Credibility of Crime Allegations*

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Abstract. The lack of hard evidence in allegations about sexual misconduct makes it difficult to separate true allegations from false ones. We provide a model in which victims and potential libelers face the same costs and benefits from making an allegation, but the tendency for perpetrators of sexual misconduct to engage in repeat offenses allows semi-separation to occur, where a true victim reports with a higher probability than a libeler does. Our model also explains why reports about sexual misconduct are often delayed, and why the public rationally assigns less credibility to these delayed reports than to contemporaneous ones.

Keywords. corroboration; repeat offenses; delayed reporting; encouragement effect; information escrow

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1. Introduction

In a he-said-she-said situation, such as an alleged rape or sexual assault, a single uncorroborated report is often not enough evidence for the authorities to arrest or prosecute the alleged perpetrator. An accumulation of allegations can, however, lead to an arrest or prosecution.

The Bill Cosby trial grabbed national headlines in 2017. It stemmed from an allegation made by Andrea Constand in 2005 alleging that Bill Cosby, a comedian, drugged and raped her in 2004. This was the first public rape allegation against Cosby. No charge was made at the time. Within the same year, three additional similar allegations against Bill Cosby arose, alleging assaults that happened in the 1970s and 1980s. Still no arrest was made. A new wave of allegations surfaced in 2014 and 2015, with over 50 women alleging sexual crimes that happened from 1965 to 2008. Bill Cosby was arrested and charged in 2015 in relation to the 2005 allegation by Andrea Constand. The trial ended in mistrial.[1]

The Jerry Sandusky sexual abuse case is another notable example. Over a hundred incidents of abuse of children were alleged over time against the former football coach, but the first report in 2008 was met with disbelief. The attorney general told the alleger in 2008 that authorities needed more victims to charge Sandusky. Sandusky was not arrested until the second report came from a witness in late 2010, reporting an incident that happened more than ten years before.[2]

It is understandable that the public is not convinced by a single report alleging sexual crimes. It is a classical asymmetric information problem, where a true victim cannot easily separate himself or herself from a libeler who makes a false accusation. A libeler can be motivated by a grudge, political motives, publicity, or potential financial gains. The possibility of wrongful accusations is particularly relevant in the case of allegations about sexual misconduct, because the line between proper and improper conduct is somewhat blurred. A "libeler" may be just misinterpreting the situation without intending any malice. Because of the lack of hard evidence in a sexual crime, if a victim finds it worthwhile to report, a potential libeler will often find it worthwhile to make an accusation as well. The existence of false accusations is a legitimate concern. In 2014, *Rolling Stone* published

[1] Details of this case were widely reported in newspapers. We obtained our sources mostly from the Wikipedia article, "Bill Cosby Sexual Assault Allegations."

[2] See the October 19, 2012, story, "Sandusky Victim 1 Steps Out of Shadows, Says Justice Took Too Long," *20/20*, ABC News.

an article, "A Rape on Campus," accusing three Duke Lacrosse team players of gang rape two years before. The magazine had to retract the article in its entirety in 2015 because it was discovered that the rape allegation was fabricated. The National Sexual Violence Resource Center documented in 2012 that, in various studies of reports of sexual assaults, the percentage of reports that are found to be false ranges from 2 to 10 percent.[3] For example, a multi-site study of eight U.S. communities including 2,059 cases of sexual assault found a 7.1 percent rate of false reports (Lonsway, Archambault and Lisak 2009). Most of the time, there is no way to verify whether an allegation is true or false.

This paper studies the incentives to allege a crime by victims or by potential libelers in a two-period setup. There are possibly multiple potential allegers who can make public but unverifiable reports against the same person. These allegers can choose whether or not to report, as well as when to report. We aim to address three major questions regarding this type of allegations. First, allegations of sexual crimes are often made of incidents that happened a long time ago, which we call *delayed reports*. These delayed reports can come from victims who are delaying to report a true crime, as demonstrated by the Sandusky case, or from libelers who are choosing to make false accusations long after the time of interaction with the accused. Why do delayed reports appear so often in this type of allegations? Second, given the lack of hard evidence and the possibility of false accusations, how much credence should be given to allegations that are unsubstantiated by witnesses or physical evidence? Third, a delayed report is typically met with suspicion. For example, in October 2016 Trump supporters have started the hashtag #NextFakeTrumpVictim by attacking the sexual assault allegations against Donald Trump with tweets that read, for example, "Why didn't these 'victims' come forward 30 years ago? Could've scored a hefty sum from a billionaire." Is such skepticism justified?

A key to our analysis is that sexual crimes are often committed by recidivists, who have a tendency to engage in repeat offenses against other victims. According to the Rape, Abuse & Incest National Network (RAINN), more than half of all alleged rapists have at least one prior conviction. Taking into account the low reporting rate and the low conviction rate,[4] this statistic suggests a strong tendency for rapists to engage in repeat offenses. In addition, the medical literature suggests that "pedophilia is a sexual orientation and

[3] See `https://www.nsvrc.org/sites/default/files/Publications_NSVRC_Overview_False-Reporting.pdf`.

[4] RAINN estimates that only 310 out of 1000 rape cases are reported, out of which 11 will get referred to prosecutors and 7 will result in a felony conviction.

unlikely to change."[5] In this paper, we assume that a true victim expects a higher chance that another victim exists who may provide corroboration than a potential libeler does.

The possibility of the existence of another victim or another potential libeler produces a free-riding problem. Because a single accusation is often insufficient evidence to cause the authorities to take action, individuals have an incentive to take a wait-and-see approach and delay making an allegation until another allegation arises. In our benchmark model, an individual with relatively low reporting cost always reports immediately, while an individual with higher reporting cost makes a delayed report if and only if there is another report against the accused.[6]

On the surface, given that there is a higher chance of having a corroborator for a victim than for a libeler, one might suspect that a victim is more inclined to wait for others to report first in order to delay the cost of making an allegation. We argue that this reasoning is not correct, because it assumes that the future corroborator's reporting behavior is not affected by the history he or she observes. In fact, the future corroborator is more likely to report if there has been a previous report, so the higher incentive to lead and encourage the future corroborator to report dominates the motive to delay reporting costs for individuals with low reporting costs. This dynamic *encouragement effect* works in the opposite direction of the standard free-riding effect in public good provision. Because guilty agents have a higher tendency of recidivism than do innocent ones, the encouragement effect figures more prominently for true victims than for potential libelers. This effect causes true victims to be less inclined to make a delayed report than do potential libelers. The fact that true victims tend to make immediate crime allegations with a higher probability in turn lends credence to such allegations, allowing a semi-separating equilibrium to exist even when true victims and potential libelers face the same costs and benefits from making an allegation. In other words, even though allegations are unsubstantiated by hard evidence, they do contain information that may prompt the authorities into taking action.[7]

Our model also justifies the public's skepticism toward delayed reports. If there is another allegation against a person, victims or libelers who took a wait-and-see approach will no longer shy from making an allegation because corroborated reports are more con-

[5] See "Pessimism about Pedophilia," *Harvard Mental Health Letter*, July 2010.

[6] This potential free-riding incentive is called a "first mover disadvantage" by Ayres and Unkovic (2012).

[7] This information comes from equilibrium inference, which may not constitute evidence that is admissible in court. However, it may be sufficient to induce the authorities to conduct further investigations that lead to arrest or prosecution.

vincing than a single report. But since we show that libelers have a greater probability of taking a wait-and-see approach than victims do, the public rationally assigns less credibility to delayed reports than to contemporaneous ones. The public is rightly skeptical because delayed reports are more likely to have been made "opportunistically."

The communication game described in this paper is different from a cheap talk game (Crawford and Sobel 1982). Here the action of reporting carries a cost, while the action of not reporting does not. Reporting is directly costly for many reasons. A reporter often has to reveal facts about themselves that are not positive, such as the use of drug and alcohol, which can lead to social stigma, suspension from school, or loss of scholarships.[8] The reporter faces possible retaliation from the accused because of the public nature of the report. Investigations are emotionally and physically exhausting themselves. Sable et al. (2010) find that the top three reasons that women do not report are (1) shame, guilt, embarrassment, (2) fear of retaliation, and (3) confidentiality concerns. The easier thing to be do is to not allege a sexual crime.

In order to highlight the difficulties in separating truthful allegations from fake ones, we purposefully avoid the traditional channel of signaling arising from payoff differences. Both a true victim and a potential libeler in our model have the same costs of reporting and the same payoffs from the authorities' decisions.[9] In this sense, our model is different from a standard signaling game of Spence (1973). In our model, different types (victim or libeler) would behave in exactly the same way if they are sure that another victim or libeler does not exist. It is the assumption that victims and libelers expect different probabilities that another alleger may exist which causes their equilibrium strategies to be different.

This paper is related to Chassang and Miquel (2016), a study of unverifiable reporting by whistleblowers. They take a mechanism design approach, in which the cost of reporting arises endogenously as retaliation from the accused. In their model there is a single monitor who may potentially "blow the whistle" to report on inappropriate behavior of an agent. Our paper focuses more on the incentive issues that arise when possibly more than one victim (or more than one libeler) can make allegations against the same agent in a dynamic setting. We adopt a reduced-form approach by taking the distribution of re-

[8] An alleger of rape at Brigham Young University was suspended because of the revelation that she used illegal drugs. See "At Brigham Young, A Cost in Reporting a Rape," *The New York Times*, April 26, 2016.

[9] In Chandrasekhar, Golub and Yang (2017), different types have the same costs and benefits from taking a signaling action (asking for help), and partial separation is achieved in equilibrium because the distribution of benefits are different for different types.

porting costs as given, but there is discounting in reporting costs if allegers make delayed reports.[10] For sexual harassment in the workplace, the exogenous reporting costs in our model may reflect the possibility of retaliation by the accused or by the employer,[11] and these costs can be substantially lower if the alleger has left the firm by the time he or she makes a delayed report.

Chamley and Gale (1994) study a model of endogenous delay in a framework in which there is informational externality but no payoff externality. They show that potential investors may delay the project in the hope of learning about the existence of other potential investors (which is good news in their setup). Their model also exhibits clustering in investment decisions, similar to the appearance of follow-on reports after the first allegation is made in our model. In our model of allegations about sexual crimes, the externality involved is a direct payoff externality coming from the possibility of corroboration. Delay may also occur in the investment game of Gale (1995), because the benefit of investing increases in the number of investors and investing early before the others is money-losing initially. He finds that in some equilibrium there is an encouragement effect: investing early encourages others to invest. The literature on the dynamic provision of public goods (e.g., Fershtman and Nitzan 1991; Marx and Matthews 2000) also focuses on payoff externalities, but the existence of other players is not taken to be uncertain in that literature or in Gale (1995). Furthermore, our paper analyzes how the endogenous timing of reporting behavior affects the credibility of these reports, which is not an issue in the dynamic public good provision problem.

In Section 2 of the paper, we lay out the setup of our signaling game. Section 3 analyzes the equilibrium we are most interested in—a corroboration equilibrium in which multiple reports may happen on the equilibrium path and some reports may be delayed. We provide a brief discussion of other types of equilibria in Section 4. In section 5, we extend the benchmark model in different ways and discuss how these modifications affect the analysis and our main conclusions. Our formal model provides a framework to study a recently developed reporting system of sexual crimes: the online *information escrow* (Ayres and Unkovic 2012). Such an analysis is developed in Section 6 of the paper. An information escrow allows people to place allegations into an escrow on the condition that the

[10] The role of delay in facilitating communication has been studied in a different context by Damiano, Li and Suen (2012) and Eso and Fong (2008).

[11] In a sample of 86 state workers studied by Loy and Stewart (1984), 62 percent reported retaliation by their employers following their responses to harassment.

allegations are transferred to the authorities if and only if a pre-specified number of allegations are lodged against the same person. A system, using a pre-specfied number of two, called the "Callisto reporting system," has been developed into operation and is adopted by eight universities by 2017.[12] The basic idea is that information escrows can remove victims' incentive to wait for corroboration. We point out, however, that the credibility of two reports from a Callisto system is lower than the credibility of two reports outside a Callisto system. Depending on the standard of credibility expected by the authorities to take action, forcing all reports to go through the Callisto system may sometimes cause victims to be less forthcoming in reporting crimes than without the Callisto system.

2. The Model

An agent A can be of two types: "guilty" or "innocent." Agent A is active for two periods. In each period, A hurts a person (and therefore breaks the law) with independent probability p if A is a guilty type. If A is innocent, a potential libeler holding a grudge against A appears with independent probability q in each period. In the model the behavior of A is non-strategic. The focus of our analysis is the behavior of victims and potential libelers. The existence of victims and the existence of potential libelers are mutually exclusive.

Suppose A is a guilty type. For $t = 1, 2$, we let V_t represent the victim hurt by A in period t. If V_1 and V_2 do not exist, then nothing happens in this model. Because crimes are perpetrated in secrecy (unless there is a report of the crime), the victim of A does not know whether A had committed a similar crime before nor whether A will commit a similar crime in the future. We capture this uncertainty by assuming that V_t does not know whether she lives in period 1 or period 2. Ex ante, she assigns probability $\frac{1}{2}$ to each of these two possibilities.

A victim derives utility from getting A arrested. We normalize this payoff to 1. However, reporting a crime is costly. We denote the cost of reporting by c and assume that it is an independent draw from the uniform distribution on $[0, 1]$. A victim knows her own cost c, but outsiders do not observe her c. The victim applies a discount factor $\delta < 1$ to benefits that are obtained or costs that are incurred a period later.

Victim V_1 is harmed by A in period 1 (although she does not know that she lives in period 1). She has two chances to lodge a complaint. First, she can report the crime against her immediately in period 1. Let $\alpha(c)$ represent the probability that she chooses to

[12] Further information about this system is available at `https://www.projectcallisto.org/`.

immediately report the crime. In the ensuing analysis, we define $a \equiv \mathrm{E}[\alpha(c)]$, where the expectation is taken over possible realizations of c. Second, if V_1 does not report in period 1, she can lodge a delayed report at the end of period 2, after learning whether or not another victim has made a complaint against A. We let $\hat{\alpha}_1(c)$ represent the probability that V_1 lodges a delayed report in period 2 if she has learned that another complaint has been made, and let $\tilde{\alpha}_1(c)$ represent the probability that she lodges a delayed report in period 2 if no other victim has made a complaint.

Victim V_2 is harmed in period 2. She has only one chance to lodge a complaint. If no one has accused A before, then V_2 does not know whether she is V_1 or V_2. In this case, her strategy is the same as that of V_1 in period 1, i.e., she reports the crime immediately with probability $\alpha(c)$, but she will have no chance to lodge a delayed report because she lives in the last period.[13] If someone has lodged a complaint against A, then V_2 observes this report and knows that she lives in period 2. We use $\hat{\alpha}_2(c)$ to represent the probability that V_2 complains against A, knowing that there is a prior allegation against him. Any complaint made against A is assumed to be public knowledge.[14]

The prior probability that A is a guilty type is μ_0. With probability $1-\mu_0$, A is innocent. An innocent A faces a potential libeler in each period with independent probability q. We let L_1 and L_2 represent the potential libelers in period 1 and period 2, respectively. These potential libelers (if they exist) hold a grudge against A and derive a payoff of 1 from getting A arrested. Their costs of lodging a complaint are independent draws from the uniform distribution on $[0,1]$, and their discount factor is δ. In other words, the payoff structure for potential libelers is identical to that for true victims. A priori, it is not obvious whether the costs and benefits of making an allegation are higher or lower for potential libelers than for true victims. We make the assumption that their payoffs are identical to highlight the difficulty of making inferences based on systematic differences in payoffs. For convenience, we will sometimes refer to potential libelers directly as libelers, even though they may not choose to make an allegation in equilibrium.

The information structure for libelers is very similar to that for victims as well. If no prior complaint has been filed against A, a libeler does not know whether she is L_1 or L_2, and she lodges a complaint immediately with probability $\beta(c)$. In the subsequent analysis, we define $b \equiv \mathrm{E}[\beta(c)]$. All other notations parallel those for victims: L_1 files a

[13] For example, we may assume that the whereabouts of agent A are no longer traceable after period 2.

[14] Section 5.1 considers an extension in which a report against A is observed by another alleger only with some probability.

delayed report with probability $\hat{\beta}_1(c)$ after L_2's complaint; L_1 files a delayed complaint with probability $\tilde{\beta}_2(c)$ if L_2 does not file a complaint; and L_2 files a complaint with probability $\hat{\beta}_2(c)$ after L_1's complaint. The only difference in the information between a libeler and a victim is that the former knows A is innocent while the latter knows A is guilty. As a result, a libeler assigns prior probability q to the existence of another libeler, whereas a true victim assigns prior probability p to the existence of another victim. Crucially, we maintain the following assumption throughout the paper:

Assumption 1. $p > q$.

Assumption 1 captures the fact that sexual crimes are likely to be perpetrated by repeat offenders.[15] Thus, a true victim of A should expect a high likelihood that her story can be corroborated by similar victims of A. On the other hand, the existence of potential libelers tends to be more idiosyncratic. If a person holds a personal grudge against innocent A, this person may not assign a high probability that another person will hold a similar grudge against A.

If a report alleges that a crime happened in the same period, we call it a *contemporaneous report*. If a report alleges a crime a period earlier, we call it a delayed report. The decision maker (the police authorities, for example) also does not know which period she is in, and assigns prior probability $\frac{1}{2}$ to either possibility. If no one makes a complaint against A (we denote this event by ϕ), the decision maker cannot arrest A. She decides whether or not to arrest agent A after the following observable outcomes: (1) there was only one contemporaneous report in the current period (event r); (2) there was only one delayed report in the current period (denoted R); (3) there was only one contemporaneous report in the previous period and no report in the current period (event $r\phi$); (4) there was one contemporaneous report previous period and another contemporaneous report in the current period (event rr); and (5) there was one contemporaneous report in the current period followed by one delayed report (event rR). For $\mathscr{E} \in \{r, R, r\phi, rr, rR\}$, let $\mu(\mathscr{E})$ represent the decision maker's posterior belief that A is a guilty type conditional on event $\mathscr{E}$. For simplicity, we just assume that the decision maker is bound to arrest A as soon as $\mu(\mathscr{E})$ is greater than or equal to some threshold standard $\hat{\mu}$, which is taken to be exogenous.[16] The game ends at the end of period 2 or whenever A is arrested. The passage

[15] Groth, Longo and McFadin (1982) find that the majority of the sexual crime offenders had been convicted more than once for a sexual assault. Moreover, on average, they admitted to having committed two to five times as many sex crimes for which they were not apprehended.

[16] The threshold standard can be determined by the decision maker's costs of making type I and type II

of time over a period is something that everyone can experience, so if a victim or a libeler finds that she can still report after a whole period has passed, she knows that she is in period 2. Similarly, if the decision maker knows that she can still make an arrest after a whole period has passed, she knows that she is in period 2.

The timing of the game when A is guilty is illustrated in Figure 1. The timing of the game when A is innocent is the same, with V_t replaced by L_t for $t = 1, 2$.

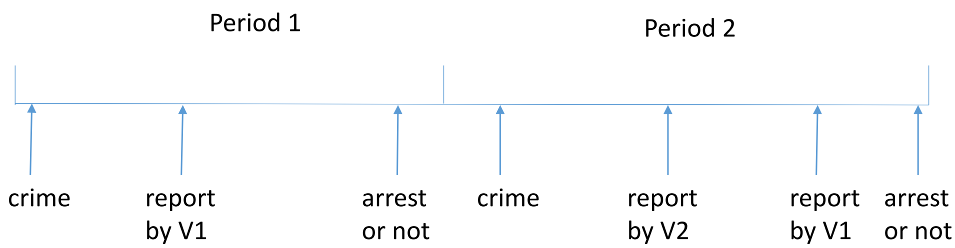

Figure 1. *The timeline when A is guilty. This figure shows the case in which A strikes a victim in each period. If there is no crime, there is no reporting decision. If there is no report, there is no arrest decision.*

3. Corroboration Equilibrium with Occasional Delay

In this section, we focus on an equilibrium in which events rr and rR both appear with positive probability on the equilibrium path; that is, it is possible to observe multiple allegations against the same agent, and sometimes these allegations are delayed. In such an equilibrium, both rr and rR lead to an arrest; otherwise they will not appear in equilibrium. Moreover the events r or $r\phi$ will not lead to an arrest, because if they do, then no one will follow up with a report. Similarly, the event R does not lead to an arrest, because if it does, then one will always delay a report and rr or rR will not appear in equilibrium.

In other words, we look for an equilibrium in which A is arrested if and only if there are two allegations against him. We refer to this type of equilibrium as a "corroboration equilibrium with occasional delay," or simply a *corroboration equilibrium*.

Let $l(\mathscr{E})$ represent the likelihood ratio of event $\mathscr{E}$ (given the guilty type relative to the innocent type). For any fixed prior μ_0, there is a monotone relationship between $\mu(\mathscr{E})$ and $l(\mathscr{E})$. Thus, one can also say that the decision rule of the authorities is to arrests A

errors.

as soon as $l(\mathscr{E}) \geq \hat{l}$, where $\hat{l} = \hat{\mu}(1-\mu_0)/(\mu_0(1-\hat{\mu}))$. We sometimes refer to $\hat{l}$ as the *standard of proof*. The existence of a corroboration equilibrium requires $l(rr)$ and $l(rR)$ to be greater than or equal to the standard of proof $\hat{l}$, and $l(r)$, $l(R)$, and $l(r\phi)$ to be less than $\hat{l}$. We proceed by assuming these conditions, and then verify that they indeed hold in equilibrium.

Given the above assumed conditions of the likelihood ratios, a silent victim V_1 who observes another person lodging a report against A in period 2 will surely lodge a delayed complaint, because doing so gives a payoff of 1 at a cost $c \leq 1$. Therefore, $\hat{\alpha}_1(c) = 1$ for any c. Similarly, a victim V_2 who knows of a prior complaint against A will also lodge a complaint upon being hurt. Therefore, $\hat{\alpha}_2(c) = 1$ for any c. On the other hand, a silent victim V_1 has no incentive to report against A at the end of period 2 if no other victim had come forward. Therefore, $\tilde{\alpha}_1(c) = 0$ for any c. The payoff structure of libelers is identical to the payoff structure of true victims. Thus, $\hat{\beta}_1(c) = \hat{\beta}_2(c) = 1$ and $\tilde{\beta}_1(c) = 0$ for any c.

Consider now a victim of A who has not seen a prior accusation against A. For convenience, we label her a *fresh victim* (even though she may be the second victim if the first one did not report). A fresh victim can entertain three possibilities:

1. Another victim does not exist (the probability of this event is $1-p$).
2. She is V_1, and another victim V_2 exists in period 2 (the probability is $\frac{1}{2}p$).
3. She is V_2, and another victim V_1 exists but did not report (the probability is $\frac{1}{2}p(1-a)$.)

The sum of these probabilities is $1-\frac{1}{2}pa$.

In the first eventuality, one report is not sufficient to arrest A because $l(r) < \hat{l}$. Therefore, reporting immediately is futile (i.e., the payoff is 0). In the second eventuality, reporting immediately will encourage the future victim V_2 to report because $\hat{\alpha}_2(c) = 1$. The discounted benefit is δ. In the third eventuality, reporting immediately will cause the past victim V_1 to come forward with a delayed report because $\hat{\alpha}_1(c) = 1$. This leads to the arrest of A in the same period, with a payoff of 1. Therefore, if the fresh victim has reporting cost c, the expected net payoff from reporting immediately is

$$-c + \frac{(1/2)p}{1-(1/2)pa}\delta + \frac{(1/2)p(1-a)}{1-(1/2)pa}. \tag{1}$$

If the fresh victim does not report immediately, then only in the second eventuality can she follow up with a delayed report provided that V_2 makes a complaint against A. The probability that V_2 will make a complaint conditional on this eventuality is a, and the discounted net benefit is $\delta(1-c)$. Therefore, the expected net payoff from not reporting immediately is

$$\frac{(1/2)p}{1-(1/2)pa}a\delta(1-c). \tag{2}$$

Let $f(c,a;p)$ represent the payoff difference between reporting immediately and not reporting immediately for a fresh victim, given that other victims are adopting the strategies $\hat{\alpha}_1(c)=1$, $\hat{\alpha}_2(c)=1$, $\tilde{\alpha}_1(c)=0$, and $\mathrm{E}[\alpha(c)]=a$:

$$f(c,a;p)=-c+\frac{(1/2)p}{1-(1/2)pa}\delta(1-a(1-c))+\frac{(1/2)p(1-a)}{1-(1/2)pa}.$$

For any a and p, $f(\cdot,a;p)$ is strictly decreasing, with $f(0,a;p)>0>f(1,a;p)$. Therefore, there exists $\hat{c}(a,p)$ satisfying $f(\hat{c}(a,p),a;p)=0$, such that the best response is to report immediately (i.e., choose $\alpha(c)=1$) if and only if $c\leq\hat{c}(a,p)$. Because $a=\mathrm{E}[\alpha(c)]$ and the distribution of c is uniform, equilibrium requires $\hat{c}(a^*,p)=a^*$.

In a similar fashion, the payoff difference between reporting immediately and not reporting immediately for a *fresh libeler* (i.e., a libeler who does not observe a prior report against *A*) is $f(c,b;q)$. Equilibrium requires that $f(b^*,b^*;q)=0$, with the fresh libeler person choosing $\beta(c)=1$ if and only if $c\leq b^*$.

Lemma 1. *In a corroboration equilibrium, fresh victims report immediately against A with a strictly higher probability than do fresh libelers. Moreover, a^* increases in p and δ, and b^* increases in q and δ.*

Proof. In a corroboration equilibrium, a^* satisfies $F(a^*;p)=0$, where

$$F(a;p)\equiv f(a,a;p)=\frac{1/2}{1-(1/2)pa}\left(-a(2-pa)+p\delta(1-a(1-a))+p(1-a)\right). \tag{3}$$

It is straightforward to verify that $F(\cdot;p)$ is single-crossing from above, with $F(0;p)>0>F(1;p)$. Hence there exists a unique $a^*\in(0,1)$ such that $F(a^*;p)=0$. Since $F(a;p)$ increases in p whenever $F(a;p)=0$, by the implicit function theorem, an increase in p raises a^*. Because the equilibrium b^* satisfies $F(b^*;q)=0$, $p>q$ implies $a^*>b^*$. Finally, because $F(a;p)$ increases in δ, a^* is increasing in δ. Likewise, b^* is increasing in δ. ∎

Given a fresh victim's reporting cost c, $f(c,a;p)$ is decreasing in a. This means that if other fresh victims are more likely to report immediately (a increases), then a fresh victim is less likely to do so ($\hat{c}(a,p)$ decreases). This strategic substitution in reporting immediately among fresh victims (or fresh libelers) reflects the public good nature of crime allegations when a single report is not sufficient to lead to arrest. Each victim who has not observe an allegation against A has an incentive to take a wait-and-see approach. If another report later comes to surface, the fresh victim can reduce the cost by lodging a delayed report. If no other report comes to surface, the fresh victim can eliminate the cost of making a futile report. The downside of this approach is that A may not be arrested if (1) the fresh victim is V_2 and V_1 did not report, or (2) V_2 does not choose to be the first one to report. Both of these two events are less likely when a is higher, so the downside risk is smaller when a is higher, which explains the strategic substitution effect.

It may appear that the free-riding problem[17] is more severe for fresh victims than for fresh libelers because p (the probability that another victim exists) is greater than q (the probability that another libeler exists)—in equation (2), the payoff from not reporting immediately is increasing in p. However, free-riding is not the only incentive in our setting, as the model also exhibits complementarity between the existence of the two reporters through an encouragement effect. First, if a fresh victim is V_1, and if V_2 exists, then by reporting immediately the fresh victim raises the probability that V_2 will report the crime from $\mathrm{E}[\alpha(c)] = a$ to $\hat{\alpha}_2(c) = 1$. Second, if a fresh victim is V_2 but V_1 did not report, then by reporting immediately the fresh victim raises the probability that V_1 will report the crime from $\tilde{\alpha}_1(c) = 0$ to $\hat{\alpha}_1(c) = 1$. Both of these encouragement effects are more important for victims than for libelers because $p > q$—in equation (1), the payoff from reporting immediately is increasing in p. These encouragement effects outweigh the free-riding effect to cause fresh victims to report immediately with a higher probability than fresh libelers do.

Lemma 2. *In a corroboration equilibrium, two contemporaneous reports against A are assigned a greater credibility than one current report corroborated by a delayed report. Moreover, if $p \leq \frac{2}{3}$, we have $l(rR) > p^2/q^2$.*

Proof. Suppose agent A is guilty. the event $\mathscr{E} = rR$ is observed only when both V_1 and V_2 exist, and V_1 has cost above a^* and V_2 has cost below a^*. The probability of this event is $p^2 a^*(1-a^*)$, and the likelihood ratio is $l(rR) = p^2 a^*(1-a^*)/(q^2 b^*(1-b^*))$. The event $\mathscr{E} = rr$ is observed only when both V_1 and V_2 exist, and both have costs below a^*. The likelihood ratio is $l(rr) = p^2 a^{*2}/(q^2 b^{*2})$. By Lemma 1, $a^* > b^*$, which implies $l(rr) >$

[17] When free-riding on the other alleger, one eventually still needs to file a report to corroborate if the other reports, but filing later saves expected reporting costs.

$l(rR)$.

From the equation $F(a^*; p) = 0$, we can verify that $a^* = \frac{1}{2}$ when $p = \frac{2}{3}$ and $\delta = 1$. Since a^* increases in p and δ (Lemma 1), $q < p \leq \frac{2}{3}$ implies $b^* < a^* < \frac{1}{2}$ for any $\delta < 1$. Hence, $b^*(1-b^*) < a^*(1-a^*)$, and we obtain $l(rR) > p^2/q^2$. ■

Lemma 2 is consistent with common attacks on the credibility of accusations that surface long after the alleged crimes. In a corroboration equilibrium, true victims are more likely than the libelers to lodge a contemporaneous complaint against A if there is no prior complaint against him, but everyone (true victim or not) can secure an arrest of A if there is already a prior complaint. Because libelers are more likely to take a wait-and-see approach, the public rationally believes that delayed reports are more likely to be "opportunistic" and assigns less credibility to them.

If victims and libelers were non-strategic and always report, the likelihood ratio from having two reports would be p^2/q^2. Lemma 2 shows that $l(rR) > p^2/q^2$ as long as p is not too large. Because $a^* > b^*$ in our model, having a contemporaneous report against an agent A is strong indication that A is guilty. As long as p is not too large, so that $b^* < a^* < \frac{1}{2}$, this effect is more than enough to offset the skepticism toward a delayed report to cause rR to be more credible than two reports from non-strategic actors.

Proposition 1. *A corroboration equilibrium exists if and only if*

$$\hat{l} \in (\underline{l}^*, \overline{l}^*] \equiv \left(\frac{p(2-p)a^*}{q(2-q)b^*}, \frac{p^2 a^*(1-a^*)}{q^2 b^*(1-b^*)} \right].$$

Moreover, there exists $\overline{p}(\delta)$, which is decreasing in δ and greater than $\frac{2}{3}$, such that the range $(\underline{l}^*, \overline{l}^*]$ is non-empty for all $p \leq \overline{p}(\delta)$.

Proof. Suppose A is a guilty type. Given the strategy profile in a corroboration equilibrium, there are two possibilities that lead to the event r: (1) the current period is period 1 and V_1 reported (this happens with probability $\frac{1}{2}pa^*$); and (2) the current period is period 2, V_1 didn't exist, and V_2 reported (this happens with probability $\frac{1}{2}(1-p)pa^*$). Therefore, the probability of observing r given A is guilty is $\frac{1}{2}pa^*(2-p)$. Similarly, the probability of observing r given A is innocent is $\frac{1}{2}qb^*(2-q)$. This gives $l(r) = \underline{l}^*$. The event $r\phi$ happens if V_1 exists and makes an immediate report but V_2 does not exist, which occurs with probability $p(1-p)a^*$. The corresponding likelihood ratio is $l(r\phi) = p(1-p)a^*/(q(1-$

$q)b^*) < \underline{l}^*$. In the proof of Lemma 2, we show that $l(rR) = \overline{l}^* < l(rr)$. The event R is off-equilibrium. We can assign an off-equilibrium belief such that $l(R) < \hat{l}$. This establishes that a corroboration equilibrium exists if and only if $\hat{l} \in (l(r), l(rR)]$.

The range $(\underline{l}^*, \overline{l}^*]$ is non-empty if and only if

$$\frac{p(1-a^*)}{2-p} > \frac{q(1-b^*)}{2-q}.$$

The left-hand-side of the above is equal to the right-hand-side when $p = q$. Since $p > q$, it suffices to show that the left-hand-side is increasing in p, which is equivalent to

$$2(1-a^*) - p(2-p)\frac{\partial a^*}{\partial p} > 0. \tag{4}$$

By implicit differentiation of (3),

$$\frac{\partial a^*}{\partial p} = \frac{(1+\delta)(1-a^*(1-a^*))}{2+(1+\delta)p(1-2a^*)} = \frac{2a^*}{p\,(2+(1+\delta)p(1-2a^*))},$$

where the second equality holds because $F(a^*;p) = 0$ implies $(1+\delta)(1-a^*(1-a^*)) = 2a^*/p$. Suppose p and δ are such that $a^* < \frac{1}{2}$. Then, we have $\partial a^*/\partial p < a^*/p$, and therefore the left-hand-side of (4) is greater than or equal to $2(1-\frac{1}{2}) - (2-p)\frac{1}{2} > 0$. By Lemma 2, we conclude that inequality (4) holds for all $p \le \frac{2}{3}$.

This argument also shows that we must have $a^* > \frac{1}{2}$ whenever

$$q(a^*, p, \delta) \equiv 2(1-a^*) - p(2-p)\frac{(1+\delta)(1-a^*(1-a^*))}{2+(1+\delta)p(1-2a^*)} = 0.$$

For $a^* > \frac{1}{2}$, $q(a^*, p, \delta)$ is decreasing in a^*, p, and δ. By Lemma 1, this implies $Q(p, \delta) \equiv q(a^*(p, \delta), p, \delta)$ is decreasing in p and δ. Thus, the locus $\overline{p}(\delta)$ that satisfies $Q(\overline{p}(\delta), \delta) = 0$ is decreasing in δ, with $Q(p, \delta) > 0$ for all $p < \overline{p}(\delta)$. ■

Proposition 1 states that a corroboration equilibrium exists whenever the standard of proof $\hat{l}$ falls in the range $(l(r), l(rR)]$. Because rr is more credible than rR, and r is more credible than $r\phi$, the accused agent A will be arrested if and only if there are two reports lodged against him.

The range $(l(r), l(rR)]$ may be empty, in which case a corroboration equilibrium does not exist. This may occur because, for very high values of p and δ, the event rR is even less credible than r.[18] The reason is that rR reveals that the first alleger chose to not report right away. Since libelers are more likely to take this wait-and-see approach, this brings down the belief, reflected in the ratio $(1-a^*)/(1-b^*)$. If both p and δ are close to 1, then $1-a^*$ would be close to 0, causing a contemporaneous report followed by a delayed report to be less credible than just one contemporaneous report.

Proposition 1 also establishes that the existence of a corroboration equilibrium is guaranteed whenever p or δ is not too large. Specifically, for any δ, a corroboration equilibrium always exists if $p \leq \frac{2}{3}$. Suppose, for example, that $p = 0.3$, $q = 0.1$, and $\delta = 0.8$. Then, in a corroboration equilibrium, $a^* \approx 0.22$ and $b^* \approx 0.08$. In other words, more than three-quarters of the fresh victims do not report the crimes against them immediately. In such an equilibrium, $l(rr) \approx 64.86$ and $l(rR) \approx 20.47$, meaning that two contemporaneous reports are more than three times as credible as a contemporaneous report corroborated by a delayed one. A corroboration equilibrium exists if and only if $\hat{l} \in (7.21, 20.47]$. If victims and libelers were to always lodge a complaint immediately (e.g., if they are non-strategic), the credibility of two current reports would be $l(rr) = p^2/q^2 = 9$. Thus, for $\hat{l} \in (9, 20.47]$, agent A would never get arrested if victims and libelers behaved non-strategically by always reporting immediately, but A will be arrested with some probability in the corroborated equilibrium of our model. More generally, $p \leq \frac{2}{3}$ implies $a^* < \frac{1}{2}$, and hence $a^*(1-a^*) \geq b^*(1-b^*)$. This ensures that $l(rR) \geq p^2/q^2$. The fact that true victims are more likely to make allegations against A than libelers are in a corroboration equilibrium lends credence to such allegations.

The criminal justice system is imperfect and has to strike a balance between the possibilities of punishing the innocent (type I error) and letting go the guilty (type II error). In our model, type I error occurs because libelers wrongly accuse A even though he had not broken the law. Given that there is at least one libeler, the probability that agent A will be arrested in a corroboration equilibrium is:

$$\Pr[\text{type I}] = \frac{q^2}{1-(1-q)^2}\left(1-(1-b^*)^2\right), \tag{5}$$

where the fraction is the probability that there are two potential libelers given that there is at least one, and the second term is the probability that at least one of L_1 and L_2 has a reporting cost less than b^* (which will lead to two reports because the other one will follow up). Similarly, given that there is at least one victim, the probability that the evidence

[18] For example, when $p = 0.9$, $q = 0.8$ and $\delta = 0.95$, we have $a^* \approx 0.69$ and $b^* \approx 0.59$. Then $l(r) \approx 1.21 > 1.12 \approx l(rR)$.

against him does not reach the standard of proof in a corroboration equilibrium is:

$$\Pr[\text{type II}] = \frac{p^2}{1-(1-p)^2}(1-a^*)^2 + \frac{2p(1-p)}{1-(1-p)^2}. \tag{6}$$

The first term is the conditional probability that neither V_1 nor V_2 lodges a complaint. The second term is the conditional probability that A has hurt only one victim, so the evidence is never sufficient to reach the threshold regardless of whether the victim lodges a complaint or not.

Proposition 2. *In a corroboration equilibrium, the probability of type I error increases in q and δ, and the probability of type II error decreases in p and δ.*

Proof. From equation (5), the probability of type I error increases in q and in b^*. Lemma 1 establishes that b^* increases in q and δ. Therefore, Pr[type I] increases in q δ. From equation (6), Pr[type II] decreases in p and in a^*. Since a^* increases in p and δ, Pr[type II] decreases in p and δ. ■

An increase in the probability of repeat offense p by a guilty agent A has two effects on the probability of his getting away with punishment. The first effect is mechanical: a higher p raises the chance that there are two victims to report his crime. The second effect works through the response of the victims: a victim who expects the existence of another victim is more likely to report the crime through the encouragement effect. Both effects tend to reduce the probability of not having A arrested.

In a corroboration equilibrium, fresh victims face a trade-off between encouraging others to report the crime and delaying to pay the cost of reporting. Greater patience δ makes the latter option less attractive and hence increases the probability that they report immediately. When people are more forthcoming in making an allegation against A, the probability of type I error increases and the probability of type II error decreases.

We may also consider the effects of reporting costs on reporting behavior and on the probabilities of type I and type II errors. Suppose the cost of reporting is uniformly distributed on $[0, \overline{c}]$, with $\overline{c} \leq 1$. An increase in $\overline{c}$ represents a first-order stochastic increase in reporting cost. In a corroboration equilibrium, if the strategy is for a fresh victim to lodge a complaint against A if and only if her reporting cost is lower than some critical value $\hat{c}$, then $a = \mathrm{E}[\alpha(c)] = \hat{c}/\overline{c}$, and therefore the critical type must have cost $\overline{c}a$. The equilibrium value of a is given by the indifference condition:

$$f(\overline{c}a, a; p) = \frac{(1/2)}{1-(1/2)pa}\left(-\overline{c}a(2-pa) + p\delta(1-a(1-\overline{c}a)) + p(1-a)\right) = 0.$$

The payoff difference $f(\bar{c}a, a; p)$ is single-crossing from above in a and is decreasing in $\bar{c}$. Therefore, we have $\partial a^*/\partial \bar{c} < 0$. Not surprisingly, a stochastic increase in reporting cost causes people to be less forthcoming in making an allegation. This reduces the probability of type I error but raises the probability of type II error.

4. Other Types of Equilibria

4.1. Other equilibria with a corroboration flavor

In the previous section, we focus on the corroboration equilibrium, in which agent A is arrested if and only if there are two reports against him. The corroboration equilibrium, provided that it exists, is not the only equilibrium in our model. Multiple equilibria exist because beliefs are self-confirming. For example, if rR does not lead to arrest, then no one has an incentive to make a delayed report. Because rR does not occur in equilibrium in this case, we can assign off-equilibrium beliefs such that rR is not credible enough to cause an arrest, hence confirming the equilibrium construction. In this subsection, we consider two other types of equilibria in which corroboration is a necessary (but not sufficient) condition for making an arrest. In the first type, agent A is arrested only when both reports against him are contemporaneous. We call this an rr-equilibrium. In the second type, agent A is arrested only when one report is contemporaneous and the other is delayed. We call this an rR-equilibrium.

In an rr-equilibrium, the event rR does not lead to an arrest. Therefore, a silent V_1 who has not reported in period 1 has no incentive to file a delayed report against A upon learning that V_2 has reported. Unlike in a corroboration equilibrium, we therefore have $\hat{\alpha}_1(c) = 0$ for all c. On the other hand, as in a corroboration equilibrium, we still have $\tilde{\alpha}_1(c) = 0$ (V_1 will not report in period 2 if no one reports against A) and $\hat{\alpha}_2(c) = 1$ (V_2 will report if she learns that V_1 has already made a report) in an rr-equilibrium.

We continue to use a to denote the probability of reporting right away by a fresh victim, and will use a_{rr} to denote its equilibrium value. Likewise, b_{rr} is the equilibrium probability of reporting immediately by a fresh libeler. In an rr-equilibrium, reporting immediately gives a fresh victim a payoff of

$$\frac{(1/2)p}{1-(1/2)pa}\delta - c.$$

Not reporting gives her a payoff of 0, as delaying the report will certainly lead to no arrest. The equilibrium probability of a fresh victim reporting right away when there is no prior report is the unique solution for a to:

$$F_{rr}(a;p) \equiv \frac{(1/2)p}{1-(1/2)pa}\delta - a = 0. \tag{7}$$

Comparing (7) to (3) in the earlier section, we see that both the benefit from reporting immediately and the benefit from delaying to report are smaller in an rr-equilibrium than in a corroboration equilibrium. Moreover, using (7), we obtain

$$F(a_{rr};p) = \frac{(1/2)p(1-a_{rr})}{1-(1/2)pa_{rr}} - \frac{(1/2)p}{1-(1/2)pa_{rr}}\delta a_{rr}(1-a_{rr}) > 0.$$

This implies $a_{rr} < a^*$, because $F(\cdot;p)$ is single-crossing from above. Therefore, the overall effect of not allowing corroboration with delay as sufficient ground for arrest is to discourage fresh victims from making a report immediately, as it removes the chance that an immediate report will encourage past victims who did not report to come forward by filing delayed reports.

Consider next an rR-equilibrium. In such an equilibrium, because a second contemporaneous report will not lead to arrest, we have $\hat{\alpha}_2(c) = 0$ (while we still have $\hat{\alpha}_1(c) = 1$ and $\tilde{\alpha}_1(c) = 0$, as in a corroboration equilibrium). The payoff to a fresh victim from reporting immediately reporting is

$$\frac{(1/2)p(1-a)}{1-(1/2)pa} - c,$$

which comes from the possibility that V_1 exists but has not reported. On the other hand, not reporting gives a fresh victim a payoff of

$$\frac{(1/2)p}{1-(1/2)pa}a\delta(1-c),$$

which comes from the possibility of reporting later if V_2 exists and makes a report. Let a_{rR} be the equilibrium probability that a fresh victim reports immediately, and let b_{rR} be the equilibrium probability that a fresh libeler reports immediately. Then, a_{rR} is given by the unique solution for a to the following equality:

$$F_{rR}(a;p) \equiv \frac{(1/2)p(1-a)}{1-(1/2)pa} - a - \frac{(1/2)p}{1-(1/2)pa}a\delta(1-a) = 0. \tag{8}$$

Comparing (8) to corresponding equation (3) that characterizes a^* in a corroboration equilibrium, since the payoff from reporting immediately is reduced but the payoff from not reporting remains unchanged, we have $a_{rR} < a^*$.

Proposition 3. *(a) There exists a non-empty interval $(\underline{l}_{rr}, \overline{l}_{rr}]$ such that an rr-equilibrium exists if and only if $\hat{l}$ is in that interval. In this equilibrium, $b_{rr} < a_{rr} < a^*$. Moreover, $\overline{l}_{rr} > \overline{l}^*$; and if $p \leq \frac{2}{3}$ then $\underline{l}_{rr} > \underline{l}^*$.*

(b) There exists a non-empty interval $(\underline{l}_{rR}, \overline{l}_{rR}]$ such that an rR-equilibrium exists if and only if $\hat{l}$ is in that interval. In this equilibrium, $b_{rR} < a_{rR} < a^*$. Moreover, $\overline{l}_{rR} > \overline{l}^*$; and if $p \leq \frac{2}{3}$ then $\underline{l}_{rR} > \underline{l}^*$

The proof of Proposition 3 is in the Appendix. In both the rr-equilibrium and the rR-equilibrium, fresh victims are less likely to report immediately compared to the case in a corroboration equilibrium. Furthermore, because $\hat{\alpha}_1(c) = 0$ in an rr-equilibrium and $\hat{\alpha}_2(c) = 0$ in an rR-equilibrium (these two quantities are both equal to 1 in a corroboration equilibrium), the overall probability that a victim or a libeler will make an allegation is lower compared to that in a corroboration equilibrium.

Compared to a corroboration equilibrium, an rr-equilibrium and an rR-equilibrium both reduce type I error but increase type II error, for two reasons: (1) each reduces the set of events under which A is arrested; and (2) the probability that a fresh victim or fresh libeler will report immediately is lower. On the other hand, Proposition 3 also shows that arrests in an rr-equilibrium or an rR-equilibrium are more credible than the event rR in a corroboration equilibrium (assuming p is not too large). Thus, even if the standard of proof $\hat{l}$ is so high that a corroboration equilibrium does not exist, it is still possible that the model will admit an rr-equilibrium or an rR-equilibrium.

The event rR is off the equilibrium path in an rr-equilibrium, and likewise for the event rr in an rR-equilibrium. Standard refinements are not sufficient to rule out these two types of equilibria. Nevertheless, because both rr and rR are observed in reality, we believe that the corroboration equilibrium is the most relevant equilibrium to focus on.

4.2. Lower standard of proof and no-corroboration equilibrium

The probabilities of type I and type II errors can be affected by the standard of proof $\hat{l}$. Consider the case where one report against agent A is sufficient to lead to arrest. In such a case, no one will have an incentive to file a second report against the same person; so rr and rR are off-equilibrium events. We call this type of equilibrium a *no-corroboration equilibrium*. The existence of a no-corroboration equilibrium requires $l(r) \geq \hat{l}$ and $l(R) \geq \hat{l}$. Since the event r is sufficient for arrest, the event $r\phi$ is irrelevant. We first assume that these conditions hold, and subsequently verify that this is true for some values of $\hat{l}$.

Suppose agent A is guilty. If a victim of A has seen a prior accusation against him, there is no point for her to report because one report is sufficient to punish A. Therefore $\hat{\alpha}_1(c) = \hat{\alpha}_2(c) = 0$ for all c. On the other hand, if a silent victim V_1 observes no one coming forward to complain against A in period 2, she will make a delayed report because the event R is sufficient to lead to arrest. This means that we have $\tilde{\alpha}_1(c) = 1$ in a no-corroboration equilibrium.

For a fresh victim (who does not see a prior accusation against A), the payoff from reporting immediately is $1-c$. The payoff from not reporting immediately is

$$\frac{(1/2)p}{1-(1/2)pa}\delta(a+(1-a)(1-c)) + \frac{(1/2)(1-p)}{1-(1/2)pa}\delta(1-c) + \frac{(1/2)p(1-a)}{1-(1/2)pa}. \tag{9}$$

The first fraction is the conditional probability that this victim is V_1 and V_2 exists. With probability a, V_2 reports the crime and V_1 gets δ; and with probability $1-a$, V_2 does not report the crime and V_1 lodges a delayed report and gets $\delta(1-c)$. The second fraction is the conditional probability that she is V_1 and V_2 does not exist. In this case, she lodges a delayed report at the end of period 2 and gets $\delta(1-c)$. The final term is the conditional probability that she is V_2 and V_1 exists but did not report. If she does not report, V_1 will lodge a delayed report and V_2 gets 1.

Let $f_{nc}(c,a;p)$ represent the difference between $1-c$ and (9), and define $F_{nc}(a;p) \equiv f_{nc}(a,a;p)$. We have:

$$F_{nc}(a;p) = \frac{(1/2)}{1-(1/2)pa}\left((1-a)(2-pa) - p\delta\,(1-a(1-a)) - (1-p)\delta(1-a) - p(1-a)\right).$$

Since $F_{nc}(0;p) > 0 > F_{nc}(1;p)$ and $F_{nc}(\cdot;p)$ is single-crossing from above, there exists a unique a_{nc} such that $F_{nc}(a_{nc};p) = 0$. In a no-corroboration equilibrium, the strategy of a fresh victim is $\alpha(c) = 1$ (i.e., report immediately) if and only if $c \leq a_{nc}$. Similarly, the strategy of a libeler who sees no prior report against A is $\beta(c) = 1$ if and only if $c \leq b_{nc}$, where $F_{nc}(b_{nc};q) = 0$.

Proposition 4. *A no-corroboration equilibrium exists if and only if*

$$\hat{l} \leq \bar{l}_{nc} \equiv \frac{pa_{nc}(2-pa_{nc})}{qb_{nc}(2-qb_{nc})}.$$

Comparing the outcome in a no-corroboration equilibrium to that in a corroboration equilibrium: (a) the probability that a fresh alleger will lodge a contemporaneous report is higher (i.e., $a_{nc} > a^*$ and $b_{nc} > b^*$); (b) the probability of convicting an innocent A is higher; and (c) the probability of acquitting a guilty A is lower.

Proof. A no-corroboration equilibrium exists only if the standard of proof is lower than the likelihood ratio corresponding to event r, i.e., $\hat{l} \leq l(r) = \bar{l}_{nc}$. Lemma 3 in the Appendix establishes that $l(R) \geq l(r)$. Hence, $l(r) \geq \hat{l}$ implies $l(R) \geq \hat{l}$. Since rr and rR are off-equilibrium events, we can assign off-equilibrium beliefs such that $l(rr) \geq \hat{l}$ and $l(rR) \geq \hat{l}$. Given these beliefs, there is no profitable deviation from the strategy profile of a no-corroboration equilibrium.

Evaluate $F_{nc}(a; p)$ at $a = a^*$, and use the fact that $F(a^*; p) = 0$, we obtain

$$F_{nc}(a^*; p) = \frac{1/2}{1-(1/2)pa^*}(2 - pa^* - (1-p)\delta(1-a^*) - 2p(1-a^*)) > 0.$$

Since $F_{nc}(a; p)$ is single-crossing from above, we must have $a_{nc} > a^*$. A similar argument shows that $b_{nc} > b^*$.

If there are two libelers, L_1 either makes a contemporaneous report or a delayed report in a no-corroboration equilibrium. If there is only one libeler and this libeler is L_2, she makes a contemporaneous report with probability b_{nc}. Therefore, the overall probability of type I error in a no-corroboration equilibrium is

$$\frac{q^2}{1-(1-q)^2} + \frac{2q(1-q)}{1-(1-q)^2}\left(\frac{1}{2} + \frac{1}{2}b_{nc}\right),$$

which is greater than (5). Similarly, the probability of type II error is

$$\frac{2p(1-p)}{1-(1-p)^2}\left(\frac{1}{2}(1-a_{nc})\right),$$

which is less than (6). ■

Note that $F_{nc}(a; p)$ is decreasing in p. This implies that $\partial a_{nc}/\partial p < 0$. Hence, $p > q$ implies $a_{nc} < b_{nc}$. In a no-corroboration equilibrium, there is no "encouragement effect" to motivate a fresh victim to report immediately in order to induce a future or past victim to report. As a result, only the free-rider effect is present, and the free-rider effect is stronger the more likely that another victim exists. Hence a fresh victim has a higher incentive to free ride than a fresh libeler does and, as a result, reports with a lower probability. This implies that a no-corroboration equilibrium exists only if the standard of proof $\hat{l}$ is so low that one will be arrested based on a single report even if the victim and the libeler have the same pooling behavior (i.e., as if they were non-strategic).

Corollary 1. *A no-corroboration equilibrium exists only if* $\hat{l} < p/q$.

Proof. We show that $\bar{l}_{nc} < p/q$. Because $a_{nc}(2-pa_{nc})/(b_{nc}(2-qb_{nc}))$ is equal to 1 when $p = q$, it suffices to show that $a_{nc}(2-pa_{nc})$ decreases in p, which is true because the derivative is equal to $-a_{nc}^2 + 2(1-pa_{nc})\partial a_{nc}/\partial p$, which is negative. ■

With a lower standard of proof, it is not surprising that both true victims and libelers are more forthcoming in lodging complaints about A—we have $a_{nc} > a^*$ and $b_{nc} > b^*$. The advantage is that a guilty agent is more likely to be punished; the disadvantage is that it comes with a much higher chance of type I error.

There exist other types of equilibria with a no-corroboration flavor. In all such equilibria, agent A is sometimes arrested when there is only one report (delayed or not) against him. In the first type, which we call an r-equilibrium, agent A is arrested in event r but not in event R. In the second type, which we call an R-equilibrium, agent A is arrested in event R but not in event r. The key features of these equilibria are quite similar to those for the no-corroboration equilibrium described in Proposition 4. We summarize these features in the following proposition.

Proposition 5. *In an r-equilibrium, fresh victims report immediately with a lower probability than do fresh libelers. In an R-equilibrium, neither fresh victims nor fresh libelers ever report immediately. Each of these two types of equilibria exists only if the standard of proof $\hat{l}$ is below p/q.*

Allowing only one report to lead to arrest eliminates the encouragement effect for fresh victims to report immediately. Proposition 5 shows that an r-equilibrium and an R-equilibrium share the same feature that a victim reports right away with a lower probability than a libeler when there is no prior report. This adverse selection of allegers in turn implies that the standard of proof has to be so low that the public is willing to arrest someone based on a single report while knowing that a libeler is more active in reporting than a victim (i.e., lower than p/q). Because such standard of proof seems to us to be an implausibly low standard, and because we do observe multiple allegations (rr or rR) in reality, we choose to focus on the corroboration equilibrium in the remainder of this paper.

5. Model Extensions

5.1. Partially unobservable reports

In the benchmark model, any allegation against A is public knowledge. In reality, it is possible that a report made by one alleger is not observed by another alleger. The observability of a report depends, for example, on how famous the accusers or the accused are. When a celebrity is involved, an allegation gets more media coverage and is thus more visible to other potential allegers.

In this subsection, we modify the model by assuming that V_2 does not observe a prior report by V_1 with some probability $\epsilon \in (0,1)$. Similarly, V_1 does not observe a report made by V_2 in period 2 with the same probability ϵ. On the other hand, the reports are always visible to the authorities responsible for making an arrest.

For a fresh victim, the payoff from reporting immediately is:

$$-c+\frac{(1/2)p}{1-(1/2)pa(1-\epsilon)}\delta(1-\epsilon)+\frac{(1/2)p(1-a)}{1-(1/2)pa(1-\epsilon)}(1-\epsilon)+\frac{(1/2)pa\epsilon}{1-(1/2)pa(1-\epsilon)}. \quad (10)$$

If the fresh victim is V_1 and V_2 exists, there is some chance that V_2 will not see her report; so the payoff is only $\delta(1-\epsilon)$. If the fresh victim is V_2 and V_1 has not reported, then by reporting immediately V_2 can encourage V_1 to make a delayed report with probability $1-\epsilon$. If the fresh victim is V_2 and she does not observe the prior report by V_1, then V_2 can secure A's arrest by reporting immediately; so the payoff is 1.

The payoff from not reporting immediately for the fresh victim is:

$$\frac{(1/2)p}{1-(1/2)pa(1-\epsilon)}a(1-\epsilon)\delta(1-c), \quad (11)$$

because a silent victim V_1 will observe a report by V_2 with probability $a(1-\epsilon)$ and get a payoff $\delta(1-c)$ if V_2 exists.

Taking the difference between (10) and (11), the equilibrium probability of reporting right away by the fresh victim, denoted a_{par}, is the solution of a to the following equation:

$$\frac{1/2}{1-(1/2)pa(1-\epsilon)}((1-\epsilon)[-a(2-pa)+p\delta(1-a(1-a))+p(1-a)]-\epsilon a(2-p))=0.$$

The term in square brackets is equal to 0 at $a=a^*$ (the equilibrium probability in the benchmark model). Since the left-hand-side is single-crossing from above in a and is negative at $a=a^*$, we have $a_{par}<a^*$. Because partial observability reduces the strength of the

encouragement effect, a victim is less likely to come forward in making a fresh allegation. The same logic applies to a libeler. Given that ϵ tends to be smaller when the accused is more famous, both fresh victims and fresh libelers will report more against a more famous person.[19]

5.2. Serial dependence

A key assumption of our model is that $p > q$ (Assumption 1). In the benchmark model without serial dependence, $p > q$ embodies two conceptually separate assumptions: (1a) the probability that a victim exists given A is guilty is higher than the probability that a libeler exists given A is innocent; and (1b) the probability that a victim assigns to the event that another victim exists is higher than the probability that a libeler assigns to the event that another libeler exists. Even if (1a) does not hold, (1b) may still hold provided that we introduce serial dependence in the probability that A hurts or offends another person across the two periods—for example, if guilty agents have a greater tendency to be repeat offenders. We emphasize that our results are mainly driven by (1b) rather than (1a).

To see this point more clearly, we abandon the independence assumption in the benchmark model and consider the following correlation structure:

Guilty A

	V_1	no V_1
V_2	$p\lambda_g$	$(1-p)\lambda_g$
no V_2	$(1-p)\lambda_g$	$1-(2-p)\lambda_g$

Innocent A

	L_1	no L_1
L_2	$q\lambda_i$	$(1-q)\lambda_i$
no L_2	$(1-q)\lambda_i$	$1-(2-q)\lambda_i$

The entry in each cell represents the probability of the corresponding combination. For example, if A is guilty, the probability that both V_1 and V_2 exist is $p\lambda_g \in (0,1)$. Note that the marginal probability that V_1 exists is λ_g, and the marginal probability that V_2 exists is also λ_g. Conditional on one victim's existence, the probability that another victim exists is p. A higher value of p indicates a higher degree of correlation across the two periods. As we mention in the introduction, many sexual crimes are perpetrated by repeat offenders. On the other hand, if an innocent agent inadvertently offends another person, there is no presumption that this will happen again in the next period. We can capture this difference by the assumption that $p > q$. If $\lambda_g = \lambda_i$ and $p > q$, then (1a) does not hold but (1b) does.

[19] A caveat is that a more famous person tends to be more powerful, which may imply a higher threat of retaliation and thus a higher cost of reporting against him.

From the perspective of a fresh victim, the probability that another victim exists is p. Therefore, the expected payoff from reporting immediately and the expected payoff from not reporting immediately are identical to (1) and (2), respectively, of the benchmark model. It follows that her equilibrium probability of reporting immediately is the same a^* of Section 3. Similarly, a fresh libeler reports immediately with probability b^*. In this modified model with correlation, the event rR is observed with probability $p\lambda_g a^*(1-a^*)$ when the state is "guilty" and observed with probability $q\lambda_i b^*(1-b^*)$ when the state is "innocent." So,

$$l(rR) = \frac{p\lambda_g a^*(1-a^*)}{q\lambda_i b^*(1-b^*)}.$$

The event r is observed under two possibilities when the state is "guilty": (1) the current period is period 1 and V_1 reported (this happens with probability $\frac{1}{2}\lambda_g a^*$); or (2) the current period is period 2, V_1 didn't exist and V_2 reported (this happens with probability $\frac{1}{2}(1-p)\lambda_g a^*$). Therefore the corresponding likelihood ratio is:

$$l(r) = \frac{\lambda_g(2-p)a^*}{\lambda_i(2-q)b^*}.$$

A corroboration equilibrium exists if and only if $\hat{l} \in (l(r), l(rR)]$.

In the case of $\lambda_g = \lambda_i$, a report in a setup with a single period cannot have any information value because there is no difference between the two states. However, with correlation across periods, a report in a corroboration equilibrium has some level of credibility as long as $p > q$, even when $\lambda_g = \lambda_i$. The tendency of a guilty agent to be a recidivist causes a fresh victim to expect that another (past or future) victim may be present to corroborate her report. Thus the encouragement effect causes her to report immediately with a greater probability than does a libeler, which in turn lends credence to her report.

5.3. Delay of the initial report

In our benchmark model, a delayed report is always preceded by a contemporaneous report in a corroboration equilibrium. In reality, sometimes even the first report against an accused is significantly delayed. For example, the first two allegations of sexual assault (almost simultaneously in 2016) against Larry Nassar, a former physician of the USA Gymnastics team, were delayed for 16 years and 17 years, respectively. The alleged crimes happened when the allegers were 18 and 15 years old, so a large part of the time of silence were spent when the allegers were adults. This means the delay had to do with something more than just the immaturity of the allegers. In this section, we show that the delay of the first report can be an equilibrium outcome if we also allow V_1 to report in the second period before V_2 can.

In Figure 2, we modify the timeline of the benchmark model by allowing V_1 to have a chance to make a delayed report in period 2 before she learns about the existence of another report against A. If V_1 does not utilize this chance, she still has another chance to make a delayed report after V_2 has her chance to report. The timeline for potential libelers is modified in a similar manner.

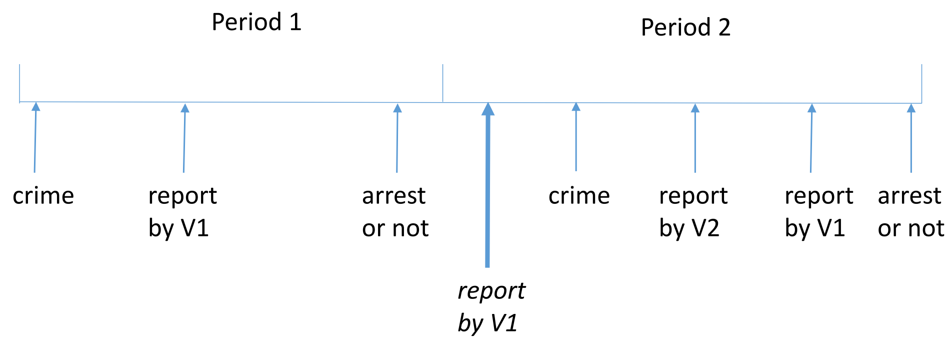

Figure 2. *The modified timeline when A is guilty. Victim V_1 can make a delayed report in period 2 before knowing whether V_2 reports or not. If V_2 reports, V_1 will have another chance to make a delayed report before the end of period 2 provided that she has not already done so.*

In this modified setting, if V_1 reports in period 2 followed by V_2's report, we denote the event by Rr. If V_1 reports in period 2 and there is no report by V_2, we denote the event by $R\phi$. We will focus on a corroboration equilibrium in which agent A is arrested if and only if there are two reports against him (i.e., in the events rr, rR, or Rr).

By the time of second period, V_1 already knows that he is V_1. If she has not yet reported, by reporting in period 2, she will get payoff $p-c$ because with probability p, V_2 exists and will follow up with a report. By not reporting in period 2, V_1 will get $pa(1-c)$ because V_2 will report with probability a, after which V_1 can follow up with a report. Therefore, the cutoff type (denoted $\hat{c}_g$) of V_1 who is indifferent between reporting and not reporting in period 2 before V_2's turn to report is determined by $p-\hat{c}_g = pa(1-\hat{c}_g)$, which gives

$$\hat{c}_g(a) = \frac{p(1-a)}{1-pa}.$$

Any V_1 whose cost is below $\hat{c}_g(a)$ will lead with a report in period 2 if she has not reported before. The subscript g denotes the state that A is guilty. Similarly, for the state that A is innocent, $\hat{c}_i(b) = q(1-b)/(1-qb)$.

There are two cases to consider: (a) $\hat{c}_g(a) > a$; and (b) $\hat{c}_g(a) \leq a$. However, only case (a) is relevant;[20] we therefore focus on case (a). In this case, some types of victim with $c \in (a, \hat{c}_g(a)]$ will choose not to report immediately but wait until period 2 to lead with a delayed report.

Consider a fresh victim who has not seen a prior report. There are three possibilities:

1. Another victim does not exist (the probability of this event is $1-p$).
2. She is V_1, and another victim V_2 exists in period 2 (the probability is $\frac{1}{2}p$).
3. She is V_2, and another victim V_1 exists but did not report (the probability is $\frac{1}{2}p(1-\hat{c}_g(a))$.)

The expected net payoff from reporting immediately is:

$$-c + \frac{(1/2)p}{1-(1/2)p\hat{c}_g(a)}\delta + \frac{(1/2)p(1-\hat{c}_g(a))}{1-(1/2)p\hat{c}_g(a)}.$$

A victim V_1 with cost $c < \hat{c}_g(a)$ will report in period 2 prior to V_2 does if V_1 does not report immediately. For such V_1, her expected net payoff from not reporting immediately is:

$$\frac{(1/2)p}{1-(1/2)p\hat{c}_g(a)}\delta(1-c) + \frac{(1/2)(1-p)}{1-(1/2)p\hat{c}_g(a)}(-\delta c).$$

By the same logic as in the benchmark model, the equilibrium probability that a fresh victim will report immediately, denoted a_{del} is the solution in a to the following equation:

$$F_{del}(a;p) \equiv \frac{1/2}{1-(1/2)p\hat{c}_g(a)}\left(-a(2-p\hat{c}_g(a)) + p\delta a + p(1-\hat{c}_g(a)) + (1-p)\delta a\right) = 0.$$

It is straightforward to show that a unique $a_{del} \in (0,1)$ exists, and that a_{del} increases in p and δ.

Proposition 6. *Suppose V_1 can make a delayed report in period 2 before V_2 has her chance to report. Then, in a corroboration equilibrium, (a) V_1 reports immediately in period 1 if $c \leq a_{del}$; (b) V_1 makes a delayed report in period 2 before V_2 has her chance to report if*

[20] In case (b), $c > a$ implies $c > \hat{c}_g(a)$. Any type who does not report immediately when she is a fresh victim will choose to wait in period 2 rather than leading with a delayed report. Then the condition that determines the equilibrium value of a is the same as in the benchmark model, i.e., a satisfies $F(a;p) = 0$. But since $\delta < 1$, $F(a;p) = 0$ implies $p(1-a+a^2) > a$, which contradicts $\hat{c}_g(a) \leq a$.

$c \in (a_{del}, \hat{c}_g(a_{del})]$; and (c) V_1 makes a delayed report in period 2 after observing that V_2 has reported if $c > \hat{c}_g(a_{del})$. Compared to the corroboration equilibrium in the benchmark model, $a_{del} < a^* < \hat{c}_g(a_{del})$.

Proof. Suppose $\delta = 1$. Then the option for V_1 to make a delayed report before knowing V_2 has reported or not has no value to V_1 because there is no discounting. This implies $a_{del} = \hat{c}_g(a_{del}) = a^*$ for $\delta = 1$. Now, $a_{del} - \hat{c}_g(a_{del})$ is increasing in δ because a_{del} increases in δ. Thus, $a_{del} - \hat{c}_g(a_{del}) < 0$ for all $\delta < 1$. Furthermore, because $\hat{c}_g(a_{del})$ decreases in δ while a^* increases in δ, we have $\hat{c}_g(a_{del}) > a^*$ for all $\delta < 1$.

For any $\delta < 1$, the condition $F_{del}(a_{del}; p) = 0$ can be written as:

$$-a(2 - p\hat{c}_g(a_{del})) + \delta a_{del} + p(1 - \hat{c}_g(a_{del})) = 0.$$

The fact that $\hat{c}_g(a_{del}) > a_{del}$ implies

$$-a(2 - pa_{del}) + \delta a_{del} + p(1 - a_{del}) > 0.$$

Moreover, $\hat{c}_g(a) > a$ if and only if $a < p(1 - a + a^2)$. This implies that

$$-a(2 - pa_{del}) + p\delta(1 - a_{del} + a_{del}^2) + p(1 - a_{del}) > 0,$$

which is equivalent to $F(a_{del}; p) > 0$. Since $F(\cdot; p)$ is single-crossing from above, we obtain $a_{del} < a^*$. ■

This corroboration equilibrium exists if and only if

$$\max\{l(r), l(R\phi), l(r\phi)\} < \min\{l(rr), l(Rr), l(rR)\}.$$

For example, when $p = 0.3$, $q = 0.1$, and $\delta = 0.8$, we have $a_{del} \approx 0.199$, $\hat{c}_g(a_{del}) \approx 0.256$, $b_{del} \approx 0.076$ and $\hat{c}_i(b_{del}) \approx 0.093$. In this case, $\max\{l(r), l(R\phi), l(r\phi)\} = l(r) \approx 2.89$ and $\min\{l(rr), l(Rr), l(rR)\} = l(Rr) \approx 30.176$. Therefore, $l(r) < l(Rr)$ and the corroboration equilibrium exists for $\hat{l} \in (l(r), l(Rr)]$. Compared to the benchmark model in which $a^* \approx 0.22$ and $b^* \approx 0.08$, V_1 (or L_1) in the benchmark model is less likely to report in period 1, but is more likely to have reported in period 2 before V_2 (or L_2) chooses to report.

6. Callisto Reporting System

An online sexual assault reporting system called Callisto has been adopted by eight universities by late 2017. This reporting system allows a student to log a report into the system under the precondition that it will only be released to the school if another student names the same perpetrator, an option called "match." The system also allows reporting to the school authority directly, but the system does not allow any potential reporter to see other reports in the system. The non-profit organization that founded this believes that sexual assault is prevalent on campus, the reporting rate is low, and repeat offenders are not stopped.[21] The Callisto reporting system falls into the definition of an "information escrow" by Ayres and Uncokiv (2012), because Callisto allows people to transmit information to it under seal and only have the information forwarded under pre-specified conditions.[22]

In this section, we examine the outcome assuming that a school uses Callisto as the reporting channel, while keeping the basic setup the same. The action choice for the school is to investigate and discipline the accused or not. We assume that an infinitesimally small cost is incurred when one enters a report into the system, and cost c is incurred when the report is submitted to the school authority because only then the potentially unflattering conduct of the alleger is known and the emotionally exhausting investigation begins.

The Callisto system potentially can create three distinguishable events to the school in our two period setup: (1) no report (denoted ϕ); (2) two reports and both are not delayed (rr); and (3) two reports and one of which is delayed (rR). Any time when only one report is in the system, the system shows no report to the school. To give reporters strict incentive to report, either rr or rR should lead to an investigation and possibly disciplinary action. For there to be an interesting issue, no report from the Callisto system should lead to no action by the school. We focus on the corroboration equilibrium, in which both rr and rR cause the school to take investigative or disciplinary action. This requires $\hat{l} \leq l(rr)$ and $\hat{l} \leq l(rR)$.

First, observe that for a victim or a libeler, using the "match" option is better than reporting directly to the school through the Callisto system. If there is already another corroborating report, then it makes no difference. If there has not been one, then using the "match" option can avoid wasting the reporting cost or can delay the reporting cost if the corroborating report comes in the future. Second, logging the complaint into the

[21] See the Callisto website, `https://www.projectcallisto.org/what-we-do/`.

[22] Sometimes, journalists perform a role that is similar to an information escrow. They do not publish a story until they have gathered a few allegations from different sources. For example, *The New York Times* broke the story on Harvey Weinstein in October 2017 after gathering allegation from multiple women. The accusers were not paying the cost of publicly accusing Harvey Weinstein until several pieces of corroboration were available and the news article was published.

system right away is better than waiting to log it later, as long as the chance of having a corroborator is not infinitesimally small. Therefore, in any corroboration equilibrium, a victim or a libeler logs the complaint into Callisto with no delay. This means that the event rr occurs with probability p^2 if the accused is guilty, or with probability q^2 if the accused is innocent.

Because the event rR is off the equilibrium path, the reports are only submitted to the school when the event is rr. The likelihood ratio corresponding to this event is $l(rr) = p^2/q^2$. For this event to be sufficient for the school to take action, we must have $\hat{l} \leq p^2/q^2$. The only other possible observable event on the equilibrium path is ϕ. The likelihood ratio corresponding to this event is $l(\phi) = (1-p^2)/(1-q^2)$, which has to be less than $\hat{l}$ in a corroboration equilibrium. Because rR is off-equilibrium, we can assign an off-equilibrium belief such that $\hat{l} \leq l(rR)$. This establishes the following result.

Proposition 7. *Under a Callisto reporting system, a corroboration equilibrium exists if and only if*

$$\hat{l} \in (\underline{l}_{Cal}, \bar{l}_{Cal}] \equiv \left(\frac{1-p^2}{1-q^2}, \frac{p^2}{q^2} \right].$$

Because of the stronger incentive to report by both victims and libelers, the equilibrium probability of reporting immediately satisfies $a_{Cal} > a^*$ and $b_{Cal} > b^*$. However, because $a_{Cal} = b_{Cal}$ while $a^* > b^*$, two reports (rr) from the Callisto system do not carry the same level of credibility as two reports (rr) without the Callisto system. In fact, two reports (rr) in the Callisto system may even carry less credibility than the event rR without the Callisto system if p is not very large. By Lemma 2, if $p \leq \frac{2}{3}$ then $l(rR)$ in the benchmark model is greater than $\bar{l}_{Cal}$. Therefore, if $p \leq \frac{2}{3}$ and $\hat{l} \in (\bar{l}_{Cal}, \bar{l}^*]$, the standard of proof is so high that victims have no incentive to pay the infinitesimally small cost of lodging a complaint, knowing that even two reports are not sufficient to cause the school to take action under the Callisto system. On the other hand, the same standard of proof will induce a positive equilibrium probability of reporting a^* without the Callisto system. In other words, adopting the Callisto system can potentially backfire if maintaining credibility of the allegations is a serious concern.

7. Conclusion

Many allegations about sexual crimes and misconduct are difficult to handle because they often leave behind no physical evidence. Victims usually do not have hard evidence to prove the existence of the crime, which gives libelers ample opportunities to fake as victims. This paper shows that, despite this difficulty, allegations without hard evidence have a certain level of credibility. First, an allegation proves the existence of an individual who has the intention of either a victim or a libeler. This fact alone carries some credibility because a true criminal has a higher chance of facing such an individual than an innocent person does. Second, the tendency of sexual criminals to recidivism gives a victim more confidence about the existence of another potential corroborator than a libeler. As a result, in a corroboration equilibrium a victim is more motivated to encourage other potential corroborators by leading with a first report against the accused than a libeler is against an innocent person. This difference in equilibrium behavior boosts the credibility of a contemporaneous report, while reducing the credibility of a follow-up report that alleges a crime occurring a long time ago.

The interpreter of crime allegations in our model is the police and the prosecution team, who can take into account the entire history of reports to reach a decision of whether to search, arrest or prosecute. For cases of less severe sexual harassment, the decision maker may be the human resources department of the employer company, which may also use Bayesian inference to reach a decision on whether the accused should be punished or not. We would like to caution that our setup does not directly apply to the decision of the trial judge or jury because current U.S. law largely forbids a trial from including "prior bad acts," "reputation," or "opinion" testimonies into consideration, due to the federal rule of evidence Rule 404.

Also absent in our model is the settlement between the accused and the accuser, and the confidentiality clauses typical in settlement agreements. This clearly played a role in the lack of some public allegations of crimes. Neither do we consider possible behavioral responses by the agent being accused. We simply assume that this agent will continue to hurt (or to inadvertently offend, in case he is innocent) another person with the same probability even if there is a prior public complaint against him. Incorporating these more realistic features into our model is an agenda for further research.

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Appendix

Proof of Proposition 3. (a) We have shown in the text that $a_{rr} < a^*$. Note also that b_{rr} satisfies $F_{rr}(b_{rr}; q) = 0$. Since $F_{rr}(a; p)$ is single-crossing from above in a and increasing in p, $q < p$ implies $b_{rr} < a_{rr}$.

In an rr-equilibrium, event rr occurs with probability $p^2 a_{rr}$. The corresponding likelihood ratio is $l(rr) = p^2 a_{rr}/(q^2 b_{rr})$. Two events lead to the event r. Either the current period is period 1 and V_1 reports (this happens with probability $\frac{1}{2} p a_{rr}$), or the current period is period 2 and V_1 either did not exist or did not report while V_2 reports (this happens with probability $\frac{1}{2}(1-pa_{rr})pa_{rr}$). Therefore, $l(r) = p(2-pa_{rr})a_{rr}/(q(2-qb_{rr})b_{rr})$. Substituting $a_{rr} = p\delta/(2-pa_{rr})$ and $b_{rr} = q\delta/(2-qb_{rr})$, we obtain $l(r) = p^2/q^2$. Therefore, an rr-equilibrium exists if

$$\hat{l} \in (\underline{l}_{rr}, \bar{l}_{rr}] \equiv \left(\frac{p^2}{q^2}, \frac{p^2 a_{rr}}{q^2 b_{rr}} \right].$$

The event $r\phi$ occurs when V_1 exists and makes a report, but V_2 does not exist. The corresponding likelihood ratio is $l(r\phi) = p(1-p)a_{rr}/(q(1-q)b_{rr}) < \underline{l}_{rr}$. The events R and rR are off-equilibrium, and we can assign off-equilibrium beliefs such that their corresponding likelihood ratios are below the standard of proof.

Since $a_{rr} > b_{rr}$, it is obvious that the interval $(\underline{l}_{rr}, \bar{l}_{rr}]$ is non-empty. To establish that $\bar{l}_{rr} > \bar{l}^*$, we show

$$\frac{a_{rr}}{b_{rr}} > \frac{a^*(1-a^*)}{b^*(1-b^*)}.$$

Because these two sides are equal when $p = q$, it suffices to show that $a^*(1-a^*)/a_{rr}$ decreases in p, which requires

$$\frac{1-2a^*}{a^*(1-a^*)} \frac{\partial a^*}{\partial p} < \frac{1}{a_{rr}} \frac{\partial a_{rr}}{\partial p}.$$

If $a^* \geq \frac{1}{2}$, then the above condition is satisfied. So, assume $a^* < \frac{1}{2}$. In this case, the above condition is equivalent to

$$\frac{1-2a^*}{(1-a^*)(2+(1+\delta)p(1-2a^*))} < \frac{1}{2-2pa_{rr}},$$

which holds for all $a < \frac{1}{2}$.

Finally, we establish that $p \leq \frac{2}{3}$ implies $\underline{l}_{rr} > \underline{l}^*$. Since the latter is equivalent to

$$\frac{(2-p)a^*}{(2-q)b^*} < \frac{p}{q},$$

it is sufficient to establish that $(2-p)a^*/p$ decreases in p, i.e.,

$$-2a^* + (2-p)p\frac{\partial a^*}{\partial p} = -2a^* + (2-p)\frac{2a^*}{2+(1+\delta)p(1-2a^*)} < 0.$$

This inequality holds because $p \leq \frac{2}{3}$ implies $a^* < \frac{1}{2}$.

(b) We have shown in the text that $a_{rR} < a^*$. As in part (a) of the proof, $q < p$ implies $b_{rR} < a_{rR}$.

In an rR-equilibrium, the likelihood ratio corresponding to event rR is $l(rR) = p^2 a_{rR}(1-a_{rR})/(q^2 b_{rR}(1-b_{rR}))$, and the likelihood ratio corresponding to event r is $l(r) = p(2-p)a_{rR}/(q(2-q)b_{rR})$. The event $r\phi$ occurs whenever V_1 exists and makes a report (because V_2 does not report as rr does not lead to arrest). The corresponding likelihood ratio is $l(r\phi) = pa_{rR}/(qb_{rR}) > l(r)$. An rR-equilibrium exists if

$$\hat{l} \in (\underline{l}_{rR}, \bar{l}_{rR}] \equiv \left(\frac{pa_{rR}}{qb_{rR}}, \frac{p^2 a_{rR}(1-a_{rR})}{q^2 b_{rR}(1-b_{rR})} \right].$$

The events R and rr are off-equilibrium, and we can assign off-equilibrium beliefs such that their corresponding likelihood ratios are below the standard of proof.

To show that the interval $(\underline{l}_{rR}, \bar{l}_{rR}]$ is non-empty, we need to show that $p(1-a_{rR}) > q(1-b_{rR})$. It suffices to show that the left-hand-side of this inequality is increasing in p, which requires

$$1 - a_{rR} - p\frac{\partial a_{rR}}{\partial p} = 1 - a_{rR} - \frac{2a_{rR}}{2+(1+\delta)p(1-2a_{rR})} > 0.$$

It is straightforward to verify that $F_{rR}(\frac{1}{2}; p) < 0$. Since $F_{rR}(\cdot; p)$ is single-crossing from above, we have $a_{rR} < \frac{1}{2}$, which implies that the above displayed inequality condition holds.

Next we show that

$$\frac{a^*(1-a^*)}{b^*(1-b^*)} < \frac{a_{rR}(1-a_{rR})}{b_{rR}(1-b_{rR})}.$$

It is sufficient to show that $(a^*(1-a^*))/(a_{rR}(1-a_{rR}))$ decreases in p, i.e.,

$$\frac{1-2a^*}{a^*(1-a^*)}\frac{\partial a^*}{\partial p} - \frac{1-2a_{rR}}{a_{rR}(1-a_{rR})}\frac{\partial a_{rR}}{\partial p} < 0.$$

Plugging in the partial derivatives, this is equivalent to

$$\frac{1-2a^*}{(1-a^*)(2+(1+\delta)p(1-2a^*))} - \frac{1-2a_{rR}}{(1-a_{rR})(2+(1+\delta)p(1-2a_{rR}))} < 0,$$

which reduces to

$$(1+\delta)p(1-2a^*)(1-2a_{rR})(a^*-a_{rR}) < 2(a^*-a_{rR}).$$

Since $a^* > a_{rR}$, the above inequality is true. This establishes that $\bar{l}^* < \bar{l}_{rR}$.

Finally, we show that $p \leq \frac{2}{3}$ implies

$$\frac{(2-p)a^*}{(2-b)b^*} < \frac{a_{rR}}{b_{rR}}.$$

It suffices to show that $(2-p)a^*/a_{rR}$ decreases in p, which is equivalent to

$$-1 + \frac{4(2-p)(1+\delta)(a^*-a_{rR})}{(2+(1+\delta)p(1-2a^*))(2+(1+\delta)p(1-2a_{rR}))} < 0.$$

The left-hand-side is increasing in δ. Therefore, it is sufficient to establish that

$$-1 + \frac{2(2-p)(a^*-a_{rR})}{(1+p(1-2a^*))(1+p(1-2a_{rR}))} < 0.$$

From equations (3) and (8), we obtain

$$2(a^*-a_{rR}) = p\delta - p(1+\delta)(a^*(1-a^*) - a_{rR}(1-a_{rR})) < p\delta,$$

because $p \leq \frac{2}{3}$ implies $a^* < \frac{1}{2}$. Hence, $2(2-p)(a^*-a_{rR}) < 1$, which establishes that $\underline{l}^* < \underline{l}_{rR}$. ■

Proof of Proposition 5. (a) Let E denote the set of events $\mathscr{E}$ such that $l(\mathscr{E}) \geq \hat{l}$ (i.e., the set of events that lead to an arrest). In an r-equilibrium, $r \in E$ and $R \notin E$. If $r \in E$, then it does not matter whether any of $r\phi$, rr and rR is in E. The events $r\phi$ and rr will not appear because the game ends right after r. The event rR is off equilibrium because within a period after r no one has incentive to make a delayed report.

In an r-equilibrium, reporting immediately gives a fresh victim $1-c$. Not reporting gives her $\frac{1}{2}pa\delta/(1-\frac{1}{2}pa)$ (when the victim is V_1 and V_2 exists and reports with probability a). The equilibrium probability of reporting right away, denoted a_r is defined by the solution to the following equation:

$$F_r(a;p) \equiv 1 - a - \frac{(1/2)pa}{1-(1/2)pa}\delta = 0.$$

A fresh libeler reports right away with probability b_r, which satisfies $F_r(b_r;q) = 0$. Since $F_r(a;p)$ is single-crossing from above in a and is decreasing in p, a_r is decreasing in p. From this we obtain $a_r < b_r$.

The event r occurs when either V_1 reports immediately (which happens with probability pa_r), or when V_2 reports immediately if V_1 does not report (which happens with probability $(1-pa_r)pa_r$). The corresponding likelihood ratio is $l(r) = (2-pa_r)pa_r/((2-qb_r)qb_r)$. Thus, an r-equilibrium exists if and only if

$$\hat{l} \leq \bar{l}_r \equiv \frac{(2-pa_r)pa_r}{(2-qb_r)qb_r}.$$

The event R is off equilibrium, and we can assign off-equilibrium beliefs such that $l(R) < \hat{l}$. Note that $\bar{l}_r < p/q$ if and only if $(2-pa_r)a_r/((2-qb_r)b_r) < 1$. This condition is true because $p > q$ and $(2-pa_r)a_r$ is decreasing in p.

(b) We next consider an R-equilibrium, in which $R \in E$ but $r \notin E$. If $r \notin E$, then $r\phi$ is not in E. Otherwise, after r, no one (victim or libeler) will report. So the belief after $r\phi$ should be the same as the belief after r, which forms a contradiction. It follows that there are only four possible types of R-equilibrium:

(i) $r \notin E$, $R \in E$, $rr \in E$, $rR \in E$.

(ii) $r \notin E$, $R \in E$, $rr \notin E$, $rR \in E$.

(iii) $r \notin E$, $R \in E$, $rr \in E$, $rR \notin E$.

(iv) $r \notin E$, $R \in E$, $rr \notin E$, $rR \notin E$.

Consider case (i). For a fresh victim, reporting immediately gives a payoff of

$$\frac{(1/2)pa}{1-(1/2)pa}\delta + \frac{(1/2)p(1-a)}{1-(1/2)pa} - c.$$

Not reporting gives payoff of

$$\frac{(1/2)pa}{1-(1/2)pa}\delta(1-c) + \frac{(1/2)p(1-a)}{1-(1/2)pa} + \frac{(1/2)(1-pa)}{1-(1/2)pa}\delta(1-c),$$

because any V_1 can delay reporting to achieve an arrest even if V_2 does not exist. Thus, not reporting immediately dominates reporting immediately even when $c = 0$. It follows that the equilibrium probabilities of reporting immediately by fresh victims and fresh libelers are $a_R = b_R = 0$. Only event R occurs in equilibrium; rr and rR are off-equilibrium events.

The likelihood ratio associated with event R is p/q. Thus, an R-equilibrium exists if and only if

$$\hat{l} \leq \bar{l}_R \equiv \frac{p}{q}.$$

In case (ii), the payoff from reporting immediately is smaller than that in case (i) (because the first term of that payoff becomes 0 when rr does not lead to arrest), but the payoff from not reporting immediately remains the same as that in case (i). It follows that not reporting immediately still dominates reporting immediately. The equilibrium probabilities of reporting immediately are $a_R = b_R = 0$, and this equilibrium exists if and only if $\hat{l} \leq p/q$.

In case (iii), the payoff difference between reporting immediately and not reporting immediately for a fresh victim is

$$f_R(c, a; p) \equiv \left(\frac{(1/2)pa}{1-(1/2)pa}\delta - c \right) - \left(\frac{(1/2)p(1-a)}{1-(1/2)pa} + \frac{(1/2)(1-pa)}{1-(1/2)pa}\delta(1-c) \right).$$

Thus, $f_R(a, a; p) = 0$ if and only if

$$pa\delta - a(2-pa) - p(1-a) - (1-pa)\delta(1-a) = 0.$$

The left-hand-side of the above is convex in a and is negative at $a = 0$ and at $a = 1$. Therefore, $f_R(a, a; p) < 0$ for all $a \in [0, 1]$. The only equilibrium probabilities of reporting consistent with this case are $a_R = b_R = 0$, and this equilibrium exists if and only if $\hat{l} \leq p/q$.

In case (iv), the payoff from reporting immediately is smaller than that in case (iii), but the payoff from not reporting immediately remains the same as that in case (iii). It follows that not reporting immediately still dominates reporting immediately. The equilibrium probabilities of reporting immediately are $a_R = b_R = 0$, and this equilibrium exists if and only if $\hat{l} \leq p/q$. ∎

Lemma 3. *In a no-corroboration equilibrium,* $l(R) > l(r)$.

Proof. We first provide an upper bound to $\partial a_{nc}/\partial p$. By implicit differentiation,

$$\frac{\partial a_{nc}}{\partial p} = -\frac{1 - a_{nc}^2 + \delta a_{nc}^2}{2 + 2p\delta a_{nc} - 2pa_{nc} - \delta}.$$

This expression is decreasing in δ; evaluating it at $\delta = 0$ gives the following upper bound:

$$\frac{\partial a_{nc}}{\partial p} \leq -\frac{1-a_{nc}^2}{2(1-pa_{nc})}.$$

The likelihood ratio corresponding to event R is

$$l(R) = \frac{p(1-a_{nc})(1-pa_{nc})}{q(1-b_{nc})(1-qb_{nc})}.$$

Hence, $l(R) > l(r)$ if and only if

$$\frac{(1-a_{nc})(1-pa_{nc})}{a_{nc}(2-pa_{nc})} > \frac{(1-b_{nc})(1-qb_{nc})}{b_{nc}(2-qb_{nc})}.$$

The derivative of the left-hand-side with respect to p has the same sign as:

$$-a_{nc}^2(1-a_{nc}) - \left(a_{nc}(1+p-2pa_{nc})(2-pa_{nc}) + 2(1-pa_{nc})^2(1-a_{nc})\right)\frac{\partial a_{nc}}{\partial p}.$$

Using the upper bound for $\partial a_{nc}/\partial p$, the above expression is greater than

$$\frac{1-a_{nc}}{2(1-pa_{nc})}\left(a_{nc}(1-a_{nc})(1+p)(2-pa_{nc}) + 2(1-pa_{nc})^2\right),$$

which is positive. Hence, $p > q$ implies $l(R) > l(r)$. ■