Overshooting of (Useful) Cultural Practices

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Prior research has traditionally examined how useful practices spread in organizations and how they develop over time. However, it has been observed that practices can "overshoot," either because there is over-diffusion—some agents adopt to the detriment of organizational performance—or because there is over-sophistication—the practice is overly developed, becoming too elaborate and reducing organizational performance. Independent models of over-diffusion and over-sophistication have been proposed; this paper integrates both aspects in a simple and unified model of overshooting. We offer a cultural evolution model that studies how interaction dynamics among employees are able to diffuse and stabilize an equilibrium of under-performing cultural practices, and at the same time, over-develop the practice so its sophistication goes beyond productive levels. People adopt practices from others based on information about the practice's true productive value (including its decreasing marginal return as it diffuses), but also influenced by social dynamics with other employees, such as social pressure and status. Our model clarifies under which circumstances over-diffusion and over-sophistication can happen, and how these two elements of overshooting relate to one another. We map our model in detail to two cases: process management practices (e.g., six sigma) and Uber's aggressive culture.

Key words: culture, cultural practices, over-diffusion, over-sophistication, runaway effect, cultural evolution theory, dynamic model, multilevel model

1. Introduction

Operations management (OM) has examined processes and methods that organizations introduce in order to enhance performance or efficiency—they can be examined with respect to costs, risks and benefits, similar to investments. However, processes are not only formal methods and procedures but also organizational, and thus social, artifacts, which pose issues of psychology and culture (Hopp 2018, 2005).

Management scholars have long examined cultural practices, defined broadly as the individual or group behavior that is learned socially from others (Szulanski (1996), Argote (2024), Nicolini et al. (2022), Schein (2010), Henrich (2016), Boyd and Richerson (1985), Brahm and Poblete (2024), Loch et al. (2025b)). Cultural practices usually include behavior that is tacit (hard to explain in words), informal (hard to contract for and enforce), and socially transmitted between peers; however, they also include explicit and formally specified behavior, as well as behavior acquired vertically (from bosses/leaders), as long as the transmission is social/cultural, that is, it happens via learning from others (rather than imposed/enforced via authority/contract). This broad definition includes individually transmitted behavioral traits, such as techniques, skills, or behavioral norms, and collective behavior, such as processes, routines, or resource allocation criteria.

Most frequently, cultural practices are assumed to be adopted by firms and organizational members because they help firms to be more productive (consistent with the view in OM). In economics, the assumption is either one of selecting practices via rational foresight, as in organizational economics (Gibbons and Roberts 2013), or because selection weeds out firms with worse practices (Jovanovic 1982). In organizational learning, while transmission of practices may be faulty, they are always deemed useful for the adopter (Argote and Ingram 2000, Argote 2024). In organizational culture, Schein (2010) has a strong functional view of cultural practices, as those that persist and are transmitted to new organizational members because they work.

However, there is a strand of the literature that indicates that good practices may "over-diffuse," being adopted by firms or organizational members although they are detrimental to their productivity (Abrahamson and Rosenkopf 1993, 1997, Piazza and Abrahamson 2020). Systematic empirical evidence (Pierce and Aguinis 2013) has referred to this phenomenon, the turning bad of initially good practices, as the "too much of a good thing" (TMGT) effect. A classic case, highlighted by Benner and Tushman (2003), is the adoption of process management practices (e.g., TQM, lean, six sigma), which tend to be productive when applied to the manufacturing areas of the firm but to backfire when applied to more innovation-oriented activities, such as R&D, marketing, and product development. A few formal models exist in management that examine over-diffusion, but they have some limitations. Abrahamson and Rosenkopf (1993) use a combination of a bandwagon effect (social and legitimacy pressures dominate as more organizations adopt a practice) and ambiguity

(an absence of objective productivity measurements to counteract social pressures). This model becomes a "fads" model because ambiguity and social pressure are too strong. The second model is Vermeulen (2018a), which does not include social pressure but assumes that a practice is unproductive from the get-go and diffuses only because somehow the organization and its members are mistaken and perceive it as productive because of ambiguity. This model does not allow for good practices to go bad as they diffuse, or for the absence of ambiguity.[1]

Further, cultural practices, in addition to over-diffusion, may also be subject to "over-sophistication", meaning they become elaborated to a level of complexity (or fanciness) that they become less useful or even detrimental over time. The anthropological literature shows this can be the case, providing examples from several cultures around the globe, such as the Moai statue construction on Easter Island, and harm-inducing tattooing and resource-wasting production of oversize yams in parts of Polynesia. Boyd and Richerson (1985) developed models of "cultural runaway traits", that is, traits that develop beyond any reasonable level of usefulness to the point of endangering the survival of the group. This model builds on the well-known existence of runaway traits in biology, such as the size of the peacock's tail or giant antlers of the extinct Irish elk. However, the Boyd and Richerson model is too complex to make parsimonious managerial predictions in organizations. Further, no systematic evidence has been collected of this phenomenon in management. Nonetheless, there is no shortage of documented case studies. For example, Isaac (2019) documents how the organizational culture and its associated practices in Uber (the ride-hailing company) underwent a ratcheting process in which its initial "competitive, move fast and go-get-them" culture—which was useful in an environment that rewarded first-mover advantage—slowly turned into a hyper competitive, win-at-all-cost, unethical, and toxic culture that allowed no dissent and ultimately threatened the very survival of the company. The example clearly suggests that fads are not the only culprit, but an elaboration of initially sensible behaviors that then become exaggerated and dysfunctional (we link this example to our model in Section 6).

We offer a cultural evolution model in which practices that offer a higher fitness (or payoff) to organizational members slowly diffuse through imitation, and in which organizational members may pay a cost to innovate in order to increase the sophistication of the practice. Difference in fitness between an established and a new, more sophisticated practice is driven by a change in productivity and cost of effort, and a social interaction payoff we label "status" (from doing what others do or from the inherent legitimacy of the practice). Productivity is subject to decreasing returns as more agents adopt it, and the status payoff that a practice provides is reduced with its

[1] Another type of model, in the tradition of game theory, is provided by Kreps et al. (1990), Gibbons (2006), and Gibbons and Henderson (2012), in which social interactions can produce stable and persistent heterogeneity in practices, some good and some bad, across groups/organizations. Young (2015) provides the analogous evolutionary version of the multiple equilibria story.

adoption. The productivity and effort payoffs—the gap between these constitute the organization's profit—are assumed to be decreasing and increasing, respectively, with respect to sophistication; thus, there is a level of sophistication that maximizes profits.

Our model generates several findings. First, we find that a new practice diffuses when the benefits provided by its added productivity (net of decreasing returns) and status benefit overcome its added cost. Second, compared to a fully informed principal that can optimize, there is over-diffusion of the practice in the evolutionary equilibrium, that is, the equilibrium that arises when agents slowly copy over time those agents that fare better. This over-diffusion arises because of two reasons. On the one hand, agents are attracted to the practice by status although it is immaterial for firm profits; on the other, even if status is absent, over-diffusion may occur because agents do not fully incorporate the negative externality they impose on others through benefit dilution. Third, an innovator introduces a new practice of higher sophistication when the benefit of being the first adopter (as described in the first result) overcomes the cost of innovating. More importantly, over-sophistication (new practices introduced beyond the optimal sophistication) arises whenever the status benefit (after decreasing returns of a practice) is higher than the cost of innovating. Decreasing returns provide more "room" for an innovation, because productivity of the baseline practice has decreased as it diffused. Taken together, the second and third results indicate that overshooting of both kinds—over-diffusion and over-sophistication—can happen even if the practice's returns are knowingly negative, provided that the status benefit is large enough; moreover, it also indicates that even if status benefits are absent, overshooting can happen due to the presence of adoption dilution.

Fourth, we find that as the sophistication level increases, the equilibrium level of diffusion is reduced and thus, the over-sophistication reduces the level of over-diffusion. Fifth, we show that a "runaway" scenario—the practice is driven to its technical sophistication limit and is used by everyone—is *only* possible when status benefits are sufficiently high (and cannot happen only through adoption dilution). Sixth, if we add causal ambiguity—payoffs are not perceived by agents to be deteriorating—and bandwagon effects—in which social pressure increases with the adoption of the practices (rather than decreasing with adoption as in status concerns)—to our model, then equilibrium diffusion and sophistication of a practice further increase. Notice these two ingredients are central to the previous models of over-diffusion (see Abrahamson and Rosenkopf (1993), Vermeulen (2018a)), and thus, our model shows that practice overshooting can happen more generally than the previous models proposed.

Overall, the model in this paper integrates the two aspects of overshooting, over-diffusion and over-sophistication, into one parsimonious model with common elements and forces. It expands previous models of over-diffusion by making it less dependent on overly strong social pressure

(derived from legitimacy concerns) and ambiguity (c.f., Abrahamson and Rosenkopf (1993, 1997)) and misperception (c.f., Vermeulen (2018a)), allowing for over-diffusion driven by status concerns and decreasing returns, even if lower productivity is observable by agents; it also provides a workable representation of over-sophistication (simpler than Boyd and Richerson (1985)). The identified drivers of over-diffusion and over-sophistication can serve as guides for managerial intervention; the findings offer hypotheses that can be empirically tested in further work.

We map our model and its findings to two well documented cases. First, we show how our model can explain the documented overshooting of "Process Management Practices" such as TQM, Lean, and Six Sigma (Benner and Tushman 2003). We illuminate two aspects of this case that remained unexplained: i) diffusion beyond manufacturing into areas such as innovation and R&D occurred even though the detrimental effect on firm performance were likely known, ii) the historical sequence of process management practices did not unfold as fad-like dynamic with no progression (as they were viewed by Abrahamson and Rosenkopf (1993, 1997)), but really reflected an increase in sophistication of these practices (which also led to a reduction in their diffusion). Second, we map our model to the 2018 crisis in Uber, and show that instead of the wide-spread "bad leader" narrative, in which Uber's crash was a consequence of its founder and CEO's character, it is much more likely that the social-dynamic gears that we laid out in our model were at play, and that social pressure was strong enough to generate a full runaway dynamic that threatened the survival of the firm.

After discussing previous work in Section 2, Section 3 introduces a motivating example, IBM's overshooting in bureaucracy. Section 4 presents our multilevel dynamic model in two parts: first we present a model of over diffusion, and then we incorporate how the level of elaboration or sophistication evolves over time. In Section 4 we also discuss further insights and extensions, such as over-sophistication reducing over-diffusion and the role of ambiguity. Section 5 maps the model to real world cases, process management practices and the aggressive culture at UBER, which we discuss in detail. These cases provide realism and illustrate how the model can be practice-relevant. Finally, Section 6 summarizes with a general discussion and conclusion.

2. Related Prior Work

We have identified two streams of relevant modeling work. The first has its origins in evolutionary anthropology and has sought to formalize and understand how culturally encoded behaviors may become exaggerated in society and organizations, that is, over-sophistication (this tracks work on genetic traits in biology, where the term "runaway traits" is used). The second stream of work has modeled why practices may over-diffuse in organizations to the point where they become detrimental to organizational performance.

Overall, this review shows that: i) only a couple of models have examined over-sophistication, focusing on cultural traits without any application to organizations; ii) two types of models have considered over-diffusion of practices, and they identify only two specific contributing factors: either strong social pressures (the bandwagon effect), leading to 'faddish" adoption of a practice, or a mistaken perception of a practice's usefulness when it really is detrimental; and iii) there is plenty of empirical evidence for over-diffusion, but only sparse case evidence for over-sophistication.

2.1. Models of Runaway Traits

In biology, the concept of traits that can experience runaway cycles has been well understood since the early work by Fisher (1930). The basic idea is that sexual selection may boost traits that are useful in obtaining mates but possibly detrimental to survival. The classic example is that of the giant antlers (weighing up to 50 kg and measuring 4 m across) of the Irish elk, which became extinct 7,700 years ago because the massive antlers helped males in mating fights but made them too slow to evade or fight predators. Boyd and Richerson (1985) were the first to generate a formal cultural evolutionary theory (CET) model of runaway trait dynamics in human culture. Individuals copy several traits of another individual (behavior, beliefs, techniques, tools, customs, etc.) based on a prestigious "signal" trait displayed by the other individual, for example, the number of successful hunts. This imitation dynamic with relentless competition may lead to over-hunting, which is wasteful (because the meat cannot even all be processed), and moreover, it crowds out other useful activities. The term "runaway cycle" refers to a situation where the over-hunting becomes unchecked by internal correcting forces, growing without limit until it endangers the survival of the tribe. The authors provide examples in aboriginal cultures that fit this model, such as widespread and harm-inducing tattooing and resource-wasting production of oversize yams in parts of Polynesia.

Cultural evolution literature has continued to acknowledge that prestige bias in learning from others (which helps individuals not in actual mating fights but in ritualized symbolic social competition) can generate maladaptive traits in society (Richerson and Boyd (2008), Henrich (2016)). Runaway traits have been cited to explain the evolution of human cooperation (Nesse (2007, 2016) and other social traits (Crespi et al. 2022, Rendell et al. 2011). This literature has not further developed Boyd and Richerson's original model of runaway traits. One reason is that this model is complex and not easy to extend. We propose a simpler model of diffusion with runaway dynamics; we use only one trait with prestige-biased imitation, as well as an impact on organizational performance.

A key idea, namely that exaggerated consumption or action may be caused by social comparison, was elaborated by the economist Robert Frank (Frank 1985, 2001, 2012, Heffetz and Frank 2011).

Inspired by evolutionary ideas, he provided a formal model of positional goods, in which the benefit/utility of the good for the user depends on whether others can use it too. For example, the benefit of wearing a new luxury suit in a job interview depends on the quality of the suits of the other applicants. A social dilemma arises: each individual has the incentive to consume more of the good (buy a more expensive suit) in order to get an edge (or avoid a disadvantage), but all individuals would be better off by limiting their consumption. Notice there is no need for a bias (although it may help), but simply an incentive problem created by people paying attention to relative positions. Frank's model is static and does not allow for a runaway dynamic, but it contains the core phenomenon of a social dilemma fueled by a relative evaluation. Our model is explicitly evolutionary and contains two-dimensional comparisons in the domain of organizations.

2.2. Models of the Adoption of Detrimental Practices

In this section we review three models that study why organizations may adopt detrimental practices but do not consider runaway dynamics. The first is the concept of multiple equilibria in organizational culture. This literature studies cultural practices whose content and/or diffusion is informal or reflects beliefs and values (Chatman and O'Reilly (2016), Schein (2010)). A part of this literature uses game theory to identify cultural practices as stable self-enforcing equilibrium outcomes of interactions among organizational members (Kreps et al. (1990), Gibbons and Henderson (2012), Hermalin (2013)). These scholars emphasize that interaction dynamics can diffuse and stabilize different combinations of behaviors, as a result of which many organizations may get stuck in a bad (underperforming) equilibrium of Gibbons (2006), Gibbons and Henderson (2012), Kreps et al. (1990). Thus, this work also (like ours) departs from the "functional" flavor of mainstream organizational culture research in which useful cultural practices are selected (Schein 2010). However, this practice-as-interaction equilibrium view implicitly assumes that among multiple possible equilibria, the ones that arise are random and can therefore be inferior. Our model also takes a game theory approach (of an evolutionary bent), but goes beyond the notion of multiple equilibria to consider how systematic and well-known behavioral characteristics can favor certain interaction equilibria; we also examine adoption (diffusion) and sophistication simultaneously.[2]

Second, Vermeulen (2018a) uses a simulation model in which a detrimental practice may persistently be adopted by organizations (the organization is the unit of analysis in the context of an industry) when i) the practice is spuriously related to performance (although in reality it may not be), ii) there is causal ambiguity (i.e., it is hard to know whether and how the practice relates to

[2] There is a line of research using evolutionary game theory that makes sense of harmful societal norms, such as foot-binding and dueling, using the same idea of norms as self-enforcing patterns of behavior/practices; see the review by Young (2015). Models in cultural evolution lay out the social influence forces, as well as the complications, that have to be navigated to dislodge these harmful practices Efferson et al. (2020).

performance), and iii) the practice diffuses faster than it kills the host organization (analogous to a virus). The author provides several examples from management literature (also see the book Vermeulen (2018b)), and detrimental practices in the medical field, for example, *in vitro* fertilization services. We are consistent with Vermeulen in focusing on organizations and in considering the evolution of a practice. We depart in that our focus is on the social dynamics inside an organization, our model doesn't require causal ambiguity, we use a formal model with closed form solutions, and our model goes beyond practices that are always detrimental (as assumed by Vermeulen), considering practices that are initially beneficial but become detrimental when they are overused and over-elaborated.

Third, a literature in organization theory has studied and modeled "management fashion and fads" (see the review by Piazza and Abrahamson (2020)), the notion that management practices are adopted not (only) rationally but (also) in the manner of trends, to be abandoned when the"next big thing" comes along. A bandwagon model of this type was proposed by Abrahamson and Rosenkopf (1993, 1997) (focusing on an inter-organizational level of analysis, but the dynamics are parallel to our intra-organizational analysis): A sufficient number of adopters creates social bandwagon pressure, which captures the legitimacy and mimetic pressures by stakeholders (and community members) (DiMaggio et al. 1983, Selznick 1996) and which may override a cost–benefit analysis of the practice.[3] The model requires causal ambiguity of the practice, because otherwise the practice may not take off initially when there are no adopters and no social pressure. As more organizations adopt, there comes a point where even organizations for whom the economic benefit is negative will adopt the practice because of the strength of the bandwagon effect. This model can explain the diffusion of a practice, although it focuses on just one of the possible drivers. Piazza and Abrahamson (2020) reviews evidence consistent with this two-stage adoption process. For example, Tolbert and Zucker (1983) shows how civil service reform (e.g., procedures, training, and insulation from politics) was adopted by US cities at the turn of the 19th century. They show that the first cities adopted civil service reforms as rational efficiency enhancements, but later city adopters simply followed legitimate organizational practice.

The crucial difference with our model is how a sequence of practices in a population is conceptualized. We model this as an evolution of practice adoption over time (where diffusion, as well as sophistication of the practice, changes with the organization); the fads approach, in contrast, sees the progression of practices as subsequent bandwagons that occur one after the other: once a practice has invaded and become stable, with the help of causal ambiguity, a new practice can

[3] The "old" version of institutional theory would be willing to see a "functional" element present in these legitimacy pressures, which are thus ultimately related to economic value. The "new version" spearheaded by DiMaggio et al. (1983) instead sees these pressures as based on conventional symbols that don't carry any functionality and are unrelated to economic value.

acquire legitimacy and displace the old one.[4]. This is due to the strength of bandwagon pressure, which increases with the number of other organizations having adopted. Just a small number of new adopters (especially if they are more prestigious) can be sufficient to tilt the balance toward a new practice. In contrast, in our case, the "social pressure" depends much less strongly on how many others have adopted than in bandwagon models; we believe this is a more plausible assumption in within-firm dynamics. This difference is not trivial. Take the historical sequence of kaizen, quality circles, TQM, ISO, six sigma, lean, and lean six sigma. Our model interprets this as an increase in practice sophistication (see Section 5), whereas the fads literature interprets these as unrelated fads, as reiterations of old operation principles under new guises (see Piazza and Abrahamson (2020)).

A final, more subtle, difference is the role of ambiguity, as we have mentioned earlier. Our model does not require ambiguity—practice overuse can happen even if performance effects are visible, but ambiguity can exacerbate the runaway effect because it dulls the available corrective considerations (see Section 5).[5]

2.3. Empirical Evidence

The field of management has collected evidence of practices that were adopted although they were detrimental to performance. A prominent example is total quality management (TQM), ISO, lean, kaizen, six sigma, and related process management practices. Benner and Tushman (2003, 2002), Benner and Veloso (2008) provide thorough reviews of the performance impact of these methodologies. As these practices spread inside organizations, became entrenched, and increased sophistication, operational efficiency improved, but at the cost of a decreased capacity to innovate, adapt, and explore. The overall net long-term result was not infrequently negative (especially in times of a changing environment). A modern related example is the discipline of "agile," which was developed in coding and then spread to other domains and functions inside organizations (for example, general project management), its usefulness becoming less than clear and sometimes detrimental (Rigby et al. 2018).

Vermeulen (2018a) provides several well-documented examples of adoptions of detrimental practices. One example is *in vitro* fertilization in the UK: the success rates of clinics were public information, and thus clinics had an incentive to select easier cases (e.g., women in their 20s) to

[4] This literature argues that new management practices are disproportionately introduced by entities with an interest in diffusing new practices, such as consultants, gurus, academics, and centers. This is related to our corollaries after Proposition 2 in Section 5.

[5] A paper closely related to ours is Feylessoufi et al. (2024). Like we do, they model the adoption of practices inside an organization using evolutionary game theory, where productivity benefits and social comparison affect adoption. While they find that there can be over-adoption of a practice, they focus on how firms can navigate the process of adoption via proper calibration of incentives and upfront training.

be able to publicize high rates. This practice of selection spread across many clinics, but it had the unintended negative consequence of making those clinics less competitive in the long run (Stan and Vermeulen 2013). Vermeulen (2018a) proposes in his book the idea of innovating by"subtracting," meaning a capability to systematically prune (suspectedly) unproductive practices.

Pierce and Aguinis (2013) document the existence of a widespread "too-much-of-a-good thing effect" (TMGT). This effect describes a pattern in which practices start out with "seemingly monotonic positive relations with performance, [but they] reach context-specific inflection points after which the relations turn asymptotic and often negative" (p. 313). The authors document this across many management practices, such as structures of control and of individual consideration from leaders; enriching jobs with more autonomy, responsibility, and meaning; hiring applicants with more experience; formal planning in new ventures or startups; organizational identification of employees; and organizational citizenship behavior. The authors conclude that "The TMGT effect accounts for an apparent paradox in organizational life: ordinarily beneficial antecedents causing harm when taken too far" (p. 314).

2.4. Non-Detrimental Practices in Management

The two most influential bodies of research addressing the diffusion of practices in organizations are the organizational learning literature (Argote and Ingram 2000, Argote 2012, Argote et al. 2021) and the communities of practice literature (Lave and Wenger 1991). They provide a rich understanding of knowledge and practice transfer or sharing in organizations and communities (see the recent reviews by Argote (2024), Nicolini et al. (2022)). However, neither has engaged with the evidence summarized in the last two sections; they have not studied how detrimental practices spread, or whether and why practices may become detrimental as they spread or as their sophistication increases. While they do mention that practices may have decreasing returns, experience complications in their diffusion, and may be forgotten if not used, in general they conceptualize cultural practices as beneficial when adopted.

3. Motivating Example: Presentation Practices at IBM

Before diving into the formal model, we motivate its importance by showcasing a bureaucratic practice at IBM in the 1980s, which overshot its usage to the point where it became detrimental (Gerstner 2003, Tufte 2006). The practice consists of the formal presentation style (with supporting technology) at the company.

It is possible to distinguish three eras. First, in the Watson era (the 1950s and 1960s), precision, uniformity, and formality in communication and presentation were prioritized, reflecting the personal values of Thomas J. Watson Sr. and Jr. the presentation format was simple: typed or

printed slides for overhead projectors, structured outlines, no visual flair, a formal and deferential-to-authority tone, and a strict dress code (dark suits, white shirts, conservative ties). During the mainframe dominance era of the 1970s, technical and bureaucratic rigor increased in the presentations: text-heavy slides with dense technical jargon; flowcharts, system diagrams, and performance tables were common; IBM used proprietary tools like Graphpak and Script/VS; scripts had no storytelling—just facts, forecasts, and features; the emphasis was placed on precision over persuasion, and presenters were expected to "know the numbers" and avoid speculation. The third era was in the 1980s, in which the bureaucratic style peaked. Presentations became bloated, with slides decks often exceeding 100 slides with exhaustive detail. An elaborate and dense technical jargon, acronyms, and internal IBM language evolved, filling out the presentations. Presentations typically began with an organizational chart, showing where the presenter fit in the hierarchy—emphasizing internal status over content relevance. A specific lingo arose for presentations: "Crisp up, tweak, and swizzle" (polishing a presentation foil), "Level-set" (aligning understanding at the start of a meeting), "Down-level" (referring to an outdated version of a document).

This presentation style practice developed alongside an accompanying formalized disagreement ritual, the "non-concur," which slowed or even paralyzed decision-making (we describe this, along with the wider cultural background, in Appendix 1).

4. A Multilevel Dynamic Model of Practice Overshooting

This section provides the details of our multilevel dynamic model of practice overshooting. We split the presentation of the model into two parts. The first subsection examines practice over-diffusion—how a practice of a given sophistication diffuses through an organization to areas where it shouldn't. The second subsection models a practice's sophistication—the degree of fanciness (or elaboration) of the practice—and how rewards and efforts may promote over-sophistication (which may, in turn, also affect diffusion). We illustrate the model throughout using our motivating IBM presentations example.

4.1. The First Model: Diffusion of a Practice

We take the level of sophistication of the practice as fixed for now. This implictly supposes that diffusion happens relatively quickly, relative to the evolution of the practice's sophistication—this is a reasonable approximation, as the evolution of sophistication often involves technology, which takes longer to introduce.

In terms of our motivating example, we look at a situation where a new presentation method has become available, say, powerpoint slides, in an organization where people would normally give an oral report and possibly hand out a photocopied table with numbers. But someone is introducing

the use of powerpoint slides to the organization having seen them somewhere else. The model suggests some conditions under which this practice might spread or not, and to what extent.

We use a mechanism that has been widely used in models of cultural evolution, where individuals meet at random points in time and imitate practices they observe and perceive to be superior to their own. In our situation, this corresponds to employees giving presentations to one another in meetings of various sizes. The meetings are scheduled according to work requirements, which are unrelated to who uses what presentation style; therefore, we can treat the meeting encounters (for the purpose of imitation of presentation style) as random.

From a meeting, agents (employees) obtain an outcome as a function of their presentation styles; these outcomes depend on the functional performance of the presentation style, but also on a comparison between their own presentations and their peers'. After a meeting, agents may possibly change their presentation styles for the next round of meetings (perhaps once a month). It is important to note here that a critical feature of cultural dynamics is that the agents decide themselves whether to adopt (imitate) a practice they have encountered. They do so partially influenced by organizational rewards, but also by social dynamics among their peers—if the practice was completely imposed and monitored by processes or by management, we would not have cultural dynamics. In practice, the adoption of many practices is heavily influenced by cultural dynamics, even in cases where some official process guidelines exist.

The dynamics of how the use of the practice evolves in this organization depends on how the agents perceive their payoffs. In a given period, let's call the share of agents using practice 0 (the oral report) p_0, so the share of agents using practice P (Powerpoint) is $p_P = (1 - p_0)$. The payoff, or "fitness," for an agent from choosing a practice in interactions with colleagues has two components: First, some reflection of "performance," for example, a successful presentation with impact, which will create a positive evaluation from management. Second, employees compare themselves to others in using practices, which may confer social status (consistent with previous work in organizational theory).[6] Equation (1) describes the payoffs from different choices of presentation by a given agent.

$$f(0) = \beta - p_0 c - p_P s \tag{1}$$

$$f(P) = \beta - e + \Pi - p_p c + p_0 s \tag{2}$$

Agents using any type of practice enjoy a baseline productivity β that avoids negative fitnesses (a standard assumption in cultural evolution models). The fitness of using the old practice, $f(0)$,

[6] Status rests on a favorable comparison with others based on any socially recognized marker. This may be based on an idiosyncratic claim of "doing something differently from others", but also on a sense of legitimacy of the practice itself, as seen by the organization. It is important to note here that we use legitimacy not in the sense of Abrahamson and Rosenkopf (1993), who see it being based on how many other people use the practice, which directly leads to a bandwagon, or social pressure that increases with adoption levels. We use legitimacy as resting, with status, on the practice, and therefore not necessarily increasing with the level of adoption.

reduces the baseline value for an employee. It confers a status disadvantage $-s$ for the fraction of agents p_P who actually do use the new presentation style, compared to whom the focal employee will have a social status disadvantage. And finally the performance is discounted by $-cp_0$, as more colleagues use the practice generates a dilution effect: many practices are most productive for the first few users, but subsequent usage is less well tuned to the additional users' needs, or they are less qualified, so productivity per head diminishes as more and more marginal users are included.

The fitness from using the new presentation practice is $f(P)$. The agent needs to spend extra effort, e, to use the better presentation (developing a professional powerpoint presentation costs more time than orally reporting with a few data tables), and in turn the presentation has a higher performance (versus the old style) of Π. As with the old practice, this performance is discounted by $-cp_P$, as more colleagues that use the new practice generate a dilution effect. Finally, the agent reaps the social status benefit only for the fraction p_0 of colleagues who use the old practice (or the old presentation style).

This way of writing payoffs is an average, or aggregated, description of the typical payoff for an agent who chooses the associated action. This is standard in cultural evolution models. Appendix 7.2 shows how the same payoffs arise from a description of individual interactions when people meet one-on-one; there, we also discuss other possible ways of deriving these payoffs.

With these fitnesses, we can now estimate how the practice spreads: it is natural to suppose that agents tend to (gradually) migrate toward the more successful strategy, and this is precisely the usual rule of change in cultural evolution, known as "replicator dynamics" (here we include time indices to express that this is the change from one period to the next):

$$\frac{d}{dt}p_P(t) = k[p_P(t)p_0(t)][f(P,t) - f(0,t)]. \tag{3}$$

This describes the dynamics of a partial migration of some agents after one round from the lower-payoff practice toward the higher-payoff practice: a fraction of randomly chosen agents decide to switch in a period. k is a scalar (if k is small, the adjustment will occur slowly). By the structure of this dynamic law, both shares are always bounded between 0 and 1.

We now have the pieces in place to understand under which circumstances the new practice, P, might be adopted at all, and under which circumstances it might be adopted by a part of or the entire agent population, and under which circumstances adoption might be an "overuse," that is, when it is higher in equilibrium than would be most productive for the organization.

As can be observed from Equation (3), this depends on the difference between the fitness of the old and new practices. This difference is:

$$f(P) - f(0) = -e + \Pi - (p_P - p_0)c + s. \tag{4}$$

This fitness difference for the innovator, or the first to introduce the new practice (the PowerPoint slides) into the organization (so $p_P = 0$), is $-e + \Pi + c + s$. Adoption takes place when agents observe that the innovator performs better than other people in the organization. This happens if the net performance benefit (productivity minus extra effort) from using the undiluted new practice versus the diluted old practice, boosted by the status benefit, s, and the dilution, c, in practice 0, is positive.[7] This means that advantageous and "cool" new practices can still fail to take hold if the effort from using them is just too great. For example, the use of deep-learning AI to write letters and summarize texts before the arrival of ChatGPT was so laborious (one had to study how deep learning networks function) that the technologies were not adopted (even though they could already provide at least some of the benefits). Only when ChatGPT made usage much less laborious, did its usage spread.

Full adoption takes place if for every share of users, people employing the new practice perform better. Since the productivity benefit per person of the new practice decreases with dilution, the test is whether there is still an advantage at full adoption, $p_P = 1$. This is the case if $-e + \Pi + s - c > 0$, or, in other words if the status benefit continues to outweigh the effort of producing the new practice even with dilution at the maximum level.

Between these diffusion extremes, when $c > |s - e + \Pi|$, diffusion of the practice will only be partial. Adopters will spread until the fitness difference between them in Equation (4) disappears. The equilibrium becomes:

$$\hat{p}_P = \frac{s - e + \Pi}{2c} + 1/2 \text{ (equilibrium adoption)} \quad (5)$$

$$\Pi - e = c(p_p - p_0) - s \text{ (equilibrium productivity per agent)} \quad (6)$$

$$f(0) = f(P) = -c + (c - s)(\frac{s - e + \Pi}{2c} + 1/2) + \beta \text{ (equilibrium agent fitness including status).} \quad (7)$$

Now we can ask whether the organization might be overusing the practice in any of these three equilibria, obtaining lower than possible productivity. This is indeed possible: Obviously, there is no overuse in the no-adoption equilibrium. But in the partial adoption equilibrium, we can ask what the *optimal* adoption percentage would be, which would maximize the productivity of the practice for the organization (note that this excludes status, which is a perception by the agents).

The optimal level solves $max_{p_0} f(0) + p_p f(P)$ with s set to zero.[8] This optimal adoption would be $p_P^* = \frac{-e+\Pi}{4c} + 1/2$. It can easily be seen that $p_P^* < \hat{p}_P$. Therefore, we can conclude that the

[7] The dilution, c, captures the fact that those doing worse with the previous practice have more room to gain from adopting the new practice at first. This may be unrealistic if agents that don't benefit from practice 0, for example because they're novices, are also less likely to benefit from P and thus won't be the first group to adopt. However, all insights remained unchanged if Equation (1) does not include the term $p_0 * c$. This case would mean that the original practice doesn't have decreasing returns from over-diffusion, which is also unrealistic. We believe the reality lies between these two cases.

[8] In our specific model, changes due to s cancel each other out between $f(0)$ and $f(p)$, so it is not strictly required to set $s = 0$. But, in general, this is required, as s is not a payoff that the organizations cares about.

spontaneous cultural diffusion of the practice will result in adoption being higher than is productive. The reason is that the users of the practice get an extra status "kickback" when they interact with non-users. This result is consistent with a classic observation in CET, which is known as "Roger's Paradox": diffusion of a practice may be too high if left to unguided culture.

But overuse can also happen in the full adoption case: From Equation (13), fitness at $p_P = 1$ becomes $-e + \Pi - c$, because social status benefits disappear and performance is diluted when everyone uses it. So there is overuse with full implementation whenever $e > \Pi - c$ and $e < \Pi - c + s$. This can become *negative* if the dilution, c, is large enough.

Figure 1 illustrates how the model works. Panel A shows an internal equilibrium (the practice diffusion where the two fitnesses cross, at $p_P = 0.75$), and panel B shows a full diffusion equilibrium (where agents would still switch to P). In A, the optimum diffusion is at $p_P = 0.57$; in B, the optimum diffusion is at $p_P = 0.67$.

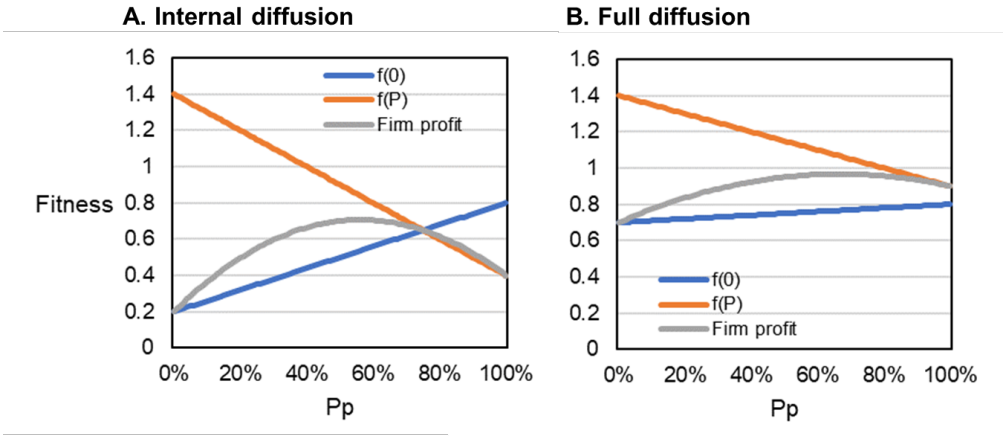

Figure 1 **Illustration of internal and full diffusion.** In both panels, the blue and orange lines track the fitnesses of practice 0 and P, respectively. The gray line tracks aggregate fitness. Panel **A** has parameters $s = 0.2$, $e = 0.6$, $\Pi = 0.8$, and $c = 0.8$. Panel **B** changes the decreasing return to $c = 0.3$.

We summarize these findings in Proposition 1 (with formal proof in Appendix 7.3).

PROPOSITION 1. *Suppose agents routinely use an established practice, 0 (the use of oral presentations in our motivating example), and one agent introduces a new practice, P (PowerPoint slides). Suppose agents meet at random intervals using one of the two practices, the payoffs from the interchange are described by Equations (1–2) and the specifications underneath, and the agents change their presentation choice from one period to the next according to the dynamic law in Equation (3).*

Then the following equilibria can arise (all of them are evolutionary stable, ESS[9]): (1) No Adoption. $p_P = 0$ *in equilibrium if* $s - e + \Pi + c \leq 0$. *(2) Interior Equilibrium. The new practice will be accepted by at least some agents if the benefit of the first agent from using the practice* $s - e + \Pi + c > 0$. *The practice will be adopted by an equilibrium fraction as described in Equation (5), if* $-c < s - e + \Pi < c$. *(3) Full Adoption. All agents will adopt the practice in equilibrium if* $s - e + \Pi > c$.

In an interior equilibrium, the organization is overusing the practice, that is, the adoption level that would maximize the organization's payoff is lower. This is also the case at full adoption, if $e > \Pi - c$. □

4.2. Evolving Practice Sophistication in a Two-Level Model

In the previous section we argued that it is possible for a managerial practice to spread through the organization to the point of overuse (too many users, including marginal ones). But we took the *level of sophistication* of the practice as constant. We now endogenize the level of sophistication and show how diffusion and sophistication interact.

Suppose the organization has (via diffusion, as described in the previous section) arrived at a widespread use of the practice, not at the "yes versus no" level but at some level of sophistication that we refer to as l.

Now suppose that an innovator discovers a small improvement, δ, in the level of sophistication, for example by seeing a presentation in another organization or by being sent a demonstration (this is analogous to the innovator of the previous section, only that the innovation is not all-or-nothing but a small improvement). Discovering this improvement costs the innovator an effort (investment) of i. We assume for simplicity that this investment cost in the innovation is constant, but the model works in the same way if the cost increases in the level of sophistication already achieved, because further improvements tend to become more involved.

An innovation, in the context of our presentation example, may be the introduction of animations, or free-drawing graphics, or the embedding of a video. The innovation has two effects. First, it changes performance. However, more is not necessarily better: some additional sophistication improves presentation clarity and performance, but too much *reduces* performance, for example, by overloading the presentation with too many complexities or by making special effects so slick that they distract from the core messages.

Therefore, we now take the productivity and effort functions Π and e as differentiable functions of sophistication, $\Pi(l)$ and $e(l)$. Let's suppose $\Pi(l)$ has decreasing returns, so it is concave (consistent

[9] ESS, or evolutionary stable equilibrium, is a more stringent equilibrium than a Nash equilibrium: not only does no participant unilaterally want to change, but moreover, this equilibrium cannot be moved by entrants with a different strategy. We show a formal proof of the proposition and of the ESS characteristic in Appendix 7.3.

with observations in the literature that there can be "too much of a good thing"), and the effort $e(l)$ is convex, so that overall return from the technology as a function of the level of sophistication $-e(l)+\Pi(l)$ is concave, with a unique maximum at l^*. This implies that the derivative $-e'(l)+\Pi'(l)$ is decreasing positive if $l<l^*$, zero at $l=l^*$ and negative for $l>l^*$.

There is a maximum possible level of sophistication, $\bar{l}$. This limit might be imposed by technical or cost considerations, or it might be imposed by the performance deterioration from the exaggerated sophistication level, which threatens the organization's viability. The key is that the limit is exogenously imposed. In our discussion example, it could be that very sophisticated presentation effects require the screen resolution to be higher than the budget of the organization allows. Note that our model allows a situation where $l^*>\bar{l}$, that is, the organization *could* benefit from even higher sophistication of the practice if it were feasible. This is a case where the practice is indeed beneficial, regardless of how far the level of sophistication is advanced. But this is often not the case, because practices driven very far tend to be costly, inflexible, or confusing.

As before, introducing the new level of sophistication allows agents that use it to enjoy a status level, s, that is decreasing with the proportion of people using it.

The sequence of events in the model is now as follows: Each period starts with some distribution over levels of sophistication, l (this corresponds to the absence of the practice in the model of adoption in the last section, but now is the ESS from the previous period that might be full or partial adoption of the previous practice level). At the beginning of the period, an improvement innovation, δ, might enter the population with one innovator, just like in the previous section, but with a small sophistication increase.

Now the diffusion unfolds as described in the model of the last section, including possible non-adoption, only that Π and e are now functions of the sophistication level $l+\delta$, as specified. By the end of the period, the population converges to an ESS equilibrium through imitation, as described in the previous model.

To simplify the exposition, we first assume that the status quo or 'starting point" in every period is a situation where everybody has the same level of sophistication, l; we show in the appendix that under reasonable assumptions the same result holds if the starting point is one of partial adoption.

The fitness functions are now similar to those in the previous section, with the difference that benefits from the practice are a function of the level of sophistication. We need to understand the conditions under which the innovator is willing to invest i to obtain the sophistication. We assume delta is small, so that for any function, $f(l+\delta)-f(l)$ can be approximated by $\delta f'(l)$. Fitness levels are now as follows.

$$f(l) = \beta - e(l) + \Pi(l) - sp_{l+\delta} - cp_l \tag{8}$$
$$f(l+\delta) = \beta - e(l+\delta) + \Pi(l+\delta) + sp_l - cp_{l+\delta}$$
$$f(l+\delta) - f(l) = s + \delta(-e'(l) + \Pi'(l)) - (p_{l+\delta} - p_l) * c.$$

There are three terms in the difference, all with a straightforward interpretation. The first is the status benefit from using the better practice. The second is the total return of the practice (productivity enhancement minus the effort of using it), and the third is the decrease in productivity when more (and less productive) people use the practice.

The innovator does not yet have to face the productivity deterioration from less appropriate users, so the condition for the inventor to invest expresses that the payoff must exceed the investment:

$$s + \delta(-e'(l) + \Pi'(l)) + c > i. \tag{9}$$

Observe that from the previous section we had that the adoption condition is $s + \delta(-e'(l) + \Pi'(l)) + c > 0$, so there will always be some level of adoption if there is a practice innovation.

In a way analogous to the previous section, we can show that Proposition 1 holds in this setting. With partial adoption, the diffusion extent is always greater than optimal. And full adoption takes place in conditions in which partial adoption is optimal.

Now we are in the position to examine whether the risk of overusage of a practice is mitigated or acerbated by endogenizing the sophistication level of the practice by introduction by an innovator. We check how far innovators are willing to go in pushing sophistication upwards.

The condition $s + \delta(-e'(l) + \Pi'(l)) + c > i$, can be understood as a stopping rule. As long as the condition holds, innovators will continue to increase the level of sophistication. Observe that the left-hand side of the equation is a linear transformation of a decreasing function, and therefore it is decreasing. Whether the sophistication will be excessive or not depends on a simple condition. If $s + \delta(-e'(l^*) + \Pi'(l^*)) + c > i$, then at the optimal level of sophistication the innovators continue to introduce more (over-)sophistication. Finally, observe that, given our assumptions, $\delta(-e'(l^*) + \Pi'(l^*) = 0$, and so the condition for excessive sophistication can be simplified to $s + c > i$. Whenever there is enough status ("kudos" from colleagues or praise by the manager), some innovator will bring additional sophistication increments into the practice.

There are now two cases of too much sophistication in equilibrium. If $\delta(-e'(\bar{l}) + \Pi'(\bar{l}) + s + c > i$, then the innovation process never stops until it reaches the technical maximum. This may be because the net productivity improvement (after effort cost) is indeed so advantageous that this is in the interest of the organization. But it may also be the case that the individual status or legitimacy

benefits of the innovators make the difference and motivate further sophistication increments, even if it is not productive to do so.

If this condition holds, then the process of innovation stops only at the maximum feasible sophistication, $\bar{l} > \hat{l} > l^*$ beyond the optimal level.[10]

Before we can characterize the equilibrium, it is necessary to characterize the conditions for full adoption in this setting. Full adoption requires the difference in fitness to be positive at $p_p = 1$, that is it requires $s + \delta(-e'(l) + \Pi'(l)) - c > 0$. Since the derivative is decreasing in l, it becomes more and more difficult for the innovation to be fully implemented in the organization as the level of sophistication increases. In other words, at higher sophistication of the practice, we expect more partial adoption (and if so, lower adoption) in equilibrium.

However, if $c < i$, that is, the dilution of productivity from more inappropriate users is small compared to the investment necessary to introduce the sophistication innovation, then there is always full adoption. In other words, the level of sophistication grows until it runs into the external feasibility limit, AND any sophistication level is always fully adopted by the entire organization. This is the runaway scenario, where the practice becomes sophisticated without end and with everyone swept along.

We can now characterize the equilibria of the two-tier model, both in terms of level of sophistication and of diffusion, as follows. Suppose the organization starts with a sophistication level of zero, and then an innovator introduces a sophistication level l. Then the equilibrium sophistication, $\hat{l}$ and equilibrium diffusion, $\hat{p}$ are characterized in Proposition 2 (formal proof in Appendix 7.4).

PROPOSITION 2. *Suppose in every period an innovator can choose to introduce a slightly higher sophistication level of the practice (from l to $l+\delta$) into the organization. If the practice improvement is introduced, it spreads according to the diffusion dynamics of Proposition 1. Then after sufficient periods, there are two sophistication equilibria, $\bar{l}$ and $\hat{l}$, and within each, two possible diffusion equilibria, $\hat{p}_P$ (excluding non-adoption), as shown in Table 1. All equilibria are ESS.* □

We show in Appendix 7.5 that if the status quo has two levels of sophistication, the resulting ESS is the same as if only one level is present.

4.3. Extensions

Proposition 1 states that whenever there is an interior diffusion equilibrium (where part of the organization adopts the practice), this equilibrium exhibits overuse: the adoption of the practice is higher than optimal for productivity because adoption offers the agent a chance to enjoy a status, or legitimacy, benefit (when meeting with a less sophisticated adopter).

[10] These two results are directly analogous to the model by Boyd and Richerson (1985:266–267). In the runaway equilibrium, the practice "wants to" grow beyond the externally imposed technical limit.

Table 1 Equilibrium cases

	Interior sophistication $(\hat{l} < \bar{l})$ (if $\delta[\Pi'(\hat{l}) - e'(\hat{l})] + s + c = i$)	***Sophistication at upper limit*** $(\bar{l})$ (if $\delta[\Pi'(\bar{l}) - e'(\bar{l})] + s + c \geq i$)
Interior diffusion $(\hat{p}_{l+\delta} < 1)$	if $c > s + \delta[\Pi(\hat{l}) - e(\hat{l})] > -c$, then $\hat{p}_{l+\delta} = \frac{s+\delta[-e'(\hat{l})+\Pi'(\hat{l})]}{2c} + \frac{1}{2}$	if $c > s + \delta[\Pi(\bar{l}) - e(\bar{l})] > -c$, then $\hat{p}_{l+\delta} = \frac{s+\delta[-e'(\bar{l})+\Pi'(\bar{l})]}{2c} + \frac{1}{2}$
Full diffusion $(\hat{p}_{l+\delta} = 1)$	if $s + \delta[\Pi(\hat{l}) - e(\hat{l})] \geq c$, then $\hat{p}_{l+\delta} = 1$	if $s + \delta[\Pi(\bar{l}) - e(\bar{l})] \geq c$, then $\hat{p}_{l+\delta} = 1$

However, the higher the level of sophistication in equilibrium, the lower is the net productivity benefit of adoption for an agent, $[-e'(\hat{l}) + \Pi'(\hat{l})]$, because of the decreasing returns of the practice and the increasing effort of adoption. Therefore, the following corollary holds.

Corollary 1: Diffusion Becomes Harder with Increasing Sophistication. As the sophistication level increases, the equilibrium adoption level decreases. In other words, as the practice spirals to higher sophistication, full adoption becomes harder to achieve. If the status benefit of adoption or the agent is high enough to make up for the productivity deterioration from higher sophistication and from the spread to lower-productivity users, full adoption remains possible. We illustrate Corollary 1 in Figure 2.

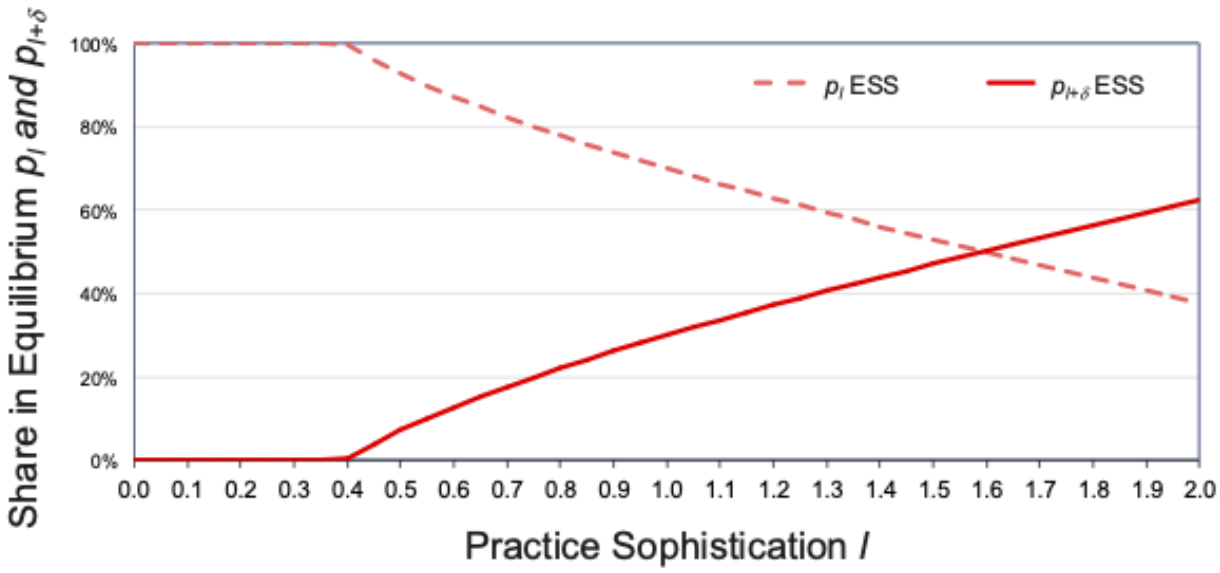

Figure 2 **Illustration of Corollary 1.** As sophistication increases, the equilibrium share of the new practice $p_{(l+\delta)}$ decreases, while the share of the old practice, p_l, increases. To model e and π as a function of l, we use: $e(l) = 0.3 + l^2/2$ and $\pi(l) = 0.5 + 2 * \sqrt{\pi}$. The function $\pi(l) - e(l)$ is positive between $l = 0$ and $l = 2.6$, with a maximum in $l = 1$. We assume $\delta = 0.05$.

Corollary 2. Runaway Scenario: In our terminology, a runaway scenario means that the practice is driven to its technical sophistication limit *and* is used by everyone. This happens in bottom right quadrant of proposition 2's table: if the status benefit s from a more sophisticated practice plus the difference between (diminishing) marginal productivity benefit and marginal cost $(\Pi'(\hat{l}) - e'(\hat{l}))$ plus the decreasing return c of the practice outweighs the innovation costs i, *and* if the status s plus the marginal productivity $(\Pi'(\hat{l}) - e'(\hat{l}))$ outweighs the decreasing returns c. Notice that beyond optimal sophistication the term $\Pi'(\hat{l}) - e'(\hat{l})$ is negative, and thus, if $s = 0$ there is no possible runaway because $c \geq 0$ and thus the full diffusion condition is not satisfied. In other words, the runaway scenario only occurs due to status: when it is so strong that the practice dominates behavior beyond all reasonable productivity bounds.

The interpretation is that agents, although quite possibly aware that the practice is, at this point, unproductive, are so seduced by the use of the practice enabling them to shine, or be legitimate, compared to others, that they adopt it anyway. This is not as unusual as one may think; we give an example in the next section, and academic readers may think of using an advanced research method even in cases where it is not necessary and does not add value.

At this point, we stress that our results do not require the presence of causal ambiguity of the productivity function or of a bandwagon effect. Causal ambiguity in our model can be represented by a productivity function, Π, that does not deteriorate with sophistication and/or the absence of a marginal user productivity deterioration, c, because productivity data are noisy. A bandwagon effect in our model corresponds to the status or legitimacy benefit, s, increasing in adoption (the more people have adopted, the stronger the network benefit becomes). Both phenomena make runaway practices more likely to occur, growing the risk of a runaway effect, but neither is necessary.

Corollary 3: Causal Ambiguity and Bandwagon Effects. In the presence of causal ambiguity (agents do not perceive that Π deteriorates with increasing sophistication) or a bandwagon effect (status s increases as a function of diffusion p_P), equilibrium diffusion and sophistication of a practice increase.

This result creates a direct connection between our model and previous theoretical accounts of practice diffusion in management literature (Abrahamson and Rosenkopf 1993, Vermeulen 2018). Our results suggest that runaway practices can happen more generally than they realized.

Corollary 3 also has a direct connection to Corollary 1. When practice sophistication has already developed, achieving wide diffusion becomes harder because of the decreasing returns of adoption. This can, however, be counteracted by either causal ambiguity or by a bandwagon effect (Corollary

3). This creates an incentive for the innovators, or for external parties who would like to "sell" the practice (or some software that enables the practice's adoption), to "advertise" the practice with an artificially boosted bandwagon, or by obfuscating the real productivity benefits of the practice.

Corollary 4: Adoption Dilution Enables a Sophistication Increase. Proposition 2 also suggests that when a practice has a higher level of dilution from diffusion (when less appropriate users adopt the practice), this leads to a higher likelihood of (over)sophistication (larger dilution provides 'more room" for the innovator to shine with a slightly improved practice), but at the same time, it leads to lower levels of (over)diffusion. In contrast to higher status, which would drive stronger over-shooting of both types, higher adoption dilution leads to more over-sophisticated practices that diffuse less—smaller "pockets" of the firm becoming "fancier".

In summary, our model has immediately relevant managerial implications: (1) Create an acknowledgment of the legitimacy and status of using the practice, in order to get it off the ground. (2) However, the organization should make a continuing effort to keep evaluating the productivity benefits of the practice as it evolves and diffuses (estimate the performance function, $\Pi - e$, and the deterioration from wider usage, c), so the status effect does not lead to overuse as the productivity of the practice runs into decreasing returns or into causal ambiguity. (3) The organization should actively discourage a bandwagon effect of increasing status from network effects or advertising, because this exaggerates the status pull towards ever-increasing sophistication. In particular, senior managers should avoid falling into the trap of encouraging exaggerated status for the usage of a practice that they like, as this is almost a guarantee of encouraging a large , or even a runaway effect. These managerial recommendations are empirically testable.

5. Examples

In this section, we present two real examples that illustrate different aspects of the dynamics presented in the models. We draw these examples from academic literature, books, and business press articles. We restrict these examples to well-documented cases, which allow us to provide a rich account. The first example is of interior sophistication (left panel in Proposition 2); and the second example illustrates runaway sophistication (right panel in Proposition 2). All of the important quantities of the model are summarized in Table 2.

5.1. Interior Sophistication: Process Management Practices

Process management practices view organizations as collections of processes, or activities that, taken together, produce output for customers, which can be external (end customers) or internal (another department) (Benner and Tushman 2003). These practices involve "concerted efforts to

Table 2 Summary of examples

	Process Management Practices	**Aggressive Culture at UBER**
Π	Improved yields, productivity, and quality well documented for manufacturing/operations.	Moving fast, breaking things and saying sorry, and bold/competitive ethos support race for market share and network economies.
s	Practice promotes adherence to and mastery of the method, and the firm's formal strategy further promotes normative pressures and prestige.	Heavy shadow of CEO Kalanick paired with strong formal and informal pressures to behave according to culture.
c	When the practice diffused beyond manufacturing into areas such as R&D and support functions, it stifled innovation and adaptation. Diffusion occurred despite known penalty.	As Uber grew, clear negative impact of culture in new back-office functions such as HR and legal (but less detrimental than over-sophistication).
l	The sequence kaizen, TQM, ISO, lean, six sigma, BRP, and lean six sigma represent increases in sophistication. Probably some over-sophistication but no runaway.	Ratcheting-up in culture's intensity from 2010 to 2017 crisis, despite early warnings of dysfunction by 2016.
e, i	Considerable costs of diffusing the practice, e.g., up to 1.5% of wage bill.	Considerable wellbeing and mental health costs, especially minorities, as well as costs of non-compliance with the law.
New insight	1) Diffusion beyond manufacturing although reduction of benefits was known. 2) Historical sequence of practices is not fad-like (with no progression), but an increase in sophistication with lower diffusion.	Dominant narrative of Uber's crash being Kalanik's doing is incomplete; instead, runaway cultural gears were set in motion, which were very costly to undo after CEO's departure.

map, improve and adhere to processes" (ibid, p. 238), and "using measures of process effectiveness and statistical methods to continually eliminate variation in processes and outputs" (ibid, p. 240). They come under different names, such as kaizen, TQM, lean, ISO, six sigma, and business process re-engineering (BPR). While they have differences, "they share a core focus on measuring, improving, and rationalizing organizational processes" (ibid, 240).

The benefits of process management practices include: i) increased yields and productivity, ii) less rework, iii) fewer non-value added activities, iv) streamlining handoffs, v) more consistent and higher quality, and vi) increased customer satisfaction. These benefits have been documented by academic research and practitioner reports in manufacturing and related core/primary processes (the areas for which these techniques were primarily designed). Thus, connecting to our model, at first, implementing these practices provides a clear positive Π.

Status s**.** Process management practices share the principle of promoting the adherence to organizational processes. This focus on adherence generates a normative pressure to employees, which can easily generate an additional social benefit to employees if they adhere and employ the practice (such as reputation or admiration), or a social penalty if they don't. Companies, in the pursuit of adoption, can create formal instances that buttress and propel this social process. For example, General Electric CEO Jack Welch pushed the six sigma methodology as part of GE's culture and identity; a hierarchy of experts was created (e.g., green belts, black belts, master black belts) carrying a badge of honor and prestige; and promotions and appointment to important projects required six sigma certification.[11]

Diffusion $p_{l+\delta}$**.** Adoption of six sigma practices was at first constrained to their original domain of manufacturing, logistics, and operations. But amid the pressure for others to also be seen to contribute, they spread to all other domains of the organizations, such as accounting and finance, R&D, marketing, human resources, and corporate development. Benner and Tushman (2003) documents how frequent full adoption became in the 1990s, especially at GE, where it included all areas.

Diffusion Dilution c**.** Academic research in the 1990s and 2000s struggled to find the performance benefits of adopting these practices for the whole organization (Benner and Tushman 2003), which was surprising given the benefits that had initially been documented for operations and manufacturing. The reason behind this puzzle is that as the methods spread into R&D, marketing, and product development, they stifled innovation and adaptation capacity, because TQM methods focus on measurable efficiency and variance reduction, driving out at least some of the risky activities associated with innovation and flexible adaptation (Benner and Tushman 2003). In particular, radical innovation (more than incremental innovation) was significantly affected by process management practices. An example is lean project management, which is at best useful in perfectly predictable projects of very limited novelty, but it suffocates novel projects where more ambitious outcomes are desired (Loch et al. 2025a).

Strikingly, over-diffusion happened in spite of managers having, through experience and measurement, as well as accompanying academic research, a grasp of the impact of the dilution from marginal users, c, on the practice's productivity, Π. Given the measurement focus of TQM practices, it is unlikely that firms did not know of the dilution from over-diffusion. But diffusion was not stopped—although the reasons have never been openly discussed, we can imagine that perhaps senior managers wanted to keep the motivation from a common endeavor, or individual social benefits overrode decision-making for everyone.

[11] Another source of status and prestige from the adoption of these practices was via instances such as the prestigious and highly sought-after Malcom Balridge National Award for companies excelling in TQM, and the certification ISO 9001 becoming necessary to conduct business with governments, large companies, and others.

Sophistication Increase δ. New process improvement practices clearly experienced a progression and sophistication increase over time. They had their origins in the 1950s and 1960s in Japan with the movement of continuous improvement (kaizen). In the 1970s and 1980s, these practices were enshrined in TQM, which gained a reputation and spread widely in the US, Europe and other developed economies. In the 1980s and 1990s, lean manufacturing (developed at Toyota) diffused in the West; six sigma was developed at Motorola and championed by General Electric, and spread quickly in the 1990s and early 2000s; the ISO 9000 quality certification became a growing international standard from the 1990s onwards; and finally, BPR gained traction in the same period. Each built upon or responded to the limitations of its predecessors, often adding structure, analytical depth, or broader applicability. Kaizen is about small, daily improvements driven by employees in a decentralized way. TQM formalized kaizen into a *cultural philosophy* that integrated quality into every aspect of the organization. ISO 9001 formalized this by providing a formal certification framework. Lean complemented TQM by directing its focus to the *removal of waste and non-value-adding activities*, continuously streamlining processes rather than taking them for granted. Then, business process re-engineering went beyond incrementalism, specifically TQM, and strove to *design processes from scratch* to radically improve performance. In contrast, the focus of Six Sigma was adding more *statistical rigor* to TQM. Many companies went through these stages, adopting sequentially different practices. Specifically, GE used TQM programs in the 1980s before the adoption of six sigma. They pioneered *lean six sigma* practices in the early 2000s, which combined lean's focus on speed and waste reduction with six sigma's emphasis on quality and statistical control. While prior literature conceptualized this historical sequence of practices as fads, all reincarnating the same principles in different guises without any progression, our model provides a rationale for how they built on one another in a procession of increasing sophistication. Finally, notice that our model predicts that increased sophistication means a reduction in equilibrium diffusion (corollary 1). This seems to be in place in process management practices: the more sophisticated "lean six sigma" diffused to fewer firms than either it predecessors did ("lean" or "six sigma"), and ISO 9001 diffused to fewer firms that is predecessor TQM.

Sophistication Upper Limit $\bar{l}$. Process management practices might have increased their sophistication in the 2010s (e.g., adding big data, increasingly sophisticated analytics, machine learning, or AI). However, this is not the case. After 2010s, they stagnated. This suggests that the stopping condition for sophistication in Proposition 2 might have been met. The combination of wide diffusion with increasing the bureaucratization of marginal additions became so costly that many companies stopped further expansions or even pulled back.

Specifically, the costs of process management practices, both the investment of introducing new variants (term i in the model) and the effort cost of executing them (term e in the model), in

training and problem-solving time, have been considerable. For example, training for control charts or statistics takes several weeks of employee time plus instruction cost; a six sigma project may take a month of employee time—in some plants that we know, workers spend almost 50% of their time on training and project work rather than the assembly line (with labor cost representing only 3% of product cost, this only amounts to 1.5% of product costs, but it is still a major item in a plant's budget). Therefore, the costs of these practices were sufficiently high to prevent a runaway effect—they may have over-diffused (and maybe over-elaborated as in the case of lean six sigma), but there is no evidence that practices ran into a technical or organization-threatening limit.

5.2. Maximum Sophistication: Aggressive Culture at Uber

Maximum sophistication $\bar{l}$ is an exogenous limit to sophistication. This may be a technical limit that company procedures or economics impose, or it may be drastic managerial action when a runaway evolution of the practice may affect the organization in a significative way, including threatening its viability.

This example builds on extensive public information about Uber and the detailed account of Uber's rise and the 2017 crisis by Isaac (2019). Uber's organizational culture, in the first few years after its founding in 2009, displayed a typical Silicon Valley startup ethos: fast, aggressive, and disruptive. In particular, Uber's culture could be summarized in the following four beliefs: *Engineering excellence and user experience* (the team was laser-focused on solving pain points for riders and drivers through excelling tech), *speed prioritized over perfection* (rapid iteration and deployment were prioritized over polished processes), *disruption was a core value* (rebels against incumbents, breaking rules to innovate, operating with an "ask forgiveness, not permission" mindset), and *meritocracy with edge* (ideas and assertiveness mattered, but so did aggression, confrontation, all-in mindset and competitiveness).

This culture worked because it matched the economic challenge the company was facing. Strong network economies in the ride-hailing business meant that only one or two players would become dominant in given geographical areas (cities, states/regions, countries). Thus, moving fast, being willing to say sorry rather than ask for permission, and having a hyped and highly bold/competitive ethos, were useful. In the terminology of our model, the Π of the culture was positive at the start.

Given the importance of growth, scale, and network economies in Uber's early days, increases in intensity of the four beliefs were probably still useful: in our model's terminology, $l < l^*$ and thus $\Pi'(l) > 0$). Therefore, it is not surprising that the cultural grew in intensity. This increase was reflected in several "mantras" that evolved inside Uber as it grew: *"Always be hustling"* (employees were encouraged to push boundaries, often at the expense of rules and norms), *"toe-stepping"* (encouraging employees to challenge others, even if it meant being confrontational), *"principled*

confrontation" (framed as a value, but often led to hostile interactions), and *"super-pumped"* (a term used internally to describe the intense, all-in mentality expected of employees).

Status and Legitimacy s. The intensity of the Uber culture grew, also supported by legitimacy considerations and social and normative pressures. Behaving according to the culture was actively encouraged and rewarded. Founder and CEO Travis Kalanick had a strong, centralized leadership style, and the culture reflected its bold, confrontational, and non-apologetically ambitious style. Dissent was often discouraged. Relative performance rankings were aggressively used. Success was often rewarded regardless of how it was achieved. Loyalty to leadership was valued over collaboration or ethical concerns. Leadership tolerated or ignored complaints (creating a hostile environment for many, especially women). In other words, the magnitude of the social rewards, s, was high, and thus the stage was set to support further increases in l despite it going beyond l^*.

The overshooting of the sophistication (or here, rather, intensity) of the cultural dynamics was reflected in several warning signs that became clear (and public) by the mid-2010s: Employees were expected to be constantly available and deliver results under pressure; burnout was common and turnover was high; Uber slowly became known for its cut-throat internal culture, where performance was prioritized over ethics or collaboration; the company often entered markets without legal clearance; Uber frequently clashed with regulators and local governments; and reports of sexism, harassment, and inappropriate behavior started to bubble up.

There was clearly also over-diffusion of the culture: As the company grew, new back-office areas, such as HR, finance/accounting, and legal/compliance, also had to adopt the practices of an aggressive, careless, growth-driven culture, but its benefits in support functions were even less positive, and more detrimental, than in the core sales and business development areas.

But the sophistication overshooting was the most damaging. It caused a reckoning in 2017, when CEO Travis Kalanick was forced to resign. This happened after a series of scandals and controversies that severely damaged the company's reputation and internal culture:

- *Sexual Harassment Allegations.* A former (female) employee published a blog post in February 2017, detailing systemic sexual harassment and discrimination and a toxic workplace culture.
- *Greyball Program.* Uber was caught using a secret software tool called Greyball to evade law enforcement in cities where its service was restricted or banned.
- *Legal Battles and Regulatory Pressure.* Uber faced multiple lawsuits, including one from Google's Waymo over alleged theft of trade secrets. The company became heavily scrutinized by regulators around the world for its aggressive expansion tactics.
- *Public Relations Disasters.* Kalanick's behavior became public. For example, a video surfaced showing him arguing with an Uber driver about falling fares, where he looked out of touch with his own workforce.

• *Toxic Corporate Culture.* An internal investigation led by former US Attorney Eric Holder found widespread issues with Uber's culture, including a lack of diversity, poor leadership practices, and tolerance of inappropriate behavior.

After the crisis, SoftBank acquired a 15% stake in Uber with a 30% discount; this quantifies the *reduction in value,* Π*,* as the aggressive cultural practices overshot beyond l^*.

In the general business press, the story of Uber's clash is characterized as a consequence of CEO Travis Kalanick's personality and style, reflected in the company's culture. However, our model suggests that, while leaders play an important role in setting the culture, the wheels of a cultural runaway process provide the lever that affects the entire organization. The leader influences the elements of the runaway, for example in setting up formal/informal pressures reflected in s and p_p. But the overshooting dynamic also requires the gradual behavior adjustment of 6,000 employees (Uber's size in 2015) in a way described by our model. Consistent with this diagnosis, the turnaround after Kalanick's departure was slow and extremely laborious, involving a cultural overhaul that included making old Uber loyalists redundant, deep structural/operational changes, and much symbolic work with internal and external audiences (Isaac 2019).

6. Discussion and Conclusion

The adoption and overshooting of cultural practices has been a puzzle in operations and management research. Practices are adopted, in principle, to enable an organization to achieve higher performance. New practices often do offer advantages to the organization, but there is ample evidence that they easily overshoot, or are over-used, and become too much of a good thing (Pierce and Aguinis 2013). Management theory has not produced robust explanations for why organizations engage in such over-adoption. The two main drivers proposed are the bandwagon, or social pressure for conformity that grows with the number of users (Abrahamson and Rosenkopf 1993, 1997), and causal ambiguity, or the inability of the organization to measure and recognize when a practice's performance value diminishes (Vermeulen 2018a). Although these drivers may sometimes be at work, they at best represent partial isolated effects, not necessary for overshooting to occur, and they do not offer a compelling explanation of the possible fundamental organizational drivers that lie behind overshooting.

This paper has developed a theory of the overshooting of practices. The theory builds on established insights of when trait runaway dynamics occur in biology, and it shows with what modifications this phenomenon also applies in cultural practices in organizations. In biology, a runaway effect fundamentally requires two objective functions to be at work in parallel: the survival fitness and the offspring production fitness of the organism. Because of sexual selection, the two may differ and pull in different directions: the long and heavy tail of the male peacock increases the bird's mating chances but represents a significant survival challenge for the bird in evading predators.

Our theory develops the idea that an analogous interplay between two objective functions can be found in the evolution of practices: First, practices are introduced in organizations for performance reasons, analogous to survival fitness in biology. Indeed, if the performance considerations of a widely entrenched practice are sidelined, the very survival of the organization (or of the management team) may be at stake. But second, practices cause social comparisons of legitimacy, organizational compliance, and sophistication status, which may drive adoption even when the adopters are no longer adding value, and an increase in practice sophistication even when the exaggerated sophistication level is no longer effective. This may not take the form of a bandwagon (i.e., the status benefit may not increase with the number of users), and there may be no causal ambiguity—it may be known that performance is no longer served, but people will want to be part of the highly regarded adopter group anyway (and management may not want to demotivate people). Just like a runaway dynamic of traits in biology may cause species to go extinct, runaway practices may damage organizations—we have shown one example in which practice overshooting likely contributed to the exchange of the senior management team.

Our theory includes practice (productivity) performance that has diminishing returns as a function of its sophistication and as a function of wide diffusion (dilution when marginal users keep joining), it includes an effort and investment cost of introducing the practice that may increase in sophistication, and it includes a status or legitimacy benefit for the adopting agents from joining an organizational activity that is positively regarded. This is the minimal set of influences that span a fundamental explanation of where overshooting comes from. With this theoretical understanding, additional idiosyncratic influences can be added to the theory without falling into disjointed, isolated partial accounts. In summary, this theory offers the potential to change the question of overshooting practices from a theoretical puzzle (and isolated partial accounts) into a coherent body of explanations that can be empirically tested and then modified and expanded.

The theory also offers direct managerial implications; for example, management can make sure it is aware of how far the status benefit dimension of the practice for adopters deviates from the productivity performance dimension of the practice, and if the two grow too far apart, cultural work may be required to counter-steer. We have given three industrial examples, and we suggest here, in the conclusion, that this may also be relevant in management research. Every few years, the discussion of the "ivory tower" research in business schools flares up. It is related to a cultural evolution of "research theory and methods sophistication" being subject to the drivers of overshooting that we have described. Business academics are evaluated on theory production and methods sophistication. This was certainly useful for enhancing the standing of business schools originally (in the 1960s). But it may have reached a point where it may threaten the performance

of a business school, if we accept this performance should be related to an ability to teach practitioners concepts that help them to better manage, and to influence managerial practice. There is evidence that at least some business research (end even teaching) has moved away from practitioner relevance toward basic social science research (as performed in psychology, sociology, and economics). Applying this theory to our own profession by collecting structured empirical evidence for or against the theory in this article may be of value to business research.

Models are only the first step of further studies, subject to empirical testing and then refinement (or rejection). Empirical testing not of isolated phenomena but of the collection of drivers of practice overshooting is certainly necessary here. Testing the theory (with modifications) in different contexts may reveal that practice overshooting is perhaps widespread, not only in organizations but also in industries, in politics, in societies, and internationally. This raises the possibility that cultural practice overshooting may be an important and understudied contributor to widespread unproductive dynamics.

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7. Appendix

7.1. Background for the Motivating Example of IBM Presentation Style Practices

The presentation-foils practice was, of course, not the only cultural dynamic happening at IBM; rather, it was an example of a bundle of practices that led to bureaucratization. We provide some background here, providing a high-level summary of the evolution of IBM's culture (Gerstner 2003, Tufte 2006).

IBM faced a deep crisis in the late 1980s and early 1990s that threatened its viability and required a dramatic transformation, led by Gerstner. In 1991, IBM reported a loss of $2.8 billion, the largest in its history at the time. In 1992, the loss ballooned to $5 billion, setting a record for the largest annual corporate loss in US history at that point. IBM's market value plummeted by over 50% between 1987 and 1993, and 100,000 layoffs between 1991 and 1994 (unprecedented for a company priding itself on lifetime employment). The company had failed to adapt to the rise of personal computing, client–server architectures, and open systems (away from mainframes). Gerstner and other observers blamed a slow, bureaucratic, and conformist culture that had been growing inside of IBM for decades.

In the 1950s and 1960s, the early days of IBM, Thomas J. Watson instilled three basic beliefs into the company's culture: "respect for the individual," "excellence in everything we do," and "superior customer service." This was the period in which IBM built up the dominance that it would enjoy in the late 1960s, 1970s, and early 1980s. In this period, the culture slowly changed. IBM became paternalistic, with a promise of lifetime employment in return for loyalty. The belief "respect for the individual" (based on Watson's belief of treating everyone with dignity and fairness) morphed into "entitlement" and an implicit promise of job security and benefits, conflict avoidance, and resistance to change being tolerated under the guise of respect. The belief "excellence in everything we do" became excessive analysis and perfectionism. Hierarchy and bureaucracy grew: there were clear chains of command and deference to seniority; employees wore dark suits and white shirts, with dress codes becoming symbolic of discipline and order; titles and status were highly emphasized—organizational charts were central to identity; decision-making was slow and consensus-driven; and executives often "presided" over processes rather than actively leading or executing. A culture geared toward process, formality, and execution was functional while IBM was the dominant IT global player around mainframes, as market challenges were absent and thus execution was paramount (challenges came from antitrust cases in the 1970s, rather than competitors).

It is in this context that the formal presentation style practice evolved, reflecting and supporting the general formal culture. The presentation practice became even more influential because of the

non-concur discussion formalism, "non-concur" being a term for internal disagreement or vetos supported by an elaborate institutionalized practice. This could sometimes paralyze decision-making: By the late 1980s, the non-concur system formally allowed any IBM employee—at virtually any level—to register disagreement with a proposed decision or plan. By declaring non-concur, an individual or unit could effectively block or delay a decision, even if it had been developed through extensive cross-functional collaboration. There were official non-concur coordinators in each division or industry group. It was tied to IBM's strategic and commitment planning cycles, and there were guidelines and instructions for how to file a non-concur. A non-concur management system (NCMS) tracked these objections. Escalation could go all the way up to the CEO if necessary. The system was a distorted outgrowth of IBM's value of "respect for the individual." While it had started decades earlier as a way to foster constructive and respectful dissent that can foster debate, better ideas, and innovation, it had devolved over the years into a dysfunctional veto system that was frequently used for the wrong reasons and became bogged down in layers of approvals and documentation, making it harder to move quickly on new ideas. The latter term, and overall conservatism at IBM, bred defensive and risk-averse presentations.

7.2. Model Specification With Payoffs From Individual Encounters

Instead of characterizing the payoffs for the employees (agents) in the aggregate, as in the model description in the text, we may derive them from the aggregation of multiple random one-on-one encounters, each between two agents who present to each other. We can write the outcomes for the agents from one encounter as follows.

Table 3 Symmetric normal-form payoff table. (The payoffs displayed accrue to the player on the left.)

Outcomes:	**Practice 0**	**Practice P**
Practice 0	$\beta - c, \beta - c$	$\beta - s, \beta - e + \Pi + s$
Practice P	$\beta - e + \Pi + s, -s$	$\beta - e + \Pi - c, -e + \Pi - c.$

The table represents payoffs from two agents that meet. If both have the old technology production is normalized to β, and there is congestion or decreasing marginal returns from both using the same technology c. If an agent using the new technology meets an agent using the old technology the agent using the new technology exerts effort in exchange for higher productivity $-e + \Pi$ and also obtains status s, while the agent using the old technology suffers from decreased status. Finally if both choose the new technology there is no gain from status, and decreasing marginal returns appear again. If you calculate the expected fitness of an agent when the proportion of other agents choosing the new technology p, you obtain exactly the payoffs $F(P)$ and $F(0)$ presented in the body of the paper.

7.3. Proof of Proposition 1

To prove the proposition, it is useful to introduce some notation. Define a strategy in this setting as the probability p of using the new technology. Let $F(P,p) = -e+\Pi-pc+(1-p)s$ be the payoff an agent obtains in an encounter of using the new technology when the other agents follows the strategy p (that is, an expected fraction p of them use the new technology). This is exactly the same as in the body of the paper but we have included the strategy of the rest of the population explicitly. In an analogous way define $F(0,p) = -(1-p)c-ps$ for the initial technology. Then the expected payoff of an agent that uses strategy q if the rest of the population follows strategy p is $E(q,p) = qF(P,p)+(1-q)F(O,p)$. An ESS is a stricter form of a Nash equilibrium, so in this case it suffices to show that the strategies described in Proposition 1 are ESS.

Formally, Maynard Smith and Price specify two conditions for a strategy q to be an ESS. A strategy q is ESS if for all $p \neq q$, either $E(q,q) > E(p,q)$ or $E(q,q) = E(p,q)$ and $E(q,p) > E(p,p)$. We consider the three cases in the proposition.

Suppose first $s-e+\Pi+c<0$ then it is easy to check that $F(0,p) > F(P,p)$ for any p. As a result $E(0,p) > E(1,p)$ for any p and it is also true that $E(0,0) > E(p,0)$, and so $q=0$ (no adoption) satisfies the condition 1 of an ESS.

Suppose second that $s-e+\Pi > c$ then it is easy to check $F(P,p) > F(0,p)$ for any p. As a result $E(1,p) > E(0,p)$ for any p and it is also true that $E(1,1) > E(p,1)$, and so $q=1$ (full adoption) satisfies the condition 1 of an ESS.

Suppose third that $-c \leq -e+\Pi \leq c$. In this case, it is easy to check that at $\hat{p} = \frac{s-e+\Pi}{2c} + 1/2$, $F(P,\hat{p}) = F(0,\hat{p})$. Therefore, $E(\hat{p},\hat{p}) = E(q,\hat{p})$ for every q, and so the first equality of the second condition, holds.

To prove that the second inequality of the second condition holds, notice that $F(1,q)$ is decreasing in q while $F(0,q)$ is increasing in q. We will take first the case $q > \hat{p}$. Observe that by definition $E(q,q) = E(\hat{p},q) + (q-\hat{p})(F(P,q) - F(0,q))$. So, for the second inequality to hold, we must show that $F(P,q) - F(0,q) < 0$.

To prove that $F(P,q) - F(0,q) < 0$ remember that by construction $F(P,\hat{p}) - F(0,\hat{p}) = 0$ we also know that $q > \hat{p}$ and so since the first term is decreasing while the second is increasing, we know that $F(P,q) - F(0,q) < 0$ which concludes the proof. The case $q < \hat{p}$ is analogous.

7.4. Proof of Proposition 2

For a given period, following the introduction of an innovation l, the proof of the resulting ESS is exactly the same os proposition 1, provided that at most two sophistication levels can coexist, (we shoe this later) therefore we only need to show the two possible sophistication equilibria. To do this, consider the condition $s+\delta(-e'(l)+\Pi'(l))+c > i$ that determines wether an innovation

is introduced at the beginning of each period. And remember that by definition $-e(l)+\Pi(l)$ is concave and so $-e'(l)+\Pi'(l)$ is decreasing in l. If $s+\delta(-e'(\bar{l})+\Pi'(barl))+c>i$, then by the previous argument, $s+\delta(-e'(l)+\Pi'(l))+c>i$ for every l, and so sophistication never stops until it reaches its technical maximum.

If there exists $\hat{l}<\bar{l}$ so that $s+\delta(-e'(\bar{l})+\Pi'(\bar{l}))+c=1$, then by monotonicity for any $l<\hat{l}$ a new innovation is introduced and the process stops when it reaches the first $l>\hat{l}$. Because we assume marginal innovations are relatively small, this level can be approximated by $\hat{l}$.

7.5. Proof of Corollary 3

If there is ambiguity (agents do not fully perceive that Π decreases with sophistication, then "perceived" payoffs become.

$$f(l)=-e(l)+\Pi(l)-sp_{l+\delta}-cp_l \tag{10}$$
$$f(l+\delta)=-e(l+a\delta)+\Pi(l+a\delta)+sp_l-cp_{l+\delta}$$
$$f(l+\delta)-f(l)=s+a\delta(-e'(l)+\Pi'(l))-(p_{l+\delta}-p_l)*c.$$

Where a is the ambiguity parameter that takes value 1 if there is no ambiguity and value 0 under full ambiguity. In this setting, the condition for the inventor to invest expresses that the "perceived" payoff must exceed the investment:

$$s+a\delta(-e'(l)+\Pi'(l))+c>i. \tag{11}$$

Observe that from the previous section we had that the adoption condition is $s+a\delta(-e'(l)+\Pi'(l))+c>0$, so there will always be some level of adoption if there is a practice innovation. Finally remember that the condition $s+a\delta(-e'(l)+\Pi'(l))+c>i$. Now the condition for full runaway is $s+a\delta(-e'(\bar{l})+\Pi'(\bar{l}))+c>i.$, the left hand side is decreasing in a so the more ambiguity there is, the more likely that there is going to exist runaway. Also both diffusion and sophistication of the diffusion increases, as shown in the results now presented in the following table. The proof for

Table 4 Equilibrium cases

	Interior sophistication $(\hat{l}<\bar{l})$ (if $a\delta[\Pi'(\hat{l})-e'(\hat{l})]+s+c=i$)	***Sophistication at upper limit*** $(\bar{l})$ (if $a\delta[\Pi'(\bar{l})-e'(\bar{l})]+s+c\geq i$)
Interior diffusion $(\hat{p}_{l+\delta}<1)$	if $c>s+a\delta[\Pi(\hat{l})-e(\hat{l})]>-c$, then $\hat{p}_{l+\delta}=\frac{s+a\delta[-e'(\hat{l})+\Pi'(\hat{l})]}{2c}+\frac{1}{2}$	if $c>s+a\delta[\Pi(\bar{l})-e(\bar{l})]>-c$, then $\hat{p}_{l+\delta}=\frac{s+a\delta[-e'(\bar{l})+\Pi'(\bar{l})]}{2c}+\frac{1}{2}$
Full diffusion $(\hat{p}_{l+\delta}=1)$	if $s+a\delta[\Pi(\hat{l})-e(\hat{l})]\geq c$, then $\hat{p}_{l+\delta}=1$	if $s+a\delta[\Pi(\bar{l})-e(\bar{l})]\geq c$, then $\hat{p}_{l+\delta}=1$

bandwagon effects is similar and therefore omitted.

7.6. Proof that at Most Two Sophistication Levels Coexist in Equilibrium

Here, we show that if the status quo has two levels of sophistication (we call them l and $l-\delta$), the resulting ESS is the same as if only level l were present in the status quo. This is sufficient for our model to be complete. In order to do this, we need to show that if three levels of sophistication coexist, the lower level never survives in the resulting ESS. For this, we need to specify three co-existing fitness levels. We assume that being two levels below the state of the art generates a status quo loss of $\bar{s} > s$.

$$\begin{aligned} f(l) &= -e(l) + \Pi(l) - sp_P - cp_0 \qquad (12)\\ f(l+\delta) &= -e(l+\delta) + \Pi(l+\delta) + s(p_0) + \bar{s}(1 - p_P - p_0) - cp_p \\ f(l-\delta) &= -e(l-\delta) + \Pi(l-\delta) - \bar{s}(p_P + p_0) - c(p_p + p_0) \\ f(l+\delta) - f(l-\delta) &= 2\delta(-e'(l) + \Pi'(l)) - (p_P - p_u) * c + 2sp_0 + \bar{s}p_p. \end{aligned}$$

A sufficient condition for at most two levels to survive in the resulting ESS is that the last term is positive for all possible combinations of types. It is therefore sufficient if the last condition holds at $p_p = 1$; therefore a sufficient condition for at most two types to survive is

$$\bar{s} + 2\delta(-e'(l) + \Pi'(l) > c.$$

A sufficient condition for the model to have at most two levels surviving at the same ESS time is that the status loss for being two generations away from the state of the art is sufficiently large.