Received: 9 June 2022 | Accepted: 3 July 2023

DOI: 10.1111/ecin.13178

ORIGINAL ARTICLE

Economic Inquiry

Pre-play promises, threats and commitments under partial credibility

Tigran Melkonyan[1] | **Surajeet Chakravarty**[2]

[1]University of Alabama, Tuscaloosa, Alabama, USA

[2]University of Exeter, Exeter, UK

Correspondence
Surajeet Chakravarty.
Email: s.chakravarty@exeter.ac.uk

Abstract

The paper examines how pre-play communication between players with partial credibility affects the ensuing strategic interaction. We consider an environment where players are uncertain about the economic and psychological costs of reneging on promises but learn these at the time of their implementation. We demonstrate that in the equilibrium both players make promises. The latter are partially effective in terms of achieving collusive outcomes and improving the players' payoffs under strategic complementarity, where promises are used to signal future collusive behavior. In contrast, under strategic substitutability the ability to make a promise can be used to signal future aggressive behavior and one of the players may even get a lower expected (before the type is revealed) payoff than in the game without communication.

KEYWORDS

collusion, honesty, informal agreements, pre-play communication, strategic complementarity, strategic substitutability

JEL CLASSIFICATION

C72, D91

We promise according to our hopes, and perform according to our fears.

François VI de la Rochefoucauld, French author of maxims and memoirs

Thou ought to be nice, even to superstition, in keeping thy promises, and therefore equally cautious in making them.

Thomas Fuller, English churchman and historian

Abbreviations: BA, British Airways; DOJ, Department of Justice; GE, General Electric.

Managing Editor: Stefano Barbieri

1 | INTRODUCTION

Many strategic interactions are preceded by an exchange of messages regarding the involved parties' intended behavior. Team members working on a joint project often coordinate their actions by communicating with each other. They also make promises regarding project milestones and the amount of time and other resources they are planning to devote to the project. Those of us who had coauthors or worked on team projects probably experienced this first-hand. Leaders of some countries often threaten other countries and leaders with trade restrictions and economic sanctions as well as promises of favorable treatment in case of "good behavior." A plethora of strategic social interactions is also accompanied by promises and threats. An exchange of wedding vows is an example. Such communication is sometimes "cheap talk" in the form of costless preplay messages (Charness, 2000; Cooper et al., 1992; Ellingsen & Östling, 2010; Farrell, 1987, 1988; Jacquemet et al., 2019). However, very often preplay communication is at least partially credible due to various costs associated with reneging on previously made promises. The focus of the present study is on the latter settings.

One of the drivers of such credibility is the innate aversion of many individuals to lying. A rather extensive literature in economics has generated ample evidence that people are intrinsically averse to lying (Abeler et al., 2014, 2019; Charness, 2000; Gneezy, 2005; Hurkens & Kartik, 2009; Sánchez-Pagés & Vorsatz, 2007). There also exists a substantial literature in psychology that documents cognitive costs of deception (Debey et al., 2014; Van Bockstaele et al., 2012). There is even neural-level evidence that deception is associated with emotional conflict (Baumgartner et al., 2009; Gamer, 2011). Given the sophisticated cognitive mechanisms associated with deception, there is a significant variation in the tendency to lie both between and within individuals (Debey et al., 2014; Gamer, 2011; Gneezy et al., 2013; Verschuere et al., 2011). The same individual may implement the promised action on one occasion, even though taking such action results in forgoing significant benefits, and renege on a promise on a different occasion. As a result, many individuals may have partial credibility for truth-telling. Moreover, when making promises we are often not certain whether we are going to honor them.[1] This may be a result of ex ante uncertainty about the psychological and economic costs and benefits of reneging on previously made promises.

Our objective is to examine whether and how pre-play communication between players with partial credibility may affect strategic interactions. We are particularly interested in the relationship between the actions with and without communication and the relative efficiency, from the perspective of the players, of the equilibrium outcomes under these two scenarios. To address these questions, the paper examines games where before choosing their actions the players exchange messages containing promises to implement certain actions when they are later called upon to move. It is assumed that at the time of creating such informal agreements the players are uncertain what their economic and psychological costs of reneging on an agreement will be at the time of action implementation. Thus, each player is uncertain whether she and her opponent will be truthful to their promises. Formally, there are two player types; honest and dishonest. The honest types suffer a high psychological or economic cost by deviating from the promised action and, as a result, always keep their promises. In contrast, the dishonest types do not feel any remorse, discomfort or other cost associated with reneging on a previously made commitment. This uncertainty is resolved immediately prior to the action choice at which point each player's honesty becomes her private information.

We develop a general framework to analyze strategic situations with promises and apply it to analyze two broad classes of games: games with strategic complements and games with strategic substitutes (Bulow et al., 1985; Gal-Or, 1985; Milgrom & Roberts, 1990; Roy & Sabarwal, 2010; Sabarwal, 2021; Topkis, 1998). The results vary across the two environments (Potters & Suetens, 2009). Under strategic complementarity, both players promise and choose actions that are less "aggressive" than the actions in the game without communication. Moreover, both players benefit from the ability to form an informal agreement. This materializes because the ability to make a promise, albeit partially credible, results in a "less aggressive" best-response correspondence for the opponent. When both players engage in pre-play communication, both are less aggressive and, as a result, partial collusion is achieved.

Under strategic substitutability, both players choose to communicate and at least one of the players promises an action that is more aggressive than her action in the game without communication. When the game is symmetric, the other player also chooses to promise an action that is more aggressive than in the game without communication. In this case, the dishonest types of both players end up choosing relatively non-aggressive actions. However, the honest types keep their promises and choose actions that are more aggressive than the actions without communication.[2] From the perspective of the two players, communication is a double-edged sword under strategic substitutability. It allows the dishonest types to "coordinate" on less aggressive actions but only at the expense of more aggressive choices by the honest types. The benefits of communication are consequently muted under strategic substitutability. This contrast in behavior and the resultant market outcomes under strategic complements and strategic substitutes can be traced to Bulow et al. (1985) and Haltiwanger and Waldman (1991). However, until now very little effort has been devoted to studying the interplay between the strategic environment and communication.[3]

In addition to the motives for pre-play communication mentioned above, announcements and informal agreements may be used by firms to engage in anti-competitive behavior. Real-world examples of such collusion are abundant. An early highly publicized example is offered by the 1960s–1970s interaction between GE and Westinghouse in the turbine generators market. In 1963, GE decided to publish its pricing policy. Westinghouse followed suit in 1964. GE and Westinghouse used the mechanism to communicate their intentions and to collude on prices. While initially the Department of Justice (DoJ) was unable to put forth a successful case against the anti-competitive practices of the duopoly, DoJ settled with GE and Westinghouse in 1976 and the two companies agreed to eliminate the practice of revealing their pricing strategies (Hay, 1982).

A more recent example involves the collusion between British Airways (BA) and Virgin Atlantic. In 2007, BA was fined £121.5m ($246m) by the UK Office of Fair Trade[4] and $300m by DoJ for colluding with Virgin Atlantic between 2004 and 2006 to fix prices on long-haul flights. It is not surprising that evidence against colluding firms in many anti-trust cases is comprised of communication records between the colluding firms or testimonies about such communication. According to Guardian (2007), "It is understood the collusion began when the former head of communications at BA, Iain Burns, phoned his counterparts at Virgin Atlantic to discuss surcharge plans…." Thus, in contrast to the GE-Westinghouse case, the communication was conducted in secret, but the intention was similar.

When such collusive behavior is present under Bertrand competition, our model predicts that the firms will promise to choose prices above the levels that would be chosen in the absence of communication. For the symmetric game, the actual price choices of (dishonest) firms fall between the promises and equilibrium actions of the game without communication. Thus, pre-play communication allows firms to partially collude on higher prices and improves profits of both firms. These results are in line with the experimental findings of pre-play communication in a Bertrand setting reported by Fonseca and Normann (2012). Similarly to the present paper, they suggest that a promise made by a player creates a belief on the part of opponent about the action that will be taken by the former. Fonseca and Normann (2012) find that communication leads to collusion and higher profits.

Firms may also communicate to gain advantage over their competitors. In 1970s–1980s, the Titanium Oxide industry was an oligopoly where DuPont was the largest producer. DuPont planned to increase its market share to 65% by 1985. To achieve this objective, DuPont announced to the industry that it would expand its capacity (Ghemawat, 1984), a behavior that is also predicted by our model. DuPont's rivals assigned a low likelihood to the event that the threat was credible and kept their capacity largely intact. In the end, DuPont's bluff did not work.

Our framework has a number of additional applications including various interactions between policy makers, politicians, and business people. The findings also shed light on the interactions where, as a result of high costs of contract enforcement, the involved parties have to rely on informal agreements. Such arrangements are prevalent in both developing (Mesquita & Lazzarini, 2008) and developed (Allen & Lueck, 1992; Hunt & Hayward, 2018) countries. In addition to the studies using naturally-occurring data, there are experimental investigations of informal agreements. Kessler and Leider (2012) conducted a study of informal agreements and found that these were very effective in terms of eliciting first-best behavior when the experimental subjects' actions were strategic complements. Although pre-play communication does not allow the parties to achieve the first-best in our paper, this result is in the spirit of our finding regarding the effect of communication on collusion.[5]

One can interpret our framework as reflecting imperfect commitment power on the part of strategic parties. That is, the players are uncertain about own and opponents' commitment power when they make their promises. Our model, thus, encompasses numerous strategic interactions where enforcement of commitments depends on external forces. These include a variety of formal and informal contractual arrangements, commitments by political parties and candidates, international commitments by governments of different countries, and many other interactions. There is a long-standing literature, dating at least as far as Schelling (1956, 1960), that investigates the strategic advantages and disadvantages of the ability to constrain future actions. A significant part of this literature focuses on the role of commitment in bargaining (Chung & Wood, 2019; Crawford, 1982; Miettinen, 2020; Muthoo, 1996). Similarly to the present study, commitments have a binary success probability in these studies. However, the "commitment technology" and the strategic interaction during the implementation stage are different. Furthermore, we consider a different class of games.

Precommitments can also be used to gain first-mover advantage in oligopoly competition. This literature originated from Dixit (1980) and Kreps and Scheinkman (1983) who examine how the ability to choose publicly observable capacity in the beginning of a strategic interaction affects the ensuing competition among firms. The initial capacity choices are followed by a quantity competition in the former study and by a price competition in the latter. Boccard and Wauthy (2004) extend Kreps and Scheinkman (1983) to a framework with imperfect commitment. Although commitment is also imperfect in the present paper, the types of the imperfections and the mechanisms behind them are very different. Similarly to Kreps and Scheinkman (1983), the firms in Boccard and Wauthy (2004) first choose capacities and subsequently compete in prices. But in contrast to Kreps and Scheinkman (1983), the firms can increase production beyond capacity at some cost. In our paper, the imperfection of the commitment mechanism stems from behavioral forces and has uncertain nature. Moreover, our framework does not restrict the relationship between the actual action choice and promised action while the actual output choice is weakly greater than the capacity choice in Boccard and Wauthy (2004). Not surprisingly, we obtain qualitatively different results.

Hamilton and Slutsky (1990) introduced an observable delay game in the context of an oligopoly where firms first choose the timing of their future actions (quantities or prices) and subsequently implement them. A sizable literature on endogenous timing emerged (Amir & Stepanova, 2006; Van Damme & Hurkens, 1999). A closely related literature considers the effects of pre-commitment to certain sets of actions on the ensuing strategic interactions (see, e.g., Bade et al., 2009; Catonini, 2021; Kalai et al., 2010; Renou, 2009; Romano & Yildirim, 2005). In contrast to these studies, information is (ex post) asymmetric and the commitment is uncertain in the present study[6] and, as a result, very different strategic forces are at play.

Our work is also related to the literature on pre-play communication (see, e.g., Ben-Porath & Dekel, 1992; Hurkens, 1996; Kartik et al., 2007; Kartik, 2009). The purpose of communication in these studies is to signal private information held by the players. The messages in our model play a different role—they soften or intensify the subsequent competition as a result of a "partial commitment" capacity of the players.

The most related paper in this strand of literature to our work is Miettinen (2013). In his framework, players enter into pre-play informal agreements and exhibit guilt aversion. Contrary to the present paper, the information is always symmetric in Miettinen (2013). In his analysis, Miettinen (2013) focuses on incentive-compatible agreements, for which the players fulfill their promises, and Pareto-efficient equilibria. In contrast, only honest players keep their promises in the present paper while dishonest players have full flexibility in their choices as they do not experience any guilt from reneging on promises.[7] Another key difference is that pre-play messages in the present paper have a very different strategic effect on the post-communication interaction.

The rest of the paper is organized as follows. In the next section, we introduce our model. The subsequent section characterizes the equilibrium behavior for each of the game's stages. We also compare equilibria with and without communication and investigate their efficiency properties. The final section contains concluding remarks and a discussion of future research.

2 | THE MODEL

2.1 | The timing of moves and payoffs

Consider a strategic interaction between two players, 1 and 2. The strategic interaction takes place over three stages; dates 0, 1 and 2. At date 2, also called the implementation stage, players 1 and 2 simultaneously and independently choose their actions. Player i's action choice in this stage is denoted by $\sigma_i \in \mathbb{R}_+$. At date 1, also called the information revelation stage, the players learn private information about their preferences. We will spell out the full details of this stage in the following paragraphs. At date 0, called the communication stage, players 1 and 2 simultaneously and independently make promises/threats regarding the actions that they will choose from the set of actions available to them at date 2. Similarly to Crawford (1982), each player has the option of not sending a message to her counterpart. We denote this choice by N. Let the resulting pair of promises be denoted by $\left(\sigma_1^p, \sigma_2^p\right)$, where $\sigma_i^p \in \{N\} \cup \mathbb{R}_+$ is player i's promise.

Suppose that reneging on a promise made during the communication stage may be costly to either player. There is uncertainty in each player's (and her opponent's) mind whether she can costlessly renege on the promise and choose something other than the promised action. Thus, during the communication stage the players are not sure whether psychological and other costs of lying will be sufficiently large to prevent reneging on previously made promises.

For each player, there are two possible realizations of the player's type. Under one of them, a player can costlessly renege on her promise, provided she has made one. Under the other, it is prohibitively costly to renege and the player implements her promise.[8] Formally, let t_i denote player i's type.[9] The variable t_i can assume two values; h (for "honest") with probability π_i and d (for "dishonest") with probability $1 - \pi_i$. At date 1, after making their promises and before actions are chosen at date 2, each player learns her type (whether she can costlessly renege on promises [if any] made earlier) but doesn't learn the other player's type. Thus, in the eyes of the opponent each player has initial reputation for honesty. Given our assumption, there are four possible events on the space of possible types of the two players: (1) $t_1 = t_2 = d$, (2) $t_1 = d$, $t_2 = h$, (3) $t_1 = h$, $t_2 = d$, and (4) $t_1 = t_2 = h$. In what follows, we will call the strategic interaction with $\pi_1 = \pi_2 = 0$ as *the game without communication*.

The timing of the resolution of uncertainty reflects many real-life scenarios. At the time of making a promise, people often cannot tell with certainty what their actual cost of reneging will be. They may allow both for the possibility where they will not be feeling morally obligated to live up to their promises and for the possibility where moral considerations, such as guilt, constrain them to fulfill their early pledges. Economic benefits and costs may also swing the pendulum in either direction. For example, a team member may find it hard to honor a prior promise to spend certain amount of time on a joint project in light of new projects and responsibilities.

It is assumed that the players cannot engage in communication after they learn their private information at date 1. Rather, the players simultaneously and independently choose their actions at date 2. There are a number of reasons for the assumption that promises are made only when information is symmetric. First, a player may learn her type right before making her choice. It is not uncommon for people to vacillate till the "last minute" before making a decision. This will make it impractical to make promises after learning own type. Second, the physical "rules" of the game may stipulate that messages are exchanged well in advance of action choices so that these messages are sent under symmetric information. Third, when players use communication for illegal collusion, repeated communication may significantly increase the chance of detection, and therefore the firms may choose not to communicate the second time (Kuhn, 2001, p. 171; Kuhn & Vives, 1995).[10]

Player i's ($i = 1, 2$) payoff function $u_i(\sigma_i, \sigma_j, \sigma_i^p; t_i)$ depends on the actions σ_i and σ_j chosen by players i and j (where $i \neq j$) at date 2, the action σ_i^p she promised at date 0, and her type:

$$u_i(\sigma_i, \sigma_j, \sigma_i^p; h) = \begin{cases} v_i(\sigma_i, \sigma_j), & \text{if } \sigma_i = \sigma_i^p \in \mathbb{R}_+ \text{ or } \sigma_i^p = N \\ -\infty, & \text{if } \sigma_i \neq \sigma_i^p \neq N \end{cases} \quad \text{and}$$
$$u_i(\sigma_i, \sigma_j, \sigma_i^p; d) = v_i(\sigma_i, \sigma_j),$$

where $v_i(\sigma_i, \sigma_j)$ is a twice continuously differentiable function that is strictly concave in σ_i for all σ_j.[11] Thus, the promise/commitment is "fully irreversible" for honest types while it is "fully reversible" for dishonest types (Crawford, 1982; Schelling, 1956). Given this assumption, honest type h will always choose to keep her promise. It then follows that player i's expected payoff in the beginning of date 0 will inherit all properties of the function $v_i(\sigma_i, \sigma_j)$, including twice continuous differentiability, on the restricted domain where $\sigma_i = \sigma_i^p$ for honest types.

We also suppose that, for all σ_j, $\lim_{\sigma_i \to 0+} \frac{\partial v_i(\sigma_i, \sigma_j)}{\partial \sigma_i} = \infty$ and $\lim_{\sigma_i \to \infty} \frac{\partial v_i(\sigma_i, \sigma_j)}{\partial \sigma_i} = 0$. In what follows, we will focus on two broad classes of games; games with strategic complements and games with strategic substitutes. A game has strategic complements (strategic substitutes) if $\frac{\partial v_i(\sigma_i, \sigma_j)}{\partial \sigma_i \partial \sigma_j} \geq 0$ $\left(\frac{\partial v_i(\sigma_i, \sigma_j)}{\partial \sigma_i \partial \sigma_j} \leq 0\right)$ for all $i = 1, 2$ and all $\sigma_i, \sigma_j \in \mathbb{R}_+$. A game has positive (negative) externalities if each player's payoff is increasing (decreasing) in the opponent's action.[12]

We focus on the case where there is a unique equilibrium. Polydoro (2011) extends Gabay and Moulin's (1980) findings on uniqueness to Bayesian Nash equilibria of incomplete information games. If, in addition to the requirements that we imposed, the game has strategic complements and the payoff functions $v_i(\sigma_i, \sigma_j)$ exhibit strict diagonal dominance, which requires $\left|\frac{\partial^2 v_i(\sigma_i, \sigma_j)}{\partial (\sigma_i)^2}\right| > \left|\frac{\partial^2 v_i(\sigma_i, \sigma_j)}{\partial \sigma_i \partial \sigma_j}\right|$ $\forall i$, then by Theorem 2.1 in Polydoro (2011) our game has a unique equilibrium. When the game has strategic substitutes, equilibrium uniqueness can be guaranteed by using Corollary 2.1 in Polydoro (2011), which, in addition to strict diagonal dominance, requires existence (for conditions ensuring existence, see, e.g., Yannelis, 1998). Ui (2016) provides alternative conditions guaranteeing existence and uniqueness of equilibrium in Bayesian games. These conditions are also applicable to our model.[13] In what follows, we assume that at least one of these sets of conditions are satisfied so that the equilibrium is unique.[14]

3 | ANALYSIS AND FINDINGS

3.1 | The implementation stage

As an equilibrium notion, we use the following set of requirements on the pair of strategy profile and beliefs, also called an assessment. First, we require that each player's beliefs about the opponent's type in the beginning of date 2 coincide with the former player's beliefs in the beginning of date 0. This condition is in the spirit of "no-signaling-what-you-don't-know" condition (Fudenberg & Tirole, 1991). Second, we require that the assessment be sequentially rational at each information set (Kreps & Wilson, 1982). Given the relationship of our requirements with the equilibrium notion in Fudenberg and Tirole (1991) and the fact that there is no canonical definition of "perfect Bayesian equilibrium" (Mailath, 2019), we refer to an assessment that satisfies our two conditions as perfect Bayesian equilibrium (PBE).

We solve the game backwards to determine the perfect Bayesian equilibrium of the game. Consider date 2, at which point in the game the players "reached an informal agreement" to play actions $\left(\sigma_1^p, \sigma_2^p\right)$ and learned their types. There are four possible scenarios differentiated by whether each player chose to make a promise at date 0 or decided to "remain silent." Under the first scenario (case (i)), neither player sends a message. Under the second scenario (case (ii)), both players make promises. Finally, under the remaining two scenarios (cases (iii) and (iv)), one of the players does not send a message while the other does. We first characterize behavior for each of these scenarios. Our analysis subsequently determines which of these scenarios materializes in the equilibrium.

Under the first scenario (case (i)), the information revealed to the players at date 1 has no effect on the strategic interaction. At date 2 the players will simply choose their actions in an independent and simultaneous fashion and their choices will be independent of their types. The date-2 equilibrium actions, denoted by $\left(\tilde{\sigma}_1^n, \tilde{\sigma}_2^n\right)$, are given by the solution to the following system of equations:

$$\frac{\partial v_i\left(\tilde{\sigma}_i^n, \tilde{\sigma}_j^n\right)}{\partial \sigma_i} = 0 \text{ for } i = 1, 2 \text{ and } j \neq i.^{15} \tag{1}$$

These are exactly the same actions that would be chosen in the game that only contained the date-2 stage. For this reason, we will call $\sigma_1^n(\sigma_2)$ and $\sigma_2^n(\sigma_1)$, that are implicitly defined by the equations in (1), as the *best response functions without communication*.

Consider now the scenario where both players make promises (case (ii)). An honest type of either player will choose the promised action; $\sigma_i = \sigma_i^p$ if player i is honest. Thus, we only need to consider the actions of dishonest players. Let σ_i denote the strategy of dishonest player i.

When a player, say player 1, has a complete reputation for honesty ($\pi_1 = 1$), her opponent's actions at date 2 will be entirely guided by the promise made by player 1 at date 0. When both players have complete reputation for honesty and they make promises at date 0, the strategic interaction effectively takes place only at date 0 as each player always implements the action promised at date 0. In this case, both the promises and actions chosen by both players at date 0 in the game with communication coincide with the actions chosen in the game without communication. Combining this with our observation above about behavior when both players lack reputation for honesty ($\pi_1 = \pi_2 = 0$), we immediately reach the following conclusion. *When either both players lack any reputation for honesty or both have complete reputation for honesty and make promises, the two players choose actions that coincide with the equilibrium actions in the game without communication.*

Returning to the general case where both players make promises, the expected payoff of type d of player i is given by

$$\pi_j \cdot v_i\left(\sigma_i, \sigma_j^p\right) + \left(1 - \pi_j\right) \cdot v_i\left(\sigma_i, \sigma_j\right). \tag{2}$$

It follows from Equation (2) that a dishonest player's payoff is independent of the promise that she has made. Using Equation (2), we obtain that player i's best-response function $\sigma_i^B\left(\sigma_j; \sigma_j^p\right)$ is implicitly given by

$$\pi_j \cdot \frac{\partial v_i\left(\sigma_i^B, \sigma_j^p\right)}{\partial \sigma_i} + \left(1 - \pi_j\right) \cdot \frac{\partial v_i\left(\sigma_i^B, \sigma_j\right)}{\partial \sigma_i} = 0 \text{ for } i = 1, 2. \tag{3}$$

It follows immediately from Equation (3) and the definitions of strategic complementarity and strategic substitutability, that when the players' actions are strategic complements the best-response function $\sigma_i^B\left(\sigma_j; \sigma_j^p\right)$ is increasing in both σ_j and σ_j^p and when the actions are strategic substitutes the function $\sigma_i^B\left(\sigma_j; \sigma_j^p\right)$ is decreasing in both σ_j and σ_j^p. To verify the monotonicity properties, consider, for example, the effect of player j's promise on player i's best-response function. Differentiating Equation (3) with respect to σ_i^B and σ_j^p and re-arranging, we obtain $\frac{d\sigma_i^B}{d\sigma_j^p} = -\frac{\pi_j \cdot \frac{\partial^2 v_i\left(\sigma_i^B, \sigma_j^p\right)}{\partial \sigma_i \partial \sigma_j^p}}{\pi_j \cdot \frac{\partial^2 v_i\left(\sigma_i^B, \sigma_j^p\right)}{\partial (\sigma_i)^2} + (1-\pi_j) \cdot \frac{\partial^2 v_i\left(\sigma_i^B, \sigma_j\right)}{\partial (\sigma_i)^2}}$, which is non-negative (non-positive) under strategic complementarity (strategic substitutability).

On occasion, we will call $\sigma_1^B\left(\sigma_2; \sigma_2^p\right)$ and $\sigma_2^B\left(\sigma_1; \sigma_1^p\right)$ as *the best response functions with communication*. Note also that the system of Equation (3) implicitly defines the date-2 Nash equilibrium actions of dishonest types of the two players, which are denoted by $\left(\widehat{\sigma}_1\left(\sigma_1^p, \sigma_2^p\right), \widehat{\sigma}_2\left(\sigma_1^p, \sigma_2^p\right)\right)$. The monotonicity properties of the date-2 Nash equilibrium actions in the date-0 promises follow immediately from the properties of games with strategic complements and strategic substitutes and the system of Equation (3). Under strategic complementarity, $\widehat{\sigma}_i\left(\sigma_1^p, \sigma_2^p\right)$ is increasing in both σ_1^p and σ_2^p for all $i = 1, 2$. Under strategic substitutability, $\widehat{\sigma}_i\left(\sigma_1^p, \sigma_2^p\right)$ is increasing in σ_i^p but decreasing in σ_j^p for all $i, j = 1, 2$ with $i \neq j$.

To gain more intuition into the implications of these monotonicity properties, consider Bertrand and Cournot competitions. Our findings for the case of strategic complements suggest the following behavior under Bertrand competition. When a player promises to choose a relatively high price, which can be coined as "collusive" or "less competitive," it makes her opponent behave less competitively in the implementation stage (since $\sigma_i^B\left(\sigma_j; \sigma_j^p\right)$ is increasing in σ_j^p). Moreover, when a player promises to choose a relatively high price, both players end up choosing higher prices in the implementation stage (since $\widehat{\sigma}_i\left(\sigma_1^p, \sigma_2^p\right)$ is increasing in both σ_1^p and σ_2^p). Thus, by promising a higher price a player can elicit "collusive" behavior by both herself and her opponent. The effect is different under Cournot competition. In contrast to Bertrand competition, when a player promises to produce a relatively low output, which again can be coined as "collusive" or "less competitive," it makes her opponent behave more competitively in the implementation stage (since $\sigma_i^B\left(\sigma_j; \sigma_j^p\right)$ is now decreasing in σ_j^p). Furthermore, by promising a lower output a player ends up behaving less competitively but her opponent behaves more competitively in the implementation stage. In other words, to make the opponent behave less competitively a player needs to signal that she will be behaving aggressively in the implementation stage.

Now that we have characterized behavior in cases (i) and (ii), it is left to examine the two scenarios where one of the players makes a promise while the other does not (cases (iii) and (iv)). Suppose that player 1 makes a promise while player 2 does not. An honest type of player 1 will choose the promised action; $\sigma_1 = \sigma_1^p$ if player 1 is honest. Let σ_1 denote the strategy of dishonest player 1. Player 2's action choice will be independent of her type since she has not made any promises. Let σ_2 denote the strategy of player 2.

The expected payoff of the dishonest type of player 1 is given by

$$v_1(\sigma_1, \sigma_2).$$

In contrast, the expected payoff of player 2 is given by

$$\pi_1 \cdot v_2\left(\sigma_2, \sigma_1^p\right) + (1 - \pi_1) \cdot v_2(\sigma_2, \sigma_1).$$

It follows from these expressions that player 1's dishonest type's best-response function $\sigma_1^n(\sigma_2)$ and player 2's best-response function $\sigma_2^B\left(\sigma_1; \sigma_1^p\right)$ are given, respectively, by

$$\begin{gathered} \frac{\partial v_1(\sigma_1, \sigma_2)}{\partial \sigma_1} = 0 \text{ and} \\ \pi_1 \cdot \frac{\partial v_2\left(\sigma_2, \sigma_1^p\right)}{\partial \sigma_2} + (1 - \pi_1) \cdot \frac{\partial v_2(\sigma_2, \sigma_1)}{\partial \sigma_2} = 0. \end{gathered} \tag{4}$$

One can immediately observe that the first equation in (4) coincides with the first equation in (1) while the second equation in (4) coincides with the second equation in (3). The system of Equation (4) implicitly defines the date-2 Nash equilibrium actions of the two players, which are denoted by $(\widehat{\sigma}_1(\sigma_1^p, \varnothing), \widehat{\sigma}_2(\sigma_1^p, \varnothing))$.[16] Under strategic complementarity, both $\widehat{\sigma}_1(\sigma_1^p, \varnothing)$ and $\widehat{\sigma}_2(\sigma_1^p, \varnothing)$ are increasing in σ_1^p. Under strategic substitutability, $\widehat{\sigma}_1(\sigma_1^p, \varnothing)$ is increasing in σ_1^p while $\widehat{\sigma}_2(\sigma_1^p, \varnothing)$ is decreasing in σ_1^p. The scenario where player 2 makes a promise while player 2 does not is symmetric to the preceding scenario.

To compare the behavior under the four scenarios above, we characterize the relationship between the best-response functions without communication $\sigma_i^n(\sigma_j)$ and with communication $\sigma_i^B\left(\sigma_j; \sigma_j^p\right)$:

Lemma 1

1. *Suppose the game has strategic complements. Then,*

$$\sigma_i^B\left(\sigma_j; \sigma_j^p\right) \geq \sigma_i^n(\sigma_j) \textit{ if and only if } \sigma_j^p \geq \sigma_j. \tag{5}$$

2. *Suppose the game has strategic substitutes. Then,*

$$\sigma_i^B\left(\sigma_j; \sigma_j^p\right) \leq \sigma_i^n(\sigma_j) \textit{ if and only if } \sigma_j^p \geq \sigma_j. \tag{6}$$

Proof See Supporting Information S2. ■

Figures 1–4 illustrate Lemma 1.[17] Figures 1 and 2 represent a game with strategic complements. The best-response curves are upward sloping in this case. Figure 1 corresponds to the case where the promises σ_1^p and σ_2^p exceed the respective date-2 Nash equilibrium actions $\tilde{\sigma}_1^n$ and $\tilde{\sigma}_2^n$ of the game without communication. In accordance with the first part of Lemma 1, player 1's (2's) best-response curve when her opponent makes a promise is below (above) player 1's (2's) best-response curve in the game without communication for all values of the opponent's action below the level promised by the opponent. Figure 2 depicts the case where both players' promises σ_1^p and σ_2^p are smaller than the Nash equilibrium of the game without communication. Finally, Figures 3 and 4 demonstrate the relationship between the best-response curves with and without communication for a game with strategic substitutes.

It is informative to illustrate the relationship between the two parts in Lemma 1 by noting that a game with strategic substitutes can be transformed into a game with strategic complements by reversing the ordering of the actions for one of the players. Consider a game with strategic substitutes and reverse the order of player i's action from σ_i to $-\sigma_i$.[18] The resulting game exhibits strategic complementarity (see, e.g., Amir, 2005) and it immediately follows that the first and second parts of Lemma 1 are equivalent.

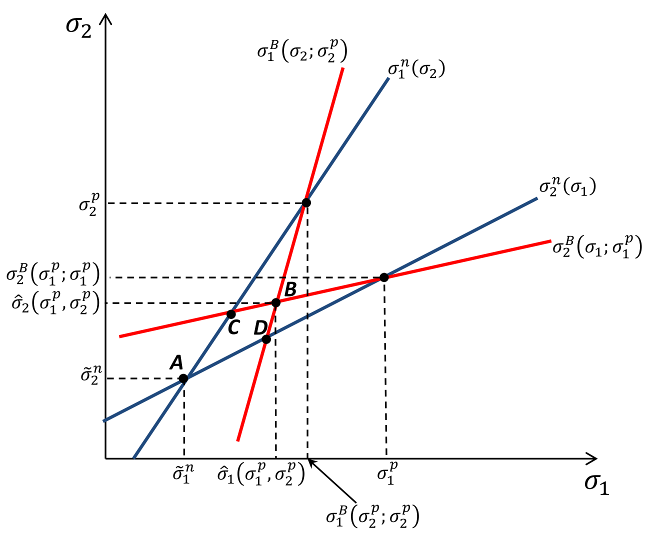

FIGURE 1 Equilibrium with and without communication: strategic complements and $\sigma_i^p > \tilde{\sigma}_i^n$ $(i = 1,2)$.

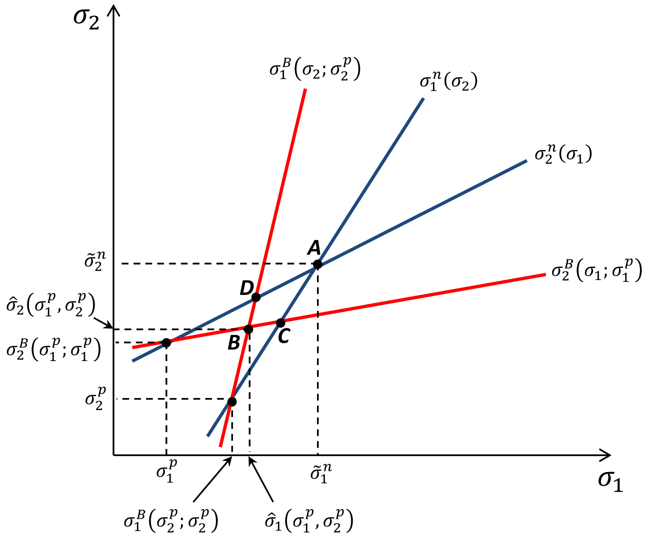

FIGURE 2 Equilibrium with and without communication: strategic complements and $\sigma_i^p < \tilde{\sigma}_i^n$ $(i = 1{,}2)$.

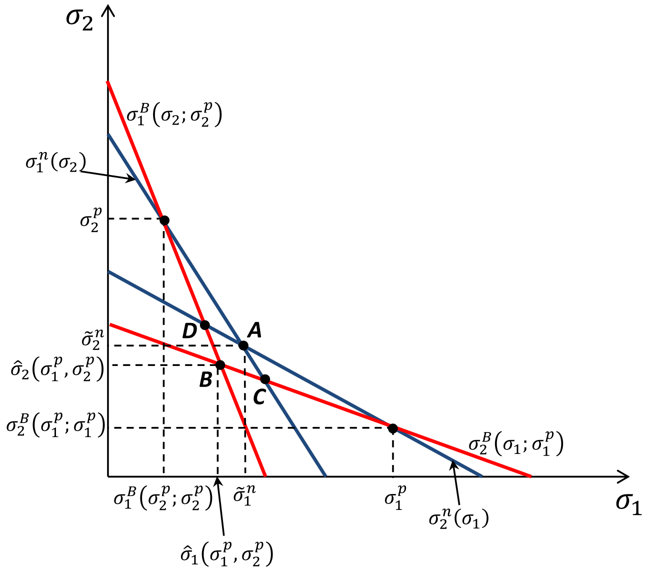

FIGURE 3 Equilibrium with and without communication: strategic substitutes and $\sigma_i^p > \tilde{\sigma}_i^n$ $(i = 1{,}2)$.

A further examination of the conditions in Lemma 1 and Figures 1 and 2 reveals the relationship for the case of strategic complements between the date-2 equilibrium actions without communication and with communication by at least one player:

Lemma 2 *Suppose the game has strategic complements.*

1. *Suppose both players make promises.*

   a. *if* $\sigma_i^p \geq \tilde{\sigma}_i^n \ \forall i,$ *then* $\hat{\sigma}_i(\sigma_1^p,\sigma_2^p) \geq \tilde{\sigma}_i^n \ \forall i$ *and* $\sigma_i^p \geq \hat{\sigma}_i(\sigma_1^p,\sigma_2^p)$ *for at least one* $i = 1,2$.
   b. *if* $\sigma_i^p \leq \tilde{\sigma}_i^n \ \forall i,$ *then* $\tilde{\sigma}_i^n \geq \hat{\sigma}_i(\sigma_1^p,\sigma_2^p) \ \forall i$ *and* $\hat{\sigma}_i(\sigma_1^p,\sigma_2^p) \geq \sigma_i^p$ *for at least one* $i = 1,2$.
   c. *if* $\sigma_i^p \geq \tilde{\sigma}_i^n$ *and* $\sigma_j^p \leq \tilde{\sigma}_j^n$ for $i \neq j,$ *then* $\sigma_i^p \geq \hat{\sigma}_i(\sigma_1^p,\sigma_2^p)$ *and* $\hat{\sigma}_j(\sigma_1^p,\sigma_2^p) \geq \sigma_j^p$.

2. *Suppose only player* $i \in \{1,2\}$ *makes a promise.*

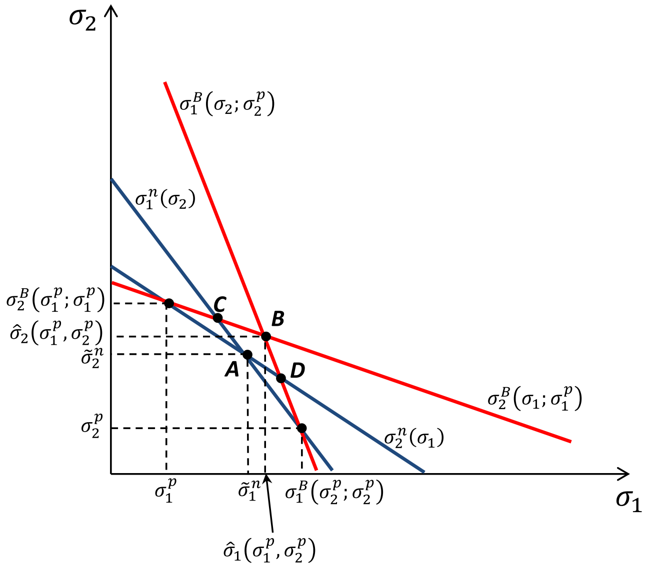

FIGURE 4 Equilibrium with and without communication: strategic substitutes and $\sigma_i^p < \tilde{\sigma}_i^n$ ($i = 1,2$).

a. if $\sigma_i^p \geq \tilde{\sigma}_i^n$, *then* $\sigma_i^p \geq \hat{\sigma}_i\left(\sigma_j^p, \varnothing\right)$ *and* $\hat{\sigma}_j\left(\sigma_i^p, \varnothing\right) \geq \tilde{\sigma}_j^n \ \forall j$.

b. if $\sigma_i^p \leq \tilde{\sigma}_i^n$, *then* $\sigma_i^p \leq \hat{\sigma}_i\left(\sigma_j^p, \varnothing\right)$ *and* $\hat{\sigma}_j\left(\sigma_i^p, \varnothing\right) \leq \tilde{\sigma}_j^n \ \forall j$.

When the promised actions exceed the equilibrium actions without communication (part 1(a) of Lemma 2), the equilibrium actions with communication, represented by point B in Figure 1, end up exceeding the corresponding equilibrium actions without communication, represented by point A in Figure 1. The reverse holds when the promised actions are lower than the equilibrium actions without communication (part 1(b) of Lemma 2 and point B in Figure 2).

When one of the players promises an action that is higher than her equilibrium action in the game without communication while the reverse holds for the other player, the relationship between the date-2 equilibrium actions with and without communication is ambiguous. However, the relationships between the promised and chosen actions are unambiguous. If a player promises to choose an action higher (lower) than the equilibrium action in the game without communication, her chosen action is smaller (greater) than her promise. Thus, promises of relatively large (small) actions are followed by undershooting (overshooting) of these promises in this case.

When only player i makes a promise, her best-response function is given by $\sigma_i^n\left(\sigma_j\right)$ $(j \neq i)$ while her opponent's best-response function is given by $\sigma_j^B\left(\sigma_i; \sigma_i^p\right)$. Consider, for example, the case where player 1 promises to choose action $\sigma_1^p \geq \tilde{\sigma}_1^n$ while player 2 does not make any promises. The date-2 equilibrium actions under this scenario are given by point C in Figure 1. Note that the equilibrium actions of both players exceed the equilibrium actions of the game without communication, which is reflected by point C lying to the northeast of point A in Figure 1.

Part 1(a) of Lemma 2 reveals that when both players promise actions that are larger than the equilibrium actions in the game without communication, at least one of the players ends up over-promising in the sense that her promise exceeds her dishonest type's choice: $\sigma_i^p \geq \hat{\sigma}_i\left(\sigma_1^p, \sigma_2^p\right)$. Note that one of the players may end up under-promising. This can happen when her opponent promises a relatively large action.

To gain more intuition into Lemma 2, suppose, for the sake of illustration, that $\frac{\partial v_i\left(\sigma_i, \sigma_j\right)}{\partial \sigma_j} \geq 0$ for $i \neq j$ so that an increase in the opponent's action exerts a positive externality on a player.[19] Suppose also that the best-response curves are linear as depicted in Figures 1–4. In this case, the inverse of the slope of player 1's best-response line (and the slope of player 2's best response line) reflects how "aggressive" player 1's (player 2's) response is to her opponent's actions. Player j invites a relatively less aggressive behavior by her opponent when she makes a promise that exceeds her own Nash equilibrium action $\tilde{\sigma}_j^n$ in the game without communication than when her promise is less than $\tilde{\sigma}_j^n$. As a result, *both players choose relatively large equilibrium actions, or "less aggressive" actions, when they promise relatively more.* This, in turn, has reciprocal benefits for each player.

We now turn to the case of strategic substitutes:

Lemma 3 *Suppose the game has strategic substitutes.*

1. *Suppose both players make promises.*

$$a.\ \text{if } \sigma_i^p \geq \tilde{\sigma}_i^n\ \ \forall i,\ \text{then } \sigma_i^p \geq \hat{\sigma}_i\left(\sigma_1^p, \sigma_2^p\right)\ \ \forall i \text{ and } \tilde{\sigma}_i^n \geq \hat{\sigma}_i\left(\sigma_1^p, \sigma_2^p\right) \text{ for at least one } i = 1, 2.$$
$$b.\ \text{if } \sigma_i^p \leq \tilde{\sigma}_i^n\ \ \forall i,\ \text{then } \hat{\sigma}_i\left(\sigma_1^p, \sigma_2^p\right) \geq \sigma_i^p\ \ \forall i \text{ and } \hat{\sigma}_i\left(\sigma_1^p, \sigma_2^p\right) \geq \tilde{\sigma}_i^n \text{ for at least one } i = 1, 2.$$
$$c.\ \text{if } \sigma_i^p \geq \tilde{\sigma}_i^n \text{ and } \sigma_j^p \leq \tilde{\sigma}_j^n \text{ for } i \neq j,\ \text{then } \sigma_i^p \geq \hat{\sigma}_i\left(\sigma_1^p, \sigma_2^p\right) \geq \tilde{\sigma}_i^n \text{ and } \tilde{\sigma}_j^n \geq \hat{\sigma}_j\left(\sigma_1^p, \sigma_2^p\right) \geq \sigma_j^p\ .$$

2. *Suppose only player $i \in \{1, 2\}$ makes a promise.*

$$a.\ \text{if } \sigma_i^p \geq \tilde{\sigma}_i^n,\ \text{then } \sigma_i^p \geq \hat{\sigma}_i\left(\sigma_i^p, \varnothing\right) \geq \tilde{\sigma}_i^n \text{ and } \tilde{\sigma}_j^n \geq \hat{\sigma}_j\left(\sigma_i^p, \varnothing\right) \text{ where } j \neq i.$$
$$b.\ \text{if } \sigma_i^p \leq \tilde{\sigma}_i^n,\ \text{then } \tilde{\sigma}_i^n \geq \hat{\sigma}_i\left(\sigma_i^p, \varnothing\right) \geq \sigma_i^p \text{ and } \hat{\sigma}_j\left(\sigma_i^p, \varnothing\right) \geq \tilde{\sigma}_j^n \text{ where } j \neq i.$$

Similarly to the illustration of the relationship between the two parts of Lemma 1, it is informative to reverse the order of one of the players' actions in order to relate Lemmas 2 and 3. For concreteness, consider changing player 1's action from σ_1 to $-\sigma_1$. It then follows that part $1(a)$ of Lemma 2 is equivalent to part $1c$ of Lemma 3 for $j = 1$ and $i = 2$ while part $1(b)$ of Lemma 2 is equivalent to part $1(c)$ of Lemma 3 for $j = 2$ and $i = 1$. Furthermore, part $1(c)$ of Lemma 2 for $j = 1$ and $i = 2$ is equivalent to part $1(a)$ of Lemma 3 while part $1(c)$ of Lemma 2 for $j = 2$ and $i = 1$ is equivalent to part $1(b)$ of Lemma 3. Finally, a similar relationship can be established between part 2 of Lemma 2 and part 2 of Lemma 3.

A comparison of Lemmas 2 and 3 reveals differences between behavior under strategic substitutes and strategic complements. For the sake of contrasting the two scenarios, consider the case of symmetric games where both players promise the same amount. Under strategic substitutability and in contrast to strategic complementarity, when both players promise actions larger than those in the game without communication they end up choosing actions smaller than those in the game without communication. This case is depicted in Figure 3. Under the reverse scenario where the promised actions are smaller than the equilibrium actions without communication, the date-2 equilibrium actions with communication are larger than the equilibrium actions without communication (see Figure 4). The difference from the case of strategic complements stems from two factors: (i) the best-response functions are increasing (decreasing) in the opponent's action under strategic complementarity (strategic substitutability) and (ii) the best-response functions are increasing (decreasing) in the action promised by the opponent under strategic complementarity (strategic substitutability).

When only one of the players makes a promise under strategic substitutability, the relationship between the date-2 equilibrium actions with and without communication depends on whether the promise made by a player exceeds that player's equilibrium action without communication. When it does, the player who makes a promise ends up choosing an action that exceeds her equilibrium action without communication while the reverse relationship holds for her opponent. Consider, for example, the case where player 1 promises to choose action $\sigma_1^p \geq \tilde{\sigma}_1^n$ while player 2 does not make any promises. The date-2 equilibrium actions under this scenario are given by point C in Figure 3, for which $\hat{\sigma}_1\left(\sigma_1^p, \varnothing\right) \geq \tilde{\sigma}_1^n$ and $\tilde{\sigma}_2^n \geq \hat{\sigma}_2\left(\sigma_1^p, \varnothing\right)$.

3.2 | The communication stage

Consider now the game that starts at date 0. In accordance with the previous subsection, we examine cases (i)–(iv). The scenario where neither player makes a promise (case (i)) is trivial since, as we have already pointed out, the strategic interaction in this case is equivalent to the corresponding game without communication.

Suppose now that both players make promises. Given that the dishonest players choose $\left(\hat{\sigma}_1\left(\sigma_1^p, \sigma_2^p\right), \hat{\sigma}_2\left(\sigma_1^p, \sigma_2^p\right)\right)$ at date 2 while the honest players keep their promises, player i's expected payoff in the beginning of date 0 is given by

$$\begin{aligned}&\pi_i\pi_j \cdot v_i\left(\sigma_i^p, \sigma_j^p\right) + \pi_i(1-\pi_j) \cdot v_i\left(\sigma_i^p, \widehat{\sigma}_j\left(\sigma_1^p, \sigma_2^p\right)\right) \\ &+(1-\pi_i)\pi_j \cdot v_i\left(\widehat{\sigma}_i\left(\sigma_1^p, \sigma_2^p\right), \sigma_j^p\right) + (1-\pi_i)(1-\pi_j) \cdot v_i\left(\widehat{\sigma}_i\left(\sigma_1^p, \sigma_2^p\right), \widehat{\sigma}_j\left(\sigma_1^p, \sigma_2^p\right)\right),\end{aligned} \tag{7}$$

where each summand corresponds to one of the four realizations of the players' types.

We let $\sigma_i^{Bp}\left(\sigma_j^p\right)$ denote player i's ($i = 1, 2$) best-response functions for this stage of the game. The messages that constitute a part of the Perfect Bayesian Nash equilibrium are denoted by $\left(\widehat{\sigma}_1^p, \widehat{\sigma}_2^p\right)$. These best-response functions and equilibrium promises are defined in the Supporting Information S2.

Figures 5 and 6 illustrate these best-response functions for the cases of strategic complements and strategic substitutes, respectively. The positioning of these best-response functions relative to the best-response functions $\sigma_i^n(\cdot)$, which is derived in the proof of the following proposition, reveals the differences in behavior between the cases of strategic complements and strategic substitutes. As one might expect, the best-response function $\sigma_i^{Bp}(\cdot)$ is upward-sloping for the case of strategic complements but downward-sloping for the case of strategic substitutes.

The following proposition spells out the relationship between the equilibrium actions with and without communication as well as compares the equilibrium promises and date-2 actions:

Proposition 4 [20]*Suppose that both players make promises.*

1. *Suppose that the game has strategic complements.*
   a. *If the game has positive externalities, then*

$$\widehat{\sigma}_i^p \geq \tilde{\sigma}_i^n \;\&\; \widehat{\sigma}_i\left(\widehat{\sigma}_1^p, \widehat{\sigma}_2^p\right) \geq \tilde{\sigma}_i^n \;\; \forall i \text{ and } \widehat{\sigma}_i^p \geq \widehat{\sigma}_i\left(\widehat{\sigma}_1^p, \widehat{\sigma}_2^p\right) \text{ for at least one } i. \tag{8}$$

   b. *If the game has negative externalities, then*

$$\widehat{\sigma}_i^p \leq \tilde{\sigma}_i^n \;\&\; \widehat{\sigma}_i\left(\widehat{\sigma}_1^p, \widehat{\sigma}_2^p\right) \leq \tilde{\sigma}_i^n \;\; \forall i \text{ and } \widehat{\sigma}_i^p \leq \widehat{\sigma}_i\left(\widehat{\sigma}_1^p, \widehat{\sigma}_2^p\right) \text{ for at least one } i. \tag{9}$$

2. *Suppose that the game has strategic substitutes.*
   a. *Suppose also that the game has negative externalities. Then, one of the following two scenarios will materialize:*

$$\begin{aligned}&i.\; \widehat{\sigma}_i^p \geq \tilde{\sigma}_i^n \;\&\; \widehat{\sigma}_i^p \geq \widehat{\sigma}_i\left(\widehat{\sigma}_1^p, \widehat{\sigma}_2^p\right) \;\; \forall i \text{ and } \tilde{\sigma}_i^n \geq \widehat{\sigma}_i\left(\widehat{\sigma}_1^p, \widehat{\sigma}_2^p\right) \text{ for at least one } i, \\ &ii.\; \widehat{\sigma}_i^p \geq \widehat{\sigma}_i\left(\widehat{\sigma}_1^p, \widehat{\sigma}_2^p\right) \geq \tilde{\sigma}_i^n \text{ and } \tilde{\sigma}_j^n \geq \widehat{\sigma}_j\left(\widehat{\sigma}_1^p, \widehat{\sigma}_2^p\right) \geq \widehat{\sigma}_j^p \text{ where } i,j \in \{1,2\} \text{ and } j \neq i.\end{aligned} \tag{10}$$

   If, in addition, the game is symmetric and the players promise the same actions then

$$iii.\; \widehat{\sigma}_1^p = \widehat{\sigma}_2^p \geq \tilde{\sigma}_1^n = \tilde{\sigma}_2^n \geq \widehat{\sigma}_1\left(\widehat{\sigma}_1^p, \widehat{\sigma}_2^p\right) = \widehat{\sigma}_2\left(\widehat{\sigma}_1^p, \widehat{\sigma}_2^p\right).$$

   b. *Suppose also that the game has positive externalities. Then, one of the following two scenarios will materialize:*

$$\begin{aligned}&i.\; \widehat{\sigma}_i^p \leq \tilde{\sigma}_i^n \;\&\; \widehat{\sigma}_i^p \leq \widehat{\sigma}_i\left(\widehat{\sigma}_1^p, \widehat{\sigma}_2^p\right) \;\; \forall i \text{ and } \tilde{\sigma}_i^n \leq \widehat{\sigma}_i\left(\widehat{\sigma}_1^p, \widehat{\sigma}_2^p\right) \text{ for at least one } i, \\ &ii.\; \widehat{\sigma}_i^p \leq \widehat{\sigma}_i\left(\widehat{\sigma}_1^p, \widehat{\sigma}_2^p\right) \leq \tilde{\sigma}_i^n \text{ and } \tilde{\sigma}_j^n \leq \widehat{\sigma}_j\left(\widehat{\sigma}_1^p, \widehat{\sigma}_2^p\right) \leq \widehat{\sigma}_j^p \text{ where } i,j \in \{1,2\} \text{ and } j \neq i.\end{aligned} \tag{11}$$

   If, in addition, the game is symmetric and the players promise the same actions then

$$iii.\; \widehat{\sigma}_1^p = \widehat{\sigma}_2^p \leq \tilde{\sigma}_1^n = \tilde{\sigma}_2^n \leq \widehat{\sigma}_1\left(\widehat{\sigma}_1^p, \widehat{\sigma}_2^p\right) = \widehat{\sigma}_2\left(\widehat{\sigma}_1^p, \widehat{\sigma}_2^p\right).$$

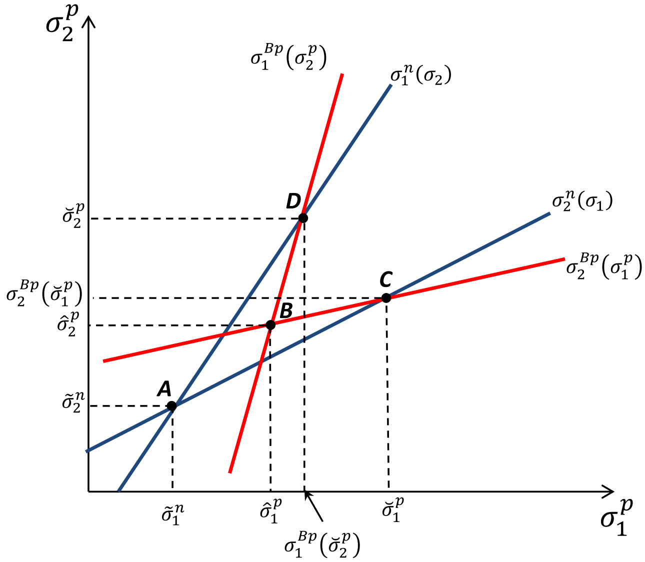

FIGURE 5 Equilibrium promises with communication and equilibrium date-2 actions without communication: strategic complements.

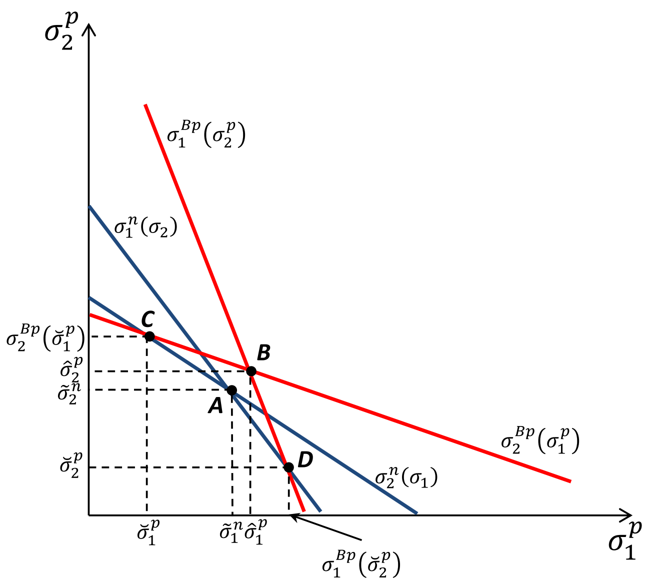

FIGURE 6 Equilibrium promises with communication and equilibrium date-2 actions without communication: strategic substitutes.

Proof See Supporting Information S2. ■

Thus, for strategic complements with positive externalities, the equilibrium date-2 actions exceed the equilibrium actions of the game without communication. Moreover, the promise of at least one player exceeds the date-2 action of her dishonest type. The other player may over- or under-promise in the equilibrium. Figure 5 [21] depicts the case where both players over-promise. However, it is not difficult to envision a scenario where one of the players, say player 1, promises an action that is relatively large compared to player 2's promise so that the curves $\sigma_1^{Bp}(\cdot)$ and $\sigma_2^{Bp}(\cdot)$ intersect to the northeast of point *D* in Figure 5. In that case, player 1 would over-promise while player 2 would under-promise.

In the game with strategic complements and positive externalities, relatively large actions can be naturally interpreted as more collusive. From part 1 of Proposition 4, both players make promises that are relatively collusive in the sense that both promises exceed the respective equilibrium actions in the game without communication; $\hat{\sigma}_i^p \geq \tilde{\sigma}_i^n \ \ \forall\, i$. A player behaves less aggressively ex post (corresponding to flatter best-response curves in Figure 5) when ex ante her opponent promises to choose a relatively collusive action. As a result, the actual choices made by both honest and dishonest players exceed the respective equilibrium actions in the game without communication. Thus, the players manage to achieve a "collusive" outcome. Note also that the level of "collusion" characterized in Proposition 4 is in general different from the level of "collusion" that the players would choose were they able to perfectly and jointly commit to their actions. Finally, similar behavior and results materialize under strategic complements with negative externalities.

The equilibrium behavior is different under strategic substitutability. Consider the case of strategic substitutes with negative externalities. In this case, relatively large actions can be interpreted as less collusive. For illustration purposes, consider the scenario in part 2(a)(i) of Proposition 4 and suppose, in addition, that $\tilde{\sigma}_i^n \geq \hat{\sigma}_i(\hat{\sigma}_1^p, \hat{\sigma}_2^p)\ \forall i$. This case is depicted in Figure 6. Both players promise to choose actions that exceed their actions in the game without communication. That is, in contrast to the game with strategic complements, both players promise not to be collusive. A player's promise to be non-collusive leads to a non-aggressive behavior by her opponent. Thus, the players achieve collusion by promising to be non-collusive. Note that in our game honest types always keep their promises. When these promises involve non-collusive actions, behavior of honest types, who end up choosing non-collusive actions, counterbalances the behavior of dishonest types, who end up choosing collusive actions. In contrast, both effects work in the same direction under strategic complementarity.

When the equilibrium behavior is characterized by part 2(a)(ii) of Proposition 4, one of the players promises an aggressive action $(\hat{\sigma}_i^p \geq \tilde{\sigma}_i^n)$ while the other promises a collusive action $(\tilde{\sigma}_j^n \geq \hat{\sigma}_j^p)$. The actual choices of dishonest types of these players fall between their promises and the equilibrium actions in the game without communication. Both types of the player who promises a non-collusive action end up choosing a non-collusive action. In contrast, both types of the player who promises a collusive action end up choosing a collusive action. Thus, the former player gains a strategic advantage over the latter under the scenario in part 2(a)(ii).

A public goods game (Ledyard, 1994) is an example of a game with strategic substitutes and positive externalities. To illustrate the implications of our analysis for such games, consider, for example, the symmetric case characterized in part 2(b)(iii) of Proposition 4. In this case, both players will promise to make relatively small contributions to the public good. Each player makes such a promise to incentivize her counterpart to make a relatively large contribution. And, indeed, both dishonest types choose contributions that are higher than those in the game without communication. However, the honest types choose relatively small contributions. Thus, as in the case of strategic substitutes with negative externalities, the benefits of communication are muted.

Contrasting parts (a) and (b) of Proposition 4, we note that the results are "sharper" for the case of strategic complements than for the case of strategic substitutes. More generally, asymmetric Nash equilibria in a parametrized game with strategic substitutes may lack monotonicity properties and additional conditions need to be imposed to ensure it (Roy & Sabarwal, 2010; Sabarwal, 2021).

Consider now the case where only one of the players, say player 1, makes a promise.[22] The honest type of player 1 will implement her promise while the dishonest type will choose according to $\hat{\sigma}_1(\sigma_1^p, \varnothing)$. In contrast, both types of player 2 will choose according to $\hat{\sigma}_2(\sigma_1^p, \varnothing)$. Hence, player 1's expected payoff in the beginning of date 0 is given by

$$\pi_1 \cdot v_1(\sigma_1^p, \hat{\sigma}_2(\sigma_1^p, \varnothing)) + (1 - \pi_1) \cdot v_1(\hat{\sigma}_1(\sigma_1^p, \varnothing), \hat{\sigma}_2(\sigma_1^p, \varnothing)), \tag{12}$$

where the first summand corresponds to the event where player 1 is honest while the second summand corresponds to the event where she is dishonest.

Let $\hat{\sigma}_1^{p_1}$ denote player 1's equilibrium promise. We show in the Supporting Information S2 that:

Lemma 5 *Suppose that only one of the players, say player 1, makes a promise.*

1. *Suppose that the game has strategic complements.*
   a. *If the game has positive externalities, then*

$$\hat{\sigma}_1^{p_1} \geq \hat{\sigma}_1(\hat{\sigma}_1^{p_1}) \geq \tilde{\sigma}_1^n \text{ and } \hat{\sigma}_2(\hat{\sigma}_1^{p_1}) \geq \tilde{\sigma}_2^n. \tag{13}$$

   b. *If the game has negative externalities, then*

$$\widehat{\sigma}_1^{p_1} \le \widehat{\sigma}_1\left(\widehat{\sigma}_1^{p_1}\right) \le \tilde{\sigma}_1^n \textit{ and } \widehat{\sigma}_2\left(\widehat{\sigma}_1^{p_1}\right) \le \tilde{\sigma}_2^n. \tag{14}$$

2. *Suppose that the game has strategic substitutes.*
   a. *If the game has negative externalities, then*

$$\widehat{\sigma}_1^{p_1} \ge \widehat{\sigma}_1\left(\widehat{\sigma}_1^{p_1}, \varnothing\right) \ge \tilde{\sigma}_1^n \textit{ and } \tilde{\sigma}_2^n \ge \widehat{\sigma}_2\left(\widehat{\sigma}_1^{p_1}, \varnothing\right). \tag{15}$$

   b. *If the game has positive externalities, then*

$$\widehat{\sigma}_1^{p_1} \le \widehat{\sigma}_1\left(\widehat{\sigma}_1^{p_1}, \varnothing\right) \le \tilde{\sigma}_1^n \textit{ and } \tilde{\sigma}_2^n \le \widehat{\sigma}_2\left(\widehat{\sigma}_1^{p_1}, \varnothing\right). \tag{16}$$

Proof See Supporting Information S2. ■

Thus, under strategic complementarity with positive externalities, player 1 promises to choose an action that is higher than her equilibrium action in the game without communication. The actual choices of the two players at date 2 (point C in Figure 1) exceed their respective equilibrium choices in the game without communication (point A in Figure 1). Thus, even when only one player sends a message under strategic complementarity with positive externalities, the players end up choosing actions that are higher than those when the players cannot communicate. In other words, the players choose actions that more collusive than those in the game without communication.

As one could have expected, behavior is again different under strategic substitutability. For concreteness, consider a game with strategic substitutes and negative externalities (part 2(a) of Lemma 5). Player 1 promises to choose an action greater than the equilibrium action without communication and ends up choosing an action between her promise and her equilibrium action of the game without communication. In contrast, player 2 chooses an action that is smaller than the equilibrium action in the game without communication. Thus, both player 1's promise and action choice are less collusive than her choice in the game without communication. In contrast, player 2's action choice is more collusive than in the game without communication.

Now that we have characterized the equilibrium behavior for all permutations of decisions by the two players whether to make a promise, it is left to determine which players, if any, will send messages in the equilibrium of the game. Prior to stating our next result, we introduce the following terminology. We will say that player i gains ex ante compared to the game without communication if her expected payoff (7) in the beginning of date 0 evaluated at $\left(\widehat{\sigma}_1^p, \widehat{\sigma}_2^p\right)$ exceeds her payoff $v_i\left(\tilde{\sigma}_i^n, \tilde{\sigma}_j^n\right)$ in the game without communication. With this terminology, we have:

Proposition 6 [23]*Both players make promises, denoted by* $\left(\widehat{\sigma}_1^p, \widehat{\sigma}_2^p\right)$ *and given by*

$$\begin{aligned}
&\pi_i\pi_j \cdot \frac{\partial v_i\left(\widehat{\sigma}_i^p, \widehat{\sigma}_j^p\right)}{\partial \sigma_i} + \pi_i(1-\pi_j) \cdot \left(\frac{\partial v_i\left(\widehat{\sigma}_i^p, \widehat{\sigma}_j\left(\widehat{\sigma}_1^p, \widehat{\sigma}_2^p\right)\right)}{\partial \sigma_i} + \frac{\partial v_i\left(\widehat{\sigma}_i^p, \widehat{\sigma}_j\left(\widehat{\sigma}_1^p, \widehat{\sigma}_2^p\right)\right)}{\partial \sigma_j}\frac{\partial \widehat{\sigma}_j\left(\widehat{\sigma}_1^p, \widehat{\sigma}_2^p\right)}{\partial \sigma_i^p}\right) \\
&+ (1-\pi_i)(1-\pi_j) \cdot \frac{\partial v_i\left(\widehat{\sigma}_i\left(\widehat{\sigma}_1^p, \widehat{\sigma}_2^p\right), \widehat{\sigma}_j\left(\widehat{\sigma}_1^p, \widehat{\sigma}_2^p\right)\right)}{\partial \sigma_j}\frac{\partial \widehat{\sigma}_j\left(\widehat{\sigma}_1^p, \widehat{\sigma}_2^p\right)}{\partial \sigma_i^p} = 0 \textit{ for } i,j = 1,2 \textit{ and } i \neq j,
\end{aligned} \tag{17}$$

in the equilibrium if the game has

1. *Strict strategic complements* $\left(\frac{\partial v_i}{\partial \sigma_i \partial \sigma_j} > 0\right)$ *with strict positive or negative externalities*

$$\left(\frac{\partial v_i}{\partial \sigma_j} > 0 \textit{ or } \frac{\partial v_i}{\partial \sigma_j} < 0 \textit{ for all } i,j = 1,2 \textit{ with } i \neq j\right),$$

or

2. *Strict strategic substitutes* $\left(\frac{\partial v_i}{\partial \sigma_i \partial \sigma_j} < 0\right)$ *with strict negative or positive externalities*

$$\left(\frac{\partial v_i}{\partial \sigma_j} < 0 \text{ or } \frac{\partial v_i}{\partial \sigma_j} > 0 \, for \, all \, i, j = 1, 2 \, with \, i \neq j\right).$$

Moreover, in the case of strategic complementarity (part 1) both players gain ex ante compared to the game without communication.

Proof See Supporting Information S2. ■

The proof of the proposition proceeds by starting from the scenario where neither player makes a promise and demonstrating that both players will find it advantageous to deviate and send a message. We then show that when only one of the players makes a promise the other player unambiguously benefits from also making a promise. As a result, both players make promises in the equilibrium.

Propositions 4 and 6 reveal that the ability to form informal agreements may have different welfare implications under strategic complementarity and strategic substitutability. For concreteness, consider a game with strategic complements and positive externalities. In this case, both honest and dishonest players choose date-2 actions that are more collusive than the actions in the game without communication. Since each player's payoff and marginal payoff are increasing in the opponent's action, both players gain from the ability to communicate and collude on less aggressive actions (for details, see the proof of Proposition 6).

Consider now a game with strategic substitutes and negative externalities. From Proposition 4, there are two qualitatively different types of behavior in this case. Under the scenario characterized in part 2(a) of Proposition 4, both players promise/threaten to choose aggressive actions and at least one of the players chooses a non-aggressive action, which has a positive effect on the opponent's expected payoff. On the other hand honest types always keep their promises and choose aggressive actions. Such choice has an adverse effect on the opponent's expected payoff. Which of these countervailing effects dominates depends on the players' absolute and relative reputations for honesty.

In the case characterized in part 2(b) of Proposition 4, one of the players promises an aggressive action while the other promises a collusive action. The actual choices of dishonest types of these players fall between their promises and the equilibrium actions in the game without communication. Both types of the former player end up choosing an aggressive action while both types of the latter player end up choosing a collusive action. As a result, the former player's expected payoff is higher than in the case without communication while the latter player's expected payoff is lower.

Application of the first part of Proposition 6 to Bertrand competition, which is one of the best known examples of a game with strategic complements, has the following implications. When the firms communicate with each other they promise to choose prices that are higher than the non-cooperative prices without communication. Since there is a possibility that each firm may renege on its promise, the prices that are actually chosen by the "dishonest" firms fall short of the corresponding promised prices but they are still higher than their levels in the game without communication. Finally, the firms' profits increase as a result of partial collusion under communication. One can easily draw implications of the second part for the Cournot model.

As we pointed out above, the communication does not affect the strategic interaction when both players are honest or dishonest with certainty. For Bertrand games with reputation levels between these two extremes, the communication allows the two firms to promise and set prices above their levels in the game without communication. Such outcome is preferred from the ex ante (before learning own type) and ex post (after learning own type) perspectives of the two firms. At the same time, it adversely affects the social welfare compared to the game without communication. From the ex ante point of view of the two firms, there are optimal levels of the firms' reputations for honesty that maximize their ex ante aggregate profit. The social welfare is likely to be relatively low under such reputation levels.

The application of our analysis to oligopolistic competition provides a channel for collusion that is distinct from the existing explanations. Most of the accounts of collusion are cast in dynamic settings (see, e.g., Green & Porter, 1984; Kreps et al., 1982; Maskin & Tirole, 1988a, 1988b). Similarly to the present paper, Melkonyan et al. (2018) study collusion in a static setting. The mechanisms behind collusion in Melkonyan et al. (2018) and the present paper are, however, completely different. Communication is not modeled in the former while it drives collusion in the latter. Melkonyan et al. (2018) consider a non-Nash equilibrium concept, coined virtual bargaining equilibrium (VBE), and demonstrate that Bertrand firms collude under VBE. In contrast, the present paper stays within the boundaries of orthodox analysis by focusing on a perfect Bayesian Nash equilibrium. Although partial collusion materializes in the present paper as well, the actual levels of prices chosen in the two frameworks are in general different. Furthermore, the VBE of Cournot competition coincides with the Nash equilibrium. In contrast, the perfect Bayesian Nash equilibrium of Cournot competition with communication is different from the Nash equilibrium of the corresponding game without communication. As we demonstrated above, it entails collusion under certain scenarios.

4 | CONCLUSION

The paper examined strategic interactions where players make promises about future actions. At the time when messages are exchanged, the parties are imperfectly informed about the economic and psychological costs of fulfilling their promises. We determine the effect that promises have on the strategic incentives in the subsequent interaction. These are different under strategic complementarity and strategic substitutability. Under the former, promising a less aggressive action makes a player's opponent respond less aggressively in the ensuing interaction. In contrast, under strategic substitutability, a promise of a relatively non-aggressive action evokes a more aggressive response by the opponent. This countervailing channel reduces the benefits of pre-play communication under strategic substitutability. For the case of strategic complements, pre-play communication, which can be interpreted as forming an informal agreement, leads to a Pareto improvement over the scenario without communication from the perspective of both players. In contrast, under strategic substitutability a player's expected payoff may be lower compared to the case with no communication. Thus, the interplay between communication and strategic environment, which has not received adequate attention in the existing literature, plays a key role on behavior and associated welfare outcomes.

In the case of Bertrand competition, the informal agreement allows the firms to partially collude on higher prices. The degree of collusion depends on the initial reputations for honesty as well as on demand and cost parameters. Interestingly, when the players have too much or too little reputation for honesty the players' ability to collude is restricted. When the players have very low reputations (π is close to 0), each player is believed with a very small probability and, as a result, the promises have a relatively small effect on the subsequent strategic interaction. When the players have very high reputations (π is close to 1), each player's promise is implemented with a very high probability. Since with a very high probability the strategic interaction effectively takes place during the communication stage and it is almost identical to the Bertrand game without communication, the promises are not effective instruments to collude on high prices for high initial reputations. In the limiting cases with completely honest or completely dishonest players, there is no room for collusion at all.

A number of important strategic interactions fall outside the classes of games with strategic complements and games with strategic substitutes. These include contests and many games of social cooperation and negotiation. It will be informative to examine how pre-play communication affects behavior. It will also be interesting to consider games with more than two players and examine how their number affects the effectiveness of informal agreements. There are a number of noteworthy extensions that involve richer informational structures including both ex ante (pre-communication) and ex post (post-communication) private information. In our model, each player is either completely honest or completely dishonest. In reality, some individuals may have certain predisposition for honesty but may renege on their promises when the benefits of doing so are sufficiently large. One way to model this possibility is by assuming that players have heterogeneous lying costs distributed over some interval of types. Our conjecture is that the equilibrium behavior in such interactions may have a "threshold form," where players whose lying costs are below some threshold level fulfill their promises while those above the threshold renege. It will be interesting to explore the relationship between the level of promised action and the threshold that emerges in the equilibria of such strategic interactions.[24]

In some interactions, individuals may have an opportunity to communicate both before and after learning their types.[25] Although there are a number of approaches to define an "honest" type in this kind of interaction, we focus on the definition of an honest type where the latter never makes new promises that contradict her previous promises and never chooses actions contradicting her promise. If the dishonest type mimics the honest type by repeating the latter's first and second promises (which are the same), this message does not reveal any information about that player's type and the strategic interaction has the same outcome as the model examined in the present paper. Under strategic complementarity, the dishonest type has a clear incentive to copycat the honest type since she gains from sending the same message under this scenario and any other message would be ignored. Furthermore, the honest type does not have an incentive to separate from the dishonest type. Thus, the interaction does not change from the addition of interim communication under strategic complementarity. The effect of interim communication on behavior seems to be more intricate for strategic substitutes and we leave to future research the investigation of the case where players can exchange messages twice in this case and whether such exchange can be beneficial to the players.

The natural next step is to test the model's predictions using a laboratory experiment. Designing an experiment with an information structure that resembles that of our model seems a challenging exercise. However, it has a large potential of shedding new light on the role of informal agreements in shaping strategic interactions.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

ENDNOTES

[1] In addition to psychological and short-run economic costs, lying may involve long-run economic costs. For example, a player may have an incentive to maintain or develop reputation for honesty so that she is later viewed in a positive light. We sidestep such long-run costs by analyzing a one-shot interaction.

[2] Similarly to the case of strategic complements, this finding is a result of the change in the players' "aggressiveness," as characterized by the slopes of their best-response curves.

[3] Ozkes and Hanaki (2019) find that free-form communication eliminates the "strategic environment effect" in the sense that their subjects exhibit the same level of collusion under strategic complementarity and strategic substitutability. However, they consider a different communication format and repeated interactions, which prevents a comparison of their experimental results with our theoretical predictions.

[4] The fine imposed by the UK Office of Fair Trade was later reduced to £58.5m.

[5] The content of the informal agreements in Kessler and Leider (2012) is exogenous and the first-best is one of the two action choices in the informal agreements. In contrast, the promised actions are endogenous in the present paper.

[6] In a typical model in the literature on pre-commitment, there is limited or no flexibility to reverse a choice of a variable once a commitment regarding that variable is made. Dixit (1980) and Kreps and Scheinkman (1983) are examples of complete ex post choice rigidity. For an example of limited flexibility, see, for example, Bade et al. (2009) where the players gradually restrict their actions. In contrast to these settings, we examine an environment with ex ante uncertainty about flexibility as an honest player is completely inflexible while a dishonest person is completely flexible.

[7] Note also that (ex ante and ex post) Pareto efficient outcomes are not achievable in our model.

[8] Thus, we assume that "a lie is a lie" so that the cost of lying, when it is not costless, does not depend on the magnitude of the lie. Although our assumption is reasonable under a variety of circumstances, there are situations where an individual's cost of lying is a strictly increasing function of the difference between the promised and implemented actions. For studies that model this type of cost functions, see, for example, Muthoo (1995), Battigalli and Dufwenberg (2009), and Miettinen (2013). We leave the examination of these interesting and important cases in our framework to future research.

[9] The term "type" is used in the same sense as Harsanyi (1967) only for the games starting at date 1 where each player learns her type.

[10] See the discussion of this issue in the paper's last section.

[11] The assumption that it is prohibitively costly for honest types to renege on previously made commitments is in line with many game theoretic models. For example, certain types are "non-strategic" in standard reputation models.

[12] Consider the sum of constant elasticity of substitution and affine functions: $u_1(x_1,x_2) = \left(\alpha x_1^r + \beta x_2^r\right)^{1/2r} + (\gamma x_1 + \delta x_2)$ for $0 < r \leq 1$, $\alpha \geq 0$, $\beta \geq 0$ and $\gamma \leq 0$. This function satisfies all of the restrictions imposed in this paragraph. It is characterized by strategic complementarity (substitutability) when $r < 0.5$ ($r > 0.5$). When $\delta > 0$, the payoff function exhibits a positive externality. When $\delta < 0$, there is a set X of (x_1,x_2) pairs such that the payoff function exhibits a negative (positive) externality on X (complement of X). Thus, this function satisfies the assumptions of our model and has the flexibility to allow for both strategic complementarity/substitutability and positive/negative externalities.

[13] To be more precise, one can first apply these conditions to the second stage of our game (where the players learn their types and subsequently choose their actions) and subsequently to the overall game.

[14] Cheap talk games are frequently characterized by multiple equilibria (e.g., Crawford & Sobel, 1982; Rabin, 1994). In the present paper, the talk is not cheap and communication has a different role. As a result, the considerations that give rise to multiplicity of equilibria in cheap talk games are not at play here.

[15] The Inada-type conditions imposed on the payoff functions ensure interior solutions.

[16] We chose this notation to preserve consistency with the corresponding notation when both players make promises.

[17] For illustration purposes, we demonstrate our findings using linear best-response functions that arise from quadratic utility functions. Note, however, that all of our findings hold for general utility functions.

[18] Formally, if the function $v(\sigma_i, \sigma_j)$, defined for $\sigma_i \in \mathbb{R}_+$, has strategic substitutes in (σ_i, σ_j) then the function $w(\eta_i, \sigma_j)$, where $\eta_i \equiv -\sigma_i$, exhibits strategic complements in (η_i, σ_j) for $\eta_i \in \mathbb{R}_-$.

[19] This condition is satisfied by payoffs under Bertrand competition, for example.

[20] Proposition 4 covers all possible permutations of strategic complements/substitutes and positive/negative externalities when the domain of actions and promises is $\mathbb{R}_+$. One can derive an analog of Proposition 4 for the domain $\mathbb{R}_-$ by reversing the order of both players' actions.

[21] $\breve{\sigma}_1^p$ and $\breve{\sigma}_2^p$ in Figures 5 and 6 are characterized in the proof of Proposition 4 in Supporting Information S2.

[22] As you will see in what follows, the main reason for considering this case and proving the following lemma is to demonstrate (in Proposition 6 below) that in the equilibrium both players make promises.

[23] We assume strict inequalities for the first- and second-order derivatives to break indifference of the players between making and non making promises.

[24] We thank an anonymous referee for suggesting this extension of our analysis. We leave a formal treatment of this environment to future research.

[25] In the rest of the paragraph it is assumed that at the time of the second exchange of messages, each player knows that her opponent knows own type. However, sometimes her opponent might be unaware about this and the equilibrium signal sent by a player after learning own type might be completely uninformative. In this case, the strategic interaction will yield equilibrium behavior akin to the one characterized in the present paper.

[26] Under our assumptions of single-crossing best-response curves, the equilibrium actions of the two players when the game is symmetric are identical; $\tilde{\sigma}_1^n = \tilde{\sigma}_2^n$. These assumptions also guarantee that the players choose the same actions in the game with communication, $\widehat{\sigma}_1(\widehat{\sigma}_1^p, \widehat{\sigma}_2^p) = \widehat{\sigma}_2(\widehat{\sigma}_1^p, \widehat{\sigma}_2^p)$, provided the players made the same promise.

REFERENCES

Abeler, J., Becker, A. & Falk, A. (2014) Representative evidence on lying costs. *Journal of Public Economics*, 113, 96–104. Available from: https://doi.org/10.1016/j.jpubeco.2014.01.005

Abeler, J., Nosenzo, D. & Raymond, C. (2019) Preferences for truth-telling. *Econometrica*, 87(4), 1115–1153. Available from: https://doi.org/10.3982/ecta14673

Allen, D.W. & Lueck, D. (1992) The back forty on a handshake: specific assets, reputation, and the structure of farmland contracts. *Journal of Law, Economics, and Organization*, 8, 366.

Amir, R. (2005) Supermodularity and complementarity in economics: an elementary survey. *Southern Economic Journal*, 71(3), 636–660. Available from: https://doi.org/10.1002/j.2325-8012.2005.tb00664.x

Amir, R. & Stepanova, A. (2006) Second-mover advantage and price leadership in Bertrand duopoly. *Games and Economic Behavior*, 55(1), 1–20. Available from: https://doi.org/10.1016/j.geb.2005.03.004

Bade, S., Haeringer, G. & Renou, L. (2009) Bilateral commitment. *Journal of Economic Theory*, 144(4), 1817–1831. Available from: https://doi.org/10.1016/j.jet.2009.03.004

Battigalli, P. & Dufwenberg, M. (2009) Dynamic psychological games. *Journal of Economic Theory*, 144(1), 1–35. Available from: https://doi.org/10.1016/j.jet.2008.01.004

Baumgartner, T., Fischbacher, U., Feierabend, A., Lutz, K. & Fehr, E. (2009) The neural circuitry of a broken promise. *Neuron*, 64(5), 756–770. Available from: https://doi.org/10.1016/j.neuron.2009.11.017

Ben-Porath, E. & Dekel, E. (1992) Signaling future actions and the potential for sacrifice. *Journal of Economic Theory*, 57(1), 36–51. Available from: https://doi.org/10.1016/s0022-0531(05)80039-0

Boccard, N. & Wauthy, X. (2004) Bertrand competition and Cournot outcomes: a correction. *Economics Letters*, 84(2), 163–166. Available from: https://doi.org/10.1016/j.econlet.2003.11.020

Bulow, J.I., Geanakoplos, J.D. & Klemperer, P.D. (1985) Multimarket oligopoly: strategic substitutes and complements. *Journal of Political Economy*, 93(3), 488–511. Available from: https://doi.org/10.1086/261312

Catonini, E. (2021) Self-enforcing agreements and forward induction reasoning. *The Review of Economic Studies*, 88(2), 610–642. Available from: https://doi.org/10.1093/restud/rdaa051

Charness, G. (2000) Self-serving cheap talk: a test of Aumann's conjecture. *Games and Economic Behavior*, 33(2), 177–194. Available from: https://doi.org/10.1006/game.1999.0776

Chung, B.W. & Wood, D.H. (2019) Threats and promises in bargaining. *Journal of Economic Behavior and Organization*, 165, 37–50. Available from: https://doi.org/10.1016/j.jebo.2019.07.002

Cooper, R., DeJong, D.V., Forsythe, R. & Ross, T.W. (1992) Communication in coordination games. *Quarterly Journal of Economics*, 107(2), 739–771. Available from: https://doi.org/10.2307/2118488

Crawford, V.P. (1982) A theory of disagreement in bargaining. *Econometrica*, 50(3), 607–637. Available from: https://doi.org/10.2307/1912604

Crawford, V.P. & Sobel, J. (1982) Strategic information transmission. *Econometrica*, 50(6), 1431–1451. Available from: https://doi.org/10.2307/1913390

Debey, E., De Houwer, J. & Verschuere, B. (2014) Lying relies on the truth. *Cognition*, 132(3), 324–334. Available from: https://doi.org/10.1016/j.cognition.2014.04.009

Dixit, A. (1980) The role of investment in entry-deterrence. *The Economic Journal*, 90(357), 95–106. Available from: https://doi.org/10.2307/2231658

Ellingsen, T. & Östling, R. (2010) When does communication improve coordination? *The American Economic Review*, 100(4), 1695–1724. Available from: https://doi.org/10.1257/aer.100.4.1695

Farrell, J. (1987) Cheap talk, coordination, and entry. *The RAND Journal of Economics*, 18(1), 34–39. Available from: https://doi.org/10.2307/2555533

Farrell, J. (1988) Communication, coordination and Nash equilibrium. *Economics Letters*, 27(3), 209–214. Available from: https://doi.org/10.1016/0165-1765(88)90172-3

Fonseca, M.A. & Normann, H.-T. (2012) Explicit vs. tacit collusion—the impact of communication in oligopoly experiments. *European Economic Review*, 56(8), 1759–1772. Available from: https://doi.org/10.1016/j.euroecorev.2012.09.002

Fudenberg, D. & Tirole, J. (1991) Perfect Bayesian equilibrium and sequential equilibrium. *Journal of Economic Theory*, 53(2), 236–260. Available from: https://doi.org/10.1016/0022-0531(91)90155-w

Gabay, D. & Moulin, H. (1980) On the uniqueness and stability of Nash-equilibria in noncooperative games. In: Bensoussan, A., Kleindorfer, P.R. & Tapiero, C.S. (Eds.) *Applied stochastic control in econometrics and management science*. New York: North-Holland, p. 271.

Gal-Or, E. (1985) First mover and second mover advantages. *International Economic Review*, 26(3), 649–653. Available from: https://doi.org/10.2307/2526710

Gamer, M. (2011) Detection of deception and concealed information using neuroimaging techniques. In: Verschuere, B., Ben-Shakhar, G. & Meijer, E. (Eds.) *Memory detection: theory and application of the concealed information test*. Cambridge: CambridgeUniversityPress, pp. 90–113.

Ghemawat, P. (1984) Capacity expansion in the titanium dioxide industry. *The Journal of Industrial Economics*, 33(2), 145–163. Available from: https://doi.org/10.2307/2098506

Gneezy, U. (2005) Deception: the role of consequences. *The American Economic Review*, 95(1), 384–394. https://doi.org/10.1257/0002828053828662

Gneezy, U., Rockenbach, B. & Serra-Garcia, M. (2013) Measuring lying aversion. *Journal of Economic Behavior and Organization*, 93, 293–300. Available from: https://doi.org/10.1016/j.jebo.2013.03.025

Green, E.J. & Porter, R.H. (1984) Noncooperative collusion under imperfect price information. *Econometrica*, 52(1), 87–100. Available from: https://doi.org/10.2307/1911462

Guardian (2007) BA fined £270m and now faces £300m lawsuit, 2 August, 2007. https://www.theguardian.com/business/2007/aug/02/britishairways.theairlineindustry1

Haltiwanger, J. & Waldman, M. (1991) Responders versus non-responders: a new perspective on heterogeneity. *Economic Journal*, 101(408), 1085–1102. Available from: https://doi.org/10.2307/2234428

Hamilton, J. & Slutsky, S. (1990) Endogenous timing in duopoly games: Stackelberg or Cournot equilibria. *Games and Economic Behaviour*, 2(1), 29–46. Available from: https://doi.org/10.1016/0899-8256(90)90012-j

Harsanyi, J.C. (1967) Games with incomplete information played by "Bayesian" players, I–III part I. The basic model. *Management Science*, 14(3), 159–182. Available from: https://doi.org/10.1287/mnsc.14.3.159

Hay, G. (1982) Oligopoly, shared monopoly, and antitrust law. *Cornell Law Review*, 67, 439–481.

Hunt, R.A. & Hayward, M.L. (2018) Value creation through employer loans: evidence of informal lending to employees at small, labor-intensive firms. *Organization Science*, 29(2), 284–303. Available from: https://doi.org/10.1287/orsc.2017.1182

Hurkens, S. (1996) Multi-sided pre-play communication by burning money. *Journal of Economic Theory*, 69(1), 186–197. Available from: https://doi.org/10.1006/jeth.1996.0043

Hurkens, S. & Kartik, N. (2009) Would I lie to you? On social preferences and lying aversion. *Experimental Economics*, 12(2), 180–192. Available from: https://doi.org/10.1007/s10683-008-9208-2

Jacquemet, N., Luchini, S., Rosaz, J. & Shogren, J.F. (2019) Truth-telling under oath. *Management Science*, 65(1), 426–438. Available from: https://doi.org/10.1287/mnsc.2017.2892

Kalai, A.T., Kalai, E., Lehrer, E. & Samet, D. (2010) A commitment folk theorem. *Games and Economic Behavior*, 69(1), 127–137. Available from: https://doi.org/10.1016/j.geb.2009.09.008

Kartik, N. (2009) Strategic communication with lying costs. *The Review of Economic Studies*, 76(4), 1359–1395. Available from: https://doi.org/10.1111/j.1467-937x.2009.00559.x

Kartik, N., Ottaviani, M. & Squintani, F. (2007) Credulity, lies, and costly talk. *Journal of Economic Theory*, 134(1), 93–116. Available from: https://doi.org/10.1016/j.jet.2006.04.003

Kessler, J.B. & Leider, S. (2012) Norms and contracting. *Management Science*, 58(1), 62–77. Available from: https://doi.org/10.1287/mnsc.1110.1341

Kreps, D.M. & Scheinkman, J.A. (1983) Quantity precommitment and Bertrand competition yield Cournot outcomes. *The Bell Journal of Economics*, 14(2), 326–337. Available from: https://doi.org/10.2307/3003636

Kreps, D. & Wilson, R. (1982) Sequential equilibrium. *Econometrica*, 50(4), 863–894. Available from: https://doi.org/10.2307/1912767

Kreps, D.M., Milgrom, P., Roberts, J. & Wilson, R. (1982) Rational cooperation in the finitely repeated prisoners' dilemma. *Journal of Economic Theory*, 27(2), 245–252. Available from: https://doi.org/10.1016/0022-0531(82)90029-1

Kuhn, K.U. (2001) Fighting collusion by regulating communication between firms. *Economic Policy: A European Forum*, 32(April), 167–197. Available from: https://doi.org/10.1111/1468-0327.00073

Kuhn, K.U. & Vives, X. (1995) *Information exchanges among firms and their impact on competition*. Luxemburg: Office for Official Publications of the European Community.

Ledyard, J.O. (1994) *Public goods: a survey of experimental research*. Munich: University Library of Munich.

Mailath, G.J. (2019) *Modeling strategic behavior: a graduate introduction to game theory and mechanism design*. World Scientific Books.

Maskin, E. & Tirole, J. (1988a) A theory of dynamic oligopoly, I: overview and quantity competition with large fixed costs. *Econometrica*, 56(3), 549–569. Available from: https://doi.org/10.2307/1911700

Maskin, E. & Tirole, J. (1988b) A theory of dynamic oligopoly, II: price competition, kinked demand curves, and Edgeworth cycles. *Econometrica*, 56(3), 571–599. Available from: https://doi.org/10.2307/1911701

Melkonyan, T., Zeitoun, H. & Chater, N. (2018) Collusion in Bertrand versus Cournot competition: a virtual bargaining approach. *Management Science*, 64(12), 5599–5609.

Mesquita, L.F. & Lazzarini, S.G. (2008) Horizontal and vertical relationships in developing economies: implications for SMEs' access to global markets. *Academy of Management Journal*, 51(2), 359–380. Available from: https://doi.org/10.5465/amj.2008.31767280

Miettinen, T. (2013) Promises and conventions–an approach to pre-play agreements. *Games and Economic Behavior*, 80, 68–84. Available from: https://doi.org/10.1016/j.geb.2013.03.002

Miettinen, T. (2020) A review on commitment tactics in bargaining under complete information. Prepared for the book "Current research and future directions in bargaining." Hyndman, K. and Karagözoglu, E. (eds.).

Milgrom, P. & Roberts, J. (1990) Rationalizability, learning, and equilibrium in games with strategic complementarities. *Econometrica*, 58(6), 1255–1278. Available from: https://doi.org/10.2307/2938316

Muthoo, A. (1995) A bargaining model with players' perceptions on the retractability of offers. *Theory and Decision*, 38(1), 85–98. Available from: https://doi.org/10.1007/bf01083170

Muthoo, A. (1996) A bargaining model based on the commitment tactic. *Journal of Economic Theory*, 69(1), 134–152. Available from: https://doi.org/10.1006/jeth.1996.0041

Ozkes, A. & Hanaki, N. (2019) *Talkin' bout cooperation*. Working Paper.

Polydoro, A. (2011) *A note on uniqueness of Bayesian Nash equilibrium for supermodular incomplete information games*. Mimeo, University of Rochester.

Potters, J. & Suetens, S. (2009) Cooperation in experimental games of strategic complements and substitutes. *The Review of Economic Studies*, 76(3), 1125–1147. Available from: https://doi.org/10.1111/j.1467-937x.2009.00548.x

Rabin, M. (1994) A model of pre-game communication. *Journal of Economic Theory*, 63(2), 370–391. Available from: https://doi.org/10.1006/jeth.1994.1047

Renou, L. (2009) Commitment games. *Games and Economic Behavior*, 66(1), 488–505. Available from: https://doi.org/10.1016/j.geb.2008.05.001

Romano, R. & Yildirim, H. (2005) On the endogeneity of Cournot-Nash and Stackelberg equilibria: games of accumulation. *Journal of Economic Theory*, 120(1), 73–107. Available from: https://doi.org/10.1016/j.jet.2003.12.005

Roy, S. & Sabarwal, T. (2010) Monotone comparative statics for games with strategic substitutes. *Journal of Mathematical Economics*, 46(5), 793–806. Available from: https://doi.org/10.1016/j.jmateco.2010.05.005

Sabarwal, T. (2021) *Monotone games: a unified approach to games with strategic complements and substitutes*. Palgrave Macmillan, Springer.

Sánchez-Pagés, S. & Vorsatz, M. (2007) An experimental study of truth-telling in a sender-receiver game. *Games and Economic Behavior*, 61(1), 86–112. Available from: https://doi.org/10.1016/j.geb.2006.10.014

Schelling, T.C. (1956) An essay on bargaining. *The American Economic Review*, 46, 281–306.

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

Topkis, M.D. (1998) *Submodularity and complementarity*. Princeton: Princeton University Press.

Ui, T. (2016) Bayesian Nash equilibrium and variational inequalities. *Journal of Mathematical Economics*, 63, 139–146. Available from: https://doi.org/10.1016/j.jmateco.2016.02.004

Van Bockstaele, B., Verschuere, B., Moens, T., Suchotzki, K., Debey, E. & Spruyt, A. (2012) Learning to lie: effects of practice on the cognitive cost of lying. *Frontiers in Psychology*, 3, 526. Available from: https://doi.org/10.3389/fpsyg.2012.00526

Van Damme, E. & Hurkens, S. (1999) Endogenous Stackelberg leadership. *Games and Economic Behavior*, 28(1), 105–129. Available from: https://doi.org/10.1006/game.1998.0687

Verschuere, B., Spruyt, A., Meijer, E.H. & Otgaar, H. (2011) The ease of lying. *Consciousness and Cognition*, 20(3), 908–911. Available from: https://doi.org/10.1016/j.concog.2010.10.023

Yannelis, N.C. (1998) On the existence of a Bayesian Nash equilibrium. In: *Functional analysis and economic theory*. Berlin: Springer, pp. 291–296.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Melkonyan, T. & Chakravarty, S. (2023) Pre-play promises, threats and commitments under partial credibility. *Economic Inquiry*, 1–21. Available from: https://doi.org/10.1111/ecin.13178