"THE STRATEGIC SUPPLY OF PRECISIONS"

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ABSTRACT

We analyze the incentive of an agent, with private knowledge and a given reputation, to reveal information. The agent is formally seen as controling the accuracy of surveys of a standard decision-theoretic model. This approach yields testable predictions about messaging behavior: people with good standing will not provide further precisions; people with bad standing will do so, but sometimes only if they are actually good.

Keywords: Signaling, decision analysis.

1. INTRODUCTION

Signaling arises when an interested party (e.g., a firm, a job candidate) has access to more relevant information than its counterpart (e.g., an investor, an employer). Such knowledgeable agent can then choose which amount of information to share, in what kind of package.

In a world where knowledge of concrete circumstances is necessarily disseminated across millions of individuals, signaling should be omnipresent. Only recently, however, has signaling been formally studied and applied to various circumstances.[2] The models proposed so far, however, have described the choice between specific signaling devices, without explicitly addressing matters of informational content (e.g. precision). Hence, many important signaling phenomena still lack explanation. How do agents use signaling devices when the information they can send through these devices can vary? In financing, for instance, why do some firms voluntarily announce additional managerial forecasts (Waymire (1985))?

Our paper is a first attempt at providing a framework for an information-theoretic treatment of signaling. We build a simple model around two main questions: 1) When does it pay a sender to give a precise message, and when is a simpler, "hazier" message

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[2] Early signaling models can be found in Spence (1974)'s seminal book. Since then, many specific signals have been studied: let us simply mention, for instance, education (Spence (1973)), warranties (Grossman (1981)), prices (Farrell (1980), Wolinsky (1983)), and advertising (Kihlstrom and Riordan (1984)).

just as good if not better?, 2) When does it pay a receiver to analyze, at some cost, a sophisticated message, and when is immediate decision preferable? This model is presented in the next section. It is an extensive form game with imperfect information that, we believe, captures several neglected aspects of signaling situations. Two applications are presented in section 4; they are related to marketing and financial economics. Section 5, finally, is devoted to sketching avenues for future research.

2. THE MODEL

Statistical decision theory distinguishes between two types of decisions: decisions to act without delay, and decisions to collect further information. Models in this field have so far captured situations where the latter decisions yield a fixed, given, exogenous amount of decrease in uncertainty. We will now attempt to describe what happens when the amount of decrease in uncertainty is controlled by an opportunistic agent.[3]

Consider the game in extensive form depicted in figure 1.

There is an agent to whom nature discloses its current state. This state can be good (g) or bad (b). There is also a decision

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[3] Notable contributions to this topic are two recent papers by Winkler and Gaba (1988) and Gaba (1989). They consider sampling from manipulated data. The extent of the manipulation, however, is taken as exogenous.

maker whose actions, given the state of nature, determine both his and the agent's payoffs. The decision maker does not know the real state of nature. He just assigns a prior probability π to the state of nature being good.

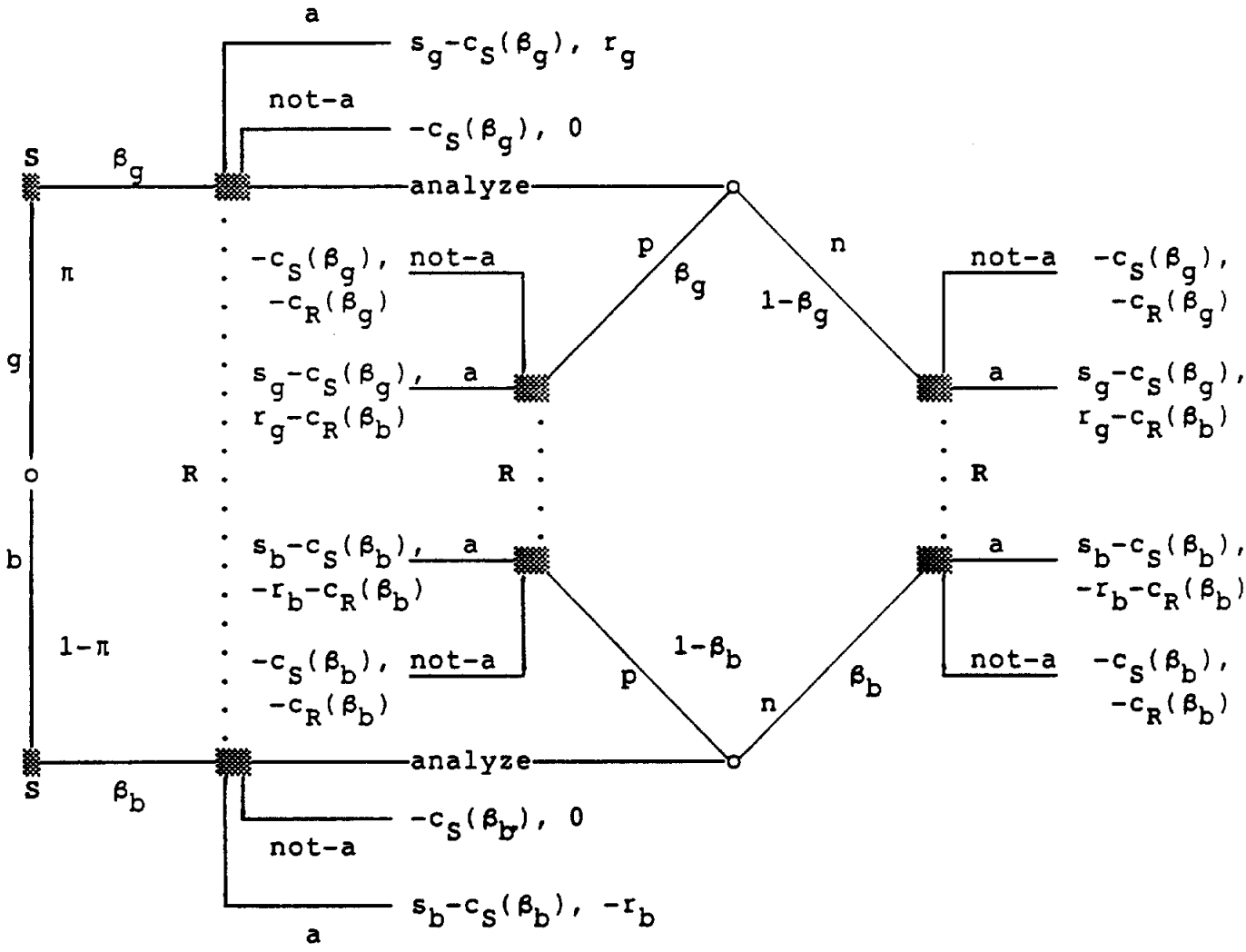
The agent, labeled (S) for "sender", may provide the decision maker with some precisions (β_i, $i = g,b$) about the state of nature. The decision maker, denoted (R) for "receiver", has then to choose between acting (a) immediately, droping the whole issue (not-a), or postponing the decision until a careful analysis of (S)'s message has been performed (analyze). If the state of nature is good, an analysis will yield a positive recommendation (p) with probability β_g, while a bad state of nature will lead to a negative advice (n) with probability β_b.

If (R) decides to act now, his payoff is r_g (> 0) if the state of nature is good and $-r_b$ (< 0) if the state of nature is bad. The outcome for (S) is s_g (> 0) minus some signaling cost $c_S(\beta_g)$ if the state of nature is good, and s_b ($0 < s_b < s_g$) minus $c_S(\beta_b)$ if the state of nature is bad.

If (R) chooses to drop the issue now, his payoff is 0 for any state of nature. The sender then gets $-c_S(\beta_g)$ under a good and $-c_S(\beta_b)$ under a bad state of nature.

If the decision maker analyzes the message, his payoff depends of course on the subsequent action he takes. If he decides to act, his net gain is r_g minus an analysis cost $c_R(\beta_g)$ when the state of nature is good, and $-r_b-c_R(\beta_b)$ when the state is bad. In this case (S) gets $s_g-c_S(\beta_g)$ or $s_b-c_S(\beta_b)$ with a good

or a bad state of nature **respectively.** If, on the other hand, (R) prefers not to act, he ends up paying only the cost of analysis, while (S) bears the cost of providing precisions.



<u>figure 1</u>: the game in extensive form

This last set of payoffs completes the description of the game. Such a game has many interpretations, some of which are presented in section 4. We shall now exhibit its "most plausible" outcomes.

3. EQUILIBRIA

In games like the actual one players are usually assumed to be "sequentially rational", i.e. at each decision node a decision is chosen that is optimal for the remainder of the game. In order to capture this behavior one may solve the game using the perfect Bayesian equilibrium solution concept. Perfect Bayesian equilibria (PBE) are found by backward induction, using Bayes's rule whenever possible to compute the players' beliefs at each information set. In doing so one also has to take into account beliefs about out of equilibrium actions.

Before computing the PBE of the actual game, we make the following assumptions about the communication and analysis cost functions.

ASSUMPTIONS: The cost functions $c_S(\cdot)$ and $c_R(\cdot)$ are strictly increasing and differentiable on [0.5,1]. Also $c_S(\beta) = c_S(1-\beta)$ and $c_R(\beta) = c_R(1-\beta)$. Finally, $c_S(0.5) = c_R(0.5) = 0$.

Examples of such functions are $c_S(\beta) = c_R(\beta) = 1 - H(\beta)$, where $H(\cdot)$ is the entropy function of information theory:
$H(\beta) = -[\beta\log_2(\beta) + (1-\beta)\log_2(1-\beta)]$.[4]

Consider the last stage of the game. There the receiver must choose between a, not-a, or a mix of these, on the basis of

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[4] See Pierce (1980) for a lucid introduction to information theory.

having arrived at either a **positive** (p) or a negative (n) conclusion. Note that this stage would never be reached if $\beta_g \neq \beta_b$, because then the receiver could infer the true state-of-nature upon reception of the message, and be able to decide without having to perform any analysis. Without loss of generality, let us assume that $\beta_g \geq 0.5$. Then the receiver chooses a (not-a) whenever he arrives at a positive (negative) conclusion.

Now, at stage 2, the receiver has to select between a, not-a, analyze or a mix of these. If $\beta_g \neq \beta_b$, the receiver's best response is clearly to act when he sees β_g and not to act otherwise. If $\beta_g = \beta_b = \beta$, then $P(g|\beta) = \pi$, $P(b|\beta) = 1-\pi$, so acting immediately yields the expected payoff $\pi r_g - (1-\pi)r_b$ while analyzing yields $\pi\beta r_g - (1-\pi)(1-\beta)r_b - c_R(\beta)$. Given the decisions that would be taken at the next stage, analyzing is preferred if and only if

(1) $\pi\beta r_g - (1-\pi)(1-\beta)r_b - c_R(\beta) \geq 0$ (it is better than not-a),

and

(2) $(1-\pi)\beta r_b - \pi(1-\beta)r_g - c_R(\beta) \geq 0$ (it is better than a).

This behavior of the receiver is then taken into account by the sender in choosing the precision of his revelations at the first stage of the game.

At **equilibrium** the amount of precision β that is consented by the sender may or may not vary with the actual state of nature. The equilibrium is usually called a **screening equilibrium** if β does vary; it is called a **pooling equilibrium** if β does not vary.

Some pooling and screening equilibria are illustrated in

figure 2. We denote β_0 the maximand of $[\beta s_g - c_s(\beta)]$, β_1 the smallest β required to make analysis profitable, and β_2 the unique point such that $c_s(\beta) = s_b$. We also focus on the case $s_g > s_b$; the opposite situation $s_g \leq s_b$ requires a totally similar treament.

Only one pooling equilibrium may subsist when the receiver is "optimistic", i.e. $\pi r_g - (1-\pi)r_b > 0$. This is the content of the following proposition.

PROPOSITION 1: If $\pi r_g - (1-\pi)r_b > 0$, i.e. the receiver is optimistic, an equilibrium is a pooling one where the sender provides minimal precisions $\beta = 0.5$ and the receiver takes action a.

PROOF: Beliefs of the receiver that support the equilibrium of the proposition are $P(g|\beta) = \pi$ for all β in $[0.5,\beta_2]$ and $P(g|\beta) = 1$ for β in $(\beta_2,1]$. ▒

Both pooling and screening equilibria can occur, however, when the receiver is "neutral", i.e. $\pi r_g - (1-\pi)r_b = 0$, or "pessimistic", i.e. $\pi r_g - (1-\pi)r_b < 0$. These equilibria can be "justified" by the receiver making the following observations:

1) Only the bad-type sender has an incentive to provide an amount of precisions lower than β_0;

2) Anybody can provide an amount of precisions higher than β_0, but only the good-type sender can afford $\beta > \beta_2$.

PROPOSITION 2: If $\pi r_g - (1-\pi)r_b = 0$, i. e. the receiver is neutral , some equilibria are

pooling ones: if $s_b - c_s(\beta_0) > (1-\beta_0)s_g$ senders of both types provide identical precisions $\beta_g = \beta_b = \max(0.5,\beta_0)$ and the receiver analyzes messages.

or **screening ones:** if $s_b - c_s(\beta_0) \leq (1-\beta_0)s_g$ the good-type sender provides an amount of precisions β_g just above β_2 while the bad-type one offers minimal precisions $\beta_b = 0.5$; the receiver then takes action a at $\beta \geq \beta_2$ and not-a when $\beta = 0.5$.

PROOF:

Beliefs that support the above pooling equilibrium are $P(g|\beta) = 0$ for $\beta < \max(0.5,\beta_0)$, $P(g|\beta) = \pi$ for all β between $\max(0.5,\beta_0)$ and β_2, and $P(g|\beta) = 1$ for β in $(\beta_2,1]$.

The receiver's beliefs that support the screening equilibrium are $P(g|\beta) = \pi$ for all β in $[0.5,\beta_2)$ and $P(g|\beta) = 1$ for β in $[\beta_2,1]$. ▒

PROPOSITION 3: Let $\underline{\beta} = \max(\beta_0,\beta_1)$. If $\pi r_g - (1-\pi)r_b < 0$, i. e. the receiver is **pessimistic**, some equilibria are

pooling ones: if $s_b - c_s(\underline{\beta}) > (1-\underline{\beta})s_g$ both types of senders send the same amount of precision $\beta_g = \beta_b = \underline{\beta}$ and the receiver chooses to analyze messages.

or **screening ones:** if $s_b - c_s(\underline{\beta}) \leq (1-\underline{\beta})s_g$ the good-type sender provides an amount of precisions β_g just above β_2 while the bad-type one offers minimal precisions $\beta_b = 0.5$; the receiver then takes action a at $\beta \geq \beta_2$ and not-a when $\beta = 0.5$.

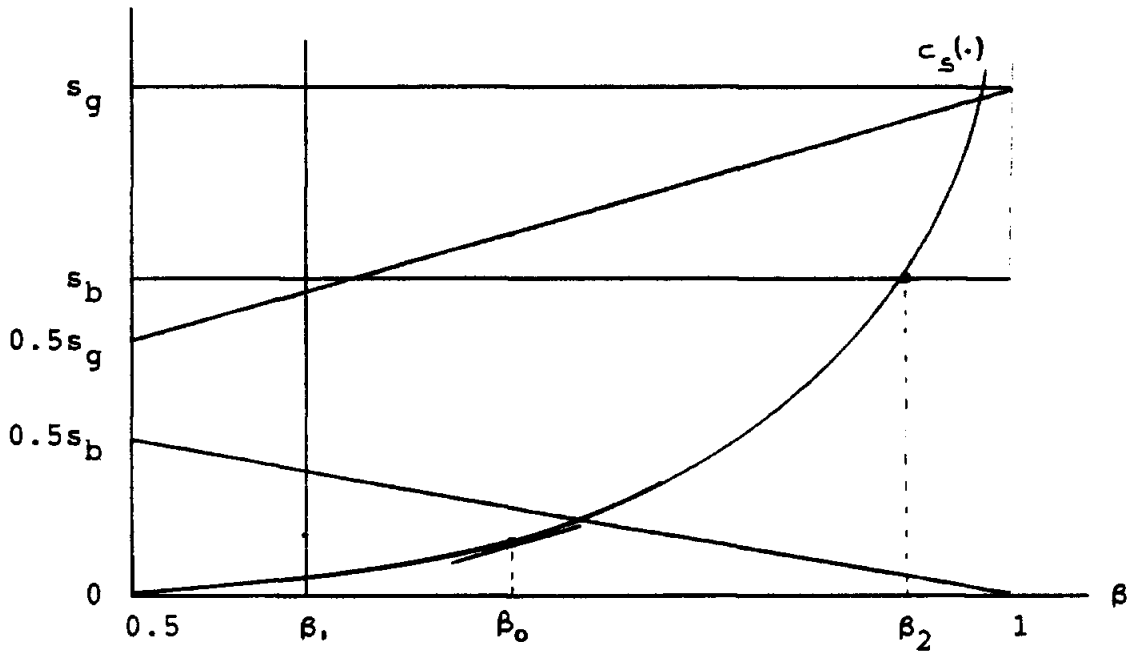

figure 2a: pooling equilibrium under pessimism

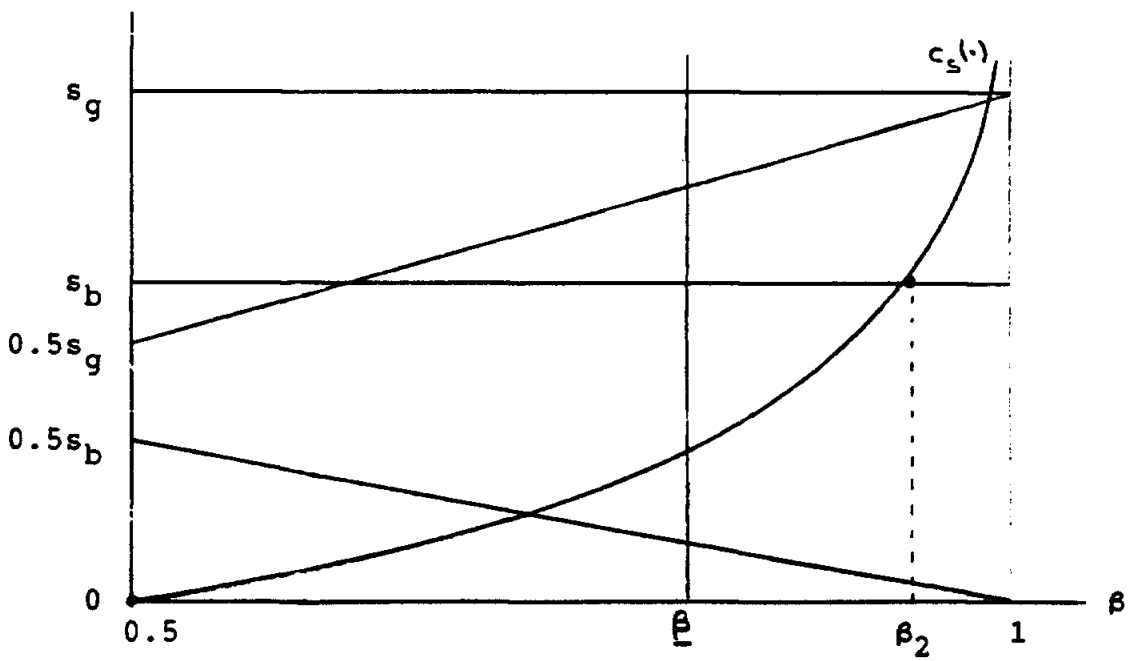

figure 2b: a screening equilibrium with pessimism

PROOF:

Beliefs supporting the pooling equilibrium are $P(g|\beta) = 0$ for β in $[0.5,\underline{\beta})$, $P(g|\beta) = \pi$ for β in $[\underline{\beta},\beta_2]$ and $P(g|\beta) = 1$ for β in $(\beta_2,1]$.

Screening equilibria can be supported by $P(g|\beta) = 0$ for β in $[0.5,\underline{\beta})$, $P(g|\beta) = \pi$ for β in $[\underline{\beta},\beta_2)$ and $P(g|\beta) = 1$ for β in $[\beta_2,1]$. ▒

We shall next turn to the interpretation of the present model and its propositions.

4. INTERPRETATIONS

The model presented in section 2 is very general. It can be applied every time there exist information asymmetry between two agents and resources can be committed to send <u>and</u> to analyze messages. Here, we chose to analyze two different types of strategies typically discussed respectively in the marketing and fianancial economics literatures.

<u>a) Marketing</u>

An interesting application concerns marketing. The firm (= S) decides how to present a product. One costly method consists in offering a free examination period for the product. The analysis is costly for the consumer (= R): it implies time and some risk

that the product might not be taken back.

What do we observe? The system is mostly used for new products or when they are "too good to be true", i.e. when the receiver is in a pessimistic mood.[5]

b) Financial economics: issue of securities

The announcement of a forthcoming securities issue is a special case of event happening to the firm and triggering some signal to be sent, for which the moods of the market and the related costs are fairly well documented.

Imagine that the firm has decided to issue a given type of securities. We consider two variations of the game:

1) the firm plans to issue equity,

2) the firm plans to issue riskless bonds.

The firm then decides how it wants to advertise and to execute the issue: it can choose an informative and costly approach, or use a cheaper, not very informative approach (β=.5). Then the market decides (to approve the issue and) to buy the new securities (= a) or not (= not-a) or to analyze the information available before deciding whether it wants to act or not. The costly method of issuing securities consists in making many announcements and using the full service of investment bankers. The low cost method consists in using rights issues or using

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[5] Consider the following example: miracle drugs to lose weight in 20 days have a x days trial period. Diet products sold in pharmacy do not have this.

shelf registration.[6]

What do we observe? The market is pessimistic (optimistic) when an equity (bond) issue is announced (see Asquith (1986), Mikkelson and Partch (1986)). The abnormal return at the announcement, i.e. the change in value created by the announcement only, is negative for equity issues and zero or positive for bond issues. It can be interpreted as a rational reaction of the market to the forthcoming game (π is 20% for equity issues, 50% for bonds issues). We know that a large proportions of firms use the informative and costly method (high β) for equity issues and not for bond issues. (See also Brealey and Myers (1984) puzzle # 6: Why don't firms use rights? we do not know). Nearly all US firms use underwriters for their equity issues. Shelves are used mostly by safe firms, for low risk securities like riskless bonds. We also observe that the legislator and the investors spend ressources and time acquiring the documents published by the firm about the issue.

5. CONCLUSION AND EXTENSIONS

The paper is an attempt to study economic signals according to <u>both</u> their type and informational content. An informed agent provides a decision maker with messages that are more or less

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[6] Shelf registration allows firms to issue equity very fast and without lengthy filings. See Smith (1986) for the respective costs of the different methods.

accurate and costly. Then the decision maker, who can observe the accuracy of the received information, chooses to act, not to act, or to analyze further the signals at a cost and a probability of finding out that increase with the accuracy of the data. In this context it appears that 1) an agent with good standing will not send signals of greater precision, 2) an agent with bad standing will do so, but sometimes only when he is truly good.

The actual analysis could be improved in a number of ways. Most importantly, the model yields much too many equilibria; we argued that the ones we selected were "plausible", but a formal argument is still needed to reduce the set of possible equilibria to the ones that are stated in the propositions.

The paper leads nevertheless to several interesting research avenues. In a finer analysis of the informational content of signals, one could try to relax the strong assumption we made that the receiver could identify the exact amount of precisions; for instance, the receiver could be able to perceive only the entropy of messages. One could also see signals as composed of several bits of information of various accuracy; what proportion of good and bad pieces of information would then exist in a signal that must carry a given total amount of precisions?

Regulation issues could also be discussed. When would legislation be helpful? Is it rational to observe in the market a <u>coexistence</u> of voluntary and costly information transfers organized by firms and legislation requiring minimum information from certain firms or in special circumstances? Our analysis of

the pessimistic case points out circumstances where regulation may not be necessary.

On the empirical side, note that the probability of a correct conclusion being drawn when the optional analysis is carried out is endogeneous in the current model. That is, using the vocabulary of statistics, the type I and type II errors of hypothesis tests are endogeneous. Such an approach should perhaps be adopted in designing empirical tests of the signaling strategies of firms.[7]

There is also here a classification of signals based on the degree of prior pessimism and optimism of decision makers (for example measured by the average abnormal reaction to the signal). Such a classification may allow a better comparison of the relative effects and importance of different signals, especially of those signals that can carry a variable amount of information.

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[7] Intuitively, different significance levels may be needed for different types of events to have valid comparisons. Christie (1983) advises to adjust the significance level of event studies for the increase in uncertainty on event days. The adjustment would add to the discussion on the quality of event studies (Brown and Warner (1980), Klein and Rosenfeld (1987).

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