A Signal-Jamming Model of Persuasion: Interest Group Funded Policy Research

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Abstract

This paper examines interest group funded policy research in a persuasion game context. In previous work in this area it has been assumed that the interest group is the only producer of research and that research is strategically disclosed to a policy maker. I assume that research is both produced exogenously and by an interest group, and that research is randomly observed by the policy maker when it is not disclosed. The motivating example is interest group involvement in the funding of research on climate change.

I find that the interest group is sometimes better off funding research that is randomly observed ('jamming' the policy maker's signal) than strategically disclosing research. When this occurs the policy maker is made worse off by interest group research funding, despite all research being unbiased. For other parameter values the interest group prefers to strategically disclose research results; in these cases, as in previous related literature, the policy maker's welfare is improved by interest group funded research.

JEL Classification Numbers: C72, D82, D83, Q54

Keywords: Persuasion Games, Research Funding, Information Search, Lobbying, Disclosure, Climate Change.

*The title of this paper pays homage to Fudenberg and Tirole (1986), with a nod to Shapiro (2006). I am very grateful to my advisors, Edi Karni and Matthew Shum, for all of their help. I also thank Joseph E. Harrington, Jr., Robert Moffitt, Kevin Thom and Jimmy Chan for helpful comments. All errors are mine. Address: Daniel Stone, JHU–Department of Economics, 3400 N. Charles St., Baltimore, MD 21218. Email: stone@jhu.edu.

1 Introduction

This paper examines the effects of strategic research funding and reporting by a special interest group (SIG) on policy making under uncertainty. Typically in this literature it is assumed that the SIGs are the only producers of research and source of new information for the policy maker (PM).[1] In reality, however, research on policy issues is often produced by both interested and non-interested parties. That is, there exist some research producers who do not have direct economic interests in the policy outcome. Moreover, the PM does not necessarily rely on the SIG to provide it with information–the PM may (stochastically) observe research not 'lobbied'[2] by the SIG when this research is in the public domain. The focus of this paper is on how the presence of exogenously (non-interest group) funded research affects the incentives of a SIG to strategically fund and disclose research, and the welfare effects of the SIG's actions in this context.

The motivating example for this work is SIG-funded research on the uncertain costs of anthropogenic climate change. Numerous firms, industry associations and even nations with revenues based on fossil fuel sales donated substantial amounts of money to think tanks and individual researchers to conduct research on global warming in the last 20 years. This research often entered the public domain and may have been observed–and confused with non-interest group funded research–by policy makers. Two especially interesting examples of academic researchers who received funding that was not always clearly reported are Pat Michaels, a climate scientist at the University of Virginia, and Robert Balling, a professor of geography at Arizona State University. The two disclosed under oath at a 1995 Minnesota state commission that they had received \$165,000 and \$300,000, respectively, over the previous few years from private sources (Gelbspan (1997)). Michaels noted he had been sponsored by Western Fuels, a trade group for the US coal industry, and Balling by Cyprus Minerals, German and British coal groups, and the Kuwaiti government. Please see the appendix for more detail on SIG-funded climate change research.

SIGs of course also fund research that may be indistinguishable from non-interest group funded research in many other areas. For example, organic food and cell phone firms have supported research on the health effects of their products (Asami, Hong, Barrett, and Mitchell (2003), Huss, Egger, Hug, Huwiler-Müntener, and Röösli (2007)). The analysis in this paper is even relevant to the seminal persuasion game situation: a seller attempting to persuade an uninformed buyer. Independent assessments of the product (such as consumer media surveys) could be interpreted as exogenously funded research in this case. It is plausible that firms solicit these surveys to try to influence consumers, and the effects of such strategic solicitation on the sophisticated consumer's

[1] What is referred to here as 'research funding' is sometimes called 'information search' in other literature.

[2] The term 'lobby' is used in this paper to refer to information transmission, as is common in this literature. Some may find this usage disconcerting, as the term often connotes something more sordid than the communication of honest research. But lobbying does indeed often consist of the provision of policy-relevant information; see, for example, Schlozman and Tierney (1986).

welfare are unclear.

This paper falls in the persuasion game literature due to the assumption that information is 'hard,' or verifiable–the SIG cannot manipulate actual research results. Milgrom (2007) provides a review of non-political persuasion games. This distinguishes this work from many other papers on the welfare effects of informational lobbying, such as Potters and van Winden (1992) and Ball (1995), and surveyed by Grossman and Helpman (2001) and van Winden (2003), which assume the content of messages sent by the SIG is arbitrary and are more appropriately classified as cheap talk games.

In most persuasion games the quantity of information available is fixed. The benchmark result, found by Milgrom and Roberts (1986), is that when the decision maker is sophisticated there is full revelation despite strategic disclosure and a lack of competing interested parties. Numerous subsequent papers have developed models in which the quantity of information is endogenous and SIGs can search for hard facts that can then be used to influence a PM. Austen-Smith (1994) extends Crawford and Sobel (1982) and finds that information transmission is enhanced by endogenizing the quantity of information held by the SIG. Lagerlof (1997) finds that allowing one SIG to search for and strategically reveal information to a PM often benefits both the PM and a competing SIG. Bennedsen and Feldmann (2006) confirm that a SIG's ability to search for information provides what they call a (positive) 'information externality' to the PM. They focus on the interaction of campaign contributions and information search, and find that having the ability to make contributions reduces the incentives of SIGs to search for information. Henry (2007) uses a more elaborate research technology assumption and focuses on the problem of strategic funding and disclosure of research results by a pharmaceutical firm when the total quantity of research is unobserved by the PM. He finds that in equilibrium the PM makes the full information decision and actually forces the SIG to fund more research than it would with observable research quantity.

These papers all assume that the SIGs are the only source of new information for the PM. Implicitly, the SIG has no choice but to report its private information that it wants the PM to observe. The model developed in this paper departs from this previous literature by allowing for both exogenous and interest group funded research. Further, it is assumed that SIG-funded research enters the public domain, and thus may be observed by the PM without being reported by the SIG. As a result, the SIG has three strategic choices: 1) whether or not to fund research, 2) whether or not to disclose research results, and 3) conditional on disclosing results, which results to disclose. It turns out that in some equilibria the SIG funds research and strategically *avoids* reporting any of the research results (lobbying). These are exactly the equilibria for which SIG-funding harms PM welfare. This negative welfare effect occurs in spite of the modeling assumption that all research is 'honest'–researchers are homogeneous and their results are unaffected by the source of funding. While this assumption is admittedly not always realistic it is made to serve as a benchmark; if interest group research funding is found to produce negative welfare effects even in this idealized state we can infer it likely does the same in the real world.

In the model of this paper the PM is made worse off by the SIG funding honest research and not lobbying results for the following reason. I assume that the source of research funding is not observed by the PM, making SIG and exogenously funded research in a sense indistinguishable. When the exogenous research is the SIG's private information, the SIG decides whether to fund additional research based on the exogenous research results. This strategically funded research can potentially crowd out the exogenous research observed by the PM. For example, if the SIG is ExxonMobil and the exogenous research is evidence of climate change, the SIG might fund additional research and hope it will be evidence against climate change. If the exogenous research is evidence against climate change, the SIG might not fund additional research, in essence letting the exogenous research speak for itself.

Strategic funding thus causes the PM to be more likely to draw research favorable to the SIG independent of the true state of the world. In the Exxon example, the PM is more likely to observe 'anti-climate change' research whether or not climate change is the true state. This weakens, or 'jams', the signal of the PM and makes the policy choice worse on average. The SIG prefers to signal-jam–strategically fund research and avoid lobbying–because if it lobbies the PM can be skeptical and force full disclosure. When the SIG funds and does not lobby it is essentially pooling (from the perspective of the PM) with the SIG that does not even fund. As a result, when the SIG does not lobby and anti-climate change research is randomly drawn, the PM does not know whether or not the study was funded, and is best off playing the 'no climate change' policy.

For other prior beliefs about the state, SIG and PM incentives are aligned and they both benefit from additional research in the same situations. On average, the SIG funds less research and lobbies more frequently for these parameter values. Thus, the model predicts that research funding and lobbying may be substitutable strategies, and the respective expenditures would be negatively correlated in a time series sample. Further, when lobbying dips and research funding increases the welfare effects of SIG-funding are negative. On the other hand, for other ranges of parameter values lobbying and research funding are complementary strategies, and when this occurs the SIG's actions are socially beneficial. Hence, the sign of the correlation between funding and lobbying expenditures in time series data is associated with the sign of the social welfare effect of the SIG's actions.

The later sections of the paper, in addition to exploring changes in some of the model's assumptions, are useful for examining the model from different angles. In Section 4 I drop the assumption that the SIG can only fund a single study. There is an interesting benchmark result that for some parameter values the SIG sometimes funds an infinite number of studies and completely drowns out the exogenous research. Although the PM knows the SIG does this, the SIG is still made better off by this action, and the PM is sometimes worse off. In Section 5 I discuss introducing a competing SIG. I find that even if the the competitor has symmetric costs and benefits, the original SIG will continue to signal-jam, making the PM worse off in expectation, if the original SIG has a sufficiently large advantage in its ability to observe exogenous research. Section 6 provides concluding remarks, including a discussion of policy implications and directions for future research.

2 The model

The model is based on that of Potters and van Winden (1992). There are two actors, a PM and a SIG. There is an unobserved state of the world, θ, and a policy, x, which affects both of their payoffs. The policy is of course chosen by the PM. For concreteness we can think of θ_1 as representing the climate change state, and θ_2 the no climate change state. x_1 would be the regulatory policy, and x_2 the no regulation option. The state and policy spaces, and payoffs are represented in the following matrix:[3]

	θ_1	θ_2
x_1	$(1,0)$	$(0,0)$
x_2	$(0,1)$	$(1,1)$

The PM's payoff is listed first and both payoffs are normalized to one. The payoffs imply that the PM prefers to match the policy to the state, and the SIG always prefers that the x_2 policy be played. Results are qualitatively similar to those found allowing the policy choice to come from a more general set.[4] I use the binary policy choice model primarily for transparency and tractability, however, it is not unrealistic. Many policy choices are more aptly described as discrete than continuous. Regarding climate change in the late 1990s and early 2000s the main policy choice was in fact binary: whether or not to adopt the Kyoto Protocol.

The SIG and PM share a prior, $p = Pr(\theta = \theta_2)$. Beliefs about θ are updated using research reports that are modeled as noisy signals that can take the value s_1 or s_2. The signal probabilities are $\pi_1 = Pr(s_2|\theta_1), \pi_2 = Pr(s_2|\theta_2)$ with $\pi_2 > \pi_1$. This implies $Pr(\theta_2|s_2) \geq p$ and $Pr(\theta_2|s_1) \leq p$. If s_1 is considered a positive signal, we can also think of π_2 as the probability of a true negative, and π_1 as the probability of a false negative.

This research technology assumption is suggested by Potters and van Winden in an extension of their model; Austen-Smith (1998) models research in a similar way and the assumption used by Henry is also similar in spirit. The assumption is different from that used in many models in which information search is randomly either perfectly informative or uninformative (see e.g. Dewatripont and Tirole (1999)). The noisy signal assumption, to be clear, is necessary for the results obtained in this paper.

[3]Potters and van Winden specify different payoffs for each state, and their results actually depend on this state-dependence. Results here would easily extend to state-dependent payoffs but are simpler when the payoffs are constant.

[4]This is true holding other aspects of the game fixed. Results do qualitatively change when both the policy choice and research signals are continuous, unbounded variables.

This is because it allows for conflicting research results; the SIG can fund research that results in s_2 even when another study turned out to be s_1. But I do not believe this is problematic as the noisy signal assumption does seem to be realistic for most policy issues. Certainly for an issue as complex as climate change research is never perfectly informative and researchers sometimes make 'mistakes'. Even if climate change is not the true state of the world surely it is possible to produce research indicating that it is, and vice versa.

For simplicity I assume that the cost of both funding research and lobbying (presenting research to the PM) is zero. The point of this model is not to examine the cost/benefit tradeoff of funding and/or lobbying, thus, including these costs only creates unnecessary complication. As discussed shortly it is assumed that the SIG can only fund a limited amount of research, which in essence serves the same purpose as including a funding cost. I do assume that when the SIG is indifferent between either funding and not funding, and lobbying and not lobbying, the SIG chooses the latter option. This helps to eliminate uninteresting mixed strategy equilibria.

The action sequence is presented in the condensed game tree shown below. The game begins when nature selects the state of nature and the realization of an exogenously, or non-interest group funded, study, $s^1 \in \{s_1, s_2\}$. The SIG observes s^1 with probability ω. If the SIG observes s^1 the SIG then decides whether to fund an additional study.[5] Let $\phi(s^1) = Pr(\text{fund}|s^1)$ (ϕ for **f**und) denote the SIG's funding strategy. After making its funding decision the SIG can lobby. Let $\lambda(\widetilde{s}|\bar{s}) = Pr(\text{lobby } \widetilde{s}|\bar{s})$ (λ for **l**obby) denote the SIG's lobbying strategy, in which $\bar{s}$ is the existing study or studies, and $\widetilde{s} \in \mathcal{P}(\bar{s})$ is the disclosed study or studies. For example, if $\bar{s} = (s_1, s_2)$ then $\widetilde{s}$ could be s_2, s_1, (s_1, s_2) or $\emptyset$. When $\widetilde{s} = \emptyset$ the SIG does not lobby. (In the game tree shown when the SIG lobbies it is implicit that $\widetilde{s}$ is non-empty.)

The primary contribution of this paper is the examination of the case in which when the SIG does not lobby the PM takes a random draw from the pool of available research. This assumption is meant to reflect the fact that policy makers do in fact observe policy-related research that is not brought to them directly by a SIG; however, their observation of this research is limited and stochastic. This assumption is not appropriate for a SIG-specific policy issue such that the PM would know that the SIG is responsible for all research on the subject. In this case, such as for a pharmaceutical product in development, SIG-funded research may not be in the public domain and there may not even exist non-SIG funded research. But for most policy issues, including climate change, this is not the case: a great deal of research is in the public domain, and the PM randomly observes some of this research. It is also assumed w.l.o.g. that the PM does not draw research if the SIG lobbies.[6] The assumption that the PM draws one, and exactly one, study from the pool of research also does not qualitatively

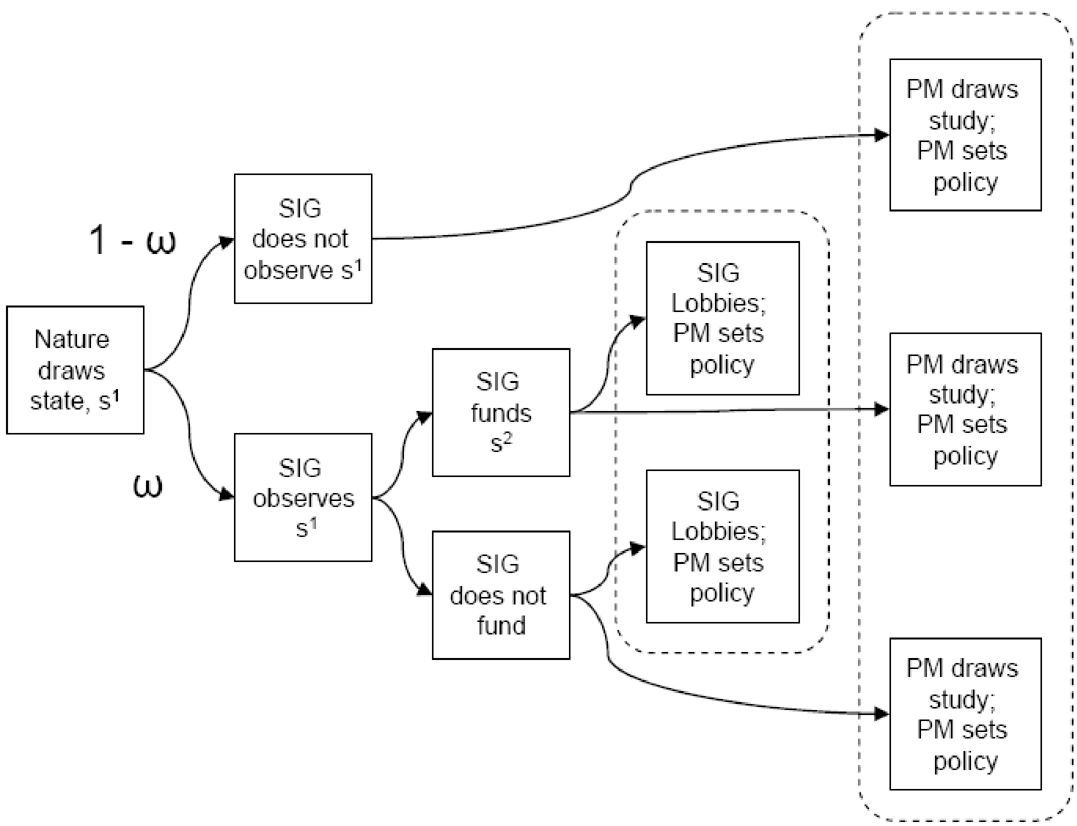
[5] The SIG could also fund if it did not observe s^1, and knew it did not observe s^1, but it never benefits from this.

[6] It turns out that the PM always makes the full information decision when the SIG lobbies so the draw is not necessary. Because of this the 'L-principle' (Glazer and Rubinstein (2006)) is not applicable to this model, as it is only used when the message sender is prevented by assumption from transmitting full information.

affect the results; what is essential is that the PM is sufficiently likely to randomly observe research not lobbied.

The final key assumption that should be re-stated clearly is that the PM cannot observe whether or not a study was SIG-funded. Of course, given the assumption that the PM is sophisticated it is aware of this lack of information and takes it into account when updating beliefs. This assumption is not always realistic, but as discussed in the introduction there are many cases of researchers not clearly reporting their sources of funding. The source of funding for think tank studies in particular may be difficult for PMs to observe. It is also possible that even when funding is reported this is not observed by the SIG. For example, a study might be mentioned in the media and observed by a PM without the study's funding source being mentioned. This issue is discussed further in the concluding remarks of this paper.

The PM consequently has two information sets at which it makes the policy decision; one in which it observes one study randomly drawn and one in which it observes one or two studies lobbied by the SIG. Let $\sigma(\widetilde{s}^i) = Pr(x_2|\widetilde{s}^i)$ denote the PM's strategy, in which $i \in \{L, NL\}$ denotes whether or not the observed $\widetilde{s}$ was lobbied (L) or not lobbied (NL). To further simplify, I assume the PM plays x_1 when indifferent between policy options.



Let $\widetilde{p}(\widetilde{s})$ denote the PM's updated beliefs about the probability of θ_2 given its observation of $\widetilde{s}$. A sequential equilibrium will then consist of strategies and beliefs $(\phi^*, \lambda^*, \sigma^*, \widetilde{p})$ that satisfy the following conditions:[7]

Rational belief updating:

$$\widetilde{p}(\widetilde{s}) = \frac{Pr(\widetilde{s}|\theta_2, \lambda^*, \phi^*)p}{Pr(\widetilde{s}|\lambda^*, \phi^*)} \quad \text{(Bayes' rule | SIG's strategy)},$$

$$\widetilde{p}(\widetilde{s}) = \frac{Pr(\widetilde{s}|\theta_2, \phi^*)p}{Pr(\widetilde{s}|\phi^*)} \quad \text{if } \lambda^*(\widetilde{s}) = 0; \tag{1}$$

PM maximization:

$$\sigma^*(\widetilde{s}) = 0(=1) \leftrightarrow \widetilde{p}(\widetilde{s}) > (\leq) 1/2; \tag{2}$$

SIG maximization:

$$\phi^*(s^1) = 1(=0) \leftrightarrow \Sigma_i[0.5(\sigma^*(s^{1,NL}) + \sigma^*(s_i^{NL}))\lambda^*(\emptyset|s^1, s_i) + \sum_{\widetilde{s}\neq\emptyset} \sigma^*(\widetilde{s}^L)\lambda^*(\widetilde{s}|s^1, s_i)] > (\leq)$$
$$\sigma^*(s^{1,L})\lambda^*(s^1|s^1) + \sigma^*(s^{1,NL})\lambda^*(\emptyset|s^1) \tag{3}$$

$$\lambda^*(\emptyset|\mathbf{s}) = 1 \leftrightarrow \frac{1}{|\bar{s}|}\Sigma_{s^{NL}\in\bar{s}}\ \sigma^*(s^{NL}) \geq \sigma^*(\widetilde{s}^L)\ \ \forall \widetilde{s}^L \neq \emptyset \in \mathcal{P}(\bar{s}), \forall s^{NL} \in \bar{s}$$

$$\lambda^*(\widetilde{s} \neq \emptyset|\bar{s}) > 0 \rightarrow \widetilde{s} \in \bar{s},\ \ \sigma^*(\widetilde{s}^L) \geq \sigma^*(\widetilde{s}^{\prime,L})\ \forall \widetilde{s}^{\prime} \in \bar{s},$$

$$\sum_{\widetilde{s}\in\mathcal{P}(\bar{s})} \lambda^*(\widetilde{s}|\bar{s}) = 1. \tag{4}$$

While the notation here gets somewhat unwieldy, the interpretation is straightforward. Condition 1 says the PM updates beliefs using Bayes' rule, given knowledge of how the SIG's strategy affects the probabilities. If the PM observes signals off the equilibrium path beliefs are updated conditioning on the funding strategy and assuming the signal is reported by those 'most likely' to deviate.[8] Condition 2 says the PM plays x_2 if its updated belief that $\theta = \theta_2$ is greater than 0.5 (this is the cut-off belief value because the PM's payoffs from matching the policy to the state are symmetric across states). I assume for simplicity and w.l.o.g. that the PM plays x_1 when its expected payoff from the two policy choices are equal. The third condition says the SIG funds only if funding possibly increases the chance of the PM playing the desired policy, given that the SIG makes the optimal lobbying decision after funding. Note that there are no mixed strategies due to the assumptions that neither the PM nor SIG randomizes when indifferent. The optimal lobbying strategy is given by condition 4; the SIG lobbies non-trivially ($\widetilde{s} \neq \emptyset|\bar{s}$) if and only if the chance of the PM playing the desired policy given lobbying is strictly greater than the expected payoff from not lobbying ($\frac{1}{|\bar{s}|}\Sigma_{s^{NL}\in\bar{s}}\ \sigma^*(s^{NL}) < \sigma^*(\widetilde{s}^L)$). This also reflects the assumption that the SIG does not randomize when indifferent between not lobbying and

[7]The L/NL superscripts are omitted when unnecessary.

[8]The term 'most likely' is used as by Potters and van Winden; it refers to those with the weakest disincentive to deviate from the equilibrium strategy.

lobbying.

3 Equilibria and Welfare

The interesting actions occur when $p \in (\frac{\pi_1^2}{\pi_1^2+\pi_2^2}, \frac{1-\pi_1}{2-\pi_1-\pi_2}]$.[9] It is useful to partition this range into sub-intervals, which I denote A, B, C and D, respectively corresponding to $(\frac{\pi_1^2}{\pi_1^2+\pi_2^2}, \frac{\pi_1(1+\omega/2(1-\pi_1))}{\pi_1(1+\omega/2(1-\pi_1))+\pi_2(1+\omega/2(1-\pi_2))}]$, $(\frac{\pi_1(1+\omega/2(1-\pi_1))}{\pi_1(1+\omega/2(1-\pi_1))+\pi_2(1+\omega/2(1-\pi_2))}, \frac{\pi_1(2-\omega(1+\pi_1))}{\pi_1(2-\omega(1+\pi_1))+\pi_2(2-\omega(1+\pi_2))}]$, $(\frac{\pi_1(2-\omega(1+\pi_1))}{\pi_1(2-\omega(1+\pi_1))+\pi_2(2-\omega(1+\pi_2))}, \frac{\pi_1(1-\pi_1)}{\pi_1(1-\pi_1)+\pi_2(1-\pi_2)}]$, and $(\frac{\pi_1(1-\pi_1)}{\pi_1(1-\pi_1)+\pi_2(1-\pi_2)}, \frac{1-\pi_1}{2-\pi_1-\pi_2}]$. The interpretation of the endpoints of these intervals will be discussed later in this section, but it can be easily shown that they monotonically increase given the assumption $\pi_2 > \pi_1$.

It is also useful to define the *baseline* as the case in which the SIG is unable to fund research. In the baseline the exogenous research is still produced and the PM always observes it,[10] and $\sigma^*(s_2) = 1 - \sigma^*(s_1) = 1$ if $p \in (\frac{\pi_1}{\pi_1+\pi_2}, \frac{1-\pi_1}{2-\pi_1-\pi_2}]$ and $\sigma^*(s) = 0\ \forall s$ if $p \leq \frac{\pi_1}{\pi_1+\pi_2}$.

3.1 Equilibria

The equilibria strategies are characterized in the following proposition.

Proposition 3.1. *There is a unique equilibrium in prior intervals A, C and D, and there are two equilibria in interval B ('Demanding' and 'Undemanding'):*

$p \in$	*SIG*	*PM*
A	$\phi^*(s_2) = 1 - \phi^*(s_1) = 1$; $\lambda^*(s_2, s_2 \vert \bar{s} = (s_2, s_2)) = \lambda^*(\emptyset \vert \bar{s} \neq (s_2, s_2)) = 1$	$\sigma^*(s_2, s_2) = 1 - \sigma^*(\tilde{s} \neq (s_2, s_2)) = 1$
B	*Demanding: Same as A*; *Undemanding:* $\phi^*(s_1) = 1 - \phi^*(s_2) = 1$; $\lambda^*(\emptyset \vert \bar{s}) = 1, \forall(\bar{s})$	*Demanding: Same as A*; *Undemanding:* $\sigma^*(s_2^{NL}) = 1; \sigma^*(s_2^L) = \sigma^*(s_1) = 0$
C	*Same as B-Undemanding*	*Same as B-Undemanding*
D	$\phi^*(s_1) = 1 - \phi^*(s_2) = 1$; $\lambda^*(s_2 \vert \bar{s} = (s_1, s_2)) = \lambda^*(\emptyset \vert \bar{s} \neq (s_1, s_2)) = 1$	$\sigma^*(s_2^L) = \sigma^*(s_2^{NL}) = 1; \sigma^*(s_1^{NL}) = 0$

Please see the appendix for a discussion of the proof. The SIG sometimes funds research in all equilibria. It obtains its desired policy by lobbying in A and D and by funding and not lobbying, or signal-jamming, in C. In B it does either, depending on the equilibrium.

[9] The most plausible equilibria for other parameter values are those in which the SIG never funds or lobbies.

[10] It does not matter whether or not the SIG can lobby in this case; either way the PM always observes s^1.

In interval A, p is sufficiently low that the SIG needs two s_2's to cause $\widetilde{p}$ to be greater than 0.5 (to convince the PM to play x_2, the SIG's desired policy). Thus the SIG funds when $s^1 = s_2$, since this is the only way it can obtain a second s_2. Since the PM never randomly observes two signals, the SIG must lobby and present the information directly to the PM to be sure the PM obtains the information. If the SIG does not lobby two s_2's then p is sufficiently low that $\widetilde{p}$ is less than 0.5, regardless of which signal is drawn. Consequently, if the SIG does not lobby (s_2, s_2) the PM plays x_1 $(\sigma^* = 0)$.

The same logic holds for the demanding equilibrium in B. In the undemanding equilibrium in B the SIG can obtain its desired policy with a single s_2 (hence the term 'undemanding')–but only if it's not lobbied. This is because in B p is sufficiently high such that in the baseline $\widetilde{p}(s_2) > 0.5$. If the PM randomly draws s_2, the chance that this was the exogenous study is sufficiently high that $\widetilde{p}$ is still greater than 0.5. Thus, if the exogenous research does result in s_2 and the SIG observes it, the SIG will not lobby since it is sure this study will be observed by the PM and cause it to play x_2. This gives the SIG an incentive to fund when $s^1 = s_1$, in hopes that the funded study will be s_2. If this occurs, the SIG can not lobby the single s_2, however, as the PM will suspect (correctly) that this was the funded study, and that the SIG is withholding the unfavorable exogenously funded s_1. Thus, the SIG is better off hoping the funded s_2 is randomly observed than reporting it and being certain it is observed. This is the signal-jamming action–the SIG's strategically funded research jams the exogenously funded signal the PM otherwise would have received.

In interval C the same logic holds for the strategies, but the undemanding equilibrium becomes the unique equilibrium. This is because the PM can no longer demand two s_2's credibly. p is sufficiently high, and the chance that the SIG observed s^1 sufficiently low, that if the SIG does not lobby two s_2's and the PM draws s_2^{NL} the PM is best off playing x_2. That is, suppose the PM is demanding and expects the SIG to fund when $s^1 = s_2$ and report (s_2, s_2). Then suppose the PM receives no report and randomly draws s_2^{NL}. In interval C now p is sufficiently high that $\widetilde{p}(s_2^{NL}) > 0.5$ regardless of the SIG's funding strategy because there is a chance that $\bar{s} = s_2^{NL}$, which would occur if the SIG did not observe s^1. This causes the PM to play $\sigma^*(s_2^{NL}) = 1$, which in turn causes the SIG to deviate to the undemanding equilibrium funding and lobbying strategies.

In D, p is sufficiently high that with full information $\widetilde{p}(s_1, s_2) > 0.5$. As a result, while the SIG's funding strategy does not change, its lobbying strategy does. It can now report a single s_2 and obtain its desired policy. Even though the PM knows the SIG is withholding s_1 this does not affect the PM's optimal response. The SIG prefers to lobby s_2 when $\bar{s} = (s_1, s_2)$ so that it does not rely on the 50-50 chance that the PM draws the s_2. If the PM draws s_1 it knows $\bar{s} \in \{s_1, (s_1, s_1)\}$ and plays x_1.

3.2 Welfare

There are a number of interesting conflicting dynamics occurring in these equilibria making the welfare effects of the SIG's strategic behavior, for both the PM and SIG, unclear. The SIG is often funding honest research, which we might reasonably expect to benefit the PM; however, the research is funded strategically and sometimes crowds out exogenously funded research, which could harm PM welfare. Moreover, since research funding is free it presumably benefits the SIG, but this may not be the case if suspicion causes the PM to demand more evidence supporting the SIG's desired policy.

To analyze the welfare effects of funding formally they are defined for the PM and SIG, $\Delta W_i, i \in \{PM, SIG\}$, as the difference between expected welfare with the SIG being able to fund a second study ('fund') and the baseline ('nofund'). Note that outcomes are still stochastic in the 'nofund' case, as they depend on the exogenous research result.

$$\begin{aligned}
\Delta W_{PM} &= E(W_{PM}|\text{fund}) - E(W_{PM}|\text{nofund}) \\
&= Pr(x_1|\theta_1, \text{fund})Pr(\theta_1) + Pr(x_2|\theta_2, \text{fund})Pr(\theta_2) \\
&\quad -[Pr(x_1|\theta_1, \text{nofund})Pr(\theta_1) + Pr(x_2|\theta_2, \text{nofund})Pr(\theta_2)], \\
&= [Pr(x_1|\theta_1, \text{fund}) - Pr(x_1|\theta_1, \text{nofund})](1-p) \\
&\quad +[Pr(x_2|\theta_2, \text{fund}) - Pr(x_2|\theta_2, \text{nofund})]p; \qquad (5)
\end{aligned}$$

$$\begin{aligned}
\Delta W_{SIG} &= [Pr(x_2|\theta_1, \text{fund}) - Pr(x_2|\theta_1, \text{nofund})](1-p) \\
&\quad +[Pr(x_2|\theta_2, \text{fund}) - Pr(x_2|\theta_2, \text{nofund})]p. \qquad (6)
\end{aligned}$$

The signs of these welfare effects are more interesting than the algebraic expressions, and can be determined unambiguously for each equilibrium. They are given in the following proposition.

Proposition 3.2. *The signs of the welfare effects of strategic funding and reporting are:*

$p \in$		ΔW_{SIG}, ΔW_{PM}
A	$p \leq \frac{\pi_1}{\pi_1+\pi_2}$	+, +
	Otherwise	-,+
B	*Demanding:*	-,+
	Undemanding:	+,-
C		+,-
D		+,+

For both the PM and SIG there exist equilibria in which welfare is improved and worsened by strategic funding. There are also equilibria in which both parties benefit from funding, but there are no equilibria in which both parties are worse off.

When p is in the lower part of A and all of D (p is either very low or high) funding benefits both the PM and SIG. In these intervals the parties' incentives are aligned; they both benefit from additional information in the same situations. In fact, because of this the SIG has nothing to hide and the PM always makes the full information decision in these intervals. And because the amount of information the PM obtains increases since the SIG sometimes funds research, the PM is better off. The SIG is also better off in spite of, what, for practical purposes is full information, because the SIG is able to strategically determine when to produce new information. The SIG does this, of course, when the optimal policy given s^1 alone is x_1 and a funded s_2 is capable of changing the policy to x_2. This means that SIG-funding, while socially beneficial, only changes the policy in one direction in these intervals. It is also worth noting that while funding benefits the PM stochastically (in expectation) in these intervals, funding benefits the SIG deterministically. That is, while it is possible in these intervals for the PM to play the correct policy without funding but the incorrect policy with funding, there are no cases here in which the SIG obtained its desired policy without but not with funding.

When p is in B, C or the upper part of A, there is more of a tension between the players. The full information decision is not necessarily made in any of the equilibria in these intervals. In A and the demanding equilibrium of B, the SIG is made worse off due to this tension. In the baseline in these intervals $\sigma^*(s_2) = 1$. With strategic funding, the PM is suspicious of a single s_2. It forces the SIG to produce a second s_2 to obtain its desired policy. This result is very similar to Henry's finding that more research is funded when the quantity of research is not observed by the decision-maker; what he calls 'the cost of proving your honesty.' In his model the decision maker obtains more information due to strategic disclosure and always makes the full information decision. In the model of this paper, even in these demanding equilibria the PM sometimes does not make the full information decision. This occurs when the PM randomly draws $s^1 = s_2$ that was not observed by the SIG–the PM is suspicious and plays x_1, while with full information it would have played x_2.

When p is in C or $B - Undemanding$, the SIG is better off and the PM is worse off due to funding. In both of these cases the SIG never lobbies, but simply funds strategically and hopes that the funded study will be s_2 and drawn by the PM. In spite–or actually because–of this passive aggressive behavior the PM is sometimes fooled and the SIG is able to obtain its desired policy more often than without strategic funding.

In these cases, the SIG never funds when $s^1 = s_2$. The PM consequently always observes an exogenously funded s_2. Given the SIG's funding and lobbying strategy, $\widetilde{p}(s_2) > 0.5$, thus the PM plays x_2. Since the SIG takes advantage of this and funds when $s^1 = s_1$, clearly the SIG obtains its desired policy (deterministically) more frequently than without funding. The PM, on the other hand, gains no useful information from the funding. The SIG only funds in cases in which, with full information, funding is of no practical value. (The SIG funds when $s^1 = s_1$ and with full information both $\widetilde{p}(s_1, s_1)$ and $\widetilde{p}(s_1, s_2)$ are less than 0.5.)

One might ask, why does the PM not simply fund its own research when p is in these intervals, and ignore the potentially jammed signal. The answer is that the PM could of course do this–but it would still be made worse off as a result of SIG-funding. Without SIG funding the PM observed free exogenous research; with SIG-funding the PM would be incurring the cost of funding its own research. Although this cost is assumed away in the basic model above, it is still fair to say that incurring it, without gaining any information, would make the PM worse off. And even if the PM funded its own research it would still benefit from drawing from the pool of research; although the distribution of this research is changed by strategic funding, it is still useful information.

To sum, when p is somewhat high or low the players' incentives are aligned and no information is hidden in equilibrium. When p is moderate information can be hidden due to either suspicion or signal-jamming (and *not* due to strategic disclosure). When information is hidden the welfare effects of funding for the PM and SIG take opposite signs.

3.3 Commitment

Thus far it has been assumed that the PM and SIG are unable to communicate or credibly commit to any actions prior to the start of the game. It is interesting to explore the ramifications of varying this assumption for both of the players.

For the PM, suppose it can commit to playing a particular σ^* prior to the SIG's potential observation of s^1. For the SIG, suppose it can commit to playing a particular (ϕ^*, λ^*) and/or reporting s^1 when it wishes. Further, suppose when the SIG reports s^1 the SIG can lobby for the PM to fund additional research and the PM does so when this research is of informational value (i.e. when the research results potentially change the optimal policy). The term 'lobby' in this context refers to the SIG requesting that the PM take an action rather than the SIG just reporting information. The sophisticated PM might be willing to fund when asked to when it is in fact made better off by this research. I henceforth refer to this as 'bargaining lobbying' to distinguish it from informational lobbying, since the SIG is in effect bargaining to minimize its share of the cost of funding additional research.

Optimal commitment is then characterized in the following proposition.

Proposition 3.3. *1. The PM commits to* $\sigma^*(s_2, s_2) = 1 - \sigma^*(\widetilde{s} \neq (s_2, s_2)) = 1$ *if* $p \in (\frac{\pi_1^2}{\pi_1^2+\pi_2^2}, \frac{\pi_1(1+\omega/2(1-3\pi_1))}{\pi_1(1+\omega/2(1-3\pi_1))+\pi_2(1+\omega/2(1-3\pi_2))}]$. *This interval comprises A, B and part of C. (Assuming the SIG cannot commit.)*

2. The SIG commits to reporting $s^1 = s_2$ *with bargaining lobbying if* $p \in A$; *to the funding/lobby strategy* $\phi^*(s_1) = 1 - \phi^*(s_2) = 1; \lambda^*(\emptyset|\bar{s}) = 1, \forall(\bar{s})$ *without bargaining lobbying if* $p \in B$; *and the* *funding/lobbying strategy* $\phi^*(s) = 0, \lambda^*(\emptyset|\bar{s}) = 1, \forall(\bar{s})$ *with bargaining lobbying when* $s^1 = s_1$ *if* $p \in D$. *(Assuming the PM cannot commit.)*

3. The only equilibrium that exists independent of commitment is the signal-jamming equilibrium when $p \in (\frac{\pi_1(1+\omega/2(1-3\pi_1))}{\pi_1(1+\omega/2(1-3\pi_1))+\pi_2(1+\omega/2(1-3\pi_2))}, \frac{\pi_1(1-\pi_1)}{\pi_1(1-\pi_1)+\pi_2(1-\pi_2)}] \equiv C' \subset C$, *in which* $\Delta W_{SIG} > 0$ *and* $\Delta W_{PM} < 0$.

The proposition implies that the PM and SIG will commit to, respectively, the demanding and undemanding strategies when p is in B. This is not surprising given the welfare results discussed above. It is more interesting that the PM would be better off committing to a strategy different from the one it plays in equilibrium when p is in $(\frac{\pi_1(2-\omega(1+\pi_1))}{\pi_1(2-\omega(1+\pi_1))+\pi_2(2-\omega(1+\pi_2))}, \frac{\pi_1(1+\omega/2(1-3\pi_1))}{\pi_1(1+\omega/2(1-3\pi_1))+\pi_2(1+\omega/2(1-3\pi_2))}] \subset C$. The PM benefits from committing to preventing itself from playing x_2 if it randomly draws an s_2 in this sub-interval, since this forces the SIG to continue to play the demanding funding and lobbying strategies. It is also worth noting that when the SIG can commit and engage in bargaining lobbying, the SIG only funds research when funding is socially harmful ($p \in C$).

Perhaps most importantly, part 3 of the proposition states that regardless of the ability of the PM and/or the SIG to commit, the players will be in the signal-jamming equilibrium when p is in C'. In this sub-interval p and the chance that the SIG does not observe s^1 $(1-\omega)$ are sufficiently high that the PM will not commit to the demanding strategy. p is sufficiently low, though, that if the SIG reported $s^1 = s_1$ the PM would not be willing to fund a second study. As a result, the unique equilibrium is one in which the PM randomly observes research, and the SIG funds a second study when it observes $s^1 = s_1$, which makes the SIG better off and the PM worse off than they are in the baseline. Within this model commitment can not be used as a device to eliminate socially harmful signal-jamming equilibria.

3.4 Funding and Lobbying Comparative Statics

The comparative statics of the funding and lobbying likelihoods, ex ante to the realization of s^1, are straightforward. For simplicity, I focus here on the no commitment case in which the players are in the demanding equilibrium in prior interval B. Let ϕ^*_{p,π_1,π_2} denote the ex ante probability the SIG funds a second study, and $\lambda^*_{p,\pi_1,\pi_2}$ denote the same for lobbying. I also henceforth make the additional assumption that $\pi_2 > 0.5 > \pi_1$. This is a very weak and reasonable assumption; it simply means that the probabilities of the true negative and true positive signals are both greater than one half.

Proposition 3.4. *1. a)* ϕ^*_{p,π_1,π_2} *is increasing in all of its arguments if* $p \in A \cup B$. *Otherwise,* ϕ^*_{p,π_1,π_2} *is decreasing in all of its arguments. b)* $\underset{p}{\text{argmax}}\ \phi^*_{p,\pi_1,\pi_2}$ *is equal, or arbitrarily close, to* $\frac{\pi_1(2-\omega(1+\pi_1))}{\pi_1(2-\omega(1+\pi_1))+\pi_2(2-\omega(1+\pi_2))}$, *the boundary between* B *and* C.

2. a) $\lambda^*_{p,\pi_1,\pi_2}$ *is increasing in all of its arguments if* $p \in A \cup B$. $\lambda^*_{p,\pi_1,\pi_2} = 0\ \forall p, \pi_1, \pi_2$ *if* $p \in$

C and $\lambda^*_{p,\pi_1,\pi_2}$ *is increasing in* π_1*, decreasing in* π_2 *and ambiguously affected by* p *if* $p \in D$. *b)* $\underset{p}{argmax}\ \lambda^*_{p,\pi_1,\pi_2} \in \{\frac{\pi_1(2-\omega(1+\pi_1))}{\pi_1(2-\omega(1+\pi_1))+\pi_2(2-\omega(1+\pi_2))} \cup D\}$.

The proofs for all of these claims are trivial. The point of these statements is to formalize a few of the model's predictions. One is that research funding is most likely, and lobbying least likely, when beliefs are moderately pessimistic from the perspective of the SIG. Research funding is most likely when p is on or near the boundary of B and C, and lobbying is least likely when $p \in C$. And two, research funding and lobbying expenditures may be negatively correlated in a sample over which beliefs change substantially. For example, if p shifted down from D to C over a time frame the model predicts that funding would be lower when lobbying is higher and vice versa.

Figure 1 depicts these theoretical predictions graphically, and shows how the probabilities are similar in the cases in which commitment is allowed. In all three cases (no commitment, PM commitment and SIG commitment), while lobbying and funding probabilities may move in the same direction *within* prior intervals, they move in starkly different directions *across* intervals. This contrast is especially strong in the SIG-commitment case, in which the SIG either funds or lobbies in a particular interval, but never does both. Moreover, in all three panels funding probabilities are at their highest when p is in C, the interval for which lobbying does not occur and p is moderately low.

Theoretically, if we had data on PM beliefs, exogenous research results and SIG research funding, we could test some of these implications in a more precise manner. Since the modeled situation is admittedly idealized, particularly in its assumption of a savvy PM, it is not clear whether these results are empirically testable propositions. In addition, acquiring data across issues and over time on research funding and lobbying activity may not be feasible.

Still, the first prediction is at least consistent with the Union of Concerned Scientists' claim that ExxonMobil primarily used PR to influence climate change policy during a period in which policymaker beliefs about the existence of costly anthropogenic climate change were, generally speaking, moderately strong (U.C.S. (2007)) (i.e. p was 30-50%). And in Figure 2 I attempt to provide some evidence consistent with the second prediction. These data are suggestive at best, since they are quite crude and the research funding data were actually collected by a SIG on the opposite side of the issue. But research funding and lobbying show signs of being substitutes in the graph. From 2002-2005 research funding rose substantially, while lobbying declined somewhat, and in 2006 both series moved sharply in opposite directions. Their correlation over the period is -43.3%, but this number is largely driven by the 2006 data.

The theory in the model above predicts that SIG-funded research responds to new research that opposes the SIG's desired policy, and that SIG-funding does not occur for priors below some threshold (and above another). Perhaps the increase in funding in the early 00s was due to a new research development at the time causing p to decrease: "In January 2000, the National Academy of Sciences skewered [the climate change skeptics']) strongest argument. Contrary to the claim that satellites finding no warming are right and ground stations showing warming are wrong, it turns out that the satellites are off" (*Newsweek*, August 13, 2007). The increase in lobbying in 2006 may have been due to a further decrease in p that occurred around that time due to the dissemination of research indicating evidence of global warming, e.g. through the film *An Inconvenient Truth*. p might then have decreased to the point at which signal-jamming was less effective, and the SIG changed strategies to focus on lobbying (either informational or bargaining).

[Figure 1]

[Figure 2]

3.5 Welfare Comparative Statics

In this section I examine welfare effects for specific values of ω and the π's. I concentrate on prior interval C', the only interval in which the equilibrium strategies are the same independent of commitment. I do not make any assumptions on where p comes from–I assume it is a random variable, whose distribution is unknown.

Before solving for some interesting parameter values, I state the following lemma.

Lemma 3.5. *If $\omega < 2/5$, then $E_p(\Delta W_{PM}|p \in C')$ is weakly decreasing in π_2 independent of the distribution of p and π_1.*

Proof. The expression for the expected PM welfare effect at a particular p is $0.5\omega[(\pi_2(1-\pi_2)+\pi_1(1-\pi_1))p-\pi_1(1-\pi_1)]$. This expression averaged over priors is $E_p(\Delta W_{PM}|p \in C') =$ $0.5\omega \int_{\frac{\pi_1(1+\omega/2(1-3\pi_1))}{\pi_1(1+\omega/2(1-3\pi_1))+\pi_2(1+\omega/2(1-3\pi_2))}}^{\frac{\pi_1(1-\pi_1)}{\pi_1(1-\pi_1)+\pi_2(1-\pi_2)}} \{[\pi_2(1-\pi_2)+\pi_1(1-\pi_1)]p-\pi_1(1-\pi_1)\}f(p)dp$. The proof follows from applying Leibniz's rule (differentiating with respect to π_2), given the assumption that $\pi_2 > 0.5$. □

This result is somewhat counterintuitive. It says that as the informativeness of the signal in state θ_2 improves the social impact of SIG-funding worsens. One would be right to associate higher π_2 with higher social welfare. But this is exactly why SIG-funding harms welfare more for high π_2–there is more to lose. The informativeness of the signal is dampened due to funding, and the dampening is greatest when the signal is originally most informative. The dampening also occurs more often when π_2 is high because in this case the PM will play x_2 given s_2, and *not* play x_2 given s_1, for a wider range of priors. Thus the interval of priors for which the SIG can change policy by funding is extended as π_2 increases. This lemma is useful in understanding the following proposition.

Proposition 3.6. *1) $E_p(\Delta W_{PM}|p \in C')$ is maximized at $\pi_1 = 0$ (for all $f(p)$, π_2 and ω) or $\omega = 1$ (for all $f(p)$, π_2 and π_1).*

2) If the distribution of p is uniform, $E_p(\Delta W_{PM}|p \in C')$ is minimized at $\omega = 0.55, \pi_1 = 0.28, \pi_2 = 1$.

Proof. To prove the first part, recall that the PM welfare effect of funding is always (weakly) negative for the prior interval C'. Since these intervals disappear when $\pi_1 = 0$ or $\omega = 1$, the welfare effect of funding is then at its maximum of zero, for all π_2 and $f(p)$.

That welfare is minimized when $\pi_2 = 1$ is not surprising, given Lemma 3.5. The expression for the welfare effect of funding averaged over p given in the proof of Lemma 3.5 is minimized using standard optimization methods. □

The intuition for the first part of this result is that when $\pi_1 = 0$, s_2 identifies the state as θ_2 precisely and consequently SIG funding–which can only change the policy from x_1 to x_2–can never be harmful. Consequently, it is not only C' that disappears, but also the rest of C and all of A and B. When $\omega = 1$ the demanding equilibrium always exists (so prior interval B essentially subsumes C), since the PM always knows the SIG observes s^1. Thus there continue to exist equilibria in which funding is socially harmful ($B - Undemanding$) but they are not unique.

Welfare is minimized for the intermediate value of $\pi_1 = 0.28$ because while for a given p welfare decreases as π_1 increases, the length of the interval of priors at which funding harms welfare also decreases in π_1 (for large π_1). There are competing effects on social welfare from increasing π_1. These effects are intuitive: as π_1 increases the SIG is more likely to get the misleading signal it wants, but the less likely the sophisticated PM is to heed this signal. The same type of intuition is true for ω; as it increases the likelihood of signal-jamming increases, but the interval at which the PM is unable to be demanding decreases.

The parameter values that maximize and minimize the PM's expected welfare effects over the entire range of priors are similar.[11]

Proposition 3.7. *If $f(p)$ is uniform,*

1) $E_p(\Delta W_{PM})$ is maximized at $\omega = 1, \pi_1 = 0, \pi_2 = 2/3$.

2) $E_p(\Delta W_{PM})$ is minimized at $\omega = 0.55, \pi_1 = 0.12, \pi_2 = 1$.

Again, when $\pi_1 = 0$ intervals A, B, and C are eliminated. The welfare benefit is maximized in D when the SIG always observes s^1 and has the chance to 'correct' s^1 sufficiently often, so π_2 can be neither too high or too low. The welfare effect is again minimized when $\pi_2 = 1$ and $\omega = 0.55$, but now at a substantially lower π_1. As can be seen in Figure 3, which depicts the PM welfare effects for all priors for various signal probabilities, if π_1 is too high the welfare benefits of high π_2 in intervals A and B outweigh the costs in C. The effects are linear and monotonically increasing in prior intervals A, C and D, and decreasing in B. The slope always increases when p moves from C to D.

[11] I continue assume that the players are in the demanding equilibrium in B for simplicity.

We conclude that SIG funding is most innocuous when there are very few false negatives (s_2's in state θ_1). SIG funding is most harmful when there are some false negatives and very few false positives (s_1's in state θ_2). Relating these qualities back to the motivating example, SIG funding would be innocuous if, given climate change is 'true' there is no research showing otherwise. The funding would be most harmful if research indicating evidence of climate change, given climate change is 'true', was noisy, and research indicating no climate change, given true no climate change, was precise.

[Figure 3]

4 Multiple Funded Studies

Results are qualitatively similar, though not quite the same, when we allow the SIG to fund more than one study. It is especially interesting to explore a benchmark in which the SIG has the ability to costlessly fund as many studies as it wishes. Modifying the notation to allow for this, let $\phi^*(N|s^1)$ now denote the probability of funding N studies given the SIG has observed s^1. Continue to assume that after funding the SIG decides which studies to report, and if the SIG reports nothing the PM takes a random draw. The following proposition characterizes equilibria and welfare effects for this case.

Proposition 4.1. *If the SIG can costlessly fund N studies after observing s^1 and $\pi_1 > 0$, then the unique equilibria strategies and welfare effects of funding are:*

	$p \in$	*Equ. Strategies*	ΔW_{SIG}	ΔW_{PM}
A	*If* $p \leq \frac{\pi_1}{\pi_1+\pi_2}$	$\phi^*(N=0\|s^1)=1; \lambda^*(\emptyset\|s^1)=1;$	*0*	*0*
		$\sigma^*(\tilde{s})=0, \forall s^1, \tilde{s}$		
	Otherwise	*None*	*?*	*?*
B		""	""	""
C	*If* $p \leq \frac{\pi_1(1+\omega(1-\pi_1))}{\pi_1(1+\omega(1-\pi_1))+\pi_2(1+\omega(1-\pi_2))}$	""	""	""
	Otherwise	$\phi^*(N\to\infty\|s_1)=\phi^*(N=0\|s_2)=1;$	+	-
		$\lambda^*(\emptyset\|\bar{s})=1, \forall \bar{s};$		
		$\sigma^*(s_2^{NL})=1, \sigma^*(s_1^{NL})=\sigma^*(\tilde{s}^L)=0, \forall \tilde{s}^L$		
D		""	+	+

("" denotes same as preceding prior interval.)

Proof. First, clearly the SIG will not be able to lobby effectively (with any number of s_2 results) given its ability to fund an unbounded quantity of research and the assumption that $\pi_1 > 0$. If the SIG could do so, it would always fund an infinite number of studies and obtain the requisite number of s_2's (independent of the true state) to obtain its desired policy. Since the SIG's lobbying here is completely uninformative it will never change the PM's policy choice, and thus the lobbying is unnecessary for the SIG obtaining its desired policy. (And by assumption the SIG never lobbies when unnecessary.)

Thus, $\lambda^*(\emptyset|\bar{s}) = 1 \; \forall \bar{s}$.

The question then is what occurs given this lack of lobbying. Suppose $\sigma^*(s_2^{NL}) = 1$ and the SIG observes s^1. If $s^1 = s_2$ the SIG optimally does nothing. If $s^1 = s_1$ the SIG's expected benefit from funding N studies, knowing that it will not lobby regardless of the results, is the probability a funded study is drawn by the PM ($N/(N+1)$) times the probability a funded study is s_2. This product is strictly increasing in N, which is why $\phi^*(N \to \infty|s_1) = 1$ given the PM's strategy.

The PM will play $\sigma^*(s_2^{NL}) = 1$ when $\widetilde{p}(s_2^{NL}|\phi^*, \lambda^*) > 0.5$. This posterior belief, given the SIG funds N studies when $s^1 = s_1$ is $\frac{\pi_2+(1-\pi_2)\omega\frac{N}{N+1}\pi_2)p}{\pi_2+(1-\pi_2)\omega\frac{N}{N+1}\pi_2)p+\pi_1+(1-\pi_1)\omega\frac{N}{N+1}\pi_1)(1-p)}$. As $N \to \infty$, this expression is greater than 0.5 when $\frac{\pi_1(1+\omega(1-\pi_1))}{\pi_1(1+\omega(1-\pi_1))+\pi_2(1+\omega(1-\pi_2))} < p$. The lower bound here is strictly less than the upper bound of C.

There is no equilibrium in B and parts of A and C because in those intervals if the SIG never funded then $\widetilde{p}(s_2^{NL})$ would be greater than 0.5. But when the SIG funds $\widetilde{p}$ becomes less than 0.5. Given the assumption that the SIG does not randomize, there is simply no equilibrium here.[12]

The calculations of the welfare effects are straightforward given the funding strategies.

□

This result shows that it is possible for the SIG to fund research effectively even when the PM knows the SIG is not constrained by cost. However, the SIG can only signal-jam in this case. In fact, SIG-funded research will completely 'drown out' the exogenous research, when the exogenous research opposes the SIG's interest and p is sufficiently high. It should also be noted that, in equilibrium, whenever the SIG funds it deterministically benefits from being able to fund research, while the PM may be made either worse or better off by funding in expectation depending on whether p is in C or D. The SIG benefits without uncertainty because its funding can only change the policy in its desired direction.

It is more realistic to suppose that the SIG funds some finite number of studies, say $N^* \geq 1$.[13] The SIG may be able to fund more than one study while maintaining the costless research production assumption if we simply assume the existence of a capacity constraint for newly produced research. Another explanation for the SIG funding N^* studies would be that funding each study has a positive cost c and N^* is the equilibrium number of studies funded given this cost. In equilibrium, if the PM knows c the PM will be able to compute the SIG's optimal number of studies to fund given the other parameters of the game, which is equivalent to the PM knowing the capacity constraint N^* faced by the SIG with costless funding. Moreover, there exists a $c > 0$ that rationalizes any N^* (given the other parameters).

[12]Alternatively we could assume that funding has a cost $c > 0$ and solve for a mixed strategy equilibrium.

[13]I continue to assume that the SIG does not fund research if it does not observe s^1. This assumption is made primarily for simplicity, but can be justified by assuming the SIG does not know when it has *not* observed s^1 with sufficient time to fund research prior to the PM's observation of research.

I conjecture, though I have not proven, that for each N^* and $\omega \in (0,1)$ there exists p, π_1 and π_2 such that $\Delta W_{PM} < 0$ and $\Delta W_{SIG} > 0$. The intuition is that for each N^*, as shown above there exists p such that $\widetilde{p}(s_2^{NL}) > 0.5$, assuming the SIG continues to play $\phi^*(0|s_2) = 1$. While we know there are welfare losses associated with the SIG causing s_2 to be drawn by funding when $s^1 = s_1$ for some priors, there will also be gains now as the SIG will be able to lobby effectively sometimes, which is why the proof is not straightforward. If $N^* > 1$ the SIG may now lobby more than one s_2 and even though this will allow the PM to infer $s^1 = s_1$ the SIG may still obtain its desired policy. For example, if $N^* = 2$ the SIG may lobby two s_2's and obtain x_2, but also not lobby when it obtains only one funded s_2. Further, I believe there is a $c > 0$ for each N^*, p, π_1 and π_2 such that $\Delta W_{PM} < 0$ and $\Delta W_{SIG} > 0$ that rationalizes the N^*.

This can be shown to be true fairly easily for the case of $N^* = 2$. Suppose $p = 0.125$, $\omega = 0.5$, $\pi_2 = 0.9$ and $\pi_1 = 0.1$. Then $\widetilde{p}(s_2, s_2, s_1) > 0.5$, thus the SIG will lobby if both funded studies are s_2 even though the PM will infer $s^1 = s_1$. But, since $\widetilde{p}(s_2^{NL}) > 0.5$ and $\widetilde{p}(s_2, s_1, s_1) < 0.5$ the SIG will not lobby if only one funded study is s_2, because then the PM will know $\bar{s} = (s_2, s_1, s_1)$. Moreover, $\Delta W_{PM} < 0$ and $\Delta W_{SIG} > 0$ and there exist $c > 0$ that rationalizes $N^* = 2$ given the other parameters.

To see why $N^* = 2$ with a constant marginal cost of funding, we simply need to show that the marginal benefit of funding a third study is less than c and the marginal benefit of funding the second study is greater than c, for some c, i.e. that the marginal benefit of the third study is less than the second. To analyze these marginal benefits it is useful to define $\widetilde{\pi}_1$ as the probability that a funded study is s_2, given $s^1 = s_1$: $\widetilde{\pi}_1 = \pi_2 \widetilde{p}(s_1) + \pi_1(1 - \widetilde{p}(s_1))$. Then the marginal benefit of a third funded study (given the PM's strategy) is $[\widetilde{\pi}_1^3 + 3\widetilde{\pi}_1^2(1 - \widetilde{\pi}_1) + 1/4(3\widetilde{\pi}_1(1 - \widetilde{\pi}_1)^2)] - [\widetilde{\pi}_1^2 + 1/3(2\widetilde{\pi}_1(1 - \widetilde{\pi}_1))] = -5/4\widetilde{\pi}_1^3 + 7/6\widetilde{\pi}_1^2 + 1/12\widetilde{\pi}_1$. The marginal benefit of a second funded study is $[\widetilde{\pi}_1^2 + 1/3(2\widetilde{\pi}_1(1 - \widetilde{\pi}_1))] - [1/2\widetilde{\pi}_1] = \widetilde{\pi}_1^2/3 + \widetilde{\pi}_1/6$. $N^* = 2$ is thus rationalized iff

$$\begin{aligned} \widetilde{\pi}_1^2/3 + \widetilde{\pi}_1/6 &> -5/4\widetilde{\pi}_1^3 + 7/6\widetilde{\pi}_1^2 + 1/12\widetilde{\pi}_1 \\ 5/2\widetilde{\pi}_1^2 - 5/3\widetilde{\pi}_1 + 1/6 &> 0, \end{aligned} \tag{7}$$

which is true for the parameter values above.

5 Competing SIGs

It is natural to ask how the above results might change if we introduce a SIG with a competing interest. Many policy issues involve competing interest groups, although their capabilities of observing, funding and disclosing research may not be symmetric. For the example of climate change, clearly there are environmental groups supporting regulatory policies that energy firms oppose. The environmental SIGs likely support this regulation at least to some extent independent of the true state of the world. The focus of this paper thus far has been on situations involving a single interested party since, as discussed in the introduction, in previous literature it has been found that competition is unnecessary for decision makers to benefit from information search and strategic disclosure. Since we have found that this is not always true when the SIG can signal-jam, the question is under what conditions will the existence of a competing SIG ensure non-negative welfare effects of funding. The standard result is that competition improves information transmission and reduces the need for decision maker sophistication to achieve full revelation (Milgrom and Roberts (1986)). It would be interesting to see if there continue to exist equilibria in which the SIGs' actions make a strategically sophisticated PM worse off in the signal-jamming model in spite of competition.

To examine this question, I return to the original single-funded study model and introduce a second SIG with an opposing interest, which I refer to as G (for Greenpeace). Let X (for EXxon) denote the original SIG.[14] G prefers that x_1 be played independent of θ, and suppose for simplicity its payoffs and costs are completely symmetric to X's. However, I allow the SIGs to have different abilities to observe s^1 (ω_X and ω_G). I assume for simplicity that the SIGs can lobby s^1 if they observe it and/or their funded study (if they fund), but they cannot lobby the other SIG's funded study. I also continue to assume for simplicity that if the SIGs do not observe s^1 (sufficiently early) they do not fund.

I find that if either SIG has a sufficiently superior ability to observe s^1, then there exists a range of priors for which the unique equilibrium is socially harmful. If the ω's are not too far apart then the SIGs 'watchdog' each other and even when one SIG attempts to fund and signal-jam, in equilibrium the PM is made better off by funding.

Proposition 5.1. *If* $\omega_G < \frac{3}{4\pi_2+3}$ *and* $p \in (\max\{\frac{\pi_1^2(1-\pi_1)}{\pi_1^2(1-\pi_1)+\pi_2^2(1-\pi_2)}, \frac{\pi_1(2-\omega_X(1+\pi_1))}{\pi_1(2-\omega_X(1+\pi_1))+\pi_2(2-\omega_X(1+\pi_2))}\}, \frac{\pi_1(1-\pi_1)}{\pi_1(1-\pi_1)+\pi_2(1-\pi_2)}]$ *then:*

1. *The unique equilibrium is* $\{(\phi_X^*(s_1) = 1 - \phi_X^*(s_2) = 1; \phi_G^*(s_2) = 1 - \phi_G^*(s_1) = 1), (\lambda_X^*(\emptyset|\bar{s}) = 1, \forall \bar{s}; \lambda_G^*(s_1|s_1 \in \bar{s}) = 1, \lambda_G^*(\emptyset|s_1 \notin \bar{s}) = 1, \forall \bar{s}), (\sigma^*(s_2^N L) = 1, \sigma^*(\widetilde{s}) = 0, \forall \widetilde{s} \neq s_2^{NL})\}$.
2. *If* $\frac{2\omega_G}{1-\omega_G} < \omega_X$*, then* $\Delta W_{PM} < 0$*. Otherwise* $\Delta W_{PM} \geq 0$.

Please see the appendix for the proof. The proposition says that if G's ability to observe s^1 is sufficiently small there exists an equilibrium in which X plays the exact same strategies as it played without competition. G reports research that opposes X's interest whenever it can, and even funds in attempt to obtain an s_1 when it observes $s^1 = s_2$. G does not fund when it observes $s^1 = s_1$ since it can obtain its desired policy by reporting a single s_1. Still, if X's ability to observe s^1 is sufficiently high relative to G's the PM is worse off in these equilibria than it would be if neither SIG could fund

[14] X and G are used rather than 1 and 2 to distinguish the SIGs because G is the new (second) SIG but prefers the first policy, hence indexing the SIGs numerically could be confusing.

or lobby. Of course, there are analogous equilibria in which G signal-jams and X watchdogs for higher p. Figure 4 graphically depicts the regions in ω_X-ω_G space for which SIG-funding is socially harmful and beneficial in these equilibria.

[Figure 4]

Perhaps it is not surprising that $\Delta W_{PM} < 0$ when ω_G is sufficiently low, since we know this is true when $\omega_G = 0$. What is interesting is that the range of priors for which there is a unique, socially harmful signal-jamming equilibria (if $\omega_G < \frac{3}{4\pi_2+3}$) is very similar to the range with the same type of equilibrium in the no competition case. This is because when p is in this range and the PM is demanding (requires two s_2's to play x_2) G has no incentive to fund. Thus, it is as if G were not even there and we know that the demanding strategies are not equilibria for p in this interval (which is a subset of C). Consequently, $\sigma^*(s_2^{NL}) = 1$ and clearly X will continue to fund and not lobby when it observes $s^1 = s_1$. The main question is when does X fund when it observes $s^1 = s_2$. It will fund in this case if it worries that G will do the same and report s_1 if it is obtained. A sufficient condition for X not to fund in this case is $\omega_G < \frac{3}{4\pi_2+3}$ (and a sufficient condition for this to hold is $\omega_G < 3/7$). X does not fund in this case not because of a direct cost of funding, but because of the chance its funded study will result in s_1 and this makes the PM less likely to draw s_2, given that G has either not funded or funded and obtained s_2.

Thus, even when the PM maintains full strategic sophistication and adding a competing SIG strategic research funding may worsen social welfare. The introduction of the competing SIG does not change the equilibrium strategies of the original SIG for many parameter values and again there is an association between funding and a lack of lobbying and negative social welfare effects of funding.

6 Concluding Remarks

This paper has demonstrated the existence of equilibria in which SIGs fund unbiased research in the presence of a strategically sophisticated policy maker. Social welfare can be improved by strategic funding, but it is worsened when the SIG funds research and strategically avoids lobbying and reporting the results. The results are in contrast to those typically found in simple persuasion games in which information search and strategic disclosure by an interested party are beneficial to the PM. The main results are robust to varying some of the key assumptions, including a lack of competing SIGs. The model predicts that research funding and lobbying are to some extent substitutable strategies for an interest group. The empirical relationship between funding and lobbying expenditures warrants further study.

Although the basic model is an extreme simplification of the real world, one can be fairly comfortable asserting the primary policy implication: that there should be mandatory disclosure of the sources of research funding. If the PM knew whether a randomly observed study was SIG or exogenously funded this would cause SIG-funding to be socially beneficial in all equilibria in the model of this paper. While full transparency of funding sources seems to be a very reasonable policy prescription for academic research, it does not appear to yet be implemented consistently across universities or journals (Elliott (2008)).

The value of transparency relates to another practical implication of the model regarding how to interpret SIG-funded research. In the media and policy discussions there is often debate on this issue; it is unknown to what (if any) extent SIG-funding should discredit the content of the research. The model of this paper says that even if SIG-funding does not affect the content of research, by observing that a study was SIG-funded it can be inferred that there likely exists other, non-SIG funded research that points in the alternative policy direction. This is a somewhat subtle way in which knowing the funder of a study is valuable information.

The model's results do not imply that SIG-funded research should be banned. But this option might be considered in cases where the enforcement of disclosure is difficult and the parameter values are such that strategic funding is expected to negatively impact policy choice. Another option in these cases is for the PM to invest more resources in searching for research and/or funding sources. The PM's ability to search for research is fixed in the basic model examined in this paper, but may be variable in the real world.

The conclusion that transparency of SIG-funding always causes the welfare effects of funding to be non-negative does rest on the assumption that the SIG cannot directly manipulate research results. If the SIG could, say, choose the π's before funding, and it chose whether to fund research before observing s^1, then signal-jamming could be socially harmful in spite of transparency.[15] Thus the policy recommendation of disclosure of funding is most usefully applied to research least likely to be manipulable by the SIG. In the sequential game transparency is still sufficient to preserve non-negative welfare effects despite endogenous π's given the sophisticated PM assumption; however, this assumption is of course questionable.[16] Another way signal-jamming could benefit the SIG in the sequential game despite transparency is if the SIG committed to always funding some research, and strategically changed the amount of research depending on early (exogenous or endogenous) research results.[17]

The model does support the theory of socially beneficial informative lobbying. We found positive welfare effects of funding in spite of the interaction of exogenous and endogenous research when the PM is sufficiently 'demanding' of evidence supporting the SIG's desired policy. This result should be

[15]The less informative SIG-funded study could crowd out the exogenous study, and the fact that it was SIG-funded would provide no information about the results of the exogenous study since the decision to fund was made before the exogenous results were known.

[16]Cain, Loewenstein, and Moore (2005) conduct an interesting experiment showing that decision makers lack the sophistication to back out this type of bias.

[17]I thank Jimmy Chan for suggesting this possibility.

viewed with caution, however, due to the strength of the assumptions regarding the PM's motives and sophistication, and the unbiasedness of research.

An important topic for future theoretical and/or empirical research is a deeper analysis of biased research. The assumption in this paper that researchers are unbiased makes the results stronger in a sense, as one would expect the social welfare effects from funding to be the same or worse when researchers have biases that the SIGs can exploit. Still, the assumption is somewhat unsatisfactory, as on some issues–climate change in particular, as described in the introduction and Appendix A–researchers do appear to produce positively serially correlated results. In the model of this paper SIGs benefit, sometimes at society's expense, by funding research and hoping to obtain *different* results: a change from s_1 to s_2. In the real world, it appears SIGs often fund research hoping for more of the *same* type of result. Perhaps SIGs influence research results through threats or incentives regarding future funding. Another possibility is that SIGs find researchers who have found evidence supporting their favored policy in the past, and provide these researchers with funding hoping they have persistent biases. It is worth modeling research bias directly to see how different information production processes affect the costs and benefits of privately funded policy research in general.

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A SIG-Funded Climate Change Research

Several individual scientists are known for having received funding from SIGs starting around 1990. For example, Pat Michaels, a climate scientist at the University of Virginia, and Robert Balling, a professor of geography at Arizona State University, disclosed under oath at a 1995 Minnesota state commission that they had received $165,000 and $300,000, respectively, over several years from private sources (Gelbspan (1997)). Michaels noted he had been sponsored by Western Fuels, a trade group for the US coal industry, and Balling by Cyprus Minerals, German and British coal groups, and the Kuwaiti government.[18] This funding has continued until recently. In February of last year (2006) Michaels received at least $100,000 from the Intermountain Rural Electric Association.[19] Both Michaels and Balling appear to have been selected by SIGs for funding as a result of the skepticism about global warming they expressed publicly in the late 80s and early 90s.[20]

Among firms, ExxonMobil has become particularly well known as a sponsor of think tank and institutional research. The corporation donates millions of dollars each year to research organizations, many of whom have devoted substantial resources to searching for information, and arguing publicly, that global warming is not a problem warranting governmental intervention. An especially interesting and timely example of this is the American Enterprise Institute (AEI)'s announcement in last February of the creation of a $10,000 award for scientific findings critiquing the most recent Intergovernmental Panel on Climate Change (IPCC) report. The AEI has received over $1 million from Exxon within the last 10 years. Exxon has also donated to many institutions not thought to be biased in its favor. Perhaps most notable is the $100 million Exxon pledged to Stanford University's Global Climate and Energy Project in 2002. Exxon has also donated to MIT and think tanks with varying ideological reputations (e.g. Brookings). Typically critics of Exxon claim that these donations are some type of front, intended to distract from the firm's sponsorship of more insidious research. My model shows that Exxon can benefit directly from new, non-ideological research – and the effect on social welfare is ambiguous.

[18]Balling and Michaels seem to be confident of the funding's effect on policy. They also seem aware of, but unconcerned by, the possibility of the funding being perceived as socially harmful. In their book, *The Satanic Gases: Clearing the Air about Global Warming* (Michaels and Balling (2000)), they say "Without Fred [Palmer, former president of Western Fuels Inc.], I truly believe the onerous Kyoto Protocol on global warming-or something like it-would be the law of this land today. The environmental community apparently agrees, too, judging from the number of television documentaries and newspaper features explaining that the only reason Americans have not cheerfully committed economic suicide to stop global warming is a pernicious industry campaign organized by Fred. Never mind that Washington spends at least *10,000 times* (their italics) as much as industry to promote its view of climate change, a tribute to federal efficiency." This last statement is likely referring to federally funded research and education programs on climate change and the authors' opinion that Washington has a view on the issue. I discuss this further in Section 5.

[19] http://abcnews.go.com/Technology/GlobalWarming/story?id=2242565&page=1

[20]Michaels wrote a 1986 Washington Post editorial arguing against anthropogenic warming. He continued to publish articles, both scholarly and intended for the general public, advocating skepticism, and wrote his first book on the subject, *Sound and Fury: The Science and Politics of Global Warming*, in 1992. Balling wrote in 1989 how increased urban populations could cause measured temperatures to increase in the Journal of Geophysical Research. In 1993 he wrote *The Heated Debate: Greenhouse Predictions Versus Climate Reality.*

B Proofs

B.1 Proposition 3.1

Proof. I show why the strategies that constitute a demanding equilibrium when $p \in B$ are no longer in equilibrium for $p \in C$. This illustrates how the equilibria strategies for the other prior intervals are found. Suppose p is in C and the SIG plays the demanding equilibrium strategies. Suppose the SIG does not obtain (s_2, s_2) and thus it does not lobby. Suppose the PM takes its random draw and draws an s_2– it will play x_2 if $\widetilde{p}(s_2) = \frac{Pr(s_2|\theta_2,\phi^*,\lambda^*)p}{Pr(s_2|\phi^*,\lambda^*)} = \frac{(Pr(s^1=s_2,\text{no } s^2|\theta_2)+Pr(s^1=s_2|\theta_2)*Pr(\text{fund } s^2,s^2=s_1|\theta_2)*Pr(s^1=s_2 drawn))p}{Pr(s_2^{NL}|\phi^*,\lambda^*)} = \frac{((1-\omega)\pi_2+\omega\pi_2(1-\pi_2)/2)p}{((1-\omega)\pi_2+\omega\pi_2(1-\pi_2)/2)p+((1-\omega)\pi_1+\omega\pi_1(1-\pi_1)/2)(1-p)} > 0.5$. This is true when p is in C. Thus $\sigma^*(s_2^{NL}) = 1$. Thus if $s^1 = s_2$ the SIG has an incentive to neither lobby nor fund (to be sure the PM draws $s^1 = s_2$), and if $s^1 = s_1$ the SIG will fund and not lobby. The SIG's change in funding strategy will not change the PM's equilibrium response to s_2^{NL}, so the equilibrium holds. □

B.2 Proposition 5.1

Proof. First, we show that the strategies are in equilibrium. Hold σ^*, ϕ_G^* and λ_G^* fixed. Clearly $\phi_X^*(s_1) = 1$ since there is a chance the initial study was not observed by G and the funded study will be s_2 and drawn by the PM. But it is not clear that $\phi_X^*(s_2) = 0$. X may have an incentive to fund in this case because G might fund and obtain and report s_1. So, $s^1 = s_2$ does not guarantee the PM will draw s_2, as it did in the no competition case.

If X funds and obtains s_2 it can guarantee its desired policy, regardless of G's actions since $\widetilde{p}(s_2, s_2, s_1) > 0.5$ for p in the interval specified in the proposition. If we show that X prefers not to fund when $s^1 = s_2$ given this condition, this is sufficient to show X plays $\phi_X^*(s_2) = 0$. Let $\widetilde{\pi}_2$ denote the probability of a study resulting in s_2 given $s^1 = s_2$: $\pi_2\widetilde{p}(s_2) + \pi_1(1 - \widetilde{p}(s_2))$. X's payoff from funding is: $\widetilde{\pi}_2 + (1 - \widetilde{\pi}_2)((1 - \omega_G)/2 + (2/3)\omega_G\widetilde{\pi}_2)$. The payoff from not funding is: $1 - \omega_G + \omega_G\widetilde{\pi}_2$. The latter is greater than the former iff

$$\omega_G < \frac{1}{(4/3)\widetilde{\pi}_2 + 1}, \tag{8}$$

which will be true given the assumption $\omega_G < \frac{3}{4\pi_2+3}$. X's lobbying strategy is straightforward given the other players' strategies.

Next we check the PM's strategy. The PM knows that there will never be more than two studies in existence given the SIGs' strategies, thus one s_1 is sufficient to play x_1 since $p < \frac{\pi_1(1-\pi_1)}{\pi_1(1-\pi_1)+\pi_2(1-\pi_2)} \leftrightarrow \widetilde{p}(s_1, s_2) < 0.5$. We thus need to check that $\widetilde{p}(s_2^L) < 0.5$ and $\widetilde{p}(s_2^{NL}) > 0.5$. For the former, $\widetilde{p}(s_2^L)$ will only be greater than 0.5 if there is a chance that s_2^L is s^1. Suppose $s^1 = s_2$ and it is observed by X, so it is possible that s_2^L is s^1. Then there are two main cases: one, G funds and obtains s_1. Then X

has no incentive to report s^1 since the policy is x_1 regardless. Two, G either funds and obtains s_2 or does not fund. Either way, x_2 will be the policy chosen whether X lobbies or not. So again, X has no incentive to lobby. Thus, if $s^1 = s_2$ it will not be lobbied by X, so it is impossible that $s_2^L = s^1$. Consequently, $\sigma^*(s_2^L) = 0$. $\sigma^*(s_2^{NL}) = 1$ if $\widetilde{p}(s_2^{NL}) > 0.5$, which we know is true for $p \in C$ without competition. It is also true with competition, since this can be shown to increase $\widetilde{p}(s_2^{NL})$ (it decreases the likelihood that the randomly drawn s_2 was funded by X).

G's strategies can be easily shown to be optimal given the other players' strategies. Likewise, the welfare effects can easily be shown. To show uniqueness, we need to look at the other equilibria candidates. One is that $\sigma(\widetilde{s}) = 0$ for all $\widetilde{s}$. Then X will never fund or lobby. But clearly $\widetilde{p}(s_2^{NL})$ will then be greater than 0.5, which will cause the PM to deviate. The main other candidate involves the PM's demanding strategy, in which it requires two s_2's to play x_2. Note that $\sigma^*(s_2^{NL})$ must be 0 because otherwise as shown above X will never produce two s_2's. The question then is how might this affect G's strategy. Since $\sigma^*(s_2, s_2, s_1) = \sigma^*(s_2, s_2) = 1$, this will cause G to never fund. This is because if X funds and obtains s_2 the policy will be x_2 independent of G's action, and if X obtains s_1 the policy will be x_1 independent of G's action (unless G lobbies s_2, which it never does). Thus, G will not fund or lobby (since it does not need to lobby if $s^1 = s_1$ to obtain x_1), and it is as if G does not exist. Since we know that the demanding strategies do not constitute an equilibrium for $p \in C$ (which we know is true for p in the interval specified), the players will revert to the signal-jamming equilibrium strategies.

$\square$

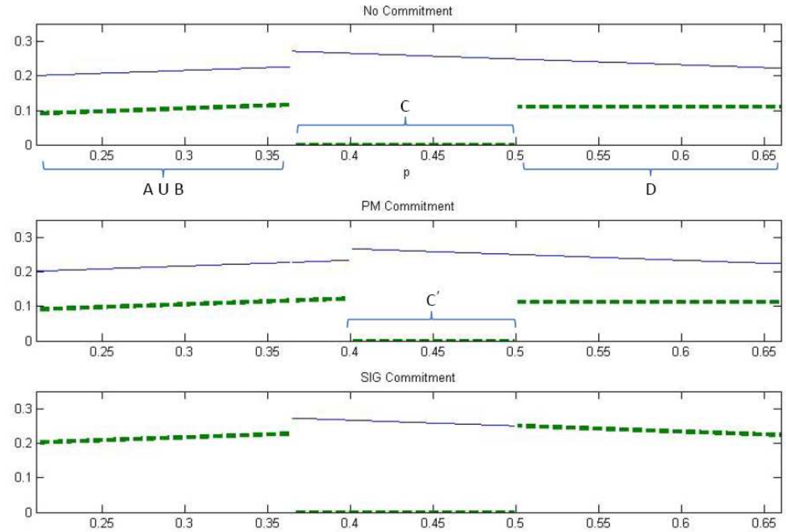

Figure 1: Research Funding, Lobbying Probabilities (solid line = Pr(fund), dashed line = Pr(lobby); $\pi_2 = 2/3, \pi_1 = 1/3, \omega = 1/2$)

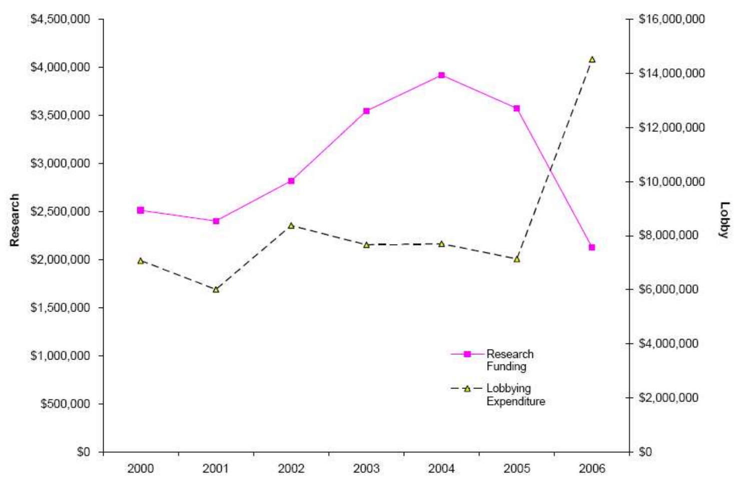

Figure 2: ExxonMobil Research Funding to Global Warming 'Denial' Groups (as defined by Greenpeace), Lobbying Expenditures, 2000-2006 (Sources: greenpeace.org, opensecrets.org)

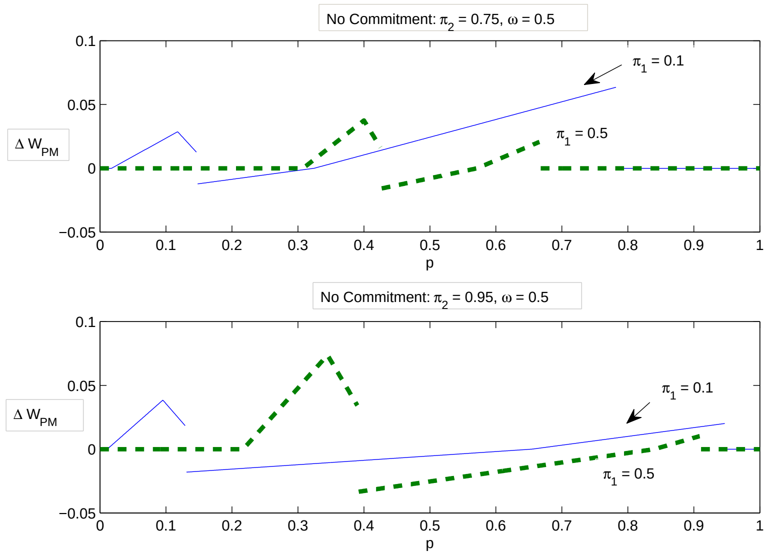

Figure 3: PM Welfare Effects of Funding (Demanding Equilibrium for $p \in B$)

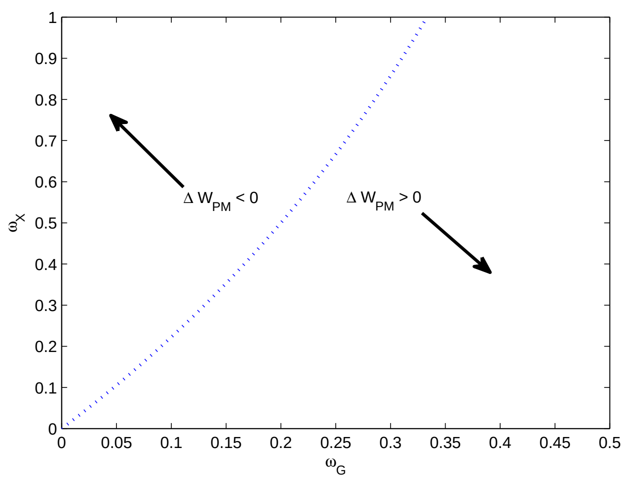

Figure 4: PM Welfare Effect Signs with Competing SIGs)