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The Strategic Manipulation of Asymmetric Climate Conflicts

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Abstract

The decision-makers choose progressive or conservative actions towards climate change. A decision-maker from a country with greater damage from climate change is more likely to be progressive than a country with lesser damage. Climate scientists can manipulate this decision-making by sending publicly observed cheap-talk messages. The likelihood of both players choosing progressive action on climate change decreases if both players are "coordination" types and the scientist is conservative. The conservative scientist can cause this by sending skeptical messages that trigger a spiral of climate change skepticism. This reduces the welfare of both decision-makers. If both players are opportunistic types, a progressive scientist can send alarming messages that cause the decision-maker from the country with greater damage from climate change to be more progressive. This reduces his welfare but benefits the other decision-maker. I show that there does not exist any communication equilibrium for either kind of scientist, for any other combination of player types.

JEL Classification: D74, D82, D83, Q54, Q58

Keywords: Climate Change; Climate Politics.

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1 Introduction

Climate scientists express a strong consensus that climate change over the past century is very likely anthropogenic, or due to human activity. Ninety-seven percent or more of climate scientists support the significance of anthropogenic climate change (see the NASA Global Climate Change website for further details). Although the consensus about climate change is strong within the worldwide scientific community, it seems that how this alarming message about climate change influences the political arena differs significantly by region. For instance, in the United States, it appears that skeptical messages about climate change are sometimes more powerful than alarming messages about climate change. Less than three percent of scientists create the skeptical messages about climate change, but in the political arena, these skeptical messages are powerful enough to compete with alarming message issued by the remaining 97%. In fact, there has been a group of scientists (contrarian scientists) who generate skepticism and denial concerning climate change by attacking climate science and scientists.[1] The international cooperation to mitigate climate change has been substantially undermined by climate change skepticism inflamed from the US (Dunlap and McCright, 2011; Dunlap 2013). The 2009 United Nations Climate Change Conference (commonly known as the Copenhagen Summit) has failed to reach an agreement from the US and China, which are the two largest emitters of greenhouse gases.

In Europe, however, climate change has been seriously dealt with the political arena since the associated risks were uncovered by science, with the European Union taking more political actions against climate change than the US and China.[2] The fundamental reason for this difference may be different levels of damage from climate change and/or different benefits from actions against climate change. Unlike the US and China, the EU has numerous member countries especially vulnerable to climate change, such as Sweden, Denmark, Fin-

[1] The *New York Times*, November 20, 2009; Hacked E-Mail Is New Fodder for Climate Dispute

[2] "[O]nly the EU has accepted binding commitments under the Kyoto Protocol, which the U.S. signed, but refused to ratify." *Climate policies in the EU and USA: Different approaches, Convergent outcomes?,* European Parliamentary Research Service, Gregor Erbach

land, Greenland, and Iceland. They are mostly Northern European countries lying close to the Arctic, which makes them more sensitive to damage from climate change, such as melting glaciers and rising surface temperature.[3] The European scientific community has been actively conducting the study of anthropogenic climate change. For example, the Climate Research Unit at the University of East Anglia (in the United Kingdom) is one of the world's leading research institutions concerned with the study of anthropogenic climate change; and their scientists have featured in the international media highlighting the latest scientific developments in the field of climate change.[4] However, the alarming messages about climate change from the European scientific community have been provocative for politicians in the US, where climate change skepticism has been inflamed.[5] It has substantially undermined the international cooperation to mitigate climate change (Dunlap, 2013).

To study how the scientists (a third party) influence international climate politics between asymmetric countries, I extend the strategy of manipulating conflict developed by Baliga and Sjöström (2012) with asymmetric players, and apply it to climate-change politics between two asymmetric decision-makers under incomplete information. I consider two asymmetric countries, A and B. Climate change presents a greater risk of damage to country A than country B. In country $i \in \{A, B\}$, a decision-maker called player i chooses either a *progressive* (P) or a *conservative* (C) action. Player i can be interpreted as the median voter or some other pivotal decision-maker in country i. The progressive action may be developing renewable energy sources, increasing the use of them, or developing/adopting technology to mitigate greenhouse gases. The conservative action may be burning more fossil fuels rather than using renewable energy, passing legislation to protect the fossil fuel industry, pulling out of an international climate agreement. Player i's choice may also involve selecting an agent

[3]Rising one Celsius degree from 0 to 1 is more detrimental than rising from from 25 to 26. The Intergovernmental Panel on Climate Change (IPCC) summary for policymakers, released in 2014, states that "[C]limate change is causing permafrost warming and thawing in high latitude regions and in high-elevation regions (high confidence)."

[4]`http://www.cru.uea.ac.uk/media`

[5]See the prepared statement of Mr. Markey of the Hearing on the Administration's View on the State of Climate Science from the 111th Congress, which Mr. Markey complains of "systematic suppression of dissenting opinion," "intimidation," "manipulation of data and models, possible criminal activity," and more.

who will take either progressive or conservative action toward climate change. For example, the median voter in the US must decide whether to support Democrats (who traditionally enact more progressive climate change policies) or Republicans (who traditionally do not).

In my model, a third-party player, a scientist (player S), sends a publicly observed cheap-talk message[6] before players A and B make their decisions. An example of a cheap-talk message might be the exposure to the media of the risks of climate change. The scientist is from country A, and can hold a range of influential positions there. For instance, he could be the leader of the skepticism movement, or alternatively, an insider at the center of politics, such as the head of the White House of Science and Technology Policy. The true preference of the scientist is commonly known. I consider two cases: a conservative (contrarian) scientist who wants player A to choose C, and a progressive scientist who wants player A to choose P. Both kinds of scientists want player B to choose P.

For a scientist's cheap-talk to matter, it must convey information. In my model, the cheap-talk message conveys information about player A's type. For simplicity, I assume that the scientist knows player A's true type, because as a political insider in country A, he would typically know more about the preference of player A than player B.

My main interest is in *communication equilibria*, where the scientist's cheap-talk is effective in the sense of influencing the equilibrium decisions of players A and B. I show the existence of such equilibria. Under some assumptions, there is even a *unique* communication equilibrium. Importantly, I find that even if multiple communication equilibria exist, they always have the same structure and the same welfare implications.

If cheap-talk is effective, then some message m_0 will make player B more likely to choose C. A conservative scientist is willing to send message m_0 only if player A also becomes more likely to choose C. Such co-varying actions must be the property of strategic complements. On the other hand, a progressive scientist is willing to send m_0 only if player A becomes more likely to choose P. Such negative correlation occurs when actions have the property of

[6]Note that the messages from scientists are not verifiable by the decision-makers. Therefore, the messages themselves are talk-costless, nonbinding, and nonverifiable claims, which make the game a cheap-talk game.

strategic substitutes. This argument implies that if the underlying game has the property of strategic complements, then only a conservative scientist can communicate effectively. By sending message m_0, the conservative scientist triggers an unwanted (by players A and B) spiral of climate change skepticism, making both players A and B more likely to choose C. Conversely, if the underlying game has the property of strategic substitutes, then only a progressive scientist can communicate effectively. By sending message m_0, the progressive scientist makes player B more likely to choose C and causes player A to choose P.

With the property of strategic complements, message m_0 can be interpreted as a "skeptical" message on climate change from the conservative scientist. This occurs only when player A is a "left moderate" who would have chosen P in the communication-free equilibrium. The skeptical message causes him to choose C instead. In contrast, skeptical messages are counter-productive when player A is a dominant strategy conservative (who always chooses C anyway). Thus, the absence of a skeptical message is actually "bad news" about player A's type in the sense that the conditional probability that player A is a dominant strategy conservative increases. This "bad news" makes player B more likely to choose C than in the communication-free equilibrium.

These arguments imply that, with strategic complements, players A and B are more likely to choose C in the communication equilibrium (whether or not a skeptical message occurs) than in the communication-free equilibrium. Because each decision-maker always wants the other to choose P, the communication-free equilibrium interim Pareto dominates the communication equilibrium for players A and B. Eliminating the conservative scientist would make all types of players A and B strictly better off. This includes player A's most conservative types, whose preferences are aligned with the conservative scientist. When preferences are aligned in this way, the scientist will not behave conservatively, but this itself alarms player B. Without the conservative scientist, climate change skepticism would not be inflamed in this way.

With the property of strategic substitutes, message m_0 can be interpreted as an "alarming" message sent by the progressive scientist. This occurs only when player A is "right moderate" who would have chosen C in the communication-free equilibrium. In the communication equilibrium, following an alarming message from the scientist, player B becomes more conservative, and player A more progressive. In fact, whether or not an alarming message occurs, player B is more likely to choose C in the communication equilibrium than in the communication-free equilibrium, and this unambiguously makes player A worse off. Thus, player A would like to ban alarming messages if he could. On the other hand, because they induce player A to choose P, alarming messages make player B better off.

My theoretical model is directly related to the work of Baliga and Sjöström (2012). Those authors examined how an extremist can influence political decision-making by sending publicly observed messages. They showed that a publicly observed cheap-talk message sent by one country's extremist can influence another country's political decisions. Specifically, an extremist can increase the likelihood of conflict between two different countries. The main difference between my model and theirs is that the decision-makers in my model are asymmetric. I examine how the third party can influence the asymmetric decision-makers in different environments. The likelihood of both players choosing progressive action on climate change decreases if actions have the property of strategic complements and the scientist is conservative. If actions have the property of strategic substitutes, a progressive scientist can send alarming messages that cause the decision-maker with greater climate change damage to be more progressive. Furthermore, I show that there does not exist any communication equilibrium for either kind of scientist, for any other combination of player types.

The basic model is discussed in Section 2. I analyze communication equilibria in Section 3. I conclude in Section 4.

2 The Model

2.1 The Game without Cheap Talk

I consider two decision-makers of countries $i \in \{A, B\}$. Players A and B are the pivotal decision-makers of countries A and B, respectively. They simultaneously choose either a *progressive* (pro-environment, renewable-energy advocative) action P or a *conservative* (pro-growth, fossil-fuel advocative) action C. The payoff for player $i \in \{A, B\}$ is given by the following payoff matrix, where the row and the column represent the payoffs for players A and B, respectively.

	Progressive	*Conservative*
P	$\mu_A - c_A,\ \mu_B - c_B$	$\mu_A - d_A - c_A,\ \mu_B - d_B$
C	$\mu_A - d_A,\ \mu_B - d_B - c_B$	$-d_A,\ -d_B$

Note that d_i captures the damage to player i of one of the two players choosing a conservative course of action. I assume that the level of damage is asymmetric between the two players. A conservative action causes damage from climate change, such as an increase in the land surface temperature, melting glaciers in the Arctic, and rising sea levels. But the the level of damage may differ across countries. μ_i captures the benefit from being progressive, which arises from actions for preventing climate change, such as mitigation of greenhouse gases and developing renewable energy sources. I assume that μ_i is asymmetric between the two countries. Note that $\mu_i \in \{A, B\}$ and $d_i \in \{A, B\}$ are common knowledge.

Notice that c_i is the cost for player $i \in \{A, B\}$ to take the progressive action P, referred to as his type. Neither player knows the other player's type. The two types, c_A and c_B, are random variables independently drawn from the distributions $F_A(c)$ and $F_B(c)$, respectively. Let $F_i \in \{A, B\}$ denote the continuous cumulative distribution function, with support $[\underline{c}, \overline{c}]$, and where $F_i'(c) > 0$ for all $c \in (\underline{c}, \overline{c})$. When players choose an action, player A knows c_A but not c_B, while player B knows c_B but not c_A.

Player i is considered a *dominant strategy progressive* if P is a dominant strategy ($d_i \geq c_i$ and $\mu_i \geq c_i$ with at least one strict inequality). Player i is considered a *dominant strategy conservative* if C is a dominant strategy ($d_i \leq c_i$ and $\mu_i \leq c_i$ with at least one strict inequality). Player i is a *coordination type* if P is a best response to P and C is a best response to C ($\mu_i \leq c_i \leq d_i$). Player i is an *opportunistic type* if C is a best response to P and P is a best response to C ($d_i \leq c_i \leq \mu_i$). Note that when both players are coordination types, the actions P and C have the properties of strategic complements, and when both players are opportunistic, P and C have the properties of strategic substitutes. Assumption 1 states that the support of F_i is big enough to include dominant strategy types of both kinds.

Assumption 1. *$\underline{c} < \mu_i < \overline{c}$ and $\underline{c} < d_i < \overline{c}$ for all $i \in \{A, B\}$.*

Suppose that player i thinks player j will choose P with probability p_j. Player i's expected payoff from choosing P is $\mu_i - c_i - d_i(1 - p_j)$, while his expected payoff from C is $\mu_i p_j - d_i$. Thus, if he chooses P instead of C, his *net* gain is

$$\mu_i - c_i + (d_i - \mu_i)p_j. \tag{1}$$

A *strategy* for player i is a function $\sigma_i : [\underline{c}, \overline{c}] \to \{P, C\}$, which specifies an action $\sigma_i(c_i) \in \{P, C\}$ for each cost type $c_i \in [\underline{c}, \overline{c}]$. In a Bayesian Nash equilibrium (BNE), all types maximize their expected payoff. Therefore, $\sigma_i(c_i) = P$ if the expression in (1) is positive, and $\sigma_i(c_i) = C$ if it is negative. If the expression (1) is zero, then type c_i is indifferent. For convenience, I assume that the player chooses P in this case.

Player i uses a *cutoff strategy* if there is a *cutoff point* $x \in [\underline{c}, \overline{c}]$ such that $\sigma_i(c_i) = P$ if and only if $c_i \leq x$. Because the expression (1) is monotone in c_i, all BNE must be in cutoff strategies. Therefore, we can restrict our attention to cutoff strategies without loss of generality. Any such strategy can be identified by its cut-off point $x \in [\underline{c}, \overline{c}]$. As there are dominant strategy progressives and conservatives by Assumption 1, all BNE must be interior: each player chooses P with probability strictly between 0 and 1.

If player j uses cutoff point x_j, the probability that he plays P is $p_j = F_j(x_j)$. Therefore, using (1), player i's best response to player j's cutoff x_j is to choose the cutoff $x_i = \Gamma(x_j)$, where

$$\Gamma_i(x) = \mu_i + (d_i - \mu_i)F_j(x). \tag{2}$$

The function Γ_i is the best-response function for player i's cutoff strategy. The best-response functions generate a unique equilibrium which is ensured by Assumption 2.

Assumption 2. $F_i'(c) < |\frac{1}{d_i - \mu_i}|$ *for all* $c \in (\underline{c}, \overline{c})$.

If F_i happens to be uniform, then there is maximal uncertainty (for a given support) and Assumption 2 is redundant. More precisely, with a uniform distribution, $F_i'(c) = \frac{1}{\overline{c} - \underline{c}}$, so Assumption 1 implies $F_i'(c) < |\frac{1}{d_i - \mu_i}|$. Note that Assumption 2 is much weaker than uniformity.

Theorem 1. *The game without cheap-talk has a unique Bayesian Nash equilibrium.*

Proof. See Appendix. □

Theorem 1 shows that–as long as Assumptions 1 and 2 hold, and whether players are coordination types or opportunistic types–there exists a unique BNE, which I refer to as the *communication-free BNE.* In equilibrium, player A chooses P if $c_i < \overline{y}$, and player B chooses P if $c_i < \overline{x}$, where $(\overline{x}, \overline{y})$ is the unique equilibrium point of $\Gamma_A(x)$ and $\Gamma_B(y)$ in $[\underline{c}, \overline{c}]$. The asymmetry of the game implies that each player uses a different cutoff point. Since $\overline{x} < \overline{y}$, player A is more likely to be progressive than player B. Note that the player who uses the lower cutoff in the communication-free equilibrium will be the player with the lower value for d. The equilibrium can be reached via iterated deletion of dominated strategies, and captures the escalating spiral of fear discussed by Shelling (1960) and Jervis (1976).

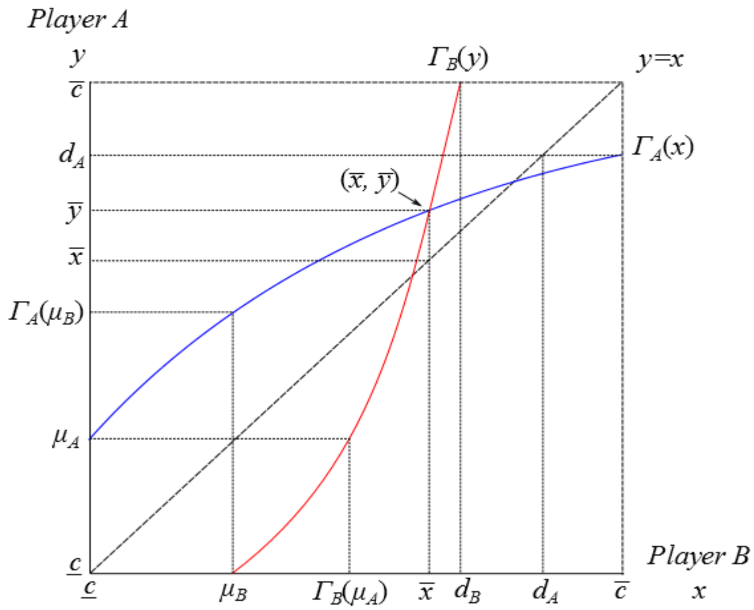

Figure 1: The Game with Coordination Types: Communication-Free Equilibrium

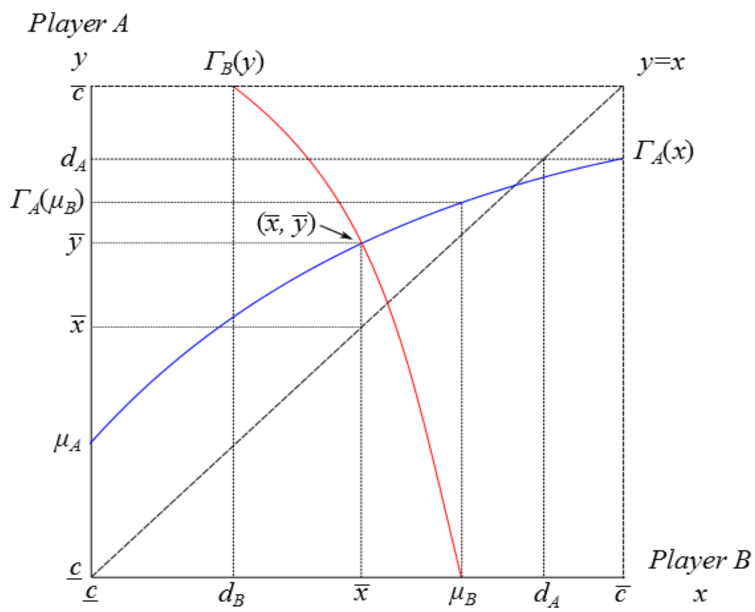

Figure 2: The Game with a Coordination type and an Opportunistic Type: Communication-Free Equilibrium

2.2 Cheap Talk

Now a third player, player S, is introduced. Player S is a scientist. His payoff function is identical to player A's, with one exception: player S's cost type c_S differs from player A's cost type c_A. Thus, player S's payoff is obtained by setting $c_i = c_S$ in the payoff matrix. There is no uncertainty about c_S. Formally, c_S is common knowledge among the three players.

Player S knows c_A, but not c_B. (More accurately, the scientist might receive some signal about player A's type; to avoid unnecessary complications, I assume that the signal is perfect, so that player S knows c_A.)

I consider two possibilities. First, if player S is a *progressive* (renewable-energy advocative) scientist, then $c_S < 0$. To put it differently, $(-c_S) > 0$ represents a *benefit* the progressive scientist enjoys if player A is progressive. When both players are opportunistic types, the progressive scientist is guaranteed a strictly positive payoff no matter what player A chooses; this payoff is however higher when player A chooses P. So the scientist always wants player A to choose P. On the other hand, when both players are coordination types, he gets a strictly positive payoff if player A chooses P, but a strictly negative payoff if player A chooses C; therefore the scientist always wants player A to choose P.

Second, if player S is a *conservative* scientist (fossil-fuel advocative), then $c_S > \mu_A + d_A$. The highest payoff the conservative scientist can obtain if player A chooses P is $\mu_A - c_S$, while the lowest payoff he can obtain when player A chooses C is $-d_A > \mu_A - c_S$. Therefore, he always wants player A to choose C. Notice that, holding player A's action fixed, the scientist (whether renewable-energy or fossil-fuel advocative) is better off if player B chooses P.

Before players A and B play the game, player S sends a publicly observed cheap-talk message, $m \in M$, where M is his message space. The time line is as follows.

1. The cost type c_i is determined for each player $i \in \{A, B\}$. Players A and S learn c_A. Player B learns c_B.

2. Player S sends a (publicly observed) cheap-talk message $m \in M$.

3. Players A and B simultaneously choose P or C.

Cheap-talk is *effective* if there is a positive measure of types that choose different actions at time 3 than they would have done in the unique communication-free equilibrium. A Perfect Bayesian Equilibrium (PBE) with effective cheap-talk is a *communication equilibrium*. Clearly, if player A and B maintain their prior beliefs at time 3, then they must act just as in the communication-free equilibrium. Therefore, for cheap-talk to be effective, player S's message must reveal some information about player A's type.

A strategy of player S is a function $m : [\underline{c}, \overline{c}] \to M$, where $m(c_A)$ is the message sent by player S when player A's type is c_A. Without loss of generality, I assume that each player $j \in \{A, B\}$ uses a conditional cut-off strategy: for any message $m \in M$, there is a cut-off $c_j(m)$ such that if player j hears message m, then he chooses P if and only if $c_j \leq c_j(m)$.

Lemma 1. *In the communication equilibrium, we can assume without loss of generality that M contains only two messages, $M = \{m_0, m_1\}$, where $c_B(m_1) > c_B(m_0)$.*

Proof. See Appendix. □

Notice that this lemma holds for any player type, and for any kind of scientist. It does not require Assumption 2.

3 Communication Equilibrium with Cheap-Talk

3.1 Conservative Cheap-Talk

I consider the case where both players are coordination types, $d_i > \mu_i$ for all $i \in \{A, B\}$. Suppose player S is a conservative scientist, $c_S > \mu_A + d_A$, and both players are coordination types. I will construct a communication equilibrium, where the conservative scientist S uses cheap-talk to decrease the likelihood of progressive cooperation on climate change below the level where it would be in the communication-free equilibrium. It is surprising that player S can do this, because c_S is commonly known. That is, it is commonly known that player S wants player B to choose P and player A to choose C. To understand the equilibrium intuitively, it helps to recall that $M = \{m_0, m_1\}$ by Lemma 1, where $c_B(m_1) > c_B(m_0)$, and to interpret message m_0 as a "skeptical attitude" towards climate change and message m_1 as a "no skeptical attitude" towards climate change.

Say that player A is a *susceptible type* if he chooses C following the message m_0, but P following m_1. The set of susceptible types is

$$S \equiv (c_A(m_0), c_A(m_1)].$$

The proof of Lemma 1 showed that if $m(c_A) = m_0$, then type c_A must be susceptible. Since the skeptical attitude makes player B more likely to choose C, player S will only send m_0 if it causes player A to change his action from P to C. On the other hand, player S wants player A to choose C and therefore strictly prefers to send m_0 whenever player A is susceptible. That is, it is optimal for player S to set $m(c_A) = m_0$ if and only if $c_A \in S$. Accordingly, message m_0 signals that player A will choose C. As argued in the proof of Lemma 1, this implies that $c_B(m_0) = \mu_B$. Therefore, if m_0 is sent then player B will choose P with probability $F_B(\mu_B)$, so player A prefers P if and only if

$$-c_A + (1 - F_B(\mu_B))\mu_A \geq F_B(\mu_B)(-d_A),$$

which is equivalent to $c_A \leq \Gamma_A(\mu_B)$. Thus, player A uses cut-off point $c_A(m_0) = \Gamma_A(\mu_B)$, where Γ_A is defined by (2).

It remains only to consider how players A and B behave when player S shows a non-skeptical attitude (message m_1). Let $y^* = c_A(m_1)$ and $x^* = c_B(m_1)$ denote the cutoff points in this case. Therefore, if m_1 is sent then player B will choose P with probability $F_B(x^*)$, so player A prefers P if and only if

$$-c_A + (1 - F_B(x^*))\mu_A \geq F_B(x^*)(-d_A),$$

which is equivalent to $c_A \leq \Gamma_A(x^*)$. Thus, $y^* = \Gamma_A(x^*)$. When player B hears message m_1, he knows that player A is not the susceptible type. That is, c_A is either below $\Gamma_A(\mu_B)$ or above y^*, and player A chooses P in the former case and C in the latter case. Therefore, player B prefers P if and only if

$$-c_B + \frac{1 - F_A(y^*)}{1 - F_A(y^*) + F_A(\Gamma_A(\mu_B))}\mu_B \geq \frac{1 - F_A(\Gamma_A(\mu_B))}{1 - F_A(y^*) + F_A(\Gamma_A(\mu_B))}(-d_B). \tag{3}$$

Inequality (4) is equivalent to $c_B \leq \Omega_B(y^*)$, where

$$\Omega_B(y) \equiv \frac{[1 - F_A(y)]\mu_B + F_A(\Gamma_A(\mu_B))d_B}{[1 - F_A(y)] + F_A(\Gamma_A(\mu_B))}.$$

Thus, $x^* = \Omega_B(y^*)$.

To summarize, any communication equilibrium must have the following form. Player S sets $m(c_A) = m_0$ if and only if $c_A \in S = (\Gamma_A(\mu_B), y^*]$. Player A's cutoff points are $c_A(m_0) = \Gamma_A(\mu_B)$ and $c_A(m_1) = y^*$. Player B's cutoff points are $c_B(m_0) = \mu_B$ and $c_B(m_1) = x^*$. Moreover, x^* and y^* must satisfy $y^* = \Gamma_A(x^*)$ and $x^* = \Omega_B(y^*)$. Conversely, if such x^* and y^* exist, then they define a communication equilibrium. Figure 3 shows a graphical illustration of a communication equilibrium.

By Assumption 2, Γ_i is increasing with a slope less than one. Since $F_i(\underline{c}) = 0$ and $F_i(\bar{c}) = 1$, $\Gamma_i(\underline{c}) = \mu_i > \underline{c}$ and $\Gamma_i(\bar{c}) = d_i < \bar{c}$. Furthermore,

$$\Gamma_i(d_i) - \mu_i = F_j(d_i)(d_i - \mu_i) < d_i - \mu_i.$$

Therefore,

$$\Gamma_i(d_i) < d_i. \tag{4}$$

Also,

$$\Gamma_i(\mu_j) = \mu_i(1 - F_j(\mu_j)) + d_i F_j(\mu_j) > \mu_i, \tag{5}$$

as $d_i > \mu_i$. Let $(\overline{x}, \overline{y})$ be the unique communication-free equilibrium point in $[\underline{c}, \bar{c}]$. Clearly, $\mu_B < \Gamma_B(\mu_A) < \overline{x}$ and $\mu_A < \Gamma_A(\mu_B) < \overline{y}$ (see Figure 3).

Notice that

$$\Omega_B'(y) = \frac{F_A'(y)(d_B - \mu_B)F_A(\Gamma_A(\mu_B))}{\{[1 - F_A(y)] + F_A(\Gamma_A(\mu_B))\}^2},$$

so Ω_B is increasing. It is easy to check that $\Gamma_B(y) > \Omega_B(y)$ whenever $y \in (\Gamma_A(\mu_B), \bar{c})$.

Moreover,

$$\Omega_B(\bar{c}) = \Gamma_B(\bar{c}) = d_B$$

and

$$\Omega_B(\Gamma_A(\mu_B)) = \Gamma_B(\Gamma_A(\mu_B)) > \Gamma_A(\mu_B),$$

where the inequality follows from (6) and the fact that Γ_B is increasing. These properties are drawn in Figure 3. Notice that the curve $x = \Omega_B(y)$ lies to the left of the curve $x = \Gamma_B(y)$ for all $y \in (\Gamma_A(\mu_B), \bar{c})$, but that the two curves intersect when $y = \Gamma_A(\mu_B)$ and $y = \bar{c}$.

As shown in Figure 3, the two curves $x = \Omega_B(y)$ and $y = \Gamma_A(x)$ must intersect at some (x^*, y^*), and it must be true that

$$\mu_A < \Gamma_A(\mu_B) < x^* < \overline{x} < y^* < \overline{y}. \tag{6}$$

By construction, $y^* = \Gamma_A(x^*)$ and $x^* = \Omega_B(y^*)$. Thus, a communication equilibrium exists. Both players A and B are strictly more likely to choose C in a communication equilibrium than in the communication-free equilibrium. To see this illustrated, notice that in the communication-free equilibrium, player A's cutoff is $\overline{y}$ and player B's cutoff is $\overline{x}$. By

(7), the cut-off points are strictly lower in the communication equilibrium; namely, $x^* < \overline{x}$ and $y^* < \overline{y}$. Thus, whenever a player would have chosen C in the communication-free equilibrium, he necessarily chooses C in the communication equilibrium. Moreover, after any message, there are types (of each player) who choose C, but who would have chosen P in the communication-free equilibrium. It follows that all types of player A and B are made worse off by communication, because each wants the other player to choose P.

For player S, the welfare comparison across equilibria is ambiguous, because cheap-talk makes both players A and B more likely to choose C. There are three specific cases. First, if either $c_A \leq \Gamma_A(\mu_B)$ or $c_A > \overline{y}$, then player A's action is the same in the communication equilibrium and in the communication-free equilibrium, but player B is more likely to choose C in the former, making player S worse off. Second, if $y^* < c_A < \overline{y}$, then player A would have chosen P in the communication-free equilibrium. In the communication equilibrium, there is the skeptical message when $y^* < c_A < \overline{y}$, but player A plays C rather than P, because player B is more likely to choose C. Third, if $\Gamma_A(\mu_B) < c_A \leq y^*$, then the skeptical message causes player A to play C, rather than P in the communication-free equilibrium. Player S gets a strictly higher payoff when player A chooses C no matter what player B chooses. Thus, player S is better off if player A switches to C.

The communication equilibrium is *unique* if the two curves $x = \Omega_B(y)$ and $y = \Gamma_A(x)$ have a unique intersection. This would be true, for example, if F were concave, because in this case both Ω_B and Γ_A would be concave. However, uniqueness also obtains without concavity, if a "conditional" version of Assumption 2 holds. Intuitively, after m_1 is sent player B knows that player A's type is either below $\Gamma_A(\mu_B)$ or above y^*. Thus, the continuation equilibrium must be the equilibrium of a "conditional" game (without communication) where it is commonly known that player A's type distribution has support $[\underline{c}, \Gamma_A(\mu_B)] \cup (y^*, \overline{c}]$ and density

$$g(c) \equiv \frac{F_A'(c)}{1 - F_A(y^*) + F_A(\Gamma_A(\mu_B))}$$

on this support. Furthermore, following m_1, player A's type y^* must be indifferent between choosing P and C. That is, in the "conditional" game, the cut-off type is y^*. Recall that Assumption 2 guarantees uniqueness in the "unconditional" communication-free game. The analogous condition which guarantees uniqueness in the "conditional" game is $g(y^*) < 1/(d_i - y)$. Thus, the "conditional" game has a unique equilibrium if the following "conditional" version of Assumption 2 holds:

$$\frac{F'_A(y)}{1 - F_A(y) + F_A(\Gamma_A(\mu_B))} < \frac{1}{d_i - \mu_i} \tag{7}$$

for all $y \in (\underline{c}, \bar{c})$. This implies, since $0 < \Gamma'_A(x) < 1$, that the two curves intersect only once, as indicated in Figure 2. Thus, as before, the requirement for uniqueness is that the distribution is sufficiently diffuse. In summary:

Theorem 2. *Suppose that player S is a conservative scientist and both players A and B are coordination types. A communication equilibrium exists. All types of players A and B prefer the communication-free equilibrium to any communication equilibrium. Player S is better off in the communication equilibrium if and only if $\Gamma_A(\mu_B) < c_A < \overline{y}$. If (8) holds for all $y \in (\underline{c}, \bar{c})$, then there is a unique communication equilibrium.*

In the communication-free equilibrium, the probability of progressive cooperation on climate change, in the sense that the outcome is PP, is $F_B(\overline{x})F_A(\overline{y})$. In the communication equilibrium, PP happens with probability $\Gamma_A(\mu_B)F_B(x^*) < F_B(\overline{x})F_A(\overline{y})$. Thus, progressive cooperation on climate change is less likely in the communication equilibrium than in the communication-free equilibrium.

To understand how the cut-off points can be uniformly higher with cheap-talk, we again interpret message m_1 as being a non-skeptical attitude towards climate change and message m_0 as being a skeptical attitude towards climate change. A spiral of skepticism occurs when player A is a coordination type, $c_A \in (\Gamma_A(\mu_B), y^*]$, who would have played P in the communication-free equilibrium. Now he plays C instead, and so does player B (except if he is a dominant strategy progressive). The players choose conservative actions following a

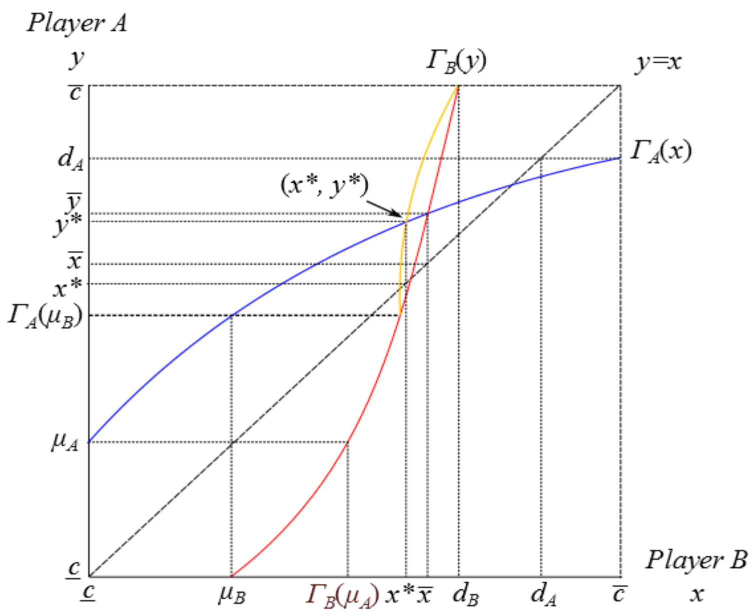

Figure 3: The Game with Coordination Types: Communication Equilibrium

skeptical attitude (m_0) because they think the other will choose a conservative action. The fact that a skeptical attitude does not show also deters cooperation, but for a different reason. In the "curious incident of the dog in the night-time" from Sir Arthur Conan Doyle's short story "Silver Blaze," , the dog did not bark at an intruder because the dog knew him well. Similarly, when player A's preferences are aligned with the conservative scientist, there is no skeptical attitude. Hence, a scientist who does not "bark" signals the possibility that player A is a dominant strategy conservative. This information makes player B want to choose C. Accordingly, the communication equilibrium has less cooperation on climate change than the communication-free equilibrium, no matter what message is sent.

3.2 Progressive Cheap-Talk

In this section, I consider the case of strategic substitutes, i.e., $d_i < \mu_i$ for all $i \in \{A, B\}$. Suppose player S is a progressive scientist and both players A and B are opportunistic types. I will construct a communication equilibrium where the progressive scientist S sends informative messages. Again, it is surprising that this can be done because c_S is commonly known. To understand the communication equilibrium intuitively, it helps to again recall Lemma 1, but now interpret message m_0 as "alarming" about climate change and message m_1 as "not alarming". Intuitively, the alarming message will make player B more conservative, and player A alert and chooses P.

Again, say that player A is a susceptible type if his action depends on which message is sent. But now, susceptible types switch from C to P when they hear message m_0. That is, the set of susceptible types is

$$S \equiv (c_A(m_1), c_A(m_0)].$$

The proof of Lemma 1 showed that if $m(c_A) = m_0$ then type c_A must be susceptible. Intuitively, since the alarming message makes player B more likely to choose C, player S would not engage in an alarming message unless player A is a susceptible type. Conversely, whenever player A is a susceptible type, the progressive scientist will engage in the alarming message, since he wants player A to choose P. Therefore, $m(c_A) = m_0$ if and only if $c_A \in S$. Accordingly, message m_0 signals that player A will choose P. As argued in the proof of Lemma 1, this implies that $c_B(m_0) = d_B$, and player A's best response to this cut-off point is $c_A(m_0) = \Gamma_A(d_B)$.

It remains only to consider how players A and B behave when the message is not alarming (m_1). Let $y^* = c_A(m_1)$ and $x^* = c_B(m_1)$ denote the cutoff points used in this case. Arguing as for the case of strategic complements, the cut-off points must satisfy $y^* = \Gamma_A(x^*)$ and $x^* = \tilde{\Omega}_B(y^*)$, where

$$\tilde{\Omega}_B(y) = \frac{[1 - F_A(\Gamma_A(d_B)]\mu_B + F_A(y)d_B}{[1 - F_A(\Gamma_A(d_B)] + F_A(y)}.$$

As shown in Figure 4, (x^*, y^*) is an intersection of the two curves $x = \tilde{\Omega}_B(y)$ and $y = \Gamma_A(x)$. With strategic substitutes, Assumption 2 implies

$$-1 < \Gamma'_A(x) < 0.$$

Furthermore, $\Gamma_A(\underline{c}) = \mu_A < \bar{c}$ and $\Gamma_A(\bar{c}) = d_A > \underline{c}$, and

$$\Gamma_A(d_B) - d_A = (1 - F_B(d_B))(\mu_A - d_A)$$

where

$$0 < (1 - F_B(d_B))(\mu_A - d_A) < \mu_A - d_A.$$

Therefore,

$$d_A < \Gamma_A(d_B) < \mu_A. \tag{8}$$

Let $(\overline{x}, \overline{y})$ be the unique communication-free equilibrium in $[\underline{c}, \bar{c}]$. Clearly, $d_A < \overline{x} < \overline{y} < \mu_A$ (see Figure 4).

Figure 4 shows three curves: $x = \tilde{\Omega}_B(y)$, $y = \Gamma_A(x)$, and $x = \Gamma_B(y)$. The curves $y = \Gamma_A(x)$ and $x = \Gamma_B(y)$ intersect at the unique communication-free equilibrium, $(\overline{x}, \overline{y})$. It is easy to check that $\Gamma_B(y) > \tilde{\Omega}_B(y)$ whenever $y \in (\underline{c}, \Gamma_A(d_B))$. Moreover,

$$\tilde{\Omega}_B(\underline{c}) = \Gamma_B(\underline{c}) = \mu_B$$

and

$$\tilde{\Omega}_B(\Gamma_A(d_B)) = \Gamma_B(\Gamma_A(d_B)) < \Gamma_A(d_B),$$

where the inequality follows from the fact that Γ_B is decreasing. Consider now (x^*, y^*) such that $y^* = \Gamma_A(x^*)$ and $x^* = \tilde{\Omega}_B(y^*)$, i.e., the intersection of the two curves $y = \Gamma_A(x)$ and $x = \tilde{\Omega}_B(y)$. Figure 4 reveals that there exists $(x^*, y^*) \in [\underline{c}, \bar{c}]^2$ such that $y^* = \Gamma_A(x^*)$ and $x^* = \tilde{\Omega}_B(y^*)$, and

$$d_B < d_A < x^* < \overline{x} < \overline{y} < y^* < \Gamma_A(d_B) < \mu_A. \tag{9}$$

Thus, a communication equilibrium exists. What impact does an alarming messages have on the probability of progressive cooperation on climate change? In the communication-free equilibrium, $\overline{x}$ and $\overline{y}$ are the cutoffs of players B and A, respectively. Now, (9) reveals that

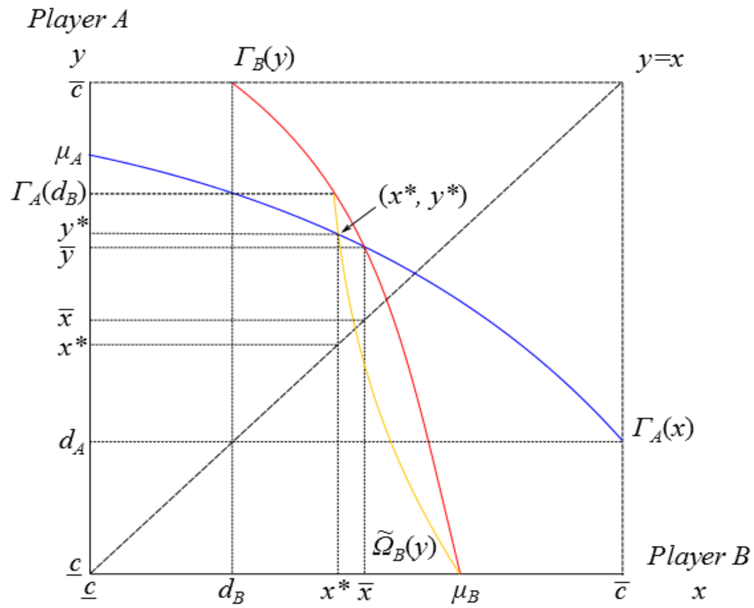

Figure 4: The Game with Opportunistic Types: Communication Equilibrium

with alarming communication, player B's cutoff points x^* and d_B are strictly lower than $\overline{x}$. Thus, any communication makes player B more conservative, no matter what message is actually sent. On the other hand, player A's cutoff points y^* and $\Gamma_A(d_B)$ are strictly higher than $\overline{y}$. Thus, communication makes player A more progressive, no matter what message is actually sent. Since one player becomes more progressive and the other less, it is not possible to unambiguously say if communication is good or bad for progressive cooperation on climate change.

The welfare effects, however, are unambiguous. As player A is more likely to play P in the communication equilibrium, player B is made better off. Conversely, as player B is more likely to play C, player A is made worse off. The progressive scientist is made better off by the alarms, because they prevent player A from choosing C. On the other hand, the "dog that did not bark" effect makes player B more likely to choose C when there are alarms, and this makes player S worse off.

Finally, consider whether the communication equilibrium is unique. Using the same argument as before, we must impose a "conditional" version of Assumption 2. Specifically,

$$\frac{F_A'(c)}{1 - F_A(\Gamma_A(d_B)) + F_A(y)} < \frac{1}{\mu_i - d_i} \tag{10}$$

for all $y \in (\underline{c}, \bar{c})$. It can be checked that (11) implies $-1 < \tilde{\Omega}_B'(y) < 0$. In this case, since $-1 < \Gamma_A'(x) < 0$, the two curves intersect only once, as indicated in Figure 4. In summary:

Theorem 3. *Suppose that player S is a progressive scientist and both players are opportunistic types. A communication equilibrium exists. All of player A's types prefer the communication-free equilibrium to the communication equilibrium. All of player B's types have the opposite preference. Player S is better off in the communication equilibrium if and only if $\overline{y} < c_A < \Gamma_A(d_B)$. If (11) holds for all $y \in (\underline{c}, \bar{c})$ then there is a unique communication equilibrium.*

3.3 Ineffective Cheap-Talk

Theorem 4. *There does not exist any communication equilibrium for either kind of scientist, for any other combination of player types.*

Proof. See Appendix. □

In a communication equilibrium, let m_1 be the message that induces player B to play P for a larger set of realizations of c_B, and m_0 to be the message that induces player B to play P for a smaller set of realizations of c_B.

Given C_S, let a_A^S be the generic action that a scientist always prefers A to choose (only the cases in which this preference is constant across a_B^S are considered). Let a_A^{-S} be player A's other action.

Since the scientist always prefers that player B plays P, a necessary condition for equilibrium is that for all types c_A such that a scientist sends m_0, it must be the case that all such types play a_A^S when m_0 is sent, but would play a_A^{-S} if m_1 were sent.

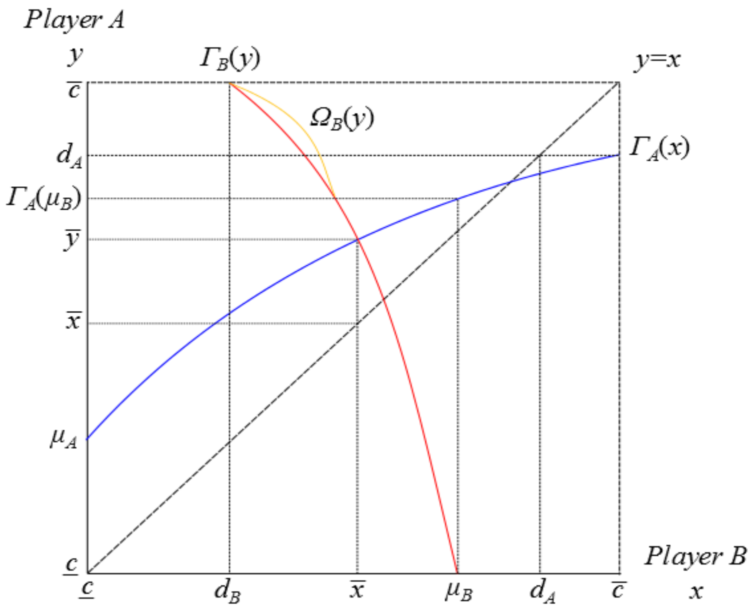

Figure 5: The Game with a Coordination Type and an Opportunistic Type: No Communication Equilibrium

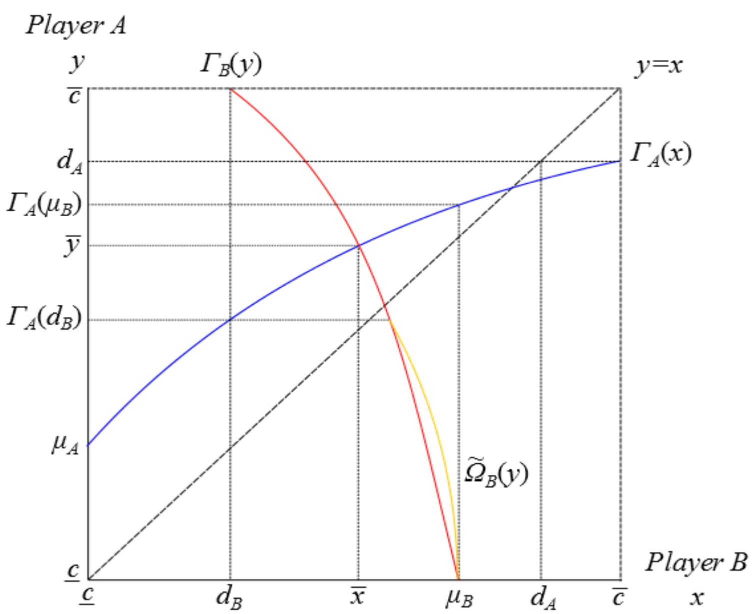

Figure 6: The Game with a Coordination Type and an Opportunistic Type: No Communication Equilibrium

However, since message m_0 being sent guarantees that player A will play a_A^S in equilibrium, this is only consistent with m_0 resulting in player B choosing C more often if C is player B's best response to a_A^S. In particular, after m_0, player B chooses C for all realizations of c_B except for those such that P is dominant for player B.

Given player B choosing C, player A having a type such that playing a_A^S is optimal after m_0, but a_A^{-S} is optimal after m_1, is possible only if a_A^S is player A's best response when player B plays C, but a_A^{-S} is player A's best response when player B plays P.

To summarize, we need: for a_A^S to be a scientist's preferred action for player A; when player A does not have a dominant action, a_A^S is player A's best response when player B chooses C; and when player A chooses a_A^S, player B's best response is C, except when P is dominant for player B.

Thus, since $a_A^S \in \{P, C\}$, there are only two possibilities for a communication equilibrium: First, the scientist prefers that player A chooses P (progressive scientist); P is player A's best response when player B chooses C; C is player B's best response when player A chooses P; or a scientist prefers that player A chooses C (conservative scientist); C is player A's best response when player B chooses C; C is player B's best response when player A chooses C.

4 Conclusion

I extend the strategy of manipulating conflict developed by Baliga and Sjöström (2012) and apply it to climate-change politics between two asymmetric decision-makers under incomplete information. The decision-makers choose progressive or conservative actions towards climate change. A decision-maker from a country with greater damage from climate change is more likely to be progressive than a country with lesser damage. Climate scientists can manipulate this decision-making by sending publicly observed cheap-talk messages. The likelihood of both players choosing progressive action on climate change decreases if both players are “coordination” types and the scientist is conservative. The conservative scientist can cause this by sending skeptical messages that trigger a spiral of climate change skepticism. This reduces the welfare of both decision-makers. If both players are opportunistic types, a progressive scientist can send alarming messages that cause the decision-maker from the country with greater damage from climate change to be more progressive. This reduces his welfare but benefits the other decision-maker. I show that there does not exist any communication equilibrium for either kind of scientist, for any other combination of player types.

For future research, one may extend the game by allowing incomplete information in other parameters, such as benefits from actions against climate change or damage from climate change.

Appendix

Proof of Theorem 1. Equilibria must be in cutoff strategies, and must be interior by Assumption 1. The best-response function Γ_i, defined by (2), is continuous, with $\Gamma_i(\underline{c}) = \mu > \underline{c}$ and $\Gamma_i(\overline{c}) = d_i < \overline{c}$; therefore it has an equilibrium point $(\overline{x}, \overline{y})$ where $\overline{x} \in [\underline{c}, \overline{c}]$ and $\overline{y} \in [\underline{c}, \overline{c}]$ are the cutoff point of player B and player A, respectively. Note that $\overline{x} < \overline{y}$ since $d_A > d_B$. If players A and B use cut-offs $\overline{y}$ and $\overline{x}$, respectively, the strategies form a BNE. It remains to show this BNE is unique. Notice that $\Gamma_i'(x) = (d_i - \mu_i)F'(x)$, so the best-response function is upward (downward) sloping if actions are strategic complements (substitutes). In either case, a well-known sufficient condition for uniqueness is that best-response functions have slope strictly less than one in absolute value. Assumption 2 implies that $0 < \Gamma_i'(x) < 1$ if $d_i > \mu_i$, and $-1 < \Gamma_i < 0$ if $d_i < \mu_i$. Hence, the best-response functions cross at most once and there is a unique equilibrium. The sufficient condition for uniqueness of the equilibrium also holds even if the players are of different types. Namely, if player A is a coordination type ($\mu_A < d_A$) and player B is an opportunistic type ($d_B < \mu_B$), the best-response functions have slope strictly less than one in absolute value as long as Assumption 2 holds. ■

Proof of Lemma 1. Suppose strategy μ_B is a part of a BNE. Because unused messages can simply be dropped, I may assume that for any $m \in M$, there is c_A such that $m(c_A) = m$. Now consider any two messages m and m'. If $c_B(m) = c_B(m')$, then the probability player B plays P is the same after m and m', and this means that each type of player A also behaves the same after m as after m'. Clearly, if all players behave the same after m and m', having two separate messages m and m' is redundant. Hence, without loss of generality, we can assume $c_B(m) \neq c_B(m')$ whenever $m \neq m'$.

Whenever player A is a dominant strategy type, player S will send whatever message maximizes the probability that player B plays P. Call this message m_1. Thus,

$$m_1 = \arg\max_{m \in M} c_B(m). \tag{11}$$

Message m_1 is the *unique* maximizer of $c_B(m)$, since $c_B(m) \neq c_B(m')$ whenever $m \neq m'$.

Player S cannot always send m_1, because then messages would not be informative and cheap-talk would be ineffective (contradicting the definition of a communication equilibrium). However, since message m_1 uniquely maximizes the probability that player B chooses P, player S must have some other reason for choosing $m(c_A) \neq m_1$. Specifically, if player S is a progressive scientist (who wants player A to choose P), then it must be that type c_A would choose C following m_1 but P following $m(c_A)$; conversely if player S is a conservative scientist (who wants player A to choose C), then it must be that type c_A would choose P following m_1 but C following $m(c_A)$. This is the only way that player S can justify sending any other message than m_1.

Thus, if player S is a progressive scientist, then whenever he sends a message $m_0 \neq m_1$, player A will play P. Player B therefore responds with P whenever $c_B < d_B$. That is, $c_B(m_0) = d_B$. However, $c_B(m) \neq c_B(m')$ whenever $m \neq m'$, so m_1 is unique. Thus, $M = \{m_0, m_1\}$.

Similarly, if player S is a conservative scientist, then whenever he sends a message $m_0 \neq m_1$, player A will play C. Player B's cutoff point must therefore be $c_B(m_0) = \mu_B$. Again, this means $M = \{m_0, m_1\}$. ■

Proof of Theorem 4. I first show that if player S is a progressive scientist, $c_S < 0$, then he cannot communicate effectively when actions are strategic complements. From Lemma 1, $M = \{m_0, m_1\}$ with $c_B(m_1) > c_B(m_0)$. Thus, player B is more likely to choose P after m_1 than after m_0. The progressive scientist wants both players A and B to play P, so he would only choose m_0 if such a message causes player A to play P. Formally, if $m(c_A) = m_0$, then we must have $c_A < c_A(m_0)$, so that type c_A chooses P when he hears message m_0. But if $c_A < c_A(m_0)$ for all c_A such that $m(c_A) = m_0$, then player B expects player A to play P for sure when player B hears m_0, so player B's cut-off point must be $c_B(m_0) = d_B$. However, with $d_B > \mu_B$, types above d_B are dominant strategy types who always play C, so it is a contradiction for $c_B(m_1) > d_B$. Thus, if player S is a progressive scientist and the game has strategic complements ($d_i > \mu_i$), then cheap-talk cannot be effective. ■

A communication equilibrium does not exist if player S is a conservative scientist, player A has strategic complements ($\mu_A < d_A$), and player B has strategic substitutes ($d_B < \mu_B$). Any communication equilibrium must have the following form. Player S sets $m(c_A) = m_0$ if and only if $c_A \in S = (\Gamma_A(\mu_B), y^*]$. Player A's cutoff points are $c_A(m_0) = \Gamma_A(\mu_B)$ and $c_A(m_1) = y^*$. Player B's cutoff points are $c_B(m_0) = \mu_B$ and $c_B(m_1) = x^*$. Moreover, x^* and y^* must satisfy $y^* = \Gamma_A(x^*)$ and $x^* = \Omega_B(y^*)$. I show that such x^* and y^* do not exist.

By Assumption 2, Γ_A is increasing and Γ_B is decreasing with a slope less than one. Since $F(\underline{c}) = 0$ and $F(\bar{c}) = 1$, $\Gamma_A(\underline{c}) = \mu_A \geq \underline{c}$, $\Gamma_A(\bar{c}) = d_A \leq \bar{c}$, $\Gamma_B(\underline{c}) = \mu_B \leq \bar{c}$, and $\Gamma_B(\bar{c}) = d_A \geq \underline{c}$. Furthermore,

$$\Gamma_A(d_A) - \mu_A = F_B(d_A)(d_A - \mu_A) < d_A - \mu_A,$$

$$\Gamma_B(d_B) - \mu_B = F_A(d_B)(d_B - \mu_B) > d_B - \mu_B.$$

Therefore, $\Gamma_A(d_A) < d_A$ and $\Gamma_B(d_B) > d_B$. Also,

$$\Gamma_A(\mu_B) = \mu_A(1 - F_B(\mu_B)) + d_A F_B(\mu_B) > \mu_A, \tag{12}$$

$$\Gamma_B(\mu_A) = \mu_B(1 - F_A(\mu_A)) + d_B F_A(\mu_A) < \mu_B. \tag{13}$$

Let $(\bar{x}, \bar{y})$ be the unique communication-free equilibrium point in $[\underline{c}, \bar{c}]$. Clearly, $\bar{x} < \Gamma_B(\mu_A) < \mu_B$ and $\mu_A < \bar{y} < \Gamma_A(\mu_B)$ (see Figure 5).

Notice that

$$\Omega_B'(y) = \frac{F_A'(y)(d_B - \mu_B)F_A(\Gamma_A(\mu_B))}{\{[1 - F_A(y)] + F_A(\Gamma_A(\mu_B))\}^2},$$

so Ω_B is decreasing. It is easy to check that $\Gamma_B(y) < \Omega_B(y)$ whenever $y \in (\Gamma_A(\mu_B), \bar{c})$.

Moreover,

$$\Omega_B(\bar{c}) = \Gamma_B(\bar{c}) = d_B$$

and

$$\Omega_B(\Gamma_A(\mu_B)) = \Gamma_B(\Gamma_A(\mu_B)) < \Gamma_A(\mu_B)$$

where the inequality follows from (6) and the fact that Γ_B is decreasing. Notice that the curve $x = \Omega_B(y)$ lies to the right of the curve $x = \Gamma_B(y)$ for all $y \in (\Gamma_A(\mu_B), \bar{c})$, but that the two curves intersect when $y = \Gamma_A(\mu_B)$ and $y = \bar{c}$. Thus, a communication equilibrium does not exist. ■

A conservative scientist cannot communicate effectively when actions are strategic substitutes. From Lemma 1, $M = \{m_0, m_1\}$ with $c_B(m_1) > c_B(m_0)$. Thus, player B is more likely to choose P after m_1 than after m_0. The conservative scientist wants player A (but not player B) to play C, so he would only choose m_0 if this message causes player A to play C. But if player A plays C for sure after m_0, player B's cutoff point must be $c_B(m_0) = \mu_B$. However, with $d_B < \mu_B$, types above μ are dominant strategy types who always play C, so it is a contradiction for $c_B(m_1) > \mu_B$. Thus, if player S is a conservative scientist and the game has strategic substitutes ($d_i < \mu_i$), then cheap-talk cannot be effective. ■

A communication equilibrium does not exist if player S is a progressive scientist, player A has strategic complements ($\mu_A < d_A$), and player B has strategic substitutes ($d_B < \mu_B$). In a communication equilibrium, the cut-off points must satisfy $y^* = \Gamma_A(x^*)$ and $x^* = \tilde{\Omega}_B(y^*)$, where

$$\tilde{\Omega}_B(y) = \frac{[1 - F_A(\Gamma_A(d_B)]\mu_B + F_A(y)d_B}{[1 - F_A(\Gamma_A(d_B)] + F_A(y)}.$$

(x^*, y^*) must be an intersection of the two curves $x = \tilde{\Omega}_B(y)$ and $y = \Gamma_A(x)$. With strategic substitutes, Assumption 2 implies

$$0 < \Gamma'_A(x) < 1.$$

Furthermore, $\Gamma_A(\underline{c}) = \mu_A > \underline{c}$ and $\Gamma_A(\bar{c}) = d_A < \bar{c}$, and

$$\Gamma_A(d_B) - d_A = (1 - F_B(d_B))(\mu_A - d_A)$$

where

$$\mu_A - d_A < (1 - F_B(d_B))(\mu_A - d_A) < 0.$$

Therefore,

$$\mu_A < \Gamma_A(d_B) < d_A. \tag{14}$$

Let $(\overline{x}, \overline{y})$ be the unique communication-free equilibrium in $[\underline{c}, \bar{c}]$. Clearly, $\mu_A < \overline{x} < \overline{y} < d_A$ (see Figure 6).

Figure 6 shows three curves: $x = \tilde{\Omega}_B(y)$, $y = \Gamma_A(x)$, and $x = \Gamma_B(y)$. The curves $y = \Gamma_A(x)$ and $x = \Gamma_B(y)$ intersect at the unique communication-free equilibrium, $(\overline{x}, \overline{y})$. It is easy to check that $\Gamma_B(y) < \tilde{\Omega}_B(y)$ whenever $y \in (\underline{c}, \Gamma_A(d_B))$. Moreover,

$$\tilde{\Omega}_B(\underline{c}) = \Gamma_B(\underline{c}) = \mu_B$$

and

$$\tilde{\Omega}_B(\Gamma_A(d_B)) = \Gamma_B(\Gamma_A(d_B)) < \Gamma_A(d_B)$$

where the inequality follows from the fact that Γ_B is decreasing. These properties are drawn in Figure x. Notice that the curve $x = \tilde{\Omega}_B(y)$ lies to the right of the curve $x = \Gamma_B(y)$ for all $y \in (\underline{c}, \Gamma_A(d_B))$, but that the two curves intersect when $y = \underline{c}$ and $y = \Gamma_A(d_B)$. Thus, a communication equilibrium does not exist. ■

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