Cheap talk: Basic models and new developments

Cheap Talk: Basic Models and New Developments*

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1 INTRODUCTION

One of the most fundamental issues in modern economic theory is the role of private information in affecting economic outcomes. It is an undeniable fact of life that in a lot of situations, there is asymmetry of information amongst agents. Some agents are likely to have better knowledge than other agents about some parameter that is pertinent to the transaction they are involved in. This basic premise underpins the large literature on incentives, signalling, screening, contract theory and mechanism design. The assumption of informational asymmetries naturally leads us to the question of information transmission. All these models try to devise schemes to facilitate the flow of information from the better informed agent to the less informed party. Economic institutions like markets or other contractual agreements are judged by their relative efficiency in tackling adverse selection or moral hazard problems.

Without downplaying the necessity and the significance of such analyses of formal mechanisms and contracts, one might also be interested in knowing what happens in the absence of such mechanisms. After all, realistically, it is impossible to write down detailed contracts covering every possible contingency that might arise in every possible transaction involving every possible agent. In fact, in their day to day lives, people undertake lots of strategic actions that are not responses to an underlying explicit contract. In some of these situations involving asymmetric information, agents do reveal certain amounts of their private information without being forced to do so by a contractual scheme. They do so voluntarily and without incurring any costs. If we think about it, we will realize that so much interaction and information sharing happens by means of costless verbal communication of non-verifiable, non-binding messages that some serious attention in understanding these informal arrangements is definitely warranted. In particular, one might ask, is it possible to share any information through informal communication? Can plain and simple talk achieve anything? At first blush, the answer will seem to be in the negative because, since talk is cheap, why would anyone ever reveal the truth? Even if one claimed to swear by honesty, what reason does anyone have to believe such claims? Are there situations where talk is cheap and yet credible?

What if the game is such that the agent without the information takes an action that is bad for the informed player as well? This is likely to happen if their interests are not completely at odds. In such a situation, cheap talk can be informative and credible even though the players are still acting solely in their self-interests. The following examples by Farrell and Rabin (1996) illustrate this issue.

Suppose a firm is deciding on hiring Ashok in one of two positions. Job 1 demands high ability and Job 2 is more appropriate for a low ability person. Ashok's ability is his private information. The firm has 50-50 prior beliefs over Ashok's ability being high or low. This situation is represented in the following table. Corresponding to each ability type and job type, the payoffs are written (the first entry is Ashok's payoff and the second one is the firm's).

		Firm	
		Job 1	Job 2
Ashok's ability	High	$2, 1$	$0, 0$
	Low	$0, 0$	$1, 2$

This is an incomplete-information game, where Ashok can be one of two types, high or low, and only the firm has a payoff-relevant action. In this situation, there is in fact no need for using costly signals like education as in Spence (1973). Plain cheap talk can resolve the issue. We consider an initial cheap talk stage added to the original game where Ashok can say either "High" or "Low" after which the firm decides on which job to offer to Ashok. In this two stage game, the following strategies constitute a Perfect Bayesian Equilibrium. Ashok says "High" when his ability is high and "Low" when his ability is low. The firm believes what Ashok says and gives him Job 1 if he says "High" and gives him Job 2 if he says "Low". Ashok, here, has no incentive to lie or, in other words, each of Ashok's types is "self-signalling". In the absence of conflict in preferences, cheap talk is capable of conveying all the information.

Let us consider a slightly modified game as represented in the following table. Ashok, now, wants to get hired for Job 1 no matter what her true ability is.

		Firm	
		Job 1	Job 2
Ashok's ability	High	$2, 1$	$0, 0$
	Low	$2, 0$	$1, 2$

In this case, independent of his actual ability, Ashok always wants the firm to believe that he has high ability. As in the previous game, Ashok has preferences over the firm's beliefs, however here, these preferences are no longer correlated with the truth. Put differently, neither type of Ashok is "self-signalling". Cheap talk is no longer credible and fails to convey any information at all. In such circumstances, using costly signals *a la* Spence (1973) might be the only way to convey private information.

In these two examples, either the conflict in interest is so high that cheap talk fails absolutely or there is no conflict and cheap talk helps reveal the complete truth. What if there is some correlation between Ashok's true type and his preference over the firm's beliefs but also some degree of conflict? This is precisely the question that was first posed and analysed in the seminal paper by Crawford and Sobel (1982) (henceforth CS).

Suppose that now, Ashok's ability lies on a continuum. It is still private information to him. Given its beliefs about Ashok's ability, the firm will offer one of a continuum of jobs. If the firm thinks Ashok has higher ability, then it will employ him in a more demanding job and pay more. The firm starts off with some prior beliefs but might want to update those after hearing what Ashok has to say. Ashok likes money and so, he has an incentive to lie and claim his ability is higher than what it truly is. However, he does not want to exaggerate too much because then he won't be able to handle the corresponding job. For example, when his ability is θ, he might most prefer that the firm believes his ability is $\theta + b$, where b is a parameter known to both the players.

What can cheap talk achieve here? One might think, well, if the firm discounts Ashok's claim by some amount c because it knows that Ashok has an incentive to exaggerate about his ability, Ashok will just take that into account and claim his ability is $\theta + b + c$ and thereby obtain his most preferred job. But the firm will realize this and hence, will not believe Ashok's claim. This chain of reasoning leads one to the conclusion that in this situation, cheap talk seems useless. This conclusion is wrong because the reasoning is fallacious. If, instead, the firm is willing to believe only one of a limited set of things about Ashok's ability, then Ashok might realize that the only available exaggerations are too large to be worthwhile. Hence, cheap talk necessarily becomes imprecise and noisy. CS showed how in such a situation, imprecise cheap talk can indeed be an equilibrium provided that Ashok does not want to exaggerate too much (b is small enough). So, cheap talk manages to convey information but only partially. The extent and quality of information transmission depends clearly on how congruent Ashok and the firm's preferences are which, in this model, is captured by the parameter b.

This survey of the cheap talk literature begins by discussing the seminal paper by CS where we distinguish cheap talk from ordinary signalling games, outline its main results and then work out in some detail the leading example (the negative-quadratic utility case) of the paper to illustrate the results. CS provide a complete characterization of the set of equilibria in their model and identify the most informative equilibrium. All equilibria in their model are essentially equivalent to partition equilibria where only a finite number of actions are taken in equilibrium and each action corresponds to an interval of states. The amount of information transmitted in equilibrium decreases as the preference divergence increases. Next, we look at two-person bi-matrix games where again, one player is better informed than the other. Unlike CS, these games involve finite states and actions. We focus on Aumann-Hart (2003) and Forges (1990) and use their examples to show how equilibrium payoffs are expanded when we allow for multiple rounds of costless signalling. We then deal with a similar extension of the CS framework by Krishna and Morgan (2004a) where they use the leading example of CS to analyse what happens when the structure of communication is more extensive and can involve multiple stages.

In Section 3 we consider general communication mechanisms, where "cheapness" is retained but "talk" is replaced by some less direct system, like a mediator. We then provide a less detailed but exhaustive survey of the remaining cheap talk literature in Section 4.

2 MODELS

2.1 The Crawford-Sobel Model

As mentioned in the introduction, the strategic interaction and information transmission between an uninformed decision maker and an informed agent was first studied in the seminal paper by CS. In the CS model, the agent is informed about the realization of a payoff relevant state of nature (can be interpreted as his type) and then sends a costless, unverifiable message to the decision maker, who then takes a decision which affects the payoff to both parties. This is the basic sender-receiver game with "cheap talk". Communication is cheap because the messages are neither costly nor binding. The sender is free to mislead or tell the truth and the receiver may or may not believe the sender. CS show that when the two players' preferences are not perfectly congruent, full revelation is not possible. They provide a complete characterization of the set of equilibria in their model and identify the most informative equilibrium. All equilibria in their model are essentially equivalent to partition equilibria where only a finite number of actions are taken in equilibrium and each action corresponds to an interval of states. The amount of information transmitted in equilibrium decreases as the preference divergence increases.

We consider the uniform-quadratic utility CS Model, as presented in the literature (see for instance, Krishna and Morgan 2004a).

There are 2 agents. The informed agent, called the sender (S), precisely knows the state of the world, θ, where $\theta \sim U[0,1]$, and can send a possibly noisy signal at no cost, based on his private information, to the other agent, called the receiver (R). The receiver, however doesn't know θ but must choose some decision y based on the information contained in the signal. The receiver's payoff is $U^R(y,\theta) = -(y-\theta)^2$, and the sender's payoff is $U^S(y,\theta,b) = -(y-(\theta+b))^2$, where $b > 0$ is a parameter that measures the degree of congruence in their preferences.

CS have shown that any equilibrium of this game is essentially equivalent to a partition equilibrium where only a finite number of actions are chosen in equilibrium and each action corresponds to an element of the partition. For $b < \frac{1}{2N(N-1)}$, where $N \geq 2$ is an integer,[1] there is an equilibrium in which the state space is partitioned into N elements, characterised by $0 = x_0 < x_1 < x_2 < \ldots\ldots < x_{N-1} < x_N = 1$, where $x_k = \frac{k}{N} + 2bk(k-N)$, in which S sends a message for each element $[x_{k-1}, x_k)$, and given this message, R takes the optimal action $y_k = \frac{x_{k-1}+x_k}{2}$. We call this the N-partition CS equilibrium.[2] For such an equilibrium, the receiver's expected payoff is $EU^R = -\frac{1}{12N^2} - \frac{b^2(N^2-1)}{3}$ while the sender's expected payoff is $EU^S = EU^R - b^2$.

Example 1 *Take $b = \frac{1}{10}$. The best CS equilibrium involves a partition with two elements. It is easy to check that the 2-partition CS equilibrium is characterised by $y_1 = \frac{3}{20}$, $y_2 = \frac{13}{20}$, and*[3] *$x = \frac{3}{10}$. Here, $EU^R = -\frac{37}{1200}$ and $EU^S = -\frac{49}{1200}$.*

2.2 Long Cheap Talk *a la* Aumann-Hart

In most applications and extensions of the theory of cheap talk since the CS model, modelers have allowed for at most one message from each player. Is this restriction a serious one? Can multiple rounds of talk achieve different outcomes? This is what motivates Aumann and Hart (2003) (henceforth referred to as AH).

AH study how cheap talk expands the set of equilibrium outcomes but unlike

[1] For $\frac{1}{4} \leq b \leq 1$, babbling is the only equilibrium.

[2] For $\frac{1}{2N(N+1)} \leq b < \frac{1}{2N(N-1)}$, the "best" equilibrium (the one that maximises EU^R) has the state space partitioned into N elements.

[3] We drop the subscript in x_1 in the 2-partition CS equilibrium for presentational simplicity in the rest of the paper.

most other papers in the literature, they do so without imposing any restrictions on the number of rounds of cheap talk that are permissible. They call this kind of communication, consisting of possibly infinite rounds, "long cheap talk". They show that indeed, long cheap talk may give rise to outcomes that are Pareto superior to all outcomes that are achievable with just a single message. In their paper, they characterize all the equilibrium outcomes in any two-person bi-matrix game (with finite states and actions) in which one player is initially better informed than the other. The characterization is mathematically quite abstract and employs the geometric concepts of *diconvexity* and *dimartingales* (Aumann and Hart 1986) in order to compute the equilibrium payoffs. These complex notions are beyond the scope of this section. Instead, we shall look at some of the examples in AH that illustrate how long cheap talk might work.

In these examples, nature chooses one of several two-person games in strategic form (bi-matrices), using a commonly known probability distribution. The chosen one is the *true* bi-matrix. The row player, Rohan, knows the true bi-matrix , but the column player, Kolika, does not. This is the *information phase.* The players then talk to each other for as long as they wish. This is the *talk phase.* After the talk phase, each player takes a single action (i.e. chooses a row or column) in the true bi-matrix. This is the *action phase.* The players then receive the payoffs that the true bi-matrix prescribes for their actions. This whole process is called the *long cheap talk game.*

One might wonder, what can Kolika possibly say? After all, she doesn't have any private information to reveal. Indeed, she is the less informed party and is the only one who has anything substantive to learn (i.e. information about exogenous parameters). While this is true, Kolika can help matters by participating in what is technically called a *joint lottery* and this device will involve messages sent jointly by both the players. So, although Kolika is not revealing any information (as we already know, she has none to reveal), she is talking to help carry out randomizations and agreements on which the long cheap talk mechanism crucially depends. The entire talk phase can be thought of as a series of revelations by Rohan and in between these revelations, the players carry out joint lotteries to come to an agreement as to what or whether further revelations will occur in the next step. Of course, all these have to be optimal given one another in order to be in equilibrium. In fact, in any given equilibrium, the revelations and agreements must occur in a particular order. Changing the order in the sequence will disrupt the equilibrium. The following examples should illuminate.

Example 2

	LL	L	C	R	RR	
T	$0, 10$	$1, 8$	$0, 5$	$1, 0$	$0, -8$	$\frac{1}{2}$

	LL	L	C	R	RR	
B	$0, -8$	$1, 0$	$0, 5$	$1, 8$	$0, 10$	$\frac{1}{2}$

This example is a finite action-finite state version of the CS model. Rohan and Kolika are playing one of two bi-matrix games, T or B, with probability $\frac{1}{2}$ each. Rohan knows the true game they are playing but Kolika does not. Kolika has to choose among LL, L, C, R or RR. Rohan has no action to choose. Before choosing an action, Kolika may talk with Rohan, who may reveal some information if he so wishes. Rohan is free to mislead Kolika and Kolika cannot verify Rohan's statements. If there is no informative communication before playing the game, Kolika's prior probabilities for T and B are $\frac{1}{2} - \frac{1}{2}$ and so, her best choice is C. This is not good news for Rohan because he then gets zero. If Rohan fully reveals which bi-matrix, T or B, is the true game being played, then Kolika will choose either LL or RR, depending on what the truth is. But, in that case as well, Rohan gets zero. In order to do better and get the payoff of 1, Rohan has to motivate Kolika to choose either L or R. Rohan can achieve such an outcome by means of partial revelation. For example, he can use a noisy channel which will convey the truth with probability $\frac{3}{4}$. From Bayes' rule, Kolika's posterior probability for T is then either $\frac{3}{4}$ or $\frac{1}{4}$, according to whether T or B is the true game. As a result, Kolika will choose either L (for truth = T) or R (for truth = B). By using this strategy, Rohan is now guaranteed a payoff of 1.

This example just demonstrates the CS idea. Sometimes, one might not want to reveal everything because there is some conflict of interest. At the same time, not revealing anything might also not be in the best interests of the informed player. Cheap talk can help via partial revelation. The cheap talk equilibrium payoff $(1, 6)$ Pareto dominates the silent game payoff $(0, 5)$.

Example 3

$$
T \quad \begin{array}{c|c|c|c|}
\multicolumn{1}{c}{} & \multicolumn{1}{c}{L} & \multicolumn{1}{c}{R} & \multicolumn{1}{c}{A} \\
\cline{2-4}
U & 6,2 & 0,0 & 3,0 \\
\cline{2-4}
D & 0,0 & 2,6 & 3,0 \\
\cline{2-4}
\end{array} \quad \frac{1}{2}
$$

$$
B \quad \begin{array}{c|c|c|c|}
\multicolumn{1}{c}{} & \multicolumn{1}{c}{L} & \multicolumn{1}{c}{R} & \multicolumn{1}{c}{A} \\
\cline{2-4}
U & 0,0 & 0,0 & 4,4 \\
\cline{2-4}
D & 0,0 & 0,0 & 4,4 \\
\cline{2-4}
\end{array} \quad \frac{1}{2}
$$

What can cheap talk do in this game? Well, it can help Rohan and Kolika achieve an expected payoff of 4. Here's how. If the true bi-matrix is T, they can conduct a $\frac{1}{2} - \frac{1}{2}$ joint lottery to decide whether to play UL or DR and if the game is B, Kolika plays A. For this to work, Kolika needs to know which is the true game. Rohan's claims will be credible, though, only if he tells Kolika the true game *before* conducting the lottery. If instead, the lottery is performed first, and it prescribes DR in T, and the true game is indeed T, then Rohan has an incentive to lie and claim that the game is actually B; this would lead Kolika to play A, giving Rohan 3 instead of the 2 he would get from being honest. So, the order in which the revelation and the joint lottery occur is absolutely crucial.

This is the first example where we require more than one round of communication. Here, the first round of cheap talk is Rohan's revelation as to which is the true game and the second round of cheap talk is essentially the performance of the lottery. It is crucial that the lottery is jointly controlled and the outcome jointly observed so that the players are satisfied that the probabilities are indeed $\frac{1}{2} - \frac{1}{2}$. How can one conduct such a lottery even when there is no random device with jointly observed outcomes? An easy solution is to have a simultaneous exchange of messages by the two players. In the second round of the talk phase, Rohan and Kolika can each send the messages a and b with probability $\frac{1}{2}$ each; then, in the action phase, they play UL if the messages were the same (aa or bb) and DR if the messages were different (ab or ba). The probability of each event is $\frac{1}{2}$ and neither player can by himself change this and once the outcome of the lottery is jointly observed, unilateral deviations from the prescribed play will lead to a loss. So, these strategies are in equilibrium.

Example 4

	LL	L	C	R	RR	
T	$1, 10$	$3, 8$	$0, 5$	$3, 0$	$1, -8$	$\frac{1}{2}$

	LL	L	C	R	RR	
B	$1, -8$	$3, 0$	$0, 5$	$3, 8$	$1, 10$	$\frac{1}{2}$

Although this game is similar in structure to the one in Example 4, some of the payoffs here have been slightly modified. With no cheap talk, the unique equilibrium payoff is still $(0, 5)$. With cheap talk, partial revelation yields $(3, 6)$, which is Pareto superior to $(0, 5)$. But, now, with cheap talk, full revelation is also an equilibrium. Rohan just tells Kolika the true game, Kolika plays either LL or RR, as the case may be and this yields a payoff of $(1, 10)$ which is also Pareto superior to $(0, 5)$. Clearly, in the talking game, Rohan prefers the first equilibrium and Kolika likes the second equilibrium more. What they can do is come to a compromise and decide on which equilibrium to play by tossing a fair coin. This will lead to a payoff of $(2, 8)$. Note, that the compromise or lottery has to precede the signalling. This is again an example with two rounds of communication but the order of signalling and compromising is different from the one in the last example.

Example 5

	LL	L	C	R	RR	A	
T	$1,10$	$3,8$	$0,5$	$3,0$	$1,-8$	$2,0$	$\frac{1}{3}$

	LL	L	C	R	RR	A	
B	$1,-8$	$3,0$	$0,5$	$3,8$	$1,10$	$2,0$	$\frac{1}{3}$

	LL	L	C	R	RR	A	
BB	$0,0$	$0,0$	$0,0$	$0,0$	$0,0$	$2,8$	$\frac{1}{3}$

This example has an equilibrium with three rounds of cheap talk. In the first round, Rohan makes a partial revelation as to whether the true game is BB or not. If it is BB, then no further talk takes place, Kolika plays A and they get the payoff of $(2,8)$. If the game is not BB, then the game is similar to the game in Example 6. One can again check that having a joint lottery followed by either a full or partial revelation by Rohan is an equilibrium and we already know that the corresponding payoff will be $(2,8)$ as well. So, the talking game's equilibrium can potentially involve a first round of signalling, a second round of compromising (the lottery) and a third round of further signalling.

The joint lottery cannot come before the first revelation because if it did and the outcome prescribed full revelation in the third round (thus giving Rohan a payoff of 1), then Rohan would have an incentive to lie in the first revelation stage and claim that the true game is BB even when it is not. Kolika would then play A and Rohan would be assured a payoff of 2 in both T and B. We have already seen from the last example that the joint lottery cannot occur after the second revelation. So, the equilibrium works only if it follows the correct sequence of signalling and compromising.

Example 6

	LL	L	C	R	RR	
T	$6, 10$	$10, 9$	$0, 7$	$4, 4$	$3, 0$	$\frac{1}{2}$

	LL	L	C	R	RR	
B	$3, 0$	$4, 4$	$0, 7$	$10, 9$	$6, 10$	$\frac{1}{2}$

This example is due to Forges (1990a). Without any cheap talk, Kolika is motivated to choose C and Rohan gets a payoff of 0. If Rohan is allowed to send only one message (i.e. only one round of cheap talk), he can fully reveal the truth; Kolika will then choose either LL or RR depending on what that truth is and Rohan gets a payoff of 6. Can Rohan do even better by using more rounds of cheap talk? The answer is in the negative if the permissible number of rounds is finite. The surprising result is that Rohan can indeed improve on the payoff of 6 only if unboundedly long conversations are allowed. In fact, there is an equilibrium yielding $(7, 9\frac{2}{7})$. We refer interested readers to the original paper by Forges (1990a) to see how this equilibrium is derived.

All the examples in this subsection point to the potential benefits of having multiple (possibly unboundedly long) rounds of cheap talk. The key insight in all such examples is the use of multiple stages of revelation combined with rounds involving joint lotteries. The exact sequence in which this combination of signalling and compromising has to take place is well defined and specific to a particular equilibrium. This kind of mechanism can vastly expand the set of achievable equilibrium payoffs.

2.3 The Krishna-Morgan Model

Although AH generalize and allow for up to an infinite number of rounds of communication, their characterization concerns two-player games with finite states and actions only. Also, the equilibrium characterization is geometric in nature and mathematically quite abstract. As a result, the theory's applicability to specific strategic situations and economic problems is not immediately apparent. It is also not clearly discernible how and when and under what conditions Pareto improvements can occur from the long cheap talk procedure of AH.

Krishna and Morgan (2004a) (henceforth KM), on the other hand, tackle an analogous problem with a continuum of states and actions but are less ambitious in terms of generality of the communication procedure. They consider the CS model and introduce *only one* additional round of communication (to be defined properly later) between the two agents. They employ a similar insight and a comparable technique as AH to show how the equilibrium payoffs of both the sender and the receiver can (almost) always be improved over their CS payoffs. Interestingly, they identify the source of these Pareto gains to be the degree of risk-aversion of the sender. This is somewhat surprising because the key to the AH insight is the usage of joint lotteries as randomization devices and additional uncertainty usually doesn't accord well with risk-aversion.

Here, we describe only a particular example to illustrate the mechanism of the KM model. Consider the same setting as in Example 1. We know from CS what the most informative equilibrium looks like with just one round of communication from the sender to the receiver. The KM model introduces an additional round of what they call "face-to-face" communication between the two agents. This face-to-face meeting consists of a simultaneous exchange of messages from each agent and is nothing but a stage that combines partial revelation and a joint lottery akin to the ones seen in AH. The following strategies are an equilibrium of this modified game.

In the first round, which is the face-to-face meeting, the sender sends a message revealing whether θ is above or below $x = \frac{2}{10}$. Furthermore, the sender and the receiver send simultaneous messages to each other in order to perform a *jointly controlled lottery*. This lottery is devised in a manner such that one can derive two events from it, say, success and failure, which occur with probabilities p and $1 - p$ (p will be determined as a part of the equilibrium).

In the second round, the sender may send an additional message to reveal some further information, depending on the outcome of the joint lottery. If the sender reveals in the first round that $\theta \leq \frac{2}{10}$, then all other messages are ignored and the receiver chooses a low action $y_L = \frac{1}{10}$ that is optimal given this information. On the other hand, if the sender reveals that $\theta > \frac{2}{10}$, then whether further revelation takes place in the subsequent round depends on which one of the two events, success or failure, that we mentioned before, occur after the joint lottery. In the event of a failure, which happens with probability $1-p$, nothing more is revealed and the receiver chooses the "pooling" action $y_P = \frac{6}{10}$ that is optimal given $\theta > \frac{2}{10}$. In the event of a success, which happens with probability p, the sender reveals in the second round of communication whether θ belongs to $\left[\frac{2}{10}, \frac{4}{10}\right]$ or $\left[\frac{4}{10}, 1\right]$. In the first subinterval, the medium action $y_M = \frac{3}{10}$ is taken and in the second subinterval, the high action $y_H = \frac{7}{10}$ is taken.

Without the uncertainty induced by the joint lottery, such a partition of the state space cannot be sustained as an equilibrium. When the state $\theta = \frac{2}{10}$, the sender strictly prefers y_M to y_L and y_L to y_P (i.e. $y_M \succ y_L \succ y_P$). So, there must exist a probability p such that when $\theta = \frac{2}{10}$, the Sender is indifferent between y_L and a $p : 1-p$ lottery between y_M and y_P. One can easily check that for all $\theta < \frac{2}{10}$, the sender will prefer y_L to this lottery and for all $\theta > \frac{2}{10}$, the sender will prefer the lottery to y_L. Therefore, these strategies are indeed incentive compatible. For this example, $p = \frac{5}{9}$.

This equilibrium transmits more information from the sender to the receiver than the best CS equilibrium (as in Example 1). In fact, in terms of ex ante expected payoffs, this equilibrium is Pareto superior to the best CS equilibrium. Here, $EU^R = -\frac{36}{1200}$ and $EU^S = -\frac{48}{1200}$.

The fact that additional uncertainty causes the welfare of risk-averse agents to improve is, at the first glance, surprising. But, as KM argue, it is precisely the risk-aversion that is the cause of the Pareto improvement. Intuitively, the reasoning is as follows: when $\theta = \frac{2}{10}$, in order to keep a *more* risk-averse sender indifferent between y_L and a $p : 1-p$ lottery between y_M and y_P, it is necessary to put *more* weight on the better action y_M. In other words, the probability of a successful conversation, p, has to increase when the degree of risk-aversion increases. For welfare to improve, this gain in probability must be sufficient to compensate for the loss of welfare arising from the event of failure and, keeping everything else fixed, the increased risk-aversion. When the sender is sufficiently risk-averse, the gains outweigh the last two effects, giving rise to Pareto superior equilibria.

3 MEDIATED TALK

It should be noted that cheap talk in the CS model (as well as in almost all subsequent models of cheap talk) is a direct form of communication. The sender directly talks to the receiver. There is no third party involved. A direction of generalization is the subject of general communication mechanisms, where "cheapness" is retained but the "talk" is replaced by a somewhat less direct system, like a mediator. The question we discuss in this section is what would happen if the services of a third party could be used? Can a mediator facilitate communication and would there be an improvement in information transmission?[4]

Ganguly and Ray (2005) (henceforth GR) introduce a mediator in the CS sender-receiver game. The mediator is impartial and not a strategic player. All that the mediator does is receive input messages from the sender and then send output messages to the receiver. So, instead of directly talking with the receiver, the sender now sends whatever information he wants about his privately known state of nature to the mediator and the mediator then makes some recommendations about actions to be taken by the receiver. The mediator may use randomizations when determining the output messages as functions of input messages. All messages are private, i.e., each message is known only to its sender and receiver. Of course, the sender may choose to lie or withhold information and the receiver is again free to follow or not follow the recommendations made by the mediator. Talk is still cheap but indirect unlike in CS.

General communication mechanisms with mediation have been studied else-

[4] This is somewhat similar to the issue of whether there exist correlated equilibria (Aumann 1974, 1987) of a normal form game that can improve upon the Nash equilibrium payoffs, the answer to which is in the work by Moulin and Vial (1978).

where (see, among others, Forges 1986, 1990b; Myerson 1982, 1986). It is worth noting that unlike those general mechanisms, here the mediator does not receive inputs from or send outputs to all the players.

It can be shown that if there is no restriction on the number of messages that the mediator can receive and send, then there exist mediated equilibria which improve on the most informative CS equilibrium (Krishna and Morgan 2004a). GR examine whether the mediator can do better than the most informative CS equilibrium when the mediator is restricted to use the same number of input and output messages as in the best CS equilibrium for a given preference divergence parameter. Why would one want to impose this kind of a constraint on the mediator? One obvious explanation is to appeal to the amount of complexity that a mediator can handle. If there are bounds on the information processing capacity of a mediator, then it is natural to ask if hiring a mediator instead of relying on direct communication is worthwhile. If increased complexity comes with a cost, then these costs have to be traded off for the benefits associated with a more sophisticated mediator.

3.1 Mediated Equilibrium

Following GR, we, in this subsection, formally present a mediated talk in which the mediator is restricted to use only 2 inputs and 2 outputs. Such a 2×2 mediated talk is given by $(x, y_1, y_2, p_{11}, p_{12}, p_{21}, p_{22})$, where, x, y_1, $y_2 \in (0,1)$, $p_{11}, p_{12}, p_{21}, p_{22} \in [0,1]$ and $p_{11} + p_{12} = 1$, $p_{21} + p_{22} = 1$. For such a talk to be an equilibrium, the incentive compatibility conditions must be satisfied. The incentive compatibility for the sender requires that $(p_{21} - p_{11})(y_1 - y_2) > 0$ and $\frac{y_1+y_2}{2} - x = b$. Note that the inequality is automatically satisfied as long as $y_1 \neq y_2$. The incentive compatibility constraints for the receiver imply the following two equations:

$$(1 - p_{12})[x(2y_1 - x)] + p_{21}[(1 - x)(2y_1 - x - 1)] = 0 \tag{1}$$

$$p_{12}[x(2y_2 - x)] + (1 - p_{21})[(1 - x)(2y_2 - x - 1)] = 0 \tag{2}$$

which can be written as:

$$y_1 = \frac{(1-p_{12})x^2 + p_{21}(1-x^2)}{2[(1-p_{12})x + p_{21}(1-x)]} \tag{3}$$

$$y_2 = \frac{p_{12}x^2 + (1-p_{21})(1-x^2)}{2[p_{12}x + (1-p_{21})(1-x)]} \tag{4}$$

We can combine all the incentive constraints into the following equation:

$$\frac{(1-p_{12})x^2 + p_{21}(1-x^2)}{4[(1-p_{12})x + p_{21}(1-x)]} + \frac{p_{12}x^2 + (1-p_{21})(1-x^2)}{4[p_{12}x + (1-p_{21})(1-x)]} - x = b \tag{5}$$

A mediated equilibrium hence is characterised by 3 variables (p_{12}, p_{21}, x), where, $x \in (0,1)$, and $p_{12}, p_{21} \in [0,1]$ satisfying (5).

Example 7 *Take $b = \frac{1}{10}$ as in Example 1.*[5] *It is easy to check that $y_1 = \frac{19}{50}$, $y_2 = \frac{31}{50}$, and $x = \frac{4}{10}$ with $p_{11} = \frac{4}{5}$, $p_{12} = \frac{1}{5}$, $p_{21} = \frac{3}{10}$, $p_{22} = \frac{7}{10}$ constitute a 2×2 mediated equilibrium. The utilities are: $EU^R = -\frac{517}{7500}$ and $EU^S = -\frac{592}{7500}$. Recall from Example 1 that for the 2-partition CS equilibrium, $EU^R = -\frac{37}{1200}$ and $EU^S = -\frac{49}{1200}$; that is, this 2×2 mediated equilibrium does not improve upon the CS equilibrium.*

Motivated by the above example, GR prove that the 2-partition CS equilibrium cannot be improved upon by a 2×2 mediated equilibrium when b is small ($b < \frac{1}{8}$). Of course, one can construct an example of a 2×2 mediated equilibrium that can improve upon the 2-partition CS equilibrium when b is large enough ($\frac{1}{8} \leq b < \frac{1}{4}$). The following example illustrates.

Example 8 *Take $b = \frac{1}{6}$. Here, the 2-partition CS equilibrium is characterised by $\{x = \frac{1}{6}, y_1 = \frac{1}{12}, y_2 = \frac{7}{12}\}$ with utilities $EU^R = -\frac{7}{144} = -0.04861111$ and $EU^S = -\frac{11}{144} = -0.07638888$. It is easy to check that $\{x = 0.2245201023, y_1 =$*

[5] Note that there exists a 2-partition CS equilibrium for $b < \frac{1}{4}$ and for $\frac{1}{12} \leq b < \frac{1}{4}$ the best CS equilibrium involves 2-partition.

$0.1745967377, y_2 = 0.6077768002, p_{11} = 0.97, p_{21} = 0.04\}$ *constitute a mediated equilibrium. The utilities here are* $EU^R = -0.04826241093$ *and* $EU^S = -0.076040188707$*. This mediated equilibrium thereby does improve upon the 2-partition CS equilibrium.*

3.2 Illustration of the Result

In this subsection, we formally illustrate the GR result for a 2×2 mediated equilibrium. It is easy to see that the CS partition equilibrium is equivalent to a mediated equilibrium and it can be identified as a "corner point" of the set of all such equilibria. GR show that the optimum of this set is attained at this corner point when the value of the parameter is small enough. To understand the result, consider the constrained maximization problem:

$$\begin{aligned}
\underset{x,p_{12},p_{21}}{\text{Maximize}} 3EU^R &= -(1-p_{12})[y_1^3 - (y_1 - x)^3] \\
&\quad -p_{12}[y_2^3 - (y_2 - x)^3] - p_{21}[(y_1 - x)^3 - (y_1 - 1)^3] \\
&\quad -(1-p_{21})[(y_2 - x)^3 - (y_2 - 1)^3] \qquad (6)
\end{aligned}$$

subject to the constraint (5), and set up the Lagrangian:

$$\begin{aligned}
L &= -(1-p_{12})[y_1^3 - (y_1 - x)^3] - p_{12}[y_2^3 - (y_2 - x)^3] \\
&\quad -p_{21}[(y_1 - x)^3 - (y_1 - 1)^3] - (1-p_{21})[(y_2 - x)^3 - (y_2 - 1)^3] \\
&\quad +\lambda \left\{ b - \frac{(1-p_{12})x^2 + p_{21}(1-x^2)}{4[(1-p_{12})x + p_{21}(1-x)]} - \frac{p_{12}x^2 + (1-p_{21})(1-x^2)}{4[p_{12}x + (1-p_{21})(1-x)]} + x \right\} \qquad (7)
\end{aligned}$$

It is easy to check that

$$\begin{aligned}
\frac{\partial L}{\partial x} &= 3(1 - p_{21} - p_{12})[(y_2 - y_1)(y_2 + y_1 - 2x)] \\
&\quad + \frac{\lambda}{4} \left\{ \begin{array}{c} 4 - \frac{(1-p_{12}-p_{21})[(1-p_{12})x^2 - p_{21}(1-x)^2]}{[(1-p_{12})x + p_{21}(1-x)]^2} \\ - \frac{(p_{12}+p_{21}-1)[p_{12}x^2 - (1-p_{21})(1-x)^2]}{[p_{12}x + (1-p_{21})(1-x)]^2} \end{array} \right\} \qquad (8)
\end{aligned}$$

$$
\begin{aligned}
\frac{\partial L}{\partial p_{21}} &= [(y_2-x)^3-(y_2-1)^3]-[(y_1-x)^3-(y_1-1)^3] \\
&\quad -\frac{\lambda}{4}\left\{\begin{array}{c} \frac{(1-p_{12})x(1-x)}{[(1-p_{12})x+p_{21}(1-x)]^2} \\ +\frac{p_{12}x(x-1)}{[p_{12}x+(1-p_{21})(1-x)]^2} \end{array}\right\} \qquad (9)
\end{aligned}
$$

$$
\begin{aligned}
\frac{\partial L}{\partial p_{12}} &= [y_1^3-(y_1-x)^3]-[y_2^3-(y_2-x)^3] \\
&\quad -\frac{\lambda}{4}\left\{\begin{array}{c} \frac{p_{21}x(1-x)}{[(1-p_{12})x+p_{21}(1-x)]^2} \\ +\frac{(1-p_{21})x(x-1)}{[p_{12}x+(1-p_{21})(1-x)]^2} \end{array}\right\} \qquad (10)
\end{aligned}
$$

We want to achieve $p_{12}=p_{21}=0$, $x=\frac{1}{2}-2b$, $y_1=\frac{x}{2}$, $y_2=\frac{1+x}{2}$ as the solution to the above maximization problem. To do this, it suffices to show that at these values, there exists λ such that $\frac{\partial L}{\partial x}=0$, $\frac{\partial L}{\partial p_{21}}<0$, and $\frac{\partial L}{\partial p_{12}}<0$. Setting $p_{12}=p_{21}=0$, $\frac{\partial L}{\partial x}=0$ we get $\lambda=-6b$. Then, using $\lambda=-6b$, we have, $\frac{\partial L}{\partial p_{12}}=-\frac{6x}{8}-\frac{6b}{4}\frac{x}{(1-x)}<0$ and finally, $\frac{\partial L}{\partial p_{21}}=\frac{3}{8}\frac{(1+4b)(8b-1)}{(1-4b)}<0$ only when $b<\frac{1}{8}$. Thus CS equilibrium is the solution to the maximization problem if $b<\frac{1}{8}$.

4 RELATED LITERATURE

Since the seminal analysis by CS, the literature on cheap talk and other communication schemes have burgeoned with growing interest especially in recent years. An excellent way to start one's journey into this challenging and stimulating world of cheap talk is to look at preexisting surveys (Farrell 1995; Farrell and Rabin 1996; Crawford 1998). The following is a list of some of the important work done in this area.

The basic cheap talk paradigm of CS, where there is one sender and one receiver and an one-dimensional state space, has been extended in various directions. Extensions include introducing multiple senders (Gilligan and Krehbiel 1989; Austen-Smith 1993; Krishna and Morgan 2001a, 2001b), multiple receivers (Farrell and Gibbons 1989a), multi-dimensional state spaces (Seidmann 1990;

Chakraborty and Harbaugh 2003, Forthcoming; Levy and Razin 2004) as well as multiple senders combined with a multi-dimensional state space (Battaglini 2002). We have already mentioned the issue of multiple rounds of cheap talk (Aumann and Hart 2003; Krishna and Morgan 2004a; R. Vijay Krishna 2004).

The problem of equilibrium refinement, as opposed to equilibrium expansion, by means of cheap talk has been studied by several authors. Some assume the existence of a common language (Myerson 1989; Rabin 1990; Matthews, Okuno-Fujiwara and Postlewaite 1991; Farrell 1993; Blume and Sobel 1995; Rabin and Sobel 1996; Zapater 1997) while others use evolutionary stability considerations (Blume, Kim and Sobel 1993; Kim and Sobel 1995; Banerjee and Weibull 2000) or perturbation techniques (Blume 1994).

The sender-receiver framework of CS where only one agent has private information and only one agent chooses a payoff relevant action is also restrictive. What is the role of cheap talk in more general games, e.g., two-player games where both might have private information and both can indulge in cheap talk and both can take decisions or choose actions? Such questions have been pursued in a complete information environment (Rabin 1994; Santos 2000) as well as in an incomplete information setting (Matthews and Postlewaite 1989; Austen-Smith 1990; Banks and Calvert 1992; Baliga and Morris 2002; Baliga and Sjostrom 2004).

General communication systems or mechanisms, consisting of a non-strategic "mediator", like the one described in the previous section, have been a source of interest to many authors (Myerson 1989; Lehrer 1996; Lehrer and Sorin 1997; Krishna and Morgan 2004a; Ganguly and Ray 2005). In two-player games of complete information with finite states and actions, general mechanisms lead to all correlated equilibria (Aumann 1974, 1987), whereas, long cheap talk leads only to all weighted averages of Nash equilibria (Aumann and Hart 2003) which is a smaller set. However, when there are more than two players, under certain assumptions, it is possible to achieve through cheap talk what a mediator can do. With complete information, essentially all correlated equilibrium payoffs in the original game are Nash equilibria in an appropriately defined cheap talk game and in the case of incomplete information, all equilibrium outcomes of general communication mechanisms are Nash equilibria of an appropriately defined cheap talk game (Forges 1986, 1990a, 1990b; Myerson 1986, 1991; Barany 1992; Ben-Porath 1998, 2003; Gossner 1998; Gossner and Vieille 2001; Urbano and Vila 2002, 2004a, 2004b; Gerardi 2004).

A different avenue of research considers what happens when a static cheap talk game is repeated. Repetition gives rise endogenously to reputational concerns and this might impose additional constraints on what can be communicated via cheap talk (Sobel 1985; Benabou and Laroque 1992; Morris 2001; Avery and Meyer 2003; Ottaviani and Sorensen 2003; Olszewski 2004). Analysing cheap talk in this repeated framework would require us to make assumptions about the nature of these reputational concerns. Does the Sender care about appearing to be well informed or does he want to be perceived as not having a large conflicting bias? He might have a bigger incentive to mask the truth and create a false perception now because this will affect his future credibility and hence future payoffs.

The theory of organization design (e.g., finding out the optimal hierarchical structure of a firm or the degree of delegation) has mostly focused on explicit state contingent complete contracts, mechanisms based on verifiable claims and different monetary incentive schemes. But it is well accepted now that incomplete contracts, informal word-of-mouth arrangements and the issues of non-verifiability, complexity and lack of commitment have a profound and complex influence on the functioning of most organizations. Cheap talk and other related communication protocols can shed light on some of these issues (Melumad and Reichelstein 1989; Melumad and Shibano 1991; Ottaviani 2000; Dessein 2002, 2003; Avery and Meyer 2003; Dessein and Santos 2003).

Embedding cheap talk in various other environments can provide us with more interesting insights. Cheap talk may be combined with "not-cheap" talk (Austen-Smith and Banks 2000; Kartik 2003). Cheap talk can also be used alongside communication that is "certifiable" or "verifiable" to a certain degree (Okuno-Fujiwara, Postlewaite and Suzumura 1990; Seidmann and Winter 1997;

Koessler 2003, 2004; Forges and Koessler 2005). Cheap talk amongst boundedly rational agents (Ottaviani and Squintani 2002; Crawford 2003) or agents who are uncertain about the degree of conflict in their preferences (Avery and Meyer 2003; Wolinsky 2003) throw up new questions that need to answered. Further unexplored territory can be sought out by analysing other general communication games (Spector 2000; Glazer and Rubinstein 2001; Dewatripont and Tirole 2003).

Most of the aforementioned work is of a purely theoretical nature. This is not to imply that applications of cheap talk to real life economic problems are unimportant or haven't received sufficient attention. In fact, much of the renewed interest in cheap talk games in recent times can be traced to increased applications of such models in diverse environments. These include the analysis of problems from political science (like legislative debates, committee hearings and voting procedures in governmental bodies), auctions, industrial organization, bargaining, announcements by the Chairman of the Central Bank of a country regarding monetary and exchange rate policies as well as advice given by experts in financial markets.[6] Experiments to test some of the predictions of the theoretical models have also been carried out (Crawford 1998; Blume, Dejong and Sprinkle 2001; Costa-Gomes 2002).

[6] See for example, Baron 2000; Chakraborty, Gupta and Harbaugh 2002; Crawford 1990; Farrell 1987; Farrell and Gibbons 1989b, 1995; Gautier and Paolini 2000, 2002; Krishna and Morgan 2004b; Kydd 2003; Li Ming 2003; Li Tao 2004; Matthews 1989; Morgan and Stocken 2003; Palfrey and Srivastava 1991; Stein 1989; Vidal 2003).

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