The breakdown of authority

Frisell, Lars

WISSENSCHAFTSZENTRUM BERLIN
FÜR SOZIALFORSCHUNG

SOCIAL SCIENCE RESEARCH
CENTER BERLIN

Lars Frisell

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Swedish Riksbank

SP II 2003 – 07

June 2003

ISSN Nr. 0722 – 6748

Research Area
Markets and Political Economy

Research Unit
Market Processes and Governance

Forschungsschwerpunkt
Markt und politische Ökonomie

Abteilung
Marktprozesse und Steuerung

Zitierweise/Citation:

Lars Frisell, **The Breakdown of Authority**, Discussion Paper
SP II 2003 – 07, Wissenschaftszentrum Berlin, 2003.

Wissenschaftszentrum Berlin für Sozialforschung gGmbH,
Reichpietschufer 50, 10785 Berlin, Germany, Tel. (030) 2 54 91 – 0
Internet: www.wz-berlin.de

ABSTRACT

The Breakdown of Authority

by Lars Frisell *

This paper studies organizations with autocratic decisionmaking, i.e., where superiors make the decisions and subordinates either defy or submit to the authority. Superiors differ in the degree to which they fear defiance. The superiors who need obedience most face a fundamental credibility problem, which, in fact, makes them the least likely to be obeyed. The subordinate's competence has conflicting effects on the superior's welfare: competent subordinates comprise better sources of information but also harsher yardsticks. The result is that superiors prefer subordinates of "medium" competence.

Keywords: Authority, organization theory, autocratic decision making

JEL Classification: D20, L20

ZUSAMMENFASSUNG

Das Versagen der Autorität

In der Arbeit werden Organisationen mit autokratischen Entscheidungsprozeduren untersucht. Bei solchen Entscheidungsprozeduren treffen Vorgesetzte Entscheidungen. Mitarbeiter können sich den Entscheidungen des Vorgesetzten unterordnen oder sich widersetzen. Die Vorgesetzten, die vom Gehorsam ihrer Mitarbeiter am stärksten abhängig sind, sehen sich einem grundlegenden Glaubwürdigkeitsproblem gegenüber, dass dazu führt, dass sie am wenigsten mit dem Gehorsam seitens der Mitarbeiter rechnen können. Die Fähigkeit eines Mitarbeiters hat einander entgegenlaufende Wirkungen auf den Payoff des Vorgesetzten: Mitarbeiter mit hoher Fähigkeit sind nützlicher als Informationsquellen, aber zugleich setzen sie strengere Maßstäbe. Vorgesetzte bevorzugen deshalb Mitarbeiter von "mittlerer" Fähigkeit.

* I thank Jonas Vlachos for helpful comments. Financial support from the Jan Wallander and Tom Hedelius Foundation is gratefully acknowledged.

"It should be needless to tell British seamen that no ship, whether manned by mutineers or not, can be handled without discipline. If I am to command the Bounty I mean to be obeyed. There shall be no injustice here. I shall punish no man without good cause, but I will have no man question my authority."

–Nordhoff and Hall, *Mutiny on the Bounty*, p. 146.

I. Introduction

Most organizations experience times when there is no room for dialogue between superiors and subordinates. Extreme urgency, prohibitive communication costs or large conflicts of interest can make plain order-giving preferable to conference.[1] In these situations the organization relies on autocratic decisionmaking and information flows primarily up-down through the hierarchy. In the terminology of Aghion and Tirole (1997), those who possess formal authority (the right to decide) must also exercise real authority (the effective control of decisions).

The best example of an organization relying on autocratic decisionmaking is, naturally, the military. The importance of swift and coordinated maneuvers in war accounts for the strict military hierarchy, where decisionmaking involves no participation of subordinates. In turn, in organizations that rely on an efficient chain of command, like the military, the exercise of authority may become an objective in itself. The ability to induce obedience ("leadership") becomes a coveted quality, and career concerns may deter superiors from using participatory methods to ensure cooperation.[2]

In this paper I provide a simple model of an autocratic organization. A superior makes a decision and needs the complete cooperation from a subordinate. Upon hearing the decision ("the order"), the subordinate uses his own information to determine whether the expected outcome of the decision is sufficiently good, if not he defies the superior. Hence, the subordinate can not affect the decision at hand, only choose not

[1] Strauss (1977) mentions other factors that may hinder subordinate participation in the decision-making process. For example, that (i) subordinates are reluctant to accept responsibility, (ii) the management culture is predominantly autocratic, (iii) subordinates differ greatly in their values and expertise (low group cohesion).

[2] Yukl (1981, p. 209) states that "[e]xtensive use of participation may cause a manager to be perceived as lacking in expertise, initiative, and self-confidence. Superiors, peers, and even subordinates may perceive the manager as a weak leader."

to participate.[3] Although defiance should be costly for both superior and subordinate, this paper studies situations where it is more damaging for the superior than for the subordinate.

Autocratic decisionmaking in itself does not mean, of course, that the power of authority is absolute. Subordinates will refuse to take actions they find highly immoral or dangerous. Janowitz (1960) concludes that, similar to the development in civilian organizations, the technological advances and increased specialization since the middle of the 19th century have driven military authority to shift from *ascribed* (pre-assigned) to *achieved* (based on performance). In other words, to induce obedience a superior must be perceived as *competent*, and more so the lesser is the cost of disobedience.[4]

My results are as follows. I classify superiors in terms of their fear of defiance. I show that superiors who are anxious to avoid defiance can not credibly make high-quality decisions, as they are tempted to mimic their subordinate's opinion. Importantly, superiors are either fully trustworthy or fully unreliable, nothing in between. The superior's utility is not generally monotone in the subordinate's informational quality, which means that a superior may either prefer a subordinate of low, high or medium competence. The less information the superior has on the subordinate's opinion, i.e., the higher is the "aloofness" in the organization, the less competent a subordinate he prefers.

This paper is closely related to Prendergast (1993) and owes much to his work. Prendergast introduced a model of "yes-men": because of subjective performance evaluation workers tend to conform to the opinions of their superiors. In the current setting, it is the superior who conforms to the opinion of the subordinate, in order to improve the chances of participation. While Prendergast focuses on a trade-off between incentives for effort and honest revelation, I study the superiors' potential credibility problem and their choice of subordinates. Hermalin (1998) studies how a leader may credibly, and efficiently, convey information to a team about the optimal level of effort to put into a project. Hermalin shows that "leading by example", i.e., providing own effort, helps alleviating the free-riding problem in the team.

[3] Sometimes this "take-it-or-leave-it"-kind of negotiations may be the choice of the subordinate. As an official of a labor union commented, "We want management to make the decisions so we can be free to start a grievance about it. Otherwise we could be accused of helping make bad decisions" (as reported by Strauss, p. 354).

[4] Or, in Simon's (1951) terminology, the smaller is the subordinate's "area of acceptance".

In so far as I consider the possibility of delegation, this paper is also related to Aghion and Tirole (1997) and Dessein (2002). Aghion and Tirole show that a principal often prefers to delegate the decision to an agent despite there being a preference divergence between the two. Dessein uses the model in Crawford and Sobel (1982) and shows that delegation can also be preferred to communication. The proviso in both cases is that the divergence in preferences is not too large relative to the principal's uncertainty about the environment. The current paper shows that a superior with credibility problems may prefer to delegate even though the subordinate is less informed than himself.

Finally, the paper also relates to the literature on trust (for a recent overview, see Harvey 2002). The view of the current paper, like that of Coleman (1990) and most economists, is that trust and trustworthiness should be regarded as equilibrium phenomena, not as (non-utility maximizing) modes of behavior. Contrary to the common repeated-game result, where any level of cooperation can be sustained as an equilibrium, trust is here either supported in full, or breaks down completely. All proofs are in the Appendix.

II. The Model

There are two agents, the captain of a ship (k) and his crew (c). The captain is about to announce a decision $d \in \Re$, say, the route for a voyage. The crew does not have the authority (the legal, economic, or physical possibilities) to change the decision, but can only obey or mutiny.[5] The crew is risk-neutral and obeys if the accuracy of the captain's decision is sufficiently high compared to the cost of mutiny. The captain's utility is likewise increasing in the decision's accuracy, but a mutiny has more severe effects for him than for the crew. For simplicity the model abstracts from other differences in preferences, and from effort provision.

The outcome of the decision depends on the state of nature ρ, which is not known with certainty. Specifically, the captain gets a signal $\rho_k = \rho + \epsilon_k$, where ϵ_k is normally distributed with zero mean and variance σ_k^2. The crew gets a signal $\rho_c = \rho + \epsilon_c$, where ϵ_c is normally distributed with zero mean and variance σ_c^2. For example, if ρ represents the best course to take, then σ_k^2 and σ_c^2 reflect the agents' navigational skills. In addition the captain receives a signal on the crew's signal, $\rho_s = \rho_c + \epsilon_s$, where ϵ_s is normally

[5] All results would hold qualitatively if the crew could amend the decision, but the cost of amending was increasing in the distance between d and the new decision.

distributed with zero mean and variance σ_s^2. The latter signal represents the fact that, even if no formal consultation takes place, by working in the same organization superiors to some extent discover their subordinates' information and predispositions. With which certitude this assessment can be made (the "aloofness") should depend on, e.g., how frequently superior and subordinate interact.[6] I assume that all signals are conditionally independent and that all variances are positive.[7]

With normally distributed signals the probability that the crew obeys is inversely related to the variance the crew ascribes to the decision. Therefor I simply represent this probability by $-Var(d \mid I_c)$, where I_c denotes the information available to the crew. The captain's utility can then be modeled as

$$U_k = -(1-\lambda)Var(d \mid I_k) - \lambda E[Var(d \mid I_c)],$$

where I_k denotes the information available to the captain, and the parameter $\lambda \in [0,1]$ reflects the captain's aversion to mutiny (relative to the crew's). All aspects of the game are common knowledge except the realizations of the private signals.

There are, of course, many reasons why superiors want to execute projects that their subordinates would reject (and vice versa). Most jobs involve perks and risks that are unequally shared by subordinates and superiors, where military enterprises are a point in case. Managers are commonly rewarded with promotion or a financial bonus when projects are successful, but enjoy limited liability when projects fail. Such factors would work to increase λ in the model. I implicitly assume that the captain cannot (completely) align interests through a contract contingent on the outcome. The reason for this may in particular be that the "outcome", i.e., the crew's utility, is not verifiable (or even observable) for third parties. Below I characterize the perfect Bayesian equilibria of this game. It is useful to start with the two extreme cases, $\lambda = 0$ and $\lambda = 1$.

[6] Naturally, subordinates have information on their superiors' opinions as well. Including this feature would attenuate, but not eliminate, the superior's (potential) commitment problem.

[7] Independence is not necessary, the important thing is that the crew has *some* information that could improve on the captain's decision.

III. Equilibria

The confident boss ($\lambda = 0$)

If $\lambda = 0$ there is no conflict of interests between captain and crew: both want to carry out the voyage in exactly the same circumstances. Hence, the captain will take the decision that corresponds to his best estimate of ρ. This decision is

$$d^C = \frac{\rho_k \sigma_s^2 + \rho_k \sigma_c^2 + \rho_s \sigma_k^2}{\sigma_c^2 + \sigma_k^2 + \sigma_s^2},$$

which has variance

$$v^C = \frac{\sigma_k^2 \left(\sigma_c^2 + \sigma_s^2\right)}{\sigma_c^2 + \sigma_k^2 + \sigma_s^2}.$$

The desperate boss ($\lambda = 1$)

If $\lambda = 1$ the captain fears mutiny so much that he is indifferent so as to which course is taken, as long as the crew obeys. He will therefor take the decision that minimizes the *perceived* variance of ρ, given his knowledge of the crew's opinion. The decision's variance conditional on the crew's signal can be decomposed into two components: the decision's unconditional variance plus its squared bias relative to the crew's expectation of ρ. In turn, the crew forms this expectation on basis of their own signal and the decision itself. Hence, the crew's beliefs might be important for determining the equilibrium decision.

Suppose the crew believes that the decision has the (unconditional) variance σ_v^2. The crew's ex post expectation of ρ is then

$$\hat{\rho}_c = \frac{d\sigma_c^2 + \rho_c \sigma_v^2}{\sigma_c^2 + \sigma_v^2}.$$

The conditional variance of the captain's decision becomes

$$Var(d \mid \rho_c) = \sigma_v^2 + (d - \hat{\rho}_c)^2 = \sigma_v^2 + \frac{\sigma_v^4}{(\sigma_c^2 + \sigma_v^2)^2} \left(d - \rho_c\right)^2.$$

Now, taking σ_v^2 as given, the conditional variance of the captain's decision, and hence the probability of mutiny, only depends on the distance $|d - \rho_c|$. This means that, regardless of which variance the crew ascribes to his decision, a desperate captain will minimize the expectation of $|d - \rho_c|$ instead of $|d - \rho|$. The optimal decision is

$$d^D = \frac{\rho_k \sigma_s^2 + \rho_s \sigma_c^2 + \rho_s \sigma_k^2}{\sigma_c^2 + \sigma_k^2 + \sigma_s^2},$$

which has variance

$$v^D = \frac{\sigma_c^4 + \sigma_c^2 \sigma_k^2 + \sigma_k^2 \sigma_s^2}{\sigma_c^2 + \sigma_k^2 + \sigma_s^2}.$$

It can immediately be seen that $v^D > v^C$, i.e., the variance of a desperate captain's decision is higher than that of a confident one's. Analogous to Prendergast, the captain's desire to increase the chances of obedience leads him to compromise the accuracy of his decision. Moreover, a rational crew will realize that the captain is distorting his decision, and adjust their beliefs accordingly. Hence, in equilibrium, d^D must also have a lower probability of obedience than d^C. A desperate captain makes both a poorer a decision and, precisely because of this, faces a higher probability of mutiny.

PROPOSITION 1: The captain's utility, and the probability of obedience, are strictly lower if the equilibrium decision is d^D than if it is d^C.

The general case

In the proposition below I show that for general values of λ, in a pure equilibrium the decision is always either d^C or d^D. Hence, there is no continuous shift from d^C towards d^D as λ is increased.[8] Roughly expressed, the preference for accurate decisions and the preference for obedience per se are mutually exclusive concerns, and at some point the latter will dominate the former. At this point the captain loses "all" credibility, and his chances of being obeyed drop abruptly. With rational individuals, credibility or trustworthiness is an equilibrium phenomenon: either a person benefits from honoring trust, in which case it will be confided to him, or he profits more from betraying it, and he shall have none.

[8] Importantly, this is not a result of the additive utility function. For example, it holds for a multiplicative specification of the kind $U_k = -Var(d \mid I_k)^\alpha * E[Var(d \mid I_c)^{1-\alpha}]$. Briefly, the (omitted) proof shows that the expression is convex in d.

When lambda is close to 0, d^C is the unique equilibrium, and when λ is close to 1, d^D is the unique equilibrium. For intermediate values of λ both equilibria are possible, and the equilibrium decision must be jointly determined with the crew's beliefs. These findings are summarized in Proposition 2 and illustrated in Figure 1.

Definitions:

$$\lambda' = \frac{\left(\sigma_k^2+\sigma_c^2\right)^2\left(\sigma_s^2+2\sigma_c^2\right)^2}{4\sigma_s^2\sigma_c^6+6\sigma_k^4\sigma_c^2\sigma_s^2+\sigma_c^4\sigma_s^4+2\sigma_c^2\sigma_s^4\sigma_k^2+2\sigma_k^4\sigma_s^4+5\sigma_c^4\sigma_k^4+5\sigma_c^8+10\sigma_k^2\sigma_s^2\sigma_c^4+10\sigma_k^2\sigma_c^6}.$$

$$\lambda'' = \frac{\left(\sigma_s^2\sigma_k^2+\sigma_s^2\sigma_c^2+2\sigma_c^2\sigma_k^2+\sigma_c^4\right)^2}{\left(\sigma_c^8+4\sigma_k^2\sigma_c^6+2\sigma_c^6\sigma_s^2+2\sigma_k^2\sigma_c^2\sigma_s^4+6\sigma_k^2\sigma_c^4\sigma_s^2+6\sigma_k^4\sigma_c^2\sigma_s^2+5\sigma_k^4\sigma_c^4+2\sigma_k^4\sigma_s^4+\sigma_c^4\sigma_s^4\right)}.$$

PROPOSITION 2: $0 < \lambda' < \lambda'' < 1$. For $\lambda < \lambda'$, d^C is the unique equilibrium, for $\lambda > \lambda''$, d^D is the unique equilibrium, and for $\lambda' \leq \lambda \leq \lambda''$ both equilibria are possible.

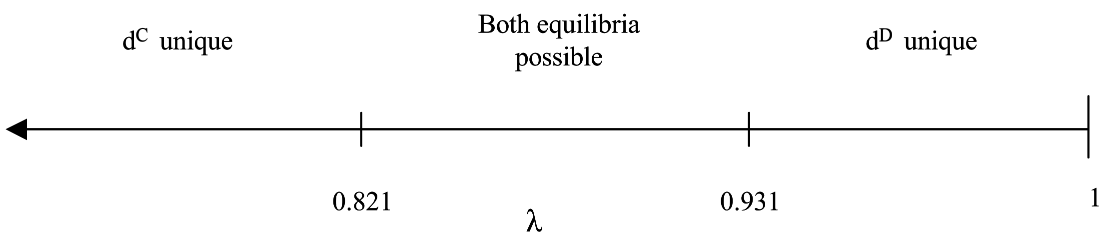

Figure 1. Equilibrium decisions as a function of λ ($\sigma_k^2 = 1$, $\sigma_c^2 = 2$, $\sigma_s^2 = 1$).

When $\lambda \in [\lambda', \lambda'']$ both pure equilibria (and one mixed) are possible. In particular, if the crew is confident that the captain makes decision d^C, this is also the captain's best response. Since the "confident equilibrium" is preferred by both parties, the existence of multiple equilibria constitutes a pure coordination problem, which could be resolved by cheap talk. (The captain could add a speech to his order saying "trust me to make decision d^C", which the crew should.) Hence, in the absence of other factors explaining why the crew should expect decision d^D, it is natural to regard d^C as the outcome in the whole range $[0, \lambda'']$. For this reason, and for brevity, the comparative statics below focuses on d^C being the equilibrium.

IV. The choice of subordinates

It is straightforward to show that a lower σ_k^2 and a lower σ_s^2 both increase the utility of equilibrium d^C, and increase the range of λ for which it is sustainable. Hence, if we originally are in a situation where $\lambda \leq \lambda''$, improving the captain's knowledge of the crew's opinion or increasing the captain's competence unambiguously increases welfare.[9] However, this is not true for the crew's competence.

When the captain has an interest in obedience per se, the crew's information has conflicting effects on his welfare: it serves as a source of information via ρ_s but also serves as yardstick by which his decision is evaluated. A lower σ_c^2 is beneficial in so far as it decreases the variance of the decision, but is detrimental as it increases the expected difference between d and $\hat{\rho}^c$, for a more competent crew will put more weight on their own signal when forming their expectation of ρ. Generally, when σ_s^2 and λ are low the "information effect" dominates, in the opposite case the "yardstick" effect dominates. In particular, if λ is very close to λ'', an increase in the subordinate's competence causes the d^C-equilibrium to disappear, which drastically reduces welfare. For intermediate cases the captain's utility is non-monotone in σ_c^2, so that the captain prefers a crew of "medium" quality.

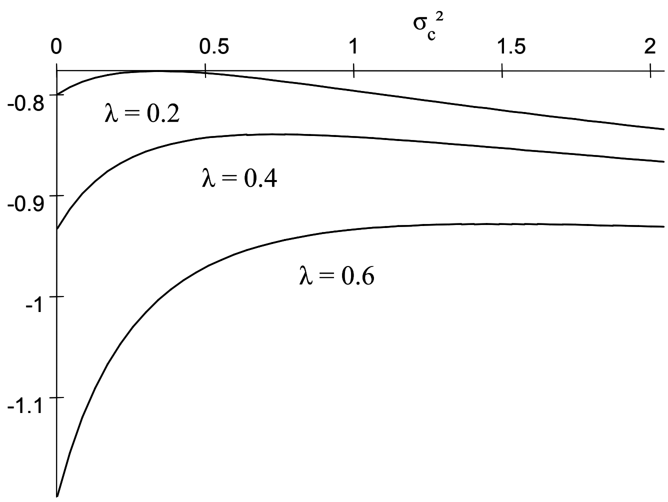

Figure 2: U_k as a function of σ_c^2, for different values of λ ($\sigma_k^2 = 1, \sigma_s^2 = 2$).

[9] This suggests that aloofness in organizations can not be motivated by purely informational reasons, only its effect on effort provision (cf. Prendergast and Crémer 1995). However, when the equilibrium is d^D, a decrease in σ_s^2 may decrease welfare. Similar to Prendergast, if $\sigma_k^2 < \sigma_c^2$, less aloofness is detrimental because it improves the captain's ability to mimic a poor signal.

PROPOSITION 3: When λ is small (large) the captain's utility is decreasing (increasing) in σ_c^2. For intermediate values of λ , the σ_c^2 that maximizes the captain's utility is interior.

The optimal σ_c^2 depends crucially on the aloofness parameter σ_s^2, since this determines to which extent the captain can make use of the crew's information. Higher aloofness always increases the optimal σ_c^2, for it reduces the crew's informational contribution without affecting the precision of their "yardstick".

PROPOSITION 4: The captain's preferred σ_c^2 is (weakly) increasing in σ_s^2.

Delegation

Naturally, if consultation with subordinates is impossible because of their reluctance to take on responsibility, or the superior's concern for displaying "strong leadership", delegation of the whole decision responsibility should be unthinkable. However, if autocratic decisionmaking is solely the result of urgency or a too broad span of control, delegation may be a viable alternative. In the current setting, delegation would mean that the crew gets to choose between making decision ρ_c (which has variance σ_c^2), and committing mutiny.

Similar to Aghion and Tirole, delegation would often be preferred when subordinates are better informed than their superiors. If $\sigma_c^2 < \sigma_k^2$ and σ_s^2 is high – which is almost synonymous with a broad span of control – the captain can not make much use of the crew's information so the crew probably makes the better decision. However, for captains with credibility problems, i.e., when d^D is the equilibrium, autocracy may actually be so ineffective that the captain would prefer to delegate even though $\sigma_c^2 > \sigma_k^2$. This means that the lack of power to commit to high-quality decisions on behalf of superiors can lead to increased delegation. In Figure 3 the captain's utility under autocracy is compared to the variance of the crew's signal. Note that $-\sigma_c^2$ is larger than U_k until σ_c^2 equals about one and a half, although σ_k^2 is just one.

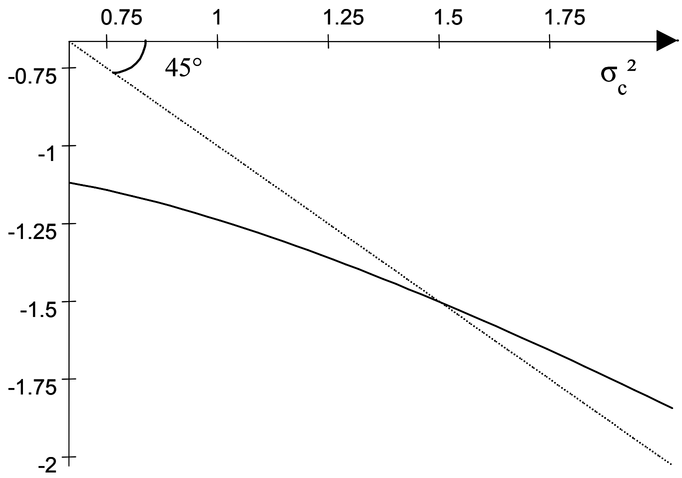

Figure 3: U_k as a function of σ_c^2 ($\sigma_k^2 = 1$, $\sigma_s^2 = 2$, $\lambda = 0.95$).

V. Conclusion

The purpose of this paper has been to study organizations under autocracy, i.e., situations where superiors make the decisions and subordinates either defy or submit to authority. The analysis focuses on superiors who "fear defiance", that is, superiors who at least on the margin are willing to compromise the quality of the decision to get their orders carried out.

I have couched the model in terms of a captain commanding his crew. The prospect of mutiny is, surely, something worth compromising a captain's integrity for. However, the phenomenon should arise whenever authorities have an interest in obedience per se, be it because of career concerns (an officer suspected of being a "weak leader"), financial gain (a manager facing small downward risk), or psychological reasons (a tired parent). I show that those superiors who are most anxious to avoid defiance can not credibly make high-quality decisions, as they are too tempted to make their decisions "appear" accurate. The result is that, ironically, these superiors are the least likely to be obeyed.

The superior's chances of achieving obedience, i.e., his "authority" or "trustworthiness", do not change gradually with her fear of defiance. Instead, authority remains intact until a certain point, where it collapses. I think this is how most people think about submission or trust: it is given and honored in its entirety, or not at all. It is hard to imagine such things as "partial trust" or a "somewhat trustworthy" person. Often superiors prefer to have subordinates who are neither very well-informed, nor very uninformed. Poorly informed subordinates contribute little to the decision's quality, but well-informed subordinates are more likely to think the superior has made a poor decision. One empirical implication is that the higher is the aloofness in an organization, that is, the less superiors and subordinates interact, the less competent subordinates we should expect.

The model is incomplete in many respects. To focus on the relationship between superior and subordinate I ignore team aspects, effectively by modeling the crew as a singular agent, and to focus on informational aspects I abstract from effort provision. The most fruitful extension however, I think, would be to model the authority relationship as a dynamic game, where the superior's "career concerns" are endogenous.

More striking for non-economists is probably the overly simplistic, "rational" way I portray the authority relationship: the subordinate estimates the expected outcome of the decision, and, mechanically, obeys or disobeys depending on this estimate. Anybody familiar with Milgram's experiments on obedience knows that the mere act of defiance was often sufficient to deter it – despite that the subjects "knew" that their actions implied extreme danger for another person. Milgram (1974) explained that the subject, in her mind, reduced herself to the experimenter's "agent", thus freeing herself of the responsibility of her actions. I think that, in line with other experiments in psychology, in addition to renouncing the responsibility of their actions, subordinates often disown their ability to assess their consequences. In autocratic organizations, this kind of subordinates should be high in demand.

APPENDIX

Denote the expected squared bias of d^C and d^D w.r.t. ρ_c, respectively,

$$b^C = \frac{\sigma_k^2\sigma_s^2 + \sigma_c^2\sigma_s^2 + \sigma_c^4}{(\sigma_c^2 + \sigma_k^2 + \sigma_s^2)},$$

and

$$b^D = \frac{(\sigma_k^2 + \sigma_c^2)\,\sigma_s^2}{(\sigma_c^2 + \sigma_k^2 + \sigma_s^2)}.$$

Note that $b^C > b^D$, i.e., d^D is indeed a better estimator of ρ_c than is d^C.

PROOF OF PROPOSITION 1:

For the sake of argument, suppose both equilibria exist for the same set parameters. The captain's utility when the equilibrium decision is v^C and v^D would be, respectively,

$$-v^C - \lambda \frac{\left(v^C\right)^2}{\left(v^C + \rho_c\right)^2} b^C \tag{A1}$$

and

$$-v^D - \lambda \frac{\left(v^D\right)^2}{\left(v^D + \rho_c\right)^2} b^D. \tag{A2}$$

Suppose, contrary to the proposition, that (A1) < (A2) for some set of parameters. Then, since $v^C < v^D$, this must also hold when $\lambda = 1$. Setting λ to 1 and using the above definitions gives that the difference (A1) - (A2) equals

$$\frac{\sigma_c^6 \left(4\sigma_c^{10} + 16\sigma_k^2\sigma_c^8 + 9\sigma_c^8\sigma_s^2 + 5\sigma_k^2\sigma_c^2\sigma_s^6 + 33\sigma_k^2\sigma_c^6\sigma_s^2 + 12\sigma_k^4\sigma_c^6 + 4\sigma_k^4\sigma_s^6 + \sigma_c^4\sigma_s^6\right)}{\left(2\sigma_k^2\sigma_c^2 + \sigma_k^2\sigma_s^2 + \sigma_c^2\sigma_s^2 + \sigma_c^4\right)\left(\sigma_k^2 + \sigma_y^2\right)\left(2\sigma_c^2 + \sigma_s^2\right)} +$$

$$\frac{\sigma_c^6 (6\sigma_c^6\sigma_s^4 + 22\sigma_k^2\sigma_c^2\sigma_s^4 + 17\sigma_k^4\sigma_c^2\sigma_s^4 + 24\sigma_k^4\sigma_c^4\sigma_s^2)}{\left(2\sigma_k^2\sigma_c^2 + \sigma_k^2\sigma_s^2 + \sigma_c^2\sigma_s^2 + \sigma_c^4\right)\left(\sigma_k^2 + \sigma_y^2\right)\left(2\sigma_c^2 + \sigma_s^2\right)} > 0,$$

a contradiction.

PROOF OF PROPOSITION 2:

Without loss of generality, suppose that the captain's decision is a convex combination of d^C and d^D. Denote the weight he puts on d^C and d^D, a and $(1-a)$, respectively. Given the crew's beliefs, σ_v^2, the captain maximizes:

$$-(1-\lambda)ad^C - (1-\lambda)(1-a)d^D - \lambda\sigma_v^2 - \lambda \frac{\sigma_v^4}{\left(\sigma_c^2 + \sigma_v^2\right)^2}(ab^C + (1-a)b^D) \tag{A3}$$

The expression is clearly linear in a. Hence, except for knife-edge cases, $a = 1$ or $a = 0$ is the unique solution to the captain's problem. Suppose first that the crew's belief is that $a = 0$, so that $\sigma_v^2 = v^D$. If the captain indeed sets $a = 0$, (A3) becomes (A2). If the captain instead would set $a = 1$, (A3) becomes

$$-v^C - \lambda \frac{(v^D)^2}{(\sigma_c^2 + v^D)^2} b^C. \tag{A4}$$

v^D is an equilibrium as long as (A2) - (A4) > 0. This difference is

$$\frac{\sigma_c^4}{(\sigma_c^2 + \sigma_k^2 + \sigma_s^2)} - \lambda\sigma_c^4 \frac{4\sigma_s^2\sigma_c^6 + 6\sigma_k^4\sigma_c^2\sigma_s^2 + \sigma_c^4\sigma_s^4 + 2\sigma_c^2\sigma_s^4\sigma_k^2 + 2\sigma_k^4\sigma_s^4 + 5\sigma_c^4\sigma_k^2 + 5\sigma_c^8 + 10\sigma_k^2\sigma_s^2\sigma_c^4 + 10\sigma_k^2\sigma_c^6}{\left(2\sigma_k^2\sigma_c^2 + \sigma_k^2\sigma_s^2 + \sigma_c^2\sigma_s^2 + 2\sigma_c^4\right)^2 \left(\sigma_c^2 + \sigma_k^2 + \sigma_s^2\right)},$$

which is strictly decreasing in λ. Setting (A2) $=$ (A4) gives that v^D is an equilibrium as long as $\lambda \geq \lambda'$. Suppose instead that the crew believes that the captain sets $a = 1$. Doing so gives the captain utility (A1), while "deviating" to $a = 0$ gives

$$-v^D - \lambda \frac{(v^C)^2}{(\sigma_c^2 + v^C)^2} b^D \tag{A5}$$

Using the definitions above gives that (A1) $>$ (A5) as long as $\lambda \leq \lambda''$. Finally, it can be immediately seen that $\lambda', \lambda'' \in (0, 1)$. Also, the difference $\lambda'' - \lambda'$ is positive (expression omitted).

PROOF OF PROPOSITION 3:

I first show that λ'' is strictly increasing in σ_c^2. Hence, by Proposition 2, at $\lambda = \lambda''$ a marginal decrease in σ_c^2 will shift the equilibrium from d^C to d^D. By Proposition 1 and continuity, this means that the captain's utility is strictly increasing in σ_c^2 at λ''. Second, I show that the captain's utility is strictly decreasing in σ_c^2 at $\lambda = 0$. Third, I show that for σ_s^2 sufficiently low, the utility of decision d^C is strictly decreasing in σ_c^2. This holds in particular in a neighborhood around λ'', which means that for sufficiently low σ_s^2, the captain's utility is non-monotone in σ_c^2.

(i) Differentiating λ'' w.r.t. σ_c^2 gives

$$\frac{2\left(\sigma_k^2\sigma_c^2+\sigma_s^4+2\sigma_c^2\sigma_s^2+\sigma_c^4\right)\left(2\sigma_k^2\sigma_c^2+\sigma_k^2\sigma_s^2+\sigma_c^2\sigma_s^2+\sigma_c^4\right)\left(\sigma_c^2+\sigma_s^2\right)\sigma_k^4}{\left(\sigma_c^8+4\sigma_k^2\sigma_c^6+2\sigma_c^6\sigma_s^2+2\sigma_k^2\sigma_c^2\sigma_s^4+6\sigma_k^2\sigma_c^4\sigma_s^2+6\sigma_k^4\sigma_c^2\sigma_s^2+5\sigma_k^4\sigma_c^4+2\sigma_k^4\sigma_s^4+\sigma_c^4\sigma_s^4\right)^2}>0.$$

(ii) Differentiating (A1) w.r.t. σ_c^2 and evaluating at $\lambda = 0$ gives

$$-\frac{\sigma_k^2}{\left(\sigma_c^2+\sigma_k^2+\sigma_s^2\right)^2}<0.$$

(iii) Differentiating (A1) w.r.t. σ_c^2 and evaluating at $\lambda = \lambda''$ and $z = 0$ gives

$$\sigma_k^6\frac{25\sigma_k^6+8\sigma_c^6+35\sigma_k^2\sigma_c^4+50\sigma_k^4\sigma_c^2}{\left(\sigma_c^4+4\sigma_k^2\sigma_c^2+5\sigma_k^4\right)^2\left(\sigma_k^2+\sigma_c^2\right)^2}>0.$$

PROOF OF PROPOSITION 4:

Differentiating (A1) w.r.t. σ_c^2 and σ_s^2 gives

$$-2\frac{\sigma_k^4}{\left(\sigma_c^2+\sigma_k^2+\sigma_s^2\right)^3}+\lambda M, \qquad \text{(A6)}$$

where M is a positive expression, omitted for brevity. Suppose, contrary to the proposition, that (A6) is positive. Then this must also hold at λ'', the highest value of λ for which d^C is an equilibrium. Evaluating (A6) at λ'' gives an (omitted) expression that is negative, a contradiction.

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