Meaningful talk*

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Abstract

The standard approach to language in economics is that talk is cheap. Here, instead, language is a social convention that affects utility. We apply this approach to the market for lemons. When the buyer and the seller arrange to meet, the words they use are signs that carry a conventional meaning, and talk is effective if mutual trust exists. Uninformative equilibria only come about with completely pessimistic expectations. In the negotiation stage, uninformative equilibria disappear if misrepresentation is costly. Utility leads words to become signals.

Resumen. En economía el enfoque estándar es tratar al lenguaje como pura sanata. Aquí en cambio el lenguaje es una convención social que afecta las preferencias. Aplicamos este enfoque al mercado de los "lemons". Cuando se encuentran vendedor y comprador, las palabras que usan son signos que transmiten un significado convencional, por lo que la comunicación es efectiva si hay confianza mutua. Los equilibrios no informativos sólo aparecen con expectativas absolutamente pesismistas. En la etapa de negociación, los equilibrios no informativos desaparecen si el engaño es costoso. Las preferencias convierten las palabras en señales.

JEL classification codes: D8, C7

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"Wisdom, which is invisible but sustains, is worth a hundred times more than the appearance of wisdom, since this appearance must, in turn, be sustained." Anonymous Sufi saying, quoted in Gilbert Sinoué, *Le livre des sagesses d'Orient*, 2000.

1 Introduction

The standard approach to language in economics is that talk is cheap. As Schelling (1960, p. 117) puts it, "Moves can in some way alter the game, by incurring manifest costs, risks, or a reduced range of subsequent choice; they have an information content, or *evidence* content, of a different character from that of speech. Talk can be cheap, when moves are not." For instance, burning the bridges behind us can convincingly communicate to the enemy that our troops are not going to retreat (Schelling 1960, p. 158), a commitment that a mere statement to that effect cannot convey. Using Schumpeter's (1942, p. 264)

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paradoxical terms, "Since the first thing man will do for his *ideal or interest* is to lie, we shall expect, and as a matter of fact we find, effective information is almost always adulterated or selective." [italics added][1] Succinctly, the standard view in economics is that misrepresentation is a pervasive problem.

We concentrate on unilateral communication, where a sender provides information to a receiver. In this setup, Crawford and Sobel (1982) formalize language as cheap talk to study the maximal amount of information an expert (the informed party) may offer the decision maker (the uninformed party) when there are incentives to lie. Cheap talk sets language apart from signals: while signals are credible because choices are differentially costly, words are not because they have no direct payoff consequences (see, e.g., Gibbons 1992 and Krishna and Morgan 2005).

Farrell (1993) points out a more fundamental problem in using cheap talk to communicate: its meaning cannot be learned from introspection, so any permutation of messages across meanings gives another equilibrium. So even when an equilibrium is informative, a major coordination problem subsists: the use of language is arbitrary, corresponding to ad hoc conventions established in each particular instance. For that reason, cheap talk models concentrate on beliefs induced in equilibrium, not on equilibrium messages (see, e.g., Wang 2009). This state of affairs strikes us as odd, given how even we as economists use language routinely to arrange a meeting. The use of natural language for coordination purposes is pervasive in markets, suggesting that it reduces transaction costs. Nobody involved expects a communication breakdown, otherwise, why bother saying anything at all?

Instead, our approach to language incorporates two features. First, as in semiotics, words are symbols, i.e., they carry an arbitrary but conventional meaning. This meaning may be reliable or not, but it is certainly comprehensible to players that share the same natural language. If these conventions are not followed, the costs of deciphering the message may be insurmountable. Second, as in psychology, words are not something objective that allows to communicate in an inexpensive way, but rather a highly subjective phenomenon. We explore in particular what happens if people differ in character, and some sellers dislike misrepresenting information.

To analyze a typical market transaction, we apply our approach to the classic Akerlof (1970) lemons model of a market with asymmetric information where there is an incentive for misrepresentation. We first ask how the seller and the buyer actually get to meet. Since the lemons market is decentralized, the pre-play communication game is a coordination game where there is a potential surplus from trade if both parties meet.

In coordination games, cheap talk models implicitly ignore the costs of deciphering messages. In our approach, the only salient interpretation of a seller's messages is of language in its ordinary sense (which even so may give rise to misunderstandings!); otherwise, a coordination failure ensues from the myriad of potential interpretations. What is at stake with language here is not its meaning, but rather its credibility. Abstracting from the concrete messages that may be sent, the communication equilibria are of two types: with mutual trust, communication is successful and leads to coordination; with distrust, communication fails. Mutual trust requires a minimal probability that both sender and receiver abide by the conventional meanings. Once subjective costs of language are introduced, a minimal probability that some sellers have an infinitesimal cost of misrepresenting intentions also suffices to discard the distrust equilibrium. Words now are not only meaningful signs, they also become signals.

In the second stage game, despite asymmetric information and an incentive to misrepresent quality, market participants share a common language: sellers who want to cheat buyers do not to pick the

[1]Mitchell (1984, p. 82) discusses how Schumpeter applies this insight to political advertising.

message "This is a lemon", but rather "This car is great". Why do those who lie overstate quality in equilibrium? Deciphering costs, as well as subjective costs of honesty, act as an anchor for meaning.

This paper relates to cheap talk models with both biased and unbiased experts, like Wang (2009); however, natural language plays no role there. Once the sender suffers disutility from misreporting private information, Kartik, Ottaviani and Squintani (2007) point out that this transforms the game from cheap talk to costly signaling. That is the case here, where, for psychological reasons, words are signals. Our analysis of senders closely relates to Callander and Wilkie (2006), where there are either honest or dishonest candidates, and the utility of honest candidates depends on campaign promises. All campaign platforms have some informative content about postelectoral intentions, a result that implies babbling equilibria are eliminated. Our costs of misrepresentation resemble the fixed (but heterogenous) honesty costs in Demichelis and Weibull (2007), but honesty there only enters lexicographically to break ties in material gains.

On the side of the receivers, this paper develops an insight in Farrell (1993) on the difference between ciphered codes and natural languages. Our point is that ciphers increase transaction costs. If deciphering costs are large enough, language becomes useless as coordination devices. That is additional, semantic, reason for why senders may have a strict preference for the use of natural language.

We describe the first stage coordination game between buyer and seller, before moving to the market for lemons that takes place in the second stage. In our setup there is two-dimensional asymmetric information, because sellers differ both in product quality and honesty. We analyze a discrete case before turning to the double continuum.

2 How do buyer and seller meet?

We first analyze the pre-play communication stage where buyer and seller arrange to meet. They are playing *rendez-vous*, a game of coordination: if they successfully meet, both parties can share the expected gains from trade.

We start by the communication problem that arises if language is cheap talk. Not only are there babbling equilibria, there are an endless number of informative equilibria using different codes. Cheap talk ignores the costs for the receiver of deciphering messages in informative equilibria where shared conventions are not used. Once these costs are taken into account, natural language provides the only informative equilibrium.

If natural language is the means of communication in markets, it becomes apparent that what is at issue in coordination games is not if language is understood, since natural language is composed of signs that carry a conventional meaning; what is at issue is whether messages are credible. If mutual trust exists, the coordination problem is solved through language; communication breaks down and there is a coordination failure only if there is absolute distrust. Furthermore, if there is a positive probability that words affect utility of some individuals, the only possible Nash equilibrium turns out to be a trust equilibrium. Hence, though a distrust equilibrium is possible, it does not resist the slightest trembles.

2.1 Cheap talk

For the buyer and seller, arranging a meeting time and place is a pure coordination game where there is an expected surplus if they meet, and none if they don't. Without loss of generality, the expected payoffs for both players from meeting can be normalized to 1, and, from not meeting, to 0.[2]

The following messages take place before buyer and seller get together in the second stage: (i) the seller posts an ad in the newspaper, with the quality of the car and a phone number; and (ii) the buyer calls the phone number listed in the ad, and the seller announces the place and time of meeting.[3]

In this stage we ignore the issue of quality, since the incentives for misrepresentation are addressed in the second stage. This leaves four pieces of information that must be conveyed from the seller (the sender) to the buyer (the receiver) in the first stage: that what is for sale is a car, the seller's phone number, the meeting time, and the meeting place. When talk is cheap, the coordination problem remains unabated. Instead of saying that a car is for sale, the seller might instead put an ad saying that a horse is for sale; instead of the true phone number, the digits could be randomly scrambled, and so on.

Since the conceptual problem of cheap talk is the same for each piece of information, we concentrate on the problems of communicating the meeting time and place. Schelling's (1960, pp. 55-56) most famous example of tacit coordination involves precisely two people who have to meet at an unspecified hour in an unspecified spot of New York. Instead of using focal points to tacitly coordinate among multiple Nash equilibria, one might think that talking beforehand over the phone is a much more trivial method of coordination. This is a game of imperfect information, since the receiver does not see the actual move of the sender, but verbal information about its stated intention is available. The possible meeting times and places are countless, but the key stumbling block turns out to be that, for each possible meeting time and place, the possible messages are also countless.

There may be cheap talk equilibria that are either uninformative, so the outcome corresponds to the mixed strategy equilibrium of the coordination game, or informative, so the outcome corresponds to one of the countless pure strategy equilibria. Our reservation about these equilibria is that in either case the exact words are irrelevant, because beliefs in cheap talk games are determined by equilibrium strategies, however that fact might be communicated from player to player in equilibrium. In other words, if these beliefs do not come from verbal communication between the players, it remains utterly unclear to us how these beliefs originate at all.

Figure 1 represents an uninformative equilibrium where the sender adopts two actions with positive probability in equilibrium, meeting left (L) or right (R) at noon. We represent the minimal messages possible, meeting left ("L") or right ("R").

<*Figure 1: Uninformative pooling equilibrium*>

In the uninformative, or babbling, equilibria, all sellers are expected to say the same thing, so the buyer does not pay attention to the equilibrium messages, and verbal communication does not prevent a coordination failure. There is nothing to give words any weight at all. We do not represent either out-of-equilibrium moves or other messages, but similar responses of the receiver at other information sets assure there is no incentive for the sender to deviate.

[2]We will later assume for simplicity, as is standard in the lemons model, that in the second stage the gains from trade accrue to sellers. This will imply that any transaction costs of putting an ad and arranging a meeting is borne by the seller. All actual sellers will have an expected surplus from trade that exceeds these transaction costs, else they would drop out of the market.

[3]This is the bare minimum of messages required to arrange the meeting. If the buyer needed to take a cab, for example, a taxi driver would need to be informed of the point of encounter.

As to the informative equilibria, though there is one equilibrium where words are used in their conventional sense, Figure 2 represents one of the innumerable "unnatural" informative equilibria where words are used in an arbitrary sense. Nobody can take any message at face value in any of these equilibria.

<Figure 2: Informative separating equilibrium>

Fixing the moves L and R, this informative equilibrium is only one of countless unnatural equilibria: the exact words are irrelevant, because beliefs are determined by the equilibrium strategies, each of which is associated to an arbitrary equilibrium message, regardless of how that association might be communicated from player to player. Random responses by the receiver at any other information set assure there is no incentive of the sender to deviate to out-of-equilibrium moves and messages.

The sheer multiplicity of informative perfect Bayesian Nash equilibria leaves us just where we started, Schelling (1960). Selection arguments suggest that the only focal point is the informative equilibrium where the natural language is used, i.e., where meeting left ("L") is used for the move L, and meeting right ("R") is used for the move R. We now explore a different argument to rule out the unnatural uninformative equilibria.

2.2 Deciphering signs

We first characterize the messages in our game resorting to the categories used in semiotics, as describe in Chandler (1994). In semiotics, words are symbols, a type of signs that are characterized by being purely arbitrary or conventional. Drawing on Ferdinand de Saussure's diadic model, and Charles S. Peirce's triadic model, of signs, these linguistic symbols are composed of three elements:[4]

(i) the signifier, a sequence of letters or sounds (e.g., the word 'lemon');

(ii) the signified, the concept that appears in our mind when we read or hear the signifier; and

(iii) the referent, the actual object a sign refers to.

The signified and the referent are also called intension (or connotation) and extension (or denotation). Without intension of some sort, words have no meaning.[5]

Though the signifier or sign vehicle is only a part of the whole, it is also customary to refer to the signifier as the "sign". For Saussure signs make sense as part of a system, in our case words are part of a language. Though words, and the whole language, are in a sense arbitrary, in another they are not: we are born into them. Language is socially and historically determined, giving rise to natural languages specific to each society: in English the words "left" and "right" are used to describe the moves L or R, in Spanish the words "izquierda" and "derecha" are. So while a language is a set of conventions (i.e., a code) to communicate meaning, it is a shared convention.[6] If a language is to be a useful coordinating device, the conventions in that language must be shared by market participants. If messages are not conveyed in a language common to all players, communication becomes a game of second-guessing, whose consequences are ignored in cheap talk.

As an example, Figure 2 is artificial in its assumption that, of all the potential moves, the sender will choose in equilibrium between only two choices, and that this may be communicated by one of two messages. This is not a good depiction of the concrete problem the receiver faces. The sender may

[4] See also http://en.wikipedia.org/wiki/Sign_(linguistics).

[5] See http://en.wikipedia.org/wiki/Intension.

[6] See also http://en.wikipedia.org/wiki/Code_(Semiotics.

potentially choose any time and place in the city, and may communicate this choice with any message that is potentially communicable. This double combination compounds the original problem of tacit coordination discussed by Schelling (1960), so in this setting the possibility of talking only complicates the coordination problem, because cheap talk introduces the need of deciphering messages, a task more suited to intelligence agencies than to market participants.

Given the receiver's ignorance of the senders intentions, a better way to describe the receiver's priors is that it believes the sender may play a random strategy where any potential time and place in the city is equally likely. Because of graphical limitations, Figure 3 only represents two of the possible actions, L and R, where the priors are that each action is adopted with probability $1/N$, and two of the possible messages, "L" and "R". This is a game of imperfect information, since the receiver does not see the actual move of the sender.

<Figure 3: Informative separating equilibrium where words are used in natural sense>

The receiver can, as Farrell (1993) notes, *understand* the different words the sender utters if a natural language is used.[7] However, Farrell does not apply this insight to the meaning of words in equilibria. There may be innumerable unnatural informative equilibria, the problem we address here. There is no salient interpretation if the words are not used in their conventional sense. In unnatural informative equilibria of a cheap talk game, this leads to an insoluble coordination problem for the receiver, since if the plain meaning of the message is not relevant, no other meaning is obvious. For example, if the message "Meet me at noon at the information booth of Grand Central Station" is not to be interpreted in a literal sense, no other meaning springs to mind to establish how to interpret the messages. This is a one-time event, so any other use of words throws both back to a coordination failure.

In light of this, cheap talk models actually do not model natural language, but rather ciphers, i.e., symbols whose meanings are artificially determined by their use in each equilibrium of each particular game using Bayes' rule (see Farrell 1993). This viewpoint ignores the insurmountable costs of figuring out and deciphering messages that market participants would face, which destroys the possibility of using talk as a cheap coordination device.

These deciphering costs imply that the only informative equilibrium that remains is the one where language is used in its natural sense. If there is the least chance that a sender is using language in the natural sense, babbling equilibria can be done away, because they do not resist the slightest tremble. We now look at this in a model that is stripped down to the bare essentials.

2.3 Communicating intentions

Since the possible moves, and the possible messages, are unbounded, a way of graphically representing the communication game in natural language that captures the gist of the matter is to completely ignore the specific moves and messages. After all, neither party is particularly interested in these details. The

[7] Farrell (1993) uses the insight that words in natural language have a meaning to show how unexpected out of equilibrium messages have a focal meaning. For Farrell, these messages destroy uninformative pooling equilibria of coordination games because they are credible. However, we show below these uninformative equilibria can subsist if expectations are utterly pessimistic. Demichelis and Weibull (2007) interpret Farrell (1993) in the sense that credibility is a property of the message, while they analyze honesty in the context of what they call the meaning correspondence (the relation between the announced message and the intended action). We follow this latter, semiotic, approach.

essential elements to coordinate a meeting are the sender's verbal message, and the receiver's reaction to that message.

Figure 4 ignores the content of the specific verbal messages, presenting the coordination problem in terms of a unilateral communication game where the seller may reveal or not the truth, and the buyer may believe or not the seller's message.[8] This is a game of imperfect information on actions, but there is verbal information on intentions. There are coordination failures if the message is not believed by the receiver, or if the message is distorted by the sender, whether the message is believed or not, because the plethora of alternatives block any alternative interpretation.

<Figure 4: Communicating intentions in coordination games>

In any distrust equilibrium where the seller sends a false message, and the buyer does not believe the message, both parties are unable to coordinate a meeting by verbal means alone. These can be characterized as "distrust" equilibria. There are a plethora of such equilibria, for example the seller can say it will be at the meeting place at twelve, when it intends to be there at 3 p.m., or to never go there at all. These equilibria correspond to the outcome of a mixed strategy equilibrium: with a indefinite number of meeting times and places, the possibility of encounter is nil.

On the other hand, in a "trust" equilibrium the seller reveals its true intentions, and the buyer believes the message. In these equilibria, verbal communication now makes a huge difference with respect to a game where both players cannot communicate. Mutual trust is blind, like faith: the receiver cannot observe the action of the sender, only the statement, but the very fact that the receiver believes the message of the sender makes the sender willing to mean what it says. An outside observer will not be able to predict which move X will take place, but after the telephone conversation where the sender says "X", the receiver will have clear expectations about the sender's move. From the receiver's point of view, it is a question of playing the pure strategy equilibrium singled out by the sender's verbal message.

What determines whether buyer and seller will end up in an optimistic, trust, equilibrium, or in a pessimistic, distrust, equilibrium? If all senders are charlatans, absolutely nothing. However, if the receiver gives an infinitesimal probability to the belief that the sender may be saying the truth, the distrust equilibrium is destroyed, because the sender has an incentive to say the truth. That is to say, the bad equilibrium does not resist the slightest trembles, so it is not a trembling hand equilibrium. This same argument holds in the more complicated setup of Figure 3, where two of the possible moves and messages are represented, if one analyzes any candidate babbling equilibrium.

In the trust equilibrium of the communication game, words carry their conventional meaning in a reliable way precisely because mutual trust confers words that role. In this regard, the semantic content of words can be understood as the result of the shared commitment by individuals of using words according to accepted social conventions, and of interpreting words according to those same codes.

2.4 Utility of words

When all sellers are charlatans, a distrust equilibrium is theoretically possible if somebody is utterly pessimistic about being believed. This setup can be generalized to introduce a cost of misrepresentation, however slight, where words affect utility. Arranging a meeting between buyer and seller becomes a game

[8] In Figure 4, we are ignoring messages that are incomprehensible, an instance where credibility is not at stake, because the message has no obvious interpretation to start with.

of imperfect and incomplete information, since the buyer does not know either the action (place and time selected) or the type of the seller (charlatan or slow), but verbal signs are available. Figure 5 shows verbal communication that takes place under imperfect and incomplete information.

<Figure 5: Communicating intentions in coordination games with incomplete and imperfect information>

Suppose the ability of misrepresentation varies, so a slow type decreases utility by ε if it is necessary to imagine a message "$m\prime$" that differs from the intention m. Once there is a positive probability there is a slow type that means what it says, the equilibrium is a trust equilibrium. Slow types have a dominant strategy, so what they say can be taken at face value. Given that the payoff to the buyer of believing the message is strictly larger than not believing it, charlatans also have an incentive to strictly say the truth.[9]

Once some sellers have an infinitesimal cost ε from thinking about saying something different from their true intentions, words are not only signs, they become signals. However, the semantic content of words is still determined by the fact that we are in a trust equilibrium, which only requires the not overly optimistic assessment that at least somebody uses language in a literal sense. A distrust equilibrium is only possible with extremely pessimistic expectations about both types and actions, for example, somebody who is disenchanted with human society and does not believe in anybody's word anymore. We explore in more detail how words become signals in the lemons model.

3 The negotiation stage

In a setup with a discrete number of types, we rephrase Akerlof's (1970) well known lemons model of markets, where the gains from trade may not be realized due to asymmetric information, as a cheap-talk game. We extend the lemons model by adding honest sellers. Our analysis has implications for verbal communication and the informative content of language. First, from a semantic point of view, we find that deciphering costs pin down the possible equilibria. Alternatively, and in line with previous work by Callander and Wilkie (2006) and Kartik et al. (2007), when words affect utility they become signals that might also pin down the number of equilibria.

3.1 Two-dimensional asymmetric information

Akerlof (1970, p. 495) introduces a model of asymmetric information which allows to make some comments on the cost of dishonesty: "*Consider a market in which goods are sold honestly or dishonestly; quality may be represented, or it may be misrepresented. The purchaser's problem, of course, is to identify quality. The presence of people in the market who are willing to offer inferior goods tends to drive the market out of existence –as in the case of our automobile 'lemons'. ... The cost of dishonesty, therefore, lies not only in the amount by which the purchaser is cheated; the cost also must include the loss incurred from driving legitimate business out of existence.*"

Not only are gains from trade prevented by dishonesty. A cost we study here is that, when all agents are dishonest, language loses meaning and becomes cheap talk. The outcome of the lemons model can

[9] If there were a cost in being trustworthy, e.g., because of being stood up, this result has to be changed to the statement that receivers believe there is a sufficiently high proportion of truthful senders in the population to compensate these costs.

in fact be interpreted as part of a cheap talk equilibrium where all sellers state they have a high quality product, regardless of actual quality. But if language is cheap talk, sellers could alternatively state they have a low quality product. Indeed, the precise words become irrelevant. This leads to a plethora of babbling equilibria. We first show how small deciphering costs are able to pin down one uninformative equilibrium, when the deciphering costs of a given message are increasing in the number of alternatives to that message that are possible.

Not all owners of lemons may be willing to misrepresent quality. Indeed, the relevance of differences in character is suggested by Akerlof (1970, pp. 498-9), when he points out that in credit markets of underdeveloped countries local moneylenders have personal knowledge of the character of the borrower that outside middlemen do not. Accordingly, we then analyze market exchange under incomplete information about quality when some people have a distaste for misrepresenting the truth. We allow individuals to differ in the quality of the good they provide, and in their personal character. This implies a framework where both the outcome and the process followed to reach it affect utility.

There is a continuum of sellers of measure 1. Each seller owns a unit of a product of quality $\theta_i \in \Theta = \{\theta_L, \theta_H\}$, where $\theta_H > \theta_L$. The quality is known to the seller, but not to the buyer, at purchase time. The opportunity cost of each seller is $\alpha\theta_i$, with $\alpha < 1$, so there are potential gains from trade, and $\alpha\theta_H > \theta_L$, so a market breakdown is possible. Each seller has an unobservable characteristic, honesty $h \in H = \{0, \chi\}$. While dishonest sellers are willing to lie about the quality of their product if that helps them sell it more profitably, honest sellers consider that unfair. Momentarily, we assume that the cost of lying χ for honest agents is larger that the greatest potential benefit $\theta_H - \theta_L$, so these sellers voluntarily reveal the quality of their product (otherwise, the equilibrium results are not affected). Buyers have no way of distinguishing between honest and dishonest sellers because honesty is unobservable, which leads to two-dimensional asymmetric information. The set of types thus includes the quality of the product and the honesty of the sellers: $T = \Theta \times H = \{\theta_L, \theta_H\} \times \{0, \chi\}$, with typical element $t = (\theta_i, h)$.

We assume that quality and honesty are independently distributed, though the only crucial requirement is that the probability of honest sellers with lemons be positive. Table 1 presents the distribution of types, where $1 - r$ is the proportion of honest sellers, and $1 - q$ is the proportion of lemons.[10] Later we will assume there is a continuum of qualities and honesty types.

		Honesty	
		$h = 0$	$h = \chi$
Quality	θ_L	$(1-q)r$	$(1-q)(1-r)$
	θ_H	qr	$q(1-r)$

Table1:Distribution of types

The utility function of each type of seller depends on the price p of the product offered by the buyer and the message m that it sends:

$$U_S(\theta_i, h, m, p) = p - \alpha\theta_i - C(\theta_i, h, m),$$

where the function $C(.)$ represents the personal cost of dishonesty:

[10] Stein and Streb (2004) and Streb (2005) introduce similar two-dimensional asymmetric information setups with the aim of analyzing how it affects the informativeness of signals.

$$C(\theta_i, h, m) = \begin{cases} h, & \text{if } m \neq \theta_i \\ 0, & \text{otherwise} \end{cases}.$$

Sellers with larger h suffer a higher cost of misrepresenting quality. An alternative interpretation, more in line with the cheap talk models, is that different people have different abilities at cheating others, with some people particularly gifted at fooling others, so the parameter h could reflect the lack of this ability (this was the interpretation in the coordination game, where slow types have an ε-cost of distorting messages, unlike charlatans who have no cost at all).

The timing is that, after nature determines type, the seller sends a message about the quality of the product, to which the buyer answers with a price offer. The seller can then accept or reject this offer. Though in a cheap talk model the seller can send any message, for now we restrict the messages to θ_H, interpreted as "This is a high quality product", and θ_L interpreted as "I must warn you this is a lemon". Formally, the message space is $M = \Theta = \{\theta_L, \theta_H\}$, with typical element m, and the strategy of the sellers is a function $m_S(t)$.

For each message the buyer forms a conjecture $\mu(m)(\theta_i)$ about the product quality of the seller that has sent the message, which we interpret as the buyer's belief that the seller that sends the message θ_i has a product of quality θ_i. The buyer makes a price offer $p \in [\theta_L, \theta_H]$ after observing message m. We denote by $p_B(m)$ the price offer the buyer makes. Since the buyer can play a mixed strategy, $p_B(m)$ is a probability distribution. In order to abstract from the bargaining problem, we assume buyers are risk neutral and are willing to pay the average quality offered on the market.[11]. Sellers will only accept a price offer greater or equal than their opportunity cost, and since buyers are foward looking they introduce this restriction in their conjectures. We denote by $\tilde{\mu}(m,p)(\theta_i)$ the buyer's conjecture that the quality of the product will be θ_i when it observes message m and offers price p. Note the difference between $\mu(m)$ and $\tilde{\mu}(m,p)$. While $\mu(m)$ is the buyer's belief about the product quality of the seller that has sent the message m, $\tilde{\mu}(m,p)$ is the buyer's belief about the product quality he will effectively recieve when he offers the price p and the seller that has sent the message m.

3.2 Deciphering costs and cheap-talk

The Akerlof (1970) lemons model can be interpreted as a cheap talk game where the message space is given by the possible qualities of the good. All sellers are dishonest, i.e., $r = 1$. Buyers know that the product is high quality with probability $q > 0$ and low quality with probability $1 - q > 0$. Since buyers are willing to pay θ_i for a quality i product and sellers are willing to sell it at $\alpha\theta_i$, there is a potential gain from trade of $(1-\alpha)\theta_i > 0$. The seller can state that the product is either low or high quality. This can be represented as a cheap-talk game in Figure 6, because the message itself has no cost to the seller.

<Figure 6: Cheap-talk game, where responses to message"high quality" or "low quality" can be high price, intermediate price or low price, and the seller can say yes or no>

Though buyers can make a continuum of price offers p in the interval $[\theta_L, \theta_H]$, in Figure 6 we only represent three offers for $m \in \{\theta_L, \theta_H\}$: $p \in \{\theta_L, \mathbf{E}_q[\theta], \theta_H\}$, where the intermediate price $\mathbf{E}_q[\theta]$ is given by

[11]This follows if demand is perfectly elastic at a price that equals the average quality that sellers effectively offer. It is also possible to derive this in a model where each seller faces two buyers who choose prices à la Bertrand (Mas-Colell et al. 1995, chap. *13*, p. ???).

$$\mathbf{E}_q[\theta] = (1-q)\theta_L + q\theta_H. \tag{1}$$

A seller can accept (a) or not ($\sim a$) the price offer made by the buyer. In particular, sellers will be willing to accept a price equal to the average expected quality if and only if the following condition holds:

$$q \geq \frac{\alpha\theta_H - \theta_L}{\theta_H - \theta_L}. \tag{2}$$

One can rule out separating equilibria because sellers of lemons always have an incentive to mimic sellers of high-quality products. A babbling equilibrium exists in which all sellers pool, stating they have a high quality product, $m = \theta_H$, regardless of actual quality. For this message to be a perfect Bayesian Nash equilibrium, the reaction to any other announcement has to be a low price. Buyers may expect that anybody who deviates from θ_H has a low quality car.[12] Besides this pure strategy equilibrium, there are innumerable other babbling equilibria in cheap talk models.[13] Since with cheap talk it is not obvious what message to pool on, one could use Schelling's (1960) selection argument among Nash equilibria, where the only focal pooling equilibrium is the one where owners of lemons mimic the message of owners of high quality cars.[14]

However, with costs of deciphering messages we can be much more specific. Except for geniuses like von Neumann who can solve complicated problems at lightening speed, the application of Descartes method of systematic doubt (cf. Kenny 2006) implies processing costs for decision makers.[15] In this case, the costs are lower than in the coordination game, because the direction of misrepresentation is quite definite: they imply either inflating or deflating quality claims. Specifically, suppose that the receiver incurs a small cost δ if the literal meaning of the message is not believed and the receiver has to image some alternative meaning.

If condition (2) is satisfied, there is no market breakdown. With deciphering costs, sellers of lemons have an incentive to overstate the quality of their car, mimicking the message of owners of high quality cars. Let the receiver incur small δ-costs if the literal meaning of the message is not believed and the receiver has to image some alternative meaning. Buyers need not doubt the message "θ_L", because the quality is always at least that high. As to message "θ_H", it might correspond to a high-quality good, but it might also correspond to a low-quality good, so there is a cost of thinking over the alternatives. As to messages other than "θ_H", they do not correspond to any actual quality in the market, so surprise should lead to even greater processing cost $\delta\prime$. With high-enough deciphering costs they are all out-of-equilibrium messages, since the equilibrium outcome cannot improve on the outcome where all sellers pool on "θ_H".

If condition (2) is not satisfied, in pure-strategy equilibria sellers of high-quality products can be expected to drop out of the market, given the transaction costs of putting an ad and talking to prospective

[12] There are other pooling equilibria where the same outcome is supported by out-of-equilibrium beliefs that the conditional probability of high quality products is low enough for condition $\mathbf{E}_q[\theta] \geq \alpha\theta_H$ not to be satisfied.

[13] There can also be hybrid equilibria.

[14] The lemon's model is somewhat similar to Example 3 in Farrell (1993). Extending Farrell's insights on the focal meaning of natural language to equilibrium messages solves the problem of non-existence of a perfect Bayesian Nash equilibrium that is neologism-proof in his Example 3: B has an incentive to mimic A, as in the lemons model, but if the equilibrium message in the pooling equilibrium is "A", no self-signaling neologism is available for A to destroy that equilibrium.

[15] Kartik et al. (2007) study receivers who are credulous or naive, so they take the messages at face value. Our receivers are all sophisticated. However, that does not rescue them from the costs of having to think something over.

buyers. Given that, sellers of lemons have an incentive to say "this is a lemon", since any other message leads receivers to reduce the price offer by the amount δ.[16]

The following proposition summarizes all possible equilibria.

Proposition 1 *Consider the lemons model with two quality types, θ_L and θ_H ($\theta_H > \theta_L$), no honest sellers ($r = 1$), and risk neutral buyers willing to pay the expected quality of the product. Suppose also there are small deciphering costs, which are null for message "θ_L", positive and equal to δ for "θ_H", and even higher for other messages. Then:*

1. *If condition (2) holds, the Perfect Bayesian Nash equilibrium is given by: $m_S(\theta_L, 0)(\theta_H) = m_S(\theta_H, 0)(\theta_H) = 1$, $\mu(\theta_L)(\theta_H) \in [0, q)$, $\mu(\theta_H)(\theta_H) = q$, $\tilde{\mu}(\theta_H, p)(\theta_H) = q$ for $p \geq \alpha\theta_H$, $\tilde{\mu}(\theta_H, p)(\theta_H) = 0$ for $p < \alpha\theta_H$, $p_B(\theta_L)(\theta_L) = 1$, $p_B(\theta_H)(\mathbf{E}_q[\theta]) = 1$. Furthermore, the equilibrium is Pareto efficient (i.e. there is no market breakdown).*

2. *If condition (2) does not hold, the Perfect Bayesian Nash equilibria are given by: $m_S(\theta_L, 0)(\theta_L) = \sigma$, $m_S(\theta_L, 0)(\theta_H) = 1 - \sigma_L$, $m_S(\theta_H, 0)(\theta_H) = 1$, $\mu(\theta_L)(\theta_H) = 0$, $\mu(\theta_H)(\theta_H) = \frac{q}{(1-\sigma_L)(1-q)+q} \in [q, 1)$, $\tilde{\mu}(\theta_L, p)(\theta_H) = 0$, $\tilde{\mu}(\theta_H, p)(\theta_H) = \frac{q}{(1-\sigma_L)(1-q)+q}$ for $p \geq \alpha\theta_H$,$\tilde{\mu}(\theta_H, p)(\theta_H) = 0$ for $p < \alpha\theta_H$, $p_B(\theta_L)(\theta_L) = 1$, $p_B(\theta_H)(\theta_H - \delta) = \frac{\delta}{\theta_H - \theta_L}$. Furthermore, all the equilibria are Pareto inefficient (i.e. there is partial market breakdown).*

Proof 1 *See the appendix.*

Note that if condition (2) hold there is no market breakdown, while if it does not hold, the probability that there is no market breakdown is $\frac{\delta}{\theta_H - \theta_L}$, which is extremely low. Thus, introducing a small deciphering cost does not change the main result of the lemons model, but it eliminates the problem of an indefinite number of equilibria in the standard cheap-talk version of the model.

3.3 Honesty and lemons

Now there is a fraction $(1 - r) > 0$ of honest sellers, with $\chi \geq \theta_H - \theta_L$, who derive utility from the outcomes and also the actions they take. The lemons model with honest sellers is no longer a cheap talk game, but rather a signaling game.[17] Nature determines the type of seller according to the probability distribution of quality and honesty in Table 1 above. Sellers then make an announcement of quality. Subsequently buyers make a price offer, which sellers can accept or not.

Honest sellers who have a high quality product will find their announcements θ_H are not credible, because dishonest sellers with a low quality product will claim the same thing. This credibility problem does not arise with honest sellers who have a low quality product, because the announcement θ_L is perfectly credible. This creates two different markets: one in which buyers know perfectly well that they are buying a low quality product, another in which they could be buying either a high or low quality product.

[16] We do not expect hybrid equilibria, unless the transaction costs of a seller from putting an ad and talking to buyers are negligible, because they need to be smaller than the δ-costs of buyers when making a price offer to a seller who says its quality is θ_H.

[17] The consequences of two-dimensional asymmetric information for signaling are analyzed by Stein and Streb (2004) for political budget cycles, and by Streb (2007) for the labor market.

The first market, associated to the message θ_L, is a standard competitive market where the quality of the commodities transacted is certain. This market is characterized by a horizontal demand function and a vertical supply function. The equilibrium boils down to a competitive equilibrium where $(1-q)(1-r)$ low quality units are transacted at a price θ_L.

In the second market, associated to the message θ_H, purchasers need to deduce the expected quality of what they are buying using the information they have about the sellers' behavior. The presence of honest sellers ($r < 1$) raises average quality in market 2. Instead of (1), average quality is now (assuming that the price offer is higher than $\alpha\theta_H$)

$$\mathbf{E}_{q,r}[\theta] = \frac{(1-q)r\theta_L + q\theta_H}{(1-q)r+q}, \tag{3}$$

Sellers will be willing to accept a price equal to $\mathbf{E}_{q,r}[\theta]$ if and only if the following condition is satisfied:

$$q \geq \frac{r(\alpha\theta_H - \theta_L)}{(1-\alpha)\theta_H + r(\alpha\theta_H - \theta_L)}. \tag{4}$$

That is to say, even if (2) is not satisfied, a Pareto efficient equilibrium may exist if there is a sufficient proportion of honest sellers. When condition (4) holds, unlike the continuum of babbling equilibria of the cheap-talk game, there is a unique semi-separating equilibrium: θ_L conveys the information that the product is a lemon, while θ_H is associated to a sufficiently high proportion of high quality products.

If condition (4) does not hold, there is a market breakdown and $p_B(\theta_H)(\theta_L) = 1$ in this second market as well. A semi-separating equilibrium exists where honest sellers that have lemons pick θ_L, while the other sellers pick θ_H; because dishonest sellers are indifferent in equilibrium between both markets, this same outcome is supported by a continuum of equilibria where some dishonest sellers of lemons say they have a lemon, as long as the proportion of dishonest sellers that are truthful is low enough for condition (4) not to hold in market θ_H. The following proposition summarizes all possible equilibria.

Proposition 2 *Consider the lemons model with two quality types, θ_L and θ_H ($\theta_H > \theta_L$), some honest sellers ($r < 1$), and risk neutral buyers willing to pay the effective expected quality of the product. Then:*

1. *If condition (4) holds, the Perfect Bayesian Nash equilibrium is given by: $m_S(\theta_L,\chi)(\theta_L) = 1$, $m_S(\theta_L,0)(\theta_H) = m_S(\theta_H,0)(\theta_H) = m_S(\theta_H,\chi)(\theta_H) = 1$, $\mu(\theta_L)(\theta_H) = 0$, $\mu(\theta_H)(\theta_H) = \frac{q}{(1-q)r+q}$, $\tilde{\mu}(\theta_L,p)(\theta_H) = 0$ for all p, $\tilde{\mu}(\theta_H,p)(\theta_H) = \frac{q}{(1-q)r+q}$ for $p \geq \alpha\theta_H$, $\tilde{\mu}(\theta_H,p)(\theta_H) = 0$ for $p < \alpha\theta_H$, $p_B(\theta_L)(\theta_L) = 1$, $p_B(\theta_H)(\mathbf{E}_{q,r}[\theta]) = 1$. Furthermore, the equilibrium is Pareto efficient (i.e. there is no market breakdown).*

2. *On the other hand, if (4) does not hold, the Perfect Bayesian Nash equilibria are given by: $m_S(\theta_L,\chi)(\theta_L) = 1$, $m_S(\theta_H,\chi)(\theta_H) = 1$, $m_S(\theta_L,0)(\theta_L) = \sigma_L$, $m_S(\theta_H,0)(\theta_L) = \sigma_H$, $\mu(\theta_L)(\theta_H) = \frac{\sigma_H qr}{\sigma_L(1-q)r+\sigma_H qr+(1-q)(1-r)}$, $\mu(\theta_H)(\theta_H) = \frac{(1-\sigma_H)qr+q(1-r)}{(1-\sigma_L)(1-q)r+(1-\sigma_H)qr+q(1-r)}$, $\tilde{\mu}(\theta_L,p)(\theta_H) = 0$ for all p, $\tilde{\mu}(\theta_H,p)(\theta_H) = \frac{q}{(1-q)r+q}$ for $p \geq \alpha\theta_H$, $\tilde{\mu}(\theta_H,p)(\theta_H) = 0$ for $p < \alpha\theta_H$, $p_B(\theta_L)(\theta_L) = p_B(\theta_H)(\theta_L) = 1$. Furthermore, all these equilibria are Pareto inefficient (i.e. there is market breakdown).*

Proof 2 *See the appendix.*

Comparing this proposition with proposition 1, we see that that the existence of trustworthy sellers makes a market breakdown less likely (condition (4) is easier to hold than condition (2)). Furthermore, honesty destroys all babbling equilibria, and confers credibility to words.

A potential problem with the semi-separating equilibrium in Proposition 2 is that dishonesty may pay. Suppose that buyers are either honest or dishonest with probabilities $(1-r)$ and r, since they are drawn from the same population as sellers. A dishonest buyer can buy a lemon in market 1 and resell it in market 2, making a profit of $\mathbf{E}_{q,r}[\theta] - \theta_L$. Hence, a proportion r of the $(1-q)(1-r)$ lemons in market 1 can go for resale in market 2, affecting negatively the price in market 2. However, buyers can resort here to a simple expedient: check whether the seller is the original owner, or somebody that is reselling it. Since the former offer lemons with probability $\frac{(1-q)r}{(1-q)r+q} < 1$, while the latter do so with probability 1, buyers can avoid exploitation by dealers if they can condition their offer on this information. This requires buyers who take advantage of involuntary signs provided by the sellers.

More generally, Akerlof (1970) remarks that "*... it is often surprising how truthful sellers are to buyers who ask the right questions, so that imperfect asymmetric information may be a less potent phenomenon than is suggested by a world view that sees all people as selfish maximizers. As Max Weber has sharply pointed out: Benjamin Franklin, in urging the utilitarian reasons for truthfulness, is himself more truthful than consistent with his own dicta.*"

Another way of overcoming asymmetric information is to look for expert advice. Customers are interested in competent and honest experts. Covey et al. (1995, pp. 240-1) point out the importance of these twin dimensions for business organizations and individuals. Two lemons problems crop up. First, is the expert competent? Second, what if the expert is willing to profit at the expense of the customer, as in Crawford and Sobel (1982) with a biased expert?

Suppose that a fraction s of the experts are either incompetent or dishonest, and consequently, they do not detect a lemon.[18] The probability that a lemon will be detected in market 2 is $(1-s)$. Assume that buyers are willing to pay an amount equal to the expected quality in the market minus the flat fee f charged by the expert. Then, if a lemon is detected in market 2 buyers are welling to pay $\theta_L - f$. If the expert does not detect a lemon, buyers are welling to pay $\mathbf{E}_{q,r,s}[\theta] - f$, where

$$\mathbf{E}_{q,r,s}[\theta] = \frac{s(1-q)r\theta_L + q\theta_H}{s(1-q)r + q}, \tag{5}$$

provided that: 1) the price offer is higher than $\alpha\theta_H$, and hence sellers with a high quality good are welling to sell it; and 2) $s[\mathbf{E}_{q,r,s}[\theta] - \theta_L] > f$, and hence dishonest sellers with a lemon prefer to lie.

Let $\bar{f} = \min\{\mathbf{E}_{q,r,s}[\theta] - \mathbf{E}_{q,r}[\theta], s[\mathbf{E}_{q,r,s}[\theta] - \theta_L]\}$. Then, if $f < \bar{f}$, expert advice can prevent a market breakdown, even when condition (3) is not satisfied, provided that $\mathbf{E}_{q,r,s}[\theta] - f > \alpha\theta_H$.

4 A continuum of types

We now generalize the model to a continuum of types. We do this in two steps: we first introduce a continuum of honesty types when there are two kinds of quality, before considering a continuum in both dimensions, quality and honesty.

[18]Note that this formulation is relatively flexible. For example, $s = \beta r$ can represent a situation in which a fraction $\beta \in [0,1]$ of the experts are incompetent, and experts are drawn from the same population as sellers, so a proportion $(1-r)$ are honest, while the rest are willing to receive a kickback from the seller.

4.1 Continuum of honesty

There are two types of quality, $\Theta = \{\theta_L, \theta_H\}$, and a continuum of honesty types, $H = [0, \chi]$, for $\chi > 0$. The probability a good is high quality is q, while honesty types are uniformly distributed with density $1/\chi$.

The timing is as follows. Nature reveals its type to the seller. The seller sends a message $m \in M = \{\theta_L, \theta_H\}$ to the buyer, who forms a conjecture $\mu : M \to \Delta(\Theta)$. For each message m, $\mu(m)(\theta_i)$ represents the conditional probability that the product is type θ_i when message m is observed. Using Bayes' Theorem

$$\mu(m)(\theta_i) = \frac{\Pr(\theta_i) \int_h m_S(\theta_i, h)(m)\, dh}{q \int_h m_S(\theta_L, h)(m)\, dh + (1-q) \int_h m_S(\theta_H, h)(m)\, dh}, \tag{6}$$

where $m_S : T \to \Delta(M)$ is the message strategy of the seller, and $m_S(\theta_i, h)(m)$ denotes the probability that a seller of type (θ_i, h) sends message m. If message m is not sent by any type Bayes' Theorem does not apply and we only require that $\mu(m) \in \Delta(\Theta)$.

Using this conjecture, the buyer makes an offer to the seller, which can be any probability measure with support in the interval $[\theta_L, \theta_H]$. Let $p_B : M \to \Delta([\theta_L, \theta_H])$ denotes the price strategy of the buyer. For each message m, $p_B(m)$ is a probability measure over $[\theta_L, \theta_H]$. Since the seller can accept or reject the offer, we must take into account the seller's response $a_S : T \times M \times [\theta_L, \theta_H] \to \Delta(A)$, where $A = \{a, \sim a\}$ (a for accept, $\sim a$ for reject). $a_S(\theta_i, h, m, p)(a)$ gives the probability that a type $t = (\theta_i, h)$ seller which sends message m accepts price $p \in [\theta_L, \theta_H]$. Note that, although the buyer can play a mixed strategy offer, the seller faces only single price. Offers will be accepted as long as $p \geq \alpha\theta_i$, so the seller's acceptance rule is given by:

$$a_S(\theta_i, p)(a) = \begin{cases} 1 & \text{if } p \geq \alpha\theta_i, \\ 0 & \text{otherwise.} \end{cases} \tag{7}$$

We use the notation $a_S(\theta_i, p)$ rather than $a_S(\theta_i, h, m, p)$, because the equilibrium acceptance rule does not depend neither on h nor on m.

Let $\tilde{\mu}(m, p)(\theta_i)$ be the probability that the buyer effectively obtains a product of quality θ_i in response to message m by offering the price $p \in [\theta_L, \theta_H]$

$$\tilde{\mu}(m, p)(\theta_i) = \frac{a_S(\theta_i, p)(a) \Pr(\theta_i) \int_h m_S(\theta_i, h)(m)\, dh}{a_S(\theta_L, p)(a)\, q \int_h m_S(\theta_L, h)(m)\, dh + a_S(\theta_H, p)(a)(1-q) \int_h m_S(\theta_H, h)(m)\, dh}.$$

Suppose that the buyer is playing a price strategy p_B, which is possible mixed for some messages. The perfectly elastic demand assumption implies that, given any message m and price p in the support of $p_B(m)$, the payment made by the buyer must be equal to the quality that the buyer expects to receive, that is

$$p = \mathbf{E}_{\tilde{\mu}}[\theta \mid m, p] = \theta_L \tilde{\mu}(m, p)(\theta_L) + \theta_H \tilde{\mu}(m, p)(\theta_H) \tag{8}$$

We use perfect Bayesian Nash equilibrium as the solution concept.

Definition 1 *A perfect Bayesian Nash equilibrium of the signaling game is a message function $m_S : T \to \Delta(M)$, a conjecture $\mu : M \to \Delta(M)$, a market price function $p_B : M \to \Delta([\theta_L, \theta_H])$, an acceptance rule $a_S : T \times M \times [\theta_L, \theta_H] \to A$, such that:*

1. m_S maximizes seller's utility given p_B and a_S;

2. μ satisfies (6), given m_S;

3. a_S satisfies (7) given p_B; and

4. p_B satisfies (8), given m_S and a_S.

We now characterize the set of perfect Bayesian Nash equilibria. Given the cost of lying, the seller's message function will be of the following form:

$$m_S(\theta_L, h)(\theta_L) = \begin{cases} 1 & \text{if } h \in [h^*, \chi], \\ 0 & \text{if } h \in [0, h^*), \end{cases}$$
$$m_S(\theta_H, h)(\theta_L) = 0 \text{ for all } h, \tag{9}$$

where h^* is endogenous and, as we show below, depends on the expected price difference in both markets in equilibrium.

The buyer's conjectures that the good is not a lemon are hence:

$$\mu(m)(\theta_H) = \begin{cases} \frac{q}{q+(1-q)\left(\frac{h^*}{\chi}\right)} & \text{if } m = \theta_H, \\ 0 & \text{if } m = \theta_L. \end{cases}$$

Since there are only two messages, $\mu(m)(\theta_L) = 1 - \mu(m)(\theta_H)$.

A seller of a high quality product decline to sell it if his reservation utility is not satisfied, while a seller of a low quality product always accept the price offer (acceptance does not depend either on honesty type or on message):

$$a_S(\theta_i, p)(a) = \begin{cases} 1 & \text{if } \theta_i = \theta_H \text{ and } p \geq \alpha\theta_H, \text{ or } \theta_i = \theta_L, \\ 0 & \text{if } \theta_i = \theta_H \text{ and } p < \alpha\theta_H. \end{cases} \tag{10}$$

Since only low quality types send message θ_L, a dominant strategy for the buyer is to offer θ_L. As to message θ_H, we restrict our attention to mixed strategies of the form $p_B(\theta_H)(\theta_L) = \sigma^*$ and $p_B(\theta_H)(p^*) = 1 - \sigma^*$, where the buyer plays with positive probability at most two values θ_L and $p^* \in [\theta_L, \theta_H]$. Then, the probability the buyer obtains a high quality product when observing message θ_H and offering price p^* is

$$\tilde{\mu}(\theta_H, p^*)(\theta_H) = \frac{a_S(\theta_H, p^*)(a)\, q}{a_S(\theta_H, p^*)(a)\, q + (1-q)\left(\frac{h^*}{\chi}\right)}, \tag{11}$$

where p^* is an endogenous variable we must determine. Since the buyer is willing to pay the expected quality $\mathbf{E}_{\tilde{\mu}}[\theta \mid \theta_H, p^*]$ and p^* is in the support of the price strategy

$$p^* = \left[\frac{(1-q)\left(\frac{h^*}{\chi}\right)}{a_S(\theta_H, p^*)(a)\, q + (1-q)\left(\frac{h^*}{\chi}\right)}\right]\theta_L + \left[\frac{a_S(\theta_H, p^*)(a)\, q}{a_S(\theta_H, p^*)(a)\, q + (1-q)\left(\frac{h^*}{\chi}\right)}\right]\theta_H. \tag{12}$$

It remains to see if sellers have an incentive to deviate. Clearly, a seller with a high quality product always prefer to tell the truth. A type h^* with a lemon must be indifferent between misrepresenting or not the truth. The cost of lying for a seller of honesty h is h; the benefit is the expected price gain from reporting θ_H instead of θ_L. If the seller reports θ_H, the price offer is $\sigma^*\theta_L + (1-\sigma^*)\,p^*$, while for report θ_L the offer is θ_L. Therefore

$$h^* = \min\left\{(1-\sigma^*)\,(p^*-\theta_L)\,,\chi\right\}. \tag{13}$$

According to (9), a seller with a lemon and $h > h^*$ does not misrepresent quality, and would incur a loss from lying because the psychic cost is larger than the pecuniary benefit. Hence, he does not want to deviate. A seller with a lemon and $h < h^*$ has a pecuniary gain larger than the psychic loss from lying, and therefore prefers to lie.

The following proposition summarizes the results.

Proposition 3 *Assume that there is a continuum of honesty types and let $\chi > 0$. If $q > \frac{\alpha\theta_H - \theta_L}{\theta_H - \theta_L}$ and $q(\theta_H - \theta_L) \geq \chi$, then the solution with no market breakdown $\sigma^* = 0$ is possible, which implies $h^* = \chi$ is binding and $p^* = (1-q)\,\theta_L + q\theta_H$. Otherwise, in all other solutions $h^* = (1-\sigma^*)\,(p^*-\theta_L)$ is binding, so the set of Perfect Bayesian Nash equilibria are given by:*

1. *Sellers send the following messages: $m_S(\theta_H,h)(\theta_H) = 1$ for all h, $m_S(\theta_L,h)(\theta_H) = 1$ for $h \in [0,h^*)$ and $m_S(\theta_L,h)(\theta_L) = 1$ for $h \in [h^*,\chi]$;*

2. *Sellers use the following acceptance rule: $a_S\,(\theta_H,p)\,(a) = 1$ if $p \geq \alpha\theta_H$, $a_S\,(\theta_H,p)\,(a) = 0$ if $p < \alpha\theta_H$, and $a_S\,(\theta_L,p)\,(a) = 1$; and*

3. *Buyers offer the following price function: $p_B\,(\theta_L)\,(\theta_L) = 1$, $p_B\,(\theta_H)\,(\theta_L) = \sigma^*$, and $p_B\,(\theta_H)\,(p^*) = 1-\sigma^*$; where p^*, h^*, and σ^* are given by*

$$p^* - \theta_L = \frac{q\chi}{2\,(1-q)\,(1-\sigma^*)}\left(\sqrt{1+\frac{4\,(1-q)\,(1-\sigma^*)\,(\theta_H-\theta_L)}{\chi q}}-1\right),$$

$$h^* = \frac{q\chi\,(\theta_H - p^*)}{(1-q)\,(p^*-\theta_L)},$$

$$0 < 1-\sigma^* \leq \min\left\{\frac{q\,(1-\alpha)\,\theta_H\chi}{(1-q)\,(\alpha\theta_H-\theta_L)^2},1\right\}.$$

Hence, a range of equilibria are possible for each value of χ.

Proof 3 *See the appendix.*

The following corollary further characterized the set of Perfect Bayesian Nash equilibria. In particular, the proposition establishes conditions for the existence of a Pareto efficient equilibrium.

Corollary 1 *Under the assumption of the previous proposition. Let $\bar{\chi} = \frac{(1-q)(\alpha\theta_H-\theta_L)^2}{q(1-\alpha)\theta_H}$*

1. *If $\chi \geq \bar{\chi}$, there is a Pareto efficient equilibrium characterized by $\sigma^* = 0$, as well as equilibria with a positive probability of disappearance of the market for high quality goods*

2. *If $\chi < \bar{\chi}$, in all the equilibria there is a positive probability σ^* that market for high quality products breaks down.*

3. *Absent transaction costs, there is never complete market disappearance, i.e., in equilibrium $\sigma^* < 1$ always.*

Figure 7 shows the set of Perfect Bayesian equilibria for the following example: $\theta_L = 4$, $\theta_H = 10$, $\alpha = .75$, $q = \frac{1}{2}$, $\chi = 1, 5, 10$.

<Figure 7: Two quality types and continuum of honesty: Perfect Bayesian equilibria>

4.2 Continuum of quality and honesty

We can generalize the setup to a continuum in both dimensions. With uniform distribution and no honesty expected quality is $\mathbf{E}[\theta] = \frac{\theta_L + \theta_H}{2}$, which simplifies to $\mathbf{E}[\theta] = \frac{\theta_H}{2}$ when $\theta_L = 0$. If all sellers were willing to misrepresent quality, then for $\theta_L = 0$ there is market breakdown if $\mathbf{E}[\theta] = \frac{\theta_H}{2} \leq \alpha\theta_H$, i.e., if $\alpha \geq \frac{1}{2}$. Following Akerlof's unraveling argument: the highest qualities drop out of the market, so average quality drops, and the process continues until we reach a situation were only the lowest quality is left on the market. If the lowest quality is $\theta_L > 0$, then the conclusion must be slightly amended to say that only qualities $\left[\theta_L, \frac{\theta_L}{2\alpha-1}\right]$ remain on the market, with average quality (and price) given by $\mathbf{E}[\theta] = \frac{1}{2}\left(\theta_L + \frac{\theta_L}{2\alpha-1}\right) = \alpha\frac{\theta_L}{2\alpha-1}$.

We consider the case of complete market breakdown under no honesty ($\theta_L = 0$, $\alpha \geq \frac{1}{2}$) and we introduce a continuum of honesty types uniformly distributed in the interval $[0, \chi]$. We conjecture that in equilibrium, all sellers with a high enough quality (denoted θ^*) at least weakly prefer to reveal the true quality of the good regardless of their honesty level, while sellers with a relative low quality may misrepresent or tell the truth depending on their honesty type. Since misrepresenting is a fixed cost, a seller that chooses to misrepresent always prefer to announce a quality level that induces the highest possible price. Thus, in equilibrium all the sellers that lie must obtain the same price, and hence they must be indifferent among all the messages that induce this price. For this reason we conjecture that in equilibrium all sellers that misrepresent quality chose the same message (denoted θ^r). Formally, the message function is given by

$$m_S(\theta, h) = \begin{cases} \theta^r & \text{if } h \in [0, h^*(\theta)] \text{ and } \theta < \theta^*, \\ \theta & \text{if } h \in [h^*(\theta), \chi] \text{ and } \theta < \theta^*, \\ \theta & \text{if } h \in [h^*(\theta), \chi] \text{ and } \theta \geq \theta^*. \end{cases} \tag{14}$$

$h^*(\theta)$ indicates the honesty type that is indifferent between misreporting and telling the truth when he has a good of quality θ.

Suppose that buyers pay whatever the sellers report if the report is lower than θ^*, while they pay a fixed price p^* when the report is higher than θ^*; that is they use the following price strategy

$$p_B(m) = \begin{cases} m & \text{if } m < \theta^*, \\ p^* & \text{if } m \geq \theta^*. \end{cases} \tag{15}$$

Since sellers observe the price offer before deciding to accept or not the deal, their acceptance rule is given by (recall that $\alpha\theta$ is the opportunity cost of a seller of type θ)

$$a_S(\theta, p)(a) = \begin{cases} 1 & p \geq \alpha\theta, \\ 0 & \text{otherwise.} \end{cases} \tag{16}$$

Given the price strategy and the subsequence acceptance rule, a seller of type (θ, h) prefers to report the true quality (misreport) if the maximum gain of misreporting $(\max\{p^*, \theta^*\} - \theta)$ is lower (higher) than the cost of lying (h). Hence, all seller of type $\theta \geq \theta^*$ prefers to tell the true only if $p^* \geq \theta^*$, while for sellers of type $\theta < \theta^*$ the decision depends on the honesty type. Thus, for each θ we can find an honesty type $h^*(\theta)$ such that all sellers with a product of quality θ and honesty $h \geq h^*(\theta)$ prefer to tell the true, while all sellers with a product of quality θ and honesty $h < h^*(\theta)$ prefer to lie. Formally,

$$h^*(\theta) = \begin{cases} \min\{p^* - \theta, \chi\} & \text{if } \theta < \theta^*, \\ 0 & \text{if } \theta \geq \theta^*. \end{cases} \tag{17}$$

Note that the sellers that prefer to misreport their quality can not do better than report $\theta^r = \theta^*$.

Finally, we assume that buyers always pay the effective expected quality, which implies that the price p^* that targets all the sellers that reports $m \geq \theta^*$ must be equal to the expected quality of the products offered precisely by the sellers that reports $m \geq \theta^*$. Formally,

$$p^* = \mathbf{E}[\theta \mid m \geq \theta^*, p = p^*] \tag{18}$$

Suppose that there is a pair of p^* and θ^* such that $p^* \geq \theta^*$ and expressions (14)-(18) are simultaneously satisfied. Then, the message function (14), the price strategy (15), and the acceptance rule (16) give a perfect Bayesian equilibrium. In order to see this, note first that with the price strategy (18) buyers obtain an expected payoff of zero in equilibrium. Since they always pay the effective expected quality, they can not do better than this using any other feasible price strategy. Second, as we showed in previous paragraphs, given this price strategy, and the acceptance rule (16), the best sellers can do is to follow the message function (14). The following proposition focuses on the case in which $p^* = \theta^*$, and shows the existence of a Pareto efficient perfect Bayesian equilibrium. It also characterizes the set of parameters for which is possible to support a Pareto efficient allocation using strategies (14)-(16).

Proposition 4 *Suppose that quality and honesty are uniformly distributed in the intervals $[0, \theta_H]$ and $[0, \chi]$ respectively. Let A and B be the following subsets of the space of parameters*

$$A = \left\{ \left(\alpha, \frac{\chi}{\theta_H}\right) : \frac{1}{2} \leq \alpha < 3 - \sqrt{6}, \frac{\chi}{\theta_H} > 0, \sqrt{6\alpha - 3} \leq \frac{\chi}{\theta_H} < \left(3 - \sqrt{6}\right) \right\},$$
$$B = \left\{ \left(\alpha, \frac{\chi}{\theta_H}\right) : \frac{1}{2} \leq \alpha < 1, \frac{\chi}{\theta_H} \geq \max\left\langle \left(3 - \sqrt{6}\right), \frac{\frac{2}{3}\alpha^3}{\alpha^2 - 2\alpha + 1} \right\rangle \right\}.$$

1. *If $\left(\alpha, \frac{\chi}{\theta_H}\right) \in A$, there is a Pareto efficient perfect Bayesian equilibrium given by (14)-(16) with $\frac{p^*}{\theta_H} = \frac{1}{6}\left(\frac{\chi}{\theta_H}\right)^2 + \frac{1}{2}$*

2. If $\left(\alpha, \frac{\chi}{\theta_H}\right) \in B$, there is a Pareto efficient perfect Bayesian equilibrium (14)-(16) with $\frac{p^*}{\theta_H} \in \left[\alpha, \frac{\chi}{\theta_H}\right]$ is a real root of the following cubic equation

$$\frac{2}{3}\left(\frac{\chi}{\theta_H}\right)^{-1}\left(\frac{p^*}{\theta_H}\right)^3 - \left(\frac{p^*}{\theta_H}\right)^2 + 2\left(\frac{p^*}{\theta_H}\right) - 1 = 0.$$

Proof 4 *See the appendix.* ■

The following corollary characterizes the frontier of the subset of the parameter space for which there is a Pareto efficient perfect Bayesian equilibrium given by (14)-(16).

Corollary 2 *Suppose that quality and honesty are uniformly distributed in the intervals $[0, \theta_H]$ and $[0, \chi]$ respectively. Let $\alpha_{\max} : (0, \infty) \to \left[\frac{1}{2}, 1\right)$ be the function that gives the maximum value of α that can be supported by a perfect Bayesian equilibrium for each possible value of $\frac{\chi}{\theta_H}$, that is*

$$\alpha_{\max}\left(\frac{\chi}{\theta_H}\right) = \begin{cases} \frac{1}{3}\left(\frac{\chi}{\theta_H}\right)^2 + \frac{1}{2} & \textit{if } 0 < \frac{\chi}{\theta_H} < \left(3 - \sqrt{6}\right), \\ \alpha^{-1}\left(\frac{\chi}{\theta_H}\right) & \textit{if } \frac{\chi}{\theta_H} \geq \left(3 - \sqrt{6}\right). \end{cases}$$

where $\alpha^{-1}(.)$ is the inverse of $\frac{\frac{2}{3}\alpha^3}{\alpha^2 - 2\alpha + 1}$ in the appropriate domain. Then, $\alpha_{\max}$ is an increasing function of $\frac{\chi}{\theta_H}$, it is strictly convex for $\frac{\chi}{\theta_H} < \left(3 - \sqrt{6}\right)$ and strictly concave for $\frac{\chi}{\theta_H} > \left(3 - \sqrt{6}\right)$.

Figure 8 shows the subset of the parameter space for which there is a Pareto efficient perfect Bayesian equilibrium.

< *Figure 8: Continuum of quality and honesty: Perfect Bayesian equilibria* >
< *Figure 9: Continuum of quality and honesty: Perfect Bayesian equilibria* >

5 Implications for communication

There are semiotic and psychological reasons to move beyond cheap talk as a model of communication.

From a semiotic viewpoint, when there is asymmetric information we do not randomly use any word in the dictionary to name something; rather, the ordinary meaning is a focal point. Moreover, if any other meaning is used, the costs of deciphering the message, to interpret what the other really meant, can transform language into a useless coordinating device. In our example of a coordination game, the costs of deciphering messages cause the only communication equilibrium to be that where natural language is used. If the sender proposes to meet at a certain place and hour, this proposal will be successful if both the sender complies with the proposal, and the receiver believes the proposal. Here, a minimal level of trust comes in: if the priors in the society are that people usually mean what they say, so words convey intentions correctly, or there is at least some people who always do that, coordination through verbal communication works in markets.

As to the other extreme, think of a society with a totalitarian regime where it is utterly costly for regular citizens to honestly express their true viewpoints. People may end up replacing the words prohibited by the government by other words, leading some words to end up meaning the opposite of their meaning in plain language, for instance "defense of liberty" may mean "persecute dissidents". In the extreme, language may become cheap talk, as George Orwell describes in his 1949 novel *Nineteen Eighty-Four* where a Ministry of Truth is charged with editing words so information serves the government's aims. Orwell calls the ensuing language "doublespeak". In this setup, where past history is continually being edited according to the current political needs of the political leadership, words can end up meaning nothing.

From a psychological viewpoint, language does not break down because words carry different weight for different people. Schelling (1960, pp. 26-27) points out that "if part of the population belong to the cult in which 'cross my heart' is (or is believed to be) absolutely binding ... they can commit themselves, the others cannot." For this cult, words are equivalent to moves, not to speech.

However, we do not need to rely on a cult of fanatics for words to acquire meaning and become signals. For most people, being truthful is less costly than making something up. Indeed, lie detector tests are based on the idea that lies can be detected by more cerebral activity. In coordination games, if there is an infinitesimal cost of misrepresentation, babbling equilibria are banished and ordinary language is meaningful. This is at most what is needed in the first stage coordination game to assure verbal communication works.

The manipulation of language seems to be in accord with the behavior in strategic arenas populated by diplomats, spies, lawyers, and so forth. But as Branton, the author of *Radical Honesty* puts it, lying has a psychic cost. Lying is not a free lunch, we can get sick from lying.

Once we incorporate the idea of remorse, prominent in Adam Smith's 1759 *Theory of Moral Sentiments*, words become signals. Hence, we expect a variety of behavior towards language, with people that are willing to manipulate language at will, and others who stick to their word. If some people derive utility from the truthfulness of what they say, this allows to analyze the informative content of language (we have left out pathological liars who derive pleasure from mistreating the other party, e.g., playing a practical joke on somebody by standing them up, or calling a 911 number when there is no emergency).

6 Final remarks

Though a market economy is based on self-interest, Coase (1976), p. 115 *confirmar*) warns in regard to Adam Smith's views that "this should not lead us to ignore the part which benevolence and moral sentiments do play in making possible the market system ... the observance of moral codes must very greatly reduce the costs of doing business with others and must therefore facilitate market transactions." As we show here, if a minimal level of trust exists, this allows to coordinate on market transactions through very simple verbal mechanisms, drastically reducing transaction costs. That is to say, a minimal level of trust is a way to explain the semantic content of language.

When we move beyond the coordination stage to the stage where there are incentives for misrepresentation, there are several ways to assure market exchange. Under asymmetric information, Akerlof (1970) points out how guarantees may allow to distinguish high quality products, since only owners of high quality products will be willing to offer them. These guarantees, which Spence (1973) generically calls signals, presupposes a well functioning legal system that makes the guarantees legally binding. The same holds for advertisements like "full customer satisfaction or your money back". Informal mechanisms may also be at work. For example, rules of reciprocity can sustain voluntary cooperation via reputational channels under repeated interactions (e.g., Kandori 1992; there are up to date references to this literature in Moscoso Boedo 2008).

The approach here explores an informal mechanism for cooperation that is not based on repeated interactions. Rather, it is based on trust, in a model where agents may not only derive utility from the outcomes but also from the actions they take. The analysis is closely linked to the informal mechanisms in North (1981, *chapters 4 and 5*), who points out that an ideology of honesty can help markets work more efficiently, and that a system that is viewed as legitimate by the citizens diminishes the costs of control. (This idea is also related to Adam Smith's *Theory of Moral Sentiments*, were Adam Smith stresses the importance of remorse to assure restraint and prevent wrongdoing.[19]) For transactions that are not covered by formal contracts, of for which it is too expensive to sue in court, informal mechanisms based on trust may relevant.

We develop a model where agents will refrain from lying in equilibrium if it does not pay off. Unlike cheap talk models, we find that in equilibrium some verbal messages will be more informative than others, holding an obvious relation to the meaning of messages in plain English. This result on words becoming signals can be contrasted to the literature on cheap talk, in which speech does not mean anything by itself. The cheap talk interpretation does not correspond to the personal experience of the authors, where dishonest people that try to push a lemon do not advertise it as "my automobile is a lemon".

In our discrete setup, we find that if the proportion of honest sellers is large enough, then the problem of market breakdown under asymmetric information can be overcome. This result can be linked to the literature on the importance of trust for the functioning of markets. Trust here depends on an ideology of honesty. However, even if the proportion of honest sellers is small, honest sellers serve as an anchor for words, leading them to have meaning.

7 Apendix

Proof of Proposition 1

Proof of Proposition 2

Proof of Proposition 3 and corollary 1

We first show that it is neither the case that all sellers with a lemon tell the truth, that is $h^* = 0$, nor that the buyer only offer the lowest price, that is $\sigma^* = 1$. Suppose that $h^* = 0$. Then the buyer is willing to offer $p^* = \theta_H$. We can rule out $h^* = 0$, $\sigma^* = 1$, as an equilibrium, because the buyer will want to deviate to any price $p^* \in [\alpha\theta_H, \theta_H)$, an offer that sellers who (truthfully) state they have a high quality good will accept. As to $h^* = 0$, $\sigma^* < 1$, this cannot be an equilibrium either, because by (13) $h^* > 0$, a contradiction. We can also rule out $h^* > 0$, $\sigma^* = 1$, which is not possible either because no seller is willing to lie if there is no potential gain.

Given that $h^* > 0$, $\sigma^* < 1$ is required in equilibrium, it is also necessary that $p^* \geq \alpha\theta_H$, because otherwise sellers of high quality products drop out of the market and the buyer will instead only be willing to offer $p^* = \theta_L$. Summing up, the equilibrium conditions are given by: (i) $p^* - \theta_L = \frac{q(\theta_H - \theta_L)}{(1-q)\left(\frac{h^*}{\chi}\right)+q}$ (12), (ii) $h^* = \min\{(1-\sigma^*)(p^* - \theta_L), \chi\}$ (13), (iii) $0 \leq \sigma^* < 1$, and (iv) $\alpha\theta_H \leq p^* \leq \theta_H$.

[19] Torrens (2008) studies how a pro-market ideology can reduce the costs of instituting an industrious society, inducing people to assign their time and effort to productive activities rather than to theft.

For $q \geq \frac{\alpha\theta_H - \theta_L}{\theta_H - \theta_L}$, if $q(\theta_H - \theta_L) \geq \chi$ all sellers of lemons misrepresent quality, but the buyer is still willing to pay $p^* = (1-q)\,\theta_L + q\theta_H$. Since this complies with the restriction $p^* \geq \alpha\theta_H$, $\sigma^* = 0$ is a solution where there is no market breakdown. It might also be possible to have solutions with $\sigma^* > 0$, where $h^* = (1-\sigma^*)\,(p^* - \theta_L)$, something we consider in the next paragraph. Likewise, if $q(\theta_H - \theta_L) < \chi$, not all sellers of lemons are willing to misrepresent quality in equilibrium, so $h^* = (1-\sigma^*)\,(p^* - \theta_L)$.

For $q < \frac{\alpha\theta_H - \theta_L}{\theta_H - \theta_L}$, it is always the case that $h^* = (1-\sigma^*)\,(p^* - \theta_L) < \chi$; because otherwise, $h^* = \chi$, and hence $p^* = (1-q)\,\theta_L + q\theta_H$, contradicting the requirement that $p^* \geq \alpha\theta_H$. Using this equality and $p^* - \theta_L = \frac{q(\theta_H - \theta_L)}{(1-q)\left(\frac{h^*}{\chi}\right) + q}$ leads to the quadratic equation $(1-q)\,(1-\sigma^*)\,(p^* - \theta_L)^2 + \chi q\,(p^* - \theta_H) = 0$. Solving this equation, the positive root $p^* = \theta_L + \frac{q\chi}{2(1-q)(1-\sigma^*)}\left[\sqrt{1 + \frac{4(1-q)(1-\sigma^*)(\theta_H - \theta_L)}{\chi q}} - 1\right]$ is the only root that falls between θ_L and θ_H. Thus, the equilibrium price p^* is a function of $0 \leq \sigma^* < 1$.

Operating algebraically on this positive root, $p^* \geq \alpha\theta_H$ if and only if $(1-\sigma^*) \leq \frac{q(1-\alpha)\theta_H\chi}{(1-q)(\alpha\theta_H - \theta_L)^2}$. Thus, if $\chi \geq \frac{(1-q)(\alpha\theta_H - \theta_L)^2}{q(1-\alpha)\theta_H}$, there exists a Pareto optimal equilibrum with $\sigma^* = 0$, as well as other equilibria where $\sigma^* > 0$. On the other hand, if $\chi < \frac{(1-q)(\alpha\theta_H - \theta_L)^2}{q(1-\alpha)\theta_H}$, all the equilibria involve a positive probability $\sigma^* > 0$ that the market of high quality goods breaks down.

Proof of Proposition 4 and corollary 2

To compute $\mathbf{E}\left[\theta \mid m \geq \theta^*, p = p^*\right]$ we must distinguish two possible cases

Case 1: $p^* > \chi$

Then

$$
\begin{aligned}
\mathbf{E}\left[\theta \mid m \geq \theta^*, p=\theta^*\right] &= \frac{\int_0^{\theta^*-\chi}\int_0^{\chi}\theta\left(\frac{1}{\chi}\right)\left(\frac{1}{\theta_H}\right)dhd\theta+\int_{\theta^*-\chi}^{\theta^*}\int_0^{\theta^*-\theta}\theta\left(\frac{1}{\chi}\right)\left(\frac{1}{\theta_H}\right)dhd\theta+\int_{\theta^*}^{\theta_H}\int_0^{\chi}\theta\left(\frac{1}{\chi}\right)\left(\frac{1}{\theta_H}\right)dhd\theta}{\Pr\left(m\geq\theta^*\right)} \\
&= \frac{\int_0^{\theta^*-\chi}\int_0^{\chi}\theta\left(\frac{1}{\chi}\right)\left(\frac{1}{\theta_H}\right)dhd\theta+\int_{\theta^*-\chi}^{\theta^*}\int_0^{\theta^*-\theta}\theta\left(\frac{1}{\chi}\right)\left(\frac{1}{\theta_H}\right)dhd\theta+\int_{\theta^*}^{\theta_H}\int_0^{\chi}\theta\left(\frac{1}{\chi}\right)\left(\frac{1}{\theta_H}\right)dhd\theta}{\frac{\theta_H-\theta^*}{\theta_H}+\frac{\chi}{2\theta_H}+\frac{\theta^*-\chi}{\theta_H}} \\
&= \frac{\int_0^{\theta^*-\chi}\int_0^{\chi}\theta\left(\frac{1}{\chi}\right)\left(\frac{1}{\theta_H}\right)dhd\theta+\int_{\theta^*-\chi}^{\theta^*}\int_0^{\theta^*-\theta}\theta\left(\frac{1}{\chi}\right)\left(\frac{1}{\theta_H}\right)dhd\theta+\int_{\theta^*}^{\theta_H}\int_0^{\chi}\theta\left(\frac{1}{\chi}\right)\left(\frac{1}{\theta_H}\right)dhd\theta}{\frac{2\theta_H-\chi}{2\theta_H}} \\
&= \frac{\int_0^{\theta^*-\chi}\frac{\theta}{\theta_H}d\theta+\int_{\theta^*-\chi}^{\theta^*}\frac{(\theta^*-\theta)\theta}{\theta_H\chi}d\theta+\int_{\theta^*}^{\theta_H}\frac{\theta}{\theta_H}d\theta}{\frac{2\theta_H-\chi}{2\theta_H}} \\
&= \frac{\frac{(\theta^*-\chi)^2}{2\theta_H}+\frac{(\theta^*)^3}{6\theta_H\chi}-\frac{\left(\theta^*\frac{(\theta^*-\chi)^2}{2}-\frac{(\theta^*-\chi)^3}{3}\right)}{\theta_H\chi}+\frac{(\theta_H)^2-(\theta^*)^2}{2\theta_H}}{\frac{2\theta_H-\chi}{2\theta_H}} \\
&= \frac{\frac{(\theta^*-\chi)^2}{2\theta_H}+\frac{(\theta^*)^3}{6\theta_H\chi}-\frac{\left(\frac{\theta^*}{2}-\frac{(\theta^*-\chi)}{3}\right)(\theta^*-\chi)^2}{\theta_H\chi}+\frac{(\theta_H)^2-(\theta^*)^2}{2\theta_H}}{\frac{2\theta_H-\chi}{2\theta_H}} \\
&= \frac{\frac{(\theta^*-\chi)^2}{2\theta_H}+\frac{(\theta^*)^3}{6\theta_H\chi}-\frac{(\theta^*+2\chi)(\theta^*-\chi)^2}{6\theta_H\chi}+\frac{(\theta_H)^2-(\theta^*)^2}{2\theta_H}}{\frac{2\theta_H-\chi}{2\theta_H}} \\
&= \frac{\frac{(\theta^*-\chi)^2}{2\theta_H}+\frac{(\theta^*)^3}{6\theta_H\chi}-\frac{(\theta^*+2\chi)\left((\theta^*)^2+(\chi)^2-2\theta^*\chi\right)}{6\theta_H\chi}+\frac{(\theta_H)^2-(\theta^*)^2}{2\theta_H}}{\frac{2\theta_H-\chi}{2\theta_H}} \\
&= \frac{\frac{(\theta^*-\chi)^2}{2\theta_H}+\frac{(\theta^*)^3}{6\theta_H\chi}-\frac{\left((\theta^*)^3+(\chi)^2\theta^*-2(\theta^*)^2\chi\right)+\left(2\chi(\theta^*)^2+2(\chi)^3-4\theta^*(\chi)^2\right)}{6\theta_H\chi}+\frac{(\theta_H)^2-(\theta^*)^2}{2\theta_H}}{\frac{2\theta_H-\chi}{2\theta_H}} \\
&= \frac{\frac{(\theta^*-\chi)^2}{2\theta_H}+-\frac{2(\chi)^2-3\theta^*\chi}{6\theta_H}+\frac{(\theta_H)^2-(\theta^*)^2}{2\theta_H}}{\frac{2\theta_H-\chi}{2\theta_H}} \\
&= \frac{\frac{(\theta^*)^2+(\chi)^2-2\theta^*\chi}{2\theta_H}+-\frac{2(\chi)^2-3\theta^*\chi}{6\theta_H}+\frac{(\theta_H)^2-(\theta^*)^2}{2\theta_H}}{\frac{2\theta_H-\chi}{2\theta_H}} \\
&= \frac{(\theta^*)^2+(\chi)^2-2\theta^*\chi-\frac{2}{3}(\chi)^2+\theta^*\chi+(\theta_H)^2-(\theta^*)^2}{2\theta_H-\chi} \\
&= \frac{-\theta^*\chi+\frac{1}{3}(\chi)^2+(\theta_H)^2}{2\theta_H-\chi}
\end{aligned}
$$

Since in equilibrium $p^* = \mathbf{E}[\theta \mid m \geq \theta^*, p = p^*]$ we have

$$\frac{p^*}{\theta_H} = \frac{1}{6}\left(\frac{\chi}{\theta_H}\right)^2 + \frac{1}{2}$$

We only need to check that $\alpha\theta_H \leq p^* \leq \theta_H$, and $p^* < \chi$. After some algebra, it is easy to see these conditions hold whenever $\alpha \in \left[\frac{1}{2}, 3-\sqrt{6}\right)$ and $\frac{\chi}{\theta_H} \in \left[\sqrt{6\alpha-3}, 3-\sqrt{6}\right)$. Therefore for each $\alpha \in \left[\frac{1}{2}, 3-\sqrt{6}\right)$ and $\frac{\chi}{\theta_H} \in \left[\sqrt{6\alpha-3}, 3-\sqrt{6}\right)$ there also exists a perfect Bayesian equilibrium given by the expressions (14)-(16) with $\frac{p^*}{\theta_H} = \frac{1}{6}\left(\frac{\chi}{\theta_H}\right)^2 + \frac{1}{2}$.

Jorge, lo que viene es el algebra de las condiciones (para que te resulte mas sencillo seguirlo y detectar posibles errores. Despues lo eliminamos)

$$\begin{aligned}
\frac{p^*}{\theta_H} &\geq \alpha \\
\frac{1}{6}\left(\frac{\chi}{\theta_H}\right)^2 + \frac{1}{2} &\geq \alpha \\
\frac{1}{6}\left(\frac{\chi}{\theta_H}\right)^2 &\geq \alpha - \frac{1}{2} \\
\frac{\chi}{\theta_H} &\geq \sqrt{6\alpha-3}
\end{aligned}$$

$$\begin{aligned}
\frac{p^*}{\theta_H} &> \frac{\chi}{\theta_H} \\
\frac{1}{6}\left(\frac{\chi}{\theta_H}\right)^2 + \frac{1}{2} &> \frac{\chi}{\theta_H} \\
\left(\frac{\chi}{\theta_H}\right)^2 - 6\left(\frac{\chi}{\theta_H}\right) + 3 &> 0
\end{aligned}$$

Hence $\frac{\chi}{\theta_H} \in \left[0, 3-\sqrt{6}\right)$ or $\frac{\chi}{\theta_H} \in \left(3+\sqrt{6}, \infty\right)$

$$\begin{aligned}
\frac{p^*}{\theta_H} &\leq 1 \\
\frac{1}{6}\left(\frac{\chi}{\theta_H}\right)^2 + \frac{1}{2} &\leq 1 \\
\frac{\chi}{\theta_H} &\leq \sqrt{3}
\end{aligned}$$

Therefore

$$\begin{aligned}
\frac{\chi}{\theta_H} &\in \left[\sqrt{6\alpha-3}, 3-\sqrt{6}\right) \\
\alpha &\in \left[\frac{1}{2}, 3-\sqrt{6}\right)
\end{aligned}$$

Case 2: $p^* \leq \chi$

Then

$$\begin{aligned}
\mathbf{E}\left[\theta \mid m \geq \theta^*, p = p^* = \theta^*\right] &= \frac{\int_0^{\theta^*} \int_0^{\theta^*-\theta} \theta \left(\frac{1}{\chi}\right) \left(\frac{1}{\theta_H}\right) dh d\theta + \int_{\theta^*}^{\theta_H} \int_0^{\chi} \theta \left(\frac{1}{\chi}\right) \left(\frac{1}{\theta_H}\right) dh d\theta}{\Pr\left(m \geq \theta^*\right)} \\
&= \frac{\int_0^{\theta^*} \frac{(\theta^*-\theta)\theta}{\theta_H \chi} d\theta + \int_{\theta^*}^{\theta_H} \frac{\theta}{\theta_H} d\theta}{\frac{(\theta^*)^2 + 2\chi(\theta_H - \theta^*)}{2\chi\theta_H}} \\
&= \frac{\frac{(\theta^*)^3}{2\theta_H \chi} - \frac{(\theta^*)^3}{3\theta_H \chi} + \frac{(\theta_H)^2 - (\theta^*)^2}{2\theta_H}}{\frac{(\theta^*)^2 + 2\chi(\theta_H - \theta^*)}{2\chi\theta_H}} \\
&= \frac{\frac{(\theta^*)^3}{3} + \chi\left[(\theta_H)^2 - (\theta^*)^2\right]}{(\theta^*)^2 + 2\chi\left(\theta_H - \theta^*\right)}
\end{aligned}$$

Since in equilibrium $p^* = \mathbf{E}\left[\theta \mid m \geq \theta^*, p = p^*\right]$, after some algebra, we have the following cubic equation

$$P\left(\frac{p^*}{\theta_H}\right) = \frac{2}{3}\left(\frac{\chi}{\theta_H}\right)^{-1}\left(\frac{p^*}{\theta_H}\right)^3 - \left(\frac{p^*}{\theta_H}\right)^2 + 2\left(\frac{p^*}{\theta_H}\right) - 1 = 0.$$

We want to show that $P(.)$ has a real root in the interval $\left[\alpha, \min\left\{\frac{\chi}{\theta_H}, 1\right\}\right]$, which means that there exists a $p^* = \mathbf{E}\left[\theta \mid m \geq \theta^*, p = p^*\right]$ and such that $\alpha\theta_H \leq p^* \leq \max\left\{\theta_H, \chi\right\}$ Note first that

$$P(\alpha) = \frac{2}{3}\left(\frac{\chi}{\theta_H}\right)^{-1}\alpha^3 - \alpha^2 + 2\alpha - 1,$$

which implies that $P(\alpha) \leq 0$ if and only if $\frac{\chi}{\theta_H} \geq \frac{\frac{2}{3}\alpha^3}{\alpha^2 - 2\alpha + 1}$. Second,

$$P\left(\frac{\chi}{\theta_H}\right) = -\frac{1}{3}\left(\frac{\chi}{\theta_H}\right)^2 + 2\left(\frac{\chi}{\theta_H}\right) - 1,$$

which implies that $P\left(\frac{\chi}{\theta_H}\right) \geq 0$ if and only if $\frac{\chi}{\theta_H} \in \left[\left(3 - \sqrt{6}\right), 3 + \sqrt{6}\right]$, and $P\left(\frac{\chi}{\theta_H}\right) \leq 0$ if and only $\frac{\chi}{\theta_H} \in \left[0, \left(3 - \sqrt{6}\right)\right] \cup \left[\left(3 + \sqrt{6}\right), \infty\right)$. Finally,

$$P(1) = \frac{2}{3}\left(\frac{\chi}{\theta_H}\right)^{-1} > 0.$$

We have to consider two possible situations. If $\frac{\chi}{\theta_H} \leq 1$, then $P(\alpha) \leq 0$ and $P\left(\frac{\chi}{\theta_H}\right) \geq 0$ whenever $\frac{\chi}{\theta_H} \in \left[\max\left\{\frac{\frac{2}{3}\alpha^3}{\alpha^2 - 2\alpha + 1}, \left(3 - \sqrt{6}\right)\right\}, 1\right]$. Hence $P(.)$ has at least one real root in the interval $\left[\alpha, \frac{\chi}{\theta_H}\right]$. On the other hand, if $\frac{\chi}{\theta_H} > 1$, then $P(\alpha) \leq 0$ and $P(1) > 0$ whenever $\frac{\chi}{\theta_H} \geq \frac{\frac{2}{3}\alpha^3}{\alpha^2 - 2\alpha + 1}$. Hence $P(.)$ has at least one real root in the interval $[\alpha, 1]$.

Summing up, whenever $\alpha \in \left[\frac{1}{2}, 1\right)$ and $\frac{\chi}{\theta_H} \geq \max\left\{\frac{\frac{2}{3}\alpha^3}{\alpha^2 - 2\alpha + 1}, \left(3 - \sqrt{6}\right)\right\}$ there exists is a perfect Bayesian equilibrium given by the expressions (14)-(16) with $\frac{p^*}{\theta_H}$ determined by a real root of the polinomial $P\left(.\right)$ in the interval $\left[\alpha, \min\left\{\frac{\chi}{\theta_H}, 1\right\}\right]$.

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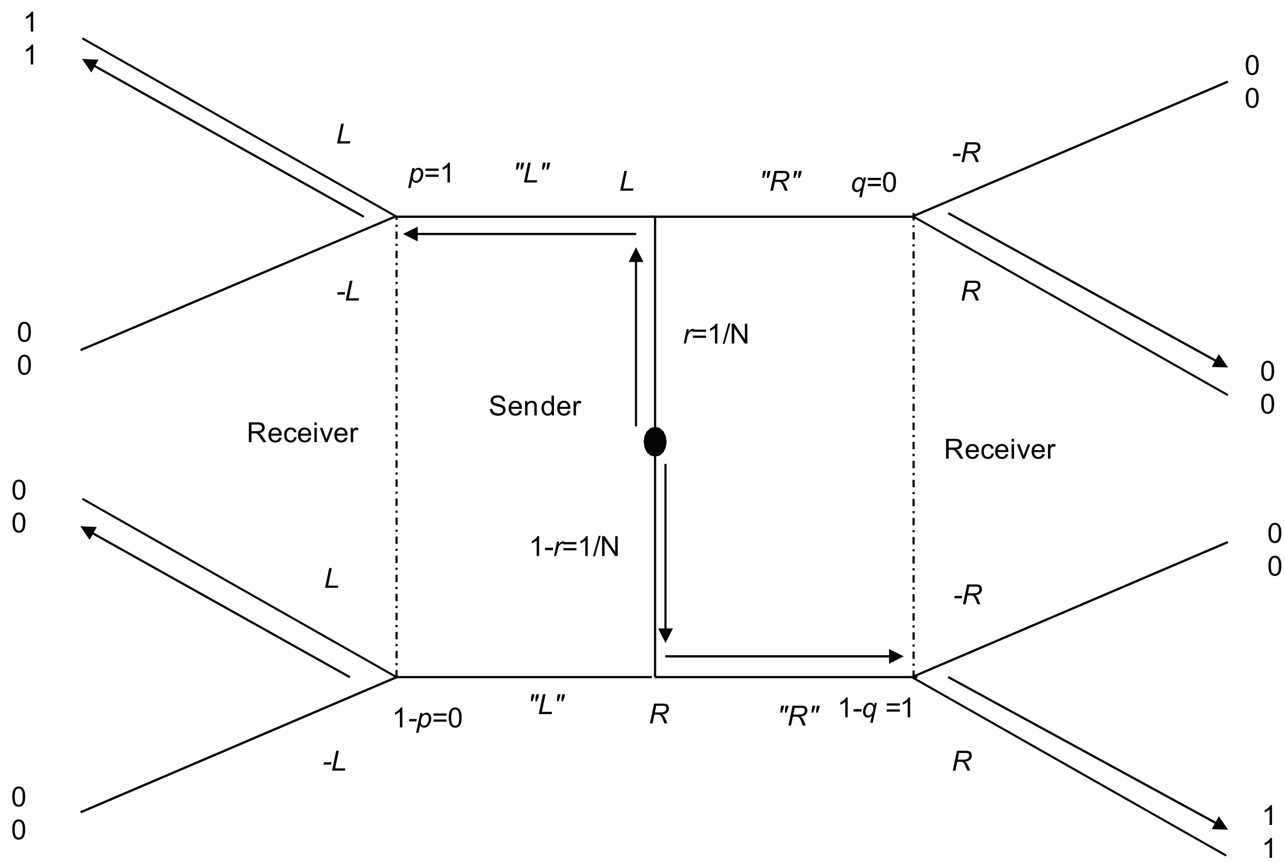

Figure 1: Uninformative pooling equilibrium

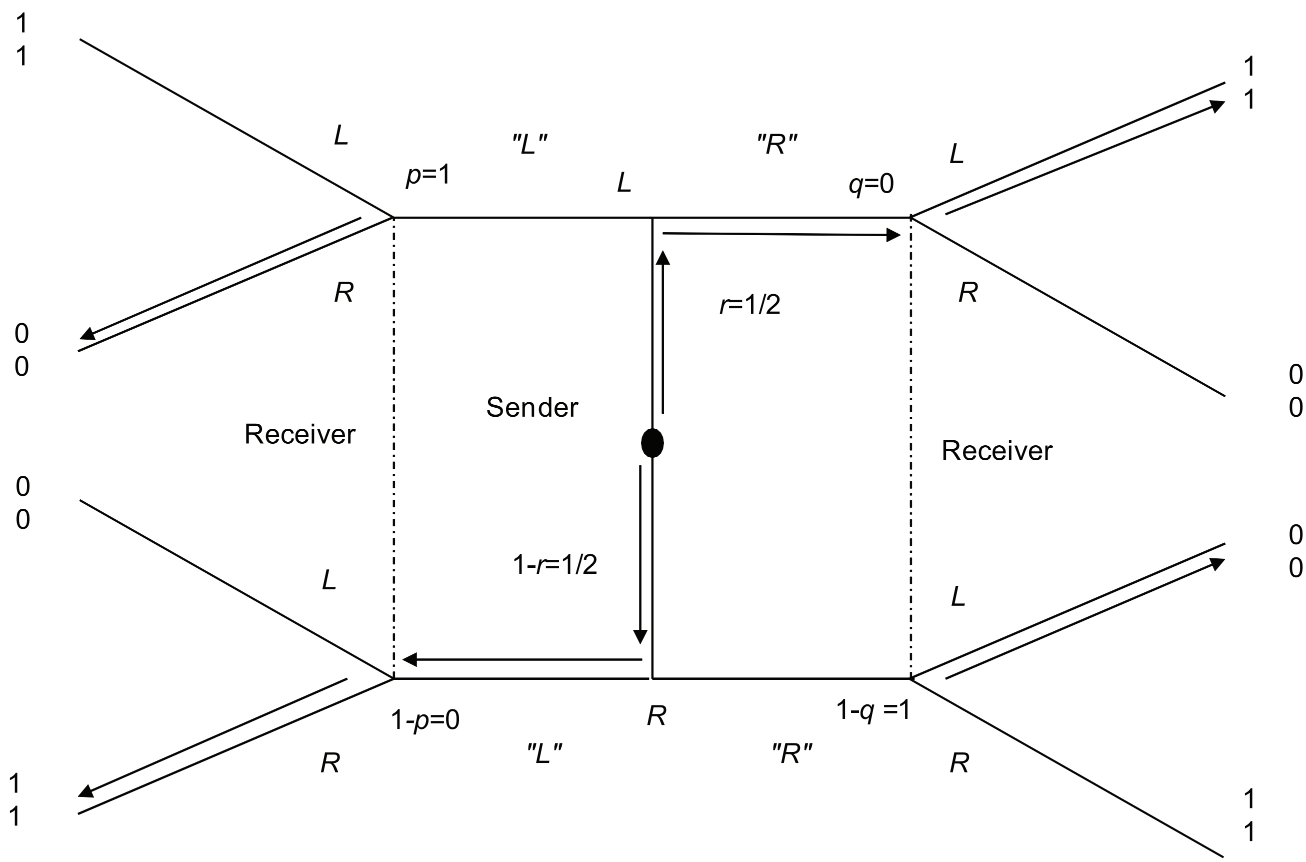

Figure 2: Uninformative separating equilibrium

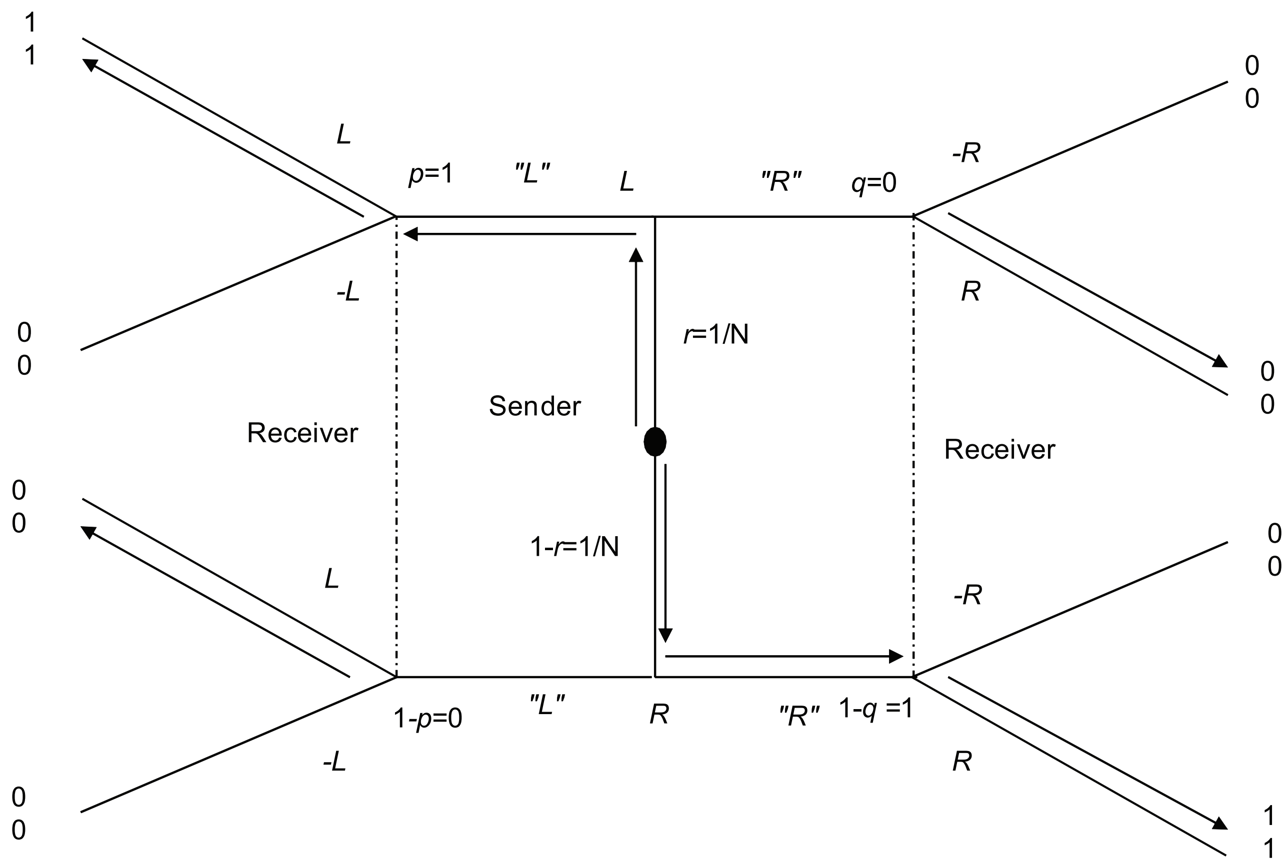

Figure 3: Informative separating equilibrium where words are used in natural sense

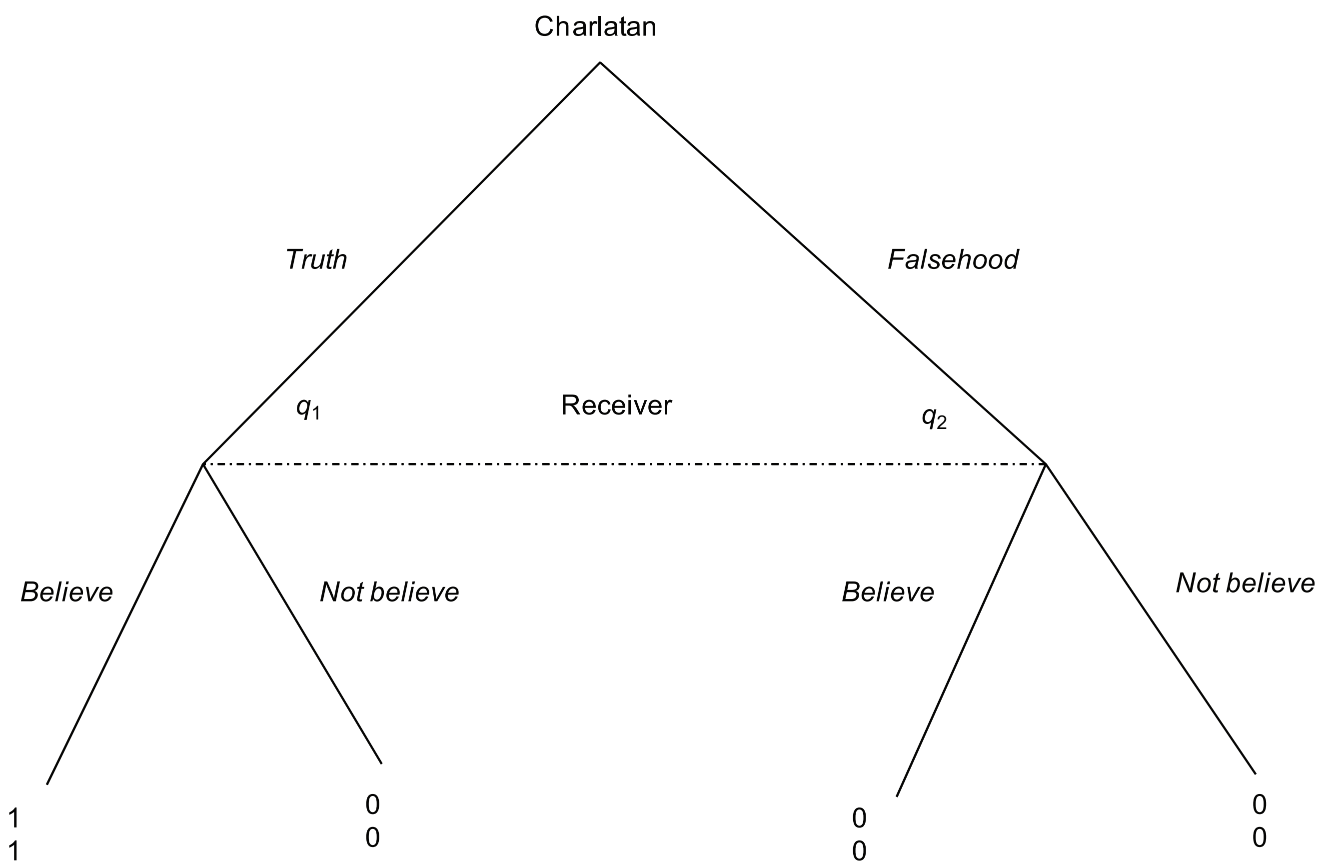

Figure 4: Communicating intentions in coordination games

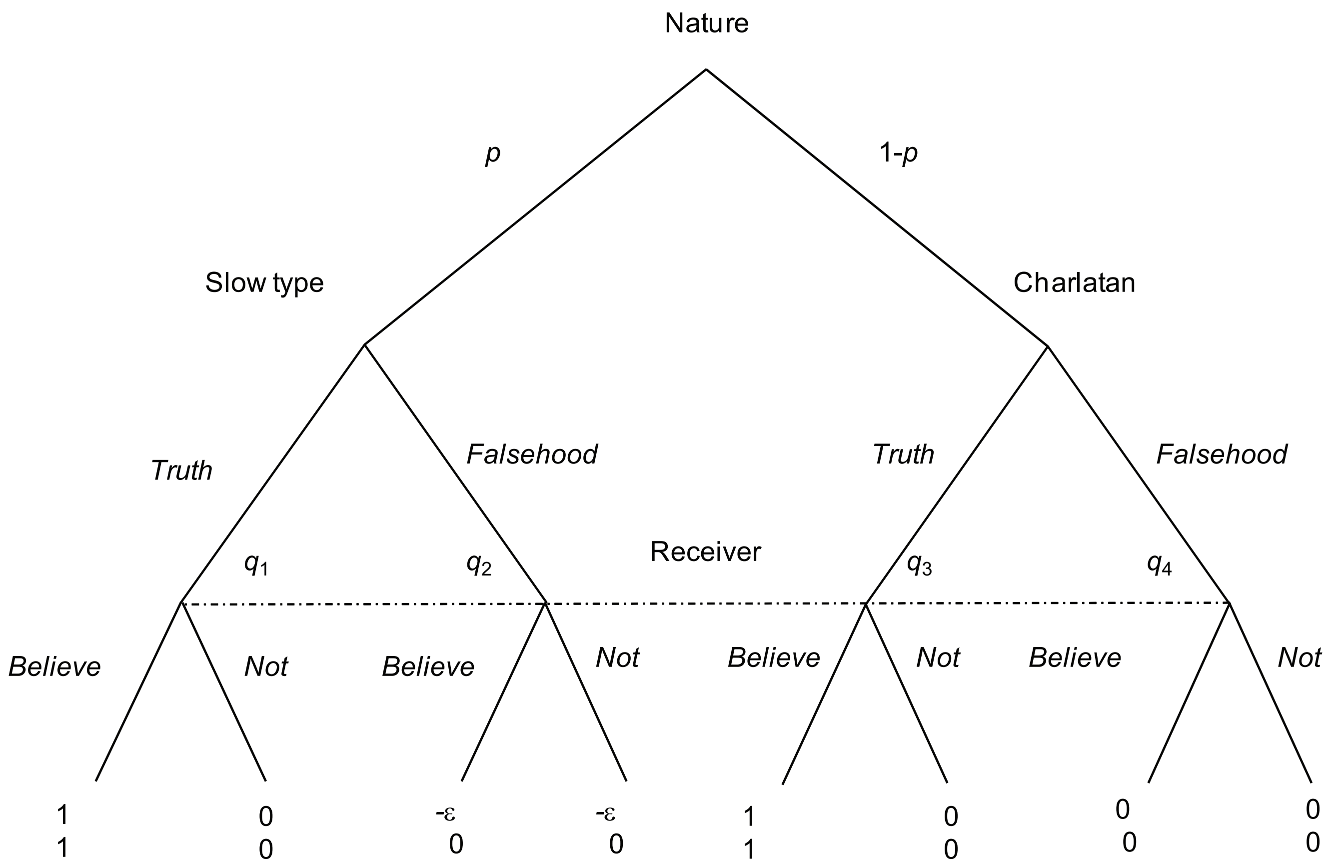

Figure 5: Communicating intentions in coordination games with incomplete and imperfect information

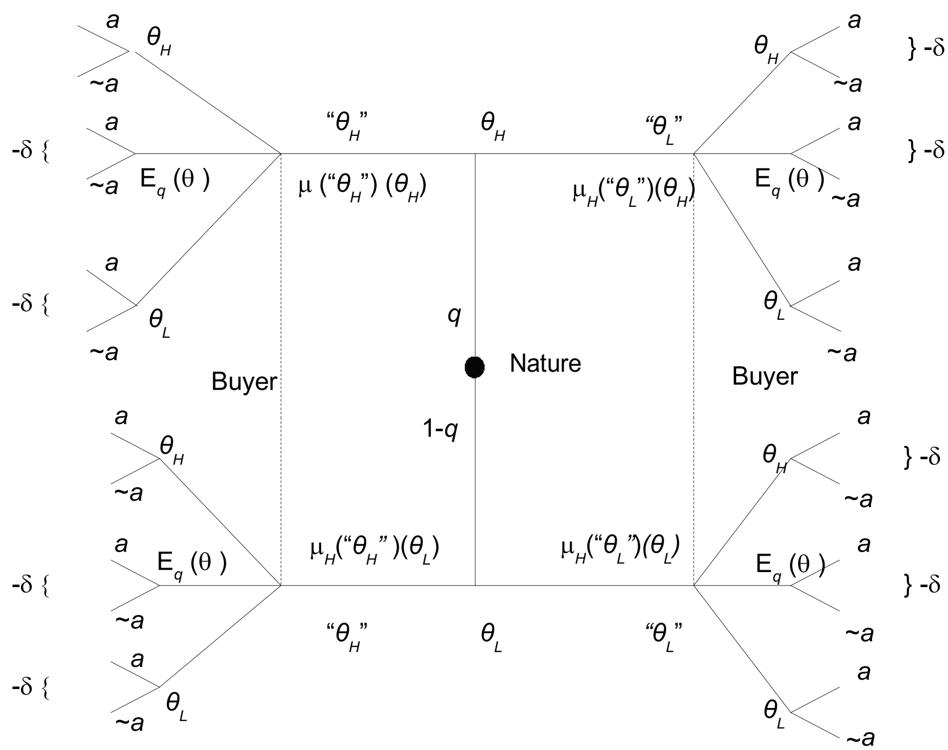

Figure 6: Cheap-talk game, where responses to messagehigh quality or low quality can be high price, intermediate price or low price, and the seller can say yes or no

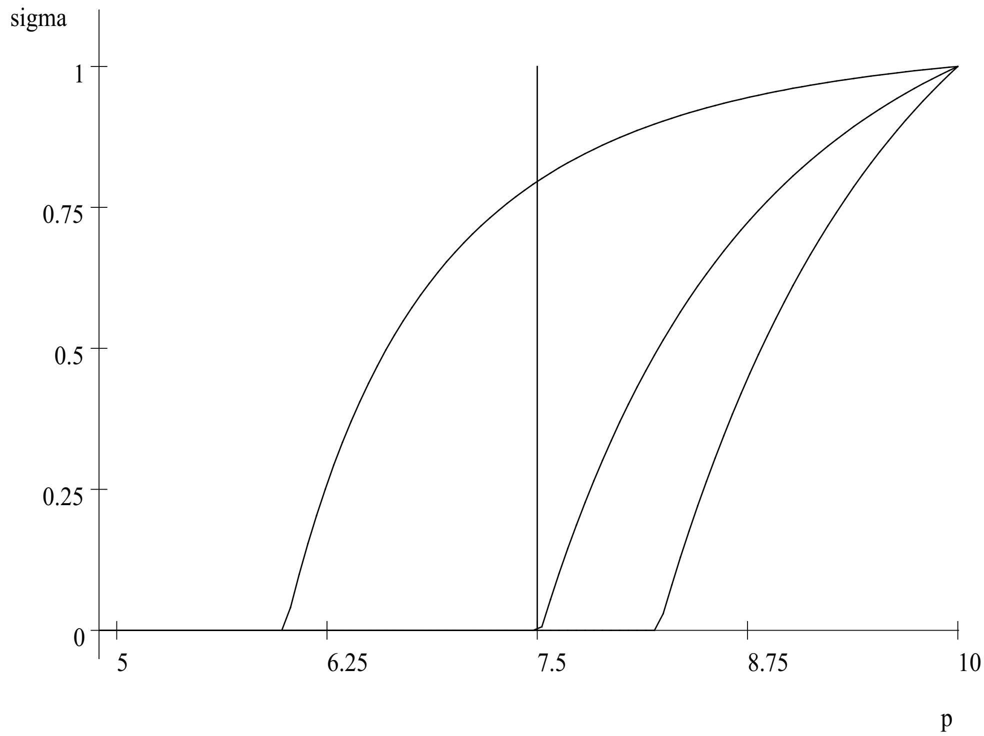

Figure 7: Two quality types and continuum of honesty: Perfect Bayesian equilibria

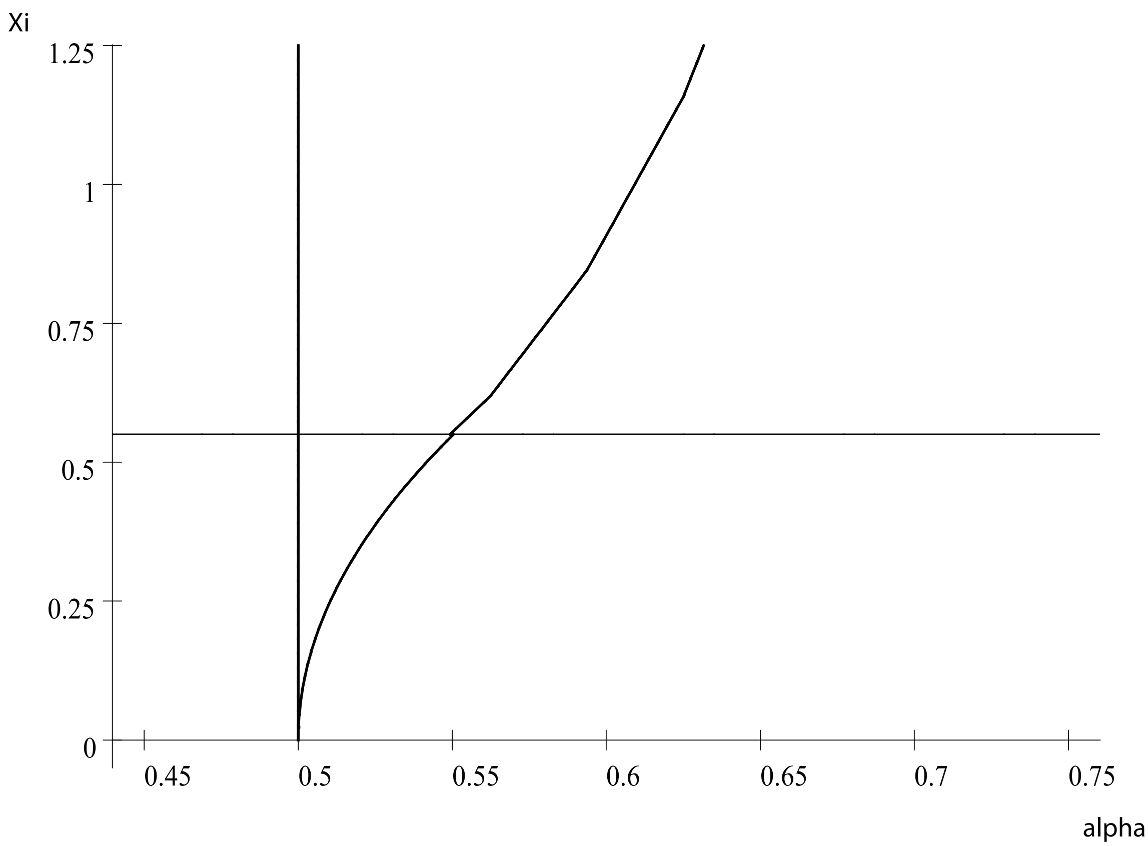

Figure 8: Continuum of quality and honesty: Perfect Bayesian equilibria

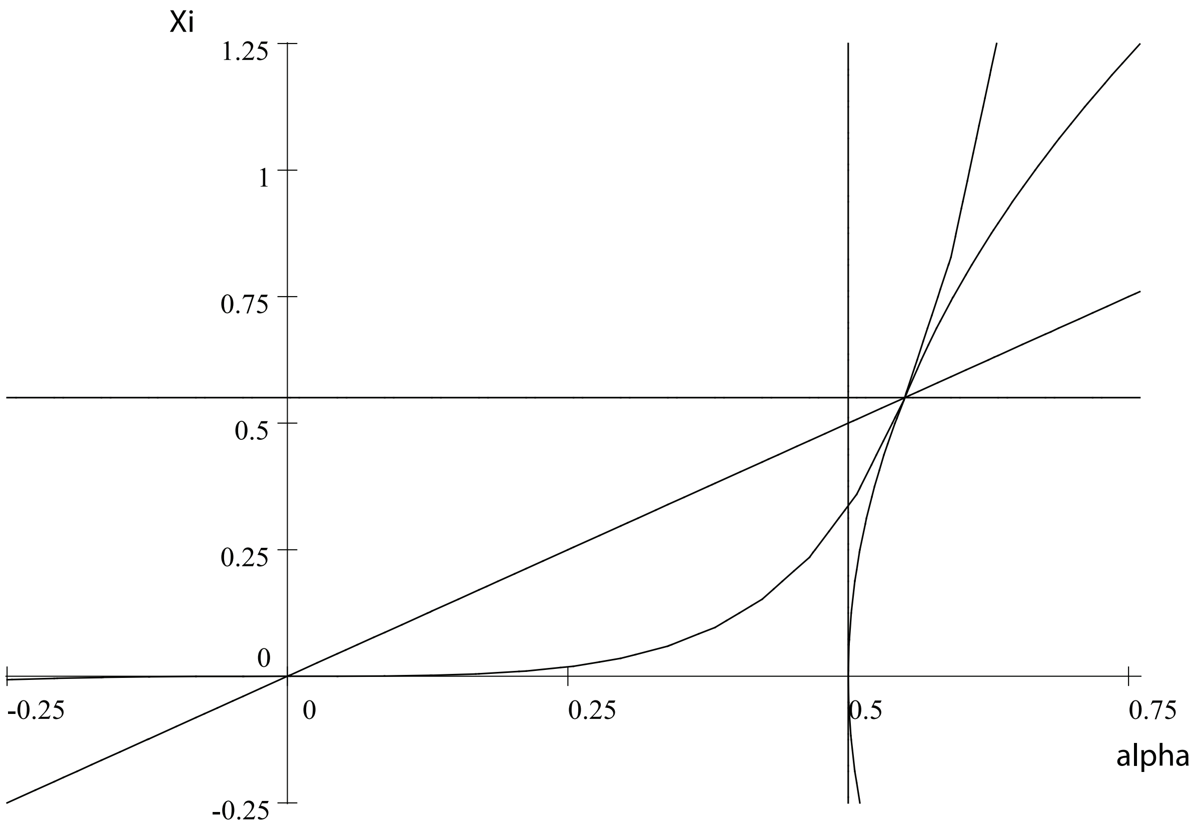

Figure 9: Continuum of quality and honesty: Perfect Bayesian equilibria