False Modesty

When Disclosing Good News Looks Bad*

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Abstract

Is it always wise to disclose good news? We find that the weakest senders with good news have the most incentive to boast about it if the receiver has any private information. Hence the act of disclosing good news can paradoxically make the sender look bad. Withholding good news is an equilibrium if standards for the news are sufficiently weak or prior expectations without the news are sufficiently favorable. Full disclosure is the unique equilibrium when standards are sufficiently difficult, when standards are sufficiently fine, or when prior expectations are sufficiently unfavorable. Since the sender has a legitimate fear of looking too anxious to reveal good news, mandating that the sender disclose the news can help the sender. The model's predictions are consistent with when faculty avoid using titles such as "Dr" or "Professor" in voicemail greetings and course syllabi.

Key words: disclosure, unraveling, countersignaling, Baysian persuasion, communication, verifiable message, private receiver information
JEL codes: D82, C78

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Don't be so humble, you're not that great.

– Golda Meir

1 Introduction

If you have good news should you disclose it? According to the standard "unraveling" result, not only is it wise to disclose good news, but it is also necessary to disclose mediocre or even bad news to avoid the perception of having even worse news (Viscusi, 1978; Grossman and Hart, 1980; Grossman, 1981; Milgrom, 1981; Milgrom and Roberts, 1986; Okuno-Fujiwara et al., 1990). This result on the power of voluntary disclosure has informed long-running debates over whether to mandate disclosure in consumer product information (Mathios, 2000), financial statements (Greenstone et al., 2006), environmental impact (Powers et al., 2011), and other areas.

Nevertheless, firms and individuals are often unsure whether to reveal good news, and nondisclosure is often observed in practice (Jin, 2005; Xiao, 2010; Jin et al., 2015; Luca and Smith, 2015). Advertisers of high quality products frequently use a "soft sell" approach, donors sometimes make anonymous donations, members of a successful group do not always emphasize their group identity, overachievers are often understated, and offenders sometimes withhold mitigating information rather than "protest too much" or "make excuses."

Most of the literature explains such anomalies by examining why the absence of good news is not treated as evidence of bad news.[1] But what if boasting about good news is itself treated as bad news? Consider whether a restaurant should post its hygiene grade from the local health department. The unraveling result implies that all restaurants should post their grades voluntarily, but many restaurants with even the best A grades choose not to (Jin et al., 2015), and indeed some communities require mandatory disclosure rather than rely on voluntary disclosure (Jin and Leslie, 2003). Why is it necessary to require A restaurants to disclose their hygiene grade? Are restaurants concerned that showing off could be a bad sign that the restaurant fears that diners do not have a good opinion of it?

These same concerns are faced by individuals. For instance, in environments where titles such as "Dr," "Professor," or "PhD" are common, can use of a title be seen not just as redundant, but as a signal that the person has some reason to fear appearing unqualified? Table 1 summarizes data on the use of titles in voicemail greetings and course syllabi by PhD-holding full-time faculty in 26 economics departments in the same U.S. state (details are in Appendix B). Even though it is costless to use a title, many faculty actively avoid them, for example substituting "instructor" for "professor" on course syllabi. In particular, faculty in the more prestigious universities with doctoral programs are significantly less likely to use a title.[2]

To understand why boasting about good news can be a sign of weakness, we analyze a standard costless disclosure game with a continuum of sender types and a finite set of verifiable messages. For instance,

[1] Standard explanations include that messages are costly so reporting mediocre news is not worthwhile (Viscusi, 1978; Jovanovic, 1983; Verrecchia, 1983; Dye, 1986; Levin et al., 2009), there is uncertainty over whether the sender has any news so those with relatively bad news pool with types who have no news (Dye, 1985; Farrell, 1986; Okuno-Fujiwara et al., 1990, example 3; Shin, 1994, 2003), the receiver does not understand the game (Dye, 1998; Fishman and Hagerty, 2003; Hirshleifer et al., 2004), there is not a complete ordering of "good news" (Seidmann and Winter, 1997; Giovannoni and Seidmann, 2007; Mathis, 2008), since information is valuable to a competitor (Dye, 1986; Okuno-Fujiwara et al., 1990) or does not optimally positition a product vertically or horizontally (Board, 2009; Celik, 2014).

[2] The t-statistics are -5.04 and -6.79 for voicemail greetings and course syllabi and show that faculty in PhD-granting departments are significantly less likely to use a title than those at non-PhD-granting departments. The differences are also significant using non-parametric tests like the Mann-Whitney rank test.

Table 1: Faculty usage of formal titles – "Dr.," "Professor," "Ph.D."

	Doctoral Universities	Non-Doctoral Universities
Voicemail title	6	33
Voicemail no title	122	88
Number of faculty	128	121
Syllabus title	1	29
Syllabus no title	123	41
Number of faculty	124	70

there is a pass-fail certificate, or a system of letter grades. We show that the classic unraveling result is not robust if we allow any noisy private receiver information about sender type, no matter how weak.[3] Such information is likely to be present in most disclosure environments, and is equivalent to the sender facing a distribution of different receivers, where better sender types face a (slightly) higher proportion of receivers with a more favorable prior about the sender. For instance, customers hear more favorable word of mouth recommendations about a good restaurant than a bad restaurant.

To analyze the interaction of the prior, the sender's message, and the receiver's private information, we develop a new statistical dominance condition that ranks the effects of truncations on conditional expectations. Under this condition, skepticism about who discloses is self-confirming in that it gives the weakest sender types who meet a standard for good news the most incentive to show off. As a result there can be a *nondisclosure equilibrium* where no types who meet a standard disclose because any type who deviates to disclosure is viewed skeptically. And, analogous to behavior in a (costly) signaling game (e.g., Feltovich et al., 2002), there can be a *countersignaling equilibrium* where lower types who meet the standard disclose, but higher types who could disclose choose to rely on the private receiver information. If there is any private receiver information, these equilibria coexist with the full disclosure (unraveling) equilibrium if the standards for good news are sufficiently weak or if the prior distribution of sender types is sufficiently favorable. These equilibria are not refined away by standard refinements such as the intuitive criterion, D1, or Pareto dominance.

Best response dynamics converge to the different equilibria depending on initial behavior.[4] If not enough high types disclose, intermediate types also stop disclosing, which further reduces the gains to disclosure, until eventually no types at all disclose. But if initial disclosure includes enough relatively high types, then higher and higher types join in, until eventually all types disclose. If initial behavior is intermediate, convergence to countersignaling is possible. Hence nondisclosure and disclosure equilibria are always robust, and countersignaling equilibria are sometimes robust.

[3]Private receiver information has been analyzed in costly signaling games (e.g., Feltovich et al., 2002; Alós-Ferrer and Prat, 2012; Daley and Green, 2014), cheap talk games (Watson, 1996; Chen, 2009; de Barreda, 2010), and Bayesian persuasion games (Kolotilin et al., 2015; Guo and Shmaya, 2017).

[4]The coexistence of multiple stable equilibria can capture the persistence of different cultural traditions for disclosure. For example, professionals in Germany traditionally use full titles, such as "Herr Professor Doktor," while professionals in England are traditionally more understated, including medical doctors who switch from "Dr" to "Mr" upon becoming a member of the Royal College of Surgeons. The multiplicity of equilibria can also capture the strategic uncertainty that firms face about whether it is appropriate to boast in a particular situation – disclosure can help or hurt depending on how it is interpreted, and different interpretations are possible in equilibrium.

That disclosure can be undermined by the interaction of information sources was first shown by Teoh and Hwang (1991), and has been explored in a variety of settings.[5] Our approach differs in that we consider a standard disclosure game and allow the private receiver information to be arbitrarily weak, in which case it serves as a robustness check on models that exclude any private receiver information. Even if the direct effect of private receiver information is minimal, it can still give worse sender types strictly more incentive to disclose, thereby inducing skeptical receiver beliefs about who discloses on and off the equilibrium path. In costly signaling games, private receiver information can sometimes overwhelm the effects of single-crossing due to signaling costs so that higher types have less rather than more incentive to signal (Feltovich et al., 2002; Alós-Ferrer and Prat, 2012; Daley and Green, 2014).[6] In our costless disclosure game there are no signaling costs so the information effect, no matter how weak, necessarily dominates.

When does the classic result of full disclosure due to unraveling still hold? We find three sufficient conditions that ensure that there is unraveling up until some point in any equilibrium, including full unraveling. First, if a standard is sufficiently tough we find that disclosure occurs in any equilibrium since even the most skeptical beliefs about which types disclose still imply that any type meeting the standard does better by disclosing. Second, if prior expectations about sender quality are low enough we also find that disclosure is ensured since even an easy standard is then sufficiently above prior expectations. Third, if standards are sufficiently fine then full unraveling is the unique equilibrium.[7]

These results offer new insight into several issues that have been debated from different perspectives. First, is the long-standing question of when disclosure should be mandatory. The existence of multiple equilibria implies that mandatory disclosure can help reveal information when senders and receivers fail to coordinate on an informative equilibrium. Similarly, having a third party disclose the news can reduce communication problems by allowing the sender to enjoy the benefits of favorable information without looking overly anxious to disclose it.

Second, is the issue of how difficult it should be to meet different standards such as those for school diplomas or other certificates of quality. We show that higher standards are less likely to allow the existence of a nondisclosure or countersignaling equilibrium, so higher standards can paradoxically induce higher certification rates.[8] Moreover, the more favorable the distribution of sender types, the higher the standard that is necessary to ensure disclosure. Hence setting lower standards for groups with an unfavorable distribution and higher standards for groups with a favorable distribution not only divides the conditional distributions

[5]They analyze a two-period game in which a firm decides whether to immediately disclose news that will eventually be made public by a different source anyway. Nondisclosure or understatement may also arise if good news in one area attracts attention to bad news in a related area (Lyon and Maxwell, 2004), if good news is only preliminary (Baliga and Sjostrom, 2001), if the sender has information on only a subset of dimensions of interest (Nanda and Zhang, 2008), if a reputation for understatement is useful for times when there is no good news (Grubb, 2011), if understatement encourages further investigation (Mayzlin and Shin, 2011), or if standards for good news are uncertain and inferred in part from who discloses (Harbaugh et al., 2011). If marketing increases consumer awareness of product quality, then it is impressive when a product has done well even without marketing (Miklós-Thal and Zhang, 2013). Such demarketing can also serve as a price discrimination strategy when there is uncertainty over consumer preferences (Kim and Shin, 2016).

[6]Single-crossing can also fail if the opportunity cost of signaling is increasing in type (Spence, 2001; Sadowski, 2016), or the direct benefits from the signal are decreasing in type (Hvide, 2003; Orzach and Tauman, 2005; Chung and Eső, 2013). Single-crossing is side-stepped if there are multi-dimensional signals but a one-dimensional state (Orzach et al., 2002; Bagwell and Overgaard, 2005), or a one-dimensional signal but multi-dimension state (Bénabou and Tirole, 2006; Araujo et al., 2007).

[7]Okuno-Fujiwara et al. (1990) require the stronger condition that there is a separate verifiable message available to each type. They allow off the equilibrium path beliefs to be skeptical about which types disclose, even though all types benefit equally from disclosure when sender preferences are state-independent and there is no private receiver information. We show that private receiver information justifies such skepticism.

[8]We take quality as given, but the same issue arises if quality is generated in part by effort at an earlier point. Costrell (1994) analyzes the tradeoff between forcing higher quality among those who meet the standard against the losses of lower rates of attainment, but this tradeoff assumes that good is news is disclosed.

in a more informative way, but it can also avoid strategic uncertainty due to multiple equilibria.

Third, the model offers new insight into the question of how fine or coarse standards should be. A large literature shows why giving different types the same grade can be beneficial, e.g., the Bayesian persuasion literature shows that precommitting to a coarse information structure is often best at maximizing the sender's ex ante payoff (e.g., Kamenica and Gentzkow, 2011; Gentzkow and Kamenica, 2016). Our results indicate that, unless disclosure is mandated, any gains from coarseness may be undermined by the existence of equilibria with nondisclosure.

Finally, the model provides necessary and sufficient conditions for the existence of nondisclosure and countersignaling equilibria based on observable properties of the common knowledge distribution of types and standards. In a three-type costly signaling game, Feltovich et al. (2002) predict that higher types are less likely to signal, but do not address the effect of public information. In a two-type costly signaling game, Daley and Green (2014) predict that signaling is less likely when public information about type is more favorable. Here we predict that costless self-promotion is less likely by higher quality senders based on both their actual quality and public measures of quality.

In the following section we provide a simple example, in Section 3 we develop a more formal model, and in Section 4 we conclude the paper.

2 Examples

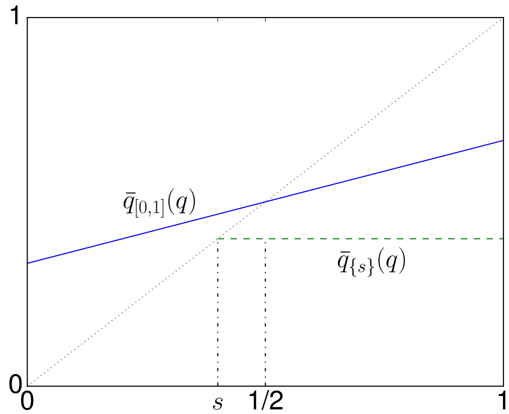
Suppose a sender's quality q has distribution F that has uniform density f on $[0, 1]$ and the sender's payoff is her expected quality as estimated by a receiver. Sender types cannot directly reveal their quality q, but if they are above some standard s they can costlessly disclose this fact. Independent of the disclosure decision, higher quality senders are more likely to face a receiver who views the sender more favorably. To capture this, let the receiver have some private information represented by a noisy binary signal $x \in \{\ell, \hbar\}$ where $\Pr[\hbar|q] = q$ so the chance of an $\hbar$ signal is higher for better senders. Let the conditional distributions be $H(q) = F(q|x = \hbar)$ and $L(q) = F(q|x = \ell)$. The sender decides to disclose or not based on the average or expected receiver estimate of the sender's quality.[9] For a sender of type $q \in Q$ denote this expectation, which is the sender's expected payoff, by

$$\bar{q}_Q(q) = \Pr[\hbar|q]E_H[q|q \in Q] + \Pr[\ell|q]E_L[q|q \in Q]. \tag{1}$$

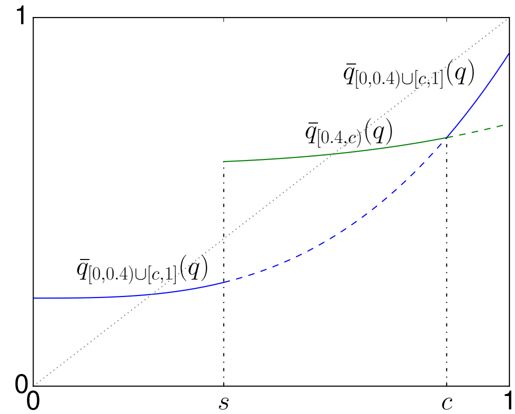
Let D be the set of types who are believed to disclose when disclosure is observed and N the set of types who are believed to not disclose when nondisclosure is observed. If the receiver expects all types $q \geq s$ to disclose, $D = [s, 1]$ and $N = [0, s)$, then clearly $\bar{q}_D(q) > \bar{q}_N(q)$ for all $q \geq s$ who can disclose, so such beliefs are confirmed in equilibrium.

Can withholding good news also arise in equilibrium? First consider a nondisclosure equilibrium where no types disclose, $N = [0, 1]$. If a sender follows the strategy of not disclosing then the sender's estimated quality is $E_H[q|q \in [0, 1]] = 2/3$ if the receiver has an $\hbar$ signal and $E_L[q|q \in [0, 1]] = 1/3$ if the receiver has an ℓ signal, implying the expected payoff from nondisclosure is $\bar{q}_N(q) = q\frac{2}{3} + (1 - q)\frac{1}{3} = 1/3 + q/3$. As seen in Figure 1a, this is increasing in q so higher types receive a higher nondisclosure payoff than lower types due to the private receiver information. Can types who meet the standard s do even better if they deviate and unexpectedly disclose? If the receiver skeptically believes that any unexpected disclosure came from the worst type who can do so, then $D = \{s\}$ so that $\bar{q}_D(q) - \bar{q}_N(q) = s - 1/3 - q/3$. Therefore if the standard is

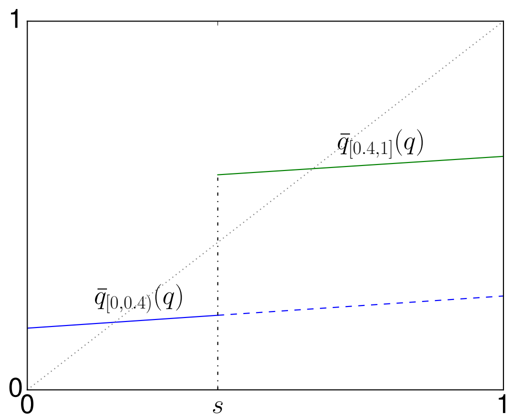
[9]The average interpretation is appropriate if the sender faces a population of receivers where proportion $\Pr[\hbar|q] = q$ have a more favorable prior H and the rest have a less favorable prior L.



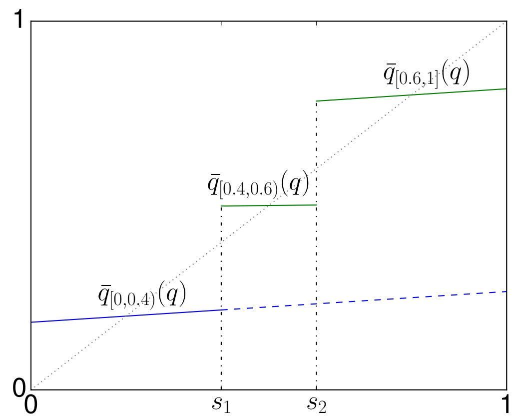
(a) Nondisclosure equilibrium: f uniform, $\Pr(H|q) = q$, $s = 2/5$



(b) Countersignaling equilibrium: f uniform, $\Pr(H|q) = q^3$, $s = 2/5$



(c) Unique disclosure equilibrium: $f(q) = 2 - 2q$, $\Pr(H|q) = q$, $s = 2/5$



(d) Unique unraveling equilibrium: f uniform, $\Pr(H|q) = q$, $s_1 = 2/5$, $s_2 = 3/5$

Figure 1: Expected payoffs as a function of q for different equilibria

sufficiently low, $s < 1/2$, the marginal sender $q = s$ loses from disclosure and higher types lose even more, so nondisclosure is an equilibrium.[10]

Skepticism about who discloses makes sense because, unlike in a standard costly signaling game, worse types have more incentive to disclose than better types. Since the worst senders meeting the standard gain the least from following the equilibrium strategy of nondisclosure, they will deviate and disclose for a wider range of belief-supportable payoffs for disclosure than other senders. Therefore standard equilibrium refinements imply that the receiver should put more weight on a deviation having come from a worse rather than better type, so skeptical beliefs are appropriate and the equilibrium cannot be refined away. Moreover, in a learning model we will show that if beliefs start out sufficiently skeptical they become more skeptical over time until play converges to the nondisclosure equilibrium.

If the standard s is sufficiently low to permit a nondisclosure equilibrium, it also permits a countersignaling equilibrium where the receiver correctly believes types $D = [s, c)$ disclose and types $N = [0, s) \cup [c, 1]$ do not disclose for some type $c \in [s, 1)$ who is just indifferent between disclosing or not. Such a c must exist because if c is very low then beliefs about who discloses are too pessimistic and type c will strictly prefer nondisclosure, and if c is very high then beliefs are too optimistic and type c will strictly prefer disclosure. Figure 1b shows a countersignaling equilibrium for the same example except the private receiver information better differentiates high types, $\Pr[\hbar|q] = q^3$. Types who just meet the standard $s = 2/5$ benefit the most from disclosure, but the net gain from disclosure $\bar{q}_D(q) - \bar{q}_N(q)$ falls until type $c = 0.87$ is indifferent. Higher types then benefit more from countersignaling and relying on the receiver's prior information to stochastically differentiate them from the lowest types. This example also has nondisclosure and disclosure equilibria with different sender types benefiting more from the different equilibria, so no equilibrium is Pareto dominant.[11] As shown in the next section, a wide range of initial behavior converges to this countersignaling equilibrium.[12]

If the standard s is sufficiently high, or if the prior distribution is sufficiently unfavorable, disclosure is the unique equilibrium. In this case even the most skeptical belief that $D = \{s\}$ makes all types want to disclose, so skepticism is not sustainable in equilibrium. In the example of Figure 1a if $s > 1/2$ instead of $s = 2/5$ then in the unique equilibrium all types $[s, 1]$ disclose. Or if the prior distribution is $f(q) = 2 - 2q$ as in Figure 1c then disclosure is the unique equilibrium even for $s = 2/5$. For instance, if there is some public information about the sender that makes the receiver think the sender is unlikely to be of high quality, then even the skeptical belief that a type who discloses is only $q = 2/5$ is still relatively favorable so all types disclose.[13]

Disclosure is also ensured if multiple standards divide up the type space sufficiently finely. In Figure 1d the prior distribution is again uniform, but now there are two standards, $s_1 = 2/5$ and $s_2 = 3/5$. Based on the prior analysis types $q \geq 3/5$ always disclose since the standard they meet is so high. But given that they disclose, in any equilibrium where lower types do not disclose the sender is at best in the region $[0, 3/5]$. Conditional on being in this region, the standard $s_1 = 2/5$ is now relatively high, so the remaining types $q \in [2/5, 3/5)$ disclose even though they would not always disclose with a single standard $s = 2/5$. For

[10]That the net gain to disclosure $\bar{q}_D(q) - \bar{q}_N(q)$ is decreasing in q is simplified here by the assumption that D is a singleton. We will show more generally in Lemmas 1- 3 of Appendix A conditions under which private receiver information ensures $\bar{q}_D(q) - \bar{q}_N(q)$ is decreasing.

[11]For the receiver, countersignaling equilibria sometimes provide more information to the receiver than a full disclosure equilibrium, e.g., in this example $c = 0.98$ is also a countersignaling equilibrium and is the most informative equilibrium.

[12]In the previous example with $\Pr[\hbar|q] = q$ a countersignaling equilibrium also exists but, based on arguments in the next section, it is not stable and play will converge to either nondisclosure or disclosure. Countersignaling with uniform f and $s = 2/5$ is stable for $\Pr[\hbar|q] = q^n$ for $n \geq 2$, as seen in Figure 2b for the case where $n = 3$.

[13]However, nondisclosure is still an equilibrium if the standard is sufficiently low, which is $s < 1/3$ in this example.

instance, if there is just a pass grade indicating $q \geq 2/5$ then disclosure of the pass grade is not ensured, but if there is an A grade indicating $q \geq 3/5$ and a B grade indicating $q \in [2/5, 3/5)$ then disclosure of both grades is ensured.

In the following two sections we formalize and generalize these ideas. We provide conditions under which private receiver information implies that the net gain from disclosure is decreasing in the sender's type. We then use this result to show when refinements permit and even require pessimistic beliefs that support a nondisclosure equilibrium, and when best response dynamics converge to pessimistic beliefs that support nondisclosure or countersignaling. We then show how finer certification standards and tougher certification standards can be used to ensure uniqueness of disclosure equilibria.

3 The model

In this sender-receiver game the sender has quality q distributed according to the smooth distribution F with density f which has support on $[0, 1]$. The sender knows the realized value of q and sends a type-restricted message v to the receiver that is potentially informative about q. The receiver does not know q but has his own binary signal $x \in \{\ell, \hbar\}$ where $\Pr[\hbar|q]$ is strictly increasing.[14] The conditional distributions $H(q)$ and $L(q)$ given these signals have respective densities $h(q)$ and $l(q)$.

We assume that $H(q)$ dominates $L(q)$ in the sense that $E_H[q|q \in [a, b]] - E_L[q|q \in [a, b]]$ is strictly decreasing in a and strictly increasing in b.[15] Such dominance implies that the impact of the receiver's private signal is increasing as the interval $[a, b]$ expands. As shown in Lemma 1, this gives the worst types who have good news the most incentive to disclose it. Lemma 2 provides two sufficient conditions for such dominance, neither of which implies the other, and at least one of which is satisfied in the above examples.[16] The first condition requires $h(q)$ increasing and $l(q)$ decreasing, which holds for F uniform even if $\Pr[\hbar|q]$ is arbitrarily close to being flat. The second condition requires the generalized hazard rate ratio $(h(q)/(H(q')-H(q)))/(L(q)/(L(q')-L(q)))$ to be increasing. As shown in Lemma 3, this condition holds if F is logconcave and $\Pr[\hbar|q]$ is linear and sufficiently flat. Hence skepticism about disclosure is justifiable not just in the above examples with significant private receiver information, but even if the private receiver information is arbitrarily weak.

The sender first learns her type q and then sends the message v. After learning x and hearing v the receiver then takes an action α. Following standard assumptions in the sender-receiver game literature, we assume that the receiver's payoff $u^R(q, \alpha)$ is maximized when the receiver's action α equals the receiver's estimate of the sender's type, e.g., $u^R(q, \alpha) = -(q - \alpha)^2$, and that the sender's state-independent payoff, u^S, is strictly increasing in α. We will present the model for $u^S = \alpha$ since all of the proofs extend trivially to u^S increasing in α.[17] Our nondisclosure and uniqueness results extend to more general u^R as long as the sender's expectation of the receiver's action α is increasing in the sender's quality q.[18]

[14] A binary signal simplifies the analysis and highlights that even weak private receiver information can allow for equilibria with nondisclosure.

[15] We refer to these as Decreasing Mean Residual Life (MRL) Differences and Increasing Mean Time to Failure (MTTF) Differences respectively. See Shaked and Shanthikumar (2007) for related dominance conditions and orderings. Most relatedly, Jewitt (2004) shows that the MRL-MTTF gap $E[q|q \in [c, 1]] - E[q|q \in [0, c]]$ is increasing (decreasing) in c for f strictly decreasing (increasing), with application to binary signaling games (e.g., Bénabou and Tirole, 2006, 2011). Our new dominance condition implies the MRL-MTTF gap is increasing faster for the dominated distribution, which is also relevant for such games.

[16] The first condition is clearly satisfied in Examples 1a, 1b, and 1d. The second condition allows for nonmonotonicities in the conditional densities as in Example 1c.

[17] We are not analyzing ex ante maximization of sender payoffs as in the Bayesian persuasion literature, so the exact shape of u^S is not relevant.

[18] This holds by Theorem 2 of Athey (2002) if $u^R(q, \alpha)$ satisfies the single-crossing property and x and q are affiliated, which holds

We consider only pure strategy equilibria so a strategy is a mapping between types and messages. Let the conditional cumulative distribution function $\mu(q|x, v)$ represent receiver beliefs about the sender's type given the message v and private information x. Our equilibrium concept is that of a pure-strategy perfect Bayesian equilibrium.

Definition 1 *A* pure-strategy perfect Bayesian equilibrium *is given by a verifiable message profile $v(q)$, a receiver action profile $a(x, v)$, and receiver beliefs $\mu(q|x, v)$ where:*

i) For all q, $v(q) \in \arg\max_{v'} E[u^S(\alpha(x, v'))|q]$;

ii) For all x and v, $\alpha(x, v) = \arg\max_{\alpha'} E_\mu[u^R(q, \alpha')|x, v]$;

iii) $\mu(q|x, v)$ is updated from the sender's strategy and F using Bayes' rule whenever possible.

Condition i) requires that the sender's message is a best response to the receiver's expected actions. Condition ii) requires that the receiver's action is a best response to the sender's message. Condition iii) requires that for any information set that can be reached on the equilibrium path, the receiver's beliefs are consistent with Bayes' rule and the equilibrium sender strategy. Since we are considering pure strategy equilibria, if Q is the set of types who are believed to have sent message v when it is observed, then $\mu(q|x, v) = \int_{t\in[0,q]\cap Q} f(t|x)dt / \int_{t\in Q} f(t|x)dt$, implying $\bar{q}_Q(q)$ is as defined in equation (1).

3.1 Single standard

We start with the case of a single pass-fail standard as introduced in the example of Figures 1a–1c. For the pass-fail standard, we assume that there is a "blank" message v_0 for nondisclosure and message v_1 for disclosure. Message v_0 is always sent by types $q \in [0, s)$ and either v_0 or v_1 may be sent by types $q \in [s, 1]$.[19] For instance, a person has a certificate to prove that she passed an exam (but nothing to prove that she failed it).

As in the example, let N be the set of types who are believed to have sent v_0 when it is observed and D be the set of types who are believed to have sent v_1 when it is observed. The net gain from disclosure $\bar{q}_D(q) - \bar{q}_N(q)$ is monotonic for any D and N by the assumption that $\Pr[\hbar|q]$ is monotonic, so sender best responses for any receiver beliefs involve: (i) no types disclose, (ii) types in an interval $[s, c)$ disclose for some $c < 1$, (iii) types in an interval $[d, 1]$ disclose for some $d \in [s, 1]$. Cases (i) and (ii) correspond to the nondisclosure and countersignaling equilibria, and case (iii, $d = s$) corresponds to the disclosure equilibrium. In the following, we examine the conditions under which each of these cases can be an equilibrium. Case (iii, $d > s$) cannot arise in equilibrium since, with the corresponding beliefs, every type will prefer to disclose. Hence (i), (ii) and (iii, $d = s$) are the only pure strategy equilibrium strategies that are possible.

Since the disclosure equilibrium always exists by the same argument as for the example, our focus is on the existence of nondisclosure and countersignaling equilibria. For nondisclosure, consider the most pessimistic beliefs about who unexpectedly discloses, so $D = \{s\}$ and $N = [0, 1]$ and $\bar{q}_D(q) - \bar{q}_N(q) = s - \bar{q}_{[0,1]}(q)$. Let

$$\hat{q} = \min\{q : q = \bar{q}_{[0,1]}(q)\} \tag{2}$$

where existence of $\hat{q}$ follows from the fact that $\bar{q}_{[0,1]}(q)$ is continuous and has range in $[0, 1]$. If $s \leq \hat{q}$ then type s will not want to disclose and all higher types have even less incentive to disclose since $\bar{q}_{[0,1]}(q)$ is increasing in q, so nondisclosure is an equilibrium.

for $\Pr[\hbar|q]$ increasing.

[19] The results are not qualitatively affected if instead sender types $q \geq s_1$ cannot disclose with probability ε for small $\varepsilon > 0$. Senders with no message to disclose are forced to pool with others who do not disclose.

In a countersignaling equilibrium, $N = [0, s) \cup [c, 1]$ and $D = [s, c)$. Suppose that $s < \hat{q}$. By the definition of $\hat{q}$ it must be that $s < \bar{q}_{[0,1]}(s)$. Therefore, for c sufficiently close to s, it must be that $\bar{q}_D(c) < \bar{q}_N(c)$. Similarly, since $\bar{q}_{[s,1]}(c) > \bar{q}_{[0,s)}(c)$, it must be that $\bar{q}_D(c) > \bar{q}_N(c)$ for c sufficiently close to 1. By continuity, these imply that there exists some $c \in (s, 1)$ such that

$$\bar{q}_{[s,c)}(c) = \bar{q}_{[0,s)\cup[c,1]}(c). \tag{3}$$

Given the indifference of type c, for this to be an equilibrium we need to show that types below c disclose and types above c do not disclose. It is sufficient to show that $\bar{q}_{[s,c)}(q) - \bar{q}_{[0,s)\cup[c,1]}(q)$ is decreasing in q. Noting the equality (3), this holds by Lemma 1 and can seen in Figure 1b.

Now consider when disclosure is the unique equilibrium. For sufficiently large s, the sender's expected payoff from non-disclosure in any candidate non-disclosure or countersignaling equilibrium is strictly bounded above by s but for any s, the sender's disclosure payoff is bounded below by s. Hence if s is sufficiently close to 1 then every sender $q \geq s$ prefers to disclose and neither nondisclosure nor countersignaling can be an equilibrium. Since disclosure, nondisclosure and countersignaling are the only possible pure strategy equilibria with a single standard, disclosure is unique. Collecting these results, we have the following:

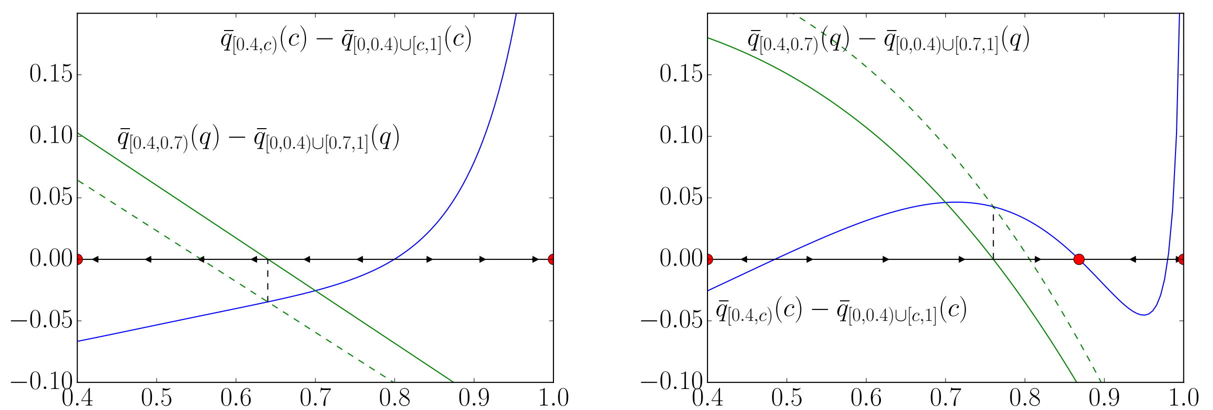
Proposition 1 (Existence) *(i) A nondisclosure equilibrium exists if and only if the standard is sufficiently low. (ii) A countersignaling equilibrium exists if and only if the standard is sufficiently low. (iii) A disclosure equilibrium always exists and is unique if the standard is sufficiently high. (iv) No other pure strategy equilibria are possible.*

The nondisclosure equilibrium is based on skeptical beliefs about which sender types unexpectedly disclose. Are these beliefs reasonable based on "forward induction" arguments about which types have the strongest incentive to deviate? The Intuitive Criterion restricts the receiver to put zero probability on a type having deviated if it would not benefit from deviation under the most favorable possible beliefs about who deviates. But in this game every type would be happy to disclose if they would be thought of as the highest type, so beliefs are unrestricted and hence skeptical beliefs survive. The D1 condition requires, in our context, that if one type benefits from a deviation for a set of rationalizable receiver best responses that is a subset of that for some other type, zero weight should be put on the former type (Cho and Kreps, 1987; Cho and Sobel, 1990; Ramey, 1996). In a nondisclosure equilibrium higher types expect to be evaluated more favorably than lower types because of the private receiver information, so they have less incentive to deviate than lower types. Therefore, not only does D1 have no power to refine away the nondisclosure equilibrium, it actually reinforces it by dictating that *out-of-equilibrium actions must be viewed skeptically*.[20] This skepticism agrees with the intuition that self-promotion when unexpected can be viewed so negatively that modesty is indeed the best policy.

We now investigate when the different equilibria can arise as the stable outcome of best response dynamics. Suppose that in each "period" the sender's strategy is a best response to receiver beliefs, where these beliefs in any period after the first period equal the previous best response strategy of the sender. If it is a best response for no types to disclose, we assume that beliefs in the next period are unchanged or otherwise sufficiently skeptical that non-disclosure remains the best response. Recall that the monotonicity of $\bar{q}_D(q) - \bar{q}_N(q)$ implies that for *any* receiver beliefs there are three cases for sender best responses. These

[20] Without private receiver information this argument, and the best response dynamics analyzed below, do not support skepticism. Since the incentive to deviate from nondisclosure is the same for each type, the receiver should maintain his original priors concentrated on the range of types who can send the verifiable message, in which case all senders will deviate from the nondisclosure equilibrium.

Figure 2: Convergence to nondisclosure, countersignaling, and disclosure



(a) Nondisclosure and disclosure: f uniform, $s = 2/5$, $\Pr[\hbar|q] = q$

(b) Nondisclosure, countersignaling and disclosure: f uniform, $s = 2/5$, $\Pr[\hbar|q] = q^3$

cases can be ranked in terms of "modesty" by who discloses: (i) nondisclosure is most modest, (ii) countersignaling is less modest and decreasingly modest for higher c and hence a larger disclosure range $[s, c]$, and (iii, $d = s$) full disclosure is least modest. Case (iii, $d > s$) where only the best types disclose trivially converges to full disclosure immediately as other types join in, so we will treat it as equivalently immodest to case (iii, $d = s$).

With this measure of modesty we have the following convergence result based on initial play by the sender that is a best response to any receiver beliefs. Parts (i) and (iii) on nondisclosure and disclosure are proven in Appendix A and part (ii) on countersignaling is proven by example below.

Proposition 2 (Convergence) *(i) Play converges to the nondisclosure equilibrium if it exists and initial behavior is sufficiently modest. (ii) Play may converge to a countersignaling equilibrium if one exists and initial behavior is intermediate. (iii) Play converges to the disclosure equilibrium if initial behavior is sufficiently immodest.*

The convergence to different equilibria can be seen from the example of Figure 1a, which is explored further in Figure 2a. The blue line in Figure 2a shows the net gain to disclosure for type c as c varies between $s = 0.4$ and 1 when types $D = [s, c)$ disclose. If initial behavior is sufficiently modest then the corresponding beliefs will induce fewer sender types to disclose the next period, thereby leading to even more pessimistic beliefs and less disclosure, until no types at all disclose. For example, the dashed line shows the first step of this convergence when the initial set of types who disclose is $D = [0.40, 0.70)$. If the receiver forms beliefs accordingly, then the gain from disclosure is $\bar{q}_{[s,0.7)}(q) - \bar{q}_{[0,s)\cup[0.7,1]}(q)$ which is negative for all types $q > 0.64$ as seen from the green line, so in the next period the set of types who disclose shrinks to $D = [0.40, 0.64)$. With these beliefs then by the same logic types $q > 0.56$ will not disclose so D shrinks to $[0.40, 0.56)$, and then finally to $[0.40, 0.44)$ after which beliefs are so pessimistic that all disclosure stops. Conversely, if initial behavior is such that all types up to $c > 0.80$ disclose, then beliefs in the next period are sufficiently optimistic to induce more and more disclosure until all types disclose. In this example the countersignaling equilibrium where only types $D = [0.40, 0.80)$ disclose is unstable because if slightly more or slightly fewer types disclose then play eventually converges to either disclosure or nondisclosure.

Countersignaling equilibria can sometimes be stable as seen in the example of Figure 1b which is further illustrated in Figure 2b. The three roots of $\bar{q}_D(c) - \bar{q}_N(c)$ are all countersignaling equilibria, but only the middle one with $c = 0.87$ is stable. Play converges to the nondisclosure equilibrium if initial play is more modest than types up to $c < 0.48$ disclose and play converges to the disclosure equilibrium if initially all types up to $c > 0.98$ or higher disclose. Within this broad range, play converges to the middle countersignaling equilibrium where only types $[0.4, 0.87)$ disclose. The dashed line shows the first step of this convergence for the case where initial behavior has types $D = [0.40, 0.70)$ disclosing. With corresponding beliefs by the receiver, $\bar{q}_{[s,0.7)}(q) - \bar{q}_{[0,s)\cup[0.7,1]}(q) > 0$ for all types $q < 0.76$, so in the next period types $D = [0.40, 0.76)$ disclose. By this process beliefs and behavior converge to the middle countersignaling equilibrium.[21]

3.2 Multiple standards

We now consider the general model where there are $N \in \mathbb{N}^+$ verifiable messages that disclose a subinterval of the sender's typespace, e.g., a system of certificates or letter grades. In particular, we assume that the type-space is partitioned into $N+1$ nonempty subintervals by a set of strictly increasing standards $\{s_1, s_2, \ldots, s_N\}$ and that the sender can send the verifiable message $v = v_j$ if and only if $q \in [s_j, s_{j+1})$ for $j = 1, 2, \ldots, N$.[22,23] Message v_0 is always sent by types $q \in [0, s_1)$ and may also be sent by higher types. Therefore a message profile is $v(q) \in \{v_0, v_j\}$ for $q \in [s_j, s_{j+1})$ and $j = 0, 1, \ldots, N$. We refer to sending v_0 as "not disclosing" and to sending any other message v as "disclosing."

As we demonstrated in Sections 2 and 3.1, the model admits to multiple equilibria. In addition to disclosure, non-disclosure, and countersignaling equilibria, for $N \geq 2$ there can be equilibria with non-disclosure of lower standards but not higher standards, and countersignaling equilibria with disclosure of intermediate standards. Given the multitude of equilibria, we focus on sufficient conditions for when a type must disclose and for when nondisclosure exists. As with a single standard, it is always an equilibrium for all types who can disclose to disclose.

Extending the argument for the single standard case, we expect that nondisclosure arises when s_j is relatively low so revealing good news is not so impressive. To check this intuition, we look for sufficient conditions on s_j such that an equilibrium exists in which v_j and any worse news is not disclosed. Consider the minimum value of q such that the expected payoff for a sender of type q is equal to q when news of v_j and lower is not disclosed. Generalizing (2), let

$$\hat{q}_j = \min\{q : q = \bar{q}_{[0,s_{j+1})}(q)\}, \tag{4}$$

where the existence of $\hat{q}_j$ follows from the fact that $\bar{q}_{[0,s_{j+1})}(q)$ is continuous in q and has range in $[0, s_{j+1}]$.[24] If the receiver skeptically believes that a sender who deviates from nondisclosure is of the lowest type who could deviate, then the highest payoff from disclosure of news v_k for $k \leq j$ is s_k. Therefore, nondisclosure is clearly an equilibrium if $s_j < \hat{q}_j$.

The following proposition summarizes these results, with details of the proof in Appendix A.

[21] Best responses may "overshoot" the countersignaling equilibrium if $\bar{q}_D(q) - \bar{q}_N(q)$ is too flat, though that is not possible in this example. Dynamics that dampen the response each period so only those with the strongest incentive to change strategies do so can prevent overshooting more generally.

[22] In an alternative formulation with the same qualitative implications a sender of type q can send message $v \in \{v_0, v_j, v_{j+1}, \ldots, v_N\}$ if and only if $q \geq s_j$

[23] Note that, following convention, we define $s_0 = 0$ and $s_{N+1} = 1$ and ignore the open/closed set distinction in the notation for the final subinterval $[s_N, s_{N+1}]$.

[24] Since $E[\bar{q}_{[0,s_{j+1})}(x)|q]$ is strictly increasing in j, it follows from Theorem 1 of Milgrom and Roberts (1994) that $\hat{q}_j$ is strictly increasing in j.

Proposition 3 (Existence – multiple standards) *(i) An equilibrium with nondisclosure by types* $q \in [0, s_{j+1})$ *exists if standard j is sufficiently low,* $s_j \leq \hat{q}_j$*. (ii) A full disclosure equilibrium always exists.*

Under our dominance condition, similar convergence results for disclosure and nondisclosure equilibria with a single standard apply to multiple standards. For example, given $c_j < s_{j+1}$ but sufficiently close to s_{j+1} for $j \geq k$ (i.e., behavior is sufficiently immodest within each interval), the best response dynamic will converge to disclosure for $j \geq k$. Similarly for nondisclosure. Of course, with multiple standards, many other stable outcomes are possible.

In the classic disclosure model without private receiver information, full disclosure is the unique equilibrium due to "unraveling." Since types with the best news will always reveal it, types with the next best news will also reveal it, and so on until all news has been revealed. With only binary news, it was shown that unraveling in our model can fail because even the types with the best available news might not reveal it. We are interested in conditions under which the best types will always reveal their news and, when there are multiple levels of news, how far unraveling will continue.

Let $\check{q}_j$ for $j = 1, 2, \ldots, N$ be the maximal payoff for nondisclosure when the receiver believes that every $q \in [s_{j+1}, 1]$ discloses.[25] Now consider unraveling. If $s_N > \check{q}_N$ then types with the best news v_N will disclose. Since $q \in [s_N, 1]$ are known to disclose, the attractiveness of nondisclosure by types with news v_{N-1} decreases. Thus types $q \in [s_{N-1}, s_N)$ will always disclose under the weaker condition that $s_{N-1} > \check{q}_{N-1}$. If these types disclose then this same logic applies to types with news v_{N-2}, etc. Because the $\check{q}_j$ are nondecreasing in j, unraveling implies that the standard for impressiveness becomes less strict as unraveling progresses from the best news down. For instance, if a PhD is sufficiently rare that it is disclosed, then it becomes more likely that an MA is disclosed, in which case it is also more likely that a BA is disclosed.

The following proposition uses these arguments to show when an equilibrium must involve a certain degree of disclosure. Unlike the classic unraveling results, this proposition does not imply that full unraveling or even any unraveling is assured. Instead, it gives conditions under which different levels of news are sufficiently impressive that they are always disclosed. In particular, a given level of news will be disclosed if it is sufficiently impressive conditional on higher levels of news being disclosed because they too are sufficiently impressive.

Proposition 4 (High standards) *Types* $q \in [s_j, 1]$ *disclose in any equilibrium if standards* s_k *for* $k \geq j$ *are sufficiently high.*

This proposition shows that full unraveling is the unique equilibrium if the verifiable news is sufficiently impressive. The following result extends the unraveling argument to show that full disclosure is the unique equilibrium if the verifiable information is sufficiently fine. When the verifiable messages separate the different types sufficiently well, the highest types have an incentive to disclose their (exceptionally) good news v_N even if they are thought of as being only of type s_N rather than from the range $[s_N, 1]$. As seen in Figure 1d for $N = 2$, given that the highest types disclose v_N, the next highest types have an incentive to disclose v_{N-1} even under skeptical beliefs if s_{N-1} is sufficiently close to s_N, etc. If the difference between standards is sufficiently close for all the verifiable messages, i.e., the message space is sufficiently fine, then the unraveling continues until all news is disclosed.

Proposition 5 (Fine standards) *Given* $N \geq 2$ *and* s_1*, types* $q \in [s_j, 1]$ *disclose in any equilibrium if standards are sufficiently fine, i.e.,* $\max_{k \geq j}\{s_{k+1} - s_k\}$ *is sufficiently small.*

[25] These critical values are derived and given by equation (A.20) in the proofs of Propositions 1 and 4 in Appendix A.

While Proposition 3 (i) shows that if standards are set low enough then nondisclosure is always an equilibrium, Propositions 4 and 5 show that if standards are set high enough or if standards are fine enough then nondisclosure cannot be an equilibrium. The following proposition shows how the distribution of sender types affects the potential for nondisclosure equilibria.

Proposition 6 (Low expectations) *(i) Types $q \in [s_j, 1]$ disclose in any equilibrium if prior expectations are sufficiently unfavorable, i.e., $F(s_j)$ is sufficiently large. (ii) If expectations are less favorable ($F(q)$ is stochastically dominated by $G(q)$), the necessary and sufficient conditions for disclosure in any equilibrium are weaker ($\check{q}_j^F \leq \check{q}_j^G$ and $\hat{q}_j^F \leq \hat{q}_j^G$).*

Part (i) implies that full disclosure is the unique equilibrium if the prior distribution F is sufficiently unfavorable (i.e., $F(s_1)$ is sufficiently large), as seen in Example 1c for the case of $N = 1$. By similar arguments, full nondisclosure is an equilibrium if F is sufficiently favorable, i.e., $F(s_N)$ is sufficiently small. Part (ii) shows that if the common knowledge distribution F is more favorable, then the conditions for the uniqueness of disclosure equilibria become stricter and the conditions for the existence of nondisclosure equilibria become less strict.

This result shows how different public information affects disclosure. For example, faculty members who are known to work at elite universities will tend to face priors (G) that have greater mass in the right tail relative to the priors (F) for faculty members at less research-focused universities. The more favorable is this public information the higher are $\check{q}_j$ and $\hat{q}_j$, so the less likely it is that $s_j > \check{q}_j$ and the more likely it is that $s_j \leq \hat{q}_j$. Looking back at Figure 1, the more favorable distribution in Figure 1a permitted nondisclosure and countersignaling equilibria, while the less favorable distribution in Figure 1c had a unique disclosure equilibrium.

4 Conclusion

A large body of research concludes that costless disclosure of good news should benefit the sender, but in practice senders often withhold good news. In this paper we consider a disclosure game when the receiver also has private information about sender quality. We show that the presence of any private receiver information, even if only slightly informative, implies that equilibria with nondisclosure by some or all types exist unless the standard for good news is restricted to sufficiently high quality senders or the prior distribution of types is sufficiently unfavorable. When there are multiple standards for news, such as letter grades, we find that the standard unraveling result of full disclosure holds if standards are sufficiently fine but need not hold generally. From a policy perspective the model supports the setting of higher and more finely distinguished standards in order to reduce the scope for nondisclosure equilibria. It also provides support for mandatory or third-party disclosure of information as a way to reduce the damage that “false modesty” can have on communication.

Appendix

A Proofs

Lemma 1 (Lower disclosure incentives for higher types) *Suppose $E_H[q|q \in [a,b]] - E_L[q|q \in [a,b]]$ is strictly decreasing in a and strictly increasing in b for all $a < b$. Then, for any $a < b$, $\frac{d}{dq'}\left(\bar{q}_{[a,b)}(q') - \bar{q}_{[0,a)\cup[b,1]}(q')\right) < 0$ for all q' if there exists q such that $\bar{q}_{[a,b)}(q) = \bar{q}_{[0,a)\cup[b,1]}(q)$.*

Proof: Letting $D = [a, b)$ and $N = [0, a) \cup [b, 1]$, note that $\bar{q}_D(q) - \bar{q}_N(q)$ equals

$$\Pr[\hbar|q](E_H[q|q \in D] - E_H[q|q \in N]) + (1 - \Pr[\hbar|q]) \left(E_L[q|q \in D] - E_L[q|q \in N]\right) \tag{A.1}$$

so $\frac{d}{dq}\Pr[\hbar|q] > 0$ implies the sign of $\frac{d}{dq}\left(\bar{q}_D(q) - \bar{q}_N(q)\right)$ equals that of

$$\left(E_H[q|q \in D] - E_H[q|q \in N]\right) - \left(E_L[q|q \in D] - E_L[q|q \in N]\right). \tag{A.2}$$

By assumption $\bar{q}_D(q) = \bar{q}_N(q)$ for some q, so from (A.1)

$$E_H[q|q \in D] - E_H[q|q \in N] \tag{A.3}$$

and

$$E_L[q|q \in D] - E_L[q|q \in N] \tag{A.4}$$

have opposite signs or equal to zero.

Suppose (A.3) is non-negative and (A.4) is non-positive. By the law of total expectations, (A.3) non-negative implies $E_H[q|q \in D] \geq E_H[q] \geq E_H[q|q \in N]$, and (A.4) non-positive implies $E_H[q|q \in N] \geq E_L[q] \geq E_L[q|q \in D]$. Together, these imply

$$E_H[q|q \in D] - E_L[q|q \in D] \geq E_H[q] - E_L[q]. \tag{A.5}$$

But this contradicts the assumption that $E_H[q|q \in [a, b]] - E_L[q|q \in [a, b]]$ is strictly decreasing in a and strictly increasing in b. Hence it must be that (A.3) is negative and (A.4) is positive, implying (A.2) is negative. ■

Lemma 2 (Decreasing MRL Differences and Increasing MTTF Differences) *Suppose H and L are smooth distribution functions where the respective densities h and l are strictly positive on $[0, 1]$.*[26] *Then, for all $0 \leq a < q < b \leq 1$, the gap $E_H[q|q \in [a, b]] - E_L[q|q \in [a, b]]$ is strictly decreasing in a and strictly increasing in b if (i) H is strictly convex and L is strictly concave or (ii) H and/or L is logconcave and the generalized hazard rate ratio*

$$\frac{h(q)}{H(q') - H(q)} \Big/ \frac{l(q)}{L(q') - L(q)} \tag{A.6}$$

is strictly increasing in $q \neq q'$ for all $q, q' \in [0, 1]$.

Proof: (i) Lemma 1(iii) of Harbaugh and Rasmusen (2016) implies that $\frac{d}{da}E_H[q|q \in [a, b]] \leq 1/2 \leq \frac{d}{db}E_L[q|q \in [a, b]]$ and $\frac{d}{db}E_H[q|q \in [a, b]] \geq 1/2 \geq \frac{d}{da}E_L[q|q \in [a, b]]$. As can be seen from the proof of the lemma, the inequalities are strict for $a \neq b$. Hence

$$\begin{aligned} \frac{d}{da}\left(E_H[q|q \in [a, b]] - E_L[q|q \in [a, b]\right) &\leq 1/2 - 1/2 = 0 \\ \frac{d}{db}\left(E_H[q|q \in [a, b]] - E_L[q|q \in [a, b]\right) &\geq 1/2 - 1/2 = 0, \end{aligned} \tag{A.7}$$

with strict inequalities for $a \neq b$.

[26] The proof can be extended to allow h and l to be zero at the endpoints.

(ii) Differentiating and simplifying,

$$\begin{aligned}\frac{d}{da}E_H[q|q\in[a,b]] &= \frac{h(a)}{H(b)-H(a)}\left(E_H[q|q\in[a,b]]-a\right)\\ \frac{d}{db}E_H[q|q\in[a,b]] &= \frac{h(b)}{H(b)-H(a)}\left(b-E_H[q|q\in[a,b]]\right)\end{aligned} \tag{A.8}$$

and similarly for $E_L[q|q\in[a,b]]$. By application of l'Hospital's rule, $\lim_{a\to b} dE_H[q|q\in[a,b]]/da = \lim_{b\to a} dE_H[q|q\in[a,b]]/db = \frac{1}{2}$ for $h(a), h(b)>0$, and similarly for $E_L[q|q\in[a,b]]$.

Again differentiating and simplifying,

$$\begin{aligned}\frac{d^2}{(da)^2}E_H[q|q\in[a,b]] &= \frac{h'(a)}{h(a)}\frac{d}{da}E_H[q|q\in[a,b]]+\left(2\frac{d}{da}E_H[q|q\in[a,b]]-1\right)\frac{h(a)}{H(b)-H(a)}\\ \frac{d^2}{(db)^2}E_H[q|q\in[a,b]] &= \frac{h'(b)}{h(b)}\frac{d}{db}E_H[q|q\in[a,b]]+\left(1-2\frac{d}{db}E_H[q|q\in[a,b]]\right)\frac{h(b)}{H(b)-H(a)}\end{aligned} \tag{A.9}$$

and similarly for $E_L[q|q\in[a,b]]$. Note that

$$\begin{aligned}\frac{d^2}{(da)^2}E_H[q|q\in[a,b]]\Big|_{a=b} &= \frac{h'(b)}{h(b)}\frac{1}{2} > \frac{l'(b)}{l(b)}\frac{1}{2} = \frac{d^2}{(da)^2}E_L[q|q\in[a,b]]\Big|_{a=b}\\ \frac{d^2}{(db)^2}E_H[q|q\in[a,b]]\Big|_{b=a} &= \frac{h'(a)}{h(a)}\frac{1}{2} > \frac{l'(a)}{l(a)}\frac{1}{2} = \frac{d^2}{(db)^2}E_L[q|q\in[a,b]]\Big|_{b=a}\end{aligned} \tag{A.10}$$

where the inequalities hold by $H \succ_{MLR} L$, which is implied by (A.6).[27]

Let $\Delta_{[a,b]} = E_H[q|q\in[a,b]] - E_L[q|q\in[a,b]]$ and recall that $d\Delta_{[a,b]}/da = 1/2-1/2=0$ at $a=b$. From (A.10) we know that $d^2\Delta_{[a,b]}/(da)^2>0$ at $a=b$ so $d\Delta_{[a,b]}/da<0$ for $a<b$ in a neighborhood of b. Suppose by way of contradiction that for some $a<b$, $d\Delta_{[a,b]}/da=0$; at such an a, define $C = dE_H[q|q\in[a,b]]/da = dE_L[q|q\in[a,b]]/da$ where $C>0$. In this case,

$$\begin{aligned}\frac{d^2\Delta_{[a,b]}}{(da)^2} &= \left(\frac{h'(a)}{h(a)}-\frac{h'(a)}{l(a)}\right)C+(2C-1)\left(\frac{h(a)}{H(b)-H(a)}-\frac{l(a)}{L(b)-L(a)}\right)\\ &> C\left(\frac{h'(a)}{h(a)}-\frac{l'(a)}{l(a)}\right)+C\left(\frac{h(a)}{H(b)-H(a)}-\frac{l(a)}{L(b)-L(a)}\right)\\ &\propto \left(\frac{h'(a)}{h(a)}+\frac{h(a)}{H(b)-H(a)}\right)-\left(\frac{l'(a)}{l(a)}+\frac{l(a)}{L(b)-L(a)}\right)\\ &= \frac{d}{da}\ln\left(\frac{h(a)}{H(b)-H(a)}\Big/\frac{l(a)}{L(b)-L(a)}\right)>0\end{aligned} \tag{A.11}$$

where the first inequality uses the constraint implied by logconcavity (or decreasing hazard rate) that $C<1$ and the implication from MLR dominance that $\frac{h(a)}{H(b)-H(a)} < \frac{l(a)}{L(b)-L(a)}$, and the last inequality follows from (A.6) for $q=a$ and $q'=b$ and from the log function being strictly increasing.[28] But if $d^2\Delta_{[a,b]}/da^2>0$ for any $a<b$ such that $d\Delta_{[a,b]}/da=0$, continuity implies that there cannot be such an a and therefore $d\Delta_{[a,b]}/da<0$ for all $a<b$.

[27]This is seen by evaluating (A.6) at $a=b$, which requires application of l'Hospital's rule twice.

[28]For $a=0$, the assumption on the (reverse) hazard rate ratio is equivalent to geometric dominance (Noe, 2017)

Following similar steps, and using the implication of logconcavity that $\frac{d}{db}E[q|q \in [a,b] < 1$ (Bagnoli and Bergstrom, 2005) and the implication of MLR dominance that $\frac{h(b)}{H(b)-H(a)} > \frac{l(b)}{L(b)-L(a)}$, yields $d\Delta_{[a,b]}/db > 0$ for all $b > a$ if

$$\frac{d}{db}\ln\left(\frac{h(b)}{H(b)-H(a)}/\frac{l(b)}{L(b)-L(a)}\right) > 0, \tag{A.12}$$

which, by rearranging the denominators, also follows from (A.6) for $q = b$ and $q' = a$. ■

Lemma 3 (Weak private receiver information) *The generalized hazard rate condition* (A.6) *holds for any logconcave F if $Pr[\hbar|q]$ is linear with a positive slope sufficiently close to zero.*

Proof: Let $\Pr[\hbar|q] = k + mq$. For presentational simplicity assume WLOG $k = 1/2$. From (A.11), the condition (A.6) for $q = a$ and $q' = b$ can be written as

$$\left(\frac{h'(a)}{h(a)} - \frac{l'(a)}{l(a)}\right) + \left(\frac{h(a)}{H(b)-H(a)} - \frac{l(a)}{L(b)-L(a)}\right) > 0 \tag{A.13}$$

or substituting and simplifying,

$$\frac{m}{1/4 - m^2a^2} + \frac{f(a)\int_a^b f(t)\,(m(a-t))dt}{\int_a^b f(t)\,(1/2-mt))\,dt\int_a^b f(t)(1/2+mt)dt} > 0\,, \tag{A.14}$$

which can be written as,

$$\frac{m}{1/4 - m^2a^2} + \frac{mf(a)\,((F(b)-F(a))\,a - (F(b)-F(a))\,E[q|q \in [a,b]]))}{(F(b)-F(a))^2\left(\frac{1}{2} - mE[q|q \in [a,b]]\right)\left(\frac{1}{2} + mE[q|q \in [a,b]]\right)} > 0, \tag{A.15}$$

or

$$\frac{m}{1/4 - m^2a^2} - \frac{mf(a)\,(E[q|q \in [a,b]] - a)}{(F(b)-F(a))\left(\frac{1}{4} - m^2E[q|q \in [a,b]]^2\right)} > 0. \tag{A.16}$$

Note that the LHS equals zero at $m = 0$. Taking its derivative with respect to m and evaluating at $m = 0$ yields,

$$4 - 4\frac{f(a)\,(E[q|q \in [a,b] - a)}{F(b)-F(a)}. \tag{A.17}$$

As seen from (A.8), this equals

$$4 - 4\frac{d}{da}E[q|q \in [a,b]], \tag{A.18}$$

which is greater than zero for logconcave F since $\frac{d}{da}E[q|q \in [a,b] < 1$, so the condition holds. The corresponding steps based on (A.8), and the implication of logconcave F that $\frac{d}{db}E[q|q \in [a,b] < 1$, establish that the condition holds for $q = b$ and $q' = a$. ■

Proof of Proposition 2: (i) For c sufficiently close to 1, $\bar{q}_{[s,c)}(c) > \bar{q}_{[0,s)\cup[c,1]}(c)$ since $\bar{q}_{[s,c)}(q) > \bar{q}_{[0,s)\cup[c,1]}(q)$ for all q as established in Proposition 1(iii). And for c sufficiently close to s, $\bar{q}_{[s,c)}(c) < \bar{q}_{[0,s)\cup[c,1]}(c)$ by continuity since $\bar{q}_{\{s\}}(s) < \bar{q}_{[0,1]}(s)$ by the existence of a [strict] nondisclosure equilibrium. Therefore there must be some $c > s$ such that $\bar{q}_{[s,c)}(c) = \bar{q}_{[0,s)\cup[c,1]}(c)$ and that $\frac{d}{dc}\bar{q}_{[s,c)}(c) > \frac{d}{dc}\bar{q}_{[0,s)\cup[c,1]}(c)$ by Lemma 1. Label the first such point c_1. Suppose initial behavior (rather than receiver beliefs) is more modest than this, $D = \emptyset$ or $D = [s, c)$ for $c < c_1$. In the former case beliefs are assumed to remain sufficiently pessimistic that the sender's best response is nondisclosure in the next period, and hence in each subsequent period. In the latter case beliefs in the next period are $D = [s, c)$ and $N = [0, s) \cup [c, 1]$. Since $c < c_1$ then $\bar{q}_{[s,c)}(c) < \bar{q}_{[0,s)\cup[c,1]}(c)$. If $\bar{q}_{[s,c)}(q) < \bar{q}_{[0,s)\cup[c,1]}(q)$ for all q then convergence to nondisclosure is complete. If $\bar{q}_{[s,c)}(q) > \bar{q}_{[0,s)\cup[c,1]}(q)$ for some q then by continuity $\bar{q}_{[s,c)}(q) = \bar{q}_{[0,s)\cup[c,1]}(q)$ for some q, implying from the proof of Proposition 1(i) that $\frac{d}{dq}\bar{q}_{[s,c)}(q) < \frac{d}{dq}\bar{q}_{[0,s)\cup[c,1]}(q)$ for all q. Then, since $\bar{q}_{[s,c)}(c) < \bar{q}_{[0,s)\cup[c,1]}(c)$, the q such that $\bar{q}_{[s,c)}(q) = \bar{q}_{[0,s)\cup[c,1]}(q)$ is strictly lower than c. So the set of types who will disclose in the next period is more modest. This continues until no types disclose and convergence on nondisclosure is complete.

(iii) For c sufficiently close to 1, $\bar{q}_{[s,c)}(c) > \bar{q}_{[0,s)\cup[c,1]}(c)$ as noted above. Consider any such c' such that $\bar{q}_{[s,c)}(c) > \bar{q}_{[0,s)\cup[c,1]}(c)$ for all $c > c'$. Suppose initial behavior is less modest than this, $D = [s, c)$ for $c \geq c'$. Beliefs in the next period are $D = [s, c)$ and $N = [0, s) \cup [c, 1]$. Note that $\bar{q}_{[s,c)}(c) > \bar{q}_{[0,s)\cup[c,1]}(c)$ since $c \geq c'$. If $\bar{q}_{[s,c)}(q) > \bar{q}_{[0,s)\cup[c,1]}(q)$ for all q then in the next period $D = [s, 1]$ and $N = [0, s)$. So convergence to disclosure is complete. If $\bar{q}_{[s,c)}(q) = \bar{q}_{[0,s)\cup[c,1]}(q)$ for some q then, from the proof of Proposition 1(iii), $\frac{d}{dq}\bar{q}_{[s,c)}(q) < \frac{d}{dq}\bar{q}_{[0,s)\cup[c,1]}(q)$ for all q. Then, since $\bar{q}_{[s,c)}(c) > \bar{q}_{[0,s)\cup[c,1]}(c)$, the q such that $\bar{q}_{[s,c)}(q) = \bar{q}_{[0,s)\cup[c,1]}(q)$ is strictly higher than c. So the set of types who will disclose in the next period is less modest. This continues until all types disclose and convergence on disclosure is complete. ∎

Proof of Proposition 3: (i) Consider the outcome in which news $v \leq v_j$ is not disclosed while news $v > v_j$ is disclosed. First consider senders $q \in [s_k, s_{k+1})$ for $k \leq j$. Assume that following an unexpected disclosure of v_k for $k \leq j$, the receiver skeptically believes that the sender must be of type s_k. This yields the lowest possible out-of-equilibrium payoff of s_k. Since $\bar{q}_{[0,s_{j+1})}(q)$ is continuous in q, it follows that $q \leq \bar{q}_{[0,s_{j+1})}(q)$ for any $q \leq \hat{q}_j$. Therefore, since $s_k \leq s_j \leq \hat{q}_j$, $\bar{q}_{[0,s_{j+1})}(s_k) \geq s_k$ so that types $q < s_{j+1}$ have no incentive to disclose.

Now consider senders $q \in [s_k, s_{k+1})$ for $k > j$. Following the argument from (i), all $q \geq s_{j+1}$ are strictly better off disclosing.

(ii) Since $\bar{q}_{[s_j,s_{j+1})}(q) > \bar{q}_{[0,s_1)}(q)$ for any $j = 1, 2, \ldots, N$, if the receiver believes that all types disclose, every type is better off disclosing. ∎

Proof of Proposition 4: For $0 < q' \leq q'' \leq 1$, define:

$$\tilde{q}(q', q'') = \sup_{Q}\{\bar{q}_Q(q'') : [0, q') \subset Q \subset [0, q'')\}. \tag{A.19}$$

This is the maximum nondisclosure payoff for a sender of quality $q = q''$ when the receiver believes that all $q \in [0, q')$ do not disclose and all $q \in [q'', 1]$ disclose. Since $\bar{q}_Q(q)$ is increasing in q, this is an upper-bound on the maximum non-disclosure payoff for any sender $q \leq q''$. Note that $\tilde{q}(q', q'')$ is continuous in q' since $F(q, x)$ is continuous in q, is nonincreasing in q' since higher q' implies a tighter restriction on Q, and is increasing in q'' since $\bar{q}_Q(q)$ is increasing in $q = q''$ and since higher q'' implies a weaker restriction on Q. Let

$$\check{q}_j = \begin{cases} q : q = \tilde{q}(q, s_{j+1}) & \text{if } j = 1 \\ \tilde{q}(s_1, s_{j+1}) & \text{if } j > 1 \end{cases} \tag{A.20}$$

where $\tilde{q}$ is given by (A.19). Since $\tilde{q}(\cdot, \cdot)$ is continuous and nonincreasing in its first argument, the fixed point $\check{q}_j$ exists and is unique. It is straightforward to see that $\check{q}_j < \check{q}_k$ whenever $j < k$. Note $\check{q}_j$ is the maximal possible nondisclosure payoff when the receiver believes that every $q \geq s_{j+1}$ disclose.

Starting with the highest types, if $s_N > \check{q}_N$ then types $q \in [s_N, 1]$ strictly prefer to disclose v_N by the definition of $\tilde{q}_N$. In this case if $s_{N-1} > \tilde{q}_{N-1}$ then types $q \in [s_{N-1}, s_N)$ strictly prefer to disclose v_{N-1} by the definition of $\tilde{q}_{N-1}$. The unraveling continues until types $q \in [s_j, s_{j+1})$ disclose v_j for $j > 1$. For the case where $j = 1$, we know that $s_1 > \check{q}_1 \geq \tilde{q}(s_1, s_2)$ since $\tilde{q}(q', q'')$ is nonincreasing in q' so that types $q \in [s_1, s_2)$ strictly prefer to disclose v_1. ■

Proof of Proposition 5: Let $\varepsilon = \min_{q \geq s_1}\{q - \tilde{q}(s_1, q)\}$. Since $[0, s_1)$ has positive mass, $\varepsilon > 0$. Starting with the highest types, suppose $1 - s_N < \varepsilon$. By the definition of ε and $\check{q}_N$, this implies $1 - s_N < 1 - \check{q}_N$, or $s_N > \check{q}_N$. By Proposition 4, news v_N is disclosed. Now suppose $s_N - s_{N-1} < \varepsilon$, which similarly implies $s_N - s_{N-1} < s_N - \check{q}_{N-1}$, or $s_{N-1} > \check{q}_{N-1}$. So by Proposition 4 news v_{N-1} is also disclosed. Continuing this process for the difference $s_{N-1} - s_{N-2}$, etc. down to the difference $s_{j+1} - s_j$, Proposition 4 implies news v_j is disclosed as long as $s_{k+1} - s_k < \varepsilon$ for $k \geq j$. ■

Proof of Proposition 6: (i) The question is whether, if the mass of F is sufficiently concentrated below a given s_j, it is assured that $\check{q}_j < s_j$. If $F(s_j)$ is sufficiently close to 1, then $\tilde{q}(s_1, s_{j+1}) < s_j$ since there is full support, since $s_1 > 0$, and since nearly all of the mass is below s_j. Thus $\check{q}_j < s_j$ for $j > 1$. Similarly for $j = 1$ the fixed point $q = \tilde{q}(q, s_2)$ must be less than s_1 so $\check{q}_1 < s_1$.

(ii) Let $\bar{q}_{Q,F}(q)$ and $\bar{q}_{Q,G}(q)$ be the expected estimates of q for distributions F and G respectively. Regarding $\check{q}_j$, stochastic domination implies that $\bar{q}_{Q,F}(q) \geq \bar{q}_{Q,G}(q)$. Therefore $\sup_Q\{\bar{q}_{Q,F}(q) : [0, q') \subset Q \subset [0, q'')\} \geq \sup_Q\{\bar{q}_{Q,G}(q) : [0, q') \subset Q \subset [0, q'')\}$, so $\tilde{q}_F(q', q'') \geq \tilde{q}_G(q', q'')$, which proves the result for $j > 1$. For $j = 1$, since $\tilde{q}(q, q'') - q$ is continuous in q and $\tilde{q}(q', q'') \in [0, 1]$ for all q, the conclusion follows directly from Theorem 1 of Milgrom and Roberts (1994). Similarly, regarding $\hat{q}_j$, $\bar{q}_{[0,s_{j+1}),F}(q) - q$ is continuous in q and $\bar{q}_{[0,s_{j+1}),F}(q) \geq \bar{q}_{[0,s_{j+1}),G}(q)$ and $\bar{q}_{[0,s_{j+1}),F}(q) \in [0, 1]$ for all q. So again the conclusion follows directly from Theorem 1 of Milgrom and Roberts (1994). ■

B Empirical example

Table 1 in the introduction provides totals of title usage by faculty. We focus on when full-time, tenure-track faculty use the title "Dr," "PhD," or "Professor" and when they go by their names alone. This decision arises in many contexts including curricula vitæ, business cards, office doors, web sites, email signatures, etc. We look at office voicemail greetings and class syllabi since a sufficiently large sample is obtainable and the choice is likely to be under the control of the faculty.

To minimize the impact of different traditions in different disciplines we focus on economics departments, and to minimize regional variation we look at all state universities in California. In particular, based on faculty lists from department websites in the summer of 2004, we consider tenure-track faculty (assistant, associate, and full professors whom we refer to collectively as "faculty") with PhDs at 26 universities in the University of California and California State University systems with economics departments, excluding one department where the department chair was the only listed faculty member. Based on whether or not the economics department has a doctoral program, we divide the sample into eight "doctoral universities" and 18 "non-doctoral universities."

We start with a sample of 430 faculty with a primary position in one of the economics departments, 226 at doctoral universities and 204 at non-doctoral universities. For voicemail greetings we called at odd hours and on holidays when the faculty member was unlikely to be present. Excluding cases where voicemail was not working, was automated without a personal greeting, or was recorded by staff, we obtained valid voicemail greetings data for 128 of the faculty in doctoral universities and 121 in non-doctoral universities.

For course syllabi we used the first listed undergraduate class on faculty web pages with a syllabus, and chose the format most likely to be handed out in class if multiple formats were listed, e.g., the .pdf format over the .html format. We obtained syllabi for 124 of the faculty at doctoral universities and 70 of the faculty at non-doctoral universities.

Based on the model we hypothesize that title usage is more likely when titles are less common. All of the economics faculty in our sample are tenure-track faculty with PhDs, but they are not immediately distinguishable to students and other observers from faculty without PhDs and from part-time instructors. As shown in Table 1, faculty at doctoral universities are significantly less likely to use titles in voicemail and syllabi. This patterns supports the hypothesis if titles are less common at non-doctoral universities. Available data from annual *Common Data Set* reports for each university are consistent with this. For the 11 non-doctoral universities with available data, the average percent of full-time faculty with a PhD or the highest degree in their field was 80.1% in 2004. For part-time faculty the comparable number was 24.5%. The doctoral universities do not collect this data individually, but those that report a percentage use an estimate from the University of California system that 98% of faculty have PhDs or the highest degree in their field. For the 13 non-doctoral universities with available data, the percent of all faculty that were full-time faculty was 55.6% in 2004. For the seven doctoral universities with such data, the same figure was 80.0%.

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