, m_i, m_j)$ denotes the contribution by country i of type c_i after sending the message m_i and receiving m_j. Let $\Gamma(m_1, m_2)$ denote the contribution subgame that follows a history in which each country sent the given messages.

To summarize, given the messaging strategies μ_i, the beliefs λ_i, and the contribution strategies s_i for each $i = 1, 2$, the sequence of play is as follows:

1. Nature privately informs each country of its type, $c_i \in T_i$.

[7] In the case of one-sided incomplete information, this means country 2 only has one message available, $M_2 = T_2 = \{c_2\}$, so we may omit the analysis of its choice in the messaging stage.

2. The two countries simultaneously send their messages, $\mu_i(c_i) \in M_i$.

3. Each country observes its ally's message, $\mu_j(c_j) \in M_j$, and updates its beliefs about its ally's type c_j to the probability measure $\lambda_i(\mu_j(c_j))$.

4. The two countries simultaneously choose how much to contribute to the joint effort, $s_i(c_i, \mu_i(c_i), \mu_j(c_j)) \geq 0$.

5. The game ends and payoffs are realized.

An *assessment* $\sigma = (\mu_1, \mu_2, s_1, s_2, \lambda_1, \lambda_2)$ is a tuple containing both countries' strategies and beliefs.

3.3 Solution Concept

As this is a multistage game of incomplete information with observed actions, the appropriate solution concept is perfect Bayesian equilibrium (Fudenberg and Tirole 1991). An assessment σ is an *equilibrium* if it satisfies the following sequential rationality and consistency conditions for each country i:

- Each type's choice of message is optimal, given the contribution strategies:

$$\mu_i(c_i) \in \operatorname*{arg\,max}_{m_i \in M_i} \int_{T_j} u_i\left(s_i(c_i, m_i, \mu_j(c_j)), s_j(c_j, \mu_j(c_j), m_i) \,|\, c_i\right) \, dF_j. \tag{3.3}$$

- In every contribution subgame $\Gamma(m_1, m_2)$, each type's choice of contribution is optimal, given its own beliefs and its ally's strategy:

$$s_i(c_i, m_i, m_j) \in \operatorname*{arg\,max}_{x_i \in X_i} \int_{T_j} u_i(x_i, s_j(c_j, m_j, m_i) \,|\, c_i) \, d\lambda_i(m_j). \tag{3.4}$$

- The beliefs $\lambda_i(m_j)$ are updated in accordance with Bayes' rule whenever possible (i.e., for all $m_j \in \mu_j(T_j)$).

Equilibria can be classified in terms of how much information is revealed in the messaging stage. At one end of the informational spectrum is a *babbling equilibrium*, in which no meaningful communication takes place because neither country's messaging strategy reveals anything about its type. Formally, an equilibrium σ is babbling if both μ_1 and μ_2 are constant functions, meaning each country sends the same message regardless of its type. At the other extreme is a *fully separating equilibrium*, in which each country's messaging strategy always reveals its type: $\mu_i(c_i) = c_i$ for all c_i.[8] Any equilibrium that is neither babbling nor fully separating is *partially separating*. As usual in cheap talk games, it is trivial to construct an equilibrium with no communication. The only requirement is that an equilibrium exist in the contribution subgame, as stated in the following lemma.

Lemma 3.2. *Consider any contribution subgame $\Gamma(m_1, m_2)$ of the game with incomplete information about costs. If each $\lambda_i(m_j)$ is either a degenerate distribution or a continuous distribution on an interval, then there exists a Bayesian Nash equilibrium of the subgame.*

Proof. See the Appendix. □

I use this result to construct a babbling equilibrium.

Proposition 3.3. *A babbling equilibrium exists.*

Proof. Let each μ_i be a babbling messaging strategy, and let every $\lambda_j(m_i)$ be the same as the prior distribution of c_i. Consider any contribution subgame $\Gamma(m_1, m_2)$. By Lemma 3.2, there exists an equilibrium of this subgame. Let each country's strategy in every subgame be the same as in the chosen equilibrium. As both countries' beliefs are the same in every subgame, these strategies satisfy sequential rationality. Since the outcome of every subgame is the same, no type of either country has an incentive to deviate from its prescribed message. Finally, beliefs are updated in accordance with Bayes' rule wherever possible. Therefore, the

[8] In general, any one-to-one function μ_i corresponds to a fully separating messaging strategy; I use the form given here for expository convenience.

assessment is an equilibrium. $\square$

The main task of this paper is to evaluate whether diplomatic communication can help countries provide public goods more efficiently. To conclude that communication matters, it is not enough to find an equilibrium in which countries reveal information—the information they exchange must also affect the amount they contribute. Accordingly, I focus on *influential equilibria*, in which cheap talk reveals information that in turn affects decisions in the contribution game. Formally, an equilibrium σ is influential if there exist types $c_i, c_i' \in T_i$ and a set of types $\tilde{T}_j \subseteq T_j$ such that $s_j(c_j, \mu_j(c_j), \mu_i(c_i)) \neq s_j(c_j, \mu_j(c_j), \mu_i(c_i'))$ and $\Pr(c_j \in \tilde{T}_j) > 0$. An influential equilibrium is non-babbling by definition, but a non-babbling equilibrium may not be influential. For example, an equilibrium in which country 1 fully reveals its type but country 2 always contributes $x_2 = 0$ on the path of play is non-babbling and non-influential.

I now present a necessary condition for messaging in equilibrium that I will use throughout the analysis to rule out influential equilibria. The condition derives from the fact that a country always prefers greater contributions by its partner. In equilibrium, no type of a country can send a message that guarantees a lower contribution by its partner than what it would receive from a different message. If deviating to an alternative message would cause some types of a country's partner to increase their contributions, it must also cause others to lower theirs. Otherwise, the country would have a strict incentive to deviate in the messaging stage, violating the requirement of equilibrium. I now state this condition formally.

Proposition 3.4. *There is no equilibrium that satisfies all of the following criteria:*

1. *There is a pair of messages $m_i, m_i' \in M_i$, with $m_i \neq m_i'$, such that $m_i = \mu_i(c_i)$ for some $c_i \in T_i$ and $m_i' = \mu_i(c_i')$ for some $c_i' \in T_i$.*

2. *For almost all $c_j \in T_j$,*

$$s_j(c_j, \mu_j(c_j), m_i') \geq s_j(c_j, \mu_j(c_j), m_i).$$

3. *There is a set of types* $\tilde{T}_j \subseteq T_j$ *such that* $\Pr(c_j \in \tilde{T}_j) > 0$ *and*

$$s_j(c_j, \mu_j(c_j), m_i') > s_j(c_j, \mu_j(c_j), m_i),$$

for all $c_j \in \tilde{T}_j$.

Proof. Take any assessment that meets the conditions of the proposition. Consider a deviation whereby type c_i of country i sends the message m_i' and then, after receiving country j's message, makes the same contribution as if it had sent the prescribed message m_i. For ease of exposition, let $s_{i\,|\,c_i}(c_j) = s_i(c_i, \mu_i(c_i), \mu_j(c_j))$ denote the contribution of type c_i that is realized when its partner sends the message prescribed for type c_j, and define $s_{j\,|\,c_j}$ analogously. By construction, $s_{j\,|\,c_j}(c_i') \geq s_{j\,|\,c_j}(c_i)$ for almost all $c_j \in T_j$, and strictly so on $\tilde{T}_j$. As p is strictly increasing, the difference in expected utility between the deviation and type c_i's proposed strategy is

$$\begin{aligned}
&\int_{T_j} \left[p\left(s_{i\,|\,c_i}(c_j) + s_{j\,|\,c_j}(c_i')\right) - p\left(s_{i\,|\,c_i}(c_j) + s_{j\,|\,c_j}(c_i)\right)\right] dF_j \\
&\qquad \geq \int_{\tilde{T}_j} \left[p\left(s_{i\,|\,c_i}(c_j) + s_{j\,|\,c_j}(c_i')\right) - p\left(s_{i\,|\,c_i}(c_j) + s_{j\,|\,c_j}(c_i)\right)\right] dF_j \\
&\qquad > 0.
\end{aligned}$$

Therefore, the assessment is not an equilibrium. □

This result places a stringent condition on influential equilibria. If some types of country j contribute more after receiving m_i' than after m_i, then there must be other types that contribute less. In other words, different types of a country must have opposite reactions to the same information. Intuitively, it is difficult to see conditions under which this might be the case. It is easier to imagine that every type contributes less as it learns its ally is willing to contribute more. In the remainder of the analysis, I give this intuition a formal foundation, showing why influential communication cannot occur in equilibrium.

4 One-Sided Uncertainty

I start with the case of one-sided incomplete information about costs, in which country 1's marginal cost of contribution is private information while country 2's is common knowledge. The main finding is that diplomatic communication is ineffective in this setting—there is never an influential equilibrium. A country that knows how much its partner is willing to contribute has no incentive to unilaterally reveal information about its own willingness. Moreover, the lack of communication in equilibrium harms public goods provision. Total contributions in equilibrium are never greater than what they would be if country 1's private information were made public.

The proof that there is no influential equilibrium is straightforward, using logic similar to the emissions-abatement example in Section 2. In an influential strategy profile, by definition, there are two messages that country 1 sends on the path of play that evoke different contributions by country 2. But it is always in a country's interest to induce its partner to contribute as much as possible. Given a choice among messages, all types of country 1 strictly prefer whichever results in country 2 expending the most effort. Therefore, in any equilibrium, either country 1 always selects the same message (so the equilibrium is babbling) or country 2 responds to every message with the same contribution. In either case, the equilibrium is not influential. I restate this logic formally in the proof of the following proposition.[9]

Proposition 4.1. *There is no influential equilibrium in the game with one-sided incomplete information about costs.*

[9] The no-communication result under one-sided incomplete information is notable in its generality. Proposition 4.1 would continue to hold even if we relaxed the background assumptions that p is continuous and strictly concave, that F_1 is continuous, and that F_1 has interval support. As long as p is strictly increasing, no influential equilibrium exists under one-sided incomplete information about costs.

Proof. In an influential assessment, there exist types c_1, c_1' such that $\mu_1(c_1) \neq \mu_1(c_1')$ and

$$s_2(c_2, \mu_2(c_2), \mu_1(c_1')) > s_2(c_2, \mu_2(c_2), \mu_1(c_1)).$$

Since country 2's type is c_2 with probability 1, by Proposition 3.4, such an assessment cannot be an equilibrium. □

The barrier to communication here is that in equilibrium, country 1 knows exactly how country 2 will respond to each possible message. Country 1, regardless of its own type, always strictly prefers the message that induces the greatest effort by country 2. As we saw in Proposition 3.4, in order for there to be an influential equilibrium, a country must have some uncertainty about how its partner will respond to the message it sends. By deviating to another message that is sent on the path of play, a country should receive more from some types of its partner and less from others. This cannot hold when the other country has only one type, as in the case of one-sided incomplete information about costs. In the next section, I examine the less straightforward case of two-sided incomplete information and find that the no-communication result still holds—it is not an artifact of the one-sided information structure.

Before turning to two-sided incomplete information, I examine the efficiency properties of the one-sided model. I find that both public goods production and aggregate welfare would be weakly greater if country 1 were able to reveal its type in equilibrium. All equilibria of the model with one-sided incomplete information are weakly *ex post* inefficient relative to the corresponding complete-information equilibrium. Strictly inefficient outcomes occur with positive probability unless country 1's marginal cost of contribution almost always exceeds country 2's (or vice versa). I begin by showing that uncertainty decreases public goods provision. If country 2's strategy were to give its stand-alone value, then types of country 1 with $c_1 < c_2$ would "top off" the total contribution to their own stand-alone values, resulting in the same total public goods provision as under complete information. However, it cannot be an equilibrium for country 2 to give its stand-alone value if there is a non-zero probability that country 1 makes a positive contribution. In this case, total provision in equilibrium sometimes falls short of the complete-information outcome but never exceeds it.

Lemma 4.2. *Let σ be any equilibrium of the game with one-sided incomplete information about costs. For all possible realizations of country 1's type $c_1 \in T_1$, the total contribution on the path of play is no greater than the equilibrium total contribution if c_1 were common knowledge:*

$$s_1(c_1, \mu_1(c_1), c_2) + s_2(c_2, c_2, \mu_1(c_1)) \leq \max\{x^*(c_1), x^*(c_2)\}. \tag{4.1}$$

If $\underline{c}_1 < c_2 < \bar{c}_1$ and $x^*(c_2) > 0$, then the above inequality holds strictly for all $c_1 \in (c_2, \bar{c}_1]$.

Proof. See the Appendix. □

Next, I show that the lower public good provision under uncertainty results in lower social welfare. Define the *ex post* social welfare function as the sum of the countries' payoffs, given their types:

$$U(x_1, x_2 \,|\, c_1, c_2) = 2p(x_1 + x_2) - c_1 x_1 - c_2 x_2.$$

This is a strictly concave function that is maximized by the country with the lower marginal cost spending $x^*(\min\{c_1, c_2\}/2)$. In any equilibrium of the complete-information game, by Proposition 3.1, the lower-cost country spends its stand-alone value $x^*(\min\{c_1, c_2\})$ and the higher-cost country spends nothing. The equilibrium outcome of the game with one-sided uncertainty, as we have just seen, is a total contribution that is even lower and may be inefficiently apportioned (i.e., with the higher-cost country spending positive effort). As the *ex post* social welfare function is strictly concave, this yields a total payoff of no greater than what it would be under complete information. This line of reasoning gives us the following proposition about social welfare.

Proposition 4.3. *In any equilibrium of the game with one-sided incomplete information about* *costs,* ex post *social welfare is always weakly lower than if c_1 were common knowledge. It is strictly lower with positive probability if $\underline{c}_1 < c_2 < \bar{c}_1$ and $x^*(c_2) > 0$.*

To summarize, in the model with one-sided incomplete information, the informed country has an incentive to misrepresent its willingness to contribute to a public good. Faced with a choice among messages, a country always prefers whichever would induce its partner to contribute the most. Since all types of the informed country would strictly prefer to send the same message, influential communication is incompatible with equilibrium. This failure to communicate holds up even though contributions to the public good and total social welfare would be greater if the country's private information were made common knowledge. Contrary to the conventional wisdom about diplomatic communication, common interests do not enable honest information transmission in this setting. I now turn to the question of whether influential communication is possible under mutual uncertainty, when a country cannot predict its partner's exact response to each possible message.

5 Two-Sided Uncertainty

I now assume both countries have private information about their marginal cost of effort. As in the analysis of the one-sided case, I focus on whether influential communication is possible in equilibrium. To rule out influential equilibria under one-sided incomplete information, I showed that the country with private information would always prefer to send the message that would induce its partner to contribute the most. This logic does not carry over immediately to the case of two-sided uncertainty. Each country, when choosing which message to send, does not know its partner's type and thus cannot exactly predict its reaction. It may not be possible to order potential messages by how much they would induce the partner to contribute—some types of country j may contribute more after m_i than m_i', while others do the reverse. To extend the logic of Proposition 4.1 to two-sided uncertainty, we must find that such a non-uniform response to messages cannot arise in equilibrium.

To rule out this kind of messaging strategy—and thereby rule out influential equilibria—I exploit the structure of the public goods game. When there is complete information, a country's equilibrium contribution weakly increases with its partner's marginal cost of effort, per Proposition 3.1. Since there are diminishing returns to contributions, a country gives less the more it expects its partner to give. By this token, a country should never give more after finding out that its partner's cost of contribution is low than after finding out it is high. A country can thus assure the greatest contribution by all types of its partner by mimicking the highest-cost type. Even though both countries are uncertain of each other's type, the incentive to misrepresent persists. This reasoning is the foundation of the proof that there is no equilibrium in which each country fully reveals its type.[10]

Proposition 5.1. *There is no fully separating influential equilibrium in the game with two-sided incomplete information about costs.*

Proof. Consider a fully separating equilibrium, in which $\mu_i(c_i) = c_i$ for all c_i. By Proposition 3.1, each type's contribution on the path of play is given by

$$s_i(c_i, c_i, c_j) = \begin{cases} x^*(c_i) & c_i < c_j, \\ x^*(c_i) - s_j(c_j, c_j, c_i) & c_i = c_j, \\ 0 & c_i > c_j. \end{cases}$$

This expression is weakly decreasing in c_j. Therefore, if the assessment is influential, it meets the conditions of Proposition 3.4, contradicting the assumption of equilibrium. □

What about partial information revelation, as in Crawford and Sobel (1982)? To make it tractable to analyze influential communication in partially separating equilibria, I impose some additional structure on the model. First, I restrict attention to *interval messaging*

[10] The exception is if each type always makes the same contribution regardless of its partner's message, in which case the equilibrium is not influential. Such an equilibrium can exist only if the countries' type spaces do not overlap.

strategies, in which each message corresponds to an interval of types. Given a messaging strategy μ_i, let $\mathcal{C}_i(m_i)$ denote the set of types of country i that send m_i. Formally, μ_i is an interval messaging strategy if every $\mathcal{C}_i(m_i)$ is convex. Babbling and fully separating messaging strategies are both special cases of interval messaging. As the type and message spaces are equivalent, there is no loss of generality in assuming that $m_i \in \mathcal{C}_i(m_i)$ for all $m_i \in \mu_i(T_i)$ under interval messaging (Fey, Kim and Rothenberg 2007). This condition implies that μ_i is weakly increasing, so higher messages correspond to higher-cost types. The assumption is solely for expository convenience and does not substantively affect the results.

Second, to obtain a closed-form expression for best responses, I impose an additional functional form assumption. As in Barbieri and Malueg's (2010; 2013) analysis of similar public goods models with incomplete information, it is easiest to characterize an equilibrium when a country's optimal contribution depends only on the expected value of its partner's contribution:

$$\arg\max_{x_i} E_{\lambda_i(m_j)}\left[u_i(x_i, s_j(c_j, m_j, m_i))\right] = \arg\max_{x_i} u_i\left(x_i, E_{\lambda_i(m_j)}[s_j(c_j, m_j, m_i)]\right). \tag{5.1}$$

A sufficient condition for equation (5.1) to hold is that the function p be quadratic, as stated in the following lemma.

Lemma 5.2. *If p is quadratic on $[0, \frac{1}{\underline{c}_1} + \frac{1}{\underline{c}_2}]$, then in any equilibrium*

$$s_i(c_i, m_i, m_j) = \max\left\{0, x^*(c_i) - E_{\lambda_i(m_j)}[s_j(c_j, m_j, m_i)]\right\} \tag{5.2}$$

for all $c_i \in T_i$, $m_i \in M_i$, $m_j \in M_j$.

Proof. See the Appendix. □

Under this additional assumption, the proof that there is no fully separating influential equilibrium can be extended to rule out influential communication with any interval messaging strategy. First, a country expects its partner to contribute more if the partner sends a “low-cost” message than if it sends a “high-cost” message. Second, a country gives less the more it expects its partner to give, per equation (5.2). Therefore, it is never in a country’s interest to send a “low-cost” message, as it would induce all types of its partner to contribute weakly more if it claimed to be a “high-cost” type. Since each country has an incentive to overstate its marginal cost of effort, there cannot be an influential equilibrium, as stated in the following proposition.

Proposition 5.3. *If p is quadratic on $[0, \frac{1}{\underline{c}_1} + \frac{1}{\underline{c}_2}]$, there is no influential equilibrium in interval messaging strategies in the game with two-sided incomplete information about costs.*

Proof. See the Appendix. □

It is plausible that the logic of this result holds for a broader class of functional forms of p. The key to the proof is that no type of a country contributes more after receiving a “low-cost” message from its partner than a “high-cost” message—the same property invoked in the proof that there is no fully separating influential equilibrium. The assumption of a quadratic functional form, by giving a closed-form expression for best responses, makes it feasible to show that this property holds. The same condition may hold for other functional forms of p, and the fact that it holds in the quadratic case gives us reason to suspect so.

The findings for two-sided incomplete information, as in the one-sided case, contradict the widely accepted notion that credible communication is possible between actors with common interests. The two countries in this game have a joint interest in providing a public good, but, under reasonable conditions, influential communication cannot occur in equilibrium. The common interest in public goods provision does not override each country’s individual preference for its partner to contribute as much as possible. As long as every type of a country wants the same thing from its partner, cheap talk diplomatic statements are uninformative. If cheap talk diplomacy is to be effective, different types of a country must have different preferences about the other country’s actions.

6 Extensions

The previous two sections have shown that, under a broad range of conditions, cheap talk diplomacy cannot help countries reveal information about their willingness to contribute to a public good. This section examines whether there can be honest communication about other sources of private information in international public goods problems. I extend the model to consider two alternative types of uncertainty. First, I assume that one country receives an additional signal about how much effort is required for the joint project to succeed. I find that there is an influential equilibrium if the signal is perfectly informative, but this result is fragile—adding a bit of noise to the signal can preclude influential communication. In the second extension, there are two avenues of contribution to the joint project, and one state has private information about which method it can provide more easily. In contrast to the previous results, influential communication is widely possible in this case. What enables information revelation is that different types of the informed country want the other country to focus on different avenues of contribution, meaning the informed country does not always strictly prefer to send the same message. When there is not just common interest but also variation in preferences, cheap talk communication can be credible.

6.1 Intelligence Sharing

In this extension, I assume one country gains additional information about the joint project and examine whether it can credibly reveal this information to its partner. For the purposes of this extension, I will interpret the public good as a joint project with a dichotomous outcome (success or failure), where the likelihood of success is increasing in the total contribution of effort. Military cooperation against a common enemy, in which the countries do not know exactly how much military power is required for victory, is one example of this kind of situation. Formally, assume that there is a random variable $y \geq 0$ such that the project succeeds (realizes its full value of 1) if the total contribution meets or exceeds

y, and fails otherwise. I call y the *threshold* for success.[11] At the outset of the game, the potential contributors do not know the value of y; they know only that it is drawn from the cumulative distribution function F_y. The *ex ante* probability of success, as a function of the total contribution, is

$$\Pr(x_1 + x_2 \geq y) = F_y(x_1 + x_2).$$

Therefore, if the allies receive no additional information about the threshold, this extension is equivalent to the original contribution game, with $p = F_y$.

In the *intelligence-sharing game*, Nature sends country 1 a signal of the threshold before contributions are chosen, and country 1 has the opportunity to pass this intelligence along to its ally. The threshold and the signal are drawn from the joint probability distribution $F_{y,z}$ on $Y \times Z$, where $Z \subseteq Y \subseteq \Re_+$ and F_y is the marginal distribution of y. This distribution is common knowledge, but only country 1 observes the realized value of z, and neither country observes the realized value of y. For each $z \in Z$, let $F_y(\cdot \mid z)$ denote the conditional distribution function of the threshold given the signal. The signal is *perfectly informative* if $z = y$, meaning country 1 learns the exact contribution level required for success. In this case, the conditional distribution function is a step function,

$$F_y(y' \mid z) = \begin{cases} 0 & y' < z, \\ 1 & y' \geq z. \end{cases}$$

The threshold and the signal received by country 1 are the only sources of uncertainty in the intelligence-sharing game. In particular, the marginal costs of contribution, c_1 and c_2, are now common knowledge.

The sequence of play in the intelligence-sharing game is essentially the same as in the original model. After observing the signal z, country 1 sends a message $m_1 \in M_1$ to its ally, where the set of potential messages is the same as the set of signals, $M_1 = Z$. A messaging

[11] On threshold uncertainty in public goods games, see Nitzan and Romano (1990), Suleiman (1997), and McBride (2006).

strategy for country 1 is a function $\mu_1 : Z \to M_1$. After receiving country 1's message, country 2 updates its beliefs about the threshold to $\lambda_2(m_1)$, a probability measure on Y. Finally, each country simultaneously selects its contribution x_i from $X_i = \Re_+$. Country 1's contribution depends both on the signal it received and the message it sent, so its contribution strategy is a function $s_1 : Z \times M_1 \to X_1$. Country 2's contribution strategy is a function solely of the message it received, $s_2 : M_1 \to X_2$.

The solution concept, as in the original model, is perfect Bayesian equilibrium, which requires sequential rationality of strategies and consistency of beliefs. In equilibrium, as before, no type of country 1 may be able to strictly increase its payoff by sending a message other than what is prescribed. This requirement gives us the incentive compatibility condition:

$$\begin{aligned} &F_y\left(s_1(z, \mu_1(z)) + s_2(\mu_1(z)) \,|\, z\right) - c_1 s_1(z, \mu_1(z)) \\ &\qquad \geq \max_{(m_1, x_1)} \left\{F_y\left(x_1 + s_2(m_1) \,|\, z\right) - c_1 x_1\right\} \quad \text{for all } z \in Z. \end{aligned} \tag{6.1}$$

In two important respects, the intelligence sharing game resembles the game with one-sided incomplete information about costs examined in Section 4. First, all types of the informed country weakly prefer greater contributions by its partner. Second, the informed country knows exactly how its partner, which has no private information, will respond to each potential message. In light of these similarities, it may seem that the logic of Proposition 4.1 would also apply here—that there can be no influential equilibrium. On the contrary, in the special case of perfectly informative signals, there is a fully separating, influential equilibrium. What distinguishes this situation from the original model is that the informed country may only weakly prefer greater contributions by its partner; in particular, it is indifferent among all contributions that meet or exceed the threshold. Influential communication is possible here, as in Agastya, Menezes and Sengupta (2007), because the informed country has no incentive to induce its partner to over-contribute.

The fully separating equilibrium under perfectly informative signaling involves the informed country free-riding on its partner as much as possible. The contributions on the path of play take one of three forms, depending on the value of the threshold:

1. *The threshold does not exceed country 2's willingness to contribute:* $z \leq \frac{1}{c_2}$.

   Country 2 gives the full amount ($x_2 = z$), and country 1 gives nothing.

2. *The threshold exceeds country 2's willingness to contribute, but not the countries' total willingness:* $\frac{1}{c_2} < z \leq \frac{1}{c_1} + \frac{1}{c_2}$.

   Country 2 gives as much as it is willing ($x_2 = \frac{1}{c_2}$), and country 1 makes up the difference ($x_1 = z - \frac{1}{c_2}$).

3. *The threshold exceeds the countries' total willingness to contribute:* $z > \frac{1}{c_1} + \frac{1}{c_2}$.

   Neither country contributes ($x_1 = x_2 = 0$).

Figure 1 illustrates each country's contribution as a function of the threshold. Why is it always in country 1's interest, given these strategies, to report its signal honestly? In the first case, country 1 receives its most preferred outcome—assured success at no cost to itself—and thus has no incentive to deviate. In the second case, there is no message country 1 could send that would induce country 2 to contribute more, so again there is no incentive to deviate. The trickiest case is the third. If country 1 falsely reported $m_1 \in (0, \frac{1}{c_1} + \frac{1}{c_2}]$, its partner would contribute a positive amount. However, the leftover amount required for success would be more than country 1 is willing to contribute, so country 1 would contribute nothing and receive nothing—the same as the outcome under the proposed strategy. Therefore, the incentive to misrepresent from the original model does not carry over to this setting. I now state the equilibrium strategies formally.

Proposition 6.1. *If the signal is perfectly informative, then there is a fully separating, influ-*

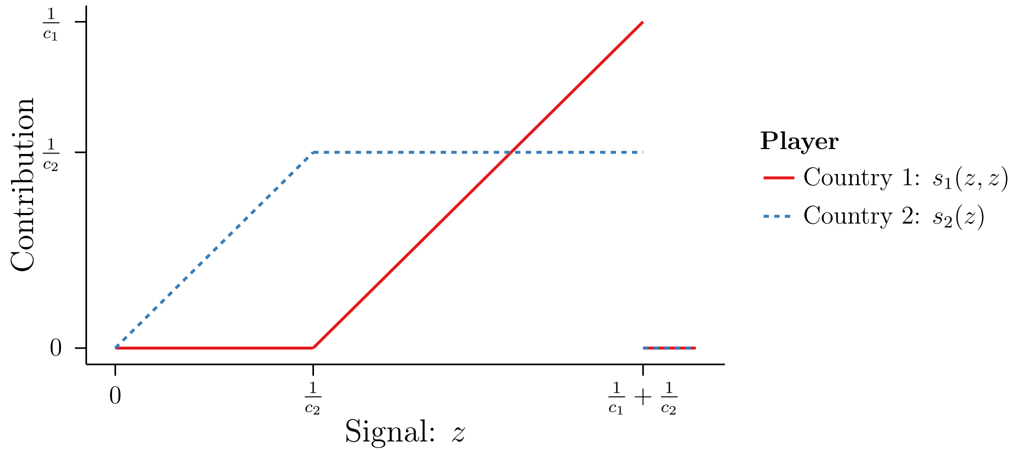

Figure 1. Contributions made by each country on the path of play in the equilibrium given in Proposition 6.1, as a function of the signal received by country 1.

ential equilibrium of the intelligence-sharing game in which:

$$
\begin{aligned}
\mu_1(z) &= z, \\
s_1(z, z) &= \begin{cases} 0 & z < \frac{1}{c_2}, \\ z - \frac{1}{c_2} & \frac{1}{c_2} \leq z \leq \frac{1}{c_1} + \frac{1}{c_2}, \\ 0 & z > \frac{1}{c_1} + \frac{1}{c_2}, \end{cases} \\
s_2(m_1) &= \begin{cases} m_1 & m_1 < \frac{1}{c_2}, \\ \frac{1}{c_2} & \frac{1}{c_2} \leq m_1 \leq \frac{1}{c_1} + \frac{1}{c_2}, \\ 0 & m_1 > \frac{1}{c_1} + \frac{1}{c_2}, \end{cases} \\
\lambda_2(m_1) &= \delta_{m_1}.
\end{aligned}
$$

Proof. See the Appendix. □

The assumption of a perfectly informative signal is crucial for this result. Because country 1 knows the exact threshold, it never has an incentive to induce its partner to contribute too much. This logic would no longer work if the intelligence country 1 received were a bit noisier. If contributions always strictly increase the probability of success—even if only slightly—there cannot be influential communication in equilibrium. A sufficient condition for this no-communication result is that country 1's signal have full support, as stated in the following proposition.

Proposition 6.2. *If $[0, \frac{1}{c_1} + \frac{1}{c_2}] \subseteq \operatorname{supp} F_y(\cdot \mid z)$ for all signals z, then there is no influential equilibrium of the intelligence-sharing game.*

Proof. See the Appendix. □

Even a quite specific signal can meet this condition. For example, consider an almost perfectly informative signal, which takes the true value y with probability $1 - \epsilon$ and is drawn from $U[0, \frac{1}{c_1} + \frac{1}{c_2}]$ with probability ϵ. For any $\epsilon > 0$, there is no influential equilibrium, according to the above proposition. In this sense, the possibility of influential communication under perfect intelligence is not robust to a small perturbation in the information environment.[12] If intelligence is insufficiently specific, a country faces the same incentive to misrepresent as in the original model—namely, to say whatever would induce its partner to contribute as much as possible.

6.2 Multiple Contribution Methods

I now consider an extension in which there are distinct methods of contribution to the public good. An effort to fight global warming might depend on reductions in both carbon and methane emissions; a joint military intervention may require both ground troops and air support. States may vary in their ability or willingness to supply each method, and they may be uncertain about which kinds of support their partners are best equipped to provide. In this extension, I assume that there are two avenues of contribution and that one state has private information about which method it can more easily provide. Unlike in the original model and the intelligence-sharing extension, I find that influential communication is broadly

[12] Not all small perturbations eliminate the possibility of communication. For example, influential equilibria may be possible if the signal is drawn from $U[y - \epsilon, y + \epsilon]$ for some small ϵ.

		Country 2			
		$(0,0)$	$(1,0)$	$(0,1)$	$(1,1)$
Country 1	$(0,0)$	$p(0,0)$ $p(0,0)$	$p(1,0)$ $p(1,0)-\alpha_2$	$p(0,1)$ $p(0,1)-\beta_2$	$p(1,1)$ $p(1,1)-\alpha_2-\beta_2$
	$(1,0)$	$p(1,0)-\alpha_1$ $p(1,0)$	$p(2,0)-\alpha_1$ $p(2,0)-\alpha_2$	$p(1,1)-\alpha_1$ $p(1,1)-\beta_2$	$p(2,1)-\alpha_1$ $p(2,1)-\alpha_2-\beta_2$
	$(0,1)$	$p(0,1)-\beta_1$ $p(0,1)$	$p(1,1)-\beta_1$ $p(1,1)-\alpha_2$	$p(0,2)-\beta_1$ $p(0,2)-\beta_2$	$p(1,2)-\beta_1$ $p(1,2)-\alpha_2-\beta_2$
	$(1,1)$	$p(1,1)-\alpha_1-\beta_1$ $p(1,1)$	$p(2,1)-\alpha_1-\beta_1$ $p(2,1)-\alpha_2$	$p(1,2)-\alpha_1-\beta_1$ $p(1,2)-\beta_2$	$p(2,2)-\alpha_1-\beta_1$ $p(2,2)-\alpha_2-\beta_2$

Figure 2. Payoff matrix for the contribution stage of the two-method game.

possible in this setting. The key to communication here is that a country's preference about its partner's actions may differ across types. For example, a country with a comparative advantage in air power may prefer that its partner mainly contribute ground forces, and vice versa. The finding is similar to Trager's (2011) results about multidimensional bargaining between adversaries.

In the contribution stage of the *two-method game*, each state decides whether to devote effort to either or both of two avenues of contribution. To keep the analysis simple, I assume the contribution to each method is dichotomous.[13] Formally, each state's action in the contribution stage is a pair $x_i = (x_i^A, x_i^B)$ of binary decisions, denoting the country's decision to contribute to methods A and B respectively. Each country's action space is $X_i = \{0,1\}^2$. The cost to country i of participating in method A is α_i, and its cost of method B is β_i. The probability of success is now a function of the total contribution to each method, denoted $p(x^A, x^B)$, which is strictly increasing in both arguments. A country's utility function in the two-method contribution game is

$$u_i(x_i, x_j \mid \alpha_i, \beta_i) = p(x_i^A + x_j^A, x_i^B + x_j^B) - \alpha_i x_i^A - \beta_i x_i^B. \tag{6.2}$$

Figure 2 contains the payoff matrix for the contribution game.

To incorporate uncertainty, I assume that country 1's cost of contributing to method B

[13]The main finding here—that an influential equilibrium exists in a nontrivial subset of the parameter space—would still hold if the action space were continuous.

is private information. Country 1's type β_1 equals β_1^L with probability $\pi \in (0,1)$ and β^H with probability $1-\pi$, where $\beta_1^L < \alpha_1 < \beta_1^H$. I call country 1 "$B$-advantaged" if $\beta_1 = \beta_1^L$ and "A-advantaged" if $\beta_1 = \beta_1^H$. The prior distribution of β_1 is common knowledge, but only country 1 observes its realized value. The other cost parameters, α_1, α_2, and β_2, are common knowledge. I assume it is never in a state's interest to contribute to a method that its ally is also contributing to.[14] This condition is equivalent to

$$
\begin{aligned}
p(2, x^B) - p(1, x^B) &\leq \min\{\alpha_1, \alpha_2\} \quad \text{for all } x^B = 0, 1, 2, \\
p(x^A, 2) - p(x^A, 1) &\leq \min\{\beta_1^L, \beta_2\} \quad \text{for all } x^A = 0, 1, 2.
\end{aligned}
$$

As in the original model, country 1 has the opportunity to send its ally a message about its type prior to the contribution stage. Let $T_1 = \{\beta_1^L, \beta_1^H\}$ denote country 1's type space, and suppose its message space is the same, $M_1 = T_1$. The definitions of strategies and beliefs are similar to those in the intelligence-sharing game. A messaging strategy for country 1 is a function $\mu_1 : T_1 \to M_1$. After receiving country 1's message m_1, country 2 updates its beliefs to $\lambda_1(m_1)$, which now is a scalar denoting the probability that $\beta_1 = \beta_1^L$. Country 1's contribution strategy is a function of both its type and the message it sent, $s_1 : T_1 \times M_1 \to X_1$. Country 2's contribution strategy is a function solely of the message it received, $s_2 : M_1 \to X_2$.

In the remainder of this section, I characterize the conditions under which there exists a *division of labor equilibrium*, which I define as an equilibrium with the following properties:

1. Country 1 honestly reveals its type in the messaging stage: $\mu_1(\beta_1) = \beta_1$ for all β_1.

2. Both methods of contribution are always supplied on the equilibrium path: $s_1(\beta_1, \mu_1(\beta)) + s_2(\mu_1(\beta_1)) = (1,1)$ for all β_1.

3. There is a division of labor between the countries that depends on country 1's type: if

[14] Influential equilibria would still exist if this condition were relaxed, though the statement of the conditions for Proposition 6.4 would become more cumbersome.

country 1 is B-advantaged, then it contributes to method B and country 2 contributes to method A, and vice versa.

The last requirement implies that a division of labor equilibrium is influential, though there may be influential equilibria of different forms as well.[15]

In order to delineate the conditions under which there is a division of labor equilibrium, it is useful to think of country 1's messages as statements about what it will do in the contribution stage. Consider the B-advantaged type's message, which can be interpreted as the statement "I will contribute to method B." For this to be credible, the B-advantaged type of country 1 must indeed prefer to do as promised, given that its ally believes the promise and chooses its own action accordingly. Farrell and Rabin (1996) call such a statement *self-committing*. It must not be in country 1's interest to trick its partner into thinking it will contribute to method B and then choose a different course of action. The following lemma states the conditions under which country 1's message is self-committing.

Lemma 6.3. *In the contribution stage of the two-method game, suppose β_1 is common knowledge. The strategy profile $\{(x_1^A, x_1^B), (x_2^A, x_2^B)\} = \{(1,0),(0,1)\}$ is a Nash equilibrium if and only if the following conditions are met:*

$$p(1,1) - p(0,1) \geq \alpha_1, \tag{6.3}$$

$$p(1,1) - p(1,0) \geq \beta_2. \tag{6.4}$$

The strategy profile $\{(x_1^A, x_1^B), (x_2^A, x_2^B)\} = \{(0,1),(1,0)\}$ is a Nash equilibrium if and only if:

$$p(1,1) - p(0,1) \geq \alpha_2, \tag{6.5}$$

$$p(1,1) - p(1,0) \geq \beta_1. \tag{6.6}$$

[15]Any influential equilibrium must entail country 2 choosing $x_2 = (1,0)$ in response to one message and $x_2 = (0,1)$ in response to the other.

Proof. See the Appendix. □

Self-commitment is necessary, but not sufficient, for a cheap-talk statement to be credible. To determine if a statement about what action a speaker will take is self-committing, we assume the statement's recipient believes the statement and examine whether the speaker indeed prefers to take the promised action. But we cannot just consider a speaker's preferences given the recipient's beliefs; we must also address its preferences about those beliefs. To this end, Farrell and Rabin (1996) say a statement is *self-signaling* if a speaker wants it to be believed if and only if it is true. In the context of a division of labor equilibrium, self-signaling requires that the B-advantaged type of country 1, which promises to contribute B, would not be better off if country 2 instead believed country 1 would contribute A and acted accordingly. Similarly, the A-advantaged type must not prefer to induce country 2 to believe it will contribute B instead of A. The following proposition summarizes the conditions under which both the self-commitment and self-signaling requirements are satisfied, and therefore a division of labor equilibrium exists.

Proposition 6.4. *In the two-method game, suppose the following conditions are satisfied:*

$$p(1,1) - p(0,1) \geq \max\left\{\alpha_1, \alpha_2, \beta_1^L\right\}, \tag{6.7}$$

$$p(1,1) - p(1,0) \geq \max\left\{\alpha_1, \beta_1^L, \beta_2\right\}. \tag{6.8}$$

There exists a division of labor equilibrium in which

$$\mu_1(\beta_1) = \beta_1,$$

$$s_1(\beta_1, \beta_1) = \begin{cases} (0,1) & \beta_1 = \beta_1^L, \\ (1,0) & \beta_1 = \beta_1^H, \end{cases}$$

$$s_2(m_1) = \begin{cases} (1,0) & m_1 = \beta_1^L, \\ (0,1) & m_1 = \beta_1^H, \end{cases}$$

$$\lambda_2(m_1) = \mathbf{1}\{m_1 = \beta_1^L\}.$$

Proof. See the Appendix. □

In contrast to the findings earlier in the paper, here we see that influential communication is possible under wide conditions. The difference between this extension and the other models is not whether the players have common interests—in each case, the players have a common stake in a public good but have incentives to free-ride. What differs is that the informed country does not always want the same thing from its partner. Under the conditions given in the proposition, the B-advantaged type of country 1 wants its partner to supply A, while the A-advantaged type wants it to supply B. Therefore, neither type has an incentive to mimic the other. The multidimensional model allows for variation in preferences, which in turn enables influential communication. These results show that diplomatic communication can help states coordinate how they contribute to international public goods—even though, as shown earlier, it is ineffective at revealing their overall level of commitment.

7 Conclusion

This paper has shown when diplomatic communication can be effective in international public goods dilemmas. The results are largely negative. There is a pervasive incentive for states to misrepresent their private information—specifically, to say whatever will get their partners to take on as much of the burden as possible. This incentive for dishonesty hampers diplomatic communication about states' willingness to contribute to a project and about how much effort is required for the project to succeed. The main exception to these negative findings is when there are distinct ways to contribute to a public good; in this case, a state may honestly reveal which form of effort it can most easily provide. These findings show why international relations scholars should not assume away the problems of communication among states with common goals. Because states do not always have an incentive to be honest with their partners, uncertainty may hamper international efforts at public goods provision even when states have a forum to talk. The role of international organizations and alliances in reducing uncertainty may not be to facilitate communication among member states, but rather to collect and disseminate information on their own.

A broader conclusion of the analysis is that common interest alone does not lead to effective diplomatic communication. An actor cannot credibly communicate through cheap talk if its private information is unrelated to its preferences over the other players' actions. This result can help us make sense of disparate findings in the literature on cheap talk diplomacy. For example, take Kydd's (2003) finding that unbiased mediators cannot credibly reveal information to bring about peace. The problem in this setting is not a lack of common interest, as the mediator and the states in crisis share an interest in avoiding war. What impedes communication is that an unbiased mediator always prefers greater concessions and will say whatever it takes to get a state to concede more. The same reasoning applies to the ultimatum bargaining model (Fearon 1995): a state has an incentive to misrepresent its resolve because it always wants a more favorable settlement, even though states in a crisis have a joint interest in settling rather than fighting. The difference between these models and those where influential communication is possible (e.g., Trager 2010, 2011) is not whether the actors have common interests, but rather whether a country's type affects what it wants other countries to do. Future studies of diplomatic communication should look for both common interests and this variation in preferences across types.

A Appendix

This section contains proofs that do not appear in the text.

Proposition 3.1. *Suppose the marginal contribution costs c_1 and c_2 are common knowledge. Without loss of generality, let $c_1 \leq c_2$. If $c_1 < c_2$, the unique Nash equilibrium of the contribution game is $(x_1, x_2) = (x^*(c_1), 0)$. If $c_1 = c_2 = c$, then (x_1, x_2) is a Nash equilibrium of the contribution game if and only if $x_1 + x_2 = x^*(c)$.*

Proof. I begin by ruling out mixed-strategy equilibria. Fix country j's strategy as a mixed strategy given by the probability measure ξ. As p is strictly concave, country i's objective function,

$$Eu_i(x_i) = \int_{X_j} p(x_i + x_j)\, d\xi - c_i x_i,$$

is strictly concave as well (Hildreth 1974). This implies any country has a unique best response to any mixed strategy by its ally, so there can be no mixed-strategy equilibrium. A further consequence of strict concavity of the objective function is that the pure strategy profile (x_1, x_2) is an equilibrium if and only if the first-order optimality conditions

$$\begin{aligned}
&x_i\,(p'(x_i + x_j) - c_i) = 0,\\
&p'(x_i + x_j) - c_i \leq 0,\\
&x_i \geq 0,
\end{aligned}$$

are satisfied for $i = 1, 2$. The proposition follows immediately. □

Lemma 3.2. *Consider any contribution subgame $\Gamma(m_1, m_2)$ of the game with incomplete information about costs. If each $\lambda_i(m_j)$ is either a degenerate distribution or a continuous distribution on an interval, then there exists a Bayesian Nash equilibrium of the subgame.*

Proof. First, suppose country 2's belief about country 1's type is a point mass on c_1'; i.e., $\lambda_2(m_1) = \delta_{c_1'}$. (The proof for the opposite case is identical.) Because country 2 believes with certainty that $c_1 = c_1'$, its strategy $s_2(\cdot, m_2, m_1)$ is a best response if and only if

$$s_2(c_2, m_2, m_1) = \max\left\{0, x^*(c_2) - s_1(c_1', m_1, m_2)\right\}.$$

To show that an equilibrium exists, we must find a value of $s_1(c_1', m_1, m_2)$ that is a best response for type c_1' of country 1 when country 2's strategy is defined as above. Let $\Psi(x_1, c_1)$ denote the best response for a given type of country 1 when it expects each type of country 2 to employ a best response to x_1:

$$\Psi(x_1, c_1) = \operatorname*{arg\,max}_{x_1' \in X_1} \left\{ \int_{T_2} p\left(x_1' + \max\left\{0, x^*(c_2) - x_1\right\}\right)\, d\lambda_1(m_2) - c_1 x_1' \right\}.$$

Because contributions above a type's stand-alone contribution are strictly dominated, we have $\Psi(x_1, c_1') \in [0, x^*(c_1')]$ for all x_1. Moreover, by the Berge Maximum Theorem (Aliprantis and Border 2006, Theorem 17.31), Ψ is continuous in x_1. Then, by the Brouwer fixed-point theorem, there exists $\hat{x} \in [0, x^*(c_1')]$ such that $\Psi(\hat{x}, c_1') = \hat{x}$. The following strategies therefore constitute an equilibrium of $\Gamma(m_1, m_2)$:

$$s_1(c_1, m_1, m_2) = \Psi(\hat{x}, c_1),$$
$$s_2(c_2, m_2, m_1) = \max\{0, x^*(c_2) - \hat{x}\}.$$

On the other hand, suppose neither message is fully revealing, so $\lambda_2(m_1)$ and $\lambda_1(m_2)$ are both continuous distributions over an interval. Each country's expected utility in the subgame, holding fixed the strategy of the other country, is

$$Eu_i(x_i \mid c_i) = \int_{T_j} p(x_i + s_j(c_j, m_j, m_i))\, d\lambda_i(m_j) - c_i x_i.$$

Differentiating gives

$$\frac{\partial^2 Eu_i(x_i \mid c_i)}{\partial x_i \partial c_i} = -1,$$

so each country's best response is non-increasing in its type. In addition, because contributions above a type's stand-alone contribution are strictly dominated and x^* is decreasing, we may restrict each country's action space in the contribution stage to $[0, x^*(\underline{c}_i)]$ without loss of generality. Therefore, by Corollary 2.1 of Athey (2001), a pure-strategy equilibrium of the subgame exists. □

Lemma 4.2. *Let σ be any equilibrium of the game with one-sided incomplete information about costs. For all possible realizations of country 1's type $c_1 \in T_1$, the total contribution on the path of play is no greater than the equilibrium total contribution if c_1 were common knowledge:*

$$s_1(c_1, \mu_1(c_1), c_2) + s_2(c_2, c_2, \mu_1(c_1)) \leq \max\{x^*(c_1), x^*(c_2)\}. \tag{4.1}$$

If $\underline{c}_1 < c_2 < \bar{c}_1$ and $x^*(c_2) > 0$, then the above inequality holds strictly for all $c_1 \in (c_2, \bar{c}_1]$.

Proof. By Proposition 4.1, in equilibrium country 2 contributes the same amount $\tilde{x}_2 \geq 0$ in response to all messages on the path of play: $s_2(c_2, c_2, \mu_1(c_1)) = \tilde{x}_2$ for all $c_1 \in T_1$. The first-order conditions for an optimal choice by country 1 then give

$$s_1(c_1, \mu_1(c_1), c_2) = \max\{0, x^*(c_1) - \tilde{x}_2\} \tag{A.1}$$

Since any contribution above a country's stand-alone contribution is strictly dominated, $x_2 \leq x^*(c_2)$. The inequality (4.1) follows immediately.

Now suppose $\underline{c}_1 < c_2 < \bar{c}_1$ and $x^*(c_2) > 0$. To prove that the inequality (4.1) holds strictly for all $c_1 \in (c_2, \bar{c}_1]$, it suffices to show that $\tilde{x}_2 < x^*(c_2)$. As $\tilde{x}_2 \leq x^*(c_2)$, equation (A.1) gives $s_1(c_1, \mu_1(c_1), c_2) > 0$ for all $c_1 < c_2$. Therefore, the first-order condition for a best response by country 2 cannot be satisfied at $x_2 = x^*(c_2)$:

$$\int_{T_1} p'\left(s_1(c_1, \mu_1(c_1), c_2) + x^*(c_2)\right) dF_1 - c_2 \\ < \int_{T_1} p'\left(x^*(c_2)\right) dF_1 - c_2 = 0. \qquad \square$$

Lemma 5.2. *If p is quadratic on $[0, \frac{1}{\underline{c}_1} + \frac{1}{\underline{c}_2}]$, then in any equilibrium*

$$s_i(c_i, m_i, m_j) = \max\left\{0, x^*(c_i) - E_{\lambda_i(m_j)}[s_j(c_j, m_j, m_i)]\right\} \tag{5.2}$$

for all $c_i \in T_i$, $m_i \in M_i$, $m_j \in M_j$.

Proof. The quadraticity assumption implies p' is linear on $[0, \frac{1}{\underline{c}_1} + \frac{1}{\underline{c}_2}]$. Moreover, in equilibrium, $s_j(c_j, m_j, m_i) \le x^*(c_j) < \frac{1}{\underline{c}_j}$ for all $c_j \in T_j$. The first-order condition for $x_i \in (0, x^*(c_i)]$ to be a best response for type c_i in the subgame $\Gamma(m_i, m_j)$ is thus

$$\begin{aligned} 0 &= E_{\lambda_i(m_j)}\left[p'\left(x_i + s_j(c_j, m_j, m_i)\right) - c_i\right] \\ &= p'\left(x_i + E_{\lambda_i(m_j)}[s_j(c_j, m_j, m_i)]\right) - c_i. \end{aligned}$$

This implies $x_i + E_{\lambda_i(m_j)}[s_j(c_j, m_j, m_i)] = x^*(c_i)$, as claimed. $\square$

Proposition 5.3. *If p is quadratic on $[0, \frac{1}{\underline{c}_1} + \frac{1}{\underline{c}_2}]$, there is no influential equilibrium in interval messaging strategies in the game with two-sided incomplete information about costs.*

Proof. Suppose, for the purposes of a proof by contradiction, that there exists an influential equilibrium in interval messaging strategies. Without loss of generality, let country 1 be the influential one, so there exist messages m_1 and m_1' in the range of μ_1 such that $m_1' > m_1$ and $s_2(c_2, \mu_2(c_2), m_1) \ne s_2(c_2, \mu_2(c_2), m_1')$ on a positive-measure subset of T_2.[16] By Proposition 3.4 and the assumption of equilibrium, there is a type $\tilde{c}_2 \in T_2$ that contributes more after receiving the message m_1 than after receiving m_1'; i.e., $s_2(\tilde{c}_2, m_2, m_1) > s_2(\tilde{c}_2, m_2, m_1')$, where $m_2 = \mu_2(\tilde{c}_2)$.

I claim that the expected total contribution in the subgame $\Gamma(m_1, m_2)$ is no greater than that in $\Gamma(m_1', m_2)$. Let $\bar{x}_j(m_i, m_j)$ denote country i's expectation of what country j will contribute, given the outcome of the messaging stage:

$$\bar{x}_j(m_i, m_j) = E_{\lambda_i(m_j)}\left[s_j(c_j, m_j, m_i)\right].$$

By Lemma 5.2, $s_2(\tilde{c}_2, m_2, m_1) > s_2(\tilde{c}_2, m_2, m_1')$ implies $\bar{x}_1(m_1, m_2) < \bar{x}_1(m_1', m_2)$, as country 2's optimal contribution is inversely related to its expectation of what country 1 will

[16] Under the form of the messaging strategy defined in Section 3.2, $m_1' > m_1$ implies that m_1' is sent by higher-cost types than m_1.

contribute. Again applying Lemma 5.2, this in turn gives

$$
\begin{aligned}
&[\bar{x}_1(m_1', m_2) + \bar{x}_2(m_1', m_2)] - [\bar{x}_1(m_1, m_2) + \bar{x}_2(m_1, m_2)] \\
&\quad = \bar{x}_1(m_1', m_2) - \bar{x}_1(m_1, m_2) \\
&\qquad\quad + \int_{T_2} \max\{0, x^*(c_2) - \bar{x}_1(m_1', m_2)\}\, d\lambda_1(m_2) \\
&\qquad\quad - \int_{T_2} \max\{0, x^*(c_2) - \bar{x}_1(m_1, m_2)\}\, d\lambda_1(m_2) \\
&\quad \geq \bar{x}_1(m_1', m_2) - \bar{x}_1(m_1, m_2) + \int_{T_2} [\bar{x}_1(m_1, m_2) - \bar{x}_1(m_1', m_2)]\, d\lambda_1(m_2) \\
&\quad = 0.
\end{aligned}
$$

Therefore, we have

$$
\bar{x}_1(m_1', m_2) + \bar{x}_2(m_1', m_2) \geq \bar{x}_1(m_1, m_2) + \bar{x}_2(m_1, m_2). \tag{A.2}
$$

To conclude the proof, I show that equation (A.2) contradicts the assumption that $m_1' > m_1$. Take any $\tilde{c}_1 \in \mathcal{C}_1(m_1)$ such that $s_1(\tilde{c}_1, m_1, m_2) = \bar{x}_1(m_1, m_2)$. If $\mathcal{C}_1(m_1)$ is a singleton, then $\tilde{c}_1 = m_1$ by definition; otherwise, $\mathcal{C}_1(m_1)$ is an interval, and the Second Mean Value Theorem for Integrals guarantees the existence of an appropriate value of $\tilde{c}_1 \in \mathcal{C}_1(m_1)$. Let $\tilde{c}_1' \in \mathcal{C}_1(m_1')$ be chosen analogously. Lemma 5.2 gives

$$
\bar{x}_1(m_1, m_2) = s_1(\tilde{c}_1, m_1, m_2) \geq x^*(\tilde{c}_1) - \bar{x}_2(m_1, m_2), \tag{A.3}
$$

$$
\bar{x}_1(m_1', m_2) = s_1(\tilde{c}_1', m_1', m_2) = x^*(\tilde{c}_1') - \bar{x}_2(m_1', m_2). \tag{A.4}
$$

By definition of a monotone messaging strategy, $\tilde{c}_1' > \tilde{c}_1$. Moreover, by equation (A.4), $x^*(\tilde{c}_1) \geq \bar{x}_1(m_1', m_2) > 0$. As the stand-alone contribution function x^* is weakly decreasing everywhere and strictly decreasing wherever it is positive, $x^*(\tilde{c}_1') < x^*(\tilde{c}_1)$. However, combining equations (A.2)–(A.4) gives

$$
x^*(\tilde{c}_1') = \bar{x}_1(m_1', m_2) + \bar{x}_2(m_1', m_2) \geq \bar{x}_1(m_1, m_2) + \bar{x}_2(m_1, m_2) \geq x^*(\tilde{c}_1),
$$

a contradiction. □

Proposition 6.1. *If the signal is perfectly informative, then there is a fully separating, influ-*

ential equilibrium of the intelligence-sharing game in which:

$$\begin{aligned}
\mu_1(z) &= z, \\
s_1(z,z) &= \begin{cases} 0 & z < \frac{1}{c_2}, \\ z - \frac{1}{c_2} & \frac{1}{c_2} \leq z \leq \frac{1}{c_1} + \frac{1}{c_2}, \\ 0 & z > \frac{1}{c_1} + \frac{1}{c_2}, \end{cases} \\
s_2(m_1) &= \begin{cases} m_1 & m_1 < \frac{1}{c_2}, \\ \frac{1}{c_2} & \frac{1}{c_2} \leq m_1 \leq \frac{1}{c_1} + \frac{1}{c_2}, \\ 0 & m_1 > \frac{1}{c_1} + \frac{1}{c_2}, \end{cases} \\
\lambda_2(m_1) &= \delta_{m_1}.
\end{aligned}$$

Proof. To construct an equilibrium, we must complete the definition of country 1's strategy, s_1, for subgames that are off the path of play—i.e., after country 1 falsely reports the signal z. Consider the subgame that follows after country 1 sends the message m_1. Country 1's interim utility function is

$$u_1(x_1 \,|\, m_1, z) = \mathbf{1}\{x_1 + s_2(m_1) \geq z\} - c_1 x_1.$$

This function is maximized at 0 or at $z - s_2(m_1)$, so a best response exists. For each case in which $m_1 \neq z$, let $s_1(z, m_1)$ be any such best response.

I proceed by showing that the proposed contribution strategies are sequentially rational. Consider country 2's strategy. After receiving the message m_1, country 2's belief about the threshold y is a point mass on m_1. Country 2's interim utility function is thus

$$u_2(x_2 \,|\, m_1) = \mathbf{1}\{s_1(m_1, m_1) + x_2 \geq m_1\} - c_2 x_2,$$

which is maximized at 0 or at $z - s_1(m_1, m_1)$. Specifically, 0 is a maximizer if country 1's contribution is sufficient for success ($s_1(m_1, m_1) \geq m_1$) or the remaining amount necessary to succeed exceeds country 2's willingness to contribute ($z - s_1(m_1, m_1) \geq \frac{1}{c_2}$). Conversely, if $0 \leq z - s_1(m_1, m_1) \leq \frac{1}{c_2}$, then $z - s_1(m_1, m_1)$ is a maximizer. It is then immediate from the definitions of $s_1(z, z)$ and s_2 that country 2's contribution strategy is optimal, given its beliefs. It is analogous to confirm that country 1's contribution strategy along the path of play ($m_1 = z$) is optimal, given country 2's strategy. In cases off the path of play ($m_1 \neq z$), country 1's contribution is optimal by construction.

The next step is to show that country 1's messaging strategy is incentive compatible—i.e., that country 1 never has an incentive to falsely report the signal it has received. If $z \leq \frac{1}{c_2}$, then country 1's proposed messaging strategy yields its first-best outcome (guaranteed success at no cost to itself), so no profitable deviation is available. If $\frac{1}{c_2} < z \leq \frac{1}{c_1} + \frac{1}{c_2}$, then deviating to any message other than z would cause country 2 to contribute weakly less, so no such deviation may be profitable. Lastly, if $z > \frac{1}{c_1} + \frac{1}{c_2}$, then the most country 1 could induce country 2 to contribute by deviating to a different message is $x_2 = \frac{1}{c_2}$. Even in that case, country 1's best response is to contribute 0, assuring failure of the joint venture and a payoff of 0, the same as under the proposed messaging strategy. Therefore, there is no profitable deviation available.

The final step is to show that country 2's beliefs are consistent with the application of Bayes' rule, which is immediate from the definition of λ_2. $\square$

Proposition 6.2. *If* $[0, \frac{1}{c_1} + \frac{1}{c_2}] \subseteq \operatorname{supp} F_y(\cdot \mid z)$ *for all signals* z*, then there is no influential equilibrium of the intelligence-sharing game.*

Proof. In an influential equilibrium, there exist signals z' and z'' such that $s_2(\mu_1(z')) < s_2(\mu_1(z''))$. Contributions $x_j > \frac{1}{c_j}$ are strictly dominated for country j, so $s_1(\mu_1(z'), z') + s_2(\mu_1(z'')) \leq \frac{1}{c_1} + \frac{1}{c_2}$. Moreover, $F_y(\cdot \mid z)$ is strictly increasing on $[0, \frac{1}{c_1} + \frac{1}{c_2}]$ by construction. Therefore, country 1 can profit by sending the message $\mu(z'')$ when the true signal is z':

$$
\begin{aligned}
&F_y\left(s_1(z', \mu_1(z')) + s_2(\mu_1(z')) \mid z'\right) - c_1 s_1(z', \mu_1(z')) \\
&\qquad\qquad\qquad < F_y\left(s_1(z', \mu_1(z')) + s_2(\mu_1(z'')) \mid z'\right) - c_1 s_1(z', \mu_1(z')).
\end{aligned}
$$

This contradicts the incentive compatibility condition (6.1). $\square$

Lemma 6.3. *In the contribution stage of the two-method game, suppose* β_1 *is common knowledge. The strategy profile* $\{(x_1^A, x_1^B), (x_2^A, x_2^B)\} = \{(1, 0), (0, 1)\}$ *is a Nash equilibrium if and only if the following conditions are met:*

$$
p(1,1) - p(0,1) \geq \alpha_1, \tag{6.3}
$$
$$
p(1,1) - p(1,0) \geq \beta_2. \tag{6.4}
$$

The strategy profile $\{(x_1^A, x_1^B), (x_2^A, x_2^B)\} = \{(0, 1), (1, 0)\}$ *is a Nash equilibrium if and only if:*

$$
p(1,1) - p(0,1) \geq \alpha_2, \tag{6.5}
$$
$$
p(1,1) - p(1,0) \geq \beta_1. \tag{6.6}
$$

Proof. I will prove the first statement; the proof of the second is analogous. Under the given strategy profile, since $x_2^B = 1$, it cannot be profitable for country 1 to deviate to any strategy with $x_1^B = 1$. Therefore, the only deviation we must consider for country 1 is $(x_1^A, x_1^B) = (0, 0)$. This deviation is unprofitable if and only if the condition (6.3) holds. Similarly, because $x_1^A = 1$ under the given strategy profile, the only deviation we must consider for country 2 is $(x_2^A, x_2^B) = (0, 0)$. This is unprofitable if and only if the condition (6.4) holds. $\square$

Proposition 6.4. *In the two-method game, suppose the following conditions are satisfied:*

$$
p(1,1) - p(0,1) \geq \max\left\{\alpha_1, \alpha_2, \beta_1^L\right\}, \tag{6.7}
$$
$$
p(1,1) - p(1,0) \geq \max\left\{\alpha_1, \beta_1^L, \beta_2\right\}. \tag{6.8}
$$

There exists a division of labor equilibrium in which

$$\mu_1(\beta_1) = \beta_1,$$
$$s_1(\beta_1, \beta_1) = \begin{cases} (0,1) & \beta_1 = \beta_1^L, \\ (1,0) & \beta_1 = \beta_1^H, \end{cases}$$
$$s_2(m_1) = \begin{cases} (1,0) & m_1 = \beta_1^L, \\ (0,1) & m_1 = \beta_1^H, \end{cases}$$
$$\lambda_2(m_1) = \mathbf{1}\{m_1 = \beta_1^L\}.$$

Proof. Let the assessment $(\mu_1, s_1, s_2, \lambda_2)$ be defined as in the proposition. I begin by completing the definition of country 1's contribution strategy, namely for subgames that are off the path of play. For the cases in which $m_1 \neq \beta_1$, let $s_1(\beta_1, m_1)$ be any best response for country 1 to $s_2(m_1)$; a best response is guaranteed to exist, as the game is finite. The goal of the remainder of the proof is to show that this assessment is an equilibrium.

I proceed by showing that the proposed contribution strategies are sequentially rational. The conditions (6.7) and (6.8) imply that equations (6.3)– (6.6) are satisfied. Therefore, by Lemma 6.3, country 2's proposed actions are best responses given its beliefs, as are country 1's proposed actions in the subgames on the equilibrium path. In the subgames off the equilibrium path, country 1's actions are best responses by construction.

Next, I show that country 1's messaging strategy is incentive compatible: neither type of country 1 can strictly improve its payoff by deviating from its messaging strategy. Consider the maximal payoff to the B-advantaged type after falsely reporting β_1^H. Since country 2 contributes $x_2^B = 1$ after receiving the A-advantaged message, we only need to consider actions with $x_1^B = 0$. The condition for the deviation to be unprofitable is thus

$$p(1,1) - \beta_1^L \geq \max\left\{p(0,1), p(1,1) - \alpha_1\right\},$$

which follows from equation (6.7) and $\beta_1^L < \alpha_1$. Similarly, the condition for it to be unprofitable for the A-advantaged type to deviate in the messaging stage is

$$p(1,1) - \alpha_1 \geq \max\left\{p(1,0), p(1,1) - \beta_1^H\right\},$$

which follows from equation (6.8) and $\beta_1^H > \alpha_1$.

The final step is to confirm that country 2's updated beliefs are consistent with Bayes' rule wherever possible, which is immediate from the definition of λ_2. □

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