# STRATEGIC DISCLOSURE OF RESEARCH RESULTS: THE COST OF PROVING YOUR HONESTY*

### *Emeric Henry*

In situations where a biased sender provides verifiable information to a receiver, I study how strategic reporting affects the incentives to search for information. Research provides series of signals that can be used selectively in reporting. I show that the sender is strictly worse off when his research effort is not observed by the receiver: he has to conduct more research than in the observable case and in equilibrium, discloses all the information he obtained. However this extra research can be socially beneficial and mandatory disclosure of results can thus be welfare reducing. Finally I identify cases where the sender withholds evidence and for which mandatory disclosure rules become more attractive.

In 2002, editors of eleven of the most prestigious medical journals, announced that they would only publish the results of studies that were entered at their start in a publicly available database.[1] Pharmaceutical firms conduct clinical trials to test the efficacy and potential side-effects of their drugs and to compare them to competitors' products. Publishing results of studies is an efficient way to influence doctors' prescriptions and patients' tastes. However, firms can conduct multiple trials and select the most favourable results. The system of mandatory disclosure adopted by medical journals is a response to the fear of such selective publishing.[2] It makes the research effort of pharmaceutical firms more observable and will influence both the information they disclose and the amount of research they perform. In the present article I study the interaction between the research and disclosure decisions, which is an essential element in many settings. The adoption of mandatory disclosure rules has subtle effects and I discover that leaving the research effort unobservable can sometimes be socially beneficial.[3]

  I study the interaction between research and disclosure in a model where a biased sender searches for information and communicates it strategically to a receiver who will take a decision impacting both their welfare.[4] The quality of the decision depends on the value of an underlying state. I suppose that the information that the sender provides on the state is verifiable, so that he can withhold some evidence but cannot fabricate it. The sender first determines how much research to perform and, once the results are obtained, what to disclose to the receiver.

  [1] This announcement was confirmed in September 2004. This applies to studies started after 1 September 2005. See declarations by the International Committee of Medical Journals ICMJE.
  [2] The system prevents the selective publishing of positive results: to be allowed to submit the results for publication, the trial needs to be registered initially, before the results are known. Note that similarly, in reaction to a series of scandals, the US Congress enacted in September 2007 the FDA Amendments Act which strengthens the disclosure requirements firms face.
  [3] I will show however that, in the case of clinical trials, mandatory disclosure can have additional benefits that will tend to dominate.
  [4] In the previous example the sender is the pharmaceutical firm and the receiver is the doctor who will decide whether to prescribe the drug, thus influencing the firm's profits.

The research technology is a central element of this model. I view research as having two essential functions for the sender. It increases his knowledge of the state but also provides pieces of evidence that can be used selectively to influence the receiver.[5] This second function is the main focus of this article. I refer to it as the strategic function of research. To study this alternative function explicitly, I had to propose a different model of research than the one commonly used in the literature.[6] In my model, I view the outcome of research as a series of infinitesimal positive or negative signals, interpreted as the results of a series of small experiments. The aggregate amount of positive signals is informative about the state. In this context, increasing the amount of research performed, improves the knowledge of the sender but also produces more positive signals that can be used to mislead the decision maker.

In this environment, I show that the sender conducts more research when his research effort is not observed by the receiver. However, in equilibrium he reveals all the information he obtained and is strictly worse off than if his research effort was observable.[7] Indeed, in the unobservable case, if the quantity of research the receiver expects is too low, the sender will have an incentive to search further, obtain more favourable evidence, conceal the unfavourable one and thus mislead the receiver into believing the state is higher. The receiver understands these incentives and knows that extra research will be conducted to mislead her, up to the point where the marginal costs equal the marginal benefits. In equilibrium, the receiver therefore knows, though she does not observe, the amount of research performed and the sender is forced to reveal all the information he obtained, as if the research effort was observable. The sender is thus strictly worse off when his research effort is not observed by the receiver. He has to incur the cost of extra research to convince her that he is not hiding any evidence, the cost of proving his honesty.

This initial important result, which rests on the strategic function of research, is used to discuss the benefits of introducing mandatory disclosure rules. I show that, under a condition that I derive, social welfare is greater when the research effort is not observed by the receiver. The sender, when he determines his research effort, ignores the benefits to the receiver of obtaining better information. In the unobservable case, the extra amount of research conducted to show that no information is withheld, can correct this ignored externality. Whether it corrects exactly or excessively determines which system is socially preferred. In particular, if the bias of the sender is not too large, mandatory disclosure proves to be socially costly.

In the second part of the article I tailor the model to examine in details two specific applications. This leads me to derive further results. I first concentrate on the application to clinical trials. In the benchmark model, the receiver is sophisticated and fully informed about the bias and the research technology. As a consequence, in equilib-

---

[5] To illustrate the second function, suppose the receiver expects the sender to run two experiments. It might be optimal for the sender to incur the cost of five experiments and to report only the two most favourable results.

[6] In most of the literature, research is modelled as a binary decision: either the sender does not search or he searches and incurs a cost $c$ to obtain one signal that is informative with a certain probability. This model does not allow us to study situations where sequences of signals are obtained and used selectively in reporting. Note that we compare these two models in more detail in Sections 2 and 5.

[7] The sender in equilibrium uses a full disclosure strategy.

rium, the sender reveals all the information he obtained. Both the assumptions and the conclusions seem too strong in the case of clinical trials.[8]

I therefore examine the case where the sender may, with some probability, face a credulous receiver who will believe all the information provided to her. The sender will then report the same number of positive signals as in the benchmark model but hide some negative results to induce the naive receiver to set his preferred policy. In such a situation, although the effect on research incentives identified in the benchmark model still exists, mandatory disclosure becomes more attractive as it leads to the implementation of the policy preferred by the receiver.[9] In a second extension, I relax the assumption that the receiver is fully informed about preferences. Specifically, I suppose that the receiver is uncertain about the bias of the sender. I show that in such circumstances, some information will be withheld in equilibrium. The sender might even conceal positive information arguing in his favour, to avoid revealing his type.

The second application I examine is the case of litigation in adversarial systems. I introduce two competing senders with opposed preferences and I find that when they compete to provide information, they conduct less research than if they were alone reporting. Given that the competitor is revealing information, the possibilities to mislead the receiver are more limited and therefore the senders need to conduct less research to prove that they are not dissimulating evidence. I also show that it is socially optimal to rest the burden of proof exclusively on the most biased agent.

The two applications that I study in more depth lead me to some interesting extensions of the model. I want to point out that there are other applications where the interplay between research and disclosure is an essential feature. For instance, the model can be applied to interest groups providing evidence to influence a decision maker. These lobby groups need to decide how much research to perform and what evidence to present.[10] The model can also be used to study media bias. The literature on this issue has sometimes considered journalists as having a desire to influence opinions of their readers or being subject to influence by politicians.[11] This bias can affect their search for information and their reporting of facts. Finally, the model can also more directly address the organisation of academia. A researcher is generally biased towards finding an interesting or surprising result. It is often expected that a certain number of robustness checks need to be presented. My model suggests that a socially excessive amount of tests could be conducted if they mostly serve to guarantee that no information has been withheld rather than to provide extra information.

I discuss the links to the existing literature in the final Section to allow for an informed comparison. Persuasion games, in which a sender communicates verifiable information to a receiver, who will take a decision affecting both their welfare have long been of interest in the literature – in particular in Milgrom (1981) and Milgrom and Roberts (1986). Milgrom's unravelling result, shows that, when the decision maker knows the quantity of information held by the sender, in every sequential equilibrium of

---

[8] Several scandals that I discuss in Section 3 revealed that pharmaceutical firms withheld negative results of trials and that the doctors and the public remained unaware of that fact.

[9] This is true if the welfare of the receiver is more important than the welfare of the sender.

[10] See Bennedsen and Feldmann (2002, 2006).

[11] See Baron (2006), Besley and Prat (2006) and Xiang and Sarvary (2007).

the game, I will observe full disclosure.[12] In these results, as in most of the literature, the information at the disposal of the sender is exogenously given.[13] My initial contribution is to endogenise the search for information and to show that the interaction between research and disclosure has important effects, in particular on the sender's welfare. My second contribution is to study the social benefits of introducing mandatory disclosure.

My article is organised as follows. In Section 1 I present the model. In Section 2 I study the interaction between research and disclosure and derive the main results of the article. I also examine the social benefits of mandatory disclosure. In Section 3 I discuss the application to clinical trials and extend the model to allow for potentially credulous receivers and uncertainty on the sender's type. In Section 4 I use the model to study trials in adversarial systems and therefore introduce competing senders. Finally in Section 5 I discuss the links with the existing literature.

## 1. Model

### 1.1. *Description of the Model*

We consider a persuasion game where the information is not exogenously given but obtained at a cost by the sender. The unknown state of interest is denoted $\theta \in [0,1]$. The sender and the receiver initially share a common prior $\pi(\theta)$ on the state.

The sender has access to a research technology that can provide information on the state. He initially decides on the quantity $Q$ of research he will perform at a unit cost $C$. A central focus of the article will be to compare cases where $Q$ is observed by the receiver to cases where it is unobservable. The outcome of research is a series of infinitesimal positive and negative signals which are privately observed by the sender. These signals can be interpreted as the results of a series of small experiments, as small pieces of evidence.[14] More specifically, if the sender conducts an amount $Q$ of research, he will obtain $x$ positive signals given by the distribution $f(x|\theta, Q)$. This aggregate amount of positive signals $x$ provides information on the value of $\theta$: the sender can derive a posterior distribution on the state $g(\theta|x, Q)$. I describe this research technology in more details in the next Section.

Once the research is performed, the sender can report a subset or all of the evidence to the receiver. I suppose throughout the article that the evidence is verifiable. We denote $r$ the quantity of positive signals the sender reports. The verifiability of the information imposes the constraint: $r \leq x$ (the sender cannot fabricate information and cannot therefore report more positive signals than he obtained). We use the formulation of Milgrom (1981) and call a strategy of full disclosure a reporting strategy that leads the receiver to set the same policy as if he observed all the signals.[15]

The receiver sets the policy $p \in \Re$. Both the sender and the receiver are affected by $p$ but they have diverging interests which could lead the sender to report select-

---

[12] The intuition is that, if some information is withheld, the decision maker considers the worst case scenario, updates her beliefs accordingly and thus the sender will always prefer to reveal all his information.
[13] One exception is a paper by Shavell (1994) that I discuss extensively in Section 5.
[14] To be more precise, I consider the continuous approximation of this series of binary signals. In that sense, signals are infinitesimal.
[15] A strategy where all the positive signals are reported, all the negative signals are withheld and the receiver understands that the hidden signals are negative is a full disclosure reporting strategy.

ively. More specifically, given a state $\theta$ and a policy $p$, the welfare of the receiver is given by $u_r(p,\theta) = -(p - \theta)^2$ whereas the welfare of the sender is $u_s(p,\theta) = -(p - \theta - \delta)^2 - CQ$.[16] The parameter $\delta$ measures the extent of the sender's bias.[17]

To summarise, the timing of the model is the following:

(1) the sender decides on $Q$, quantity of research to perform
(2) the sender conducts $Q$ and obtains signals
(3) the sender reports to the receiver a subset or all of these signals
(4) the receiver observes the report and sets the policy $p$.

### 1.2. Research Technology

I have chosen to model the outcome of research as a series of infinitesimal experiments yielding either positive or negative results. As I pointed out in the introduction, in most of the literature, the search for information is modelled as a draw of a unique signal, informative with a certain probability. This is not adapted to address the questions raised in this article for a number of reasons. First, I set out to understand how, when multiple results are obtained, they can be selectively reported. My model allows me to study the exact opportunities senders have to mislead receivers: by conducting more research, a sender can accumulate more positive signals and can replace some of the negative signals he would have reported, by this more favourable evidence. Second, the model I chose to represent the research process allows me to measure explicitly the amount of research performed and to conduct comparative statics on this variable.

I introduce some further notations and assumptions on the research technology. I denote:

- $g(x, Q)$ the unconditional distribution of signals
- $g(\theta|x, Q)$ the posterior distribution of the state given the signals and the amount of research performed
- $\mathrm{Var}[\theta|x, Q]$ the conditional variance of the posterior distribution of $\theta$ given the signals and the amount of research performed

I make the following assumptions:

(i) $f(x|\theta, Q)$ is continuously differentiable with respect to $Q$.
(ii) $\int_0^\infty \mathrm{Var}(\theta, Q) \, g(x, Q) \, dx$ is decreasing and convex in $Q$.

Assumption (ii) posits that the more research is performed, the more precise its outcome becomes on average: on average the variance of the posterior decreases with $Q$. The marginal gains in precision are therefore decreasing in $Q$. This is a reasonable property for the results of experiments: if a researcher conducts more research, he becomes better informed but the marginal gains in understanding decrease as his knowledge improves.

---

[16] $CQ$ is the amount spent by the sender on research. The utility of the sender is therefore assumed to be quasi separable in money.

[17] Indeed, if the state is known, the receiver's preferred policy $p$ equals $\theta$, whereas the sender's ideal policy is $p = \theta + \delta$.

Finally, it is important to note that throughout this article, I concentrate on pure strategy equilibria. I show at various points in the text that the qualitative results would not be affected if I considered mixed strategy equilibria.

## 2. The Cost of Proving Your Honesty

### 2.1. *Disclosure of Research Results*

One of the important goals of this article is to compare cases where the research effort is observable to cases where it is unobservable. I show that this difference has important consequences, both in terms of social and individual welfare. In particular I show that the sender is always strictly worse off when his research effort is not observed by the receiver. I concentrate on sequential equilibria of this game.[18] I start by presenting the results in the observable case.

PROPOSITION 1. *All sequential equilibria of the game with observable research effort are characterised by:*

  (*i*)  *The seller uses a strategy of full disclosure.*
  (*ii*) *The sender conducts an amount of research $Q_0$ solution to:*

$$C = -\frac{\partial}{\partial Q'}\left[\int_0^\infty \mathrm{Var}(\theta, Q')g(x, Q')\mathrm{d}x\right]\Big|_{Q'=Q_0}$$

*Proof.* See Appendix.

Result (*i*) states that the policy will be set as if the receiver observed all the information obtained by the sender. There could be multiple reporting strategies corresponding to this behaviour. In all of those, the sender reveals all his positive signals and the receiver understands that all the information that is withheld is negative.[19] This result follows the unravelling result in Milgrom (1981) and Milgrom and Roberts (1986). When the receiver knows the amount of research performed, her belief in a sequential equilibrium, if some information is withheld, is one of extreme scepticism. Thus the sender does not have incentives to withhold information. Given this reporting strategy, result (*ii*) states that the sender will conduct an amount of research such that the marginal cost equals the marginal benefits from getting better information (i.e benefits from decreasing the variance of the posterior). Note however that he does not take into account the benefits of better information for the receiver.

I now turn to the case where the quantity of research performed by the sender is not observed by the receiver. In this case research not only serves to provide better information but also has a strategic function for the sender: conducting more research allows

---

[18] For instance there exists a Nash equilibrium such that the receiver ignores all the information provided to him and the sender does not communicate any evidence. Given that the information is verifiable, if it is provided to him, it is unreasonable for the receiver to ignore it.
[19] Here are two examples of full disclosure reporting strategies. In the first, all the information held by the sender is revealed to the receiver. In the second, all positive signals are revealed and all negative withheld.

him to accumulate more positive evidence and potentially report selectively. This strategic function that I unveil underlies the results in the following Proposition.

PROPOSITION 2. *All sequential equilibria of the game with unobservable research effort are characterised by:*

   (*i*)  *The sender uses a strategy of full disclosure.*
  (*ii*)  *The sender conducts an amount of research $Q^*$ solution to:*

$$C = -\frac{\partial}{\partial Q'}\left[\int_0^\infty \mathrm{Var}(\theta, Q')g(x, Q')\mathrm{d}x\right]\Big|_{Q'=Q^*}$$
$$-2\delta\int_0^1\int_0^\infty \frac{\partial}{\partial Q'}[\mathrm{E}(\theta, Q')]\big|_{Q'=Q^*}f(x|\theta, Q^*)f(\theta)\mathrm{d}x\mathrm{d}\theta$$

 (*iii*)  *More research is performed than when the research effort is observable: $Q_0 < Q^*$.*
 (*iv*)  *The sender is strictly worse off than if his research effort was observable.*

   *Proof.* See Appendix.

Proposition 2 states that in equilibrium, the sender conducts more research in the unobservable case (result (*iii*)) but in equilibrium uses a reporting strategy that reveals all the information he obtained (result (*i*)) and as a consequence would strictly prefer his research effort to be observed (result (*iv*)). I now provide the intuition for these results.

Let me start with result (*iii*). Suppose the receiver expects the sender to conduct the low amount of research $Q_0$ as in the observable case. The sender will have an incentive to search further and obtain more positive signals. He will then still report the quantity of signals the receiver expects, but replace some negative signals by positive ones to mislead her. The receiver understands these incentives and knows that extra research will be conducted to mislead her, up to the point where the marginal benefits equal the costs. This trade-off characterises the equilibrium amount of research $Q^*$ as expressed in the equation of result (*ii*).

Result (*ii*) states that in equilibrium the marginal cost of research $C$ equals the marginal benefits, composed of two terms. The first term represents, as in the observable case, the marginal benefits from obtaining a better knowledge of the state (i.e decreasing the variance of the posterior). The second term corresponds to the strategic function of research: it represents the potential benefits from conducting more research in order to obtain more positive signals and thus mislead the receiver.[20]

The case of medical journals mentioned in the Introduction gives some partial evidence in support of result (*iii*). Editors of eleven of the most prestigious medical

---

[20] I note that the amount of research conducted in equilibrium would be identical if the infinitesimal messages were only informative with probability $\sigma$. Given an equilibrium amount of research $Q^*$ and a report $r$, the receiver would set a policy $r/\sigma Q^*$. By choosing a quantity of research $Q'$, the sender would therefore expect to obtain $\sigma\theta Q'$ signals and induce the policy $\sigma\theta Q'/\sigma Q^* = \theta Q'/Q^*$. All the derivations are therefore identical to those of Proposition 2 and the equilibrium amount of research conducted is the same.

Table 1

*Percentage of Publications in NEJM Sponsored by a Pharmaceutical Company*

|  | Sep 04 | Oct 04 | Nov 04 | Dec 04 | Jan 05 | Feb 05 | Mar 05 | Apr 05 |
|---|---|---|---|---|---|---|---|---|
| Before Mand. Disclosure | 26 | 31 | 37 | 25 | 20 | 6 | 26 | 29 |

|  | Sep 05 | Oct 05 | Nov 05 | Dec 05 | Jan 06 | Feb 06 | Mar 06 | Apr 06 |
|---|---|---|---|---|---|---|---|---|
| After Mand. Disclosure | 16 | 7 | 26 | 11 | 14 | 20 | 24 | 25 |

journals announced that they would only publish the results of studies that were entered at their start in a publicly available database, starting September 2005.[21] In effect, these journals decided to move from a system where the research effort was unobservable to one where it could be at least partially observed. I collected data on the publications of one of the journals that committed to this system, the *New England Journal of Medicine* and recorded the number of published studies that were sponsored by an industrial group, presumably the most biased studies.[22] We see in Table 1, that this percentage decreased consistently after the adoption of the disclosure rule.[23] Overall, the percentage of publications sponsored by a pharmaceutical group decreased from 25% to 18%.[24] This is suggestive, although imperfect, evidence that adopting a system with observable research effort decreases the amount of research performed in equilibrium by biased agents.[25]

Result (*i*) states that, in equilibrium, although the sender performs more research and his research effort is unobservable, he uses a reporting strategy that reveals all the information he obtained. The intuition is that the receiver knows all the parameters of the game and thus, in equilibrium, can compute, though she cannot observe, the quantity of information obtained by the sender. Therefore, Milgrom's unravelling result applies as in Proposition 1. I point out however that this result relies both on the sophistication of the receiver and on the assumption that the receiver has perfect knowledge of all the parameters of the game (preferences, cost of research...). I show in Section 3 that if these conditions are relaxed, withholding of negative and sometimes positive results will occur in equilibrium.

An important consequence of the previous results is that the sender is strictly worse off when his research effort is unobservable (result (*iv*)). In equilibrium the receiver can determine how much research was conducted and the sender is forced to reveal all

---

[21] See declaration by ICMJE.

[22] The ideal would have been to obtain the percentage of submitted studies sponsored by pharmaceutical companies but the journal editors did not keep information about sponsors for all of the manuscripts sent to them. However, note that during that period, the number of submissions to the *New England Journal of Medicine* was rather stable (3,430 submissions in 2004 and 3,595 in 2005).

[23] It decreased in every month except for the months of July and April.

[24] This is a significant difference at the 10% level.

[25] This is imperfect evidence given that (*a*) it is still early to judge the effect of such requirements as these studies take time (*b*) there are only data on publications and therefore I am implicitly assuming that the ratio of publication to research is constant (*c*) most importantly pharmaceutical companies have concerns other than publication that can encourage them to conduct research although this is an important channel to communicate results to doctors.

the information he obtained (result (*ii*)). The situation is as if the sender's research effort was observable. However, when his research effort is observable, his optimal choice is to conduct a lower amount of research $Q_0$ (result (*iii*)). The extra research he performs therefore decreases his welfare. The sender has to incur an extra cost just to prove his honesty, to demonstrate he is not hiding any evidence. This extra cost, as the following corollary suggests, could have important consequences.

COROLLARY 1. *The amount of additional costly research conducted when the research effort is unobservable is increasing in the bias: $Q^* - Q_0$ is increasing in $\delta$.*

*Proof.* See Appendix.

Corollary 1 states that the cost a sender needs to incur to prove his honesty is increasing in his bias. Consider the application of the model to lobbying. Moderate environmental NGOs such as the National Research Defence Council tend to lobby decision makers directly, providing, for instance, detailed reports produced by their own scientists. Groups such as Greenpeace, considered to hold more extreme views, favour public actions and demonstrations. Corollary 1 suggests that part of the explanation is that informational lobbying is much more costly for extreme groups given that they need to provide more evidence to the decision maker to prove they are not withholding information.

### 2.2. *Welfare Impact of Mandatory Disclosure*

I have shown in the previous Section that the welfare of the sender is greater when his research effort is observed by the receiver. However, I have not yet determined the overall impact on social welfare. I address this in the following proposition and in particular I determine the consequences of implementing mandatory disclosure rules. Adopting mandatory disclosure is equivalent to moving from a system where the research effort is unobservable to one where it is observable.[26]

PROPOSITION 3. *Under the following condition, mandatory disclosure decreases social welfare:*

$$-2\delta \int_0^1 \int_0^\infty \frac{\partial}{\partial Q'} [\mathrm{E}(\theta, Q')]|_{Q'=Q_W} f(x|\theta, Q_W) f(\theta) \mathrm{d}x \mathrm{d}\theta < \frac{C}{2}$$

*where $Q_W$ is the socially optimal amount of research given by:*

$$\frac{C}{2} = -\frac{\partial}{\partial Q'} \left[ \int_0^\infty \mathrm{Var}(\theta, Q) g(x, Q') \mathrm{d}x \right]|_{Q'=Q_W}$$

*Proof.* See Appendix.

Proposition 3 provides a sufficient condition for the surprising result that mandatory disclosure decreases social welfare. The intuition is that the sender does not take into

---

[26] The rules could require the disclosure of the research effort, not the results, as in the case of the medical journals. My previous results show that this does not matter. Indeed if the research effort is observable, the sender will in equilibrium disclose all the information he obtained. Intuitively, if a pharmaceutical company registers a trial initially and does not disclose the result, it can be inferred that these results were unsatisfactory.

account the benefits of his research for the receiver and therefore, when the research effort is observable, conducts a socially insufficient amount of research ($Q_0 < Q_W$ where $Q_W$ is the social optimum). In the unobservable case, the strategic consideration increases the amount of research conducted in equilibrium and can potentially correct the ignored externality. The sufficient condition in Proposition 3 guarantees that the strategic function does not actually overcorrect and lead to an excessive research effort.

COROLLARY 2. *There exists $\delta^* > 0$ such that mandatory disclosure decreases social welfare if and only if $\delta \leq \delta^*$.*

If the bias of the sender is not too large, the socially optimal arrangement is one where the receiver does not observe the research effort of the sender. The intuition is that the ignored externality is independent of the bias of the sender.[27] On the contrary, the strategic function is increasing in the bias. Therefore, if the bias is large, the strategic consideration overcorrects this externality. However, when the bias is small, this extra research conducted to prove that no information is withheld will be socially valuable.[28]

Furthermore, mandatory disclosure only seems easily implementable when the relation between the sender and the receiver is well established and formalised. This is the case for pharmaceutical companies and medical journals. It is also the case for lawyers and juries.[29] However it seems harder to implement in situations such as the communication between an interest group and a politician. In these cases taxing research used to influence can be an alternative method. The previous results can be reinterpreted in the following way.

COROLLARY 3. *The optimal tax (or subsidy) in the case of lump sum redistribution (or tax) when research is unobservable is given by:*

$$\tau^* = -2\delta \int_0^1 \int_0^\infty \frac{\partial}{\partial Q'} [\mathrm{E}(\theta x, Q')]|_{Q'=Q_W} f(x|\theta, Q_W) f(\theta) \mathrm{d}x \mathrm{d}\theta - \frac{C}{2}.$$

The social optimum is always attainable with a tax or a subsidy. As was emphasised in Proposition 3, whether $\tau^*$ is a tax or subsidy depends on whether the strategic considerations in the unobservable case overcorrect the ignored externality. I also emphasise that throughout this article I use a very specific context where research is used not only to attain better knowledge of the phenomenon but also to influence a decision maker. I do not make any statements about taxing research in general.[30] Finally, note that an alternative to taxing research would be to tax reports directly, for instance tax lobby groups for the time spent with a politician or the amount of

---

[27] Note that the fact the externality is independent of the bias of the sender is true because of quadratic preferences. Other assumptions on preferences might therefore change our results.

[28] We point out once again that this is reliant on the sophistication of the receiver and we show in Section 3 that considering naive receivers can increase the attractiveness of mandatory disclosure.

[29] I could imagine a similar system where lawyers would need to declare, at the start of the case, funds they spend searching for evidence, to be able to use the results during the trial.

[30] I also emphasise that the tax does not make the research effort observable. The tax declaration submitted to the IRS is not available to the public, and even if it were it would be hard to allocate an aggregate amount to different issues. Furthermore, an alternative solution could be to tax the research providers.

information provided. This would tend to have the same effects but would target directly research used to influence the decision maker.

In the next Sections I consider a number of applications of my model that lead me to relax some assumptions of the benchmark model and derive some further results. The first application, which I have already mentioned, is the reporting of clinical trial results by pharmaceutical firms. I tailor my model to this setting, and introduce in turn, credulous receivers and receivers uncertain about senders' preferences. I show it changes the full disclosure conclusion and the welfare impact of mandatory disclosure. The second application focuses on cases with competing senders, for instance trials in adversarial regimes.

In some of these extensions, I use a special version of the model that isolates the strategic function of research. Specifically, I suppose that the distribution of signals takes the particular functional form $f(x \mid \theta, Q) = 1_{x=\theta Q}$: if the sender conducts an amount $Q$ of research, he knows for sure he will obtain $\theta Q$ positive signals and will therefore be able to infer the exact value of the state. Research is immediately informative and thus the social optimum and the equilibrium amount of research in the observable case is to conduct and infinitesimal amount of research. Nevertheless, Proposition 2 applied to this special case indicates that in the unobservable case, the sender is forced to conduct a strictly positive amount of research $Q^* = 2\delta E(\theta)/C$. This model, therefore isolates the strategic function of research. The extra amount of research the sender performs when his research effort is not observed by the receiver is socially wasteful but, as I emphasised in this Section, serves the purpose of convincing the receiver of the sender's honesty.

## 3. Reporting of Clinical Trials

Recent scandals in the pharmaceutical industry, such as the Vioxx case (an anti-inflammatory drug proven to increase the risk of cardiovascular events) or the Paxil case (an anti-depressant that could increase the suicide rates among children), have attracted the public's interest in the possible withholding of negative results by pharmaceutical companies. Medical journals and regulatory authorities are increasingly focused on this issue. Legislation of disclosure started with the FDA Modernisation Act of 1997 that established a public clinical trials registry (clinicaltrials.gov) and called for the registration of trials for 'serious or life threatening diseases'. This law did not fundamentally change the habits in the industry. For instance it was reported that by 2002 only 48% of cancer drug trials had been registered. Recent scandals prompted new efforts to regulate disclosure, leading to the FDA Amendment Acts in September 2007 that mandate the disclosure of a larger set of trials.

The results of Section 2 highlight a potential adverse effect of mandatory disclosure that has been generally ignored in the debates on these issues. Forcing the senders to disclose their results can decrease the amount of research performed in equilibrium. These results suggest that the adoption of a system of mandatory disclosure should be accompanied by measures to encourage research. In Section 2 I presented suggestive evidence on the effect of disclosure requirements on publication rates in medical journals. I believe other pieces of evidence could be exploited. For instance, stronger disclosure requirements could also have an impact on the number of trials aimed at

finding new applications for existing drugs. Pharmaceutical firms could refrain from conducting such tests out of fear of finding negative side-effects of their already commercialised products. Based on information I collected from the FDA website, the number of efficacy supplements approvals decreased from 107 in 2004 to 96 in 2005 and 85 in 2006 and 2007.[31] These types of trials are designed to test new indications, new dosage or new routes of application of already approved drugs. Note that 2004 was the year when most of the scandals made headlines and when regulatory authorities became increasingly focused on these issues. This can be seen as suggestive evidence that mandatory disclosure can reduce or change the focus of research efforts and underlines the fact that more systematic empirical work along those lines needs to be conducted.

The model I used in the previous Section allowed me to highlight this interesting effect of disclosure requirements on research incentives. However, some of the conclusions do not seem in accordance with our motivational example. For instance, one of the striking results of the previous Section is that, in equilibrium, the sender employs a full disclosure reporting strategy. This conclusion seems at odds with the example of the drug Vioxx where the public was initially unaware of the potentially lethal side-effects of the drug. This result in my model is due to the sophistication of the receiver and to her perfect knowledge of the environment. In this Section I adopt different approaches to tailor our model more closely to the application to clinical trials. I discover that the conclusion relative to overall social welfare is in certain cases modified.

### 3.1. *Credulous Receivers*

The model I used in Section 2 assumed that the receiver was highly sophisticated. This assumption seems particularly strong in the context of the application to clinical trials. Not all doctors have the time or experience to determine what type of evidence could be withheld by pharmaceutical firms. They might not update their beliefs based on non disclosure of certain tests. To account for this feature, I modify my benchmark model slightly. I suppose that the receiver of the information can be of two types: she is either sophisticated (with probability $q$) or credulous (with probability $1 - q$). The sophisticated type is identical to the receiver in the benchmark model: she understands the incentives of the sender and knows that the sender will attempt to deceive her. On the contrary, the credulous type believes all the information that is provided to her and makes her decision purely based on that evidence. Under this assumption, I can revisit the results of Proposition 2.

PROPOSITION 4. *All sequential equilibria of the game with unobservable research effort and credulous types are characterised by:*

- (*i*)    *The sender reveals all positive signals he obtains and adapts his report of negative signals to induce the credulous type to set the sender's preferred policy.*
- (*ii*)   *The sender conducts an amount of research $Q^*(q)$ solution to:*

---

[31] I collected data on efficacy supplements of type N and SE1-SE7 from the FDA website. Note that if one concentrates only on types N and SE1 that are more specifically trials aimed at finding new applications for existing drugs, the numbers go from 58 in 2004 and 2005, 59 in 2006 to 38 in 2007.

$$C = -\frac{\partial}{\partial Q'}\left[\int_0^\infty \mathrm{Var}(\theta, Q')g(x, Q')\mathrm{d}x\right]\Big|_{Q'=Q^*(q)}$$
$$- q2\delta \int_0^1 \int_0^\infty \frac{\partial}{\partial Q'}[\mathrm{E}(\theta, Q')]\Big|_{Q'=Q^*(q)} f(x|\theta, Q^*)f(\theta)\mathrm{d}x\mathrm{d}\theta.$$

(*iii*)   *The sender conducts more research than when his research effort is observable*
    *($Q_0 < Q^*(q)$) but less than if he was only faced with a sophisticated receiver*
    *($Q^*(q) < Q^*$).*

*Proof.* See Appendix.

The first result states that the sender can always deceive the credulous receiver and induce her to adopt his preferred policy.[32] The intuition is the following. Regardless of the amount of research performed and of the results obtained, the sender reports the same amount of positive signals as if he was facing only a sophisticated type. The amount of negative signals is then used to influence the credulous type. Note that the sophisticated type ignores the report of negative results. She has beliefs about the amount of research performed and, based on these beliefs and the positive signals reported, sets her preferred policy. On the contrary, the credulous type takes into account all the information provided to her, ignoring the fact that the sender could report selectively.

To illustrate this intuition, consider a specific case. Suppose that given an amount of research $Q$ and an amount of positive results obtained $x$, the sender's preferred policy is $p_0 \le 1$. The sender cannot fabricate results and therefore cannot report more positive results than he obtained. It is therefore possible that the best the sender can do when faced with a sophisticated receiver is to report all $x$ positive signals he gathered and induce a policy $p < p_0$.[33] However, when he faces a credulous receiver and reports $x$ positive signals, he can induce any policy in the interval $[p, 1]$ by adapting the number of negative signals reported. For instance to induce a policy $p = 1$, he can report no negative signals. Therefore, by reporting an intermediate amount of negative signals, the sender can induce the credulous receiver to adopt his preferred policy $p_0$.

The second part of Proposition 4 uses these results on the optimal reporting strategy to determine the sender's research decision. The difference between the optimal amount of research performed in this case compared to the case of Proposition 2 is that the strategic effect (second line) has a weight $q$ attached to it. Indeed, with probability $(1 - q)$, the receiver is credulous and there is no need to conduct extra research to convince her that no information is being withheld. This concern is only relevant if the sender is faced with a sophisticated receiver. Note that as $q$ converges to zero, the amount of research performed converges to $Q_0$. The goal of research in that case is strictly to minimise the variance of the posterior distribution.

---

[32] The only exception is when the sender's preferred policy is greater than 1. The naive receiver can then be induced to choose a policy exactly equal to 1.

[33] If the belief of the sophisticated receiver is that the sender performed an amount of research $Q$, he sets the policy as if the information was $x$ positive signals and $(Q - x)$ negative.

It is essential to determine how this variation on the initial model, aimed at capturing the application to clinical trials more precisely, affects the conclusions on the welfare impacts of mandatory disclosure rules. In the presence of credulous receivers, mandatory disclosure has two effects. First, as previously noted it reduces the amount of research performed in equilibrium. This could have negative welfare consequences since the sender often performs socially insufficient amounts of research. However the existence of credulous receivers has a second consequence. Without mandatory disclosure, the credulous receiver sets the sender's preferred policy, whereas when mandatory disclosure is introduced she sets her own preferred policy. If the receiver and the sender receive the same weight in the social welfare function, this does not impact overall welfare given the quadratic shape of preferences.[34] However, if the receiver's welfare is deemed more important, this second effect will argue in favour of mandatory disclosure. Note that this appears to be a reasonable assumption in the case of the pharmaceutical industry: the weight I put on the welfare of doctors and patients should probably be higher than the weight on the firms' utility. If I note $a$ the weight put on the receiver's welfare in the social welfare function (social welfare becomes $a(p - \theta)^2 - (p - \theta - \delta)^2$), we obtain the following result:

COROLLARY 4. *If $a > 1$ there exists a benchmark value $q^*(a)$ such that if $q \leq q^*(a)$ mandatory disclosure increases social welfare*

*Proof.* See Appendix.

Corollary 4 indicates that as it becomes increasingly likely that the receiver is credulous, mandatory disclosure becomes the socially preferred policy. As the probability that the receiver is sophisticated converges to zero, the amount of research performed in the case without mandatory disclosure ($Q^*(q)$) converges to the mandatory disclosure case ($Q_0$). The effects on research incentives are therefore identical. However, as $q$ converges to zero, without mandatory disclosure, the receiver nearly always sets the sender's preferred policy. Given the weights in the social welfare function this will induce a negative overall effect on social welfare. Mandatory disclosure becomes the socially preferred policy. The results of this Section therefore highlight that, although the effect of mandatory disclosure on research incentives, highlighted in Section 2, are always relevant, in certain applications, such as clinical trials, adopting the policy preferred by receivers is essential and argues in favour of mandatory disclosure requirements.[35]

### 3.2. *Uncertain Bias*

The benchmark model makes strong assumptions about the sophistication of the receivers (issue addressed in the previous Section) but also about the information they hold. In this Section I address the second concern. Specifically, I assume that the receiver is uncertain about the bias of the agent. I suppose that the bias can take two

---

[34] This would not necessarily be true for other types of preferences.
[35] The two effects of mandatory disclosure, (1) on research incentives (2) on the match between the chosen policy and the receiver's preferred policy, appear quite general. Furthermore the sophistication of the receiver, that could be captured in various way, changes the relative importance of these factors.

values: $\delta_L$ with probability $q$ and $\delta_H$ with probability $1 - q$, and that both types are biased in the same direction $(\delta_H > \delta_L > 0)$. A possible interpretation is that the receivers (medical journals, doctors or patients) are unaware of all the financial incentives of the companies, such as the expected profits from the drug, factors that influence the sender's bias. Furthermore, to simplify the exposition, I consider the special case where the distribution of signals takes the particular functional form $f(x|\theta, Q) = 1_{x=\theta Q}$ (as discussed at the end of Section 2). In this context I obtain the following result:

PROPOSITION 5. *All sequential equilibria of the game with uncertain bias and unobservable research effort are characterised by:*

(i)   *The low type will conduct less research than the high type* $(Q_L^* < Q_H^*)$.
(ii)  *For a certain range of results, the high type will withhold positive information (if $x \in [Q_L^*, Q_b]$, the high type reports $x_r < x$).*

*Proof.* See Appendix.

The intuition for result (*i*) is the following: at his equilibrium level of research, the marginal gains for the low type from searching for more information to mislead the receiver equal the marginal costs. The high type, who is more biased, obtains greater marginal gains from increasing his research effort, but faces the same marginal costs. Therefore, in equilibrium, the receiver expects more research from the high type as described in result (*i*).

Result (*ii*) surprisingly states that in equilibrium, the high type might withhold positive information that goes in his favour. This occurs when he obtains results that indicate an intermediate value for the state. If the range of positive results is close to $Q_L^*$ but slightly greater, the sender prefers hiding some positive information in order to avoid revealing his type and have the information he provides be judged on a stricter basis. This seems in accordance with the example of the clinical trial called 'Vigor study' conducted by Merck, that was the first to suggest that Vioxx might increase the risk of cardiovascular incidents. This trial was initially meant to show that the drug had fewer side-effects on the stomach and intestines than the other drugs in its category, and successfully proved this. However, both the positive and negative results were withheld.

In the following Proposition I provide some further characterisation of the equilibrium behaviour for a specific distribution of the state: $\theta \sim U[0, 1]$.

PROPOSITION 6. *Under the assumption that $\theta \sim U[0, 1]$, when research is unobservable, there exits a sequential equilibrium characterised by the amounts $Q_0 < Q_L < Q_B < Q_H$ such that:*

(i)   *If the amount of positive results $x$ is such that $x \in [0, Q_0]$, both types use full disclosure reporting strategies.*
(ii)  *If the amount of positive results $x$ such that $x \in [Q_0, Q_L]$, both types pool on one message $r$ and the receiver sets a unique policy $n$.*
(iii) *If the high type obtains an amount of positive results $x$ such that $x \in [Q_L, Q_B]$, he withholds some positive information and the receiver sets policy $n$.*

(*iv*)    *If the high type obtains an amount of positive results x such that x ∈ [$Q_B, Q_H$], he uses a full disclosure reporting strategy.*

(*v*)    *The low type conducts less research than if his type was known with certainty.*

This Proposition shows that when the research effort is unobservable, two additional costs could exist in this model with uncertainty. First, result (*iii*), in accordance with Proposition 5 indicates that positive information might be withheld in equilibrium. Result (*ii*) suggests an additional cost might arise: for a certain range of results (in [$Q_0, Q_L$]), neither type is able to transmit the information he obtained credibly and they pool on a single report. The policy chosen by the receiver will therefore be suboptimal. Result (*v*) indicates that less research is conducted by the low type in equilibrium than if his type were known. The intuition is that, in the reporting phase, it is harder to transmit information credibly and therefore the marginal benefits from conducting more research to mislead the receiver are smaller.

In this Section I have tailored the model to the application to clinical trials. When the sender faces potentially credulous or imperfectly informed receivers, he will not reveal in equilibrium all the information obtained. The sender withholds negative signals but might also hide some positive signals to avoid revealing his type. Finally I show that this will change the attractiveness of mandatory disclosure regulation. If the probability that the receiver is credulous is sufficiently high, mandatory disclosure increases social welfare, in spite of the effect on research incentives highlighted in Section 2, as the policy preferred by the receiver will be implemented.[36]

# 4. Competing Senders

In adversarial judicial systems, the decision maker relies on the information provided by the interested parties. My model is adapted to examine this setting if I consider that the decision maker (the judge or the jury) makes inferences from the evidence produced, possibly about withheld information, and does not naively decide based solely on the information provided. I am aware that some rules limit the amount of updating that can be performed.[37] However, it seems difficult to prevent juries from making inferences in all circumstances. My model can be viewed as an extreme case where the decision maker is completely unconstrained.

To study this environment, I need to extend the model to allow for competing senders gathering information independently and transmitting it strategically to the decision maker. Specifically, I suppose the utility function of sender 1 is given by $u_1 = -(p - \theta - \delta_1)^2$ and that of sender 2 is $u_2 = -(p - \theta - \delta_2)^2$ (with $\delta_1 > 0$ and $\delta_2 < 0$). I suppose that the receiver knows the type of both agents. As specified in the previous Section, I use the special case of the model that isolates the strategic

---

[36] Note that mandatory disclosure will also increase social welfare in the case of uncertainty that I considered. However, I considered the special case where all extra research is a social waste (the information is immediately revealed). It would be interesting to examine the more general case.

[37] In some situations, juries are asked to draw no conclusion from the fact that one party does not provide evidence.

function of research, where the distribution of signals takes the particular form $f(x \mid \theta, Q) = 1_{x=\theta Q}$.

In this Section, I choose to describe the reports made by the senders as reports on the state. The actual reports are the aggregate amounts of positive and negative signals, but given a set of beliefs of the receiver (that are correct in equilibrium), they are equivalent to reporting the state. Let $p(\theta_1, \theta_2)$ be the policy set by the decision maker when she receives message $\theta_1$ from sender one and $\theta_2$ from the second sender. On the equilibrium path, in the next Proposition, both senders employ a full disclosure reporting strategy and therefore $p(\theta, \theta) = \theta$. Furthermore, off the equilibrium path, I impose the following restriction on the belief function.

RESTRICTION A. $p(\theta_1, \theta_2) \in [\theta_2, \theta_1]$

Restriction A does not correspond to a particular refinement but is a reasonable restriction on beliefs. Indeed, sender 1 observes perfectly the state and is biased towards a higher policy, so he would not voluntarily hide positive signals; the state cannot be larger than $\theta_1$. In the same way, sender 2 will never hide negative signals therefore the state cannot be smaller than $\theta_2$. Under this Restriction on beliefs we obtain the following result.

PROPOSITION 7. *Under restriction A, all sequential equilibria where the quantity of research conducted by the sender is not observed by the receiver, are characterised by:*

(*i*)   *Both types use full disclosure reporting strategies.*
(*ii*)  *The equilibrium amounts of research $Q_1, Q_2$, conducted by each sender are less than if they were alone to report: $Q_j < 2\delta_i E(\theta)/C, i = 1, 2$.*

*Proof.* See Appendix.

The natural conjecture is that competition between senders increases the amount of research conducted in equilibrium. Proposition 7 leads to the opposite conclusion: both senders conduct less research than if they were alone to provide information to the decision maker. The intuition rests on the fact that the information provided by both parties are perfect substitutes. Given that the other sender is revealing truthfully his information in equilibrium, the marginal benefits from searching for more signals to mislead the receiver are smaller than if he were alone to report. Indeed the receiver will also take into account the information provided by the competitor.[38]

I can also use these results to comment on the allocation of the burden of proof. I interpret the burden of proof to be policy set by the receiver $p(\theta_1, \theta_2)$ when the two senders produce conflicting reports. For instance if $p(\theta_1, \theta_2) = \theta_1$ the burden of proof rests entirely on sender 2. I determine the functional form for $p(\theta_1, \theta_2)$ that maximises social welfare.

---

[38] This result remains valid in the general setup of Section 3 where research has both a strategic function and an information gathering role. The results on competition obtained in Proposition 7 generalise on both accounts. The result for the strategic function is identical. Furthermore, the fact that the other sender is obtaining information to gain a better knowledge of the state, also reduces the benefits from research as an information tool for the first sender. Combining these two effects, in the general setup, I also obtain that less research will be conducted by each sender than if they were alone reporting.

Corollary 5. *To maximise social welfare, the burden of proof should rest entirely on the most biased party.*

*Proof.* See Appendix.

As I pointed out previously, in this special case of the model, where research is immediately informative, the social optimum is to conduct an infinitesimal amount of research, sufficient to reveal the state perfectly. The socially optimal belief function will therefore minimise the aggregate amount of research conducted by both senders. Section 2 showed that the most biased party needs to conduct more socially wasteful research to convince the receiver he is not withholding any information. Thus to minimise the aggregate amount of research, the burden of proof should rest entirely on the most biased sender to remove his capacity to influence the decision and thus his incentives to conduct more research to mislead the receiver.

## 5. Related Literature

The contribution of this article can be seen in several ways. First, I introduce endogenous information acquisition in a persuasion game. I show that when the sender's research effort is not observable, he conducts more costly research to prove he is not withholding evidence. Second, I evaluate the social benefits of introducing mandatory disclosure of research results. I show that a social arrangement where research is unobservable can be socially preferred when the bias of the sender is not too large. I qualify that when the sender can be credulous. I also introduce uncertainty on the type of the sender and show that it can lead to withholding in equilibrium, including of positive results.

This article belongs to the literature on persuasion games and is related to the seminal papers by Milgrom (1981) and Milgrom and Roberts (1986). These papers introduce the so called 'unravelling result'. They show that, in situations where the decision maker knows the quantity of information held by the sender, in every sequential equilibrium of the game, the reporting strategy is one of full disclosure. The equilibrium is supported by the sceptical beliefs of the receiver.[39] Given such beliefs, the sender will have incentives to reveal all the information he obtained.[40] These initial papers have generated a large literature attempting to relax the full disclosure result.[41] I introduce endogenous information acquisition in such a game and show that in equilibrium, the receiver knows, even though he does not observe, the amount of information obtained, and the unravelling result applies.

Endogenous information acquisition is also examined in Shavell (1994) in a specific persuasion game where sellers can make expenditures to acquire information on the value of a good. The model of information search is the classical one where a unique signal is obtained, informative with a certain probability. Shavell shows that when

---

[39] If some information is withheld, the sender assumes the worst case scenario. These are the only admissible beliefs in equilibrium.

[40] The sender who obtained the best information, reveals everything and by induction, all types will have an incentive to disclose all their information.

[41] For instance Shin (1994), Dye (1985), Verrechia (2001). Van Zandt and Vives (2006) provide a general result characterising conditions under which disclosure will occur.

information acquisition is unobservable, the probability of searching increases, a similar result to the one I obtain in Proposition 2 result (*iii*). However the focus of his paper and the mechanism underlying this result differ greatly from my own. Shavell's model is based on the existence of different types of sellers having different costs in acquiring information. A type with low cost of searching, searches more often and hides bad signals, pretending to be a high type who did not search. The consequences of this result are therefore different from those in my model. He finds that information is withheld in equilibrium (as opposed to Proposition 2 result (*i*)). More importantly, the low types are strictly better off when their research effort is unobservable whereas the high types are strictly worse off.[42] In my model, where I study selective reporting, Proposition 2 result (*iv*) concludes that the sender is always strictly worse off as he needs to conduct more costly research to prove he is not withholding information.

Jovanovic (1982) considers a different question: the problem of disclosure by a seller who initially holds information but can only disclose it at a cost to a buyer. He shows, that the seller conducts a socially excessive amount of disclosure. As in the paper by Shavell, the types with the worst signals are strictly better off if their signal is not publicly observable. Furthermore, in Jovanovic's model, decreasing the cost of disclosure will always be socially beneficial. This illustrates the fact that the cost of disclosure plays a very different role than the cost of research aimed at obtaining valuable information.

A recent contribution by Milgrom (2008) discusses related issues. He examines whether a seller will conduct costly testing of his product to provide verifiable evidence to a buyer. He also notes that a seller has more incentives to test when his effort is not observed by the buyer.[43] However, in the context of his model, the search for information is always excessive from a social point of view. In our model, the extra amount of research performed can be socially beneficial as it corrects an ignored externality.

I noted in the Introduction that one of the applications of this model could be to the literature on media bias. In that respect my work is linked to the paper by Xiang and Sarvary (2007) on competition between news outlets. In their model the media have a binary choice: they can obtain a small quantity of signals about the underlying state at no cost or they can spend more resources and obtain a larger quantity of information. In the second case, as in my article, they can select some of the pieces of information if they want to bias their reporting. Furthermore, they face two types of consumers: some who want the news to be biased in the direction of their beliefs and some who desire to uncover the truth. They find that an increase in media bias can increase the quality of information for the non-biased consumers, a result reminiscent of our Corollary 1.

I also mentioned in the Introduction the application to lobbying. Bennedsen and Feldmann (2002, 2006) examine the search and transmission of information by a lobby group. In Bennedsen and Feldmann (2002) they show that the lobby group has a

---

[42] I use the notation introduced in Shavell (1994). Consider the lowest type facing cost 0 to obtain information. Under mandatory disclosure, he obtains $E(v)$ whereas when his search is unobservable he can expect $E(v \geq v^*) + v^* P(v \leq v^*) v > E(v)$. On the other hand the type facing the highest cost will not search and will obtain $v^* < E(v)$, thus strictly preferring mandatory disclosure.

[43] As Milgrom (2008) highlights, this result is also similar to the result on moral hazard by Akerlof (1976), the so called rat race. Each type of worker exerts more effort than socially optimal to differentiate himself from other types.

higher incentive to search for information when faced with a legislature rather than a single agenda setter. The search effort is supposed to be observed by the receiver and results in a single signal that is informative with a certain probability. Bennedsen and Feldmann (2006) examine the interaction between informational lobbying and political contributions.[44]

Finally, I can also mention a few other articles more remotely related. The introduction of endogenous search for information has lead to surprising results in other contexts (Persico, 2000). The competition between information providers was studied in a different context by Dewatripont and Tirole (1999).[45]


## 6. Conclusion

In this article I study the interaction between research and disclosure in a persuasion game. I find that when the research effort of the sender is not observed by the receiver, the sender's welfare is reduced as he needs to conduct more research to prove he is not withholding information. This extra amount of research can nevertheless be socially beneficial and I highlight the fact that mandatory disclosure should thus be implemented with caution. I also discuss applications to the disclosure of clinical trial results and to judicial systems.

The seminal papers by Milgrom (1981) and Milgrom and Roberts (1986) have given rise to a large literature trying to find circumstances where the unravelling result does not hold. Section 3 in my article highlights two situations where this could occur. The first is one where the sender is potentially credulous. The second is one where the receiver is uncertain about certain parameters of the game. This second situation could even lead to withholding of positive results. Note that in both situations, the interaction between research and disclosure proves to be essential. However, there still remains a number of situations where the opportunities to withhold information are poorly understood. In particular, one interesting direction is to examine cases where the receiver is unaware of the different discoveries the sender could potentially make. This article highlights that examining research and disclosure decisions jointly is essential to approach these type of questions.

Empirical validation could also be an interesting avenue for future research. In this paper I present some suggestive evidence based on the new policy adopted by the International Committee of Medical Journal Editors and on the number of trials aimed at finding new applications for existing drugs. More systematic analysis of these data could lead to exciting work. The challenge however is to obtain a measure of research activity before the adoption, when the research effort was still unobservable.

---

[44] The research in this case also leads to a single signal but they suppose in this paper that the search effort is unobservable. In a working version of that paper they compare the observable and unobservable search case and show that the probability of searching is higher when the search effort is not observed. This is similar to Shavell's result and to my Proposition 2 result (*iii*). Part of the discussion relative to Shavell's paper also applies here.

[45] They examine, in a system where contracts specify payments as a function of information obtained, whether a system with competing advocates dominates one with a single non partisan decision maker. They show that when evidence is not concealable, the advocacy system is strictly optimal: it gives incentives for information gathering without abandoning rents.

# Appendix

In a previous version of the article, the results of Propositions 1 to 3 were first presented for a special case of the model where the distribution of signals took the particular functional form $f(x|\theta, Q) = 1_{x=\theta Q}$ (model also used in Sections 3 and 4). This simplified the exposition of the proofs and the derivations of the results. In particular for Proposition 2, the equilibrium amount of research was given by: $Q^* = 2\delta E(\theta)/C$. The derivations for Propositions 1 to 3 in this special case are available upon request.

PROPOSITION 1 *The receiver can observe the amount of research performed by the sender. Furthermore, the utility function of the receiver is strictly concave in p. The unravelling result in Milgrom and Roberts (1986) Proposition 2 applies. The sender uses a full disclosure reporting strategy in all sequential equilibria: he reveals all the positive signals and if signals are withheld, the receiver knows that they are negative.*

Given that the sender's reporting strategy is one of full disclosure, I determine the amount of research performed by the sender. The sender solves the following problem:

$$\max_{Q'} - \int_0^\infty \int_0^1 [\mathrm{E}(\theta|x, Q') - \theta - \delta]^2 f(x|\theta, Q')\pi(\theta)\mathrm{d}x\mathrm{d}\theta - CQ'.$$

We have by Bayes' rule $f(x \mid \theta)\pi(\theta) = g(\theta \mid x)g(x)$, so the problem can be rewritten:

$$\max_{Q'} - \int_0^\infty \int_0^1 (\mathrm{E}[\theta, Q'] - \theta - \delta]^2 g(\theta, Q')g(x, Q')\mathrm{d}x\mathrm{d}\theta$$

$$+ 2\int_0^\infty \int_0^1 [\mathrm{E}[\theta, Q'] - \theta]\delta g(\theta, Q')g(x, Q')\mathrm{d}x\mathrm{d}\theta$$

$$- \delta^2 \int_0^\infty \int_0^1 g(\theta, Q')g(x, Q')\mathrm{d}x\mathrm{d}\theta - CQ'$$

By definition $\int_0^1 [\mathrm{E}(\theta|x, Q') - \theta]g(\theta, Q')\mathrm{d}\theta = 0$ and $\int_0^1 [\mathrm{E}(\theta, Q') - \theta]^2 g(\theta|x, Q')\mathrm{d}\theta = V(\theta, Q')$ so the problem is:

$$\max_{Q'} - \int_0^\infty \mathrm{Var}(\theta|x, Q')g(x, Q')\mathrm{d}x - \delta^2 - CQ'.$$

Assumption (*ii*) specified in the description of the model guarantees that this problem has a unique solution given by the first order conditions of Proposition 1.

PROPOSITION 2 *I proceed in two steps to prove the different claims of Proposition 2. In step 1 I examine the reporting strategy and in step 2 we determine the optimal research decision.*

*Step 1: Reporting strategy*

Let $Q^*$ be the amount of research conducted in equilibrium. I first point out that on the equilibrium path, when the sender conducts an amount of research $Q^*$, Milgrom's unravelling result applies as in Proposition 1. The main object of the Proof is therefore to determine the reporting strategy out of equilibrium.

Suppose the sender conducts an amount of research $Q'$ and obtains results $x$. His desired policy is then $p_o = \mathrm{E}(\theta|x, Q') + \delta$. I distinguish two cases: (1) $p_o > 1$ (2) $p_o \leq 1$.

*Case* (1): $p_o > 1$. In this case the optimal policy is never attainable. Indeed, because $\theta \in [0, 1]$, in all sequential equilibria, the receiver always sets a policy in the interval $[0, 1]$. Given that the preferences of the sender are single peaked, he wants to induce the highest possible policy. If $x \leq Q^*$, the report $r = x$ is optimal and is on the equilibrium path. If $x > Q^*$, the sender can obtain policy 1 by reporting $r = Q^*$. Regardless of the beliefs of the receiver off the equilibrium

path, he cannot obtain a higher policy. His optimal reporting strategy is therefore $r = Q^*$ independently of the receiver's beliefs.

*Case (2):* $p_o \leq 1$. In this case the sender's preferred policy is potentially attainable. His ideal report is $r_0$ such that $\mathrm{E}(\theta|r_o, Q^*) = \mathrm{E}(\theta|x, Q') + \delta$. However, the verifiability constraint imposes $r_o \leq x$. In this case if $r_o \leq x$, the optimal report is $r = r_o$. If $r_o > x$, given that the preferences of the sender are single peaked, the sender wants the highest policy possible. His optimal reporting strategy is then $r = x$.[46]

To summarise the results, in all sequential equilibria, the optimal reporting strategy will depend on the number $x$ of positive results obtained. There are three types of intervals to consider. I use the following notation:

$A_k$ such that if $x \in A_k$ the optimal reporting strategy is $r = x$

$B_k$ such that if $x \in B_k$ the optimal reporting strategy is $r = Q^*$

$C_k$ such that if $x \in C_k$ the optimal reporting strategy is $r = r_o$ that guarantees the preferred policy. There could be multiple intervals of each type and for step 2 I consider the most general case where the exact number of intervals of each type is left unspecified.

*Step 2: Optimal research decision*

Given his reporting strategy, the sender chooses $Q'$, the amount of research he performs, as the solution to:

$$\max_{Q'} - \int_0^1 \int_{\cup A_k} [\mathrm{E}(\theta, Q^*) - \theta - \delta]^2 f(x|\theta, Q')\pi(\theta)\mathrm{d}x\mathrm{d}\theta$$
$$- \int_0^1 \int_{\cup B_k} (1 - \theta - \delta)^2 f(x|\theta, Q')\pi(\theta)\mathrm{d}x\mathrm{d}\theta$$
$$- \int_0^1 \int_{\cup C_k} [\mathrm{E}(\theta, Q') + \delta - \theta - \delta]^2 f(x|\theta, Q')\pi(\theta)\mathrm{d}x\mathrm{d}\theta - CQ'.$$

Indeed, on intervals $A_k$, the receiver sets policy $p = \mathrm{E}(\theta|x, Q^*)$, on interval $B_k$ she sets policy $p = 1$ and on $C_k$ the sender's preferred policy $\mathrm{E}(\theta|x, Q') + \delta$ is implemented.

The problem of the sender can be rewritten:

$$\max_{Q'} - \int_0^1 \int_{\cup A_k} \left\{ [\mathrm{E}(\theta|x, Q^*) - \theta - \delta]^2 - [\mathrm{E}(\theta, Q') - \theta]^2 \right\} f(x|\theta, Q')\pi(\theta)\mathrm{d}x\mathrm{d}\theta$$
$$- \int_0^1 \int_{\cup B_k} \left\{ (1 - \theta - \delta)^2 - [\mathrm{E}(\theta, Q') - \theta]^2 \right\} f(x|\theta, Q')\pi(\theta)\mathrm{d}x\mathrm{d}\theta$$
$$- \int_0^1 \int_0^\infty [\mathrm{E}(\theta, Q') - \theta]^2 f(x|\theta, Q')\pi(\theta)\mathrm{d}x\mathrm{d}\theta - CQ'.$$

As in the Proof of Proposition 1, I can rewrite the third term as a function of the variance. The objective becomes:

$$\max_{Q'} - \int_0^\infty \mathrm{Var}(\theta, Q')g(x, Q')\mathrm{d}x - CQ'$$
$$- \int_0^1 \int_{\cup A_k} \left\{ [\mathrm{E}(\theta|x, Q^*) - \theta - \delta]^2 - [\mathrm{E}(\theta|x, Q') - \theta]^2 \right\} f(x|\theta, Q')\pi(\theta)\mathrm{d}x\mathrm{d}\theta$$
$$- \int_0^1 \int_{\cup B_k} \left\{ (1 - \theta - \delta)^2 - [\mathrm{E}(\theta, Q') - \theta]^2 \right\} f(x|\theta, Q')\pi(\theta)\mathrm{d}x\mathrm{d}\theta.$$

[46] Given that $r_o > x$ and that $\mathrm{E}(\theta|r_o, Q^*) = \mathrm{E}(\theta|x, Q') + \delta \leq 1$ in case 2, $x \leq Q^*$.

I determine the first order conditions of this maximisation problem:

$$C = -\frac{\partial}{\partial Q'}\left[\int_0^\infty \text{Var}(\theta, Q')g(x, Q')\mathrm{d}x\right]$$

$$-\int_0^1 \int_{\cup A_k} \{[\mathrm{E}(\theta, Q^*) - \theta - \delta]^2 - [\mathrm{E}(\theta|x, Q') - \theta]^2\}\frac{\partial f}{\partial Q'}(x|\theta, Q')\pi(\theta)\mathrm{d}x\mathrm{d}\theta$$

$$+2\int_0^1 \int_{\cup A_k} \frac{\partial \mathrm{E}}{\partial Q'}(\theta, Q')[\mathrm{E}(\theta, Q') - \theta]f(x|\theta, Q')\pi(\theta)\mathrm{d}x\mathrm{d}\theta$$

$$-\int_0^1 \int_{\cup B_k} \{(1 - \theta - \delta)^2 - [\mathrm{E}(\theta, Q') - \theta]^2\}\frac{\partial f}{\partial Q'}(x|\theta, Q')\pi(\theta)\mathrm{d}x\mathrm{d}\theta$$

$$+2\int_0^1 \int_{\cup B_k} \frac{\partial \mathrm{E}}{\partial Q'}(\theta, Q')[\mathrm{E}(\theta, Q') - \theta]f(x|\theta, Q')\pi(\theta)\mathrm{d}x\mathrm{d}\theta.$$

Given that the reporting strategy is continuous, all the derivatives at the boundaries of the intervals cancel out and thus do not appear in this expression.[47]

For $Q^*$ to be an equilibrium these first order conditions need to be satisfied at $Q^*$. I consider the first order conditions at the limit when $Q'$ converges to $Q^*$. The first thing to observe is that $\cup A_k \to [0, +\infty]$ and $\cup B_k \to \emptyset$.[48] Given that $f(x \mid \theta, Q')$ is continuously differentiable, the integrands in the last two terms of the previous expression are continuous. I therefore conclude that when $Q'$ converges to $Q^*$, these two terms converge to zero and overall the first order conditions become:

$$C = -\frac{\partial}{\partial Q'}\left[\int_0^\infty \text{Var}(\theta, Q')g(x, Q')\mathrm{d}x\right]\Big|_{Q'=Q^*}$$

$$+\int_0^1 \int_0^\infty \delta[2\mathrm{E}(\theta, Q^*) - 2\theta - \delta][\frac{\partial f}{\partial Q'}(x|\theta, Q')]|_{Q'=Q^*}\pi(\theta)\mathrm{d}x\mathrm{d}\theta$$

$$+2\int_0^1 \int_0^\infty [\frac{\partial \mathrm{E}}{\partial Q'}(\theta, Q')]|_{Q'=Q^*}[\mathrm{E}(\theta, Q^*) - \theta]f(x|\theta, Q^*)\pi(\theta)\mathrm{d}x\mathrm{d}\theta.$$

I first examine the 3rd term:

$$2\int_0^1 \int_0^\infty \left[\frac{\partial \mathrm{E}}{\partial Q'}(\theta, Q')\right]|_{Q'=Q^*}[\mathrm{E}(\theta, Q^*) - \theta]f(x|\theta, Q^*)\pi(\theta)\mathrm{d}x\mathrm{d}\theta$$

$$= 2\int_0^\infty \left[\frac{\partial \mathrm{E}}{\partial Q'}(\theta, Q')\right]|_{Q'=Q^*}g(x, Q')\left[\int_0^1 [\mathrm{E}(\theta, Q^*) - \theta]g(\theta|x, Q^*)\mathrm{d}\theta\right]\mathrm{d}x = 0.$$

I then simplify the second term:

$$\int_0^1 \int_0^\infty \delta[2\mathrm{E}(\theta, Q^*) - 2\theta - \delta]\left[\frac{\partial f}{\partial Q'}(x|\theta, Q')\right]|_{Q'=Q^*}\pi(\theta)\mathrm{d}x\mathrm{d}\theta$$

$$= -\int_0^1 \int_0^\infty \delta^2 \left[\frac{\partial f}{\partial Q'}(x|\theta, Q')\right]|_{Q'=Q^*}\pi(\theta)\mathrm{d}x\mathrm{d}\theta$$

$$+\int_0^1 \int_0^\infty 2\delta[\mathrm{E}(\theta, Q^*) - \theta]\left[\frac{\partial f}{\partial Q'}(x|\theta, Q')\right]|_{Q'=Q^*}\pi(\theta)\mathrm{d}x\mathrm{d}\theta.$$

[47] For instance consider $x_k$ at the boundary between an interval $A_k$ and $C_k$. The expression for the first order conditions should also contain the term $\int_0^1 [\partial x_k/\partial Q']\{[\mathrm{E}(\theta|x_k, Q^*) - \theta - \delta)^2 - [\mathrm{E}(\theta|x_k, Q') - \theta]^2\}\pi(\theta)\mathrm{d}\theta$. However at the boundary $x_k$ between these intervals $\mathrm{E}(\theta|x_k, Q^*) = \mathrm{E}(\theta \mid x_k, Q') + \delta$ and this term cancels out. Following the same reasoning, all terms at the boundaries disappear.

[48] Indeed at the limit, when the receiver has the right beliefs about the quantity of research, there is no more opportunities to hide information, therefore the ideal policy from the point of view of the sender is never attainable.

$\int_0^1 \int_0^\infty f(x|\theta, Q') \, \pi(\theta)\mathrm{d}x\mathrm{d}\theta = 1$. The derivative with respect to $Q'$ yields: $\int_0^1 \int_0^\infty \delta^2[\partial f(x|\theta, Q')/\partial Q']|_{Q'^*}\pi(\theta)\mathrm{d}x\mathrm{d}\theta = 0$.

Also $\int_0^1 \int_0^\infty [\mathrm{E}(\theta|x, Q') - \theta] \, f(x|\theta, Q') \, \pi(\theta)\mathrm{d}x\mathrm{d}\theta = 0$. I consider the derivative with respect to $Q'$ to simplify the second term:

$$\int_0^1 \int_0^\infty 2\delta[\mathrm{E}(\theta, Q^*) - \theta]\left[\frac{\partial f}{\partial Q'}(x|\theta, Q')\right]|_{Q'=Q^*}\pi(\theta)\mathrm{d}x\mathrm{d}\theta$$

$$= -2\delta \int_0^1 \int_0^\infty \left[\frac{\partial \mathrm{E}}{\partial Q'}(\theta, Q')\right]|_{Q'=Q^*}f(x|\theta, Q^*)\pi(\theta)\mathrm{d}x\mathrm{d}\theta.$$

Therefore, the first order conditions of the initial maximisation problem can be rewritten:

$$C = -\frac{\partial}{\partial Q'}\left[\int_0^\infty \mathrm{Var}(\theta, Q')g(x, Q')\mathrm{d}x\right]|_{Q'=Q^*}$$

$$- 2\delta \int_0^1 \int_0^\infty \frac{\partial}{\partial Q'}[\mathrm{E}(\theta, Q')]|_{Q'=Q^*}f(x|\theta, Q^*)\pi(\theta) \, \mathrm{d}x\mathrm{d}\theta.$$

I have therefore shown result (*ii*). Let me now prove the other claims of Proposition 2:
(*iii*) $\partial \mathrm{E}(\theta \mid x, Q')/\partial Q'$ is negative because the number of positive signals is weakly increasing in the quantity of research performed.

$\int_0^\infty \mathrm{Var}(\theta, Q')g(x')\mathrm{d}x$ is convex in $Q'$ according to the hypothesis made on the variance. I use these two properties to compare the first order conditions that characterise the equilibrium amounts of research with the first order condition of Proposition 1. I find that $Q_0 < Q^*$.

(*i*) As previously explained, in equilibrium, the receiver knows although she does not observe, the amount of research performed in equilibrium. Therefore, Milgrom's unravelling result applies and the equilibrium reporting strategy is one of full disclosure.

(*iv*) In equilibrium, all the information is revealed. Therefore it is as if the research effort was observable by the receiver. In the observable case, the optimal choice of the receiver is to conduct an amount of research $Q_0$. The extra research is therefore costly for the sender and he is strictly worse off in the unobservable case.

PROPOSITION 3 *I first determine the amount of research $Q_W$ conducted at the social optimum. $Q_W$ is the amount of research that maximises the sum of the sender's and the receiver's welfare. It is solution to:*

$$\max_{Q'} -\int_0^\infty \int_0^1 [\mathrm{E}(\theta, Q') - \theta - \delta]^2 f(x|\theta, Q')\pi(\theta) \, \mathrm{d}x\mathrm{d}\theta$$

$$- \int_0^\infty \int_0^1 [\mathrm{E}(\theta, Q') - \theta]^2 f(x|\theta, Q')\pi(\theta) \, \mathrm{d}x\mathrm{d}\theta - CQ'.$$

The first order conditions corresponding to this problem are:

$$\frac{C}{2} = -\frac{\partial}{\partial Q'}\left[\int_0^\infty \mathrm{Var}(\theta, Q')g(x, Q')\mathrm{d}x\right]|_{Q'=Q_W}.$$

First note that $Q_O < Q_W$: in the observable case, the sender conducts a socially insufficient amount of research as he ignores the benefits of extra research for the receiver. I also previously derived the result $Q_O < Q^*$. However, I now need to compare $Q^*$ and $Q_W$ to determine whether social welfare is higher when the research effort is not observed by the receiver. From result (ii) of Proposition 2, an amount of research $Q_W$ is attainable in the unobservable case if the following unit tax on research is imposed:

$$\tau = -2\delta \int_0^1 \int_0^\infty \frac{\partial}{\partial Q'}[\mathrm{E}(\theta, Q')]|_{Q'=Q_W}f(x|\theta, Q_W)f(\theta) \, \mathrm{d}x\mathrm{d}\theta - \frac{C}{2}.$$

In that case the first order conditions that characterise $Q^*$ that I obtained in Proposition 2 are equivalent to the first order conditions characterising the social optimum $Q_W$. Therefore I have shown that by imposing such a tax on research, an amount $Q_W$ will be conducted. Note that this proves Corollary 3.

If $\tau \leq 0$, the amount of research at the social optimum is greater than the amount $Q^*$ conducted when research is not observed by the receiver (in the unobservable case, research needs to be subsidised to approach the social optimum). A direct consequence is that the amount of research conducted in the unobservable case is closer to the social optimum than in the observable case (the ordering is in this case $Q_0 < Q^* < Q_W$). Given that the welfare function is concave in $Q$, $\tau \leq 0$ is a sufficient condition such that social welfare is greater when research is unobservable. This is the result stated in Proposition 3.

COROLLARY 2 *Let $\delta_0$ be such that if the sender has bias $\delta_0$, social welfare is greater when the research effort is unobservable. From the Proof of Proposition 3 the socially optimal amount of research $Q_W$ does not depend on the bias $\delta$.[49] On the contrary, $Q^*$ is strictly increasing in the bias. Thus for all senders with bias $\delta \leq \delta_0$ social welfare is also greater when the research effort is unobservable.*

Let $\delta_0'$ be such that if the sender has bias $\delta_0'$, social welfare is greater when the research effort is observable. For identical reasons, for all senders with bias $\delta \geq \delta_0'$ social welfare is also greater when the research effort is observable.

Finally, when $\delta \to 0$, the sufficient condition of Proposition 3 is satisfied. Therefore there always exists $\delta^* > 0$ such that social welfare is greater when the research effort is unobservable if and only if $\delta \leq \delta^*$.

COROLLARY 3 *This Corollary is proved as part of the Proof of Proposition 3 when the socially optimal tax or subsidy is derived.*

PROPOSITION 4 *I follow the steps of Proposition 2 and examine how the results are affected by the possibility of facing credulous receivers.*

*Step 1: Reporting strategy*

I start with the reporting strategy. I show that the sender still reports the same number of positive signals as when he faced only the sophisticated type but adapts the number of negative signals to deceive the credulous receiver.

I use the same distinction as in Proposition 2 between the cases (1) $p_0 > 1$ (2) $p_0 \leq 1$.[50]

*Case (1): $p_0 > 1$.* In this case the best the sender can do is to induce the receiver to set the policy $p = 1$. To induce the credulous receiver to do so, it is sufficient to report no negative signals. Furthermore the amount of positive signals will be determined by the sophisticated type's reaction and is therefore identical to the amount in Proposition 2 (if $x \leq Q^*$ the report is $r = x$ and if $x > Q^*$ the report is $r = Q^*$)

*Case (2): $p_0 \leq 1$.* I show that in this case the sender will always be able to induce the credulous receiver to set policy $p_0$ while reporting the amounts of positive signals as in Proposition 2. In Proposition 2, the sender, faced with a sophisticated receiver, had an ideal report $r_0$ such that $E(\theta | r_0, Q^*) = E(\theta | x, Q') + \delta s$. The verifiability constraint imposed $r_0 \leq x$. Similarly, in this case, if $r_0 \leq x$, the optimal report is $r = r_0$ positive signals and $(Q^* - r_0)$ negative signals. Both the sophisticated type and the credulous type will set policy $p_0$. If

---

[49] The first order conditions that characterise $Q_W$ are independent of $\delta$.
[50] Where $p_0$ is his desired policy: $p_0 = E(\theta | x, Q') + \delta$.

$r_0 > x$, the optimal strategy when faced with a sophisticated receiver is to report an amount of positive signals $r = x$. I now need to show that the amount of negative signals can be adapted such that the credulous receiver sets policy $p_0$. The sender can induce the credulous receiver to adopt any policy between $[\mathrm{E}(\theta \mid x, Q'), 1]$ by adapting the amount of negative signals. He can therefore obtain $p_0 \in [\mathrm{E}(\theta \mid x, Q'), 1]$ by choosing the correct amount of negative signals.

To summarise the results as in the Proof of Proposition 2, in all sequential equilibria, the optimal reporting strategy will depend on the number $x$ of positive results obtained and can be in one of three intervals: $A_k$ such that if $x \in A_k$ the optimal reporting strategy is $r = x$ positive signals. Policy $p_0$ is set by the credulous receiver and policy $\mathrm{E}(\theta \mid x, Q^*)$ by the sophisticated receiver $B_k$ such that if $x \in B_k$ the optimal reporting strategy is $r = Q$ positive signals. Policy 1 is set by both types of receivers $C_k$ such that if $x \in C_k$ the optimal reporting strategy is $r = r_0$ positive signals. Policy $p_0$ is set by both types of receiver.

*Step 2: Optimal research decision*

Given this reporting strategy, I reconsider the research decision of the sender. The amount of research performed $Q'$ is solution to:

$$\max_{Q'} - q \int_0^1 \int_{\cup A_k} [\mathrm{E}(\theta|x, Q^*) - \theta - \delta]^2 f(x|\theta, Q')\pi(\theta) \, \mathrm{d}x\mathrm{d}\theta$$

$$- (1 - q) \int_0^1 \int_{\cup A_k} [\mathrm{E}(\theta, Q') + \delta - \theta - \delta]^2 f(x|\theta, Q')\pi(\theta) \, \mathrm{d}x\mathrm{d}\theta$$

$$- \int_0^1 \int_{\cup B_k} (1 - \theta - \delta)^2 f(x|\theta, Q')\pi(\theta) \, \mathrm{d}x\mathrm{d}\theta$$

$$- \int_0^1 \int_{\cup C_k} [\mathrm{E}(\theta, Q') + \delta - \theta - \delta]^2 f(x|\theta, Q')\pi(\theta) \, \mathrm{d}x\mathrm{d}\theta - CQ'.$$

The problem of the sender can be rewritten:

$$\max_{Q'} - q \int_0^1 \int_{\cup A_k} \{[\mathrm{E}(\theta, Q^*) - \theta - \delta]^2 - [\mathrm{E}(\theta, Q') - \theta]^2\} f(x|\theta, Q')\pi(\theta) \, \mathrm{d}x\mathrm{d}\theta$$

$$- (1 - q) \int_0^1 \int_{\cup A_k} \{[\mathrm{E}(\theta, Q') + \delta - \theta - \delta]^2 - [\mathrm{E}(\theta, Q') - \theta]^2\} f(x|\theta, Q')\pi(\theta) \, \mathrm{d}x\mathrm{d}\theta$$

$$- \int_0^1 \int_{\cup B_k} \{(1 - \theta - \delta)^2 - [\mathrm{E}(\theta, Q') - \theta]^2\} f(x|\theta, Q')\pi(\theta) \, \mathrm{d}x\mathrm{d}\theta$$

$$- \int_0^1 \int_0^\infty [\mathrm{E}(\theta, Q') - \theta]^2 f(x|\theta, Q')\pi(\theta) \, \mathrm{d}x\mathrm{d}\theta - CQ'.$$

The objective becomes:

$$\max_{Q'} - \int_0^\infty \mathrm{Var}(\theta, Q')g(x, Q')\mathrm{d}x - CQ'$$

$$- q \int_0^1 \int_{\cup A_k} \{[\mathrm{E}(\theta, Q^*) - \theta - \delta]^2 - [\mathrm{E}(\theta, Q') - \theta]^2\} f(x|\theta, Q')\pi(\theta) \, \mathrm{d}x\mathrm{d}\theta$$

$$- \int_0^1 \int_{\cup B_k} \{(1 - \theta - \delta)^2 - [\mathrm{E}(\theta, Q') - \theta]^2\} f(x|\theta, Q')\pi(\theta) \, \mathrm{d}x\mathrm{d}\theta.$$

The only change is the factor $q$ that precedes the second term. The calculation of Proposition 2 can therefore be reproduced and the first order conditions of the initial maximisation problem can be rewritten:

$$C = -\frac{\partial}{\partial Q'} \left[ \int_0^\infty \text{Var}(\theta, Q') g(x, Q') dx \right]|_{Q'=Q^*}$$
$$- 2\delta q \int_0^1 \int_0^\infty \frac{\partial}{\partial Q'} [\text{E}(\theta, Q')]|_{Q'=Q^*} f(x|\theta, Q^*) \pi(\theta) \, dx d\theta..$$

This concludes the Proof of Proposition 4.

COROLLARY 4 *As q converges to zero, $Q^*(q)$ converges to $Q_0$.*

As $q$ converges to zero, without mandatory disclosure, the policy set by the receiver converges to the sender's preferred policy. With mandatory disclosure, the policy set by the receiver is her preferred policy. Given that $a > 1$ for small values of $q$, mandatory disclosure will increase overall welfare.

PROPOSITION 5 *I remind the reader that I use in the rest of the proofs a special version of the model that isolates the strategic function of research. Specifically, I suppose that the distribution of signals takes a particular form $f(x|\theta, Q) = 1_{x=\theta Q}$: if the sender conducts an amount Q of research, he knows for sure he will obtain $\theta Q$ positive signals and will therefore be able to infer the exact value of the state. Note that with this functional form, result (ii) of Proposition 2 indicates that in a case with a single sender, the amount of research conducted is $Q = 2\delta\text{E}(\theta)/c$.[51] I prove the result in the case where biases are large, i.e the sender always wants to report all the positive signals he obtains, but the results are also valid with small biases.*

- (*i*) Suppose in equilibrium $Q_L = Q_H$. Both types will then employ the same reporting strategy of full disclosure. In that case, the equilibrium condition for the low type is given by $Q_L = 2\delta_L\text{E}(\theta)/C$. So if $Q_L = Q_H$, the consequence is that $Q_H < 2\delta_H\text{E}(\theta)/C$ and therefore this cannot be an equilibrium condition as according to the proof of Proposition 2 the high type would have incentives to search further to mislead the receiver. Therefore, in equilibrium, $Q_L < Q_H$.
- (*ii*) Assume there exists an equilibrium where all the positive information is always reported by both types. Suppose the high type obtains an amount of positive signals $x = Q_L^* + \epsilon$ ($\epsilon$ infinitesimal), if he reports all his positive information, he reveals his type and the policy is therefore set at $p = (Q_L^* + \epsilon)/Q_H^*$. If he hides part of his results, and reports $x = Q_L^*$ he will obtain a strictly higher policy: $p = Q_L^*/[pQ_L^* + (1-p)Q_H^*]$. Therefore this cannot be equilibrium behaviour. For a certain range of results $x$, some positive signals will be withheld.

PROPOSITION 6 *According to Proposition 5, in all equilibria, if the high type obtains an amount of positive signals close but greater than $Q_L$, he will not report all of these signals. However, there cannot exist an equilibrium where, in such situations, the high type always report $Q_L$ positive signals. Indeed, the low type would then never report $Q_L$ and the equilibrium would break down. Therefore, there exists 2 values $Q_0$ and $Q_B$ such that:*

If research yields a quantity of positive signals in $[0, Q_0]$, all the signals are reported.

If research yields a quantity of positive signals in $[Q_0, Q_B]$ ,both types pool their reports and the decision maker sets a policy $n$.

If research yields a quantity of positive signals in $[Q_B, Q_H]$, the high type uses a reporting strategy of full disclosure.

In the case where the state $\theta$ is uniformly distributed on the interval $[0, 1]$, the following properties have to be true in equilibrium:

[51] For that particular research function I have $f(x|\theta, Q) = 1_{x=\theta Q}$ and $\text{E}(\theta|x, Q) = x/Q$.

$Q_B$ is such that $n = Q_B/Q_H$ (at $Q_B$, the high type is indifferent between reporting truthfully and revealing his type and obtaining the policy $n$).

$n = q(Q_L - Q_0)/Q_L + (1 - q)[(Q_B - Q_0)/Q_H]$. The policy is set at the expected value of the state given the reports.

Finally, we prove result $(v)$. I study in this example a particular equilibrium where at $Q_0$, the sender is exactly indifferent between obtaining $n$ and reporting $Q_0$. This means I impose the condition $n = qQ_0/Q_L + (1 - q)Q_0/Q_H$. However, other equilibria exist where $n > qQ_0/Q_L + (1 - q)Q_0/Q_H$. Under this condition I obtain $n = q/(1 + q)$.

The amount of research $Q'$ is solution to:

$$\max_{Q'} - \int_0^{\frac{Q_0}{Q'}} \left[ q\frac{\theta Q'}{Q_L} + (1 - q)\frac{\theta Q'}{Q_H} - \theta - \delta_i \right]^2 f(\theta)\mathrm{d}\theta - \int_{\frac{Q_0}{Q'}}^{\frac{n}{Q'}} (n - \theta - \delta_i)^2 f(\theta)\mathrm{d}\theta$$
$$- \int_{\frac{n}{Q'}}^{\frac{Q_H}{Q'}} \left( \frac{\theta Q'}{Q_H} - \theta - \delta_i \right)^2 f(\theta)\mathrm{d}\theta - CQ'.$$

The first order conditions for the low type can be written

$$-2 \int_0^{\frac{Q_0}{Q_L}} \left( \theta\frac{n}{Q_0} \right) \left( \frac{Q_L}{Q_0}\theta n - \theta - \delta_L \right) f(\theta)\mathrm{d}\theta = C.$$

I want to show that $Q_L$ is smaller than if his type was known. A consequence of the previous equation is that:

$$2 \int_0^{\frac{Q_0}{Q_L}} \left( \theta\frac{n}{Q_0} \right) \delta_L f(\theta)\mathrm{d}\theta = C + 2 \int_0^{\frac{Q_0}{Q_L}} \left( \theta\frac{n}{Q_0} \right) \left( \frac{Q_L}{Q_0}\theta n - \theta \right) f(\theta)\mathrm{d}\theta > C.$$

Therefore, using the uniform distribution, I have $\delta_L Q_0/Q_L^2 n > C$ and because $Q_0 < Q_L$, I have $Q_L < \delta_L/C$. This second term is exactly the amount of research performed if the type was known, when the state is distributed uniformly.

PROPOSITION 7 *In equilibrium, sender 2 uses a reporting strategy of full disclosure, so the problem of sender 1 is:*

$$\max_{Q'} - \int_0^{Q^*/Q'} \left[ p(\frac{\theta Q'}{Q^*}, \theta) - \theta - \delta \right]^2 f(\theta)\mathrm{d}\theta - \int_{Q^*/Q'}^1 [p(1, \theta) - \theta - \delta]^2 f(\theta)\mathrm{d}\theta - CQ'.$$

The first order conditions are:

$$C = -2 \int_0^{Q^*/Q'} \frac{\theta}{Q^*} \frac{\partial p}{\partial \theta_1} \left( \frac{\theta Q'}{Q^*}, \theta \right) \left[ p(\frac{\theta Q'}{Q^*}, \theta) - \theta - \delta \right] f(\theta)\mathrm{d}\theta.$$

The first order conditions at the equilibrium become:

$$Q^* = \frac{-2}{C} \int_0^1 \theta\frac{\partial p}{\partial \theta_1}(\theta, \theta)[p(\theta, \theta) - \theta - \delta]f(\theta)\mathrm{d}\theta = \frac{2\delta}{C} \int_0^1 \theta\frac{\partial p}{\partial \theta_1}(\theta, \theta)f(\theta)\mathrm{d}\theta.$$

This gives have: $\partial p/\partial\theta_1(\theta, \theta) = \lim_{h \to 0}\{[p(\theta + h, \theta) - p(\theta, \theta)]/h\}$

Restriction A implies $\theta \leq p(\theta + h, \theta) \leq \theta + h$. Therefore, I have $0 \leq \partial p/\partial\theta_1(\theta, \theta) \leq 1$.

So, we find $Q^* \leq 2\delta/C \int_0^1 \theta f(\theta)\mathrm{d}\theta$

COROLLARY 5 *In this special case of the model, the social optimum is to conduct an infinitesimal amount of research, sufficient to reveal perfectly the state. Therefore the belief function that maximises social*

*welfare is one that minimises the aggregate amount of research conducted $Q_1^* + Q_2^*$. From the Proof of Proposition* 6, *I know that:*

$$Q_1^* + Q_2^* = \frac{2\delta_1}{C} \int_0^1 \theta \frac{\partial p}{\partial \theta_1}(\theta, \theta) f(\theta) \mathrm{d}\theta - \frac{2\delta_2}{C} \int_0^1 \theta \frac{\partial p}{\partial \theta_2}(\theta, \theta) f(\theta) \mathrm{d}\theta.$$

It is immediate to see that if $\delta_1 > -\delta_2 > 0$, the optimal solution is to set $p(\theta_1, \theta_2) = \theta_2$ (i.e set $\partial p / \partial \theta_1(\theta, \theta) = 0$).

*London Business School*

## References

Akerlof, G. (1976). 'The economics of caste and of the rat race and of other woeful tales', *Quarterly Journal of Economics*, vol. 90, pp. 599–617.

Baron, D. (2006). 'Persistent media bias', *Journal of Public Economics*, vol. 90, vol. 1–36.

Bennedsen, M. and Feldmann, S. (2002). 'Lobbying legislatures', *Journal of Political Economy*, vol. 110, pp. 919–45.

Bennedsen, M. and Feldmann, S. (2006). 'Informational lobbying and political contributions'. *Journal of Public Economics*, vol. 90, pp. 631–56.

Besley, T. and Prat, A. (2006). 'Handcuffs for the grabbing hand: media capture and government accountability' *American Economic Review*, vol. 96, pp. 720–36.

Dewatripont, M. and Tirole, J. (1999). 'Advocates', *Journal of Political Economy*, vol. 107, pp. 1–39.

Dye, R. (1985). 'Disclosure of nonproprietary information', *Journal of Accounting Research*, vol. 23, pp. 123–45.

FDA website, http://www.fda.gov/cder/rdmt/

Jovanovic, B. (1982). 'Truthful disclosure of information', *Bell Journal of Economics*, vol. 13, pp. 36–44.

Milgrom, P. (1981). 'Good news and bad news: representation theorems and applications', *Bell Journal of Economics*, vol. 12, pp. 350–91.

Milgrom, P. (2008). 'What the seller won't tell you: persuasion and disclosure in markets', *Journal of Economic Perspectives*, vol. 22, pp. 115–31.

Milgrom, P. and Roberts, J. (1986). 'Relying on the information of interested parties', *Rand Journal of Economics*, vol. 17, vol. 18–32.

Persico, N. (2000). 'Committee design with endogenous information', *Review of Economic Studies*, vol. 71, pp. 165–91.

Shavell, S. (1994). 'Acquisition and disclosure of information prior to sale', *Rand Journal of Economics*, vol. 25, pp. 20–36.

Shin, H. (1994). 'The burden of proof in a game of persuasion', *Journal of Economic Theory*, vol. 64, pp. 253–64.

Van Zandt, T. and Vives X. (2006). 'Monotone equilibria in Bayesian games of strategic complementarities', *Journal of Economic Theory*, vol. 134, pp. 339–60.

Verrechia, R. (2001). 'Essays on disclosure', *Journal of Accounting and Economics*, vol. 32, pp. 97–180.

Xiang, Y. and Sarvary, M. (2007). 'News consumption and media bias', *Marketing Science*, vol. 26, pp. 611–28.