Hierarchies and Coverup*

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Abstract

What facilitates coverups of wrongdoings in multilayer hierarchies? If a supervisor expects his superiors to cover up, his incentive to cover up increases as his cost of (own) internal exposure increases and cost of external exposure decreases. By diffusing supervisors' responsibility for the hierarchy's loss from external exposure, a deeper hierarchy produces a "pass-the-buck" effect that inspires coverup incentives. A hierarchy's (ex ante) expected loss from a coverup externally exposed could accordingly be larger than its loss from an earlier internal exposure. This dynamic sheds light on the decades-long coverup of abuse of minors in the Roman Catholic Church; the U.S. Army's multi-level coverup of the My Lai Massacre; and the futile fabrication of safety test results in the Aircraft Brake Scandal.

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> When all are guilty, no one is: Confessions of collective guilt are the best possible safeguard against the discovery of culprits, and the very magnitude of the crime the best excuse for doing nothing.
>
> —Hannah Arendt

1 Introduction

Occasional exposures of coverups by the police, hospitals and universities reveal a troubling truth: pillar institutions of society all too often deliberately suppress, conceal or ignore damning information.[1] Rather than clean house, punish bad actors and help victims, reputable organizations of all stripes reflexively cover up wrongdoing, protect perpetrators and aggravate victims' harm (Ambler 2016). In what "often start small[] and grow into scandals that tarnish the reputations of entire institutions" (Conan 2012), coverups not only condone wrongful behavior, but also debase moral norms and erode public trust.

A notorious example is the decades-long coverup of world-wide abuse of minors in the Roman Catholic Church. Widely reported in the first time in 2002 by the *Boston Globe*, the *Globe*'s investigation revealed that Church officials in the Archdiocese of Boston had regularly covered up reports of child abuse by clergymen (Robinson 2002). In Pennsylvania between 2016 to 2018 a grand jury had reviewed massive evidence containing credible allegations against over 300 predator priests in six dioceses involving over 1000 child victims (Couloumbis et al. 2018). "The main thing was not to help children", concluded the grand jury, "but to avoid 'scandal'" (Allegheny Grand Jury Report 2018: 2). The local coverups around the world had been facilitated by a global policy of silence and secrecy authorized by a series of popes who have each followed in his predecessors' footsteps.[2]

The persistence of institutional coverups has been attributed to such factors as fear of legal liability, lack of accountability, and toxic organizational culture. Yet, given that institutional coverups typically requires the active participation of more than one hierarchy's level, the prevalence and scale of coverups remain confounding. For a coverup to succeed, there seems to be a need for high-level coordination among various individuals along the hierarchy's chain of control. Although some institutions are ruled from top down, in many others

[1] *Police brutality.*—In the case of the unaccounted-for death of 25-year old Freddie Gray in a Baltimore police transport van in 2015, "a multiagency bureaucracy erased from history the original trauma of his fatal injury as well as the accounts of those who witnessed it" (Barron 2024).

Hospitals' treatment of patients' poisoning.—"The [movie] Good Nurse makes a persuasive case that, as he switched from hospital to hospital [for 15 years beginning in 1988, nurse Charles] Cullen was able to conceal his lethal poisoning . . . of patients . . . thanks to for-profit hospitals [in New Jersey] covering up potential liability" (Smith 2022).

University's knowledge of abuse.—According to an investigation report, "[There were] numerous cases where [Michigan State] university apparently knew of but did little about accusations of sexual assaults committed by its [team physician Larry Nassar for almost 30 years]" (Bird 2018).

[2] As of 2018, the Roman Catholic Church "has paid out nearly $4 billion in lawsuits over allegations of clerical sexual abuse" arising as early as the 1980s (Zogbi 2018).

high-level officials do not fully control decisions made by their predecessors or lower-level subordinates. Another puzzling aspect of institutional coverups is that they are often harmful to the organization, particularly when the coverup is likely to be externally exposed. The organization in such circumstances would have incurred smaller exposure loss had hierarchy levels witnessing the wrongdoing exposed it early on. Compounding the quandary is that coverups are frequently carried out by men and women who otherwise possess strong moral compass on behalf of institutions whose *raison d'être* is public service.

"In order to understand cover-up," advised Sociology Professor Jack Katz, "we must understand how people in organizations cover up cover-ups, and how they manage to take anticipatory positions in which they will remain protected if the cover-up of deviance is unsuccessful" (Katz 1979: 297). This paper accordingly presupposes that coverups in organizations are a product of rational decisions of multiple supervisors along the hierarchy's ladder, each concerned with his professional standing and personal reputation should he expose an underling's wrongdoing or cover it up. The paper's starting point is that *coverup incentives intensify as supervisors' responsibility share for the hierarchy's loss from their own (internal) exposure increases and their responsibility share for the hierarchy's loss from outside (external) exposure decreases.*

To study the *incentive structure* that gives rise to multilayer coverups at decentralized hierarchies,[3] we consider a stylized model of hierarchical coverup that features full complementarity of coverup decisions. Following an act of misconduct, misbehavior or wrongdoing by an hierarchy's agent, the agent's direct supervisor must decide in the first period whether to expose the wrongdoing or to cover up. If the supervisor exposes, the game ends. If the supervisor covers up, the next supervisor up the hierarchy's ladder faces a similar choice in the second period: to expose the wrongdoing and its coverup or to continue covering up. The game proceeds along a (maximum) of $n+1$ periods, where each of the remaining supervisors must decide in turn whether to expose the wrongdoing and the erstwhile coverups or to continue covering up. If the hierarchy head covers up in period n, then in period $n+1$ the hierarchy's n coverups are publicly exposed by the media or in the courts with a fixed known probability. A coverup therefore succeeds if and only if all n supervisors choose to cover up and their concerted coverups have not been externally exposed.

We augment the model with two sets of related parameters. The first involves the progression of the *hierarchy's overall loss from exposure*. The hierarchy's overall loss from exposed wrongdoing and coverups includes damage to the hierarchy's reputation and prestige, loss of public trust and the undermining of internal authority. The hierarchy's *overall* exposure loss increases with the number of coverups because a larger number of coverups reflects a systematic failure to expose and punish deviant individuals.

[3] By "decentralized hierarchy" we mean a hierarchy in which each hierarchy level possesses independent decision-making authority.

The second set of parameters at the center of the model is the *allocation of responsibility* among the supervisors for the hierarchy's overall loss from internal or external exposure. Supervisors' responsibility share for the hierarchy's loss from their own *internal exposure* reflects the net personal cost a supervisor bears by exposing wrongdoing and previous coverups as a fraction of the hierarchy's overall exposure loss. This cost stems from internal norms requiring insiders to conceal wrongdoing to avoid reputational damage to the institution; expectations by hierarchy's members of shielding wrongdoers from external scrutiny; or loss of personal reputation for failure to hire adequate underlings or to properly train and effectively monitor them. Each supervisor's responsibility share for the hierarchy's loss from *external exposure* reflects the personal cost the supervisor bears when the wrongdoing and subsequent coverups are publicly exposed. This cost stems from the public scolding that befalls insiders for failing to act, damage to professional standing, and loss of position within the hierarchy.

We begin by characterizing the equilibrium outcome in a general hierarchy. Because of the complementarity of coverup decisions, a hierarchy covers up if and only if the probability of external exposure is sufficiently small such that each hierarchy level prefers to cover up given that all his higher-level supervisors cover up. Facilitating coverup in a multi-layered hierarchy is a "pass-the-buck" effect[4]: the anticipation that upper-level supervisors will cover up prompts lower-level supervisors to cover up; and given that lower-level supervisors cover up, upper-level supervisors are better off covering up. Lower-level supervisors thus externalize exposure costs onto higher-level supervisors. This back-and-forth effect results from (i) supervisors' asymmetric responsibility shares for the hierarchy's losses from internal and external exposure; and (ii) a sufficiently slow progression of the hierarchy's overall loss from exposure.[5]

Supervisors' shared responsibility for the hierarchy's exposure loss has a split effect on their coverup incentives. On the one hand, being responsible for only a fraction of the hierarchy's loss from *internal exposure* weakens supervisors' coverup incentives by reducing the personal cost of exposing wrongdoing. On the other hand, shared responsibility for the hierarchy's loss from *external exposure* strengthens supervisors' coverup incentives by reducing their personal costs of exposed coverup. Whether the allocation of responsibility in a hierarchy is conducive to coverup depends on supervisors' relative responsibility shares for internal and external exposure. Coverup incentives *intensify* as each supervisor bears a larger responsibility share for the hierarchy's loss from his own internal exposure; or a smaller responsibility share for the hierarchy's loss from external exposure. Accordingly, coverup incentives in a hierarchy are *minimized* when one supervisor is responsible for the smallest share of the hierarchy's loss from his own internal exposure and for the largest share

[4] We are grateful to Sepehr Shahshahani for suggesting to us this term.

[5] A hierarchy may thus cover up on the equilibrium path even if the coverup is certain to be externally exposed.

of the hierarchy's loss from external exposure. Conversely, coverup incentives are *maximized* when each supervisor is responsible for the entirety of the hierarchy's loss from his own internal exposure and for a proportional share of the hierarchy's loss from external exposure.

To understand the persistence and duration of coverup in hierarchies, we turn to comparing coverup incentives in a shallow hierarchy (consisting of n hierarchy levels) versus a deep hierarchy (consisting of $n+1$ hierarchy levels).[6] If the probability of external exposure is sufficiently small or sufficiently large, both hierarchies cover up or expose for any allocation of responsibility among the supervisors. It is only when the probability of external exposure is intermediate that a deeper hierarchy either unconditionally weakens or conditionally inspires coverup incentives relative to the shallower hierarchy, depending on the allocation of responsibility among the supervisors and the hierarchies' loss from exposure. We focus on the case in which one hierarchy exposes for any allocation of responsibility among the supervisors, whereas the other covers up for a subset of such allocations.

Whether a deeper hierarchy weakens or inspires coverup incentives relative to a shallower hierarchy depends on the balance of two countervailing forces. On the one hand, the hierarchy's loss from external exposure is larger under a deeper hierarchy, which weakens coverup incentives (terminal-loss effect). On the other hand, the loss from external exposure in a deeper hierarchy is shared among one more supervisor, which intensifies coverup incentives (responsibility-diffusion effect). Which effect outweighs the other depends on the relation between the proportional responsibility share of the deeper hierarchy's head for the hierarchy's terminal loss versus the corresponding loss ratio of highest-level and external exposure (Proposition 1). We show in particular that if the hierarchy's loss ratio of consecutive exposures is decreasing sufficiently rapidly, the responsibility-diffusion effect wanes and the terminal-loss effect intensifies with each additional hierarchy layer. By contrast, if the hierarchy's loss ratio of consecutive exposures is (weakly) increasing, the terminal-loss effect wanes and the responsibility-diffusion effect intensifies with each additional hierarchy's layer. Furthermore, the terminal-loss and responsibility-diffusion effects underlie the effect of changes in a hierarchy's exposure loss ratios on relative coverup incentives in a deeper versus shallower hierarchy (Proposition 2–3).

The paper sheds light on the protracted coverup of clergy's abuse in the Roman Catholic Church. Rather than reversing course in the face of growing evidence of wrongdoing, a series of six popes over nearly a century have each continued and expanded their predecessors' policies of silence and secrecy: expanding the scope and purview of confidential duties, shortening the duration of limitation period, and interfering with the civil duty to report abuse. Taking measures to contain the spreading abuse and unavoidably expose the extended coverup would have inevitably rendered a pope responsible for the church's loss of reputation,

[6] We assume the first $n+1$ losses from exposure are identical across an n-layer and $n+1$-layer hierarchies.

decline in influence, and diminished membership. Each pope accordingly reasoned he is best served carrying on the coverup, anticipating that his successors would follow suit. Although each pope stood to be held accountable for the coverup were it externally exposed—as perhaps was bound to happen—all the popes who partook in the silencing campaign would jointly share responsibility for the church's incrementally-decreasing losses. Furthermore, a pope's responsibility for the church's losses from public exposure was diminishing once he has retired from office and a new pope assumed his role. Because each pope's cost ratio of exposure and coverup was sufficiently large, each pope doubled down on his predecessors' policies rather than held predator priests to account and reformed the church.

The coverup in the Roman Catholic Church was in all likelihood destined to blow up; it was therefore (ex ante) detrimental to the church. Our model further explains why (and under what conditions) such coverups that are likely—or even certain—to be eventually exposed can nevertheless take place. Although early exposure of the wrongdoing or its coverup would result in lower exposure loss, hierarchy levels prefer to cover up in order to pass on part of their own (internal) exposure costs to superiors or successors. As the coverup deepen, subsequent hierarchy levels are similarly reluctant to bear the costs of exposure, knowing they can share responsibility for the hierarchy's eventual exposure loss with other hierarchy levels. The organization as a whole thus pays the price of early coverup decisions that force the hand of subsequent superiors or successors to follow suit later on.

Before turning to the remainder of the paper, it is worth noting that institutional coverup is a complex phenomenon caused by a myriad of organizational, sociological and psychological factors. The very nature of organizations, first and foremost, provide managers and supervisors with the means to suppress unfavorable information ("[successful leaders possess] privilege access to information, people, or objects [as well as] unrestrained control of organizational resource" (Ludwig & Longenecker 1993: 268). Charismatic unethical leaders, furthermore, could shape their organization in their image by appointing and nurturing subordinates who are expected to cover up unethical behavior ("'[corrupt leaders] want men that are vicious, grasping, and lusting for power. He who has the gold makes the rules'" [Howell & Avolio 1992: 45]). Finally, a sense of entitlement and omnipotence drives organization leaders to ignore established rules and rationalize improper behavior ("Many moral lapses [in organizations] can be traced back to [one's] feeling [of being] invincible, untouchable, and hyper-capable" [Wedell-Wedellsborg 2019]). This paper does *not* attempt to provide an exhaustive account of the factors and circumstances that give rise to coverups in hierarchical organizations. Its purpose instead is to focus attention on the internal incentive structure within hierarchies that produces tacit coordination among decentralized hierarchy's levels that results in a coverup.

The paper is organized as follows. After surveying related literature in the next section,

Section Three sets up the model, illustrates the main result, and discusses the key assumptions. Section Four presents the equilibrium outcomes as a function of the model's primitives. Section Five compares coverup incentives in hierarchies of different depths, illustrates the results in hierarchies of two and three layers, and considers three special cases of a hierarchy's exposure losses. Section Six examines the effect of changes in a hierarchy's loss ratios on relative coverup incentives. Section Seven discusses the implications of the paper's ideas for the Roman Catholic Church's coverup of clergymen's abuse of minors; the U.S. Army's coverup of the My Lai Massacre; and Goodrich Company's coverup of a faulty aircraft brake (in what is now known as the Aircraft Break Scandal). Section Eight concludes.

Two Supplementary Appendices accompany the paper. Supplementary Appendix A includes additional results, whereas Supplementary Appendix B contains complementary discussion.

2 Related literature

2.1 Corruption in organization

Our paper is part of a multidisciplinary literature on corruption in organizations spanning such fields as sociology, psychology, and political science.[7] Under the standard economic conceptualization originating in Banfield (1975), organizational corruption is a manifestation of a principal-agent problem (see, e.g., Groenendijk 1997). The instantiation of organizational corruption commonly involves a transaction between an agent and a third party that benefits the agent at the expense of the principal (Rose-Ackerman 1975; Søreide & Rose-Ackerman 2018). More relevant to this paper is Tirole (1986), who studies organizational corruption in a three-tier hierarchy. In Tirole's model, the hierarchy consists of a principal, a supervisor and an agent, where the supervisor's role is to report the agent's productivity type to the uninformed principal. Tirole's paper has inspired a large body of work that studies optimal contractual and institutional arrangements in hierarchical agencies in response to possible collusion between the supervisor and the agent (Laffont 1990; Kofman & Lawarree 1993; Bac & Kucuksenel 2006). Basu et al. (1992), for example, consider the minimum penalty required to deter bribery down the hierarchy chain.

Coverup as a derived form of corruption does not fall squarely within the principal-agent paradigm. In a collusion-type corruption model à la Tirole, the agent and the supervisor both obtain a pecuniary benefit from corruption at the expense of the principal. In the case of a coverup, by contrast, a hierarchy supervisor typically does not collude with a deviant agent and derives only a non-pecuniary benefit from covering up (in the form of

[7] Jancsics (2014) provides a general overview and organization of the study of corruption, observing it "has become one of the most popular topics in the social scientific disciplines."

preservation of reputation and promotion opportunities). More important, in contrast to the standard principal-agent framework, the interests of the hierarchy and its supervisors in covering up wrongdoing and subsequent coverups are not diametrically opposed. Depending on the probability of external exposure and the overall institutional loss from exposure, the preservation of the hierarchy's reputation through one or more coverups may benefit *both* the hierarchy and its supervisors. We capture the partial alignment of interest between the hierarchy and its supervisors by assuming that supervisors' cost of exposure is proportional to the hierarchy's corresponding loss.

2.2 Detection avoidance

A second related literature on detection avoidance has qualified Becker (1968)'s classical prescription of maximal sanctions coupled with low probability of detection. Malik (1990) shows that a higher sanction on an underlying offense stimulates expenses on socially-wasteful detection avoidance. Sanchirico (2006) highlights the recursive nature of detection avoidance: a higher sanction on detection avoidance creates incentives for a higher-order detection avoidance. Similar to Malik's insight, a higher sanction for detection avoidance may inspire detection avoidance. In a similar vein, Nussim & Tabbach (2009) show that a small increase in penalties across all types of proscribed activities provides offenders incentives to incur avoidance expenditures without directly affecting their choice of crime (since marginal sanctions remain the same). The result is a higher rate of crime in equilibrium.

This paper differs from previous works on detection avoidance in several respects. First, instead of allowing for different degrees of detection avoidance, we assume each hierarchy level faces a binary choice between coverup and exposure; the cost of carrying out a coverup may thus be arbitrarily small. We accordingly abstract from the effect of a coverup on the probability of detection by holding that probability fixed (see Section 3.3.3). Second, in the detection avoidance literature, the measures designed to avoid detection are taken by the perpetrator of the primary offense. Here, by contrast, the coverup of the primary illegal or unethical activity is undertaken by the hierarchy's supervisors rather than the perpetrator. Most important, rather than studying ex ante incentives to engage in illegal activities, the focus of this paper is on the strategic interplay between different hierarchy levels: each supervisor's coverup decision hinges on higher-level supervisors' coverup decisions (on- or off-the-equilibrium path). This setup is particularly suitable to institutional coverup in which supervisors who expose wrongdoing or previous coverups are likely to share responsibility both for exposing the wrongdoing and prior coverups and for their concerted coverups.

2.3 Coverups in hierarchies

In contrast to the extensive study of corruption in organizations, there has been relatively little systematic research of institutional coverups.[8] In a seminal work, Katz (1977) points out coverups reinforce moral and authoritative boundaries between organizations and society. Because exposure of wrongdoing invites external scrutiny, coverups serve to preserve the legitimacy of the organization's internal authority. Complementing his previous study, Katz (1979) brings to the fore the part played by feigned or real ignorance among different organizational levels for the effective suppression of damaging information, noting that "hierarchy and specialization promise efficiency [but also] provide incentives for cover-ups" (p. 309). Kundro & Nurmohamed (2021) highlight the effect of group loyalty in enabling coverups: group members are less likely to punish fellow members who cover up wrongdoing to protect the group. Demonstrating the consistent failure of formal accountability mechanisms in multiple real-life coverups, Grant et al. (2023) focus on the role of complicity—"the association with or participation in another person's wrongdoing"—in facilitating coverups.[9] Shaping and contributing to complicity are the human tendency to conformity and group loyalty, diffusion of responsibility among complicit actors, and the otherwise worthy standards of trust and professionalism.[10] Guiora (2020) similarly highlights the critical role of institutional enablers in facilitating and covering up sexual assaults in USA Gymnastics, the Roman Catholic Church and three public state universities (Michigan, Penn, and Ohio).

This paper formalizes and explicates some of the main themes in the extant literature on institutional coverups. We represent the degree of complicity of hierarchy's levels—accounting both for the benefits of conformity and the costs of in-group disloyalty—by supervisors' responsibility share for the hierarchy's internal loss from their own exposure: the higher supervisors' responsibility share for that loss, the stronger are their incentive to be complicit. In contrast to most previous research, the decision to be complicit is a strategic one: each supervisor's decision whether to expose the wrongdoing or to cover up depends on higher-level supervisors' decisions. We explicate the idea of diffusion of responsibility as emerging out of the relation between supervisors' responsibility shares for the hierarchy's terminal loss and the progression of the hierarchy's loss from exposure. Each supervisor's coverup decision accordingly depends both on his own and on his superiors' cost ratios of exposure and complicity.

[8] To the best of our knowledge, the only formal paper of institutional coverups is Bloch & Kranton (2022). In contrast to this paper, Block & Kranton study coverup incentives of a single supervisor (i.e., 1-layer hierarchy) in the presence of endogenous external discovery.

[9] Cf. Katz (1979): "Bureaucratic structures and ideologies of professionalism facilitate large-scale complicity in deviance by conditioning subordinates toward passive compliance" (p. 296).

[10] The term "diffusion of responsibility" was first introduced by Darley & Latane (1968) to explain individuals' greater reluctance to provide help in the presence of other potential helpers. Beyer et al. (2017) note that "[t]he presence of other people makes agents feel less responsible for the outcome of group decisions, especially those with negative consequences" (citing Mynatt & Sherman 1975 and Forsyth et al. 2002). The behavioral economic literature similarly shows that "groups make more selfish decisions than individuals" caused inter alia by "reduction of responsibility" (Brütt et al. 2020: 4).

3 A Model of Hierarchical Coverup

3.1 Setup

Hierarchy's structure.—An n-layer hierarchy consists of a set $N = (1, ..., n)$ of risk-neutral supervisors of ascending rank. We denote an i-level supervisor as Supervisor S_i^n, where the subscript $i \in N$ stands for the supervisor's rank and the superscript for the number of hierarchy levels. Each supervisor is in charge of all his lower-level subordinates: Supervisor S_i^n is in charge of Supervisors S_1^n through S_{i-1}^n for $i = 2, ..., n$.

Timing and actions.—The game unfolds over a maximum of $n+1$ periods. In period 0, there is wrongdoing by an agent of the hierarchy (our analysis is thus a post-mortem one).[11] In period 1, the agent's direct supervisor, S_1^n, must decide whether to expose the wrongdoing or to cover up. If S_1^n exposes, the game ends. If S_1^n covers up the game proceeds to the next period. In each subsequent period, Supervisor S_i^n must decide in period $i = 2, ..., n$ whether to expose or to cover up provided his direct underling, Supervisor S_{i-1}^n, had covered up in period $i - 1$. If the hierarchy head, Supervisor S_n^n, covers up in period n, then in period $n + 1$ the wrongdoing along with the hierarchy's n coverups are externally exposed—by the media or in the courts—with an exogenous probability $r \in (0, 1)$.

Hierarchy's loss from exposure.—The hierarchy's *overall* loss from internally- or externally-exposed wrongdoing or coverups in period $i \in N$ is $L_i > 0$, where L_i is strictly increasing in i. That is, the hierarchy's overall loss from exposure strictly increases each time it fails to expose the wrongdoing. Two special cases involving a hierarchy of two or more layers are noteworthy: additive overall loss and geometric overall loss. In the former case, the hierarchy's overall loss from exposure in period $i = 3, ..., n$ is equal to the sum of its overall losses in the previous periods: $L_i = \Sigma_{j=1}^{i-1} L_j$ for $i = 3, ..., n$. In the latter case, the hierarchy's loss ratio from consecutive exposures is constant: $L_i/L_{i+1} = L_{i+1}/L_{i+2}$ for $i = 2, ..., n - 1$.

Supervisors' responsibility shares.—Let $s_{ij} \in (0, 1]$ denote supervisor S_i^n's responsibility share for the hierarchy's loss from *internal exposure* in period $j \in N$, where $\Sigma_{i=1}^n s_{ij} = 1$. To fix ideas, we assume $s_{ii} = s$ for $i \in N$ and $n \geq 2$; i.e., each supervisor in a hierarchy of two or more layers is responsible for a fraction $s \in (0, 1]$ of the hierarchy's loss from his own internal exposure. Supervisor S_i^n therefore bears a cost of $s \cdot L_i$ if he exposes the wrongdoing and previous coverups.

Let $t_i^n \in [0, 1]$ denote Supervisor S_i^n's responsibility share for the hierarchy's loss from *external exposure* in the terminal period (period $n + 1$), where $i \in N$ and $n \geq 2$; we shall call this responsibility share "terminal responsibility share" (we use the terms "loss from external exposure" and "terminal loss" interchangeably). Supervisor S_i^n therefore bears a

[11] By "wrongdoing" we mean a deviation from rules or expectations that constitutes a violation of legal or moral codes.

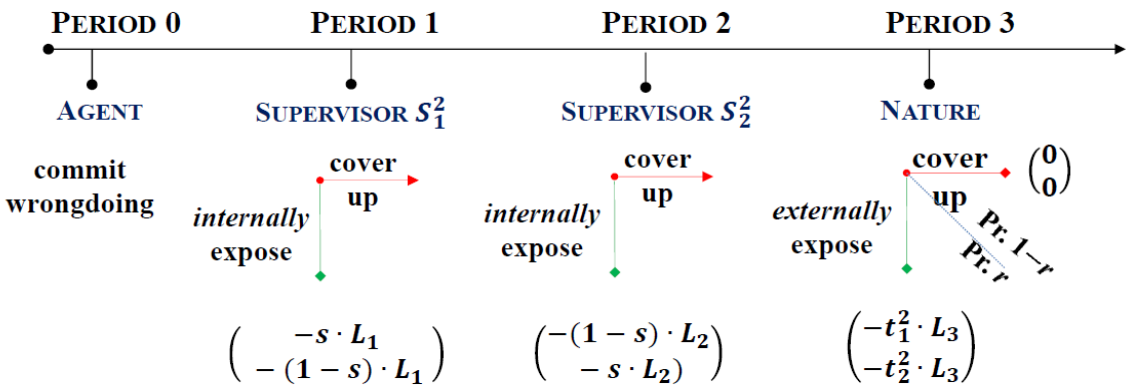


Figure 0: 2-layer Hierarchy: Timeline, Actions, and Payoffs

cost of $t_i^n \cdot L_{n+1}$ if all the hierarchy's supervisors have covered up and the hierarchy's coverup is externally exposed, where $\Sigma_{i=1}^n t_i^n \times L_{n+1} = L_{n+1}$. We assume a sole supervisor of a 1-layer hierarchy bears the entire responsibility for both internal and external exposure: $s_{11} = 1 = t_1^1$.

Figure 0 presents the timing, actions, and payoffs of two supervisors in a 2-layer hierarchy.

3.2 1- versus 2-layer hierarchy

To illustrate the germ of the paper's insight, consider coverup incentives in a 1- versus 2-layer hierarchy. A sole supervisor of a 1-layer hierarchy covers up an agent's wrongdoing in period 1 if and only if his *cost ratio* of internal versus external exposure is smaller than the probability of external exposure:

$$r < \frac{L_1}{L_2},$$

where L_1 and L_2 are, respectively, the supervisor's costs of internal exposure in period 1 and external exposure in period 2.[12]

Next, consider coverup incentives in a 2-layer hierarchy. Given that the lower-level supervisor had covered up in period 1, the upper-level supervisor covers up in period 2 if his *cost ratio* of internal versus external exposure is smaller than the probability of external exposure:

$$r < \frac{sL_2}{t_2^2 L_3},$$

where sL_2 and $t_2^2 L_3$ are, respectively, the upper-level supervisor's costs of internal exposure in period 2 and external exposure in period 3.

Given that the hierarchy head covers up in period 2, the lower-level supervisor covers

[12] Recall that the head of a 1-layer hierarchy bears full responsibility for the hierarchy's loss for both internal and external exposure: $s = t_1^1 = 1$.

up in period 1 if and only if his *cost ratio* of internal versus external exposure is smaller than the probability of external exposure:

$$r < \frac{sL_1}{t_1^2 L_3},$$

where sL_1 and $t_1^2 L_3$ are, respectively, the lower-level supervisor's costs of internal exposure in period 1 and external exposure in period 3.

Lemma 0 (coverup equilibrium: 2-layer hierarchy) *Both the lower-level and upper-level supervisors cover up if and only if* $r < \frac{s}{L_3} \min\{L_1/t_1^2, L_2/t_2^2\}$.

A 2-layer hierarchy covers up if and only if the upper-level supervisor covers up in period 2 given that the lower-level supervisor had covered up in period 1 ($r < (sL_2)/(t_2^2 L_3)$); and the lower-level supervisor covers up in period 1 given that the upper-level supervisor covers up in period 2 ($r < (sL_1)/(t_2^2 L_2)$). Both supervisors therefore cover up if and only if $r < s/L_3 \min\{L_1/t_1^2, L_2/t_2^2\}$.

Now, for given $L_1, L_2 > 0$, $\min\{L_1/t_1^2, L_2/t_2^2\}$ obtains a *maximum* value for $L_1/t_1^2 = L_2/t_2^2$ such that supervisors' terminal responsibility shares are proportional to the hierarchy's respective losses from internal exposures. Since supervisors' terminal responsibility shares add up to 1 ($t_1^2 + t_2^2 = 1$), the maximum value of $\min\{L_1/t_1^2, L_2/t_2^2\}$ is obtained for $t_i^2 = L_i/(L_1+L_2)$ for $i = 1, 2$. It follows that $\max_{\{t_1^2, t_2^2\}} \min\{L_1/t_1^2, L_2/t_2^2\} = L_1+L_2$ and hence $\max_{\{s, t_1^2, t_2^2\}} s/L_3 \min\{L_1/t_1^2, L_2/t_2^2\} = (L_1 + L_2)/L_3$. That is, the *maximal minimum* probability of external exposure that stems coverup for any allocation of responsibility between the lower-level and upper-lever supervisors is obtained when each supervisor is responsible for the hierarchy's entire loss from his own internal exposure ($s = 1$) and for a proportional share of the hierarchy's loss from external exposure.

Remark 0 (supervisors' payoffs: 2-layer hierarchy)

If $r \in (L_1/L_3, s/L_3 \min\{L_1/t_1^2, L_2/t_2^2\})$ *both supervisors cover up but the hierarchy's expected exposure loss is* larger *than if the lower-level supervisor exposes.*

If $r < s/L_3 \min\{L_1/t_1^2, L_2/t_2^2\}$, both supervisors cover up by Lemma 0. If, in addition, $r > L_1/L_3$, the hierarchy's expected terminal loss ($r \cdot L_3$) is larger than its loss from the lower-level supervisor's exposure (L_1). Therefore, both supervisors' joint expected costs are larger if the lower-level supervisor exposes than if the hierarchy covers up (because $rL_3 > L_1$). Since the lower-level supervisor must be better off covering up than exposing (for otherwise he would expose), the upper-level supervisor is worse off if the hierarchy covers up than if the lower-level supervisor exposes.

If the hierarchy covers up, the lower-level supervisor must be better off covering up than exposing. Since the sum of the supervisors' expected costs is equal to the hierarchy's

expected loss, the upper-level supervisor must be worse off when the hierarchy covers up than if the lower-level supervisor exposes. *By covering up, the lower-level supervisor externalizes exposure costs onto the upper-level supervisor, forcing the latter to cover up as well against the supervisors' joint interest.*

From Lemma 0 it follows that for any allocation of responsibility between the supervisors, a 2-layer hierarchy weakens coverup incentives relative to a 1-layer hierarchy if $r \in ((L_1 + L_2)/L_3, L_1/L_2))$; in this case, a 2-layer hierarchy exposes whereas a 1-layer hierarchy covers up. By contrast, a 2-layer hierarchy inspires coverup incentives relative to a 1-layer hierarchy if $r \in (L_1/L_2, \min\{(L_1 + L_2)/L_3, 1\})$; in this case, a 1-layer hierarchy exposes whereas a 2-layer hierarchy covers up for a subset of allocations of responsibility between the lower-level and upper-level supervisors. We say that a 2-layer hierarchy *unconditionally weakens* coverup incentives in the former case; and *conditionally inspires* coverup incentives in the latter.

The next proposition presents general conditions under which a 2-layer hierarchy either unconditionally weakens or conditionally inspires coverup incentives relative to a 1-layer hierarchy as a function of the hierarchies' exposure losses.

Proposition 0 (coverup incentives in 1- versus 2-layer hierarchy)

Let $\hat{t}_1^2(L_{1,2}) \equiv \frac{L_1}{L_1+L_2}$ *and* $\hat{t}_2^2(L_{1,2}) \equiv \frac{L_2}{L_1+L_2}$ *be, respectively, the lower-level and upper-level supervisors' terminal proportional responsibility shares.*

(1) If $L_2/L_3 \in (0, \hat{t}_1^2(L_{1,2}))$*, a 1-layer hierarchy covers up whereas a 2-layer hierarchy exposes for* $r \in (\frac{L_1+L_2}{L_3}, \frac{L_1}{L_2})$*; and*

(2) If $L_2/L_3 \in (\hat{t}_1^2(L_{1,2}), 1)$*, a 1-layer hierarchy exposes whereas a 2-layer hierarchy conditionally covers up for* $r \in (\frac{L_1}{L_2}, \min\{\frac{L_1+L_2}{L_3}, 1\})$*,*

where $\frac{L_1+L_2}{L_3} < 1$ *if and only if* $L_2/L_3 < \hat{t}_2^2(L_{1,2})$*.*

Adding a hierarchy layer to a 1-layer hierarchy accordingly has a twofold effects on coverup incentives. On the one hand, an additional hierarchy layer *increases* the hierarchy's terminal loss by $L_3/L_2 > 1$, thereby weakening relative coverup incentives (terminal-loss effect). On the other hand, an additional hierarchy layer *reduces* the (1-layer) hierarchy head's terminal proportional responsibility share by $1/\hat{t}_1^2(L_{1,2}) > 1$ (because $t_1^1 = 1$), which boosts relative coverup incentives (responsibility-diffusion effect). The net effect on relative coverup incentives therefore depends on the relation between the terminal-loss and responsibility-diffusion effect.

A 2-layer hierarchy *unconditionally* weakens coverup incentives relative to a 1-layer hierarchy if the proportionate increase in the hierarchy's terminal loss outweighs the hierarchy head's reduced terminal responsibility share in a 2- versus 1-layer hierarchy: $L_2/L_3 < \hat{t}_1^2(L_{1,2})$. By contrast, a 2-layer hierarchy *conditionally inspires* coverup incentives relative

to a 1-layer hierarchy if the hierarchy head's reduced terminal responsibility share in a 2- versus 1-layer hierarchy is smaller than the proportionate increase in the 1-layer hierarchy's terminal loss: $\hat{t}_1^2(L_{1,2}) < L_2/L_3$. Finally, if the hierarchy head's reduced terminal responsibility share in a 2- versus 1-layer hierarchy sufficiently outweighs the higher terminal loss of a 2-layer hierarchy—$L_2/L_3 > L_2/(L_1 + L_2) \equiv \hat{t}_2^2(L_{1,2})$, or, equivalently, $L_3 < L_1 + L_2$—a 1-layer hierarchy exposes whereas a 2-layer hierarchy conditionally or unconditionally covers up for $r \in (L_1/L_2, 1)$.[13] Figure 1 presents a graphical representation of Proposition 0.

Observe that a 2-layer hierarchy inspires coverup incentives relative to a 1-layer hierarchy if (but not only if) the hierarchy's loss ratios are increasing ($L_1/L_2 \leq L_2/L_3$); and that a 2-layer hierarchy conditionally covers up for $r \to 1$ if and only if the hierarchy's overall loss is infra-additive ($L_3 < L_1 + L_2$). The following example provides a concrete example of Proposition 0.

Example 0 (coverup incentives in 1- versus 2-layer hierarchy)

Suppose that a hierarchy's loss from the first and second exposure are $(L_1, L_2) = (1, 2)$*:*

(1) If $L_3 > 6$*, a 1-layer hierarchy covers up whereas 2-layer hierarchy exposes for* $r \in (\frac{3}{L_3}, \frac{1}{2})$*.*

(2) If $L_3 \in [3, 6)$*, a 1-layer hierarchy exposes whereas 2-layer hierarchy conditionally covers up for* $r \in (\frac{1}{2}, \frac{3}{L_3})$ *(increasing loss ratios for* $L_3 \in [3, 4]$*);*

(3) If $L_3 \in (2, 3)$*, a 1-layer hierarchy exposes whereas 2-layer hierarchy conditionally covers up for* $r \in (\frac{1}{2}, 1)$ *(infra-additive overall loss)*

The three parts of Example 0 are illustrated in the three equal-length line segments comprising the vertical line that equally divides the unit square in Figure 1 (the line stretching down from $(\Delta_1, \Delta_2) = (\frac{1}{2}, 1)$ to $(\Delta_1, \Delta_2) = (\frac{1}{2}, 0)$). The first part of Example 0 corresponds to $\Delta_2 = L_2/L_3 \in (\frac{2}{3}, 1)$; the second part to $\Delta_2 \in (\frac{1}{3}, \frac{2}{3}]$; and the third part to $\Delta_2 \in (0, \frac{1}{3})$.

In the remainder of the paper, we generalize Proposition 0 to hierarchies of any number of layers. In doing so, we provide further intuition for the circumstances under which a deeper hierarchy inspires coverup incentives relative to a shallower hierarchy.

3.3 Comments on modeling

3.3.1 Hierarchical decision-making

A staple of modern organizations is a hierarchical chain of command that assigns different tasks to different organizational levels. The organization's ultimate decision is commonly a product of multiple individuals occupying different positions each providing input to higher levels. A natural modeling choice for a hierarchy's decision-making process is therefore

[13] As we show in Figure 3 below, a 2-layer hierarchy covers up for any allocation of responsibility between the supervisor for a sufficiently small r.

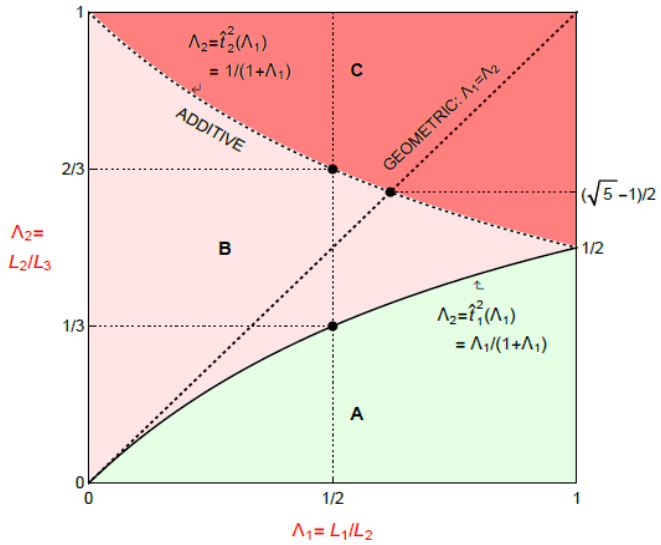


Figure 1: Coverup Incentives in 1- versus 2-layer Hierarchy. In Area A, a 2-layer hierarchy unconditionally suppresses coverup incentives relative to a 1-layer hierarchy for $r \in [(L_1 + L_2)/L_3, L_1/L_2)$; in Area B, a 2-layer hierarchy conditionally inspires coverup incentives relative to a 1-layer hierarchy for $r \in (L_1/L_2, \min\{(L_1 + L_2)/L_3, 1\}]$; and in Area C, not only does a 2-layer hierarchy conditionally inspire coverup incentives relative to a 1-layer hierarchy, but a 2-layer hierarchy may cover up even if the coverup is certain to be virtually externally exposed ($r \to 1$).

sequential decision-making: higher-level supervisors' decisions that build on lower-level supervisors' decisions.[14]

In the context of institutional coverup, lower-level supervisors decide whether to cover up by contemplating upper-level supervisors' decisions down the road should they choose to cover up. We assume that supervisors' coverup decisions are purely *complementary*: the hierarchy successfully covers up if and only if all supervisors cover up. The assumption that coverup decision are purely complementary implies that the hierarchy's levels cannot suppress or conceal information from their superiors. Assuming that the coverup may succeed if a subset of supervisors cover up—for example, by hiding information from upper-level supervisors—would render a deeper hierarchy more conducive to coverup. The assumption of pure complementarity thus militates against a multi-layer hierarchy's successful cover up.[15]

[14] Radner (1992: 1390-91) formally defines a hierarchy as a "ranked tree," where a "tree" satisfies four properties: (1) transitivity (if A is superior to B, and B is superior to C, then A is superior to C); (2) antisymmetry (if A is superior to B, then B is not superior to A); (3) existence of a unique root (a unique object D superior to all the other objects); and (4) existence and uniqueness of immediate superior (every object other than the root has exactly one immediate superior).

[15] Although the supervisors in our setup are of different ranks, the model applies equally to a succession of supervisors of the same rank. For example, a company CEO who must review decisions made by his predecessors; a university president who must decide whether to reverse policies enacted by previous presidents; or a military officer who must decide whether to keep practices adopted by former officers.

3.3.2 Cost of exposing wrongdoing

A key assumption is that a supervisor is responsible for exposing wrongdoing. One justification for this assumption is that an underling's wrongdoing is attributed to the supervisors who hired and monitored him. As Katz (1979) notes, "Managers develop interest in not enforcing their authority because deviance in their domains would reflect failure in their leadership" (p. 303). Another justification is that internal exposure of wrongdoing often violates institutional unwritten norms and expectations: "Any organization may be faced by an action of a member which embarrasses the organization. Shielding members from external perception of their deviance also shields the organization from embarrassment." (Katz 1977: 6). A supervisor is thus expected to cover up to protect the institution's reputation. Furthermore, "shielding of subordinates from outsiders . . . significantly shapes the character of the organization" (Katz 1977: 7). Organizational leaders who expose wrongdoing and punish subordinates risk being perceived as betraying their role as protectors of members of the organization. To self-justify their coverup, organizational officials may self-servingly reason the greater good of the institution outweighs the moral wrong of a coverup, allowing them to "deplore the [wrongdoing] while covering it up nonetheless for the sake of a higher value" (Grant et al. (2023)).

We assume each supervisor's responsibility *share* for the hierarchy's loss from his internal exposure is identical for all supervisors. Reflecting the greater *absolute* responsibility of a supervisor with greater authority, this assumption accords with Kennedy & Anderson (2017) who found that holding high-ranking positions makes individuals less likely to engage in "principled dissent." Because high-ranking individuals identify more strongly with their organization, they are more tolerant of unethical practices relative to low-ranking individuals. This in turn implies that the moral cost of covering up is likely to decrease along the hierarchy's chain of control.[16]

Finally, studies in social psychology have shown that in-group members tend to show preferential treatment toward fellow members (Brewer 1979; Hogg & Terry 2000; Tenbrunsel & Smith-Crowe 2008). Harnessing this observation, Kundro & Nurmohamed (2021) (KL) distinguish between "personal cover-ups as actions that individuals take to conceal their own unethical behavior, and relational cover-ups as actions that individuals take to conceal the unethical behavior of another person" (p. 874). Across three studies KL found that "in-group third parties punish relational—but not personal—cover-ups less severely than out-group third parties" (p. 892). Behind this behavioral pattern, KL suggest, is a reward for loyalty manifested by a "committ[ment] to the welfare and interests of the group" (p. 874). A supervisor's responsibility share for the hierarchy's loss from internal exposure thus

[16] Although we assume the magnitude of supervisors' costs of exposure sum up to the hierarchy's corresponding loss, our results would remain unchanged if supervisors' overall personal costs either did not exhaust or exceeded the hierarchy's overall loss.

reflects the strength of the preferential treatment accorded to relational coverups: the more in-group members view negatively exposure by hierarchy's members, the larger is the cost of exposing wrongdoing.

3.3.3 Probability of external of exposure

A twofold assumption underlying our setup is that the probability of external exposure is fixed—and therefore independent of supervisors' coverup measures; and that external exposure may occur only after all the hierarchy's levels covered up. A main purpose of coverups, however, is to reduce the probability of external exposure by suppressing and concealing information.[17] In reality, furthermore, a cover up could blow out at any time after the first hierarchy's level covered up. Both assumptions—a fixed probability of exposure that is realized after all the hierarchy's levels covered up—simplify the analysis but their relaxation would not affect the paper's core analysis.

Because at the heart of our model is a comparison exercise between hierarchies of different depths, assuming the probability of external exposure is exogenous is with little loss of generality. A larger number of coverups attempts produces opposite effects on the probability of external exposure: on the one hand, additional coverups directly reduce the probability of external exposure by further suppressing or manipulating relevant information; on the other hand, each coverup attempt prolongs the overall coverup period, which in itself tends to indirectly increase the probability of external exposure. Since the relative weight of these countervailing effects is likely to vary from case to case, we treat the probability of external exposure as fixed.

Relaxing the assumption that the probability of external exposure is realized after all the hierarchy's levels have covered up would imply that, holding fixed the allocation of responsibility among the supervisors, lower-level supervisors' coverup cost would be higher relative to the benchmark case. The main insight of the paper, however, would continue to hold if we assumed that in each period there is a fixed probability of external exposure. To drive this point home, consider a 2-layer hierarchy in which the probability of external exposure in period 1.5—after Supervisor S_1^2 covered up but before Supervisor S_2^2 made his coverup decision—is $r_0 \in (0,1)$. If Supervisor S_1^2's coverup is exposed in period 1.5, the hierarchy's loss from the interim external exposure is $L_{12} \in (L_1, L_2)$ and Supervisors S_1^2's and S_2^2's responsibility shares for the hierarchy's loss are t_1^2 and t_2^2, respectively. Given that S_1^2 had covered up, Supervisor S_2^2 covers up iff the probability of external exposure in period 2 is $r < \frac{sL_2}{t_2^2 L_3}$ (as in the benchmark case), whereas Supervisor S_1^2 covers up iff

[17] For example, a series of concealing practices regularly appeared in the diocesan files pertaining to the Catholic Church's sex abuse scandal: use of euphemisms rather than real words to describe sexual assaults; coverup investigations; sending of molesting priests to a supposed "evaluation" at church-run psychiatric treatment centers; removal of offending priests without providing background on their misconduct; non-punishment of predator priest; and lack of reporting to the police (Allegheny Grand Jury Report 2018: 3).

$r < \frac{sL_1 - r_0 t_1^2 L_{12}}{t_1^2 L_3 - r_0 t_1^2 L_3} < \frac{sL_1}{t_1^2 L_3}$ (lower than the benchmark case).[18]

4 Equilibrium Analysis

4.1 Coverup Equilibrium

We solve for a subgame perfect equilibrium by backward induction. Consider the decision of the hierarchy head, Supervisor S_n^n, to expose or to cover up in period n given that all his subordinates, Supervisors S_1^n through S_{n-1}^n, had covered up in their turn. Exposing costs the hierarchy head $s \cdot L_n$ whereas covering up costs him $r \cdot t_n^n \cdot L_{n+1}$. The hierarchy head therefore covers up if and only if

$$r < \frac{sL_n}{t_n^n L_{n+1}}. \tag{1}$$

The hierarchy head covers up if the probability of external exposure (r) is smaller than his *cost ratio* of internal versus external exposure: the ratio of his responsibility shares for the hierarchy's loss from internal and external exposure (s/t_n^n) times the hierarchy's corresponding loss ratio ($\frac{L_n}{L_{n+1}}$). If $n = 1$ (1-layer hierarchy), Eq. (1) boils down to $r < \frac{L_1}{L_2}$.[19]

Each lower-level supervisor's decision to expose or to cover up depends on his superiors' decisions to expose or cover up on or off the equilibrium path. Suppose Supervisors S_{i+1}^n through S_n^n covers up in period $i+1, ..., n$, respectively. Then Supervisor S_i^n covers up in period i if his cost exposing is greater than his cost of covering up: $sL_i > r \cdot t_i^n L_{n+1}$. Supervisor S_i^n therefore covers up if (but not only if)

$$r < \min_{j \geq i} \frac{sL_j}{t_j^n L_{n+1}}. \tag{2}$$

Supervisor S_i^n covers up if the probability of external exposure is smaller than each of Supervisors S_i^n through S_n^n's cost ratio of internal versus external exposure: the ratio of the supervisor's responsibility share for the hierarchy's loss from his own internal exposure and from external exposure (s/t_j^n) times the hierarchy's corresponding loss ratio (L_j/L_{n+1} for $j \geq i$).

Lemma 1 (coverup equilibrium) *Supervisors S_1^n through S_n^n* all *cover up if and only if* $r < s/L_{n+1} \min_{i \in N} L_i/t_i^n$.

An n-layer hierarchy covers up if the probability of external exposure is (strictly) smaller than that for which the hierarchy head covers up and every other supervisor covers up given

[18] Note that Supervisor S_1^2's cost of exposure remains sL_1 whereas his expected cost of coverup is $r_0 t_1^2 L_{12} + (1 - r_0) r t_1^2 L_3$ - the probability of interim external exposure in period 1.5 times Supervisor S_1^2's corresponding cost plus the probability of terminal expected exposure in period 3 times Supervisor S_1^2's corresponding cost.

[19] Recall that in a 1-layer hiearchy, $s = 1 = t_1^1$.

that all his superiors cover up in their turn. Lower-level supervisors cover up if they anticipate higher-level supervisors to cover up down the road. Once lower-level supervisors cover up, upper-level supervisor prefer to cover up too.

Assumption 1 (responsibility shares for internal and external exposure)
(1) $s \geq \frac{1}{n}$ *(Minimum Responsibility); and*
(2) $t_j^n \leq t_k^n$ *for* $j < k \in N$ *(Responsibility Gradation).*

Assumption 1 rules out the possibility that a supervisor's responsibility share for the hierarchy's loss from his own *internal* exposure is smaller than *every* other supervisor ($s < 1/n$); and the possibility that a lower-level supervisor's terminal responsibility share is greater than that of a higher level supervisor (i.e., it rules out $t_j^n < t_k^n$ for $j > k$). Assumption 1 is an extension of the natural bounds on supervisors' responsibility shares in a 2-layer hierarchy. An intuitive assumption in the case of a 2-layer hierarchy is that the lower-level supervisor is responsible for no less than half of the hierarchy's loss from his own internal exposure; and for no more than half of the hierarchy's loss from external exposure. Extending this reasoning to an n-layer hierarchy, an exposing supervisor bears greater responsibility for the hierarchy's loss from his own internal exposure than some other supervisor;[20] and a higher-level supervisor bears greater responsibility for the hierarchy's terminal loss than a lower-level supervisor.

Relaxation of Assumption 1, moreover, would imply in the extreme that any hierarchy of two or more layers would altogether eliminate coverup incentives if the lowest-level supervisor were either *not* responsible for the hierarchy's loss from his own *internal* exposure ($s = 0$); or *entirely* responsible for the hierarchy's loss from *external* exposure ($t_1^n = 1$). More generally, Assumption 1 reflects that the allocation of responsibility among the hierarchy's supervisors should provide each supervisor incentives for ex ante screening and monitoring by holding each of them sufficiently accountable for the hierarchy's loss from internal and external exposure.

Remark 1 (supervisors' payoffs) *If* $r \in (L_1/L_{n+1}, s/L_{n+1} \min_{i \in N} L_i/t_i^n)$, *supervisors cover up but* at least *one of Supervisors* S_2^n *through* S_n^n *is worse off than if Supervisor* S_1^n *exposes.*

If $r < s/L_{n+1} \min_{i \in N} L_i/t_i^n$, all supervisors cover up by Lemma 1. If, in addition, $r > L_1/L_{n+1}$, the hierarchy's expected terminal loss ($r \cdot L_{n+1}$) is larger than its loss from Supervisor S_1^n's exposure (L_1). It follows that Supervisor S_1^n through S_n^n's joint expected costs are smaller if Supervisor S_1^n exposes than if the hierarchy covers up (because $r \cdot \Sigma t_i \cdot L_{n+1} = rL_{n+1} > L_1$). But Supervisor S_1^n must be better off covering up than exposing for otherwise he would expose. At least one of Supervisor S_2^n through S_n^n must be worse off than if

[20] For example, if $n = 3$ and $s_{i3} < 1/3$, then either $s_{j3} > 1/3$ or $s_{k3} > 1/3$ for $j, k \neq i$.

Supervisor S_1^n exposes. For a sufficiently large probability of external exposure, therefore, lower-level supervisors externalize some of their exposure costs onto higher-level supervisors by covering up. By a similar reasoning, if $r \in (L_1/L_{n+1}, s/L_{n+1} \min_{i \in N} L_i/t_i^n)$ for any $i \in N$, at least one of Supervisors S_{i+1}^n through S_n^n is worse off than if Supervisor S_i^n exposes.[21]

4.2 Minimal and maximal coverup incentives

The next lemma presents polar allocations of responsibility among the supervisors for the hierarchy's internal and external loss from exposure for which a hierarchy has minimal and maximal incentives to cover up.

Lemma 2 (maximal and minimal coverup incentives)

The minimal probability of external exposure that unconditionally stems coverup ($s/L_{n+1} \min_{i \in N} L_i/t_i^n$) *attains–*

(1) a minimum value *under* semi-equal allocation *in which each supervisor is responsible for–*

(i) an equal share of the hierarchy's loss from his own exposure ($s = 1/n$)*; and*

(ii) a semi-equal share of the hierarchy's terminal loss of $\check{t}_i^n(i) = \mathbf{1}_{\{j \geq \check{\imath}\}} \frac{1}{n+1-\check{\imath}}$*, where* $\check{\imath} = \min_{i \in N}(n+1-i)L_i$*;*

(2) a maximum value *under* proportional allocation *in which each supervisor is responsible for–*

(i) the entire hierarchy's loss from his own exposure ($s = 1$)*; and*

(ii) a proportional share of the hierarchy's terminal loss of $\hat{t}_i^n(L_{1,\ldots,n}) = \frac{L_i}{\Sigma_{j=1}^n L_j}$.

Coverup incentives are *minimal* when one supervisor has the *smallest minimum* cost ratio of internal versus external exposure among all supervisors. If one or more supervisors' cost ratio of internal versus external exposure is greater than the smallest minimal cost ratio, coverup incentives can be increased by shifting responsibility for the hierarchy's terminal loss from the supervisor with the largest cost ratio to the supervisor with the smallest cost ratio. Now, given Assumption 1(1) ($s \geq \frac{1}{n}$), for one supervisor to bear the smallest responsibility share for his own internal exposure, all supervisors must share equal responsibility for the hierarchy's loss from internal exposure ($s = 1/n$). Plugging in $\frac{1}{n}$ into s, coverup incentives are minimized when $(L_i/n) \div (t_i^n L_{n+1})$—or, equivalently, L_i/t_i^n—obtains a minimum value. By Assumption 1(2) (t_i^n is weakly increasing in i), t_i^n obtains a maximum value when the highest $n+1-i$-level supervisors are solely and equally responsible for the hierarchy's terminal loss; each one of these supervisors must therefore be responsible for $\frac{1}{n+1-i}$ of the

[21] If supervisors' responsibility shares for another supervisor's internal exposure is weakly increasing in their rank except for the exposing supervisor ($s_{ij} > s_{ik}$ for $j > k \neq i$) then Supervisors S_1^n through S_j^n are better off and Supervisors S_j^n through S_n^n are worse off than if Supervisor S_1^n exposes, where $j \geq 1$.

hierarchy's terminal loss. Plugging in $\frac{1}{n+1-\breve{\imath}}$ into t_i^n, L_i/t_i^n, obtains a minimum value for $\breve{\imath} \in N$, where $\breve{\imath} = \arg\min_{\breve{\imath} \in N}(n+1-i)L_i$.

Coverup incentives in an n-layer hierarchy are *maximal* when each supervisor faces the *largest minimum* cost ratio of internal versus external exposure. If one supervisor has a higher cost ratio than any other supervisor's, the hierarchy's overall coverup incentives can be increased by shifting responsibility for the hierarchy's terminal loss from the supervisor with the smallest cost ratio to a supervisor with a higher cost ratio. To ensure that each supervisor is maximally responsible for the hierarchy's loss from internal exposure, each supervisor must be entirely responsible for the hierarchy's loss from his own internal exposure ($s = 1$). For supervisors' cost ratio of internal versus external exposure to be equal, each supervisor's responsibility share must be proportional to the hierarchy's loss from that supervisor's internal exposure and the hierarchy's loss from any other supervisor's internal exposure.

The next example illustrates Lemma 2 in a 2-layer hierarchy.

Example 1 (minimal and maximal coverup incentives: 2-layer hierachy)

Coverup incentives in a 2-layer hierarchy are:

(1) minimal for $s = 1/2$ *and*

(i) $(t_1^2, t_2^2) = (1/2, 1/2)$ *if* $\frac{L_1}{L_2} \leq 1/2$, *or*

(ii) $(t_1^2, t_2^2) = (0, 1)$ *if* $\frac{L_1}{L_2} > 1/2$; *and*

(2) maximal for $s = 1$ *and* $(t_1^2, t_2^2) = (\frac{L_1}{L_1+L_2}, \frac{L_2}{L_1+L_2})$.

Coverup incentives in a 2-layer hierarchy are minimal when (i) both supervisors equally share responsibility for the hierarchy's loss from internal exposure *and* (ii) (a) both supervisors equally share responsibility for the hierarchy's terminal loss if $L_1/L_2 \leq 1/2$ (if $L_1/L_2 \leq 1/2$, then $\breve{\imath}(2) = 1$ because $L_1/L_3 \leq L_2/(2L_3)$); *or* (b) the upper-level supervisor is entirely responsible for the hierarchy's terminal loss if $L_1/L_2 > 1/2$ (If $L_1/L_2 > 1/2$, then $\breve{\imath}(2) = 2$ because $L_1/L_3 > L_2/(2L_3)$). By contrast, coverup incentives in a 2-layer hierarchy are maximal when each supervisor is responsible for the entire hierarchy's loss from his internal exposure *and* for a fraction of the hierarchy's terminal loss proportional to the hierarchy's loss ratio from the supervisor's respective internal exposures.

4.3 Equilibrium outcomes

Recall from Lemma 2 that coverup incentives in an n-layer hierarchy are *minimized* under a semi-equal allocation of responsibility among the supervisors. Therefore, the *supremum* probability of external exposure that *facilitates* coverup in an n-layer hierarchy for *any*

allocation of responsibility among the supervisors is

$$\underline{r}_n(L_{1,...,n+1}) = \frac{1}{n}\frac{1}{\check{t}^n_{\check{i}}(\check{i})}\frac{L_{\check{i}(n)}}{L_{n+1}} = \frac{n+1-\check{i}}{n}\frac{L_{\check{i}(n)}}{L_{n+1}}, \tag{3}$$

where the second equality follows by substituting $\frac{1}{n+1-\check{i}}$ for $\check{t}^n_{\check{i}}(n, \Lambda_{1,...,n-1})$.

Coverup incentives in an n-layer hierarchy are *maximized* under a proportional allocation of responsibility among the supervisors. Therefore, the *minimum* probability of external exposure that *stems* coverup in an n-layer hierarchy for *any* allocation of responsibility among the supervisors is

$$\overline{r}_n(L_{1,...,n+1}) = \frac{1}{\hat{t}^n_i(L_{1,...,n})}\frac{L_i}{L_{n+1}} = \frac{\Sigma^n_{i=1}L_i}{L_{n+1}}, \tag{4}$$

where the second equality follows by substituting $\frac{L_i}{\Sigma^n_{i=1}L_i}$ for $\hat{t}^n_i(L_{i,...,n})$.

Definition 1 (conditional vs. unconditional exposure and coverup)

(a) A hierarchy unconditionally *exposes or covers up if the hierarchy exposes or covers up for* any *allocation of responsibility among the supervisors.*

(b) A hierarchy conditionally *covers up if the hierarchy covers up for a* subset *of allocations of responsibility among the supervisors.*

The next lemma presents necessary and sufficient conditions for an n-layer hierarchy to (i) unconditionally cover up; (ii) conditionally cover up; or (iii) unconditionally expose.

Lemma 3 (equilibrium outcomes)

In the unique subgame perfect equilibrium in an n-layer hierarchy:

(1) The hierarchy unconditionally covers up *if* $r \in (0, \underline{r}_n(L_{1,...,n+1})]$*;*

(2) the hierarchy conditionally covers up *if* $r \in (\underline{r}_n(L_{1,...,n+1}), \overline{r}_n(L_{1,...,n+1}))$*: there exist cutoffs* $\underline{s}_n(r, L_{1,...,n+1}) \equiv \frac{r}{\overline{r}_n(L_{1,...,n+1})}$ *and* $\overline{t}^n_i(r, s, L_i, L_{n+1}) \equiv \min\{\frac{s}{r}\frac{L_i}{L_{n+1}}, 1\}$ *for each* $i \in N$ *such that all supervisors cover up if and only if:*

(i) $s \in (\underline{s}(r, L_{1,...n+1}), 1]$ *and*

(ii) $(t^n_1, ..., t^n_n) \in [0, \overline{t}^n_1(r, s, L_1, L_{n+1})] \times ... \times [t^n_{n-1}, \overline{t}^n_n(r, s, L_n, L_{n+1})]$.

(3) the hierarchy unconditionally exposes *if* $r \in [\overline{r}_n(L_{1,...,n+1}), 1)$.

If the probability of external exposure is sufficiently small ($r \in (0, \underline{r}_n(\Lambda_{1,...,n}))$), the hierarchy covers up for any allocation of responsibility among the supervisors; the hierarchy thus *unconditionally* covers up. If the probability of external exposure is sufficiently large ($r \in [\overline{r}_n(L_{1,...,n+1}), 1]$), the hierarchy exposes for any allocation of responsibility among the supervisors; the hierarchy thus *unconditionally* exposes. If the probability of external exposure is intermediate ($r \in [\underline{r}_n(L_{1,...,n+1}), \overline{r}_n(L_{1,...,n+1}))$, the hierarchy may either cover up

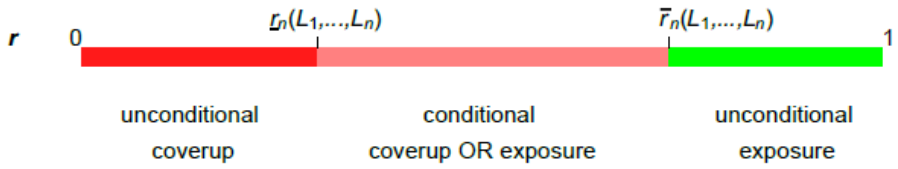


Figure 2: Equilibrium Outcomes

or expose, depending on the allocation of responsibility among the supervisors. The hierarchy *conditionally* covers up if $s/L_{n+1}\min_{i\in N} L_i/t_j^n < r$ for $i \in N$ such that, given that all his superiors cover up, each supervisor's cost ratio of internal versus external exposure is strictly less than r. Accordingly, each supervisor's responsibility share for his own internal exposure must be sufficiently high ($s > \underline{s}_n(r, L_{1,\ldots,n+1})$); and his terminal responsibility share sufficiently small ($t_i^n < \overline{t}_i^n(r, s, L_{1,\ldots,n})$). Note that a larger responsibility share of supervisors for the hierarchy's loss from internal exposure not only increases the range of probabilities of external exposure for which a hierarchy inspires coverup; it also expands the range of terminal responsibility shares for which a hierarchy does so. Figure 2 depicts the equilibrium outcomes in Lemma 3.

Lemma 4 (coverup equilibrium for $r \to 1$) *If* $\frac{L_n}{L_{n+1}} \in (0, \hat{t}_n^n(L_{1,\ldots,n}))$, *an* n*-layer hierarchy conditionally covers up for* $r \in [\underline{r}_n(L_{1,\ldots,n+1}), 1)$.

An n-layer hierarchy conditionally covers up for r arbitrarily close to 1 if each supervisor's cost ratio of internal versus external exposure under a proportional allocation of responsibility (the most conducive to coverup) is strictly greater than 1: $\frac{1}{\hat{t}_i^n(L_{1,\ldots,n})}\frac{L_i}{L_{n+1}} \geq 1$ for $i \in N$, where we substitute 1 for s and $\hat{t}_i^n(L_{1,\ldots,n})$ for $t_i^n(L_{1,\ldots,n})$ in $\frac{s}{t_i^n(L_{1,\ldots,n})}$. Because $\frac{L_i}{\hat{t}_i^n(L_{1,\ldots,n})} = \frac{L_j}{\hat{t}_i^n(L_{1,\ldots,n})}$ by definition of $\hat{t}_i^n(L_{1,\ldots,n})$, we may substitute n for i and rearrange to get $\frac{L_n}{L_{n+1}} \geq \hat{t}_n^n(L_{1,\ldots,n})$.

Interestingly, unlike a 1-layer hierarchy in which the minimum probability of external exposure that stems coverup is strictly less than 1, an n-layer hierarchy may conditionally cover up on the equilibrium path for any probability of external exposure if the hierarchy's terminal loss is smaller than the sum of its n losses from internal exposure; i.e., $L_{n+1} < \Sigma_{i=1}^n L_i$. This follows because, by Lemma 2, coverup incentives are maximal for $s = 1$ and $t_i = \frac{L_i}{\Sigma_{i=1}^n}$ for $i \in N$ such that a supervisor's cost ratio of internal versus external exposure is $L_i/(\frac{L_i}{\Sigma_{i=1}^n}L_{n+1}) = \frac{\Sigma_{i=1}^n}{L_{n+1}}$. If $L_{n+1} < \Sigma_{i=1}^n L_i$, each supervisor's cost ratio of internal versus external exposure is (strictly) larger than 1. Given that all his superiors cover up for $r \to 1$, each supervisor would rather cover up than expose. The hierarchy therefore covers up for any probability of external exposure.

The fact that a hierarchy may conditionally cover up for any probability of external

exposure helps to explain cases in which organizational wrongdoing is blatantly obvious from the start yet no hierarchy's official is willing to internally expose it. As Katz (1979) notes, "[I]nsiders to cover-ups of [various wrongdoings] have reason to hope that the cover might never be blown. But they also anticipate that it might" (p. 297). Asymmetrical allocation of responsibility among supervisors for internal versus external exposure coupled with a sufficiently bounded loss ratio from exposure could result in full-scale coverup against the hierarchy's private (ex post) interest.

5 Comparison of coverup incentives

5.1 n- versus $n+1$-layer hierarchy

In this section, we compare coverup incentives in hierarchies of different depths: n- versus $n+1$-layer hierarchies. Our purpose is to explain the persistence and duration of coverups in multi-layered hierarchies by understanding under what conditions are deeper hierarchies more conducive to coverup than shallower hierarchies.

Underlying this comparison exercise between hierarchies of different depths is the assumption that a hierarchy's loss from each of the first $n+1$ exposures is identical between hierarchies. This assumption is innocuous for the first n exposure losses because these are losses from internal exposure in both hierarchies. The $n+1$-th exposure loss, however, stems from external exposure in the case of an n-layer hierarchy and internal exposure in the the case of an $n+1$-layer hierarchy. Since by internally exposing wrongdoing the hierarchy actively and officially takes responsibility for failing to prevent wrongdoing and coverups, it stands to reason that the $n+1$-th loss from exposure should be larger in an n-layer hierarchy's than in an $n+1$-layer hierarchy—as the former stems from external exposure whereas the latter from internal exposure. Because coverup incentives decrease with the hierarchy's loss from exposure, however, relaxing this assumption would expand the range of circumstances in which an $n+1$-layer hierarchy is more conducive to coverup than an n-layer hierarchy.

Relaxing the assumption that the $n+1$-th loss from exposures is identical between hierarchies means increasing that loss in an n-layer hierarchy while holding it fixed in an $n+1$-layer hierarchy. The result that the $n+1$-layer hierarchy inspires coverup incentives would therefore be stronger if the $n+1$-th exposure loss vary between the two hierarchies. Thus, besides serving as a tractable first-order benchmark for studying relative coverup incentives in hierarchies of different depth, the assumption that the $n+1$-th loss from exposure is identical between the shallow and deep hierarchy preserves the integrity of the paper's main ideas.

Before proceeding, let

$$\overline{r}^{\min}_{n+1/n}(L_{1,\ldots,n+2}) = \min\{\overline{r}_n(L_{1,\ldots,n+1}), \overline{r}_{n+1}(L_{1,\ldots,n+2})\}$$

and

$$\overline{r}^{\max}_{n+1/n}(L_{1,\ldots,n+2}) = \max\{\overline{r}_n(L_{1,\ldots,n+1}), \overline{r}_{n+1}(L_{1,\ldots,n+2})\}$$

with a corresponding definition for $\underline{r}^{\min}_{n+1/n}(L_{1,\ldots,n+2})$ and $\underline{r}^{\max}_{n+1/n}(L_{1,\ldots,n+2})$ (from here on we shall suppress the arguments $L_{1,\ldots,}L_{n+2}$). Thus, $\overline{r}^{\min}_{n+1/n}$ and $\overline{r}^{\max}_{n+1/n}$ are the minimum and maximum of the minimum probability of external exposure that stems conditional coverup in an n- and $n+1$-layer hierarchies; whereas $\underline{r}^{\min}_{n+1/n}$ and $\underline{r}^{\max}_{n+1/n}$ are the minimum and maximum of the supremum probability of external exposure that facilitates unconditional coverup in an n-layer and $n+1$-layer hierarchies. To simplify the analysis, we shall assume that the probability of external exposure is such that one hierarchy unconditionally exposes whereas the other conditionally covers up, as reflected in the following assumption. In Supplementary Appendix A1, we show that a similar trade-off underlies the comparison of coverup incentives when one hierarchy conditionally covers up and the other unconditionally cover up. In Supplementary Appendix A2, we consider the case in which both hierarchies conditionally cover up.[22]

Assumption 2 *One hierarchy unconditionally exposes and the other conditionally covers up:* $r \in (\overline{r}^{\min}_{n+1/n}, \overline{r}^{\max}_{n+1/n})$.

If the probability of external exposure is sufficiently *small* ($r < \underline{r}^{\min}_{n+1/n}$), both an n-layer hierarchy and an $n+1$-layer hierarchy unconditionally cover up. If the probability of external exposure is sufficiently *large* ($r \geq \overline{r}^{\max}_{n+1/n}$), by contrast, both an n-layer hierarchy and an $n+1$-layer hierarchy unconditionally expose. For *intermediate low* range of the probability of external exposure ($r \in (\underline{r}^{\min}_{n+1/n}, \underline{r}^{\max}_{n+1/n})$), one hierarchy unconditionally covers up whereas the other conditionally covers up (we take this case up in an online appendix). For *intermediate middle* range of the probability of external exposure ($r \in (\underline{r}^{\max}_{n+1/n}, \overline{r}^{\min}_{n+1/n})$), both hierarchies conditionally cover up. To focus our analysis, we restrict attention to the case in which one hierarchy unconditionally exposes whereas the other conditionally covers up. This is the case in which the range of the external probability of external exposure is *intermediate high* ($r \in (\overline{r}^{\min}_{n+1/n}, \overline{r}^{\max}_{n+1/n})$).Figure 3 presents the equilibrium outcomes for different ranges of the probability of external exposure.[23]

[22] More specifically, we show that for $\overline{t}^n_i, \overline{t}^{n+1}_i < 1$ comparison of coverup incentives in the case in which one hierarchy unconditionally exposes and the other conditionally covers up also implies comparison of coverup incentives in the case in which both hierarchies conchoidally coverup up.

[23] To see why $\overline{r}^{\min}_{n+1/n} > \underline{r}^{\max}_{n+1/n}$, note that if $\overline{r}^{\max}_{n+1/n} = \overline{r}_{n+1}$ then $\overline{r}_{n+1} = \frac{\Sigma^{n+1}_{i=1} L_i}{L_{n+2}} > \frac{\Sigma^{n}_{i=1} L_i}{L_{n+1}} > \frac{n+\check{\imath}(n)-1}{n} \frac{L_{\check{\imath}(n)}}{L_{n+1}} = \underline{r}_n$; and that if $\overline{r}^{\max}_{n+1/n} = \overline{r}_n$ then $\overline{r}_n = \frac{\Sigma^{n}_{i=1} L_i}{L_{n+1}} > \frac{\Sigma^{n+1}_{i=1} L_i}{L_{n+2}} > \frac{n+\check{\imath}(n+1)}{n+1} \frac{L_{\check{\imath}(n+1)}}{L_{n+1}} = \underline{r}_{n+1}$.

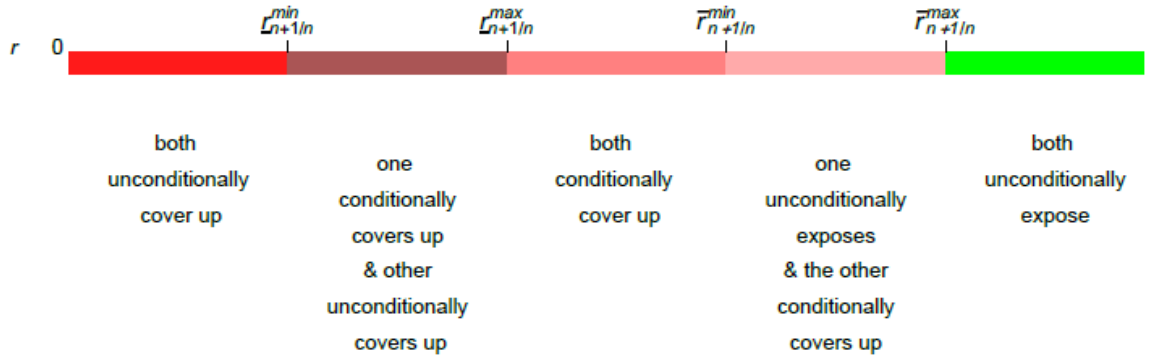


Figure 3: Equilibrium Outcomes in n- versus $n+1$-layer Hierarchy

Definition 2 (relative coverup incentives) *Relative to an n-layer hierarchy, an $n+1$-layer hierarchy–*

(1) unconditionally suppresses *coverup incentives if the $n+1$-layer hierarchy* unconditionally *exposes whereas the n-layer hierarchy* conditionally *covers up; and*

(2) conditionally inspires *coverup incentives if the $n+1$-layer hierarchy* conditionally *covers up whereas the n-layer hierarchy* unconditionally *exposes.*

The following proposition presents conditions under which an $n+1$-layer hierarchy either unconditionally weakens or conditionally inspires coverup incentives relative to an n-layer hierarchy as a function of the hierarchies' exposure losses and the probability of external exposure. For ease of exposition, we suppress the arguments of $\hat{t}^k_i(L_{1,\dots,k})$ and $\overline{r}_k(L_{1,\dots,k+1})$ for $k = n, n+1$.

Proposition 1 (coverup incentives in n- versus $n+1$-layer hierarchy)

(1) If $L_{n+1}/L_{n+2} \in (0, \min\{\Sigma_{i=1}^n \hat{t}_i^{n+1}, \hat{t}_{n+1}^{n+1}\})$, an $n+1$-layer hierarchy unconditionally weakens coverup incentives relative to an $n+1$-layer hierarchy for $r \in [\overline{r}_{n+1}, \min\{\overline{r}_n, 1\})$; and

(2) If $L_{n+1}/L_{n+2} \in (\Sigma_{i=1}^n \hat{t}_i^{n+1}, 1)$ and $L_n/L_{n+1} \in (0, \hat{t}_n^n)$, an $n+1$-layer hierarchy conditionally inspires coverup incentives relative to an $n+1$-layer hierarchy for $r \in [\overline{r}_n, \min\{\overline{r}_{n+1}, 1\})$.

Proposition 1 generalizes Proposition 0 to any number of hierarchy layers. From Lemma 3, the minimum probabilities of external exposure that unconditionally stem coverup in n- and $n+1$-layer hierarchies are, respectively, $\overline{r}_n(L_{1,\dots,n+1}) = \frac{1}{\hat{t}_i^n}\frac{L_i}{L_{n+1}}$ and $\overline{r}_{n+1}(L_{1,\dots,n+2}) \equiv \frac{1}{\hat{t}_i^{n+1}}\frac{L_i}{L_{n+2}}$. Adding a hierarchy layer to an n-layer hierarchy accordingly produces a twofold effect on coverup incentives. On the one hand, an additional hierarchy layer *increases* the hierarchy's *terminal loss* by L_{n+2}/L_{n+1}, which weakens coverup incentives (terminal-loss effect). On the other hand, an additional hierarchy layer *reduces* each supervisor's terminal

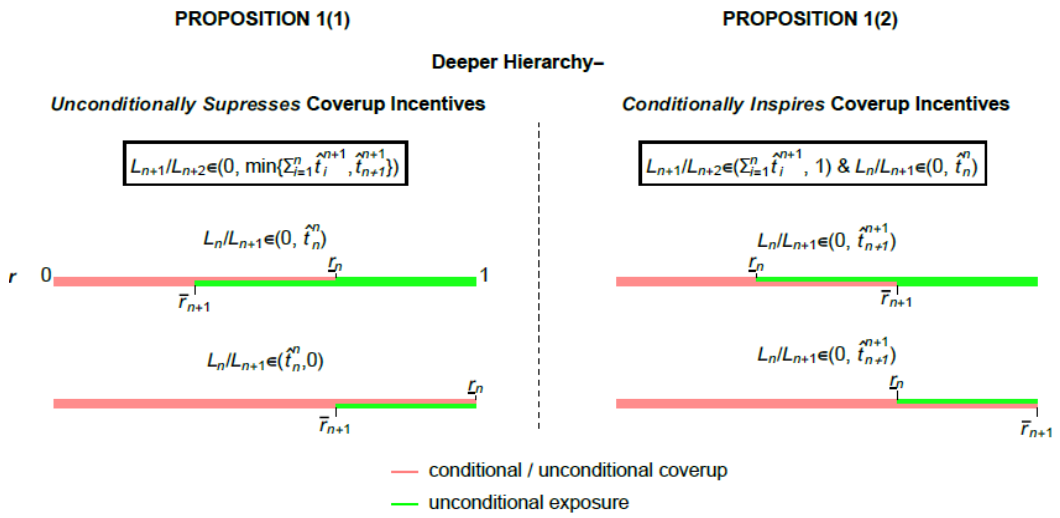


Figure 4: Comparison of Coverup Incentives. The *left panel* presents the case in which an $n+1$-layer hiearchy supresses coverup incentives relative to an n-layer hiearchy as a function of the hiearchy's exposure losses; The *right panel* presents the opposite case in which an $n+1$-layer hiearchy inspires coverup incentives relative to an n-layer hiearchy.

proportional responsibility share by $\hat{t}_i^{n+1}/\hat{t}_i^n \equiv \Sigma_{i=1}^n L_i/\Sigma_{i=1}^{n+1} L_i = \Sigma_{i=1}^n \hat{t}_i^{n+1}$, which intensifies coverup incentives (responsibility-diffusion effect). The net effect on relative coverup incentives depends on the relation between the terminal-loss and responsibility-diffusion effects.

If the terminal loss effect outweighs the responsibility-diffusion effect ($L_{n+1}/L_{n+2} < \Sigma_{i=1}^n \hat{t}_i^{n+1}$) and the deeper hierarchy does not conditionally cover up for $r \to 1$ ($L_{n+1}/L_{n+2} < \hat{t}_{n+1}^{n+1}$), the minimum probability of external exposure that unconditionally stems coverup is larger in an n-layer hierarchy than in an $n+1$-layer hierarchy. The shallower hierarchy thus conditionally covers up whereas the deeper hierarchy exposes for $r \in [\overline{r}_{n+1}, \min\{\overline{r}_n, 1\})$ (Part 1). By contrast, if the responsibility-diffusion effect outweighs the terminal loss effect ($L_{n+1}/L_{n+2} > \Sigma_{i=1}^n \hat{t}_i^{n+1}$) and the shallower hierarchy does not conditionally cover up for $r \to 1$ ($L_n/L_{n+1} < \hat{t}_n^n$), the minimum probability of external exposure that unconditionally stems coverup is larger in an $n+1$-layer hierarchy than in an n-layer hierarchy. The deeper hierarchy thus conditionally covers up whereas the shallower hierarchy exposes for $r \in [\overline{r}_n, \min\{\overline{r}_{n+1}, 1\})$ (Part 2).

If the responsibility-diffusion effect is sufficiently larger than the terminal loss effect ($L_{n+1}/L_{n+2} > \max\{\hat{t}_{n+1}^{n+1}, \Sigma_{i=1}^n \hat{t}_i^{n+1}\}$ and $L_n/L_{n+1} < \hat{t}_n^n$), not only does an $n+1$-layer hierarchy conditionally inspires coverup incentives relative to an n-layer hierarchy, but it conditionally covers up for $r \in [\overline{r}_n(L_{1,\ldots,n+1}), 1)$. The cost ratio of internal versus external exposure of one or more supervisors of the n-layer hierarchy under a proportional allocation of responsibility is strictly less than 1, whereas the corresponding cost ratio of internal versus external exposure of *all* the supervisors of the $n+1$-layer hierarchy is weakly greater than 1.

5.2 2- versus 3-layer hierarchy

To illustrate Proposition 1, consider coverup incentives in a 2- versus 3-layer hierarchy. Adding a hierarchy layer to a 2-layer hierarchy *increases* the hierarchy's terminal loss by $\frac{L_4}{L_3}$; and *reduces* Supervisor S_i^3's terminal proportional responsibility share by $\frac{\hat{t}_i^3(L_{1,2,3})}{\hat{t}_i^2(L_{1,2})} = \frac{L_1+L_2}{L_1+L_2+L_3}$ for $i = 1, 2$. If

$$\frac{L_3}{L_4} < \min\{\overbrace{\frac{L_1+L_2}{L_1+L_2+L_2}}^{\hat{t}_1^3(L_{1,2,3})\ +\ \hat{t}_2^3(L_{1,2,3})}, \overbrace{\frac{L_3}{L_1+L_2+L_3}}^{\hat{t}_3^3(L_{1,2})}\} \tag{5}$$

a 3-layer hierarchy unconditionally weakens coverup incentives relative to a 2-layer hierarchy: if $r \in (\frac{L_1+L_2+L_3}{L_4}, \min\{\frac{L_1+L_2}{L_3}, 1\})$, a 3-layer hierarchy exposes whereas a 2-layer hierarchy conditionally covers up (subspaces *A1+A2* in Figure 4; Proposition 1(1)).

By contrast, if

$$\overbrace{\frac{L_3}{L_1+L_2+L_3}}^{\hat{t}_3^3(L_{1,2})} > \frac{L_3}{L_4} > \overbrace{\frac{L_1+L_2}{L_1+L_2+L_3}}^{\hat{t}_1^3(L_{1,2,3})\ +\ \hat{t}_2^3(L_{1,2,3})} \text{ and } \frac{L_2}{L_3} < \overbrace{\frac{L_2}{L_1+L_2}}^{\hat{t}_2^2(L_{1,2})} \tag{6}$$

a 3-layer hierarchy therefore conditionally inspires coverup incentives relative to a 2-layer hierarchy: if $r \in (\frac{L_1+L_2}{L_3}, \min\{\frac{L_1+L_2+L_3}{L_4}, 1\})$, a 2-layer hierarchy exposes whereas a 3-layer hierarchy conditionally covers up (subspaces *B1+B2* in Figure 4; Proposition 1(2)).

Finally, if

$$\frac{L_2}{L_3} > \overbrace{\frac{L_2}{L_1+L_2}}^{\hat{t}_2^2(L_{1,2})} \text{ and } \frac{L_3}{L_4} > \overbrace{\frac{L_3}{L_1+L_2+L_3}}^{\hat{t}_3^3(L_{1,2,3})} \tag{7}$$

($L_3 < L_1 + L_2$ and $L_4 < L_1 + L_2 + L_3$, respectively), both a 2-layer hierarchy and a 3-layer hierarchy conditionally covers up for $r = 1$ (subspace C in Figure 5). Figure 5 provides a graphical representation of the comparison between a 2-layer and 3-layer hierarchies.

Figure 5 marks two $(\Lambda_1, \Lambda_2, \Lambda_3)$-curves along which 2- and 3-layer hierarchies produce equally-strong coverup incentives. The curve $(\Lambda_1, \hat{t}_1^2(\Lambda_1), \hat{t}_1^2(\Lambda_1))$ stretches from the origin to $(1, 1/2, 1/2)$ (marked in red) represents the case where both the hierarchy's loss ratio of highest-level and external exposure and the hierarchy head's proportional responsibility share are identical in a 2-layer and a 3-layer hierarchy.[24] The curve $(\Lambda_1, \hat{t}_2^2(\Lambda_1), 1/2)$ stretches from $(0, 1/2, 1/2)$ to $(1, 1/2, 1/2)$ (marked in black) represents an additive overall loss (see Case 1 below). Both hierarchies' coverup incentives along each curve are identical either because in both cases the terminal-loss effect exactly offset the responsibility-diffusion effect.

[24] To see that, observe that $\hat{t}_1^2(\Lambda_1) = \frac{\Lambda_1}{1+\Lambda_1}$, $\hat{t}_2^2(\Lambda_1) = \frac{1}{1+\Lambda_1}$ and $\hat{t}_3^3(\Lambda_1, \Lambda_2) = \frac{1}{(1+\Lambda_1)\Lambda_2+1}$. It follows that $(1+\Lambda_1)\hat{t}_1^2(\Lambda_1) = \Lambda_1$ and therefore that $\hat{t}_3^3(\Lambda_1, \hat{t}_1^2(\Lambda_1)) = \hat{t}_2^2(\Lambda_1)$.

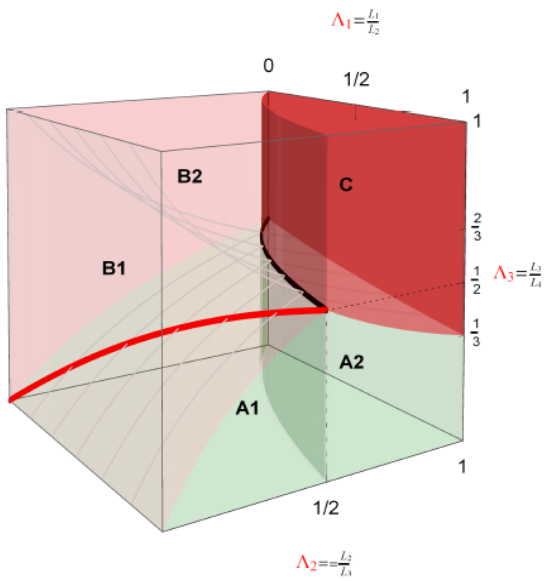


Figure 5: Coverup Incentives in 2- versus 3-layer Hierarchy. In region A1∪ A2, a 3-layer hierarchy suppresses coverup incentives relative to a 2-layer hierarchy, where in region A2 a 2-layer hiearchy conditionally covers up for $r \to 1$. In region B1∪ B2, a 3-layer hierarchy inspires coverup incentives relative to a 2-layer hierarchy, where in region B2 a 3-layer hiearchy conditinally covers up for $r \to 1$. Finally, in region C both hierarchies conditionally cover up for $r \to 1$.

5.3 Additive loss, increasing loss ratios, and geometric loss

To concretize the previous discussion, we consider three special cases of a hierarchy's overall loss function.

Case 1 (additive overall loss) *If* $L_i = \Sigma_{j=1}^{i-1} L_j$ *for* $i = 3, ..., n$, *then* $\overline{r}_n(L_{1,...,n+1}) = 1$ *for* $n \geq 2$.

If the hierarchy's overall exposure loss is additive, each hierarchy irrespective of its depth conditionally covers up for $r \to 1$. To see why, observe that adding a hierarchy layer to a 2-layer hierarchy *increases* the hierarchy's terminal loss by $\frac{L_4}{L_3} > 1$; and *decreases* Supervisor S_i^3's terminal proportional responsibility share by $\frac{\hat{t}_i^3(L_{1,2,3})}{\hat{t}_i^2(L_{1,2})} = \frac{L_i}{L_1+L_2+L_3} \div \frac{L_i}{L_1+L_2} = \frac{L_1+L_2}{L_1+L_2+L_3} = \frac{L_3}{L_4} < 1$ for $i = 1, 2$. The coverup-suppressing terminal-loss effect thus exactly offsets the coverup-inspiring responsibility-diffusion effect. For a hierarchy of 3 or more layers, the hierarchy's terminal loss increases twofold with each additional hierarchy layer, whereas each supervisor's terminal proportional responsibility share decreases by half; the former because $\frac{L_n}{L_{n+1}} = \frac{L_n}{L_1+...+L_n} = \frac{L_n}{2L_n}$; the latter because $L_n = \Sigma_{i=1}^{n-1} L_i$ implies $\frac{L_i}{\Sigma_{i=1}^{n} L_i} \div \frac{L_i}{\Sigma_{i=1}^{n+1} L_i} = 1/2$. Therefore, if an n-layer hierarchy's overall loss is additive and an $n+1$-layer hierarchy's overall loss is infra-additive, there exists responsibility allocations for which an $n+1$-layer conditionally covers up whereas an n-layer hierarchy unconditionally exposes.

Definition 3 *Let* $\Lambda_i \equiv L_i/L_{i+1} \in (0,1)$ *denote the hierarchy's* loss ratio *of internal exposure in period* i *and internal or external exposure in period* $i+1$.

We turn now to a more general special case, where the hierarchy's loss ratios of consecutive exposures is increasing in n.

Case 2 (increasing loss ratios) *If* Λ_i *is weakly increasing in* i*, then* $\overline{r}_n(L_{1,\ldots,n+1})$ *is increasing in* n.

If the hierarchy's loss ratio of successive exposures is increasing in n, a deeper hierarchy produces stronger coverup incentives than a shallower hierarchy. Consider the case of 1- versus 2-layer hierarchy. Observe that $L_1/L_2 > L_1/(L_1+L_2) = \hat{t}_1^2(L_{1,2})$. Therefore, if $L_2/L_3 \geq L_1/L_2$ then $L_2/L_3 > \hat{t}_1^2(L_{1,2})$, which by Proposition 1(2) implies that $\overline{r}_2(L_{1,2,3}) > \overline{r}_1(L_{1,2})$. More generally, $\frac{L_n}{L_{n+1}} > \frac{L_1+\ldots+L_n}{L_1+\ldots+L_{n+1}} = \Sigma_{i=1}^n \hat{t}_i^{n+1}(L_{1,\ldots,n+1})$. It follows that if $\frac{L_{n+1}}{L_{n+2}} \geq \frac{L_n}{L_{n+1}}$ then $\frac{L_{n+1}}{L_{n+2}} > \Sigma_{i=1}^n \hat{t}_i^{n+1}(L_{1,\ldots,n+1})$. By Proposition 1(2), therefore, $\overline{r}_{n+1}(L_{1,\ldots,n+2}) > \overline{r}_n(L_{1,\ldots,n+1})$. From the previous argument it then follows that if $\frac{L_i}{L_{i+1}}$ is increasing in i, then $\overline{r}_j(L_{1,\ldots,j+1}) > \overline{r}_k(L_{1,\ldots,k+1})$ for $j > k$. Intuitively, if the hierarchy's loss ratios of successive exposures is increasing in n, the responsibility-diffusion effect intensifies with n whereas the terminal-loss effect wanes with n. Coverup incentives consequently increase with the number of hierarchy layers.

The last case is the limiting case of a hierarchy with increasing loss ratios.

Case 3 (geometric overall loss) *If* $\Lambda_i = \Lambda$ *for* $i \in N$*, then* $\overline{r}_n(\Lambda_{1,\ldots,n}) = \frac{\Lambda(1-\Lambda^n)}{1-\Lambda}$ *is increasing in* n.

If the hierarchy's overall loss is geometric, the hierarchy head's terminal proportional responsibility share is $\hat{t}_n^n(\Lambda_{1,\ldots,n-1}) = \frac{1}{\Sigma_{i=1}^n \Pi_{j=i}^{n-1}\Lambda_j}$. To see why, note that $\hat{t}_n^n(L_{1,\ldots,n}) = \frac{L_n}{\Sigma_{i=1}^n L_i} = \frac{1}{(\Sigma_{i=1}^n L_i)/L_n}$, where the denominator can be written as $\frac{L_1}{L_n} + \ldots + \frac{L_n}{L_n} = \Sigma_{i=1}^n \Pi_{j=i}^{n-1}\Lambda_j$.[25] Now, if $\Lambda_i = \Lambda$ for $i \in N$, then $\hat{t}_n^n(\Lambda) = \frac{1}{\Sigma_{i=1}^n \Pi_{j=i}^{n-1}\Lambda} = \frac{1}{\Lambda^{n-1}+\Lambda^{n-2}\ldots+1} = \frac{1-\Lambda}{1-\Lambda^n}$. The minimum probability of external exposure that unconditionally stems coverup is accordingly $\overline{r}_n(\Lambda) = \frac{\Lambda}{\hat{t}_n^n(\Lambda)} = \frac{\Lambda(1-\Lambda^n)}{1-\Lambda}$, which is increasing in n and is strictly greater than 1 for a sufficiently large Λ. The minimum value of Λ for which an n-layer hierarchy conditionally covers up for any probability of external exposure rapidly decreases with n, converging to ½ as n becomes increasingly large.

As an example, consider coverup incentives in 1- versus 2-layer hierarchy. Whereas a 1-layer hierarchy exposes for $r \in (\Lambda, 1]$, a 2-layer hierarchy conditionally covers up for $r \in (\Lambda, \min\{\Lambda+\Lambda^2, 1\}]$ (because $\overline{r}_2 = \frac{L_1+L_2}{L_3} = \Lambda+\Lambda^2$). Now, $\Lambda+\Lambda^2 \leq 1$ if and only if $\Lambda \in (0, \hat{\Lambda})$, where $\hat{\Lambda} \equiv \frac{\sqrt{5}-1}{2} \approx 0.62$. For $\Lambda > \hat{\Lambda}$, therefore, $\overline{r}_2(\Lambda) > 1$: both supervisors of a

[25] For example, if $n=2$ then $\hat{t}_2^2(\Lambda_1) = \frac{1}{\Lambda_1+1} = \frac{L_2}{L_1+L_2}$, whereas if $n=3$ then $\hat{t}_3^3(\Lambda_1,\Lambda_2) = \frac{1}{\Lambda_1\Lambda_2+\Lambda_2+1} = \frac{L_3}{L_1+L_2+L_3}$.

2-layer hierarchy conditionally cover up even if the coverup is certain to be exposed ($r = 1$) provided each supervisor's responsibility share for his internal exposure is sufficiently large ($s \in (\frac{1}{(1+\Lambda)\Lambda}, 1]$); and no supervisor's terminal responsibility share significantly outweighs the other's ($(t_1^2, t_2^2) \in (0, \Lambda^2 s) \times (0, \Lambda s)$)).[26]

6 Comparative statics

To get further insight into the comparison between hierarchies of different depths, we consider the effect of a change in the hierarchy's loss ratio $\Lambda_1, ..., \Lambda_{n+1}$ on relative coverup incentives in a shallower versus deeper hierarchies. The reason we consider the hierarchy's loss ratios rather than the hierarchy's absolute losses is that it is the changes in the hierarchy's loss ratios that shape supervisors' relative coverup incentives. We restrict our analysis to the case in which $\overline{r}^{\max}_{n+1/n}(L_{1,...,n+2}) < 1$ so that both n-layer and $n+1$-layer hierarchies expose for $r \to 1$.

Note that the *ratio* of the minimum probabilities of external exposure that unconditionally stem coverup in an $n+1$-layer hierarchy and in an n-layer hierarchy can be written as

$$\frac{\overline{r}_{n+1}(\Lambda_{1,...,n+1})}{\overline{r}_n(\Lambda_{1,...,n})} = \overbrace{\frac{\hat{t}_i^n(\Lambda_{1,...,n-1})}{\hat{t}_i^{n+1}(\Lambda_{1,...,n})}}^{\text{dilution of responsibility effect}} \times \overbrace{\Lambda_{n+1}}^{\text{terminal loss effect}}$$
$$\equiv \overline{r}^{\div}_{n+1/n}(\Lambda_{1,...,n+1}), \tag{8}$$

where $i = 1, ..., n$. The first factor is the ratio of Supervisor S_i^n's terminal proportional responsibility share in an n-layer and an $n+1$-layer hierarchy; the second factor is the ratio of an n-layer hierarchy's and $n+1$-layer hierarchy's terminal losses.[27]

Proposition 2 (effect of Λ_n and Λ_{n+1} on $\overline{r}_{n+1}(\Lambda_{1,...,n+1}) \div \overline{r}_n(\Lambda_{1,...,n})$)

As Λ_{n+1} increases or as Λ_n decreases, the ratio *between the minimum probabilities of external exposure that unconditionally stem coverup in an $n+1$-layer hierarchy and in an n-layer hierarchy increases: $\frac{\partial}{\partial \Lambda_{n+1}} \overline{r}^{\div}_{n+1/n}(\Lambda_{1,...,n+1}) > 0$ and $\frac{\partial}{\partial \Lambda_n} \overline{r}^{\div}_{n+1/n}(\Lambda_{1,...,n+1}) < 0$.*

An increase in Λ_{n+1} increases the ratio between the shallower and deeper hierarchies' terminal loss. Such an increase, however, has no effect on the terminal proportional responsibility shares of the n-layer hierarchy's supervisors (which depend on $\Lambda_1 ..., \Lambda_n$). It follows

[26] Consider, for example, the case of $\Lambda = 2/3$, where $\widehat{t}_1^2 = 2/5$ and $\widehat{t}_2^2 = 3/5$. Because $\overline{r}_2(\Lambda) = \frac{\Lambda}{\widehat{t}_2^2(\Lambda)} = 10/9$, the infimum value of s under which both supervisors' cover up for $r = 1$ is $9/10$. For $s > 9/10$ and $(t_1^2, t_2^2) \in (0, 4/9s) \times (0, 2/3s)$, the upper-level supervisor covers up for any $r \in (0, 1]$ because $r_2^2(s, t_2^2, \Lambda) > 1$. Given that the upper-level supervisor covers up, the lower-level supervisor covers up for any $r \in (0, 1]$ too because $r_1^2(s, t_1^2, \Lambda) > 1$.

[27] Because $\hat{t}_{n+1}^{n+1}(\Lambda_{1,...,n}) \equiv \frac{L_{n+1}}{\Sigma_{i=1}^{n+1} L_i}$ and $\Lambda_n \equiv \frac{L_n}{L_{n+1}}$, $\hat{t}_{n+1}^{n+1}(\Lambda_{1,...,n})\Lambda_n = \frac{L_{n+1}}{\Sigma_{i=1}^{n+1} L_i} \equiv \hat{t}_n^n(\Lambda_{1,...,n})$.

that as Λ_{n+1} increases, the minimum probability of external exposure that unconditionally stems coverup (i) increases in an $n+1$-layer hierarchy; and (ii) remains unchanged in an n-layer hierarchy. Therefore, the ratio between the minimum probabilities of external exposure that unconditionally stem coverup in an $n+1$-layer hierarchy and in an n-layer hierarchy increases with Λ_{n+1}.

The effect of an increase in Λ_n on relative coverup incentives is opposite. A decrease in Λ_n leaves unchanged the ratio between the shallower and deeper hierarchies' terminal losses as well as the terminal proportional responsibility shares of supervisors of the n-layer hierarchy. To see why, recall that Supervisor S_i^n's terminal proportional responsibility share is $\frac{L_i}{\Sigma_{i=1}^n L_i}$. But $L_i = \Pi_{j=i}^{n-1}\Lambda_j$ and $\Sigma_{i=1}^n L_i = \Sigma_{i=1}^n \Pi_{j=i}^{n-1}\Lambda_j$ and therefore $\frac{L_i}{\Sigma_{i=1}^n L_i} = \frac{\Pi_{j=i}^{n-1}\Lambda_j}{\Sigma_{i=1}^n \Pi_{j=i}^{n-1}\Lambda_j}$ is a function of $\Lambda_1, ..., \Lambda_{n-1}$. Such a decrease, however, decreases the corresponding proportional responsibility shares of supervisors of the $n+1$-layer hierarchy (which is increasing in Λ_n). Because a decrease in Λ_n *increases* the ratio of supervisors' terminal proportional responsibility shares in an $n+1$-layer versus n-layer hierarchy, it increases the ratio of the minimum probabilities of external exposure that unconditionally stems coverup in the respective hierarchies.

The next proposition considers the effect of a change in $\Lambda_1, ..., \Lambda_{n-1}$ on the difference between the minimum probability of external exposure that unconditionally stems coverup in a deeper and shallower hierarchy, which difference is given by

$$\begin{aligned} \overline{r}_{n+1}(\Lambda_{1,...,n+1}) - \overline{r}_n(\Lambda_{1,...,n}) &= \frac{L_i}{\hat{t}_i^{n+1}(\Lambda_{1,...,n})L_{n+2}} - \frac{L_i}{\hat{t}_i^{n}(\Lambda_{1,...,n})L_{n+1}} \\ &\equiv \overline{r}^-_{n+1/n}(\Lambda_{1,...,n}). \end{aligned} \tag{9}$$

for $i = 1, ..., n$.

Proposition 3 (effect of $\Lambda_1, ..., \Lambda_{n-1}$ on $\overline{r}_{n+1}(\Lambda_{1,...,n+1}) - \overline{r}_n(\Lambda_{1,...,n})$)

As $\Lambda_1, ..., \Lambda_{n-1}$ decreases, the difference *between the minimum probabilities of external exposure that unconditionally stem coverup in an $n+1$-layer hierarchy and in an n-layer hierarchy increases: $\frac{\partial}{\partial \Lambda_i}[\overline{r}^-_{n+1/n}(\Lambda_{1,...,n+1})] > 0$ for $\Lambda_i = \Lambda_1, ..., \Lambda_{n-1}$.*

A decrease in $\Lambda_1, ..., \Lambda_{n-1}$ reduces the minimum probability of external exposure that unconditionally stems coverup in both an $n+1$-layer and n-layer hierarchy. Such a decrease, however, leaves unchanged the ratio of the hierarchies' terminal loss. The effect of a decrease in $\Lambda_1, ..., \Lambda_{n-1}$ on relative coverup incentives therefore depends on the corresponding *negative* effect of such a decrease on the n-layer hierarchy supervisors' proportional responsibility share for their hierarchy's terminal loss with an additional hierarchy level.

Because the decrease in $\hat{t}_i^{n+1}(\Lambda_{1,...,n})$ is steeper than the decrease in $\hat{t}_i^{n}(\Lambda_{1,...,n-1})$, the responsibility-diffusion effect intensifies relative coverup incentives in an $n+1$-layer hierar-

chy relative to an n-layer hierarchy. As a result, the *marginal* decrease in the minimum probability of external exposure that unconditionally stems coverup in an $n+1$-layer hierarchy is smaller than the corresponding decrease in an n-layer hierarchy. A decrease in $\Lambda_1, ..., \Lambda_{n-1}$ therefore increases the *difference* (although not the ratio) between the minimum probability of external exposure that unconditionally stems coverup in a deeper versus a shallower hierarchy.

Propositions 2 and 3 shed light on the shape of the plane that separates the subspaces $A1$ and $B1$ in Figure 5 (in the remaining subspaces, one or two hierarchies cover up for $r \to 1$). In the lower subspace ($A1$), a 2-layer hierarchy inspires coverup incentives relative to a 3-layer hierarchy; whereas in the upper subspace ($B1$), a 3-layer hierarchy inspires coverup incentives relative to a 2-layer hierarchy. Whereas an increase in Λ_3 increases the (Λ_1, Λ_2) plane in which a 3-layer hierarchy inspires coverup incentives relative to a 2-layer hierarchy, an increase in either Λ_1 or Λ_2 shrinks the (Λ_2, Λ_3) and (Λ_1, Λ_3) planes (respectively) in which a 3-layer hierarchy inspires coverup incentives relative to a 2-layer hierarchy. As Figure 5 further shows, the gradient of the plane separating subspaces $A1$ and $B1$ is in the direction of Λ_3 (corresponding to Λ_{n+1}), whereas the second- and third steepest ascent are in the direction of Λ_2 and Λ_1, respectively (corresponding to Λ_n and Λ_{n+1}).

Finally, Propositions 2 and 3 together imply that adding an hierarchy level involving a higher loss ratio from highest-level and external exposure (although not necessarily a smaller incremental loss) intensifies incentives to cover up. The more hierarchical layers there are involving increasingly smaller loss ratio of highest-level and external exposure, the stronger are the augmented hierarchy's coverup incentives. Faced by previous coverups, higher-level supervisors have increasingly stronger coverup incentives as the hierarchy's loss ratio of successive exposure decreases. Given that higher-level supervisors are expected to cover up, lower-level supervisors cover up as well if they bear a relatively large responsibility share of the hierarchy's loss from internal exposure and relatively small responsibility share of the hierarchy's loss from external exposure. The hierarchy ends up covering up even if most supervisors would rather have the coverup exposed early.

7 Discussion

7.1 The Roman Catholic Church: Inter-generational coverup

The paper's main insight applies to a sequence of equally-ranked administrators each succeeding his predecessor's position. Illustrating the coverup dynamic of a hierarchy with revolving heads is the extended coverup of abuse of minors in the Roman Catholic Church (RCC). Over nearly a century, a series of popes have maintained or extended a host of

measures designed to stifle information on clergymen's sexual misconduct.[28] The power of popes to influence church policies cannot be overstated; according to the doctrine of Papal supremacy, the Pope possesses "full, supreme, and universal power over the whole Church, a power which he can always exercise unhindered."[29] As ex-priest Richard Sipe noted, "[I]f you follow [the] foundation [of the sex abuse problem] it will lead you to the highest corridors of the Vatican" (Gibney 2012: 47:04).[30]

As early as 1922, Pope Pius XI approved a confidential instruction named *Crimen Sollicitationis* that was required to be "diligently kept in the secret archives of the [diocesan] curia for internal use." (Tapsell 2015: 80) *Crimen Sollicitationis* subjected information concerning clergy's sexual misconduct produced by the Church's canonical system to "permanent silence" whose breach was punishable by automatic excommunication (*id.*: 80–82). No exception was made for reporting such crimes to the civil authorities (*id.*: 82). [31] Following Pope Pios XII who maintained *Crimen Sollicitationis,* four subsequent popes extended the scope and purview of the church's confidentiality duties.

Pope John XXIII in 1962 applied *Crimen Sollicitationis* to priests in religious orders such as Dominicans, Franciscans and Jesuits, thereby "increasing the reach of that secret by some 50%" (*id.*: 85–86); in 1974 issued *Secreta Continere* that applied strict confidentiality to the very allegations of child sexual abuse (*id.*: 86); and promulgated the 1983 Code of Canon Law (replacing the 1917 code) which imposed "a five-year limitation period on any allegation of child sexual abuse against clergy" (*id.*: 93–94; Tapsell 2014: 55).[32] "Canon law under Crimen Sollicitationis and the 1917 code was bad enough," writes Kieran Tapsel, "but after the 1983 came into effect it was hopeless." (Tapsell 2024B: 64). Pope John Paul II in 2001 confirmed that the pontifical secret applied to the newly-issued procedures for child sexual abuse while making no exception for reporting crimes to civil authorities (Tapsell 2014: 94–95). Although the prohibition against reporting allegations on child sexual abuse by clergymen was lifted a year later (2002) with respect civil authorities in the United States, only in 2012 it was extended to the rest of the world (Tapsell 2024B: 68). In 2010, Pope Benedict XVI revised the norms of Pope John Paul II's decree and extended them to cases involving intellectually disabled adults and the possession of child pornography (Tapsell 2015: 96). Only in 2019 did Pope Francis in "a decision of enormous importance" abolish the pontifical secret to accusations and trials involving abuse of minors (O'Connell 2019). A

[28] The number of hierarchy levels in the RCC's coverup, in contrast to our model, was not fixed but depended on the (unknown) time of external exposure. Each pope therefore had to weigh his cost of internal exposure against the expected cost of external exposure given the uncertainty of the time of (future) external exposure. See Section 3.3.3.

[29] See Paragraph 882 of the Catechism of the Catholic Church (1997); available at https://www.vatican.va/archive/ENG0015/__P2A.HTM.

For a succinct overview of the structure of the Roman Catholic Church, see Hidalgo (2019, pp. 4–6).

[30] For a more detailed account of the coverup at the RCC, see Supplementary Appendix B1.

[31] The 1962 version of *Crimen Sollicitationis* is available at https://www.vatican.va/resources/resources_crimen-sollicitationis-1962_en.html.

[32] *Crimen Sollicitationis* had no limitation period for bringing canonical proceedings for child sexual abuse.

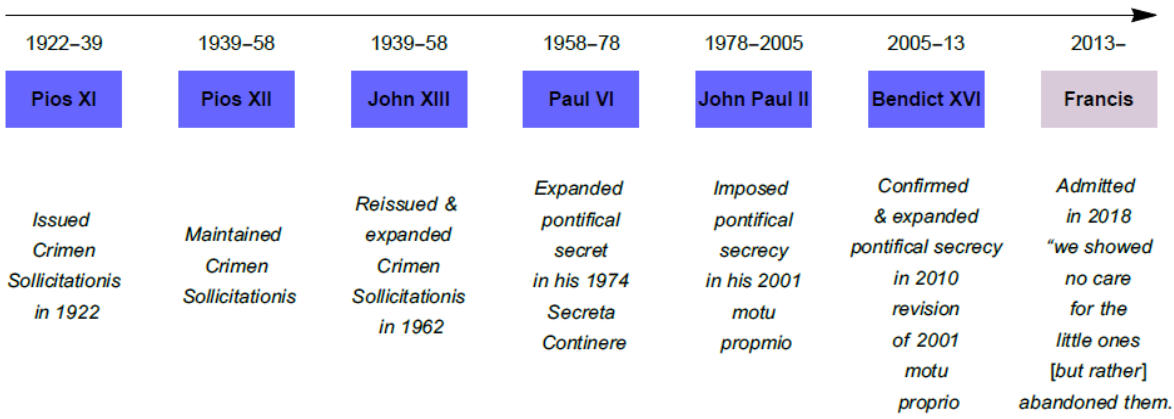


Figure 6: The Roman Catholic Church's Coverup. Over nearly a century, a series of six popes have each taken measures to stifle information on clergymen's abuse of minors. Pius XI in 1922 issued *Crimen Sollicitationis* that subjected information concerning clergy's sexual misconduct to "permanent silence." John XXIII in 1962 applied *Crimen* to priests in religious orders. In 1974 Paul VI issued *Secreta Continere* that applied strict confidentiality to the very allegations of child sexual abuse. Pope John Paul II promulgated the 1983 Code of Canon Law that imposed a five-year limitation period on any allegation of child sexual abuse. In 2001 John Paul II confirmed in his *motu proprio* that the pontifical secret applied to the newly-issued procedures for child sexual abuse. Finally, Benedict XVI in 2010 extended his predecessor's decree to cases involving intellectually disabled adults and the possession of child pornography.

timeline of the church's policies between 1922–2013 is presented in Figure 6**.**

"The rot [at the RCC] was at the top, with the six popes, imposed, maintained and extended a system of coverup through canon law" (Tapsell 2024B: 9). The mishandling of the growing abuse of minors by clergymen underscores the personal dilemma faced by six consecutive popes: to stall the epidemic of sexual crimes by reforming the church's dysfunctional system or keep up appearances by continuing the coverup. Rolling back confidentiality duties, requiring church officials to comply with local reporting laws and retroactively increasing the limitation period (among other measures) would have directly or indirectly made a pope responsible for the church's loss of reputation, influence and membership. Doing so would have inevitably undermined the pope's standing within the hierarchy and betrayed the church's expectations. The exposing pope would thus have borne the lion share of responsibility for the church's loss from external exposure (large s).

A pope's upholding and extending his predecessors' policies of secrecy and silence, by contrast, would have resulted (at worst) in sharing of responsibility for the church's losses—if the coverup were ever fully exposed—with predecessors and successors. Each pope's responsibility share for external exposure therefore had likely exceeded that of a proceeding pope and fell short of that of a succeeding pope ($t_i > t_k$ for $i > k$). Each pope further expected his share of responsibility for the church's losses as well as the church's incremental loss from exposure to be diminishing in time (t_i^n decreases with n; $L_i - L_{i-1} > L_{i+1} - L_i$). Anticipating his successors to be guided by the same reasoning, each pope followed in his predecessors'

footsteps and doubled down on the church's concerted coverup. It stands to reason, furthermore, that popes anticipated the church would take steps to obscure their role in the scandal, which further reduced their cost ratio of exposure and coverup.

7.2 The My Lai Massacre: A coverup along the chain of command

The coverup dynamic at the heart of this paper rests on two legs: supervisors bearing a sufficiently large responsibility share for the hierarchy's loss from internal (s) relative to external exposure (t_i); and the hierarchy's loss from exposure (L_i) is increasing sufficiently slowly. The U.S. military's coverup of the My Lai Massacre on starkly illustrates the personal cost-benefit calculus of commanding officers' coverup decisions. Exposing the wrongdoing and its ensuing coverups would have resulted in disciplinary action, delay or denial of promotion and loss of reputation (large s). By contrast, kicking the can down (or up) the road by covering up would have at best permanently concealed the wrongdoing and at worse divided up responsibility for the wrongdoing and its coverups among the entire chain of command according to rank ($t_i > t_j$ for $i > j$).

The My Lai Massacre involved the mass killing, rape and vandalization of property by U.S. soldiers on March 16, 1968 during the Vietnam War. The atrocities in My Lai were committed primarily by soldiers of the First Platoon of Charlie Company led by Lieutenant William Calley (Peers 1970: 2:2). Charlie Company was part of Task Force Barker, a battalion-size unit of the Americal Division, under the command of Lieutenant Colonel Frank A. Barker (*id.*: 2:1). Commanding the 11th Infantry Brigade and the Americal Division, respectively, were Colonel Oran K. Henderson (*Henderson*) and Major General Samuel W. Koster (*Koster*) (*id.*: 4:1, 5:1). Figure 7 depicts the Americal Division's chain of command.[33]

Shortly after March 16, allegations of war crimes by helicopter pilot Warrant Officer Hugh Thompson corroborated by other aviation unit personnel reached the Americal Division's headquarters (*id.*: 2:4–5; 10:13). On March 18, two days after the operation in My Lai, Koster directed his assistant to instruct Henderson to investigate the incident at My Lei (*id.*: 2:6). On the same day (March 18), Henderson questioned Medina about Thompson's report (*id.*: 10:5). Medina stated "he believed approximately 20 to 28 noncombatants had been killed during the operation" (*ibid.*). Beginning on March 19, Henderson made "a series of oral reports," which "deliberately misrepresented both the scope of his investigation and the information he had obtained" (*id.*: 2:7). Koster laid the matter to rest by accepting Henderson's findings at face value (*ibid.*). A few weeks later following Koster's instruction Henderson wrote up his oral reports reporting that "no civilians were gathered together and shot by US soldiers" and that the claim of a massacre at My Lai was "obviously a Viet Cong propaganda move to discredit the United States in the eyes of the Vietnamese people" (*id.*:

[33] For more information on the atrocities committed in My Lai and their coverup, see Supplementary Appendix B2.

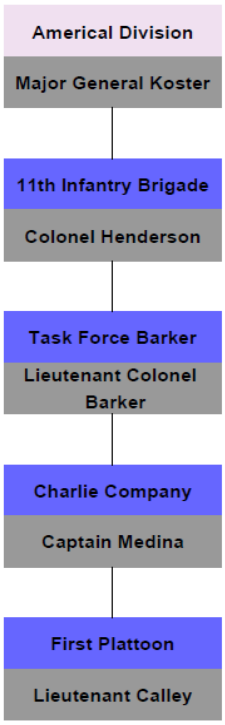


Figure 7: Americal Division Hierarchy's Coverup of the My Lai Massacre. On the morning of March 16, 1968, the First Platoon of Charlie Company led by Lieutenant William Calley engaged in "widespread killing of Vietnamese inhabitants []comprised almost exclusively of old men, women, and children[]." In response to reports by aviation unit personnel, Americal Division commander, Major General Samuel Koster, directed Colonel Oran Henderson, commander of the 11th Infantry Brigade, to investigate the incident. In reply to Henderson's questions, Captain Ernest Medina, commander of Charlie Company, stated that "approximately 20 to 28 noncombatants had been killed during the operation." Henderson subsequently made "a series of oral reports," which "deliberately misrepresented both the scope of his investigation and the information he had obtained." Accepting Henderson's findings at face value, Koster laid the matter to rest.

10:57–58).

In response to revelations of the massacre in the news media, Lieutenant General William R. Peers was appointed on November 26, 1969 to determine "[t]he adequacy of [the] investigations or inquires on [the alleged atrocities], their subsequent reviews and reports within the chain of command"; and "whether [there were] any suppression or withholding of information by persons involved in the incident" (*id.*: 1:1). On March 14, 1970, Peers submitted his final report, which concluded:

> One aspect of the Son My operation most difficult to comprehend is that the facts remained hidden for so long. **Within the Americal Division, at every command level from company to division, actions were taken or omitted which together effectively concealed from higher headquarters the events which transpired in TF Barker's operation of 16–19 March 1968**.

> Some of these acts and omissions were by design, others perhaps by negligence, and still others were the result of policies and procedures.
>
> (Peers 1970: 11:1; emphasis added).

The staged investigation of the war crimes at My Lai exemplifies the mode of coordination among hierarchy levels that facilitated the eventual coverup. Koster's instruction to Henderson to investigate Thompson's report "was a prescription for a whitewash," write Gray & Martin (2008), "because Henderson would be investigating soldiers under his own command: an adverse finding would reflect on his own performance" (pp. 101–102). Because both Koster's and Henderson's costs of internal exposure was sufficiently large (large s), Henderson preferred to cover up having every reason to expect that Koster would sign off on his investigation findings. The same goes for Medina, Charlie Company commanding officer, who lied to Henderson about the number of civilian casualties, as he eventually came to admit (Robinson 1971). Medina would not have blatantly misrepresented the actual facts had he anticipated Henderson to undertake a through investigation. By passing the buck to a higher up, each level of command from company to division diluted their personal responsibility.

7.3 The Aircraft Brake Scandal: A futile coverup

Key to facilitating hierarchical coverups is the divergence between supervisors' responsibility share for internal and external exposure. A supervisor who exposes wrongdoing is likely to bear the lion share of responsibility for the hierarchy's loss from his own exposure. The cost of failing to act, by contrast, is shared among all the supervisors who turned a blind eye to the wrongdoing. As Katz (1979) observed, "Multiple layers of strategic ignorance may develop when subordinates at each level of a long hierarchy sense that their superiors may compromise policing responsibilities in order to avoid losing face." The Aircraft Brake Scandal at B.F. Goodrich Wheel and Brake Plant (Goodrich) illustrates this coverup dynamic. A remarkable feature of this case is "the certainty with which the cover-up was doomed to failure." (Darley 1996: 28). In our model's notation, $r \to 1$.

Goodrich's plant in Troy, Ohio received in 1967 an order to supply Ling-Temco-Vought (LTV) wheels and brakes for the A7D aircraft, which LTV was building for the Air Force (Vandivier 1969: 2). Before the Air Force would purchase the brake, however, Goodrich was required to present a test-based report demonstrating the brake's military-specified safety qualifications (*ibid.*) The starting dates for flight tests were scheduled for June 1968 (Vandivier 1972: 443).

The brake proposed by Goodrich for LTV was designed by John Warren and produced and tested by Searle Lawson; both Warren and Lawson were trained in design engineering

(*id.*: 443). Managing the innovative four-disk brake project was Robert L. Sink, degree-less projects manager (*id.*: 444). Russell Van Horn, manager of the Aircraft Wheel and Brake Design Section, supervised the project and was the immediate supervisor of Sink, Warren and Lawson (*id.*: 446) Goodrich's Technical Service Section—which eventually went on to write the entire qualification report—comprised of Russell Line, the section manager; Ralph Gretzinger, the test lab supervisor; and Kermit Vandivier, a technical writer (*id.*: 445–447). Ironically, it was Vandivier, the lowest-level functionary in Goodrich's hierarchy with no engineering background who would go on to testify at a congressional hearing and publish a confessional account of what has transpired in Goodrich behind the scene.[34] Figure 8 depicts the two parallel hierarchies of Goodrich.

By December 1967, following several failed simulated landings, Lawson realized the new brake design has a critical flaw: the surface of the brake was too small to stop the aircraft without producing excessive heat that would wear away the brake's linings (*id.*: 443). Since Warren refused to admit any serious error in his own brake design, Lawson took his concerns to Sink, the project manager (*id.*). Vandivier (1972) describes Sink's considerations in dismissing Lawson's concerns:

> [T]o concede that Lawson's calculations were correct would also mean conceding that Warren's calculations were incorrect. [I]n admitting that Warren had erred, [Sink] would have to admit that he had erred in trusting Warren's judgment . . . and . . . would have to explain the whole messy situation to the Goodrich hierarchy, not only at Troy but possibly on the corporate level at Goodrich's Akron offices.

(p. 444).

Sink, furthermore, had already assured Goodrich's contractor, LTV, that work on the brake was practically completed; admitting a major design problem would have also made him lose face in the eyes of LTV (*id.*) "Sink [thus] faced immediate, certain and negative consequences for himself if he decided against the four-disc brake assembly" (Darley 1996: 30). On the other hand, "There was the possibility that the responsibility for the whole situation could be diffused among various players as time passed" (*Ibid.*) Lawson was subsequently told by *both* his superiors, Sink and Van Horn, "Regardless of what the brake does on test, we're going to qualify it" (Vandivier 1972: 446). By involving his direct supervisor, Van Horn, Vandivier explains, "Sink was looking toward that moment when blame must be borne and, if possible, shared" (*ibid.*).

On May 2, 1968, Goodrich conducted its fourteenth and final attempt to qualify the brake, which predictably resulted in a failure (*id.*: 447). Fearing for their livelihood ["bills

[34] Vandiver's testimony was corrborated by Lawson (see Vandivier 1969: 13 ["The factual data that Mr. Vandivier has presented is correct, to the best of my [Lawson] knowledge."]

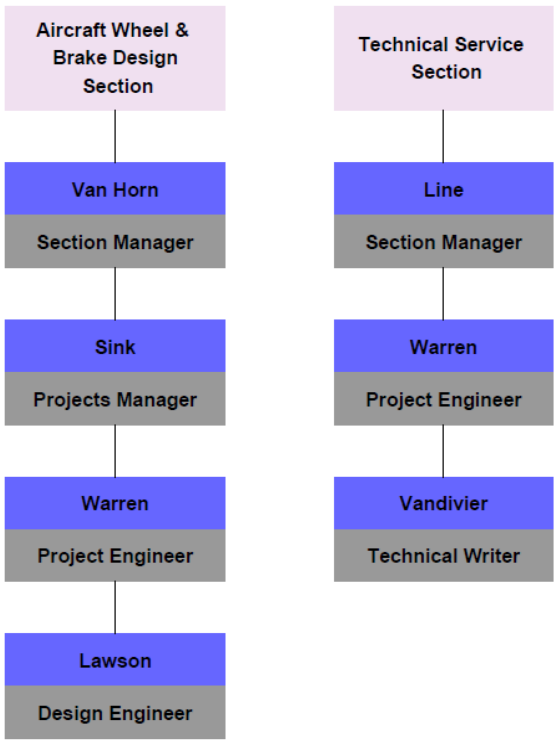


Figure 8: Goodrich Hierarchy's Coverup. Following several failed simulated landings, Design Engineer Searle Lawson realized by December 1967 the brake designed by Project Engineering John Warren was irredeemably flawed. However, Robert L. Sink, the project manager, dismissed Lawson's concerns. Both Sink and Van Horn insisted the brake must be qualified irrespective of the test results. After the brake failed the final test, Technical Writer Kermit Vandivier and his supervisor Ralph Gretzinger gave in to pressure by their Section Manger Russell Line to prepare falsified curves and displays for the qualification report.

aren't paid with personal satisfaction, nor house payments with ethical principles"], both Vandivier and his direct supervisor, Gretzinger, succumbed to pressure by their superiors to prepare falsified curves and displays for the qualification report (*id.*: 447–448). On Line's direction, Gretzinger and Vandivier went on to write up the writing portion of the report as well because "no one in the engineering department had time to write the report" (*id.*: 449). The unsigned report was officially published on June 5, 1968, with copies delivered to the Air Force and LTV (*ibid.*). Flight tests conducted soon thereafter were canceled after a few near-disasters landings (*ibid.*) After consulting his attorney, Vandivier informed the Federal Bureau of Investigation of the falsified report; Lawson followed suit (*ibid.*)

Katz (1979) explains the coverup dynamic at Goodrich:

> Everyone up the [hierarchy] line would [ignore the fraud] on the conviction that their management reputations would be destroyed if they reported fraud by their subordinates. **They all knew that in the end company representatives, in order to protect their reputations, would have to deny that their**

> **organization could have engineered an elaborate cover-up.** As a result, when near-disasters in test flights made the brake's incurable defects undeniable, the only participants whose guilty knowledge was provable were those who had confessed in an attempt to "blow the whistle."

(p. 304, emphasis added).

The events at Goodrich illustrate how the anticipation that higher-ups will "compromise [their] policing responsibility" cause subordinates to compromise their own policing responsibilities as well. Each supervisor's weighing his cost of exposure (including losing his job) against his cost of external exposure resulted in a coverup spiral. As was clear from the outset, moreover, the wrongdoing and its subsequent coverup were virtually certain to be exposed at the actual flight tests ($r \to 1$). Nevertheless, all the hierarchy levels covered up, each realizing he is best served by covering up.[35]

8 Conclusion

This paper highlights the role of responsibility sharing among supervisors for a hierarchy's loss from exposure in shaping coverup incentives. The central idea is that asymmetric allocation of responsibility for the hierarchy's loss from internal and external exposure prompts supervisors along the hierarchy's ladder to externalize exposure costs onto higher-level supervisors. The result is a snow-ball effect in which each supervisor's best interest is served by covering up wrongdoing rather than exposing it. Deeper hierarchies are more prone to coverup than shallower hierarchies if the dilution of responsibility of the deeper hierarchy's supervisors outweighs the deeper's hierarchy's larger terminal loss. This line of explanation complements the socio-psychological literature which emphasizes social mechanisms that diffuse responsibility for group decisions: "Social organizations go to great lengths to devise mechanisms for obscuring responsibility for decisions that will affect others adversely. . . . Any harm done by a group can always be attributed largely to the behavior of others" (Bandura 1999: 198).

[35] For additional information on the events at Goodrich and their aftermath, see Supplementary Appendix B3..

Appendix: Proofs

A: Lemmas 1–3

Lemma 1 (coverup equilibrium) *Supervisors S_1^n through S_n^n cover up if and only if* $r < s/L_{n+1} \min_{i \in N} L_j/t_j^n$.

Proof. (1) That $r < s/L_{n+1} \min_{i \in N} L_j/t_j^n$ implies that $r < s/L_{n+1} \min_{i \in N} L_n/t_n^n$. Therefore, by Eq. (1), the hierarchy head covers up on- or off-the-equilbrium path. Proceeding backward, given that $r < (s/L_{n+1})(L_j/t_j^n)$ for all $j = i+1, ..., n$, Supervisor S_i^n covers up on- or off-the-equilbrium path by Eq. (2). Therefore, if $r < s/L_{n+1} \min_{i \in N} L_i/L_{n+1}$, Supervisors S_1^n through S_n^n cover up on the equilibrium path.

(2) To show uniqueness, suppose $r \geq s/L_{n+1} \min_{i \in N} L_i/L_{n+1}$. There therefore exists $i \in N$ such that Supervisor S_i^n exposes on or off the equilibrium path, where $i = \arg\min_{i \in N} L_i/L_{n+1}$. We proceed to show that, given that all his superiors cover up, Supervisor S_j^n may either cover up or expose on the equilibrium path, where $j < i$. It follows that *any* one of Supervisors S_1^n through S_{i-1}^n could expose on the equilibrium path.

Suppose Supervisors S_j^n through S_{i-1}^n cover up on or off the equilibrium path for $j \in \{1, ..., i-1\}$. This implies that $\frac{s_{ji}}{s} < \frac{L_j}{L_{i+1}}$ for $j \in \{1, ..., i-1\}$ such that Supervisor S_j^n's cost ratio of internal versus external exposure is (weakly) greater that the inverse of the hierarchy's corresponding loss ratios. Now, Supervisor S_i^n exposes on the equilibrium path if $j = 1$. Suppose $j \neq 1$ and let $k = j - 1$. Supervisor S_k^n's cost of exposure is $s \cdot L_k$, whereas his coverup cost is $s_{ki} \cdot L_i$ (because, by assumption, Supervisors S_j^n through S_{i-1}^n cover up whereas Supervisor S_i^n exposes). Therefore, Supervisor S_k^n covers up if $\frac{s_{ki}}{s} > \frac{L_k}{L_i}$ and exposes if $\frac{s_{ki}}{s} \leq \frac{L_k}{L_i}$. Thus, Supervisor S_k^n may either cover up or expose given that all his superiors up to Supervisor S_{i-1}^n cover up. □

Lemma 2 (maximal and minimal coverup incentives) *The minimal probability of external exposure that unconditionally stems coverup ($s/L_{n+1} \min_{i \in N} L_i/t_j^n$) attains–*

(1) a minimum value *under* semi-equal allocation *in which each supervisor is responsible for–*

(i) the hierarchy's loss from his own exposure ($s = 1$); and

(ii) a semi-equal share of the hierarchy's terminal loss of $\check{t}_i^n(i) = \mathbf{1}_{\{j \geq \check{i}\}} \frac{1}{n+1-j}$, where $\check{i} = \min_{i \in N}(n+1-i)L_i$;

(2) a maximum value *under* proportional allocation *in which each supervisor is responsible for–*

(i) an equal share of the hierarchy's loss from his own exposure ($s = 1/n$); and

(ii) a proportional share of the hierarchy's terminal loss of $\hat{t}_i^n(L_{1,...,n}) = \frac{L_i}{\Sigma_{j=1}^n L_j}$.

Proof. (1) Consider the following program:

$$\min_{(s,t_1^n,...,t_n^n)} [s/L_{n+1} \min_{i\in N} L_i/t_i^n]$$

subject to:

$$\begin{aligned} s &\in [\tfrac{1}{n}, 1] && \text{(Responsibility Bounds)} \\ \Sigma_{i\in N} t_i^n &= 1 && \text{(Responsibility Exhaustion)} \\ t_j^n &\leq t_k^n \text{ for } j < k \in N && \text{(Responsibility Gradation).} \end{aligned}$$

The objective function is the minimum probability of external exposure that stems coverup in an n-layer hierarchy for a *specific* allocation of responsibility among the supervisors. The Responsibility Bounds constraint ensures that each supervisor is responsible for at least an equal fraction of the hierarchy's loss from his internal exposure and no more than the hierarchy's entire loss. The Responsibility Exhaustion constraint ensures that supervisors' terminal responsibility shares add up to 1. The Responsibility Gradation ensures that a supervisor's terminal responsibility share (weakly) increases with his rank (see Assumption 1).

Step 1 $\arg\min_s \frac{s}{L_{n+1}} = \frac{1}{n}$.

Observes that s/L_{n+1} is increasing in s. By the Responsibility Bounds constraint, $s \geq \frac{1}{n}$. Therefore, $\arg\min_s s/L_{n+1} = \frac{1}{n}$.

Step 2 $t_i^n \leq \frac{1}{n+1-i} \equiv \check{t}_i^n(i)$.

Suppose by contradiction that $t_i^n > \frac{1}{n+1-i} \equiv \check{t}_i^n(i)$. Because $t_j^n \geq t_k^n$ for $j < k \in N$ by the Responsibility Gradation constraint, it follows that $t_j^n \geq t_i^n$ for $j = i+1, ..., n$. Therefore, the *total* responsibility shares of Supervisor S_i^n through S_n^n is $\Sigma_{j=i}^n t_j^n = (n+1-i)t_i^n > (n+1-i)\cdot\check{t}_i^n(n,i) > 1$. But this inequality violates the Responsibility Exhaustion constraint. Therefore, $t_i^n \leq \check{t}_i^n(i)$.

Step 3 $\min_{t_i^n} \frac{L_i}{t_n^n} = \check{t}_i^n(i)$.

Observe that $\min_{i\in N} L_i/t_n^n$ is (weakly) decreasing in t_i^n. Because, $t_i^n \leq \check{t}_i^n(i)$ by Step 2, Supervisor S_i^n's terminal responsibility share that minimizes his cost ratio of internal versus external exposure is $\check{t}_i^n(n,i)$. For example, $\min_{t_1^n} \frac{L_i}{t_n^n} = \frac{1}{n}$, whereas $\min_{t_n^n} \frac{L_i}{t_n^n} = 1$.

Step 4 $\arg\min_i \min_{i\in N} L_i/t_i^n = \arg\min_i (n+1-i)L_i$.

From Step 3, the set of *candidate* minimizers of $\min_{i\in N} L_i/t_i^n$ is $\{\check{t}_i^n(1), ..., \check{t}_i^n(n)\}$. Substituting $\check{t}_i^n(i) = \frac{1}{n+1-i}$ for t_i^n in $\min_{i\in N} \frac{L_i}{t_n^n}$ gives $\min_i (n+1-i)L_i$. Therefore, $\arg\min_i \min_{i\in N} L_i/t_i^n = \arg\min_i (n+1-i)L_i$.

Step 5 $\frac{s}{L_{n+1}} \min_{i \in N} L_i/t_i^n$ *attains a* minimum value *for* $t_i^n = \check{t}_i^n(\check{i})$*, where* $\check{t}_i^n(\check{i}) = \mathbf{1}_{\{i \geq j\}} \frac{1}{n+1-\check{i}}$.

Let $\check{i} = \arg\min_i (n+1-i)L_i$. Now, by the Responsibility Gradation constraints, $t_i^n = t_{\check{i}}^n(\check{i})$ for $i > \check{i}$, whereas by the Responsibility Exhaustion constraint $\Sigma_{i=1}^n t_i^n = 1$. Therefore, $s/L_{n+1} \min_{i \in N} L_i/t_i^n$ attains a minimum value for $t_i^n = \check{t}_i^n(\check{i})$ for $i \geq \check{i}$ and $t_i^n = 0$ for $i < \check{i}$. ‖

(2) Consider the following program:

$$\max_{(s, t_1^n, \ldots, t_n^n)} [s/L_{n+1} \min_{i \in N} L_i/t_i^n]$$

subject to:

$$\begin{aligned} s &\in [\tfrac{1}{n}, 1] && \text{(Responsibility Bounds)} \\ \Sigma_{i \in N} t_i^n &= 1 && \text{(Responsibility Exhaustion)} \\ t_j^n &\leq t_k^n \text{ for } j < k \in N && \text{(Responsibility Gradation).} \end{aligned}$$

The objective function is the minimum probability of external exposure that unconditionally stems coverup in an n-layer hierarchy for a *specific* allocation of responsibility among the supervisors. The constraints follow from Assumption 1.

Step 1 $\arg\max_s s/L_{n+1} = 1$.

Because s/L_{n+1} is increasing in s, $\arg\max_s s/L_{n+1} = 1$.

Step 2 $\min_{i \in N} L_i/t_i^n$ *attains a* maximum value *value if* $t_j^n/t_k^n = L_j/L_k$ *for each* $j, k \in N$.

Suppose by contradiction that $\min_{i \in N} L_i/t_i^n$ attains a maximum value for $t_j^n/t_k^n \neq L_j/L_k$ for some $j, k \in N$. Without loss of generality, let $\arg\min_{i \in N} L_i/t_i^n = j$. This implies that $L_j/t_j^n < L_k/t_k^n$ for $j, k \in N$. Consider a small decrease in t_j^n to $t_j^{n'}$ and a corresponding small increase in t_k^n to $t_k^{n'}$ such that $L_j/t_j^{n'} < L_k/t_k^{n'}$. Because $t_j^{n'} < t_j^n$, it follows that $L_j/t_j^{n'} \leq L_j/t_j^n = \min_{i \in N} L_i/t_i^n$, which is a contradiction. Therefore, $\min_{i \in N} L_i/t_i^n$ attains a maximum value if and only if $t_j^n/t_k^n = L_j/L_k$ for each $j \neq k$. Furthermore, because $t_j^n/t_k^n < 1$ if $L_j/t_i^n = L_k/t_j^n$ for $j < k \in N$, it follows that $t_j^n < t_k^n$ for such j and k in keeping with the Responsibility Gradation constraint.

Step 3 $\min_{i \in N} L_i/t_i^n$ *attains a* maximum value *for* $t_i^n = \hat{t}_i^n(L_{1,\ldots,n}) \equiv \frac{L_i}{\Sigma_{i=1}^n L_i^n}$ *for* $i \in N$.

From Step 2, $\min_{i \in N}(L_i/t_i^n)$ attains a maximum value for $t_i^n/t_j^n = L_i/L_j$ for each $i \neq j \in N$. Multiplying through by t_j^n gives $t_j^n = (t_i^n L_j)/L_i$. Summing up over $j \neq i$ gives $\Sigma_{j \neq i} t_j^n = t_i^n \Sigma_{j \neq i} L_j/L_i$. Now, by the Responsibility Exhaustion constraint, $\Sigma_{i \in N} t_i^n = 1$ and therefore $t_i^n + t_i^n \Sigma_{j \neq i} L_j/L_i = 1$, where the second summand equals $\Sigma_{j \neq i} t_j^n$. Solving for t_i^n gives $t_i^n = \hat{t}_i^n(L_{1,\ldots,n}) \equiv L_i/\Sigma_{i=1}^n L_i^n$ for each $i \in N$. □

Lemma 3 (equilibrium outcomes)

In the unique subgame perfect equilibrium:

(1) The hierarchy unconditionally covers up *if* $r \in (0, \underline{r}_n(L_{1,...,n+1}))$*;*

(2) the hierarchy conditionally covers up *if* $r \in [\underline{r}_n(L_{1,...,n+1}), \overline{r}_n(L_{1,...,n+1}))$*: there exist cutoffs* $\underline{s}_n(r, L_{1,...,n+1}) \equiv \frac{r}{\overline{r}_n(L_{1,...,n+1})}$ *and* $\overline{t}_i^n(r, s, L_i, L_{n+1}) \equiv \min\{\frac{sL_i}{rL_{n+1}}, 1\}$ *for each* $i \in N$ *such that all supervisors cover up if and only if:*

(i) $s \in (\underline{s}(r, L_{1,...,n+1}), 1]$ *and*

(ii) $(t_1^n, ..., t_n^n) \in [0, \overline{t}_1^n(r, s, L_1, L_{n+1})] \times ... \times [0, \overline{t}_n^n(r, s, t_n, L_n, L_{n+1})]$.

(3) the hierarchy unconditionally exposes *if* $r \in [\overline{r}_n(L_{1,...,n+1}), 1]$.

Proof. (1) By Lemma 1, an n-layer hierarchy covers up if and only if $r < s/L_{n+1} \min_{i \in N} L_i/t_i^n$ for $i \in N$. Now, if $r > \min_{(s,t_1^n,...,t_n^n)}[s/L_{n+1} \min_{i \in N} L_i/t_i^n]$, there does *not* exists a responsibility allocation $(s, t_1^n, ..., t_n^n)$ such $s/L_{n+1} \min_{i \in N} L_i/t_i^n > r$ for some $i \in N$. It follows that if $r < \overline{r}_n(L_{1,...,n+1})$ the hierarchy unconditionally covers up.

(2) We proceed to show that if $r \in [\underline{r}_n(L_{i,...,n+1}), \overline{r}_n(L_{i,...,n+1})$, $s \in (\underline{s}_n(r, L_{1,...,n+1}), 1]$ and $(t_1^n, ..., t_n^n) \in (0, \overline{t}_1^n(r, s, L_i, L_{n+1})] \times ... \times (t_{n-1}^n, \overline{t}_n^n(r, s, L_i, L_{n+1})]$, then $s/L_{n+1} \min_{i \in N} L_i/t_i^n \geq r$ for some $i \in N$. It then follows from Lemma 1 that in the unique subgame perfect equilibrium all supervisors cover up.

If $s \leq \underline{s}_n(r, L_{1,...,n+1}) \equiv \frac{r}{\overline{r}_n(L_{1,...,n+1})}$, then

$$s/L_{n+1} \min_{i \in N} L_i/t_i^n \geq \frac{r}{\overline{r}_n(L_{1,...,n+1})} \times \frac{\Lambda_n}{\hat{t}_n^n(L_{1,...,n})} \geq r \tag{A1}$$

because $\overline{r}_n(L_{1,...,n+1}) \equiv \frac{\Lambda_n}{\hat{t}_n^n(L_{1,...,n})}$. Therefore, one supervisor exposes on the equilibrium path.

For $s > \underline{s}_n(r, L_{1,...,n+1})$ and $\overline{t}_i^n(r, s, L_i, L_{n+1}) \equiv \min\{\frac{sL_i}{rL_n}, 1\}$ we have

$$\begin{aligned} s/L_{n+1} \min_{i \in N} L_i/t_i^n &> \frac{s}{\min\{\frac{sL_i}{rL_{n+1}}, 1\}} \frac{L_i}{L_{n+1}} \\ &\geq \frac{s}{\frac{sL_i}{rL_{n+1}}} \frac{L_i}{L_{n+1}} \\ &= r, \end{aligned} \tag{A2}$$

for some $i \in N$. By Lemma 1, all supervisors cover up on the equilibrium path.

(3) If $r > \max_{(s,t_1^n,...,t_n^n)}(s/L_{n+1} \min_{i \in N} L_j/t_j^n)$, there exists $i \in N$ such that $s/L_{n+1} \min_{i \in N} L_i/t_i^n > r$. Because the hierarchy covers up if and only $(s/L_{n+1})(L_i/t_i^n) < r$ for every $i \in N$ by Lemma 1, it follows that if $r > \overline{r}_n(L_{1,...,n+1})$ the hierarchy unconditionally exposes. □

B: Propositions 1–3

Proposition 1 (coverup incentives in n-layer versus $n+1$-layer hierarchy)

(1) If $L_{n+1}/L_{n+2} \in (0, \min\{\Sigma_{i=1}^{n}\hat{t}_i^{n+1}, \hat{t}_{n+1}^{n+1}\})$*, an* n*-layer hierarchy conditionally covers up whereas an* $n+1$*-layer hierarchy unconditionally exposes for* $r \in [\overline{r}_{n+1}, \min\{\overline{r}_n, 1\})$*; and*

(2) If $L_{n+1}/L_{n+2} \in (\Sigma_{i=1}^{n}\hat{t}_i^{n+1}, 1)$ *and* $L_n/L_{n+1} \in (0, \hat{t}_n^n)$*, an* n*-layer hierarchy unconditionally exposes whereas an* $n+1$*-layer hierarchy conditionally covers up for* $r \in [\overline{r}_n, \min\{\overline{r}_{n+1}, 1\})$.

Proof. We proceed by proving two ancillary claims.

Claim B1 $\overline{r}_n(L_{1,\ldots,n+1}) = \frac{\Sigma_{i=1}^{n}\hat{t}_i^{n+1}(L_{1,\ldots,n})}{\hat{t}_{n+1}^{n+1}(L_{1,\ldots,n})}$.

Proof. By definition, $\Sigma_{i=1}^{n}\hat{t}_i^{n+1}(L_{1,\ldots,n+1}) = \Sigma_{i=1}^{n}L_i/\Sigma_{i=1}^{n+1}L_i$ and $\hat{t}_{n+1}^{n+1}(L_{1,\ldots,n+1}) = L_{n+1}/\Sigma_{i=1}^{n+1}L_i$. Therefore,

$$\begin{aligned}\frac{\Sigma_{i=1}^{n}\hat{t}_i^{n+1}(L_{1,\ldots,n})}{\hat{t}_{n+1}^{n+1}(L_{1,\ldots,n})} &= \frac{L_{n+1}}{\Sigma_{i=1}^{n+1}L_i} \div \frac{L_{n+1}}{\Sigma_{i=1}^{n+1}L_i} \\ &= \frac{\Sigma_{i=1}^{n}L_i}{\Sigma_{i=1}^{n+1}L_i} \\ &= \overline{r}_n(L_1, \ldots, L_{n+1}), \end{aligned} \tag{B1}$$

because by Lemma 3, $\overline{r}_n(L_{1,\ldots,n+1}) = \Sigma_{i=1}^{n}L_i/L_{n+1}$. ‖

According to Claim B1, the minimum probability of external exposure that stems coverup in an n-layer hierarchy for any allocation of responsibility among the supervisors ($\overline{r}_n(L_{1,\ldots,n+1})$) is equal to the ratio of (i) the sum of the first n-level supervisors' terminal proportional responsibility shares ($\Sigma_{i=1}^{n}\hat{t}_i^{n+1}(L_{1,\ldots,n+1})$) and (ii) an $n+1$-layer hierarchy head's terminal proportional responsibility share ($\hat{t}_{n+1}^{n+1}(L_{1,\ldots,n+1})$). The equality $\overline{r}_n(L_{1,\ldots,n+1}) = \frac{\Sigma_{i=1}^{n}\hat{t}_i^{n+1}(L_{1,\ldots,n+1})}{\hat{t}_{n+1}^{n+1}(L_{1,\ldots,n+1})}$ holds because each side is equal to $\Sigma_{i=1}^{n}L_i/L_{n+1}$: the ratio of an n-layer hierarchy's sum of losses from internal exposures and loss from external exposure. For example, in a 2-layer hierarchy, $\overline{r}_1(L_{1,2}) = \hat{t}_1^2(L_{1,2})/\hat{t}_2^2(L_{1,2}) = L_1/L_2$, because $\hat{t}_1^2(L_{1,2}) = L_1/(L_1+L_2)$ and $\hat{t}_2^2(L_{1,2}) = L_2/(L_1+L_2)$.

Claim B2 $\overline{r}_{n+1}(L_{1,\ldots,n+1}) = \frac{1}{\hat{t}_{n+1}^{n+1}(L_{1,\ldots,n+1})}\frac{L_{n+1}}{L_{n+2}}$.

By definition, $\overline{r}_{n+1}(L_{1,\ldots,n+1}) = \hat{t}_i^{n+1}(L_{1,\ldots,n+1})^{-1}\backslash(L_i/L_{n+2})$ for $i = 1, \ldots, n$. Plugging in $L_i/\Sigma_{i=1}^{n+1}L_i$ for $\hat{t}_i^{n+1}(L_{1,\ldots,n+1})$ from Lemma 2 gives

$$\frac{1}{\hat{t}_i^{n+1}(L_{1,\ldots,n+1})}\frac{L_i}{L_{n+2}} = \frac{1}{\frac{L_i}{\Sigma_{i=1}^{n+1}L_i}}\frac{L_i}{L_{n+2}}.$$

Multiplying numerator and denominator by L_{n+1} we obtain

$$\begin{aligned}\frac{1}{\hat{t}_i^{n+1}(L_{1,\ldots,n+1})}\frac{L_i}{L_{n+2}} &= \frac{1}{\frac{L_{n+1}}{\Sigma_{i=1}^{n+1}L_i}}\frac{L_{n+1}}{L_{n+2}} \\ &= \frac{1}{\hat{t}_{n+1}^{n+1}(L_{1,\ldots,n+1})}\frac{L_{n+1}}{L_{n+2}},\end{aligned}$$

because $\hat{t}_{n+1}^{n+1}(L_{1,\ldots,n+1}) = L_{n+1}/\Sigma_{i=1}^{n+1}L_i$ by definition. ‖

Now, from Claims B1 and B2 it follows that

$$\overline{r}_{n+1}(L_{1,\ldots,n+2}) - \overline{r}_n(L_{1,\ldots,n+1}) = \frac{L_{n+1}/L_{n+2} - \Sigma_{i=1}^{n}\hat{t}_i^{n+1}(L_{1,\ldots,n})}{\hat{t}_{n+1}^{n+1}(L_{1,\ldots,n+1})},$$

whose sign depends on the sign of the difference $L_{n+1}/L_{n+2} - \Sigma_{i=1}^{n}\hat{t}_i^{n+1}(L_{1,\ldots,n})$. Hence, $\overline{r}_{n+1}(L_{1,\ldots,n+2}) < / > \overline{r}_n(L_{1,\ldots,n+1})$ if $L_{n+1}/L_{n+2} < / > \Sigma_{i=1}^{n}\hat{t}_i^{n+1}(L_{1,\ldots,n+1})$.

Finally, from Lemma 4, a k-layer hierarchy conditionally covers up for $r \in [\underline{r}_k(L_{1,\ldots,k+1}), 1)$ if $L_k/L_{k+1} \in (0, \hat{t}_k^k(L_{1,\ldots,k}))$ for $k = n, n+1$. Therefore, an n-layer hierarchy exposes for $r \to 1$ if and only if $L_n/L_{n+1} < (0, \hat{t}_n^n(L_{1,\ldots n})$ whereas an $n+1$-layer hierarchy exposes for $r \to 1$ if and only if $L_{n+1}/L_{n+2} < (0, \hat{t}_{n+1}^{n+1}(L_{1,\ldots n+1})$.

To illustrate, consider the comparison between a 1-layer and 2-layer hierarchy. In this case, $\overline{r}_2(L_{1,2,3}) = (1/\hat{t}_2^2(L_{1,2})) \div (L_2/L_3)$, whereas $\overline{r}_1(L_{1,2}) = \hat{t}_1^2(L_{1,2})/\hat{t}_2^2(L_{1,2})$. Therefore, $\overline{r}_2(L_{1,2,3}) < \overline{r}_1(L_{1,2})$ and $\overline{r}_2(L_{1,2,3}) < 1$ if and only if $L_2/L_3 < \min\{\hat{t}_2^3(L_{1,2}), \hat{t}_3^3(L_{1,2}))$, whereas $\overline{r}_1(L_{1,2}) < \overline{r}_2(L_{1,2,3})$ and $\overline{r}_1(L_{1,2}) < 1$ if $L_2/L_3 > \hat{t}_2^3(L_{1,2})$ and $L_1/L_2 < \hat{t}_2^2(L_{1,2})$. □

Proposition 2 (effect of Λ_n and Λ_{n+1} on $\overline{r}_{n+1}(\Lambda_{1,\ldots,n+1}) \div \overline{r}_n(\Lambda_{1,\ldots,n})$)

As Λ_n decreases or as Λ_{n+1} increases, the ratio *between the minimum probabilities of external exposure that unconditionally stem coverup in an $n+1$-layer hierarchy and in an n-layer hierarchy increases: $\frac{\partial}{\partial \Lambda_{n+1}}\overline{r}^{\div}_{n+1/n}(\Lambda_{1,\ldots,n+1}) > 0$ and $\frac{\partial}{\partial \Lambda_n}\overline{r}^{\div}_{n+1/n}(\Lambda_{1,\ldots,n+1}) < 0$.*

Proof. That $\frac{\partial}{\partial \Lambda_{n+1}}\frac{\overline{r}_{n+1}(\Lambda_1,\ldots,\Lambda_{n+1})}{\overline{r}_n(\Lambda_1,\ldots,\Lambda_n)} > 0$ follows from the text. We therefore proceed to show that $\frac{\partial}{\partial \Lambda_n}\overline{r}^{\div}_{n+1/n}(\Lambda_{1,\ldots,n+1}) < 0$.

The *ratio* of the minimum probabilities of external exposure that stem coverup in an $n+1$-layer hierarchy and in an n-layer hierarchy can be written as

$$\overline{r}^{\div}_{n+1/n}(\Lambda_{1,\ldots,n+1}) = \frac{\hat{t}_i^n(\Lambda_{1,\ldots,n-1})}{\hat{t}_i^{n+1}(\Lambda_{1,\ldots,n})} \times \frac{\overbrace{L_{n+1}}^{\Lambda_{n+1}}}{L_{n+2}} \tag{B2}$$

for $i = 1, \ldots, n$, because $\overline{r}_{n+1}(L_1, \ldots, L_{n+2}) = \frac{1}{\hat{t}_i^{n+1}(L_{1,\ldots,n+1})}\frac{L_i}{L_{n+2}}$ and $\overline{r}_n(L_1, \ldots, L_{n+1}) = \frac{1}{\hat{t}_i^{n}(L_{1,\ldots,n})}\frac{L_i}{L_{n+1}}$. Observe that Λ_n only figures in $\hat{t}_i^{n+1}(\Lambda_{1,\ldots,n})$.

Claim B3 $\hat{t}_n^{n+1}(\Lambda_{1,...,n}) = \frac{\Lambda_n}{\Sigma_{i=1}^{n+1}\Pi_{j=i}^{n}\Lambda_j}$.

By definition, $\hat{t}_n^{n+1}(L_{1,...,n+1}) = \frac{L_n}{\Sigma_{i=1}^{n+1}L_i}$ (see Lemma 2). Dividing numerator and denominator by L_n gives $\hat{t}_n^{n+1}(L_{1,...,n+1}) = (\Sigma_{i=1}^{n+1}L_i/L_n)^{-1}$. Now, $L_i/L_n \equiv \Pi_{j=i}^{n}\Lambda_j$ because $\Lambda_j \equiv L_j/L_{j+1}$ and $L_{n+1}/L_n = 1/\Lambda_n$. Therefore, $\hat{t}_n^{n+1}(\Lambda_{1,...,n}) = \Lambda_n/\Sigma_{i=1}^{n+1}\Pi_{j=i}^{n}\Lambda_j$. For example, $\hat{t}_2^3(\Lambda_{1,2,3}) = \frac{\Lambda_2}{\Sigma_{i=1}^{3}\Pi_{j=i}^{2}\Lambda_j} = \frac{\Lambda_2}{\Lambda_1\Lambda_2+\Lambda_2+1}$.

We proceed to show that $\hat{t}_n^{n}(\Lambda_{1,...,n})$ is *increasing* in Λ_n and therefore that $\hat{t}_n^{n}(\Lambda_{1,...,n})$ *decreases* as Λ_n decreases. It follows that $\overline{r}\dot{-}_{n+1/n}(\Lambda_{1,...,n+1})$ increases as Λ_n decreases.

From Claim B3, $\hat{t}_n^{n+1}(\Lambda_{1,...,n}) = \frac{\Lambda_n}{\Sigma_{i=1}^{n+1}\Pi_{j=i}^{n}\Lambda_j}$. Partially differentiating with respect to Λ_n and letting $X(\Lambda_{1,...,n}) \equiv \Sigma_{i=1}^{n+1}\Pi_{j=i}^{n}\Lambda_j$ we get

$$\begin{aligned}
\frac{\partial}{\partial\Lambda_n}\hat{t}_n^{n+1}(\Lambda_{1,...,n}) &= \frac{\partial}{\partial\Lambda_n}\frac{\Lambda_n}{X(\Lambda_{1,...,n})} \\
&= \frac{X(\Lambda_{1,...,n}) - (X(\Lambda_{1,...,n}) - 1)}{(X(\Lambda_{1,...,n}))^2} \\
&= \frac{1}{X(\Lambda_{1,...,n})^2} \\
&> 0, \qquad \text{(B3)}
\end{aligned}$$

where the second line follows because $\Lambda_n\frac{\partial}{\partial\Lambda_n}X(\Lambda_{1,...,n}) = \Sigma_{i=1}^{n+1}\Pi_{j=i}^{n}\Lambda_j - 1$.

To illustrate, consider the case of $n = 2$. Then

$$\begin{aligned}
\frac{\partial}{\partial\Lambda_2}\hat{t}_2^3(\Lambda_{1,2}) &= \frac{\partial}{\partial\Lambda_2}\frac{\Lambda_2}{\Lambda_1\Lambda_2+\Lambda_2+1} \\
&= \frac{\Lambda_1\Lambda_2+\Lambda_2+1-\Lambda_2(\Lambda_1+1)}{\Lambda_1\Lambda_2+\Lambda_2+1} \\
&= \frac{1}{\Lambda_1\Lambda_2+\Lambda_2+1} \\
&> 0, \qquad \text{(B4)}
\end{aligned}$$

where we substitute $\Lambda_1\Lambda_2 + \Lambda_2 + 1$ for $X(\Lambda_{1,2,3})$. □

Proposition 3 (effect of $\Lambda_1, ..., \Lambda_{n-1}$ on $\overline{r}_{n+1}(\Lambda_{1,...,n+1}) - \overline{r}_n(\Lambda_{1,...,n})$)

As $\Lambda_1, ..., \Lambda_{n-1}$ decreases, the difference *between the minimum probabilities of external exposure that unconditionally stem coverup in an $n+1$-layer hierarchy and in an n-layer hierarchy increases: $\frac{\partial}{\partial\Lambda_i}[\overline{r}^{-}_{n+1/n}] > 0$ for $\Lambda_i = \Lambda_1, ..., \Lambda_{n-1}$.*

Proof. The *difference* between the minimum probabilities of external exposure that unconditionally stem coverup in an $n+1$-layer hierarchy relative to an n-layer hierarchy is

$$\overline{r}^{-}_{n+1/n}(\Lambda_{1,...,n+1}) = \frac{\Lambda_{n+1}}{\hat{t}^{n+1}_{n+1}(\Lambda_{1,...,n})} - \frac{\Sigma^{n}_{i=1}\hat{t}^{n+1}_{i}(\Lambda_{1,...,n})}{\hat{t}^{n+1}_{n+1}(\Lambda_{1,...,n})}, \tag{B5}$$

where the equality follows from Lemma 3 and Claim B1. We proceed to show that $\frac{\partial}{\partial\Lambda_i}\overline{r}^{-}_{n+1/n}(\Lambda_{1,...,n+1}) > 0$ for $\Lambda_i = \Lambda_1, ..., \Lambda_{n-1}$.

Step 1 $\frac{\partial}{\partial\Lambda_i}\hat{t}^{n+1}_{n+1}(\Lambda_{1,...,n}) < 0$.

By Definition B1, $\hat{t}^{n+1}_{n+1}(\Lambda_{1,...,n}) = \frac{L_{n+1}}{\Sigma^{n+1}_{i=1}L_i} = (\Sigma^{n+1}_{i=1}\Pi^{n}_{j=i}\Lambda_j)^{-1}$. Partially differentiating with respect to Λ_i gives

$$\begin{aligned}\frac{\partial}{\partial\Lambda_i}\hat{t}^{n+1}_{n+1}(\Lambda_{1,...,n}) &= -\hat{t}^{n+1}_{n+1}(\Lambda_{1,...,n})^2 \times \frac{\partial}{\partial\Lambda_i}\Sigma^{n+1}_{i=1}\Pi^{n}_{j=i}\Lambda_j \\ &= -\hat{t}^{n+1}_{n+1}(\Lambda_{1,...,n})^2 \times \frac{\Pi^{n}_{j=i+1}\Lambda_j}{\hat{t}^{i}_{i}(\Lambda_{1,...,i-1})} \\ &< 0, \end{aligned} \tag{B6}$$

where $\frac{1}{\hat{t}^{i}_{i}(\Lambda_{1,...,i-1})} = \Sigma^{i}_{j=1}\Pi^{i-1}_{k=j}\Lambda_j$.[36]

Step 2 $\frac{\partial}{\partial\Lambda_i}[\overline{r}^{-}_{n+1/n}(\Lambda_1, ..., \Lambda_{n+1})] < 0$.

Partially differentiating the minuend and subtrahend of $\overline{r}_{n+1;n}(\Lambda_{1,...,n+1})$ with respect to $\Lambda_i \in \{\Lambda_1, ..., \Lambda_{n-1}\}$ we get

$$\frac{\partial}{\partial\Lambda_i}\frac{\Lambda_{n+1}}{\hat{t}^{n+1}_{n+1}(\Lambda_{1,...,n})} = -\frac{\Lambda_{n+1}\frac{\partial}{\partial\Lambda_i}\hat{t}^{n+1}_{n+1}(\Lambda_{1,...,n})}{\hat{t}^{n+1}_{n+1}(\Lambda_{1,...,n})^2} > 0, \tag{B7}$$

and

$$\frac{\partial}{\partial\Lambda_i}\frac{\Sigma^{n}_{i=1}\hat{t}^{n+1}_{i}(\Lambda_{1,...,n})}{\hat{t}^{n+1}_{n+1}(\Lambda_{1,...,n})} = -\frac{\frac{\partial}{\partial\Lambda_i}\hat{t}^{n+1}_{n+1}(\Lambda_{1,...,n})}{\hat{t}^{n+1}_{n+1}(\Lambda_{1,...,n})^2} > 0, \tag{B8}$$

after substituting $1 - \hat{t}^{n+1}_{n+1}(\Lambda_{1,...,n})$ for $\Sigma^{n}_{i=1}\hat{t}^{n+1}_{i}(\Lambda_{1,...,n})$.

Eqs. (B7) and (B8) imply that an increase in $\Lambda_1, ..., \Lambda_{n-1}$ increases the minimum probability of external exposure that unconditionally stems coverup in both $n+1$-layer and n-layer hierarchies. However, because $\Lambda_{n+1} < 1$, it follows that $\frac{\partial}{\partial\Lambda_i}\overline{r}_{n+1}(\Lambda_1, ..., \Lambda_{n+1}) < \frac{\partial}{\partial\Lambda_i}\overline{r}_{n}(\Lambda_1, ..., \Lambda_{n})$. An decrease in Λ_i therefore increases the difference $\overline{r}^{-}_{n+1/n}(\Lambda_{1,...,n+1})$. □

[36] For example, for $n = 3$,

$$\frac{\Pi^{3}_{j=i+1}\Lambda_j}{\hat{t}^{i}_{i}(\Lambda_{1,...,i-1})} = \begin{cases} \Lambda_2\Lambda_3\Lambda_4 & \text{for } i = 1 \\ (\Lambda_1 + 1)\Lambda_3\Lambda_4 & \text{for } i = 2 \\ (\Lambda_1\Lambda_2 + \Lambda_2 + 1)\Lambda_4 & \text{for } i = 3. \end{cases}$$

To illustrate Propositions 2 and 3, we compare relative coverup incentives in a 2-layer versus 3-layer hierarchy.

Example B1 (coverup incentives in a 2- versus 3-layer hiearchy)

(1) As Λ_2 decreases or as Λ_3 increases, the ratio *between the minimum probabilities of external exposure that unconditionally stem coverup in a 3-layer hierarchy and in a 2-layer hierarchy increases: $\frac{\partial}{\partial \Lambda_3}\overline{r}^{\div}_{3/2}(\Lambda_{1,2,3}) > 0$ and $\frac{\partial}{\partial \Lambda_2}\overline{r}^{\div}_{3/2}(\Lambda_{1,2,3}) < 0$; and*

(2) As Λ_1 decreases, the difference *between the minimum probabilities of external exposure that unconditionally stem coverup in an $n+1$-layer hierarchy and in an n-layer hierarchy increases: $\frac{\partial}{\partial \Lambda_1}\overline{r}^{-}_{3/2}(\Lambda_{1,2,3}) < 0$.*

For $n = 2$

$$\overline{r}^{\div}_{3/2}(\Lambda_{1,2,3}) = \frac{\Lambda_3(1+\Lambda_1)}{\Lambda_2(\Lambda_1\Lambda_2+\Lambda_2+1)}$$

and

$$\overline{r}^{-}_{3/2}(\Lambda_{1,2,3}) = \Lambda_3 - (\Lambda_1\Lambda_2+\Lambda_2)(1-\Lambda_3).$$

(1) Partially differentiating $\overline{r}^{\div}_{3/2}(\Lambda_{1,2,3})$ with respect to Λ_3 gives

$$\frac{\partial}{\partial \Lambda_i}\overline{r}^{\div}_{3/2}(\Lambda_{1,2,3}) = \begin{cases} \frac{1}{\Lambda_3}\overline{r}^{\div}_{3/2}(\Lambda_{1,2,3})(\Lambda_{1,2,3}) > 0 & \text{for } i=1 \\ -\overline{r}^{\div}_{3/2}(\Lambda_{1,2,3})^2 \times \overline{r}_2(\Lambda_{1,2}) \overbrace{+}^{} \times \left(\frac{\partial}{\partial \Lambda_2}\overline{r}_3(\Lambda_{1,2,3})^{-1}\right) \times \frac{\Lambda_3}{(\Lambda_2)^2} < 0 & \text{for } i=2 \\ \frac{\Lambda_3}{\Lambda_2}\overline{r}_3(\Lambda_{1,2,3})^2 > 0 & \text{for } i=3. \end{cases}$$

(2) Partially differentiating $\overline{r}^{-}_{3/2}(\Lambda_{1,2,3})$ with respect to Λ_1 gives

$$\frac{\partial}{\partial \Lambda_1}\overline{r}^{-}_{3/2}(\Lambda_{1,2,3}) = -(1-\Lambda_3)\Lambda_2 < 0.$$

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