Information Sharing with Social Image Concerns and the Spread of Fake News*

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Abstract

We study how social image concerns affect information sharing patterns between peers. A sender receives a signal ("news") and can either share it with a peer ("receiver") or not. This signal has two attributes: a headline (e.g. arguing for or against human-induced climate change) and veracity status (based on facts and thus correlated with the state or made-up and thus uninformative). The headline is observable at no cost by everyone, while veracity status is observable to talented senders and receivers at a cost. We study the sharing patterns induced by two different social image concerns: wanting to be perceived as talented (able to recognize proper information), and wanting to signal one's worldview (posterior belief). Our model can rationalize the empirical finding that fake news may be shared with a higher propensity than proper news (e.g., Vosoughi et al., 2018). We show that both a veracity and a worldview concern may rationalize this finding, though sharing pattern are empirically distinguishable.

Keywords: Information Sharing, Social Image, Signaling, Fake News

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1 Introduction

At any given moment in time, millions of people share information with their friends, family, and other peers. The increased importance of digital social media that we experienced in the last two decades has made information sharing even easier and it significantly increased the potential reach of individuals. Information sharing is an important phenomenon, because information received by our peers is one of our most important sources of information.[1] At the same time, worries about the quality of such information and the consequences for society are becoming louder. For example, concerns were raised that misinformation during the 2016 US presidential election was undermining the public's trust in democracy[2] and misinformation spread on WhatsApp during the 2018 Brazilian presidential election may have influenced the election result[3]. Interestingly, Vosoughi et al. (2018) found that fake news may even be shared disproportionally, thus at a higher rate than proper information. The aim of this paper is to understand which situations are conducive to the spread of fake news. When and with which motive are fake news shared disproportionally? Understanding the reasons why individuals share (fake) news with their peers is a precondition for understanding the effect fake news have on society and judging the effectiveness of potential policy interventions aimed at limiting the spread of fake news.

An important reason for individuals to share information is their social image[4]. By sharing high quality information an individual can gain status. Conversely, by sharing information that turns out to be false, individuals may lose status. Moreover, information sharing may also be used to signal one's worldview. Sharing information that argues for a certain worldview may be interpreted as evidence that one supports this view. In this paper we build a theoretical model to analyze the conditions for and the consequences of information sharing, when individuals have social image concerns. For this we assume that there is an unknown binary state of the world (e.g. human activity is causing climate change vs. climate change is natural variation). We model a sender S who receives a binary signal about the state of the world that she may or may not share with a receiver R. The signal has two dimensions. First, it has a headline (e.g. arguing for or against human-induced climate change) which

[1]Empirical research has documented the importance of information sharing in a variety of circumstances, such as the adoption of micro finance (e.g., Banerjee et al., 2013), during vaccination campaigns (e.g., Banerjee et al., 2019), or prior to elections (e.g., Pogorelskiy and Shum, 2019).

[2]`https://www.brookings.edu/blog/fixgov/2022/07/26/misinformation-is-eroding-the-publics-confidence-in-democracy/`

[3]`https://www.theguardian.com/world/2019/oct/30/whatsapp-fake-news-brazil-election-favoured-jair-bolsonaro-analysis-suggests`

[4]See for example Lee et al., 2011, Lee and Ma, 2012, or Kümpel et al., 2015.

may be surprising or unsurprising to the receiver R, i.e. confirm or contradict her prior belief. We call this dimension *relevance* and it is observable to both sender and receiver without cost. Second, the signal may be proper or improper, which we call the *veracity* dimension. Proper signals are positively correlated with the underlying state of the world and are thus informative of this state. Improper signals are not correlated with the state of the world and thus contain no information. At the same time, they may be biased towards a certain state. Importantly, only high ability senders and receivers are able to ascertain the veracity status of a signal at a cost. For example, one may think of sharing the signal as the sharing of a newspaper article. Relevance can often be inferred from the headline, but to be able to judge veracity, one has to read the article, which is costly, because it takes some time to read the article and fact check it. We assume that these costs are prohibitively high for low ability senders and receivers.

Senders in our model have social image concerns - they care about how they are perceived by their peer, i.e. the receiver. These social image concerns may take different forms. We study two different types of social image concerns in this paper: 1) A concern to be recognized as someone who can distinguish proper and improper signals (i.e. a high ability type). 2) A concern to be recognized as someone with a certain worldview (i.e. a "partisan"). We model differences in worldview as differences in prior beliefs about the state of the world. Thus individuals in our model may misperceive the signal-generating process as for example in Alonso and Câmara (2016).

Our main finding is that both social status from sharing high quality information (proper signals), and social image from signaling one's worldview may cause the quality of information to deteriorate after sharing, as found in Vosoughi et al. (2018). At the same time, the exact sharing patterns predicted by each motive differ. We thus offer novel predictions that allow to empirically distinguish the different social image motives:

- With a *veracity* motive, fake news may be shared disproportionally when improper signals ('fake news') are biased to be *surprising* to the receiver. Especially *low-type senders with different priors than the receiver* share these improper signals. In these situations senders predominantly share signals that are surprising to the receiver and withhold unsurprising ones. A decrease in sharing costs exacerbates the sharing of fake news and makes disproportionate sharing more likely.

- With a *worldview* motive fake news may be shared disproportionally when improper signals are biased to *conform* to the receiver's prior. Especially *senders with similar priors* share these improper signals. In these situations senders predominantly share signals that are unsurprising to the receiver and withhold surprising ones.

In fact, conditional on being in a situation where fake news are shared disproportionately, the two social image motives lead to clearly distinguishable sharing patterns.

Additionally, we argue that understanding the incentives of the receiver may also help to think about the social image motive senders may hold in a given situation. For an equilibrium where ability signaling is possible, receivers need to engage with the shared information sufficiently such that status can be gained. At least some receivers need to ascertain the veracity status of the signal some of the time. This also implies that in situations where receivers do not engage with the signal (e.g. read the article or think critically about it), an ability motive is likely not salient to senders. In these situations, a worldview motive may be more salient, which does not rely on some receivers "fact-checking" the information shared. Instead, headlines are used to signal worldview in a low attention environment where neither sender nor receiver engage with the signal beyond registering the headline.

Our findings can contribute to the debate on how to tackle fake news sharing on social media. Pennycook et al. (2021) show that senders can be nudged to pay more attention to accuracy, which decreases sharing of fake news. Our model shows that this may not always lead to a satisfactory outcome. While in situations where fake news are shared disproportionally under a worldview motive, nudging towards accuracy (and thus an ability motive) may work, there will be other situations where ability signaling leads to worse quality of information than worldview signaling. Furthermore, the supply and properties of fake news are not fixed, but will likely adjust to the dominant motive. On the other hand, sharing costs unambiguously increase the quality of information under an ability motive. This is consistent with Henry et al. (2022) who show that each additional click required for sharing substantially reduces sharing. On the other hand, it should be noted that discouraging sharing of fake news may discourage sharing of proper information as well, with adverse consequences on the informedness of the receiver.

2 Literature

A recent literature studies the quality of information shared by peers on social media with a focus on political news. Vosoughi et al. (2018) showed that fake news, especially in the political domain, diffuse "farther, faster, deeper, and more broadly" through the Twitter social network than proper news. Allcott and Gentzkow (2017) show how fake news were heavily shared on Facebook in the lead-up to the 2016 U.S. presidential elections. In how far this is a problem, is still debated in the literature. Allcott and Gentzkow (2017) show that political news on social media are less trusted than political news from traditional news providers. In contrast, Barrera et al. (2020) show that political fake news are highly persuasive, even when identified as fake.

Studying the individual sharing decision, Guess et al. (2019) consider who is most likely to share fake news regarding the 2016 U.S. presidential election on Facebook. They show that over 65 year olds and conservative-leaning individuals were most likely to share (mostly pro-Trump) fake news. Overall though, they find that fake news were rarely shared. Regarding policies that discourage sharing of fake news, recent experiments studying either intention to share or actual sharing behavior have shown that fact checking (e.g. Henry et al. 2022, Pennycook et al. (2020a)) and accuracy nudges (e.g. Pennycook et al. 2021, Fazio 2020) can induce individuals to abstain from sharing fake news[5]. In terms of mechanisms, Pennycook et al. (2021) argue that different motives matter for sharing information on Twitter, which they experimentally influence by redirecting individuals' attention[6]. When signaling one's identity is more salient fake news are spread knowingly (when they are aligned with one's identity and in order to signal one's identity), but if accuracy becomes more important, fake news sharing is reduced.[7] We study the two motives also studied by Pennycook et al. (2021) using a formal model with an active receiver who decides whether to engage with the news and forms beliefs about the type of sender rationally. Interestingly, we find that even with an accuracy motive, fake news may be spread disproportionally, as found by Vosoughi et al. (2018). We identify and characterize settings in which fake news sharing is most problematic with each motive and derive empirical predictions that can help to distinguish between the different motives.

More broadly, our paper is related to the theoretical literature studying fake news propagation in social networks. The earliest contributions here are Acemoglu et al. (2010) and Papanastasiou (2020) who focus on how fake news propagates in a social network. However, they do not explicitly model the sharing decision. This is different in Kranton and McAdams (2022), who assume an individual shares information if and only if she believes

[5]Though Nyhan and Reifler (2015) show that fact checking may sometimes actually reinforce beliefs in fake news. Walter et al. (2020) offer a survey of the literature on how fact checking affects beliefs.

[6]Motives underlying individual's decision to share news on social media have also been studied in the field of communication studies. These studies build onto the "uses and gratifications" approach and conduct surveys about sharing intentions as well as potential gratifications. Gaining status amongst peers has been identified as a main driver of sharing decisions by this literature (e.g. Lee et al., 2011 and Lee and Ma, 2012; see Kümpel et al., 2015 for a survey).

[7]This is in line with recent evidence that people are reasonably good at detecting real from fake news (Angelucci and Prat (2021)).

with sufficient probability that the signal is proper. Our model goes a step further in that we study a more complex model of information sharing as well as considering two different motives. Importantly, as we will see below, the probability to have a fake signal alone is not sufficient to take the decision whether to share the signal. Acemoglu et al. (2021) also study information sharing and allow for fake signals. However, in their paper the rationale for sharing is not status seeking through manipulating receiver's belief about the own type, but having influence because the shared signal is forwarded to other receivers.[8]

Another related literature considers the effect of peer-to-peer information sharing on polarization. In a recent contribution Bowen et al. (2023) show that if peers hold even minor misperceptions about their friends' sharing decisions, polarization may result. As Bowen et al. (2023), we also allow for misspecifications of the signal generating process, and show how these influence the sharing of fake news under different motives.[9] One contribution of our paper to this literature is to understand better why people share news selectively.

Finally, the literature on career concerns also looks at senders that want to signal a high type to a receiver, similar to our veracity motive. Typically, signaling takes place through the choice of implementing a project (over another or keeping the status quo). Important examples of this literature are Prendergast and Stole (1996) and Ottaviani and Sørensen (2006). In contrast to this literature, signaling in our setting works through the sharing decision of the signal about the state of the world.

3 Set-Up

To study peer information sharing, we set up a simple model where a sender (S) receives a signal about an unknown state of the world and subsequently decides whether to share the signal with a receiver (R). More concretely, the state of the world is binary, $\omega \in \{0, 1\}$, and the prior probability that $\omega = 1$ is $p \in (0, 1)$, while $\omega = 0$ with the complementary probability $1 - p$.

We assume that the sender and receiver may have heterogeneous priors about. Denote the sender's prior by $p_S \in [0, 1]$. We often will identify the sender's type with her prior, $\theta^P = p_S \in [0, 1]$, thus denote the distribution of sender beliefs by $F(p_S)$. Denote the receiver's belief about p by p_R. In case $p_S \neq p_R$ we assume that players "agree to disagree" such as for

[8]Grossman and Helpman (2019) study a model of electoral competition where parties can spread fake news. They abstract from sharing of this information by peers.

[9]Relatedly, Germano et al. (2022) consider the role of the platform in fostering polarization both theoretically and empirically.

example in Alonso and Câmara (2016). We interpret differences in beliefs as differences in *world view*.

The sender (S) then receives a signal $\sigma \in \{0, 1\}$ about the state of the world $\omega \in \{0, 1\}$. The signal is either *proper*, which happens with probability $1-q$, or *improper* with probability $q \in [0, 1]$, independent of the realization of the state. A proper signal is informative of ω, while an improper one is not. In particular, $Pr[\sigma = 1|\omega = 1] = Pr[\sigma = 1|\omega = 0] = \beta$ and $Pr[\sigma = 0|\omega = 1] = Pr[\sigma = 0|\omega = 0] = 1 - \beta$ if the signal is improper, where $\beta \in [0, 1]$. β thus measures the *bias* of improper signals. If the signal is proper, $Pr[\sigma = 1|\omega = 1] = Pr[\sigma = 0|\omega = 0] = \eta > 0.5$ and $Pr[\sigma = 1|\omega = 0] = Pr[\sigma = 0|\omega = 1] = 1 - \eta$. η measures the *precision* of proper signals. This signal structure is common knowledge. Let $\mathcal{V}_i \in \{P, F, U\}$ denote the signal's *veracity* status—proper, fake/improper, or unknown as perceived by the receiver $i = R$, or sender $i = S$.

Senders may differ in their ability to learn the signal's veracity status. A high type H learns the signal's veracity at a (very small) cost. To make things simple, we assume that when indifferent, H will not inspect, but as soon as she has a strict preference she will and thus learn the veracity status of the signal. In contrast, we assume that a low type L chooses not learn the signal's veracity, due to a prohibitively high cost of doing so or plainly is unable to do so. Denote the two possible sender types by $\theta_S \in \{L, H\}$ and assume that H types occur with probability λ^S. We will refer to differences in ability to learn the signals veracity simply as differences in *ability* in the following.

To summarize, a sender is characterized by a type vector $\mathbf{\Theta_S} = \{p_S, \theta_S\}$. The distribution of types is common knowledge, while the type realization may be private information.

The setting we have in mind is the sharing of a news article that has a headline and a main text. The headline is short and observable without a cost, but only gives information on the direction of the signal $\sigma \in \{0, 1\}$. At a cost, the sender can read the article and will thus learn the arguments presented. Only H types can observe the veracity of these arguments. Some strong arguments may just be made up, even though they do sound appealing and convincing at first blush. We assume that it is too costly for L types to distinguish these from proper informative signals.

After receiving her signal $\sigma \in \{0, 1\}$, S can share it with receiver R. The goal of sharing is not to inform R about ω, but to gain status, which is a function of the belief R holds about her type $\mathbf{\Theta_S}$. For a sender interested in being perceived as able ($\theta_S = H$), expected utility derived from social status equals R's belief about her type θ_S

$$\pi^S(x) = Pr[\theta_S = H|x], \tag{1}$$

where $x \in \{\emptyset, (\sigma, \mathcal{V}_S)\}$. $\mathcal{V}_S \in \{P, F, U\}$ denotes the signal's veracity status as perceived by the sender—proper, fake, or unknown—and $\emptyset$ refers to not sharing σ. For a sender interested in social image from her worldview, utility from that motive equals

$$\pi^S(x) = -(p_S - \widehat{p}_S(x))^2, \tag{2}$$

where $\widehat{p}_S(x)$ is the perceived prior of S by R as a function of $x \in \{\emptyset, (\sigma, \mathcal{V}_S))\}$.

After the sender has made her sharing decision, the receiver R needs to choose an action $a \in \{0, 1\}$, which leads to a payoff of

$$\pi^R(a) = -(\omega - a)^2.$$

Thus, she would like to match the state with her action and choose $a = 1$ if $\omega = 1$ and $a = 0$ else. Without any additional information through the action of S, R optimally sets $a = 1$ whenever $p_R \geq 0.5$, and $a = 0$, else. This implies that some signal realizations are more relevant to her decision making than others. In particular, a signal realization that under no circumstance changes her decision is *irrelevant*. However, a signal realization that under some circumstances may change her decision (e.g. when she knows it is a proper signal and η is high enough) is *relevant*. Given $p_R \geq 0.5$, any $\sigma = 1$ confirms the decision that R would like to take based on the prior, and thus is irrelevant to her decision. A signal realization $\sigma = 0$, however, could be relevant.

Similar to the sender, some receivers are able to learn the veracity of a signal at a small cost, while others are not due to prohibitively high costs. Thus, also the receiver (R) can be of two types, $\theta_R \in \{H, L\}$, which occur with probability λ^R and $1 - \lambda^R$, respectively. A receiver of type H is able to observe the veracity of the signal at a (very small) cost, while a receiver of type L is not. As for the sender, we simply assume that when indifferent, H will not inspect and thus learn the veracity status $\mathcal{V}_R$ of the signal. As soon as she has a strict preference though, she will do so. In contrast, both receiver types are able to observe the signal itself $\sigma \in \{0, 1\}$ without cost, if it is shared with them. This immediately implies that R will never inspect a message that concurs with her prior (e.g. $\sigma = 1$ when $p_R > 0.5$). She may, on the other hand, find it in her interest to inspect a signal that does not concur with her prior ($\sigma = 0$ when $p_R > 0.5$). As for senders, a receiver R is characterized by the following type vector $\mathbf{\Theta_R} = \{p_R, \theta_R\}$. In the following we make the assumption that $\eta > p_R > \frac{1}{2}$ and thus signals $\sigma = 0$ are relevant for the receiver, while signals $\sigma = 1$ are not.

Finally, we assume that senders experience a cost of sharing signals, $c \geq 0$. Thus, a sender's expected utility equals

$$Eu[x] = \pi^S(x) - c \cdot \mathbf{1}_s$$

where $\pi^S(x)$ is social image utility (either ability or worldview) and $\mathbf{1}_s$ is an indicator function equal to 1 if the sender shares the signal and equal to zero otherwise.

We will study Perfect Bayesian equilibria, where:

- Senders choose whether to learn the veracity status of their signal as well as whether to share the signal with the receiver taking into account the receiver's optimal fact-checking strategy and ensuing beliefs about the sender's type.
- Receivers choose whether to learn the veracity status of the signal, if shared by the sender, and optimal action taking into account the fact-checking strategy and sharing strategy of the sender.
- Receiver beliefs follow from Bayes rule and the strategy of the sender, whenever possible.

4 Information Sharing to Signal Ability

4.1 Equilibrium

In this section we study situations where a sender wants to signal her ability to recognize improper signals, as defined in Equation (1). With this motive, we focus on the case where sender types only differ in their ability to recognize improper signals, not their beliefs p_S. Hence, sender's ability is the relevant dimension for gaining social image utility. High ability senders can condition their sharing decision on whether the signal they receive is relevant to the receiver *and* on the veracity of the signal, while low ability senders cannot condition on veracity and hence only decide based on how relevant their signal is. Because $p_R > \frac{1}{2}$ (by assumption), only signal realizations $\sigma = 0$ are surprising and thus relevant for the receiver.

If status can be gained because some senders are able to filter signals based on their veracity, then to gain status it also must be the case that the receiver is able to and has an incentive to check a shared signal's veracity. So we begin by asking under which conditions a high ability receiver has an incentive to fact check a shared signal. Our first formal result shows that only surprising/relevant signals will be checked in equilibrium:

Lemma 1. *If $\eta \geq p_R$, a high ability receiver checks the veracity of a shared signal if and only if the signal is surprising, $\sigma = 0$, and if the probability that such a shared surprising signal is fake is strictly positive. If $\eta < p_R$, a high ability receiver never checks a shared signal.*

The intuition for this lemma is straightforward. Checking a signal is costly, and hence is only worthwhile if it has the potential to change the decision of the receiver. If the signal is not surprising, or if the quality of a proper signal is too low, $\eta < p_R$, then independent of the signal's veracity, the optimal action of the receiver is $a = 1$. Hence, no high ability receiver will check the veracity of such a signal. However, when the signal is surprising and $\eta \geq p_R$, it has the potential to change the receiver's optimal action. Should the signal be false, then the receiver better disregard it and take the decision based solely on the prior. If, however, the signal is proper, than it should be taken into account for decision making. Because checking is not very costly for high ability receivers, it is thus optimal to check any potentially informative surprising signal, if there is a chance that the signal is fake.

From Lemma 1 it directly follows that when signals are not sufficiently informative, $\eta < p_R$, and sharing is costly, $c > 0$ no sender will share them in equilibrium. Since sharing is costly, a sender only shares a signal if it has the potential to increase status. However, if $\eta < p_R$, then a receiver never fact-checks any signal, which in turn implies that no sender can gain status from sharing. The first proposition formalizes this intuition:

Proposition 1. *Assume a sender wants to signal her ability to recognize improper signals, as defined in Equation* (1)*. If $\eta < p_R$ and $c > 0$, then there exists a unique not Pareto-dominated equilibrium. In this equilibrium, no information is shared by the sender, and off-equilibrium beliefs satisfy $\pi^D \leq \lambda_S + c$.*

We now focus attention on the more interesting case when $\eta \geq p_R$. Clearly, the sender will take into account the receiver's incentives to check signals. Because a non-surprising signal will never be checked by a receiver, the sender has no incentive to check such a signal, either. However, a surprising signal will be checked by high ability senders when they anticipate receivers to check as well, because these could induce a status gain.

Let us now consider which signals are shared by the different sender types. First note that a high ability sender who decides to check a relevant signal can condition both on the realization of σ as well as on the signal's veracity when $\sigma = 0$. On the other hand, a low ability sender can only condition on σ. Denote by κ_σ the probability that a low ability sender shares a signal with realization σ. Moreover, denote by χ_1 the probability that a high ability sender shares an unsurprising signal, and by χ_{0v} the probability that she shares a surprising signal with veracity $v \in \{\mathcal{P}, \mathcal{F}\}$. We assume without loss of generality that $\chi_{0\mathcal{P}} \geq \chi_{0\mathcal{F}}$.[10]

As typical, there are multiple Perfect Bayesian Equilibria of the game. However, in our framework standard equilibrium refinements such as the Intuitive Criterion or D1 cannot help to narrow down the set of possible equilibria. In a first step towards the main results of this section, we can show that some equilibria cannot exist:

Lemma 2. *There exists no equilibrium in which one type shares all signals, while the other type chooses not to share some signals, and one of the types receives expected utility larger than* λ_S.

The intuition for the lemma is as follows. If along the equilibrium path only the high ability type does *not* share some signals, then the low type deviates by keeping all signals for himself. If only the low type keeps some signal for himself, than status after no signal was shared is zero. If sharing costs are low, the low type deviates and shares more signals. If sharing costs are high, the high type deviates and shares no signals. Only if $c \geq \lambda_S$ can such an equilibrium exist, but then both types receive zero utility in equilibrium (the low type needs to be indifferent between not sharing and a social image utility of zero, and sharing with sharing costs and positive social image utility). Note that while such a situation is an equilibrium, it is dominated by others. In fact, for both types it is the worst possible outcome.

Our interest is in equilibria where social image utility is gained through signaling of ability. This can be done both by identifying and sharing proper signals, and by identifying and sharing fake signals. We assume status is gained through the sharing of proper signals. Then, a high ability sender has a strictly greater incentive to relay a proper and surprising signal than a fake and surprising signal, because the latter will be interpreted by high ability receivers as evidence that the sender has low ability. Therefore, we should expect the high ability sender to choose $\chi_{0\mathcal{F}} = 0$. Moreover, the signal that should yield the greatest expected status gain is a surprising and proper signal, and hence we should expect $\chi_{0\mathcal{P}} = 1$. At the same time, it is unclear whether she should withhold or share a signal that is not surprising.

The incentives of a low ability sender to imitate a high type depend on the likelihood to encounter a high type receiver. When the probability to meet a high ability receiver is large, then sharing a surprising signal is risky, in particular if q, the probability to hold a fake signal, is large. Therefore, she has an incentive not to share such a signal in this case.

[10]This implies that we focus on equilibria where a high ability sender gains status by sharing proper signals. Other equilibria exists where high ability senders gain status by sharing improper signals, which would correspond to restricting $\chi_{0\mathcal{P}} \leq \chi_{0\mathcal{F}}$. The quality of information will be worse in these equilibria, and thus we consider the most informative equilibria.

However, if the probability to meet a high ability receiver is low, then sharing a surprising signal is not very risky. Sharing an unsurprising signal is never risky, but it is also not a good way to gain status. Hence, just as in the case of a high ability sender, the probability to share a signal that is not surprising depends on the details of the equilibrium.

Despite Lemma 2, there are generally multiple equilibria of the game, the major difference between them being if unsurprising signals are shared. In the following, we focus on the equilibrium in which S does not share *any* non-surprising signals. In the appendix we discuss the other equilibria and argue that whenever there are positive sharing costs, $c > 0$, the equilibrium in which unsurprising information is withheld dominates the other equilibria.

Proposition 2. *Assume a sender wants to signal her ability to recognize improper signals, as defined in Equation* (1). *There exists* $\bar{c} \in (0, 1)$ *and a strictly decreasing function* $\bar{q}(c) \in [0, 1]$, *where* $\bar{q}(0) = 1$ *and* $\bar{q}(\bar{c}) = 0$, *as well as a threshold off-equilibrium belief* $\tilde{\pi}_1 \in (0, 1)$, *such that the following Perfect Bayesian Equilibrium exists if and only if* $c \leq \bar{c}$, $q \leq \bar{q}(c)$, *and* $\pi_1 \leq \tilde{\pi}_1$*:*

- *No non-surprising signals are shared,* $\chi_1^* = \kappa_1^* = 0$.
- *The high ability sender shares all proper surprising signals and no fake surprising signals,* $\chi_{0\mathcal{P}}^* = 1$ *and* $\chi_{0\mathcal{F}}^* = 0$.
- *The low ability sender shares a surprising signal with probability* $\kappa_0^* \in (0, 1)$.

When q and c are not too large, sharing a surprising signal with positive probability is beneficial for a low ability sender in equilibrium. Moreover, when c increases, the probability that the low ability type shares a surprising signal κ_0^* decreases. Intuitively, as c increases, sharing becomes less attractive compared to not sharing. Decreasing κ_0 means the benefits from sharing increase somewhat again, whereas the status from not sharing decreases. This way the low ability sender remains indifferent between sharing and keeping the signal. The same intuition explains why κ_0^* decreases in q (signals are more likely improper) and increases in β (signals $\sigma = 0$ are less likely improper). Moreover, κ_0^* also decreases in p_S. The reason is that as p_S increases, the low ability sender's belief that her signal $\sigma = 0$ is fake increases, which makes sharing less attractive. All other comparative statics are not as clear cut.

4.2 The Quality of Shared Information

In this section we now study the quality of shared information. Because status is derived from not sharing fake information, it seems a plausible conjecture that senders "filter" the available information for the receiver, and that as a consequence of that the quality of shared information is greater than the quality of the information received by S.

There are different meaningful measures of the quality of shared information. The measure we use is the fraction of shared information that is fake. The probability of proper news being shared is

$$\sigma^{\mathcal{P}} = (1-q)\left[p_T(1-\eta) + (1-p_T)\eta\right]\left((1-\lambda_S)\kappa_0^* + \lambda_S\right),$$

whereas the probability of fake news being shared is

$$\sigma^{\mathcal{F}} = q(1-\beta)(1-\lambda_S)\kappa_0^*.$$

Then our intuitive measure of the expected quality of shared information is

$$\gamma := \frac{\sigma^{\mathcal{F}}}{\sigma^{\mathcal{F}} + \sigma^{\mathcal{P}}}. \tag{3}$$

Naturally, when γ decreases, we interpret this as increasing quality, because the probability that a shared signal is fake is lower. Similarly, larger γ means the quality of shared information decreases.

The first result we are interested in is how the availability of social media platforms, which facilitate easy information sharing and therefore decrease the cost of sharing information with our peers, affects the quality of shared information. Many researchers have attributed increasing spread of misinformation to exactly those platforms. The next result shows that decreasing sharing cost indeed increases the share of disinformation that is shared:

Proposition 3. *Consider the equilibrium identified in Proposition 2. The fraction of all shared news that is fake increases when information sharing becomes less costly. Formally, γ weakly decreases in c.*

What is the mechanism through which sharing costs affect the spread of fake information? High ability senders never share fake information, and thus low ability senders must be the reason for this finding. A low ability sender randomizes between sharing a surprising piece of information and keeping it to himself. When the cost of sharing decreases, sharing becomes, ceteris paribus, more attractive. Increasing κ_0 decreases the possible status from sharing and increases the status from not sharing, and hence restores the balance between relaying information and keeping it. Consequently, greater sharing cost increase the quality of shared information γ.

A direct implication of our analysis is that there exists $c^*(q) > 0$ such that when the sharing cost c approaches $c^*(q)$, then κ_0^* approaches zero, and therefore γ converges to 1: only proper information is shared in such an equilibrium. To the contrary, the quality of shared information is lowest when $c = 0$. Note that $c^*(q)$ is the value of the cost parameter c that solves $q = \overline{q}(c)$.

Also the sender's belief p_S matters for the quality of information shared. The greater the sender's belief that $\omega = 1$, and thus the higher p_S, the lower κ_0^*, as explained above. Thus, low types are more conservative in their sharing decision, which improves the quality of information shared. Consequently, γ decreases in p_S. Recall that $p_R > \frac{1}{2}$. Then, γ is lowest when $p_S \to 0$, and thus the sender and the receiver maximally disagree in their belief about the state ω.

The effects of β and q are ambiguous. On the one hand, lower β and greater q decrease κ_0^* and thus increase the quality of information through a reduction of sharing by low types. On the other hand, this also directly increases the share of improper signals shared by low types, because there simply are more fake signals.

But how low can the quality of information after sharing become? For example, can we guarantee that the fraction of shared information that is fake is smaller than the expected fraction of fake information received by the sender, $\gamma < q$? This would imply that the quality of shared information increases due to filtering by senders. Unfortunately, this is not necessarily the case. As mentioned above, κ_0^* decreases not only in c, but also in the fraction of fake signals q and the bias of fake signals β. Moreover, when λ_S decreases, then the fraction of shared information coming from low ability receivers increases, and this tends to increase γ as well. Figure 1 shows how $\gamma - q$ changes as a function of $q \in [\frac{1}{10}, \frac{9}{10}]$, $\beta \in [\frac{1}{10}, \frac{9}{10}]$, and $\lambda_S \in \{\frac{1}{10}, \frac{1}{5}\}$ when $c = 0$, $\eta = \frac{2}{3}$, $\lambda_R = \frac{1}{5}$, and $p_S = p_R = p_T = \frac{2}{3}$.[11] We can see that in the example $\gamma > q$ when q and β are small. Moreover, when λ_S decreases, the parameter range such that $\gamma > q$ increases.

The example suggests that the quality of shared information is worst when β, the probability that a fake signal indicates the state is 1, is low. In this case fake news are biased towards surprising messages. To the contrary, if fake messages are biased towards the expected state, $\omega = 1$, then shared information tends to be of higher quality and thus $\gamma < q$:

Proposition 4. *Consider the equilibrium identified in Proposition 2. A sufficient condition for $\gamma < q$ is*

$$\beta > 1 - \frac{p_T(1-\eta) + (1-p_T)\eta}{1-\lambda_S}.$$

Thus only for β sufficiently small is there scope for $\gamma > q$. Note that λ_S large and p_T

[11]For these parameters, $0 < \kappa_0^* < 1$ and thus the equilibrium characterized in Proposition 2 exists.

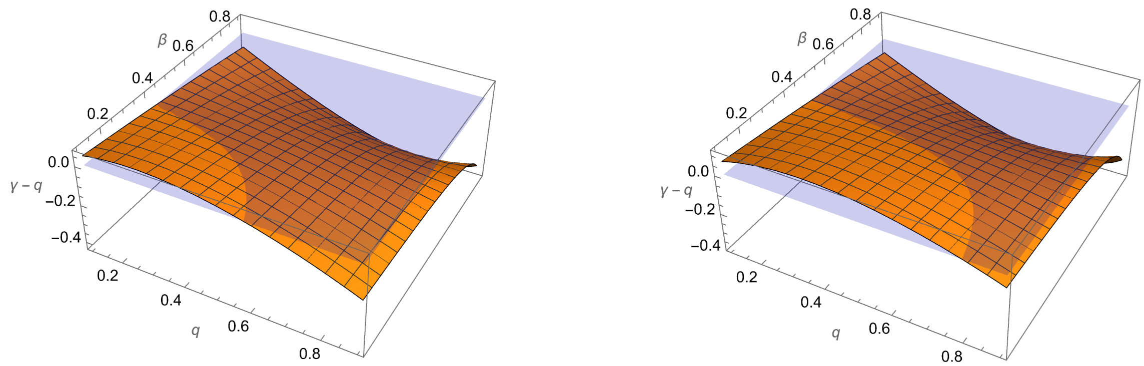

Figure 1: $\gamma - q$ as a function of q and β when $\lambda_S = \frac{1}{5}$ (left panel) and $\lambda_S = \frac{1}{10}$ (right panel), as well as $c = 0$, $\eta = \frac{2}{3}$, $\lambda_R = \frac{1}{5}$, and $p_S = p_R = p_T = \frac{2}{3}$. The light-shaded blue plane divides the positive and negative halfspace and marks $\gamma - q = 0$.

small also make this sufficient condition more likely to bind. For example, when $\lambda_S = \frac{1}{10}$, $\eta = \frac{2}{3}$ and $p_T = \frac{2}{3}$, we get $\beta > \frac{41}{81} = 0.506$ (right graph) while when λ_S increases to $\frac{1}{5}$, we get $\beta > \frac{4}{9} = 0.444$ (left graph). To conclude, the quality of information shared relative to information received is worse when β, p_S, λ_S and c are low.

5 Information Sharing to Signal Worldview

5.1 Equilibrium

Now we relax the assumption that everyone has the same prior belief. Instead, assume senders can differ in their belief and denote the distribution of prior beliefs by $F(p_S)$, where we assume that $F(p_S)$ is continuously differentiable with derivative/pdf $f(p_S)$ and this pdf is strictly positive on $[0, 1]$. We focus with this motive on situations where learning is not very important (i.e. priors are strong), for example because $\eta < p_R$, so proper signals even if known to be proper are not pivotal for the receiver's optimal action. For simplicity, we simply assume in the following that costs of inspecting veracity are sufficiently high and no receiver will inspect the signal (and thus also no sender). We also focus on situations where η is sufficiently small, as we define below.

We need to introduce some further notation. Denote by $p_S^U(p_S, \sigma)$ the posterior belief of the sender after observing her signal σ and given her prior p_S. Denote by $F(p_S^U|\sigma)$ the distribution of posteriors conditional on the signal. This is common knowledge, as is the prior belief of R, p_R.

We assume that S would like to signal her worldview. We interpret this as wanting to be perceived by the receiver as having a posterior as close as possible to her actual posterior. Thus, assume

$$\pi_S = -(p_S^U - \widehat{p}_S^U(x))^2$$

where $\widehat{p}_S^U(x)$ is the perceived posterior of S by R. As discussed above, R never inspects and learns the veracity status. Thus R only observes whether a signal is sent and the "headline" of the signal $\sigma \in \{0, 1\}$. We will focus on an equilibrium of the following form:

- senders that received signals $\sigma = 0$ share the signal iff their posterior belief lies in $[0, p_{Sl}]$,
- senders that received signals $\sigma = 1$ share the signal iff their posterior belief lies in $[p_{Sh}, 1]$.

Note that receiving $\sigma = 0$ shifts the prior towards zero and thus $p_S^U \leq p_S$, while receiving a signal $\sigma = 1$ shifts the prior towards 1 and thus $p_S^U \geq p_S$.

Denote by $\widehat{p}_R = (1-q)(\eta p_R + (1-\eta)(1-p_R)) + q\beta$ the receiver's belief that the sender received a signal $\sigma = 1$. In this prospective equilibrium, R's posterior belief about the "worldview" of the sender equals

$$\begin{aligned}
\widehat{p}_S^U(0) &= E[p_S^U | p_S^U \leq p_{Sl} \& \sigma = 0] = \int_0^{p_{Sl}} p_S^U f(p_S^U|\sigma = 0) dp_S^U / F(p_{Sl}|\sigma = 0) \\
\widehat{p}_S^U(1) &= E[p_S^U | p_S^U \geq p_{Sh} \& \sigma = 1] = \int_{p_{SH}}^1 p_S^U f(p_S^U|\sigma = 1) dp_S^U / (1 - F(p_{Sh}|\sigma = 1)) \\
\widehat{p}_S^U(\emptyset) &= \frac{\widehat{p}_R F(p_{Sh}|\sigma = 1) E[p_S^U | p_S^U \leq p_{Sh} \& \sigma = 1] + (1-\widehat{p}_R)(1 - F(p_{Sl}|\sigma = 0)) E[p_S^U | p_S^U \geq p_{Sl} \& \sigma = 0]}{\widehat{p}_R F(p_{Sh}|\sigma = 1) + (1-\widehat{p}_R)(1 - F(p_{Sl}|\sigma = 0))} \\
&= \frac{\widehat{p}_R \int_0^{p_{Sh}} p_S^U dF(p_S^U|\sigma = 1) + (1-\widehat{p}_R) \int_{p_{Sl}}^1 p_S^U dF(p_S^U|\sigma = 0)}{\widehat{p}_R F(p_{Sh}|\sigma = 1) + (1-\widehat{p}_R)(1 - F(p_{Sl}|\sigma = 0))}
\end{aligned}$$

In the proposed equilibrium, two indifference conditions need to hold

$$p_{Sl} - \widehat{p}_S^U(0) = \widehat{p}_S^U(\emptyset) - p_{Sl} \tag{4}$$

$$\widehat{p}_S^U(1) - p_{Sh} = p_{Sh} - \widehat{p}_S^U(\emptyset) \tag{5}$$

The first indifference condition characterizes the posterior of the indifferent sender that received $\sigma = 0$, the second $\sigma = 1$. Thus, a sender with posterior p_{Sl} needs to be indifferent between sending a signal $\sigma = 0$ and not sending it, and a sender with posterior p_{Sh} needs to be indifferent between sending a signal $\sigma = 1$ and not sending it. An equilibrium fulfilling these conditions always exists, as we show in the following proposition.

Proposition 5. *There exists an equilibrium with the property that $\sigma = 0$ is only shared by senders with sufficiently small posterior, $[0, p^*_{Sl}]$ while $\sigma = 1$ is only shared by senders with sufficiently high posteriors $[p^*_{Sh}, 1]$, where (p^*_{Sl}, p^*_{Sh}) solve (4) and (5).*

Now we are interested in studying how the receiver's prior belief p_R influences the equilibrium strategy of the sender in this equilibrium.

Corollary 1. *Assume $\eta > \frac{1}{2}$ and $q < 1$. Compare two receivers, receiver 1 with prior p^1_R and receiver 2 with prior $p^2_R > p^1_R$ and assume η is sufficiently low. Then receiver 1 receives more signals $\sigma = 0$ than receiver 2, and receiver 2 receives more signals $\sigma = 1$.*

We find that the more extreme the prior of the receiver, the more signals she receives that confirm her prior and the less signals she receives that contradict her prior. In that sense, echo chambers arise naturally in our setting (through the behavior of the senders that is tailored to the prior of the receiver). Thus, sharing patterns are empirically distinguishable from the ability motive, as relevant/surprising information is shared relatively little (though this depends on which equilibrium of the ability motive we compare to). The intuition is that a receiver that does not observe a signal will attach a higher probability to the sender having received a signal agreeing with her prior, than disagreeing, and thus expects the sender who does not share to have a prior contradicting her own. This makes moderate senders reluctant to not share a signal agreeing with the receiver's prior while preferring to not share a signal that disagrees with the prior. This biases sharing in the direction of the receiver's prior.

5.2 The Quality of Shared Information

Turning back to our main question, we are interested in which situations are conducive to the spread of fake news. Intuitively, since signals that align more with the prior of the receiver are shared more, improper signals will spread more, when they are biased towards the prior of the receiver. Assume that the correct prior is $p_C = \frac{1}{2}$. Thus we assume a neutral setting were both states are equally likely, but both receiver and most senders could be biased. Then, the share of improper signals relative to all signals shared equals

$$S = \frac{F(p_{Sl}|\sigma = 0)q(1-\beta) + (1 - F(p_{Sh}|\sigma = 1))q\beta}{F(p_{Sl}|\sigma = 0)P(\sigma = 0) + (1 - F(p_{Sh}|\sigma = 1))P(\sigma = 1)}, \tag{6}$$

where

$$P(\sigma = 1) = q\beta + (1-q)\frac{1}{2}$$

and

$$P(\sigma = 0) = q(1-\beta) + (1-q)\frac{1}{2}.$$

S can be seen as a measure of the quality of information after sharing. The higher is S, the lower the quality of information. Furthermore, whenever $S > q$, the quality of information deteriorates after sharing.

We now state our first result on the spread of fake news when social image concerns regarding one's worldview are relevant.

Proposition 6. *Assume $p_R > 0.5$, $\eta > 1/2$ and $q < 1$.*

- *When $\beta = \frac{1}{2}$ the quality of information does not change after sharing, $S = q$.*
- *When $\beta > \frac{1}{2}$ the quality of shared information, S, decreases in p_R.*
- *When $\beta < \frac{1}{2}$ the quality of shared information, S, increases in p_R.*

When social image concerns revolve around worldview we find that the problem of fake news sharing is especially relevant when the belief of the receiver is aligned with the bias of the fake news shared. The stronger the belief (the higher p_R), the more quality of information deteriorates if $\beta > 0.5$ and thus fake news are biased towards the belief of the receiver. This is in contrast to the previous section, in which the problem of fake news sharing was especially relevant when fake news were biased against the belief of the receiver and surprising signals were shared disproportionally.

When does an increase in p_R result in $S - q > 0$ when $\beta > \frac{1}{2}$? Inspecting Equation 6, it can be easily verified that $S > q$ will hold when $\beta > \frac{1}{2}$ and $F(p_{Sl}|\sigma = 0) < 1 - F(p_{Sh}|\sigma = 1)$, or $\beta < \frac{1}{2}$ and $F(p_{Sl}|\sigma = 0) > 1 - F(p_{Sh}|\sigma = 1)$ while $S < q$ will hold when $\beta > \frac{1}{2}$ and $F(p_{Sl}|\sigma = 0) > 1 - F(p_{Sh}|\sigma = 1)$, or $\beta < \frac{1}{2}$ and $F(p_{Sl}|\sigma = 0) < 1 - F(p_{Sh}|\sigma = 1)$. Whenever for $\beta > \frac{1}{2}$ an increase in p_R at some point leads to $F(p_{Sl}|\sigma = 0) < 1 - F(p_{Sh}|\sigma = 1)$ in equilibrium, $S > q$ results. In contrast, if for example η is very high, a high β will imply $F(p_{Sl}|\sigma = 0) > 1 - F(p_{Sh}|\sigma = 1)$ even for high p_R and thus $S \leq q$ for all p_R. Similarly, an increase in p_R may not lead to $S < q$ for $\beta < \frac{1}{2}$ when q is very large, as then $\widehat{p}_R < \frac{1}{2}$ may hold for all p_R.

To illustrate the effect of the other parameters, q, η and β, we assume that prior beliefs follow a uniform distribution, $p_S \sim U[0,1]$. We further set $p_R = \frac{2}{3}$ and thus the receiver is biased towards $\omega = 1$. [12]

Figure 2 plots $S - q$ as a function of β and q for two values of η.

[12] Results on the comparative static regarding p_R were discussed in Proposition 6. General comparative statics are harder for q, η and β, as now all conditional beliefs of the receiver, $\widehat{p}_S^U(0)$, $\widehat{p}_S^U(1)$ and $\widehat{p}_S^U(\emptyset)$ depend

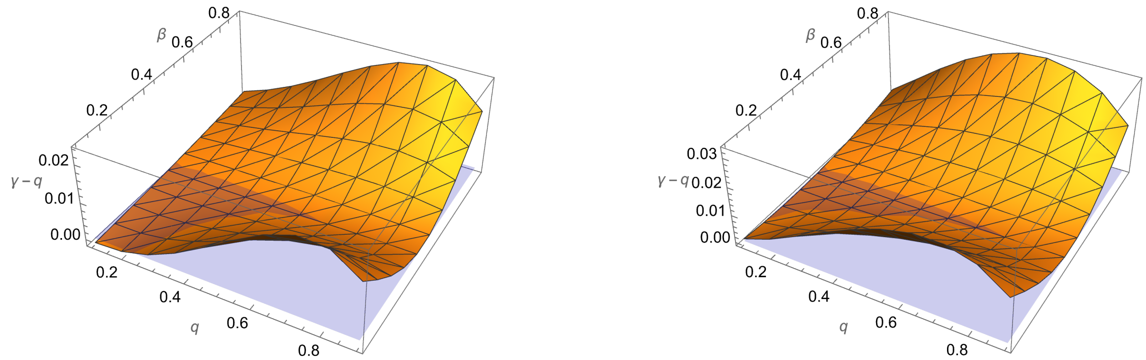

Figure 2: Quality of signals after relative to before sharing $(S - q)$ as a function of q and β, given $\eta = \frac{2}{3}$ (left panel) and $\eta = \frac{9}{10}$ (right panel), with $p_R = \frac{2}{3}$.

5.3 Receiver Welfare

Finally, we turn to welfare. Consider the situation where $\eta > 1 - p_R$ and thus the signal is potentially informative enough but fact checking costs are too high, and thus we are in the equilibrium described. How do we evaluate welfare in this setting? First of all, signals that align with her prior are not relevant to the receiver, and as we showed, relevant signals are shared relatively sparely with her. At the same time, senders do not "filter" signals conditional on their headline, thus the quality of information before and after sharing *conditional on* σ is the same. Two cases are possible. First, η is too low or q is too high and thus signal precision is not high enough the change the action of the receiver. Then sharing everything, sharing nothing and the equilibrium we characterize in this section are welfare equivalent. Second, η is sufficiently high or q is sufficiently low that signals do affect the optimal action. Then the sharing equilibrium is preferred to no sharing, but inferior to a situation where all signals are shared.

on these parameters, while for p_R it is only $\widehat{p}_S^U(\emptyset)$. On the one hand, q, η and β all influence $\widehat{p}_R$ through a change in the beliefs of the receiver. An increase in q moves it in the direction of β, an increase in η in the direction of p_R and an increase in β increases $\widehat{p}_R$. Second, all these variables influence the posterior distribution of beliefs of the sender. Extreme values of β bias updates in one direction. An increase in η polarizes the ex-post distribution of beliefs, as updating is stronger and an increase in q dampens updating. More concretely, these will influence $F(p_S|\sigma = 0)$ and $F(p_S|\sigma = 1)$.

6 Empirical Implications

In their recent work on Twitter posts, Vosoughi et al. (2018) show that fake news are shared disproportionally. Understanding why individuals share information and what role receivers play is crucial in understanding the consequences of this finding. We have found that both social status from sharing high quality information, and social image from signaling one's worldview may lead the quality of information to deteriorate after sharing. At the same time, the exact sharing patterns predicted by each motive differ:

- With a *veracity* motive this happens when improper signals are biased to be *surprising* to the receiver. Especially *low-type senders with different priors* share these improper signals.
- With a *worldview* motive this happens when improper signals are biased to *conform* to the receiver's prior. Especially *senders with similar priors* share these improper signals.

Vosoughi et al. (2018) also find the following: a) fake news are more novel than the truth, especially political news exhibit fake news cascades, and users who spread false news had significantly fewer followers. Interestingly, each of our social image motives only partially explains these findings. Under a veracity motive a) and c) are expected. a) implies that fake news are biased to be relevant, which equals *(bias β)* in our model. b) implies that it is low ability types that share fake news, which is also a prediction of the veracity model. Finally, b) seems to be more consistent with our worldview motive. Especially in political news, ideology is important and thus information seeking may not be very important for the receiver. This is found in our *(strong prior)* assumption, where signals are not actually informative. We think it would be very interesting to study these properties of fake news conditional on the type of news they represent. In very recent empirical work Pennycook et al. (2021) find that different motives matter for sharing information between peers, and they can be influenced by redirecting attention. When signaling one's identity is more salient fake news are spread knowingly (when they are aligned with one's identity), but if signaling that one is able to recognize veracity becomes more important, fake news sharing is reduced. Our model shows that this may not always lead to a satisfactory outcome. While in situations where fake news are shared disproportionally under a worldview motive, nudging towards accuracy (and thus an ability motive) may work, there will be other situations where ability signaling leads to worse quality of information than worldview signaling. Furthermore, the supply and properties of fake news are not fixed, but will likely adjust to the dominant motive.

A Mathematical Appendix

A.1 Proof of Lemma 1

Denote by $\hat{q}$ the belief of a receiver that the shared signal is fake and, slightly abusing notation, by $\hat{p}(\hat{q})$ the updated belief that $\omega = 1$ given the shared signal.

$\eta \geq p_R$. Assume the receiver received a signal $\sigma = 1$. Because $p_R > 0.5$, without checking the receiver takes action $a = 1$, getting an expected utility of $-(1 - \hat{p}(\hat{q}))$. If she checks the signal, with a probability of $\hat{q}$ she learns that the signal is fake and in that case she takes action $a = 1$ with belief $\hat{p}(1) = p$. With a probability of $1 - \hat{q}$, she learns that the signal is proper, and then she takes action $a = 1$ with belief $\hat{p}(0)$. The difference in expected utilities is

$$\begin{aligned}
\Delta^1 &= -(1 - \hat{p}(\hat{q})) + \hat{q}(1 - \hat{p}(1)) + (1 - \hat{q})(1 - \hat{p}(0)) \\
&= -1 + \hat{p}(\hat{q}) + \hat{q} - \hat{q}\hat{p}(1) + 1 - \hat{p}(0) - \hat{q} + \hat{q}\hat{p}(0) \\
&= \hat{p}(\hat{q}) - \hat{q}\hat{p}(1) - (1 - \hat{q})\hat{p}(0)
\end{aligned}$$

Now note that by Bayesian consistency,

$$\hat{p}(\hat{q}) = \hat{q}\hat{p}(1) + (1 - \hat{q})\hat{p}(0) \tag{7}$$

But this implies that $\Delta^1 = 0$. Hence, a high ability sender will never check a signal that is not surprising.

Next assume the receiver received a signal $\sigma = 0$. The quality of the signal is lower than η because the signal may be fake, and so it is unclear whether the receiver takes action 0 or 1. First assume that without checking the signal is informative enough to induce a belief $\hat{p}(\hat{q}) < \frac{1}{2}$. Then, without checking the signal, she chooses to takes action $a = 0$, yielding an expected utility of $-\hat{p}(\hat{q})$. If she decides to check the signal, she will realize with a probability of $\hat{q}$ that the signal is fake, and hence she would choose to take action $a = 1$ with expected utility $-(1 - \hat{p}(1))$. If she finds out that the signal is proper, she takes action $a = 0$ with an expected utility of $-\hat{p}(0)$. The difference in expected utilities from not checking and checking is

$$\Delta^0 = -\hat{p}(\hat{q}) + \hat{q}(1 - \hat{p}(1)) + (1 - \hat{q})\hat{p}(0)$$

Using (7), this becomes

$$\begin{aligned}
\Delta^0 &= -\hat{q}\hat{p}(1) - (1 - \hat{q})\hat{p}(0) + \hat{q}(1 - \hat{p}(1)) + (1 - \hat{q})\hat{p}(0) \\
&= -\hat{q}\hat{p}(1) + \hat{q}(1 - \hat{p}(1)) = \hat{q}(1 - 2\hat{p}(1)) < 0
\end{aligned}$$

where the last inequality follows from $\hat{p}(1) = p > \frac{1}{2}$. Hence, in this situation it is better to check the signal.

Finally, assume that without checking the signal is not very informative and we have $\hat{p}(\hat{q}) > \frac{1}{2}$. Then, without checking the signal, the receiver chooses to take action $a = 1$, yielding an expected utility of $-(1 - \hat{p}(\hat{q}))$. If she decides to check the signal, she will realize that with a probability of $\hat{q}$ the signal is fake, and hence she would takes action $a = 1$ with expected utility $-(1 - \hat{p}(1))$. If she finds out that the signal is proper, she takes action $a = 0$ with an expected utility of $-\hat{p}(0)$. The difference in expected utilities from not checking and checking is

$$\begin{aligned} \Delta^{0'} &= -(1 - \hat{p}(\hat{q})) + \hat{q}(1 - \hat{p}(1)) + (1 - \hat{q})\hat{p}(0) \\ &= \hat{p}(\hat{q}) - 1 + \hat{q} - \hat{q}\hat{p}(1) + \hat{p}(0) - \hat{p}(0)\hat{q} \end{aligned}$$

Using (7), this becomes

$$\begin{aligned} \Delta^{0'} &= \hat{q}\hat{p}(1) + (1 - \hat{q})\hat{p}(0) - 1 + \hat{q} - \hat{q}\hat{p}(1) + \hat{p}(0) - \hat{p}(0)\hat{q} \\ &= (1 - \hat{q})\hat{p}(0) - 1 + \hat{q} + \hat{p}(0) - \hat{p}(0)\hat{q} \\ &= 2\hat{p}(0)(1 - \hat{q}) - (1 - \hat{q}) = (2\hat{p}(0) - 1)(1 - \hat{q}) < 0, \end{aligned}$$

where the last inequality follows from $\hat{p}(0) < \frac{1}{2}$. Hence, also in this situation has the high ability receiver an incentive to check the signal.

$\eta < p_R$. If $\sigma = 1$, we can follow the above steps again to show that the receiver does not have an incentive to check. If $\sigma = 0$, as before the quality of the signal is lower than η because the signal may be fake. However, because $\eta < p_R$, it is clear now that the receiver takes action 1 independent of the signal's veracity. Without checking the signal, the receiver chooses to take action $a = 1$, yielding an expected utility of $-(1 - \hat{p}(\hat{q}))$.

If she decides to check the signal, she will realize that with a probability of $\hat{q}$ the signal is fake, and hence she would take action $a = 1$ with expected utility $-(1 - \hat{p}(1))$. With a probability of $1 - \hat{q}$ she finds out that the signal is proper, and she takes also action $a = 1$ with an expected utility of $-(1 - \hat{p}(0))$. The expected utility from checking is

$$-\hat{q}(1 - \hat{p}(1)) - (1 - \hat{q})(1 - \hat{p}(0)) - c = -\left(1 - \hat{q}\hat{p}(1) - (1 - \hat{q})\hat{p}(0)\right) - c = -(1 - \hat{p}(\hat{q})) - c,$$

where the last steps follows from (7). This is smaller than $-(1 - \hat{p}(\hat{q}))$, and thus the receiver won't check such a signal, either. This proves the lemma. □

A.2 Proof of Proposition 1

We first prove that not sharing is an equilibrium if off-equilibrium beliefs are sufficiently low. Imagine an equilibrium in which no information is shared. Then, along the equilibrium path, both types of senders obtain a status utility of λ_S. Deviating leads to off-equilibrium social image belief π^D and to deviation utility $\pi^D - c$. Hence, there is no incentive to deviate iff $\lambda_S \geq \pi^D - c \Leftrightarrow \pi^D \leq \lambda_S + c$. If $\lambda_S + c \geq 1$, then this is trivially fulfilled for all off-equilibrium beliefs $\pi^D \in [0, 1]$. This proves the first part of the proposition.

We next prove that any equilibrium with information sharing is Pareto-dominated by this equilibrium if $c > 0$. Assume that an equilibrium with information sharing exists. In such an equilibrium, we must have that both types share information with positive probability. If only the high ability type shares, than the receiver holds upon observing a shared signal a belief of one, and thus the low ability type would deviate and start sharing. If only the low ability type shares, than the receiver holds belief zero. and hence the low type would deviate to not sharing.

Furthermore, both types sharing with positive probability can only be an equilibrium if for both we have $\pi - c \geq \pi_\emptyset$, where π is the expected social image utility from sharing and $\pi_\emptyset$ the social image utility if no signal is shared. This means that $\pi > \pi_\emptyset$ must hold for any $c > 0$, which in turn implies that the high ability type needs to share more signals than the low ability type. Thus, the low ability type needs to randomize between sharing and not sharing therefore needs to be indifferent: $\pi - c = \pi_\emptyset$. This will also hold for the high ability type. Because a shared signal is more likely to be sent by a high ability type, a not shared signal is more likely to be held by a low type, and therefore $\pi_\emptyset < \lambda_S$. But this means that both types' utility is lower in the sharing equilibrium than in the equilibrium without sharing, and hence the sharing equilibrium is Pareto dominated. □

A.3 Proof of Lemma 2

Assume the low type shares all signals, while the high type does not. Then, upon not observing a signal, the receiver's belief about the sender's type being high is 1. But then the low type has an incentive to deviate. This proves the first part of the lemma.

Next assume the high type shares all signals, while the low type does not. This means the high type does not filter signals, and therefore veracity cannot signal status. After not observing a signal, status utility is zero, because only the low ability type keeps some signals. Note that we need to have $\kappa_0 = \kappa_1 < 1$. If we had $\kappa_1 \neq \kappa_0$, then the high ability type would share one signal realization relatively more frequently than the low ability type, and hence this signal realization would signal status. To see this, assume without loss of generality that $\kappa_1 > \kappa_0$. Then status from sharing $\sigma = 0$ is greater than status from sharing $\sigma = 1$. But this means the low ability type can gain by deviating to sharing $\sigma = 0$ more often. Hence, this cannot be an equilibrium. Therefore, it must be true that $\kappa_0 = \kappa_1 < 1$.

If $\kappa_0 = \kappa_1 < 1$, then sharing any signal realization yields the same status of $\lambda' > \lambda$, and hence a utility of $\lambda' - c$. Not sharing yields a status of zero. Therefore, the low ability type has an incentive to deviate to share more signals if $\lambda' > c$. If $\lambda' < c$, then both types have an incentive to deviate and share less. Only if $\lambda' = c$ could there be an equilibrium in which the high ability sender shares all signals, while the low ability sender keeps some signals to himself. But then both receive an equilibrium utility of zero. $\square$

A.4 Proof of Proposition 2

Define the probability from the receiver's point of view that the sender receives a surprising signal by

$$z_0^R = q(1-\beta) + (1-q)\left(p_R(1-\eta) + (1-p_R)\eta\right)$$

and the probability of receiving a proper surprising signal by

$$z_{0\mathcal{P}}^R = (1-q)\left(p_R(1-\eta) + (1-p_R)\eta\right).$$

Given our above defined notation, and assuming the claimed equilibrium probabilities $\chi_1 = \chi_{0\mathcal{F}} = \kappa_1 = 0$ and $\chi_{0\mathcal{P}} = 1$, the relevant beliefs about the sender's ability are as follows.

If a surprising signal is relayed, there are three different beliefs that can happen. A high ability receiver will check the signal's veracity and thus holds belief $\pi_{0\mathcal{F}} = 0$ if the signal is fake. If the signal is proper, the belief is

$$\pi_{0\mathcal{P}} = \frac{\lambda_S z_{0\mathcal{P}}^R}{\lambda_S z_{0\mathcal{P}}^R + (1-\lambda_S) z_{0\mathcal{P}}^R \kappa_0} = \frac{\lambda_S}{\lambda_S + (1-\lambda_S)\kappa_0}.$$

A low ability receiver does not know the signal's veracity and hence holds belief

$$\pi_{0\mathcal{U}} = \frac{\lambda_S z_{0\mathcal{P}}^R}{\lambda_S z_{0\mathcal{P}}^R + (1-\lambda_S) z_0^R \kappa_0}.$$

Note that $\pi_{0\mathcal{P}} > \pi_{0\mathcal{U}}$ because $z_0 < z_{0\mathcal{P}}$. Moreover, $\pi_{0\mathcal{P}} > \lambda_S$, because $\kappa_0 < 1$. If no signal is shared, the belief is

$$\pi_\emptyset = \frac{\lambda_S(1-z^R_{0\mathcal{P}})}{\lambda_S(1-z^R_{0\mathcal{P}}) + (1-\lambda_S)\left[(1-z^R_0+z^R_0(1-\kappa_0)\right]}.$$

Finally, the belief a low ability sender holds regarding the veracity of a surprising signal he holds is

$$\tilde{q} = \frac{z^S_{0\mathcal{F}}}{z^S_{0\mathcal{F}}+z^S_{0\mathcal{P}}} = \frac{z^S_{0\mathcal{F}}}{z^S_0}, \tag{8}$$

where $z^S_{0\mathcal{F}} = q(1-\beta) = z^S_0 - z^S_{0\mathcal{P}}$, and $z^S_0(z^S_{0\mathcal{P}})$ equals $z^R_0(z^R_{0\mathcal{P}})$ but replacing p_R by p_S. Thus, $\partial\tilde{q}/\partial q > 0$. We need these different beliefs to define the expected utility of the sender from sharing a given signal. If the sender knows a surprising signal to be proper, she receives expected utility equal to

$$u_{0\mathcal{P}} = \lambda_R\pi_{0\mathcal{P}} + (1-\lambda_R)\pi_{0\mathcal{U}} - c.$$

Sharing a signal that is known to be fake yields

$$u_{0\mathcal{F}} = (1-\lambda_R)\pi_{0\mathcal{U}} - c.$$

If the signal's veracity is not known, sharing a surprising signal yields an expected utility of

$$\begin{aligned} u_{0\mathcal{U}} &= \lambda_R\left(\tilde{q}\cdot 0 + (1-\tilde{q})\pi_{0\mathcal{P}}\right) + (1-\lambda_R)\pi_{0\mathcal{U}} - c \\ &= \lambda_R(1-\tilde{q})\pi_{0\mathcal{P}} + (1-\lambda_R)\pi_{0\mathcal{U}} - c \end{aligned}$$

Not sharing a signal implies no sharing cost c, and hence yields expected utility $u_\emptyset = \pi_\emptyset$. Finally, off-equilibrium sharing of a non-surprising signal yields $u^D_1 = \tilde{\pi}_1 - c$.

Define $\Delta := u_{0\mathcal{U}} - u_\emptyset$. In equilibrium, it must hold that the low ability sender is indifferent between sharing and keeping her signal, $\Delta = 0$. Moreover, she must weakly prefer not to share a non-surprising signal to deviating and sharing it, $u_\emptyset \geq u^D_1$. Hence, we need $u_{0\mathcal{U}} = u_\emptyset \geq u^D_1$.

First assume $\kappa_0 = 1$. (*In the following we still have* $p_R = p_S$) Then

$$\Delta|_{\kappa_0=1} = \lambda_R(1-\tilde{q})\lambda_S + (1-\lambda_R)\frac{\lambda_S z_{0\mathcal{P}}}{\lambda_S z_{0\mathcal{P}} + (1-\lambda_S)z_0} - c - \frac{\lambda_S(1-z_{0\mathcal{P}})}{\lambda_S(1-z_{0\mathcal{P}}) + (1-\lambda_S)(1-z_0)}$$

This expression is decreasing in both c and $\tilde{q}$. Thus, if $\Delta|_{\kappa=\tilde{q}=0} < 0$, then generally $\Delta|_{\kappa=\tilde{q}=0} <$

0. We have

$$\Delta|_{\kappa_0=1\wedge c=\tilde{q}=0} = \lambda_R\lambda_S + (1-\lambda_R)\frac{\lambda_S z_{0\mathcal{P}}}{\lambda_S z_{0\mathcal{P}} + (1-\lambda_S)z_0} - \frac{\lambda_S(1-z_{0\mathcal{P}})}{\lambda_S(1-z_{0\mathcal{P}}) + (1-\lambda_S)(1-z_0)} < 0$$
$$\Leftrightarrow \lambda_R + (1-\lambda_R)\frac{z_{0\mathcal{P}}}{\lambda_S z_{0\mathcal{P}} + (1-\lambda_S)z_0} < \frac{(1-z_{0\mathcal{P}})}{\lambda_S(1-z_{0\mathcal{P}}) + (1-\lambda_S)(1-z_0)} < 0$$

The LHS increases in $z_{0\mathcal{P}}$, while the RHS decreases in it. The greatest possible value it can take is z_0. Then the LHS becomes 1, and so does the RHS. But this implies that for any $z_{0\mathcal{P}} < z_0$, $\Delta|_{\kappa_0=1\wedge c=\tilde{q}=0} < 0$ holds, and thus also $\Delta|_{\kappa_0=1} < 0$ holds true. Hence, even if sharing is costless, the low ability sender will keep some signal to himself.

Next assume $\kappa_0 = 0$. Then

$$\Delta|_{\kappa_0=0} = \lambda_R(1-\tilde{q}) + (1-\lambda_R) - c - \frac{\lambda_S(1-z_{0\mathcal{P}})}{\lambda_S(1-z_{0\mathcal{P}}) + (1-\lambda_S)} \tag{9}$$

Our goal is to show that this is positive when c is sufficiently small, hence let $c = 0$. Then

$$\begin{aligned}
\Delta|_{\kappa_0=0} &= \lambda_R(1-\tilde{q}) + (1-\lambda_R) - \frac{\lambda_S(1-z_{0\mathcal{P}})}{\lambda_S(1-z_{0\mathcal{P}}) + (1-\lambda_S)} > 0 \\
&\Leftrightarrow 1 - \frac{\lambda_S(1-z_{0\mathcal{P}})}{\lambda_S(1-z_{0\mathcal{P}}) + (1-\lambda_S)} > \lambda_R\tilde{q} \\
&\Leftrightarrow \frac{1}{\lambda_R}\frac{1-\lambda_S}{\lambda_S(1-z_{0\mathcal{P}}) + (1-\lambda_S)} > \tilde{q} \\
&\Leftrightarrow \frac{1}{\lambda_R}\frac{1-\lambda_S}{\lambda_S(1-z_{0\mathcal{P}}) + (1-\lambda_S)} > \frac{z_{0\mathcal{F}}}{z_{0\mathcal{F}} + z_{0\mathcal{P}}}
\end{aligned}$$

The RHS decreases in $z_{0\mathcal{P}}$, the LHS increases in it. Hence, let $z_{0\mathcal{P}} = 0$. Then we have

$$\frac{1}{\lambda_R}(1-\lambda_S) > 1,$$

which is always true. This implies that as long as c is small enough, $\Delta|_{\kappa_0=0} > 0$. However, when c becomes large, this changes. Hence, there exists $\bar{c}$ such that if $c < \bar{c}$, then $\Delta|_{\kappa_0=0} > 0$. Because for all c it holds that $\Delta|_{\kappa_0=1} < 0$, and because Δ is a continuous function of κ_0, it follows from the intermediate value theorem that there exists $\kappa_0^* \in (0,1)$ such that $\Delta(\kappa_0^*) = 0$. Now assume $c > 0$. To prove existence of the equilibrium discussed in the proposition, we need to show that (9) is positive. Note that q enters (9) only through $\tilde{q}$, and $\tilde{q}$ increases in q. Therefore, when $\Delta|_{\kappa_0=0} > 0$ for some q', then the same is true for all $q < q'$. But does such

q' always exist? When $q \to 0$, (9) becomes

$$\Delta|_{\kappa_0=0 \wedge q=0} = 1 - c - \frac{\lambda_S(1-z_{0\mathcal{P}})}{\lambda_S(1-z_{0\mathcal{P}}) + (1-\lambda_S)} > 0.$$

As long as

$$c < \bar{c} = \frac{1-\lambda_S}{1-\lambda_S z_{0\mathcal{P}}} \in (0,1)$$

this is true. This implies that for all $c \in [0, \bar{c})$ there exists $\bar{q}(c)$ such that if $q \leq \bar{q}(c)$, then the equilibrium exists. Moreover, our above analysis reveals that $\bar{q}(0) = 1$ and $\bar{q}(\bar{c}) = 0$. That $\bar{q}(c)$ decreases in c follows from

$$\frac{\partial \bar{q}(c)}{\partial c} = -\frac{\frac{\partial \Delta|_{\kappa_0=0}}{\partial c}}{\frac{\partial \Delta|_{\kappa_0=0}}{\partial q}} = -\frac{-1}{-\lambda_S \frac{\partial \tilde{q}}{\partial q}} = -\frac{1}{\lambda_S \frac{\partial \tilde{q}}{\partial q}} < 0$$

because $\frac{\partial \tilde{q}}{\partial q} > 0$ (see (8)). When the low ability sender is indifferent between sharing and not sharing the signal, the high ability sender has a strict incentive to share a proper and surprising signal, because $u_{0\mathcal{P}} > u_{0\mathcal{U}}$. Moreover, because $u_{0\mathcal{F}} < u_{0\mathcal{U}} = u_\emptyset$, the high ability sender also keeps a fake but surprising signal to herself. Finally, no sender type has an incentive to share a not surprising signal if $\tilde{\pi}_1 - c \leq u_\emptyset \Leftrightarrow \tilde{\pi}_1 \leq c + u_\emptyset$. Such an off-equilibrium belief π^D always exists (for example $\tilde{\pi}_1 = 0$). This proves the proposition. □

A.5 Proof of Proposition 3

The comparative static result follows from totally differentiating Δ:

$$\frac{\partial \kappa_0^*}{\partial c} = -\frac{\dfrac{\partial \Delta}{\partial c}}{\dfrac{\partial \Delta}{\partial \kappa_0^*}}.$$

Because $\frac{\partial \Delta}{\partial c} = -1$, the sign of $\frac{\partial \kappa_0^*}{\partial c}$ equals the sign of $\frac{\partial \Delta}{\partial \kappa_0^*}$. Note that $u_{0\mathcal{U}}$ strictly decreases in κ_0 because both $\pi_{0\mathcal{P}}$ and $\pi_{0\mathcal{U}}$ decrease in it. Further, $u_\emptyset$ increases in κ_0. Hence, $\Delta = u_{0\mathcal{U}} - u_\emptyset$ must decrease in κ_0. Consequently, $\partial \kappa_0^* / \partial c < 0$. □

A.6 Proof of Proposition 4

Take the definition of γ:

$$\gamma := \frac{\sigma^{\mathcal{F}}}{\sigma^{\mathcal{F}} + \sigma^{\mathcal{P}}}.$$

We know that this increases in κ_0^*. Hence, let $\kappa_0^* = 1$. Then we have

$$\sigma^{\mathcal{P}}\big|_{\kappa_0^*=1} = (1-q)\left[p_T(1-\eta) + (1-p_T)\eta\right]$$

and

$$\sigma^{\mathcal{F}}\big|_{\kappa_0^*=1} = q(1-\beta)(1-\lambda_S)$$

and hence

$$\gamma|_{\kappa_0^*=1} = \frac{q(1-\beta)(1-\lambda_S)}{(1-q)\left[p_T(1-\eta)+(1-p_T)\eta\right] + q(1-\beta)(1-\lambda_S)}.$$

This is monotone decreasing in β as

$$\frac{\partial\, \gamma|_{\kappa_0^*=1}}{\partial \beta} = \frac{(1-\lambda)(1-q)q((2\eta-1)p_T-\eta)}{(\eta+(2\eta-1)p_T(q-1)-q(\beta(-\lambda)+\beta+\eta+\lambda-1))^2} < 0 \Leftrightarrow (2\eta-1)p_T - \eta < 0,$$

which is always true. To see this note that the LHS is maximized if $\eta = 1$ when $p_T > \frac{1}{2}$ and when $\eta = \frac{1}{2}$ when $p_T < \frac{1}{2}$. In the first case, the LHS is $p_T - \eta < 0$, in the latter $-p_T < 0$. Finally, if $p_T = \frac{1}{2}$, the the LHS equals $-\frac{1}{2} < 0$.

To prove the proposition we hence only need to set $\gamma|_{\kappa_0^*=1} = q$ and solve for β, which yields

$$\tilde{\beta} = 1 - \frac{(1-p_T)\eta + p_T(1-\eta)}{1-\lambda_S} < 1.$$

If $\beta < \tilde{\beta}$, then $\gamma < q$, independent of κ_0^*. This proves the proposition. □

A.7 Proof of Proposition 5

First we prove existence of equilibrium. Combining the two equations by eliminating $\widehat{p}_S^U(\emptyset)$, we get

$$\begin{aligned} 2p_{Sl} - \widehat{p}_S^U(0) &= 2p_{Sh} - \widehat{p}_S^U(1) \\ \Leftrightarrow \tfrac{\widehat{p}_S^U(1)-\widehat{p}_S^U(0)}{2} &= p_{Sh} - p_{Sl} \end{aligned}$$

This implies that in equilibrium $p_{Sl} < p_{Sh}$ needs to hold, as $\widehat{p}_S^U(1) \geq \widehat{p}_S^U(0)$ always holds by their definition (strictly so except when $\eta = 0.5$, $p_{Sl} = 1$ and $p_{Sh} = 0$). Also note that the RHS is monotone in both thresholds, increasing in p_{Sh} and decreasing in p_{Sl} and thus monotonically increasing in $p_{Sh} - p_{Sl}$. The LHS is also monotonically increasing in p_{Sh} and monotonically decreasing in p_{Sl}. Existence of equilibrium is thus not immediately clear. Let's consider the edge cases. First $p_{Sh} = p_{Sl}$: the RHS equals zero while the LHS is strictly greater than zero. Now consider $p_{Sh} = 1$, $p_{Sl} = 0$: the RHS equals 1 while the LHS equals its maximal value of 0.5. By continuity of all functions, there exists at least one pair of thresholds (p^*_{Sl}, p^*_{Sh}) solving the equation.

□

A.8 Proof of Corollary 1

Note first that an increase in p_R implies an increase in $\widehat{p}_R$ when $\eta > 0.5$ and $q < 1$. Assume that for a given $\widehat{p}^*_R$, (p^*_{Sl}, p^*_{Sh}) solve Equations 4 and 5, which we know are unique thresholds. Then for all $\widehat{p}_R < \widehat{p}^*_R$, it holds that $p_{Sl} > p^*_{Sl}$ and $p_{Sh} > p^*_{Sh}$, and for all $\widehat{p}_R > \widehat{p}^*_R$ $p_{Sl} < p^*_{Sl}$ and $p_{Sh} < p^*_{Sh}$ for η sufficiently small. To prove this, notice first that for fixed (p_{Sl}, p_{Sh}), it holds that

$$\frac{\partial \widehat{p}^U_S(\emptyset)}{\partial \widehat{p}_R} < 0.$$

In particular, the sign of this derivative turns on the sign of

$$E[p^U_S | p^U_S \leq p_{Sh} \& \sigma = 1] - E[p^U_S | p^U_S \geq p_{Sl} \& \sigma = 0].$$

If $F(p^U_S|0)$ and $F(p^U_S|1)$ were identical (which is the case for $\eta = 0.5$), this expression is negative for any (p_{Sl}, p_{Sh}). By continuity, if the precision of the signal η is sufficiently small, it will still be negative.

A decrease in $\widehat{p}^U_S(\emptyset)$ implies that sharing no message becomes strictly preferred for a sender with posterior p^*_{Sl} and signal $\sigma = 0$ than sharing the signal. Since $\widehat{p}^U_S(0)$ and $\widehat{p}^U_S(1)$ are not directly affected by a change in p_R, p_{Sl} needs to decrease in equilibrium. Similarly, sharing no message becomes strictly dominated by sharing a message for a p^*_{Sh} type sender with signal $\sigma = 1$ and thus p_{Sh} needs to decrease as well in equilibrium.

This implies that a receiver attaching a higher probability to state $\omega = 1$ (and thus to signals $\sigma = 1$) will see more messages $\sigma = 1$ and less messages $\sigma = 0$, ceteris paribus.

(NOTE: In the uniform distribution example, the condition on η does not seem constraining. Maybe in equilibrium this case is not relevant. Can we prove that

$$E[p^U_S | p^U_S \leq p_{Sh} \& \sigma = 1] - E[p^U_S | p^U_S \geq p_{Sl} \& \sigma = 0] > 0$$

is not possible in equilibrium? It seems to converge to zero when $\eta \to 1$) □

A.9 Proof of Proposition 6

First note that for $\beta = \frac{1}{2}$, $P(\sigma = 1) = \beta = \frac{1}{2}$, $P(\sigma = 0) = 1 - \beta = \frac{1}{2}$ and thus equation 6 reduces to $S = q$. Clearly, S is independent of p_R in that case proving bullet point 1 of the proposition.

Next, notice that the only expressions in Equation 6 that depend on p_R are $F(p_{Sl}|\sigma = 0)$ and $F(p_{Sh}|\sigma = 1)$ through the thresholds p_{Sl} and p_{Sh} respectively. In particular, $F(p_{Sl}|\sigma = 0)$ is increasing in p_{Sl} and $F(p_{Sh}|\sigma = 1)$ is increasing in p_{Sh}. From Corollary 1 we know that an increase in p_R leads to a decrease in both p_{Sl} and p_{Sh}. This implies that $F(p_{Sl}|\sigma = 0)$ decreases and $1 - F(p_{Sh}|\sigma = 1)$ increases with p_R. In other words, $\sigma = 0$ is shared relatively less often, while $\sigma = 1$ is shared relatively more often. If $\sigma = 1$ is relatively more likely to be improper than $\sigma = 0$, this deteriorates the quality of information shared. This will be the case when $\beta > \frac{1}{2}$. Thus the quality of information deteriorates with p_R when $\beta > \frac{1}{2}$ while it improves with p_R when $\beta < \frac{1}{2}$. □

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