Morale, Performance, and Disclosure

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Abstract

We study the optimal disclosure policy when the receiver's performance depends on his ability, which is the state and initially unknown to himself, and his morale, which is defined as his expected ability. The receiver wins if his performance meets a target and has the option to quit to avoid losing. The state is good if the receiver wins with full knowledge of the state but bad if he quits. The sender whose interest is aligned with the receiver knows the state and either discloses or withholds it to maximize her expected payoff. In the threshold disclosure equilibrium that Pareto-dominates full disclosure, the sender only discloses sufficiently bad states to boost the receiver's morale for victory in undisclosed states. In the Pareto-optimal equilibrium, the sender discloses below-morale good states to further boost the receiver's morale for victory in more states. Benevolent opaque information control improves welfare with many applications.

Keywords: disclosure, morale, performance, information.

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1 Introduction

Henry Ford said: "Whether you think you can or you think you can't, you are right" (Lumpa and Whitaker 2005, Moser et al 2011). Indeed, people's expectations about their abilities affect their performance and choice like self-fulfilling prophecies to some extent (Dweck 2006, Raab et al 2015). Our paper concerns how an informed benevolent sender can maximizes economic efficiency by choosing her disclosure policy to affect the receiver's expectation of his[1] own ability and thereby influence his decision and performance.

We establish a theoretical framework of communication between two parties, the informed sender and the uninformed receiver. The sender observes the ability of the receiver, which is the state variable of the model and is determined stochastically by Nature at the beginning. The sender then decides to either truthfully disclose the state to the receiver or withhold it from him. Given any disclosure from the sender, the receiver decides whether to accept a risky process with an uncertain outcome that depends on his performance, or opt to quit for a certain payoff. The receiver bases his decision on his expected ability given his information set, including any disclosure from the sender. The risky process can be a challenge that the receiver may choose to circumvent, a project that the receiver has the real option to abandon, or an opportunity that the receiver can pass up, etc.

The realized outcome of the risky process, if chosen by the receiver, depends on his performance. Everything else equal, the higher the receiver's ability, the better his performance. Besides ability per se, the receiver's expectation of his ability, which we define as his morale, also affects his performance. In particular, the receiver outperforms his ability when his morale is above his ability, performs precisely at his ability when his morale equals his ability, and underperforms when his morale is below his

[1]For convenience, we use "she" to refer to the sender and "he" to refer to the receiver throughout the paper.

ability. The receiver's higher morale enhances his performance, ceteris paribus. The dependence of the receiver's performance on both his ability and his morale is kept general in our setting. If the receiver accepts the risky process, then he wins if his performance meets a certain target and loses otherwise. Victory is the favorite outcome for the sender and the receiver, and losing is worse than quitting for both parties. The sender is benevolent in that she shares the same rank-order preferences as the receiver over the three possible outcomes.

If the sender always discloses the state, then the receiver always performs at his ability, and wins if his ability is good enough but quits otherwise to avoid losing. We define the state to be good when the receiver wins under full disclosure and bad when he quits under full disclosure. This full disclosure case establishes a benchmark to evaluate alternative disclosure policies. For example, suppose the sender never discloses the state and yet the receiver always wins, then no disclosure Pareto-dominates full disclosure. The reason for such performance improvement is that when the receiver never receives any information, his morale is his unconditional expectation of his ability, which is higher than the below-expectation states and hence helps the receiver outperform in these states. If the resulting outperformance is sufficient for him to win in the worst state, then victory is attained in every state. In a way, good states cross-subsidize bad states in terms of morale so that the receiver wins in all states. The paper then focuses on solving for the optimal disclosure policy in the more interesting and complex case where it is impossible to secure victory in every state.

Since the receiver's best response under full disclosure is a threshold strategy, it is natural to explore how the sender can emulate the full-disclosure outcome by a threshold disclosure strategy. Threshold disclosure policies are prevalent in seminal papers on disclosure including Jovanovic (1982), Verrecchia (1983), Dye (1985a), Jung and Kwon (1988), Shin (1994), Shin (2003), Acharya et al (2011), and Guttman et al (2014). We examine all threshold disclosure policies in our framework and look for the ones that may give the receiver a morale boost for outperformance in the right states to increase his ex ante likelihood of victory. In contrast to the common finding in disclosure models that negative news is withheld (Verrecchia 1983, Dye 1985a), the sender withholds all the good states and discloses only the worst states that defy victory in the threshold disclosure equilibrium of our model. In other words, the optimal threshold is the lowest state in which the receiver can still win, and the sender only discloses the state if it is below the threshold. The receiver wins in all states above the threshold and quits upon learning the sender's disclosure of any state below the threshold. This equilibrium Pareto-dominates full disclosure because the receiver wins in the undisclosed bad states. It is cost-ineffective to withhold the bad states below the threshold and aim for the receiver's outperformance and victory in these states because too much cross-subsidy of morale would be required from the good states. Therefore the sender effectively gives up the disclosed bad states and chooses to exhaust the receiver's morale on the better, undisclosed bad states instead.

We find further efficiency gain when the sender uses general disclosure strategies. When the sender focuses on threshold disclosure strategies, she withholds all the good states in equilibrium. The receiver's morale in an undisclosed state is above the lowest good state in the threshold disclosure equilibrium, however, implying that the withholding of the good states that are below the receiver's morale is not only unnecessary but also wasteful. These below-morale good states do not contribute positively to the receiver's morale and in fact consumes contributions from better states above his morale. In the perfect Bayesian equilibrium where the sender uses general disclosure strategies, she discloses the good states below the receiver's morale in the undisclosed states, which enables her to withhold more bad states for the receiver's victory. The receiver still wins in each undisclosed state because otherwise the sender would find it better to disclose the losing states for the receiver to quit instead. In the optimal disclosure equilibrium, the sender only discloses the below-morale good states where the receiver wins or the worst states where the receiver cannot win and quits instead. The equilibrium disclosure strategy no longer depends on the state variable monotonically. This equilibrium Pareto-dominates the threshold disclosure equilibrium because the sender withholds more bad states where the receiver wins. We also discuss how to solve for the equilibrium when the distribution of the state variable is not continuous. Our general theory is then parametrized into two models, one with a continuous state distribution and the other with a discrete state distribution. The parametric models illustrate our methodology and main results. Finally, we discuss the various applications of our theory.

Interestingly, always disclosing the state is never optimal and never happens in equilibrium, which seems surprising given the aligned preferences of the two parties. The explanation is that the sender's opaque information control actually encourages the receiver to mobilize morale and outperform in the undisclosed bad states to win. In equilibrium, no news is good news, and the receiver infers that he can win given his expected ability in the undisclosed states. The sender's intervention coarsens the receiver's information structure regarding his ability so that the same morale is mustered and the same acceptance decision is optimal in the undisclosed states that are indistinguishable to the receiver. The receiver gathers sufficient morale to attain higher performance and make better decisions in the undisclosed bad states than if he can distinguish every state. The loss of information leads to higher economic efficiency.

Our paper is related to the broad literature on morale, which is the state of mind to maintain courage, belief, self-confidence, motivation, enthusiasm, and a sense of purpose. The influence of morale on performance is well-documented in psychology (Sullivan 1941, Dweck 2006) with applications in military (Mackenzie 1992, Hughes 2012), sports (Wann 1997, Hausenblas et al 2001), performance (Karoly and Newton 2006, Raab et al 2015), education (Rosenthal and Jacobson 1992), workplace management (Mowday et al 1982, Kierein and Gold 2000, Bezuijen et al 2009), and law enforcement (Gocke 1931). Compte and Postlewaite (2004) cite ample evidence that confidence and emotions affect performance and show that biases in information processing enhance welfare. Caillet et al (2014) discuss how the state of mind affects executive performance, and along with Cass et al (2008), offer practical advice to executives and managers. Zingoni and Corey (2017) document how mindset affects employee performance. Intasao and Hao (2018) show that beliefs about creativity influence creative performance. The abundance of evidence-based research suggests that an informed sender can design disclosure to affect an uninformed receiver's morale and thereby influence his performance.

Most economic studies of morale have focused on the agent's work morale and its relationship with wage in the principal-agent relationship. Slichter (1920) pioneers the discussion of industrial morale as employees' willingness and interest to work as well as their cooperation with management. Solow (1979) explains the downward wage ridigity in macroeconomics by the negative impact of pay cuts on workers' morale. Wage positively affects productivity via its impact on work morale in Akerlof (1982), Akerlof and Yellen (1988, 1990) who take account of fairness and reciprocity. Firms weigh the benefits to productivity against labor costs in setting wages, independent of labor market conditions. Frey (1993) argues that regulating or monitoring the agent may crowd out his work morale. Bénabou and Tirole (2003) models how extrinsic incentives may crowd out intrinsic motivation as discussed in Frey (1997). Theories of work morale are supported by survey, empirical, and experimental findings (Campbell and Kamlani 1997; Frey and Oberholzer-Gee 1997; Bewley 1998, 1999; Fehr and Falk 1999; Fehr and Gächter 2000; Kube et al 2013; Breza et al 2018; Hassink and Fernandez 2018). In contrast to this literature, we do not model agency issues or wage, as our theory concerns how the benevolent sender can choose the disclosure policy to help the receiver achieve more.

Our paper is most closely related to Fang and Moscarini (2005) who, similar to existing economic theories, also analyze worker morale in the principal-agent framework. They model a worker's morale as his belief that he has high ability, which in their model of only two ability levels is informationally equivalent to our definition of morale as the economic agent's expectation of his ability. The firm and the overconfident worker agree to disagree with different prior beliefs on the worker's ability in Fang and Moscarini (2005), whereas the two parties in our paper are rational economic agents with common priors who cannot agree to disagree (Aumann 1976). If the firm offers different wage contracts to workers with different performance evaluations that are only observable to the firm, then the firm would reveal to the workers its private information regarding their abilities. In equilibrium, the firm may choose to offer the same contract to all overconfident workers even though it observes different signals about the workers' abilities. Fang and Moscarini (2005) thus rationalizes wage compression (Baker et al 1994, Bewley 1999) by overconfident worker morale. Admittedly, their pooling equilibrium bears some semblance to our limited disclosure equilibria in that the informed party does not fully reveal its private information in equilibrium. However, disclosure is not the focus in Fang and Moscarini (2005) where the no-revelation equilibrium is driven by overconfidence. In contrast, partial disclosure is optimal in our model that specifically studies the optimal disclosure policy in a pure communication game free of distractions from behavioral biases or agency conflicts. Among our main goals is to show the absence of the unraveling result in the disclosure literature.

Our paper also closely relates to the disclosure literature in economics and accounting that has identified situations where more information may be harmful. Hirshleifer (1971) shows that more disclosure eliminates risk-sharing among different economic agents, which is not in our model. Gonedes (1980), Burguet and Vives (2000), and Amador and Weill (2012) show that public disclosure may discourage private information acquisition and social learning, a mechanism we do not consider. Teoh (1997), Morris and Shin (2002), and Angeletos and Pavan (2007) show that public disclosure may reduce social welfare when there are coordination motives which are also absent from our model. Dye (1985b) shows that more mandatory disclosure may reduce total disclosure because firms with proprietary information may make less voluntary disclosure, and firms may be less able to reveal information by their choice of accounting techniques. Our sender withholds information in order to preserve the receiver's morale and improve efficiency, which is a new explanation against mandated transparency. Firms withhold nonproprietary information in Dye (1986) to avoid revealing proprietary information when managers possess both types of information, whereas our sender has no proprietary information. Grossman and Hart (1980), Grossman (1981), and Milgrom (1981) establish the unraveling result where full disclosure occurs in equilibrium. Unraveling does not prevail either due to costly disclosure as in Jovanovic (1982) and Verrecchia (1983) or the receiver's uncertainty about the sender's information endowment as in Dye (1985a), Jung and Kwon 1988), Acharya et al (2011), and Guttman et al (2014). In contrast, neither disclosure cost nor information endowment uncertainty is part of our theoretical framework. Therefore, we identify a new reason where unraveling does not occur. With an opaque disclosure policy, the sender allows the receiver's morale in good states to cross-subsidize his morale in bad states so that staying less informed enables the receiver to achieve more. The receiver's expected ability in bad states helps him outperform his ability and make better real decisions.

Our paper is related to other communication games. Lightle (2014) shows that when noisy messages from multiple expert senders are susceptible to the receiver's misinterpretations, the experts overstate their positions or send extreme messages to avoid misinterpretations in undesirable directions. In contrast, our sender never issues biased messages, and our mechanism is different from paternalistic bias driven by noisy communication, misinterpretation by the receiver, or the multiplicity of information sources. Dewatripont and Tirole (2005) model costly information transmission and endogenous mode of communication in a sender-receiver team moral hazard problem, whereas our theory is not driven by costly or hidden actions. A less biased sender adds less noise to the state variable in cheap talk games (Crawford and Sobel 1982). The unbiased sender in our model, to the contrary, chooses to leave the receiver more uncertainty to improve efficiency. Rick (2013) shows that miscommunication can improve welfare by enriching the correspondence between the sender's strategies and the receiver's posteriors. Sandeep and Ely (2011) show that limited memory of the original motive rationalizes the sunk-cost fallacy, and Bénabou and Tirole (2004) study the role of imperfect recall in self-control. Miscommunication and memory issues are absent from our model.

Our theory relates to other fields of economics. The receiver prefers late resolution of uncertainty to preserve morale that affects performance, decision, and payoff in our model. We thus offer an expectations-based explanation for the hope experienced by the participants in the timing-of-uncertainty-resolution experiments conducted by Chew and Ho (1994). Our paper provides a natural information economics setting that generates the preferences for late resolution of uncertainty axiomatized by Chew and Epstein (1989). Wen (2013) finds that the voluntary disclosure option embedded in the real option to invest makes the latter more valuable. Our paper investigates the sender's optimal disclosure policy when the receiver has a real option to abandon via the opportunity to quit after learning the sender's disclosure. We highlight the interplay between real options and disclosure policies. Finally, the receiver's expected ability in our theory corresponds to a fully rational trader's expected ability in Gervais and Odean (2001) and is a key element of corporate finance theory (Israel 1991; Dunn and Holtz-Eakin 2000).

The rest of the paper proceeds as follows. The next section sets up our theoretical framework. Section 3 describes the benchmark case of full disclosure. We also discuss when no disclosure attains the best outcome. Section 4 derives the threshold disclosure equilibrium and Section 5 presents the optimal disclosure equilibrium. Section 6 illustrates our general results by parametric models. Section 7 discusses the applications of our theory. The final section concludes.

2 The Disclosure Game

There are two parties, the sender (S, she) and the receiver (R, he). R decides whether to accept a risky process (e.g., a challenge, a project, an opportunity, etc.) that results in an uncertain outcome, or to quit for a known, deterministic outcome. If R accepts the risky process, the outcome can be either a win (W) or a loss (L). Nature determines R's ability to win, represented as the state variable X, according to its prior distribution $F_X(x)$ on $\mathcal{X} \subset \mathbb{R}$. The state can be interpreted in a relative sense: given R's ability, the more challenging the situation is, the lower X is.

S observes the value of the state x and decides to either disclose it to R or withhold it. The sender may decide to disclose nothing, but any disclosure has to be truthful. R forms his morale as his expectation of his ability

$$m_{\mathcal{I}} = \mathbb{E}[X|\mathcal{I}] \tag{1}$$

given his information set $\mathcal{I}$ that includes any disclosure from the sender. R's performance $p(m_{\mathcal{I}}, x)$ depends on his morale and his ability, and is strictly increasing in each argument. Therefore R outperforms his ability when $m_{\mathcal{I}} > x$ and underperforms when $m_{\mathcal{I}} < x$. R performs precisely at his ability when $m_{\mathcal{I}} = x$, which corresponds to the case when he knows his ability so that $\mathcal{I} = \{x\}$.

If R accepts the risky process, then he wins if his performance meets a target $\bar{p}$:

$$p(m_{\mathcal{I}}, x) \geq \bar{p}, \tag{2}$$

and loses otherwise. The outcome affects both parties' payoffs. Victory is the most preferred outcome but losing ranks below quitting (Q):

$$U_W^i > U_Q^i > U_L^i, \tag{3}$$

where U_j^i is the payoff to player $i \in \{S, R\}$ in outcome $j \in \{W, L, Q\}$. S is benevolent in the sense that she ranks the outcomes in the same order as R. The receiver's preference for quitting over losing has rich economic interpretations. For example, the receiver's decision to accept the risky process in our model can be his decision to exert costly effort, in which case wasting effort without achieving target is worse than giving up to save the effort cost. Moreover, the receiver may also incur costs for losing per se in events like military defeat or business bankruptcy. Further interpretations and applications of our modeling framework are discussed in Section 7.

Figure 1 shows the sequence of events. Nature at $t = 1$ determines the state x. At $t = 2$, S observes x and decides whether to disclose it to R. At $t = 3$, R forms his morale given his information set. At $t = 4$, R decides to either accept the risky process or quit for the safe outcome. Finally, payoffs realize at $t = 5$.

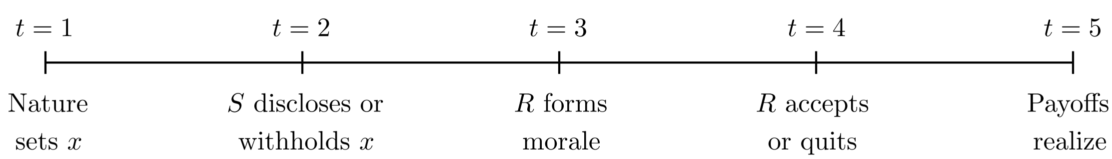

Figure 1: The Sequence of Events

We next present the benchmark case of disclosing x in all states at $t = 2$, and how no disclosure can improve welfare.

3 All or Nothing

If S always discloses R's ability x, then R's morale is $m_{\{x\}} = x$. If R accepts the risky process, then he performs at his ability and wins if

$$p(x, x) \geq \bar{p} \tag{4}$$

but loses otherwise. There is neither outperformance nor underperformance. Since R prefers winning to quitting to losing, he accepts the risky process if $p(x, x) \geq \bar{p}$ and quits otherwise.

$p(x, x)$ is increasing in x since $p(m_{\mathcal{I}}, x)$ is increasing in both arguments. Let $\bar{x}$ be the lowest ability for R to win under full disclosure:

$$\bar{x} := \inf\{x \in \mathcal{X} : p(x, x) \geq \bar{p}\}. \tag{5}$$

Then by the definition of $\bar{x}$, R would lose if he accepts given a disclosure of $x < \bar{x}$:

$$p(x, x) < \bar{p}, \tag{6}$$

and R would win if he accepts, knowing the state is $x \geq \bar{x}$:

$$p(x, x) \geq p(\bar{x}, \bar{x}) \geq \bar{p}. \tag{7}$$

Therefore R's optimal response to full disclosure depends on the threshold state $\bar{x}$. Define each state in $\mathcal{G} := \{x \in \mathcal{X} : x \geq \bar{x}\}$ as a "good" state; the rest of the states in $\mathcal{X}$ form the set of "bad" states $\mathcal{B} := \mathcal{X} \backslash \mathcal{G}$. Then R accepts the risky process and wins in good states but quits in bad states.

Table 1 summarizes how the payoffs of $i = S$ and R depend on the state x according to the outcome under full disclosure.

Table 1: Payoffs Under Full Disclosure

$x < \bar{x}$	$x \geq \bar{x}$
U^i_Q	U^i_W

The ex ante expected payoffs at $t = 1$ are

$$\Pr(\mathcal{B})U^i_Q + \Pr(\mathcal{G})U^i_W \tag{8}$$

for $i = S, R$.

If S never discloses the state, then R's morale $m_{\mathcal{X}}$ is his unconditional expected ability $\mathbb{E}[X]$. If this is sufficient morale for R to win in the worst state $\inf \mathcal{X}$:

$$p(m_{\mathcal{X}}, \inf \mathcal{X}) \geq \bar{p}, \tag{9}$$

then R wins in all states and S optimally withholds all states. R's outperformance in the bad states reverses the outcome from quitting under full disclosure to winning under no disclosure. The payoffs are U^i_W for $i \in \{S, R\}$ in all states in the no-disclosure equilibrium. No party has an incentive to deviate from having the best possible outcome in each state. No disclosure Pareto-dominates full disclosure with welfare improvement

$$\Pr(\mathcal{B})\Delta U^i_{WQ} \tag{10}$$

for $i \in \{S, R\}$, where $\Delta U^i_{WQ} := U^i_W - U^i_Q$. The welfare improvement arises from R's outperformance in the below-morale states. Proposition 1 summarizes the benchmark case of full disclosure, as well as when no disclosure improves welfare.

Proposition 1. *If S always discloses the state x, then R accepts and wins in each good state but quits in each bad state. Their expected payoffs are given by (8). If (9) holds, then S never discloses the state and R always wins in equilibrium, which attains* *the highest payoffs U_W^i for $i \in \{S, R\}$ with the associated welfare improvement over full disclosure given by (10).*

For the rest of this paper, we assume

$$p(m_{\mathcal{X}}, \inf \mathcal{X}) < \bar{p}, \tag{11}$$

so that the simple solution of no disclosure does not help R win in all states.

4 Threshold Disclosure

Since the outcome of full disclosure depends on a threshold state $\bar{x}$, this section restricts S's strategy space to threshold disclosure policies. We solve for the perfect Bayesian equilibrium and perform welfare analysis when S employs a natural and widely applied class of threshold strategies that disclose all states either above or below a certain threshold $h \in \mathcal{X}$ and withhold the rest of the states. We examine both types of threshold disclosure policies in turn. For each type, S's objective is to choose the disclosure threshold to maximize her expected payoff in equilibrium.

4.1 Withholding Negative News

Since governments, institutions, and individuals often refrain from disclosing negative information (Kothari et al 2009), conventional wisdom may suggest withholding states below h. Then for a disclosed state $x \geq h$, R's morale is $m_{\{x\}} = x$.

When S withholds the state, R believes $X < h$ and derives his morale by its definition in (1) as his expectation of the state:

$$m_{\{x<h\}} := \mathbb{E}[X|X < h] = \frac{\int_{x<h} x \, dF_X(x)}{\Pr(X < h)}. \tag{12}$$

Since h is the upper boundary of the set over which the expectation is taken, it is above

R's morale:

$$h > m_{\{x<h\}}. \tag{13}$$

Moreover, $m_{\{x<h\}}$ is increasing in h.

If $h \leq \bar{x}$, then S discloses every state in $[h, \bar{x}) \cup \mathcal{G}$. R wins in event $\mathcal{G}$ and quits in event $[h, \bar{x})$. R knows the withheld states are bad and hence quits when S withholds the state. The payoffs of S and R are no different from the benchmark case of full disclosure. For the rest of Section 4.1, consider $h > \bar{x}$ where S discloses the better part of $\mathcal{G}$ above h, but withholds its worse part $[\bar{x}, h)$ along with all bad states $\mathcal{B}$.

If R's morale in the undisclosed states is below $\bar{x}$:

$$m_{\{x<h\}} < \bar{x}, \tag{14}$$

then R may lose in state $\bar{x}$ since

$$p(m_{\{x<h\}}, \bar{x}) < p(\bar{x}, \bar{x}); \tag{15}$$

if so, then R would also lose in all bad states, and the outcome would be worse than the one under full disclosure. This is the case for continuous performance function $p(m, x)$ and distribution function $F_X(x)$ since $p(\bar{x}, \bar{x}) = \bar{p}$. Therefore the outcome is less efficient than full disclosure for many parametric specifications of our model.

The better scenario is when R's morale in the withheld states is above $\bar{x}$:

$$m_{\{x<h\}} \geq \bar{x}. \tag{16}$$

Then R wins in all good states $x \geq \bar{x}$ because

$$p(m_{\{x<h\}}, x) \geq p(\bar{x}, \bar{x}) \geq \bar{p}. \tag{17}$$

R may also win in a mildly bad state $x < \bar{x}$ since

$$p(m_{\{x<h\}}, x) \geq p(\bar{x}, x) > p(x, x). \tag{18}$$

Therefore having good states cross-subsidize bad states in the same information set can potentially help R outperform and win in some bad states. However, the better part of $\mathcal{G}$ above h is not utilized in the cross-subsidy of morale. In fact, withholding all states would boost R's morale to an even higher level:

$$m_{\mathcal{X}} \geq m_{\{x<h\}}, \tag{19}$$

which can help R win in even more states. Therefore when $m_{\{x<h\}} \geq \bar{x}$, withholding all states Pareto-dominates withholding just the states below h.

However, when S always withholds the state, R loses in some bad states according to (11). Welfare can be further improved by disclosing such states, starting from the worst state $\inf \mathcal{X}$ and going up, until R no longer loses in any state. R can improve both parties' payoffs by at least quitting in the disclosed states instead of losing. Moreover, in the process of dropping the worse part of $\mathcal{B}$ from the set of withheld states, R's morale also rises because the worst states no longer drags down the expected value of the states that are withheld. R's higher morale helps him win in more states that are withheld.

This process that improves on always withholding by disclosing worse states effectively switches our focus to the other type of threshold disclosure policies that only disclose the states below some threshold. Therefore when only threshold disclosure policies are considered, the morale cross-subsidy effect is more powerful if S withholds and thus fully utilizes all of $\mathcal{G}$ to help R outperform and win in the better states of $\mathcal{B}$ that require less help. The worse states in $\mathcal{B}$ are best disclosed for R to avoid losing by quitting. Indeed, we show in the next section how such threshold disclosure policies can obtain higher efficiency than full disclosure.

4.2 Disclosing Negative News

We now consider S's threshold strategy to only disclose the states below a threshold $h \in \mathcal{X}$ but to withhold all states above h. This section identifies the optimal threshold and shows that such opaque disclosure Pareto-dominates full disclosure.

R's morale is the state if it is disclosed. When S withholds the state, R believes $X \geq h$ and derives his morale as his expectation of the state:

$$m_{\{x \geq h\}} := \mathbb{E}[X|X \geq h] = \frac{\int_{x \geq h} x \, dF_X(x)}{\Pr(X \geq h)}. \tag{20}$$

h is the lower boundary of the set over which the expectation is taken and therefore below R's morale:

$$h \leq m_{\{x \geq h\}}. \tag{21}$$

Moreover, $m_{\{x \geq h\}}$ is increasing in h.

What threshold will S choose? If $h \geq \bar{x}$, then when S withholds the state, R knows the state is good and accepts to win. S discloses every state in $\mathcal{B} \cup [\bar{x}, h)$ for R to win in good states $[\bar{x}, h)$ and quits in all bad states. The two parties' payoffs are the same as the benchmark case of full disclosure.

We therefore consider the case of $h < \bar{x}$. Now S only discloses bad states and R quits in each disclosed state. S withholds $\mathcal{G}$ and a better part of $\mathcal{B}$, $[h, \bar{x})$, for good states to cross-subsidize R's morale in bad states. It follows that a lower h can help R in more bad states. However, if S goes overboard in such cross-subsidy by a very low h to withhold too many bad states, then condition (11) implies that R will eventually lose in the worst withheld states for a sufficiently low h. Moreover, R's morale will also be pulled low. In such situations, disclosing the worst withheld states would not only allow R to quit in such states instead of losing but also raise R's morale to win in other bad states. This implies that S should not set h so low that he loses in some very bad states despite a morale boost. Therefore it makes sense for S to choose the lowest possible threshold above which R always wins so as to fully leverage the morale cross-subsidy benefit without losing in the worst undisclosed states.

Let $\underline{x}$ be the lowest state where R can win:

$$\underline{x} := \inf\{z \in \mathcal{X} : p(m_{\{x \geq z\}}, z) \geq \bar{p}\}. \tag{22}$$

Lemma 2 summarizes the ordering of three key quantities: the threshold $\underline{x}$, the associated morale $m_{\{x \geq \underline{x}\}}$ in undisclosed states, and the boundary $\bar{x}$ between $\mathcal{B}$ and $\mathcal{G}$.

Lemma 2. $m_{\{x \geq \underline{x}\}} \geq \bar{x} \geq \underline{x}$.

It turns out that $\underline{x}$ is indeed the threshold of disclosure in equilibrium.

Theorem 3. *In the perfect Bayesian equilibrium where S uses threshold disclosure policies,*

- *S discloses each state x below $\underline{x}$ defined in (22), and R quits with morale x;*
- *S withholds states $x \geq \underline{x}$, and R accepts with morale $m_{\{x \geq \underline{x}\}}$ and wins.*

This equilibrium Pareto-dominates full disclosure.

Table 2 summarizes how payoffs vary with the state x for the disclosure policy with threshold $\underline{x}$.

Table 2: Payoffs Under the Threshold Disclosure Policy at $\underline{x}$

$x < \underline{x}$	$x \geq \underline{x}$
U_Q^i	U_W^i

The corresponding expected payoffs are

$$\Pr(X < \underline{x})U_Q^i + \Pr(X \geq \underline{x})U_W^i. \tag{23}$$

for $i = S, R$.

Contrasting Table 2 with Table 1 shows that in the equilibrium where S employs threshold disclosure policies, R wins in more states and quits in fewer states than under full disclosure. Lower transparency generates higher payoffs for S and R when $x \in [\underline{x}, \bar{x})$ without affecting their payoffs in other states. Therefore the opaque threshold disclosure policy Pareto-dominates full disclosure with welfare improvements

$$\Pr(\underline{x} \leq X < \bar{x}) \Delta U^i_{WQ} \tag{24}$$

for $i \in \{S, R\}$, where $\Delta U^i_{WQ} := U^i_W - U^i_Q$. The welfare improvement arises from R's victory in more adverse states. In this preferred equilibrium, S withholds $\mathcal{G}$ and the better part of $\mathcal{B}$, which enables R to mobilize morale to win in the undisclosed bad states. Opaqueness benefits both parties relative to transparency.

When S withholds the state, R forms a morale $m_{\{x \geq \underline{x}\}}$ that is averaged over $[\underline{x}, \bar{x}) \cup \mathcal{G}$. This elevates R's morale in the bad states withheld by S relative to the case of full disclosure. By Lemma 2, R's morale upon no disclosure in the threshold disclosure equilibrium is even higher than a good state $\bar{x}$, which enables R to accept and win in the withheld bad states $[\underline{x}, \bar{x})$.

Threshold disclosure policies are a natural, classic, and widely applied type of disclosure policies. Related papers include Jovanovic (1982), Verrecchia (1983), Dye (1985a), Jung and Kwon (1988), Shin (1994), Shin (2003), Acharya et al (2011), Guttman et al (2014), Bertomeu and Magee (2015), Jiang and Yang (2021). The optimal threshold disclosure policy we have identified improves both parties' welfare beyond the benchmark case of full disclosure. Moreover, its optimality among all threshold disclosure policies does not depend on the type of the probability distribution of the state. However, the corresponding threshold disclosure equilibrium is not necessarily the Pareto optimal perfect Bayesian equilibrium if non-threshold disclosure strategies are allowed. In the next section, we will improve on the optimal threshold disclosure policy to identify the Pareto-optimal perfect Bayesian equilibrium when S has a general strategy space.

5 Optimal Disclosure

In this section, we generalize the analysis in Section 4 to identify the perfect Bayesian equilibrium of the disclosure game when S can choose any disclosure strategy. The general strategy of S in our framework consists of states that are disclosed and states that are withheld.

Suppose S discloses all states in $\mathcal{D}$ and withholds all states in $\mathcal{A} := \mathcal{X} \backslash \mathcal{D}$. We further decompose $\mathcal{A}$ and $\mathcal{D}$ into their respective subsets of good and bad states:

$$\mathcal{D}_g := \mathcal{D} \cap \mathcal{G},\ \mathcal{D}_b := \mathcal{D} \backslash \mathcal{D}_g,\ \mathcal{A}_g := \mathcal{G} \backslash \mathcal{D}_g,\ \mathcal{A}_b := \mathcal{A} \backslash \mathcal{A}_g. \tag{25}$$

For example, the optimal threshold disclosure policy derived in Section 4 has $\mathcal{A} = \{x \in \mathcal{X} : x \geq \underline{x}\}$, $\mathcal{A}_g = \mathcal{G}$, $\mathcal{A}_b = \{x \in \mathcal{B} : x \geq \underline{x}\}$, $\mathcal{D} = \mathcal{D}_b = \{x \in \mathcal{B} : x < \underline{x}\}$, and $\mathcal{D}_g = \varnothing$.

R's morale equals the state when it is disclosed. When S withholds the state, R's morale is

$$m_{\mathcal{A}} := \mathbb{E}[X|X \in \mathcal{A}] = \frac{\int_{x \in \mathcal{A}} x\, dF_X(x)}{\Pr(X \in \mathcal{A})}. \tag{26}$$

To search for S's choice of $\mathcal{A}$ and $\mathcal{D}$ in equilibrium, we begin by asking what equilibrium outcome any optimal disclosure policy should exhibit. The outcome is no different from that under full disclosure for the disclosed states: R quits for each state in $\mathcal{D}_b$ and wins for each state in $\mathcal{D}_g$. If R quits when S withholds the state, then R only wins in states in $\mathcal{D}_g \subset \mathcal{G}$ but quits in all other states, which is no better than full disclosure and worse than the threshold disclosure equilibrium outcome in Theorem 3, Section 4. Therefore in equilibrium, R accepts the risky process in event $\mathcal{A}$. If R loses in any state in $\mathcal{A}$, then it is optimal for S to disclose such state instead, which would allow R to avoid losing and enhance $m_{\mathcal{A}}$. Therefore in equilibrium R should win in each state in $\mathcal{A}$. To sum up the equilibrium outcome, R accepts and wins in event $\mathcal{A} \cup \mathcal{D}_g$ but quits in event $\mathcal{D}_b$.

We now formalize S's optimal disclosure problem. S chooses the disclosure strategy to maximize her expected payoff:

$$\sup_{\mathcal{A} \subset \mathcal{X}} \Pr(\mathcal{D}_b) U_Q^S + \Pr(\mathcal{A} \cup \mathcal{D}_g) U_W^S. \tag{27}$$

s.t. R wins in every state $x \in \mathcal{A}$:

$$p(m_{\mathcal{A}}, x) \geq \bar{p}. \tag{28}$$

Similar to our analysis in Section 4, S helps R win in event $\mathcal{A}$ by selectively withholding some good states $\mathcal{A}_g$ and some bad states $\mathcal{A}_b$ so that R's morale upon non-disclosure is sufficient to support victory in each undisclosed state. The remaining question is what $\mathcal{A}_b$ and $\mathcal{A}_g$ are optimal.

We take the optimal threshold disclosure policy in Section 4 as our starting point and see how we can improve on it. The only possible improvement is to reduce $\Pr(\mathcal{D}_b)$ so that R wins instead of quitting with higher probability. The optimal threshold disclosure policy had $\mathcal{D}_g = \varnothing$. Can S improve efficiency by choosing a non-empty $\mathcal{D}_g$ instead? Recall that S withholds all good states to help R mobilize morale to win in some bad states. According to Lemma 2, R's morale $m_{\{x \geq \underline{x}\}}$ is higher than the lowest good state $\bar{x}$. However, the good states $[\bar{x}, m_{\{x \geq \underline{x}\}})$ that are below R's morale are subsidized by the other good states above $m_{\{x \geq \underline{x}\}}$, which is unnecessary and in fact wasteful given the scarcity of morale. Disclosing the below-morale good states would maintain victory in these states and raise morale which can help bad states. In general, we have $[\bar{x}, m_{\mathcal{A}}) \subset \mathcal{D}_g$ because disclosing them has no impact on R's victory in these states and raises R's morale to support victory in more bad states. This implies

$\inf \mathcal{A}_g \geq m_{\mathcal{A}}$. Since any state above $m_{\mathcal{A}}$ contributes to enhancing morale and should be included in $\mathcal{A}$, we have

$$\mathcal{A}_g = \{x \in \mathcal{X} : x \geq m_{\mathcal{A}}\} \tag{29}$$

and hence

$$\mathcal{D}_g = \{x \in \mathcal{X} : x \in [\bar{x}, m_{\mathcal{A}})\}. \tag{30}$$

Having split $\mathcal{G}$ into $\mathcal{A}_g$ and $\mathcal{D}_g$, we now focus on separating $\mathcal{B}$ into $\mathcal{A}_b$ and $\mathcal{D}_b$. An equivalent goal of S is to help R mobilize morale to maximize the ex ante probability of winning, which boils down to maximizing $\Pr(\mathcal{A}_b)$. To help R win in bad states leveraging morale, S can start from the highest bad states just below $\bar{x}$ that require the least help from good states and then gradually include more and more lower states from $\mathcal{B}$. Then as more bad states are included in $\mathcal{A}$, (11) implies that we eventually reach a point where R can no longer win.

What should happen next depends on whether X is a continuous random variable. If the distribution of X has atoms such as when X is a discrete or mixed random variable, the optimal disclosure of S can be different than when no value of X has a probability mass. For example, if a bad state with a large probability mass reduces R's morale upon its inclusion in $\mathcal{A}$ to the extent that R loses in this state, it may be suboptimal to stop the process of constructing $\mathcal{A}_b$. It can be optimal to skip the bad atom and move on to include the states immediately below it. In contrast, such a situation does not arise for a continuous X, and S is done constructing $\mathcal{A}_b$ as soon as the feasibility condition (28) fails for a state.

The type of the probability distribution of X made no difference when we focused on threshold disclosure strategies in Section 4. This is because maximizing the probability of winning was equivalent to optimizing the disclosure threshold since no skipping is allowed by the definition of threshold disclosure strategies. This is why we mentioned at the end of Section 4 that the equilibrium disclosure threshold identified in Theorem 3 does not depend on the type of the probability distribution of X, which is an advantage of threshold disclosure policies apart from their wide applications and natural appeal.

For general disclosure strategies, we will examine continuous X before tackling distributions with atoms.

5.1 Continuous X

Suppose X is a continuous random variable so that every state has zero probability mass. Since R wins in every state in $\mathcal{A}$, we have

$$p(m_{\mathcal{A}}, \inf \mathcal{A}) \geq \bar{p}. \tag{31}$$

Moreover, the states below $\inf \mathcal{A}$ are not included in $\mathcal{A}$ because R would lose if they are included. Therefore

$$p(m_{\mathcal{A}\cup\{x\}}, x) < \bar{p} \tag{32}$$

for state $x < \inf \mathcal{A}$.

Lemma 4 below not only specifies the ordering of some key quantities in equilibrium but also separates $\mathcal{B}$ into $\mathcal{A}_b$ and $\mathcal{D}_b$ for continuous state distributions.

Lemma 4. *In equilibrium,* $m_{\mathcal{A}} \geq \bar{x} \geq \underline{x} \geq \inf \mathcal{A}$, $\mathcal{A}_b = [\inf \mathcal{A}, \bar{x})$, $\mathcal{D}_b = [\inf \mathcal{X}, \inf \mathcal{A})$.

The equilibrium outcome is intuitive and consistent with our analysis. S discloses the worst states that do not make it into $\mathcal{A}$ for R to quit and avoid losing. $\underline{x} \geq \inf \mathcal{A}$ is also anticipated. As we have discussed, the threshold disclosure equilibrium in Section 4 withholds the below-morale good states but disclosing them would raise R's morale and allow S to withhold more bad states in which R can win. The optimal general disclosure policy completed this optimization process and hence enables R to win in states where he quits in the threshold disclosure equilibrium.

$\mathcal{A}_b$ in Lemma 4 and $\mathcal{A}_g$ in (29) imply that the full set of the undisclosed states is

$$\mathcal{A} = \mathcal{A}_b \cup \mathcal{A}_g = [\inf \mathcal{A}, \bar{x}) \cup [m_{\mathcal{A}}, \sup \mathcal{X}]. \tag{33}$$

Figure 2 illustrates the optimal disclosure strategy.

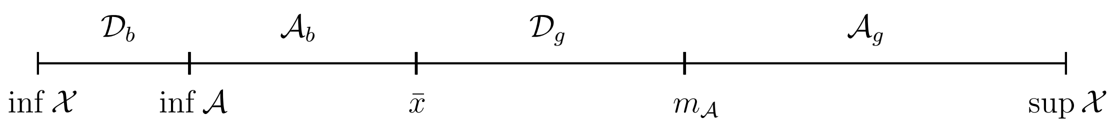

Figure 2: Disclosure in Equilibrium for Continuous X

When S withholds the state, R forms morale $m_{\mathcal{A}}$ and accepts to win. When S discloses the state, R wins in the good states in $\mathcal{D}_g$ and quits in the bad states in $\mathcal{D}_b$. Given his information set, R has no incentive to deviate. S would not withhold the states in $\mathcal{D}_b$ because otherwise R would lose according to (32). S would not disclose the states in $\mathcal{A}_b$ because such disclosure would lead R to quit instead of winning. S would not withhold the states in $\mathcal{D}_g$ because doing so would lower R's morale $m_{\mathcal{A}}$ and adversely affect the outcome in the undisclosed bad states. S would not disclose the states in $\mathcal{A}_g$ because such disclosure would also lower $m_{\mathcal{A}}$. Therefore neither R nor S would deviate and the equilibrium we have described is indeed the perfect Bayesian equilibrium of the general-strategy disclosure game.

Table 3: Payoffs Under the Optimal Disclosure Policy for Continuous X

$x < \inf \mathcal{A}$	$x \geq \inf \mathcal{A}$
U_Q^i	U_W^i

Table 3 shows how welfare depends on the state in equilibrium. The ex ante expected payoff in the perfect Bayesian equilibrium is

$$\Pr(X < \inf \mathcal{A}) U_Q^i + \Pr(X \geq \inf \mathcal{A}) U_W^i \tag{34}$$

for $i = S$ and R. The payoffs under the optimal general disclosure policy in Table 3 clearly improve on the payoffs under the optimal threshold disclosure policy in Table 2 since R wins in more states, i.e., the states in $[\inf \mathcal{A}, \underline{x})$. The optimal disclosure equilibrium Pareto-dominates the threshold disclosure equilibrium in Section 4 as well as full disclosure. The welfare improvement over the threshold disclosure equilibrium is

$$\Pr(\inf \mathcal{A} \leq X < \underline{x}) \Delta U^i_{WQ} \tag{35}$$

and the welfare improvement over the benchmark case of full disclosure is

$$\Pr(\inf \mathcal{A} \leq X < \bar{x}) \Delta U^i_{WQ}. \tag{36}$$

Such welfare improvement is possible because the threshold disclosure equilibrium withholds the unnecessary burden of the below-morale good states while any such burden is offloaded in the optimal disclosure equilibrium.

R wins with the highest ex ante probability in the Pareto-optimal perfect Bayesian equilibrium. S withholds good and bad states for R to mobilize morale in this equilibrium most preferred by both S and R. Opaqueness benefits both parties and is chosen over transparency. Theorem 5 summarizes the equilibrium and welfare analysis in this section.

Theorem 5. *If X is a continuous random variable, then in the Pareto-optimal perfect Bayesian equilibrium,*

- *S withholds each state in $\mathcal{A}$ given by (33), and R accepts the risky process with morale $m_{\mathcal{A}}$ and wins;*
- *S discloses each state x in $\mathcal{D}_g$ given by (30), and R accepts the risky process with morale x and wins;*
- *S discloses each state x in $\mathcal{D}_b$ given by Lemma 4 and R quits with morale x.*

This optimal disclosure equilibrium Pareto-dominates the threshold disclosure equilibrium and full disclosure.

5.2 X with Atoms

Now suppose X has atoms in its distribution, such as when X is a discrete random variable or a mixed random variable. Values of X with nonzero probability mass do not necessarily disrupt the equilibrium in Theorem 5; at least $\mathcal{A}_g$ and $\mathcal{D}_g$ remain the same. However, complexity may arise in splitting $\mathcal{B}$ into $\mathcal{A}_b$ and $\mathcal{D}_b$. As discussed, S's process to construct $\mathcal{A}_b$ starts from immediately below $\bar{x}$ and moves down to include worse states. If the inclusion of an atomic state would not cause R to lose in that state, then whether the state has probability mass is irrelevant. This is because S chooses to withhold the bad states that need the least help from the good states. If the atom is indeed the correct next one to withhold and its inclusion into the existing $\mathcal{A}_b$ does not cause R to lose, then S should just withhold it without treating it any differently from a set of contiguous non-atomic states with positive total probability measure. In other words, S should not skip the atom or make any other adjustment. A state x with $\Pr(X = x) > 0$ makes a difference only when

$$p(m_{\mathcal{A}^x \cup \{x\}}, x) < \bar{p} \tag{37}$$

where $\mathcal{A}^x$ denotes the set of withheld states just before including x. Define such x as "problematic" atoms, then these atoms should be disclosed for R to avoid losing. However, should S stop here and claim $\mathcal{A}^x$ as the optimal disclosure? Not yet, because S should still check the states below x to see if any of them should be withheld. S can stop only when R loses in every state below x if that state is withheld. This helps S attain the goal of maximizing R's ex ante probability to win.

Therefore S can identify the equilibrium $\mathcal{A}_b$ by following Algorithm 6 below each time that a problematic atom is encountered in the process of constructing $\mathcal{A}_b$ until the process terminates.

Algorithm 6. *Consider problematic atoms $x_1 > x_2 > ...$ and the associated sets of withheld states $\mathcal{A}^1 \subset \mathcal{A}^2 \subset ...$ just before including x_i. Each $\{x_i, \mathcal{A}^i\}$ satisfies*

$$p(m_{\mathcal{A}^i \cup \{x_i\}}, x_i) < \bar{p}. \tag{38}$$

Follow the steps below starting from $i = 1$ to construct the $\mathcal{A}_b$ in equilibrium:

1. *If each state $x < x_i$ also satisfies*

$$p(m_{\mathcal{A}^i \cup \{x\}}, x) < \bar{p}, \tag{39}$$

then the process terminates with

$$\mathcal{A}_b = (x_i, \bar{x}) \backslash \{x_1, x_2, ..., x_{i-1}\} \tag{40}$$

in equilibrium.

2. *Otherwise skip x_i and move down to include lower states until either some state x_0 with zero probability mass satisfies*

$$p(m_{\mathcal{A}^0 \cup \{x_0\}}, x_0) < \bar{p}, \tag{41}$$

or an atom x_j with $j > i$ satisfies

$$p(m_{\mathcal{A}^j \cup \{x_j\}}, x_j) < \bar{p}. \tag{42}$$

In the former case, the process terminates with

$$\mathcal{A}_b = (x_0, \bar{x}) \backslash \{x_1, x_2, ..., x_i\} \tag{43}$$

in equilibrium. In the latter case, repeat the previous and the current steps until the process terminates.

In Step 1, the fact that the algorithm reaches x_i implies that all prior problematic atoms $\{x_1, x_2, ..., x_{i-1}\}$ have been skipped and all other states above x_i have been included. The algorithm optimally terminates at a problematic atom x_i when the inclusion of every state below x_i into the set of withheld states would also cause R to lose. Otherwise, the process optimally terminates at a state with no probability mass for the same reason as in the equilibrium specified by Theorem 5.

6 Parametric Models

We illustrate our methodology and main results with two parametric models. The distribution of the state variable X has no atom in the first model and has atoms in the second one. The models in this section use the performance function

$$p(m_{\mathcal{I}}, x) = m_{\mathcal{I}} + x. \tag{44}$$

We set the performance target $\bar{p} = 0$ without loss of generality, so that $\mathcal{B} = \{x \in \mathcal{X} : x < 0\}$, $\mathcal{G} = \{x \in \mathcal{X} : x \geq 0\}$, and $\bar{x} = \inf \mathcal{G}$ according to its definition in (5). R accepts the risky process and wins in event $\mathcal{G}$ but quits in event $\mathcal{B}$ under full disclosure. Table 4 shows the associated payoffs for $i = S$ and R.

Table 4: Payoffs Under Full Disclosure

$x < 0$	$x \geq 0$
U_Q^i	U_W^i

The expected payoffs for $i = S$ and R are

$$\Pr(X < 0)U_Q^i + \Pr(X \geq 0)U_W^i \tag{45}$$

which we take as the benchmark for comparisons.

6.1 Continuous Distribution

For continuous performance function $p(m, x)$ and distribution function $F_X(x)$, the inequalities that define the key threshold states such as (5) for $\bar{x}$, (22) for $\underline{x}$, and (31) for $\inf \mathcal{A}$ hold with equality.

Consider a uniform distribution on $[a, b]$ for the state, where $a < 0 < b$. R's morale based on the prior is

$$m_{\mathcal{X}} = \mathbb{E}[X] = \frac{a+b}{2}. \tag{46}$$

Condition (9) translates into

$$\frac{a+b}{2} + a \geq 0, \tag{47}$$

which is equivalent to $b \geq -3a$. If it holds, then the optimal disclosure is $\mathcal{D} = \varnothing$ for R to win in all states, which brings out the best payoffs of U_W^i for $i \in \{S, R\}$ in every state. For the rest of this section, consider the more interesting case of $b < -3a$, which is condition (11) for the uniform distribution model.

We have $\mathcal{B} = [a, 0)$, $\mathcal{G} = [0, b]$, and $\bar{x} = 0$. If $\mathcal{A} = \varnothing$, then R accepts and wins in event $\mathcal{G}$ but quits in event $\mathcal{B}$. The corresponding expected payoffs are

$$\frac{b\, U_W^i - a\, U_Q^i}{b - a} \tag{48}$$

for $i = S$ and R under full disclosure.

6.1.1 Threshold Disclosure

We identify $\underline{x}$ to find the optimal threshold disclosure policy in Theorem 3. The optimal threshold state $\underline{x}$ is defined to satisfy

$$m_{[\underline{x}, b]} + \underline{x} = 0, \tag{49}$$

so that R wins when $\mathcal{A} = [\underline{x}, b]$, where

$$m_{[\underline{x},b]} = \frac{\underline{x} + b}{2}. \tag{50}$$

Plug this into equation (49) and solve for $\underline{x}$ to obtain

$$\underline{x} = -\frac{b}{3}. \tag{51}$$

By Theorem 3, S chooses

$$\mathcal{D} = \left[a, -\frac{b}{3}\right), \ \mathcal{A} = \left[-\frac{b}{3}, b\right] \tag{52}$$

in the threshold disclosure equilibrium, and R wins in event $\mathcal{A}$ but quits in event $\mathcal{D}$. Their expected payoffs are

$$\frac{b\,U^i_W - a\,U^i_Q}{b-a} + \frac{\Delta U^i_{WQ}}{3} \times \frac{b}{b-a}, \tag{53}$$

which exceed the expected payoffs under full disclosure. Therefore low transparency improves welfare. We have thus illustrated and validated Theorem 3 for the uniform distribution.

6.1.2 Optimal Disclosure

Theorem 5 states that to find the optimal disclosure, we need to specify $\inf \mathcal{A}$ and $m_{\mathcal{A}}$. The two quantities need to satisfy condition (31) for R to win in event $\mathcal{A}$, which becomes

$$m_{\mathcal{A}} + \inf \mathcal{A} = 0, \tag{54}$$

where R's morale in event $\mathcal{A}$ is

$$m_{\mathcal{A}} = \frac{b^2 - m_{\mathcal{A}}^2 - (\inf \mathcal{A})^2}{2(b - m_{\mathcal{A}} - \inf \mathcal{A})}. \tag{55}$$

for the uniform distribution. We thus have two equations in two unknowns. Substitute $\inf \mathcal{A} = -m_{\mathcal{A}}$ into the expression of R's morale in event $\mathcal{A}$ to obtain

$$2m_{\mathcal{A}}^2 + 2bm_{\mathcal{A}} - b^2 = 0, \tag{56}$$

which can be solved to yield

$$m_{\mathcal{A}} = \frac{\sqrt{3}-1}{2}b. \tag{57}$$

Therefore

$$\inf \mathcal{A} = \frac{1-\sqrt{3}}{2}b \approx -0.366b < -\frac{b}{3} = \underline{x}, \tag{58}$$

which implies that R indeed wins in worse states than the lowest state in which he can win under the threshold disclosure equilibrium. By Theorem 5, the optimal disclosure policy in equilibrium is

$$\mathcal{D}_b = \left[a, \frac{1-\sqrt{3}}{2}b\right), \ \mathcal{A} = \left[\frac{1-\sqrt{3}}{2}b, 0\right) \cup \left[\frac{\sqrt{3}-1}{2}b, b\right), \ \mathcal{D}_g = \left[0, \frac{\sqrt{3}-1}{2}b\right). \tag{59}$$

The corresponding expected payoffs are

$$\frac{b\,U_W^i - a\,U_Q^i}{b-a} + \frac{(\sqrt{3}-1)\,\Delta U_{WQ}^i}{2} \times \frac{b}{b-a} \tag{60}$$

which are higher than the expected payoffs in (53) for the threshold disclosure equilibrium and the expected payoffs in (48) under full disclosure. Therefore well-designed opaqueness Pareto-dominates transparency. Theorem 5 has thus been demonstrated and verified for the uniform distribution.

6.2 Atomic Distribution

Consider three states $x_l < x_m < 0 < x_h$ with associated probabilities $q_l, q_m, q_h > 0$ that add up to 1. Then $\mathcal{B} = \{x_l, x_m\}$, $\mathcal{G} = \{x_h\}$, and $\bar{x} = x_h$. R accepts and wins in state x_h but quits in states x_l and x_m under full disclosure. The corresponding expected payoffs are

$$(q_l + q_m)\, U_Q^i + q_h\, U_W^i \tag{61}$$

for $i = S$ and R.

Condition (9) is equivalent to

$$m_{\mathcal{X}} + x_l \geq 0, \tag{62}$$

where

$$m_{\mathcal{X}} = q_h\, x_h + q_m\, x_m + q_l\, x_l. \tag{63}$$

This is the simple case when $\mathcal{D} = \varnothing$ and R always wins in equilibrium. The rest of this section assumes (62) fails and tackles the complex case.

6.2.1 Threshold Disclosure

To find the optimal threshold disclosure policy in Theorem 3, we identify $\underline{x}$. The first state below $\bar{x} = x_h$ to check is x_m. In order that $\underline{x} = x_m$, R must win when $\mathcal{A} = \{x_m, x_h\}$:

$$m_{\{x_m, x_h\}} + x_m \geq 0, \tag{64}$$

where

$$m_{\{x_m, x_h\}} = \frac{q_m\, x_m + q_h\, x_h}{1 - q_l}. \tag{65}$$

The condition reduces to

$$(1 - q_l + q_m)\, x_m + q_h\, x_h \geq 0. \tag{66}$$

(66) is essentially the feasibility condition (28) for $\mathcal{D} = \{x_l\}$ in S's optimal disclosure problem for the current atomic state model. If this feasibility condition holds, then $\mathcal{D} = \{x_l\}$ in the threshold disclosure equilibrium. R wins in states x_m and x_h but quits in state x_l. The expected payoffs are

$$q_l\, U_Q^i + (q_m + q_h)\, U_W^i \tag{67}$$

for $i \in \{S, R\}$, which are higher than their expected payoffs in (61) under full disclosure.

The left-hand side of (66) exceeds the left-hand side of (62) since $(1 - q_l)\, x_m > (1 + q_l)\, x_l$, which implies that the feasibility condition for no state to be disclosed is more stringent than the feasibility condition for only x_l to be disclosed. This makes sense because withholding all states brings into $\mathcal{A}$ the worst state x_l and yet R needs to win in all states.

If (66) fails, however, then S does not withhold x_m in equilibrium because doing so would lead to R's loss in state x_m. The optimal threshold disclosure policy only withholds x_h, which is equivalent to full disclosure. Proposition 7 summarizes the threshold disclosure equilibrium of the atomic model.

Proposition 7. *In the threshold disclosure equilibrium of the atomic state model,*

1. *if (66) holds, then S only discloses state x_l, and R quits with morale x_l in state x_l but accepts with morale $m_{\{x_m, x_h\}}$ and wins when the state is undisclosed;*
2. *if (66) fails, then the outcome is equivalent to the one under full disclosure.*

Case 1 has $\underline{x} = x_m < x_h = \bar{x}$, which is consistent with Lemma 2. The optimal threshold disclosure policy, despite its opaqueness, outperforms full disclosure as stated in Theorem 3.

6.2.2 Optimal Disclosure

We now find the optimal disclosure policy examined in Section 5. It is possible for the non-threshold disclosure strategy $\mathcal{D} = \{x_m\}$ to be optimal according to Algorithm 6. This corresponds to the situation where R loses in the atomic state x_m when it is included into $\mathcal{A}$. Yet when S skips x_m in constructing $\mathcal{A}$ and moves down to withhold x_l with x_h, R can still win in state x_l if

$$m_{\{x_l, x_h\}} + x_l \geq 0, \tag{68}$$

where

$$m_{\{x_l, x_h\}} = \frac{q_l\, x_l + q_h\, x_h}{1 - q_m}. \tag{69}$$

The feasibility condition for $\mathcal{D} = \{x_m\}$ reduces to

$$(1 + q_l - q_m)\, x_l + q_h\, x_h \geq 0. \tag{70}$$

When this holds, R wins in states x_l and x_h if they are withheld. The left-hand side of (70) exceeds the left-hand side of (62) since $(x_m + x_l) q_m < 0$, which implies that the feasibility condition for never disclosing the state is more stringent than the feasibility condition for disclosing only x_m. When $\mathcal{A} = \{x_l, x_h\}$ and $\inf \mathcal{A} = x_l$, the two parties' expected payoffs are

$$q_m\, U_Q^i + (q_l + q_h)\, U_W^i \tag{71}$$

for $i \in \{S, R\}$, which exceed their expected payoffs in (61) under full disclosure. Moreover, the expected payoffs when $\mathcal{D} = \{x_m\}$ are higher than the expected payoffs when $\mathcal{D} = \{x_l\}$ if

$$q_l > q_m. \tag{72}$$

The feasibility condition for $\mathcal{D} = \{x_m\}$ is less stringent than the feasibility condition for $\mathcal{D} = \{x_l\}$ when the left-hand side of (70) exceeds the left-hand side of (66), or

$$q_m > q_l + \frac{x_l - x_m}{x_l + x_m}. \tag{73}$$

Therefore as long as q_m is sufficiently higher than q_l, then S can still disclose just x_m when (66) fails. This is precisely the complication that Algorithm 6 is designed to address. When S detects that (66) fails and moves on to try including x_l into $\mathcal{A}$, she is invoking the algorithm that tackles problematic atomic states. Proposition 8 summarizes the optimal disclosure equilibrium in the atomic state disclosure game.

Proposition 8. *In the optimal disclosure equilibrium of the atomic state model,*

1. *if (66) holds and either $q_m \geq q_l$ or (70) fails, then the equilibrium is the same as Case 1 of the threshold disclosure equilibrium in Proposition 7;*
2. *if (70) holds and either $q_m < q_l$ or (66) fails, then S only discloses state x_m, and R quits with morale x_m in state x_m but accepts the risky process with morale $m_{\{x_l, x_h\}}$ and wins when the state is undisclosed;*
3. *if (66) and (70) fails, then the outcome is equivalent to that of full disclosure.*

The equilibrium in Case 2 is unavailable under threshold disclosure policies. When S's strategy space is unrestricted, Case 2 improves both parties' expected payoffs in the optimal disclosure equilibrium relative to the threshold disclosure equilibrium. The optimal disclosure equilibrium Pareto-dominates the threshold disclosure equilibrium as well as full disclosure as shown in Theorem 5.

7 Applications

This section discusses the potential applications of our theory in various areas. The benevolent S in our model may care about R's welfare, or be in the same boat as R, or internalize R's payoff to some extent.

A social planner cares about its agents' welfare. When a nation faces a crisis such as invasion, the informed government (S) may decide not to immediately disclose the exact state of the war to avoid demoralizing the soldiers (Sullivan 1941, Mackenzie 1992, Hughes 2012) or panicking the citizens (APA 1942). Nevertheless, if the armies and the people cannot win even with elevated morale from the lack of disclosure, then disclosing the precise dire situation for withdrawal is better than incurring a disastrous loss. This was the main point of contention during World War II between former U.K. Prime Minister Neville Chamberlain who preferred negotiating peace with Hitler and his successor Sir Winston Churchill who preferred fighting till the end. In his first national address, Churchill rallied the British people to wage war and conquer enemies instead of disclosing the prospect of losing the British army in Dunkirk (Manchester and Reid 2012). Churchill successfully boosted the nation's morale and led Britain from the brink of defeat to victory, which was a major turning point of World War II (Lukacs 1999, Korda 2017). He paid much attention to wartime morale and famously said "Success is not final, failure is not fatal. It is the courage to continue that counts" (Lukacs 2002), which has inspired generations and professions to date (Briggs 2014).

A bad state was withheld with good intentions again in the U.K. 80 years later. It was not revealed until November that Prince William was hit hard by COVID-19 in April (Holden 2020). He was quoted saying "There were important things going on and I didn't want to worry anyone." Indeed, it is conceivable how demoralizing the disclosure would have been to the British people if they were told in April that the second-in-line to the throne also fell sick after the heir-to-throne Prince Charles caught the virus and the Prime Minister Boris Johnson entered intensive care (Keown 2020b). It did not hurt or hinder the public not knowing Prince William's illness in April and may have actually helped in the darkest days of isolation and despair during COVID lockdowns when many already suffered much both physically and psychologically (Anurudran et al 2020, Bade et al 2020, Greene 2020, Rudenstine et al 2020, Troutman-Jordan and Kazemi 2020, Aguilar et al 2021, Brown and Schuman 2021, Stockwell et al 2021). COVID infections of public figures indeed caused panics such as when Boris Johnson (Keown 2020a), former U.S. President Donald Trump (Li et al 2020), and actor Tom Hanks (Chiu and Barbash 2020, Imbert and Franck 2020) fell sick. Even among the reported infections, Johnson and Trump were actually much sicker than they might have appeared in earlier vague reports, according to the detailed updates months later (Adam and Booth 2020, Keown 2020b, Weiland et al 2021). Withholding the exact severity of leaders' illness may also have been well-intended to preempt demoralizing the public.

The COVID-19 pandemic is not the first crisis where a public figure's sickness went undisclosed. The same happened when former U.S. President Woodrow Wilson contracted the 1918 influenza while attending peace talks in Paris (August 2020, Karimi 2020, Siemaszko 2020, Solly 2020). In fact, the withholding of the state on the 1918 pandemic occurred at a much larger scale for a seemingly greater good of national security. The Spanish flu is a misnomer because most affected countries other than Spain were belligerents in World War I and censored media to preserve morale (Enns 2010, Maryon-Davis 2015, CDC 2018, Brown 2019). Our theory does not suggest denying a crisis or misinforming the public on the appropriate coping measures (Abutaleb et al 2020, Friedman 2020). In our model, R understands the characteristics of the challenging situation and how to succeed, whether or not S discloses the exact severity of the state. A nation engaged in World War I can promulgate and enforce public health orders against the flu without disclosing the infections or their severity among royal families or leaderships to avoid demoralizing the people. Therefore, all the anecdotal evidence are consistent with the implications of our model that withholding the state sometimes can be beneficial as it can boost the receiver's morale and increase the likelihood to win.

Our theory also applies to the business world. For instance, a consultancy's partner (S) and her consultant (R) are in the same boat since both the consultant's job security and the partner's reputation among clients rely on the consultant's performance on the client project. The highly experienced partner knows how challenging a project is but may choose not to inform or discourage the consultant if he can handle it with average confidence and enthusiasm. More generally in the workplace, a manager and an employee are in the same boat. If the worker's ability is insufficient even with a morale boost, then it is in their best interest to turn down a difficult project for outsourcing or reassignment to another team rather than failing it with severe consequences for the organization and its stakeholders. Our theory also suggests that managers may elevate the morale of employees working on a project by withholding honest criticisms from regular or interim constructive feedback and discussing them in year-end performance reviews instead (Fuchs 2007, Manso 2011, Chen and Chiu 2013).

Our theory lends itself to education and coaching. Educators and coaches (S) care about their students and candidates (R). A faculty advisor of a doctoral student may choose not to discourage the student with the bleak prospect of struggling to graduate. This helps the student stay calm and focus on producing a thesis. However, if the advisor deems the student incapable of completing a satisfactory dissertation even with reasonable buoyancy and hope, then it is best for the advisor to be upfront about her evaluation of the student's ability for him to quit the doctoral program early. Similarly, professors tend to encourage students enrolled in their courses to persist and earn the credit rather than dropping the course. If a professor teaching an advanced course perceives that a student lacks understanding of the fundamentals and is very likely to fail, however, then disclosing her honest opinion for the student to withdraw from the course is better than having him fail the course. Likewise in sports and performing arts, coaching by appropriate disclosures and cues can allow candidates to infer good expectations and outperform (Raab et al 2015).

Family members care about each other and internalize each other's payoff. A parent (S) whose child (R) faces an advanced task may choose not to discourage him with facts but allow him to attempt with zest. Family members (S) of a patient (R) who starts battling with a disease may hide the severity of the disease to encourage him to think positive and pull through. Medical workers may withhold information from patients if disclosure would increase their psychological, cognitive, and emotional burdens or cause distress in patients' decision-making or coping (Epstein et al 2010). In such situations, our paper shows that someone whose interest is aligned with the patient can be entrusted with information about the patient, which is consistent with the guidelines for medical professionals to share information with the patient's surrogate such as a family member (Epstein et al 2010). Scheier and Carver (1985) interpret optimism in the psychology and medicine literature as expectations that good things will happen. R is optimistic in our model when his expectation of his ability is good enough for him to accept the risky process. The health benefits of positive expectations are well-documented for optimistic patients (Scheier et al 1989, Schulz et al 1996). Besides fighting with illnesses, optimistic economic agents also cope better with transitions (Aspinwall and Taylor 1992) or failures (Kraaij et al 2010). Indeed, an uninformed person's informed family and caretakers can optimize disclosure to help him cope with diseases, treatments, transitions, and failures. Nevertheless, late-stage terminal diseases corresponding to the worst states in our model should probably be disclosed for the patient to make the most of his final days.

Limited disclosure from S helps R avoid the potentially negative consequences of facing a bad situation. Information avoidance enables people to retain some hope (Chew and Ho 1994, Brashers et al 2000) or wishful thinking (Elisa 2011). For example, some people prefer not knowing their HIV status and avoid testing due to fear, stress, and burden of a positive test result, the consequent adverse psychological sufferings, the stigma and discrimination associated with HIV-positive patients, the financial consequences of living with HIV, and worries about confidentiality issues (Christopoulos et al 2012, Jürgensen et al 2012, Musheke et al 2013, Krause et al 2013). Likewise, an individual affected by basiphobia (fear of falling) or acrophobia (fear of heights) would not feel fearful if he does not know or see his precarious position. These observations resonate with the implication of our theory that the economic agent's welfare can be improved by having a layer of benevolent information control. The Native American advice to "jump when you see a chasm in life for it is not as wide as you think" emphasizes the importance of courage and morale in times of difficulty. Still, mustering up morale in seemingly hopeless situations can be difficult, and the only way to not be affected by decision-relevant information is to never know it. Having S withhold good and bad states in our model saves R the trouble of sustaining morale in bad states. The power and beauty of limited disclosure and information control by someone else with aligned interest lie in the protection of the economic agent from knowing information directly that prevents mobilizing morale. It is best to let a friend help one stay in the dark if knowing will demoralize the agent and lead to suboptimal decisions.

The moral of our theory of morale and disclosure is that it can be Pareto-optimal for the benevolent sender to withhold good and bad news to help the receiver mobilize morale to survive a challenging situation. To materialize such benefits, however, the sender needs the permission to withhold information for the purpose of attaining efficiency. In practice, however, some individuals, entities, and nations are less able to withhold information than others due to disclosure laws or ethical issues. A silver lining to opaque organizations or societies with weaker disclosure laws and ethics is that they can potentially benefit more from influencing economic agents' morale, decisions, and performance than transparent organizations or societies. Such benefit may diminish over time due to the new digital age that makes it harder to withhold information compared to the old days when newspaper, radio, and television were the main sources of information. Moreover, a centralized information management and control system makes limited disclosure more accomplishable.

8 Conclusions

This paper has developed a general theory of how the economic agent's morale as his expected ability affects his performance and how a benevolent sender can maximize efficiency by choosing whether to disclose the receiver's ability to optimize his decision and performance. We show that the threshold disclosure equilibrium, where the sender only discloses the worst states that defy victory, Pareto-dominates full transparency. The sender withholds the states above the equilibrium threshold to help the receiver muster enough morale to win in all good states and the undisclosed bad states. Efficiency is further improved in the optimal disclosure equilibrium where the sender also discloses the below-morale good states, which further boosts the receiver's morale to allow him to win in more bad states. The paper identifies and analyzes a distinct situation of efficient opaqueness and information control where disclosing less achieves more. The sender's incentive is aligned with the receiver's but she nevertheless withholds information from him to enhance his welfare. Our analysis has applications in a broad set of disciplines.

Appendix: Proofs

Lemma 2 Proof. Since

$$p(m_{\{x\geq\bar{x}\}},\bar{x})\geq p(\bar{x},\bar{x})\geq\bar{p}, \tag{74}$$

we have

$$\bar{x}\geq\underline{x} \tag{75}$$

by the definition of $\underline{x}$ in (22). Moreover,

$$p(m_{\{x\geq\underline{x}\}},m_{\{x\geq\underline{x}\}})\geq p(m_{\{x\geq\underline{x}\}},\underline{x})\geq\bar{p} \tag{76}$$

implies

$$m_{\{x\geq\underline{x}\}}\geq\bar{x} \tag{77}$$

by the definition of $\bar{x}$ in (5).

Theorem 3 Proof. Suppose S sets $\underline{x}$ as the disclosure threshold. Then S withholds all states $x\geq\underline{x}$, which R anticipate in equilibrium and affects his belief on the state. When the state x is withheld, R believes $x\geq\underline{x}$ and musters a morale of $m_{\{x\geq\underline{x}\}}$.

How should R respond to S's threshold disclosure strategy? R should quit to avoid losing in each disclosed bad state. When a state $x\geq\underline{x}$ is withheld, R should accept to win as

$$p(m_{\{x\geq\underline{x}\}},x)\geq p(m_{\{x\geq\underline{x}\}},\underline{x})\geq\bar{p}. \tag{78}$$

Does S have an incentive to deviate to a different threshold? Raising threshold above $\underline{x}$ would lead to fewer states where R wins and more states where R quits, which makes both S and R worse off. We therefore consider a lower threshold $l<\underline{x}$. Then R quits in disclosed bad states below l. As S withholds more adverse states below $\underline{x}$, R's morale falls relative to $m_{\{x \geq \underline{x}\}}$:

$$m_{\{x \geq l\}} \in [l, m_{\{x \geq \underline{x}\}}]. \tag{79}$$

By the definition of $\underline{x}$ in (22), R loses at the lower threshold $l < \underline{x}$:

$$p(m_{\{x \geq l\}}, l) < \bar{p}. \tag{80}$$

Let w_l be the lowest state in which R wins:

$$w_l := \inf\{w \geq l : p(m_{\{x \geq l\}}, w) \geq \bar{p}\}. \tag{81}$$

We have $w_l > l$ by contrasting (80) and (81), implying that $m_{\{x \geq w_l\}} > m_{\{x \geq l\}}$. Therefore,

$$p(m_{\{x \geq w_l\}}, w_l) \geq p(m_{\{x \geq l\}}, w_l) \geq \bar{p}, \tag{82}$$

implying that $w_l \geq \underline{x}$ by the definition of $\underline{x}$ in (22). Thus if R accepts when the state is withheld, then he wins in states above w_l and loses in states $[l, w_l)$. Table 5 shows the corresponding payoffs for $i = S$ and R. In contrast with Table 2, the boundary state $\underline{x}$ between winning and quitting now expands into a set $[l, w_l)$ where R loses. R wins or quits in these states if the disclosure threshold is $\underline{x}$. Therefore S and R are worse off with the deviation to l than with the original threshold $\underline{x}$ if R accepts upon no disclosure.

Table 5: Payoffs Under a Threshold Disclosure Policy at $l < \underline{x}$

$x < l$	$x \in [l, w_l)$	$x \geq w_l$
U_Q^i	U_L^i	U_W^i

Since acceptance implies losing in some states for R, would he find it optimal to quit when S withholds the state? R chooses to quit upon no disclosure if

$$\Pr(X \geq w_l)U_W^R + \Pr(l \leq X < w_l)U_L^R < \Pr(X \geq l)U_Q^R. \tag{83}$$

However, in this case R quits in all states, making S and R worse off than under the disclosure with threshold $\underline{x}$.

In sum, the optimal disclosure threshold is $\underline{x}$. The welfare comparison with full disclosure is performed in the main text.

Lemma 4 Proof. R's morale when S withholds the state is the expected state in $\mathcal{A}$ and hence exceeds the lowest state in $\mathcal{A}$:

$$m_{\mathcal{A}} \geq \inf \mathcal{A}. \tag{84}$$

It follows that

$$p(m_{\mathcal{A}}, m_{\mathcal{A}}) \geq p(m_{\mathcal{A}}, \inf \mathcal{A}) \geq \bar{p} \tag{85}$$

and therefore

$$m_{\mathcal{A}} \geq \bar{x} \tag{86}$$

by the definition of $\bar{x}$ in (5). It follows that

$$m_{\mathcal{A}\cup\bar{x}} \geq \bar{x}. \tag{87}$$

We thus have

$$p(m_{\mathcal{A}\cup\bar{x}}, \bar{x}) \geq p(\bar{x}, \bar{x}) \geq \bar{p}, \tag{88}$$

which together with inequality (32) implies that

$$\bar{x} \geq \inf \mathcal{A}, \tag{89}$$

Therefore

$$\mathcal{A}_b = [\inf \mathcal{A}, \bar{x}) \tag{90}$$

in equilibrium, implying that

$$\mathcal{D}_b = [\inf \mathcal{X}, \inf \mathcal{A}). \tag{91}$$

according to their definitions in (25).

Finally, suppose

$$\underline{x} < \inf \mathcal{A} \tag{92}$$

so that $\underline{x}$ is not high enough to be included in $\mathcal{A}$, which implies

$$p(m_{\mathcal{A}\cup\{\underline{x}\}}, \underline{x}) < \bar{p} \tag{93}$$

according to (32). The difference between $\{x \in \mathcal{X} : x \geq \underline{x}\}$ and $\mathcal{A} \cup \{\underline{x}\}$ is

$$(\underline{x}, \inf \mathcal{A}) \cup [\bar{x}, m_{\mathcal{A}}), \tag{94}$$

all of which is below $m_{\mathcal{A}}$. Therefore going from $\mathcal{A} \cup \{\underline{x}\}$ to $\{x \in \mathcal{X} : x \geq \underline{x}\}$ lowers R's morale:

$$m_{\{x \geq \underline{x}\}} \leq m_{\mathcal{A}\cup\{\underline{x}\}}, \tag{95}$$

which implies

$$p(m_{\mathcal{A}\cup\{\underline{x}\}}, \underline{x}) \geq p(m_{\{x \geq \underline{x}\}}, \underline{x}) \geq \bar{p} \tag{96}$$

but contradicts (93). Therefore

$$\inf \mathcal{A} \leq \underline{x}. \tag{97}$$

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