Managing Shared Understandings in Teams*

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Abstract

We study organizational design in a team-theoretic setting where both coordination and adaptation are important. Managers, through training and hiring practices, can control the degree to which signals received by agents are correlated, which we refer to as shared understanding. We show that fostering a shared understanding can be beneficial when both adaptation and coordination are important, signals are sufficiently good, and information acquisition is costly. However, shared understanding reduces the value of acquiring information and communicating. As a result, a self-interested managers may hire for diversity if they do not internalize the cost of these activities.

Keywords: Organizational Design, Information Acquisition, Routines, Shared Understandings
JEL: D23, D83, L20, L25

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1 Introduction

Managers are often tasked with forming and training teams who must subsequently coordinate their actions and respond to changing circumstances. By laying out rules, it is easy to induce teams to coordinate actions — "everyone do A no matter what", and sometimes possible to cover all contingencies — "you do A no matter what, and I'll do B no matter what", but to encourage both coordination and adaptation team members must be allowed some level of discretion. Managers in such cases often have little direct control over the behavior of the team but do have the ability to influence outcomes through its ex ante training strategies and hiring decisions. In this article, we analyze one such strategy: inducing a correlation in the signals that agents receive, which we term **developing a shared understanding**.

Shared understanding, for us, represents the degree to which team members obtain similar information and interpret these facts in a similar manner. Consider, for example, a team of two police officers arriving separately to a crime. Each officer receives reports over the radio about the situation and must quickly decide on which of two potential exits to cover. The best outcome is for them both to cover the exit that the criminal uses to escape. Covering both exits is surely worse if the perpetrator may be dangerous, but whether coordinating on the wrong exit is better or worse than dividing their forces depends on the exact structure of payoffs. If, for example, one officer is sufficient to make a safe arrest, covering both exits is probably better, but if dividing would mean that the corresponding officer may be shot, sticking together at the wrong exit would be far better.

Through training and selection, police officers may be trained to anticipate the same criminal response to a given situation and may interpret the information sent by dispatch through the same analytic lens. Such training helps the team to coordinate their actions, which in some cases leads to better outcomes. The goal of this paper is to understand why and when a shared understanding of the world is valuable, how it interacts with other information strategies, and how an organization might use shared understandings as part of an overall information sharing strategy.

We consider a team organizational design problem with two agents who must make binary actions (A or B) and where the optimal action depends on the state. Individuals share a common prior that favors action A. They also receive a private signal about the state of the world. Individuals in the team may have correlated signals, which correspond to the team having a shared understanding.

Team members share identical payoff functions, which depend both on whether the correct action is taken by at least one team member and whether both parties coordinate on the same decision. While coordinating on the correct state is always optimal, we study cases where coordination is more important than having at least one person choosing the correct state and cases where the reverse is true. We also study the case where coordinating on the wrong state is extremely costly and where the teams payoff function is sub-additive in the number of individuals selecting the correct state, i.e., getting the first person to choose the right state is more important than getting the second person to match the state.

As in the example above, we begin by studying environments with exogenous signal quality and no ex-interim communication. We show that shared understanding matters only in cases where neither goal dominates so that rules like "everyone do A no matter what" or "you do A no matter what, and I'll do B no matter what" are not attractive. We refer to this as the "responsive range", where the efficient strategy is for the team members to respond to their signals. But even in the responsive range, shared understanding is not always valuable. Shared understandings are useful only when payoffs are super-additive in the sense that getting the second person to align their actions with the first person is more valuable than getting the first person to choose the correct state, but not so super-additive that coordination is a dominant goal and the team adopts a rule.[1] In this intermediate case, a shared understanding helps to coordinate the actions of the team while still allowing them to adapt to their own information. In the sub-additive case, in contrast, a shared understanding is detrimental because it increases the likelihood that both individuals are wrong.

We also show that the relationship between signal quality and the value of shared understanding has both an extensive and intensive margin. As signal quality improves, non-discretionary rules become less attractive, and the size of the responsive range grows. Thus, along the extensive margin, shared understandings matter for a wider range of parameter values as signal quality improves. That said, the marginal impact of shared understanding on the team's payoff is smaller for higher quality signals. This is obvious in the extreme, since if both teammates get perfect signals of the state, the level of shared understanding is immaterial.

An organization's incentives to encourage or discourage shared understandings within its teams depend on the relative importance of its twin goals of coordination and adaptation. When one of the goals dominates, rules are optimal, and there is no reason to invest in encouraging or avoiding shared understandings. Thus, managers of rule-dominated firms should be agnostic to shared understanding. In cases where coordination is a more important component of success, but adaptation remains important, organizations must cultivate a shared understanding amongst team members to ensure success. This insight helps to explain why drilling and norm formation are important parts of the training process in organizations such as the military or sports

[1] As discussed below, our cutoff condition coincides with one found by Prat (2002) that shared information structures are optimal when payoffs are supermodular. This result generalizes an earlier result by Crémer (1993) that shared knowledge is valuable in cases where complements matter.

teams where doing it wrong together is better than some people doing it right. Finally, in cases where adaptation is more important than coordination, firms should minimize shared understanding by hiring for diversity and attempting to avoid normalization.[2]

Our baseline model assumes that parties make decisions without team deliberation and that the quality of information is exogenous. These assumptions make sense in settings such as our police example, where team members are asked to respond quickly to an event and where information is being relayed from another part of the organization, but they do not capture all environments where shared understandings are likely to matter. In part 2 of our paper, we extend our model to explore how shared understandings interact with more traditional information strategies, which we broadly lump into information sharing and information acquisition.

In our extended model, we study the interaction between shared understanding and information sharing by introducing costly meetings, where team members reveal their signals ex-interim. In the super-additive domain, meetings add value by ensuring coordination; in the sub-additive case, meetings add value by ensuring that the initially more likely state is always covered. Meeting and shared understandings are always substitutes, in the sense that the team's willingness to pay for meetings decreases in the level of shared understanding. This can be seen in the extreme case where signals are perfectly correlated and meetings collapse into echo chambers where everyone shares the same opinion.

We also study how shared understanding interacts with information acquisition by allowing team members to invest in information. When a team chooses not to hold a meeting, information acquisition is decreasing in shared understanding (i.e., they are substitutes). This is because team members have an incentive to acquire better information to coordinate with other members of the team, and a shared understanding reduces the likelihood of coordination failures. However, if a team chooses to schedule a meeting, information acquisition increases with shared understanding. In this case, coordination always occurs, and shared understanding increases the chance that a poorly informed team will coordinate on the wrong state.

Finally, we use the insights from our model to explore how managers might select the level of shared understanding for a team that they have no other way of influencing. We begin by showing that the team's surplus is increasing in shared understanding without a meeting and decreasing in share understanding with a meeting. As such, when a manager has preferences aligned with the group, he will select groups based

[2] The recent book "Hidden Figures: The American Dream and the Untold Story of the Black Women Mathematicians who helped win the Space Race" by Shetterly provides a poignant example of a case where maximal diversity was likely to improve the outcome. During the Apollo era, black women of extremely high analytic ability were hired to double check computations made by computers and other employees at NASA. By hiring individuals who were of high ability but who would likely be isolated due to social factors, NASA received independent calculations that improved the chances that mistakes would be caught.

primarily on the cost of meetings.

We then explore how the optimal level of shared understanding changes for a manager who only cares about the outcome of the team but not the input costs of the group members. We view such **output-based managers** as being quite common in large organizations where managers have control over the composition and training of a team (i.e., the level of shared understanding) but where wages are set and internalized by a higher level of the hierarchy who lies outside the manager-team relationship.[3] We show that the level of shared understanding chosen by the manager is non-monotonic in information costs: for moderate information costs, an output-based managers preferences are aligned and it is optimal for the manager to cultivate a shared understanding. However, this is not the case when (i) information costs are low or (ii) when information costs are very high and the cost of direct communication isn't too high. When information costs are low, output-based managers may discourage a shared understanding in order to increase information acquisition. However, their ability to do so is constrained by the possibility that teams may move from a discretionary strategy to a rule-based strategy or one that involves a meeting. When information costs are high, an output-based manager may also seek to minimize shared understanding in order to encourage meetings and direct communication.

The rest of our paper is as follows. We discuss the related literature below. In Section 2, we develop our baseline model and discuss the case where information is fixed. In Section 3, we extend the model to also include meetings and information acquisition. Finally, in Section 4, we study the problem of a manager selecting the composition of the group both for an aligned manager and one who is outcome-based. Section 5 concludes.

1.1 Related Literature

At the broadest level, this paper contributes to the literature on team theory, which began with Marschak (1955) and was developed extensively in Marschak and Radner (1972) and Groves and Radner (1972). In contrast to the principal-agent approach, the team-theoretic approach studies cases where the interactions between team members' decisions are important but where members receive a common reward. The framework abstracts away from incentive problems—the main focus of the principal-agent framework—in order to concentrate on important issues related to information (e.g., Aoki, 1986, 1995; Bolton and Dewatripont, 1994), corporate culture (Crémer, 1993),

[3]Think, for instance, of consulting firms, investment banks, and law firms where new hires are typically hired to a pool before being assigned to or selected by managers. Long hours are typically expected in these firms and managers are likely to be judged on the outcome of projects assigned to them with little attention paid to the total number of hours their team work.

hierarchies (Geanakoplos and Milgrom, 1991; Garicano, 2000; Harris and Raviv, 2002), coordination (e.g., Kremer, 1993; Qian et al., 2006), and intra-firm competition (Alonso et al., 2015).

Our model explores how teams with different levels of shared understanding operate and communicate when faced with the problem of coordinated adaptation under distributed information. Team theoretic models of coordinated adaptation can be broken into two sorts: organizational and informational. Organizational approaches ask questions about who should be hired and who should be allocated to tasks (Dessein and Santos, 2006; Alonso et al., 2015). Informational approaches ask how much the firm should invest in information structures, and which structures to invest in (Alonso et al., 2008; Rantakari, 2008, 2013). Our model falls within the informational approach, as we are trying to analyze the conditions under which the organization performs better with a system in which agents have shared understandings. Two closely related papers are Marschak and Radner (1972) and Prat (2002), which both ask an extreme version of our question by analyzing when perfectly correlated signals outperform independent signals. We interact this question with a number of more traditional informational approaches such as investing in improved signals and having costly meetings.

Shared knowledge has been explored in the corporate culture literature, which seeks to understand the ways in which culture can help maintain cooperation amongst organizational members. Within this literature, Crémer (1993) studies a team-theoretic setting where corporate culture is the stock of knowledge that is shared between team members.[4] Shared knowledge can be optimal when coordination is important to a team, as it increases the efficiency of communication. Similar to our work, Crémer (1993) finds that shared understanding is only useful in the case where coordination adds more value to the firm than getting one of the members to make the right decision. This result is generalized in Prat (2002) which shows that shared information is optimal when payoffs are supermodular.[5]

Our paper focuses primarily on the supermodular case where shared understandings can be beneficial. As such, it complements an existing literature that concentrates on solving complex problems in environments where payoffs are submodular. As seen in Hong and Page (2001, 2004), Page (2008), and LiCalzi and Surucu (2012), diversity tends to be optimal in these settings as it allows for knowledge spillovers between

[4]Corporate culture has also been studied in a variety of other ways. For example, Kreps (1990), and the interpretation of Kreps (1990) by Hermalin (2001), study models where corporate culture is a means for selecting a particular cooperative equilibrium, amongst many, in repeated games. Lazear (1995) and Li (2016) study the emergence of corporate culture when preferences evolve through interactions or knowledge sharing while Gorton and Zentefis (2020) studies an environment where corporate culture is formed via top-down communication of the CEO's preferred culture.

[5]See also Dong et al. (2024) for an analysis of optimal cognitive diversity in a spatial settings where the nature of production and the objective criterion being applied are explored.

agents.

Our paper explores the issue of managers who strategically manage shared understanding within the firm. As such, we are related to Van den Steen (2010a) and Van den Steen (2010b), which studies how diversity influences decision-making in organizations. Van den Steen (2010a) finds that more pronounced homogeneity leads to more delegation, less monitoring, and higher effort. However, it could also discourage information collection and experimentation. Van den Steen (2010b) shows that managers in organizations are inclined to hire employees with beliefs similar to theirs since they believe that this will lead to the best results. Homogeneous beliefs are reinforced via shared experiences since individuals within successful organizations are likely to update their beliefs in the same direction. Our paper also models how a manager influences a team's shared understanding. However, we study an environment where team members jointly agree on the amount of information to acquire, at a cost, to maximize their joint surplus, while the manager ignores the cost of information collection and maximizes the team's expected output. We find that information acquisition and shared understandings are substitutes and identify cases where self-interested managers may hire for diversity to encourage information acquisition or direct communication.[6]

Finally, there is a nice empirical literature on the effects of shared understandings on performance. Psychologists have captured this idea by talking about shared mental models of the task–whether teammates have correlated ways of interpreting information pertaining the task at hand. Both in the lab (Mathieu et al., 2000) and in the field (Lem and Klein, 2006; Hallet et al., 2025), teams with more closely shared mental models of the task perform better.

2 Base Team Environment

Consider a team consisting of two agents, labeled 1 and 2, each of whom controls an inalienable decision right to choose action A or action B. There is a dichotomous unobservable state of the world $\sigma \in \{A, B\}$, and the agents share a common prior that $\sigma = A$ with probability $\pi > 1/2$. The agents also share a common state and action-dependent payoff $V(a_1, a_2|\sigma)$, where a_i is the action of agent i and σ is the state of the world. This commonality abstracts away from incentive conflicts within the team and is what makes this a team-theoretic environment. We make the following assumptions about these payoffs:

[6] Manipulating the composition of the team to encourage information acquisition is also explored in Bel et al. (2015) and Smirnov and Wait (2016). In these papers, workers vary in their familiarity with one another, and teams comprised of familiar individuals produce higher output given the same level of effort. However, the marginal return to effort is decreasing in familiarity. Thus, familiarity and effort provision are substitutes and managers may optimally match unfamiliar individuals into teams to promote effort.

Assumption 1 $V(A, A|A) = V(B, B|B) = 1$

Assumption 2 $V(A, B|A) = V(A, B|B) = V(B, A|A) = V(B, A|B) \equiv 0$

Assumption 3 $V(A, A|B) = V(B, B|A) \equiv V^C \leq 1$

Assumption 1 states that the payoff for coordinating while adapting to the state is independent of the state. Assumption 2 states that when only one player's choice matches the state, it does not matter which player matches. This value is normalized to zero and is always less than the value of coordinating and adapting to the state. Finally, Assumption 3 says that the value of coordinating on the wrong action is independent of the state. The key payoff parameter in our model is V^C, which we refer to as the **value of coordinating**.

In order to leverage results from the existing literature, it is useful to define supermodularity in our environment with regard to the payoff function V. For two actions $a_1 \in \{A, B\}$ and $a_2 \in \{A, B\}$, let $\min(a_1, a_2)$ and $\max(a_1, a_2)$ be lexicographical operators.[7] Then, supermodularity requires the following:

Definition 1 *The payoff function V is supermodular in the agents' actions if, for any two action vectors $(\hat{a}_1, \hat{a}_2)$ and $(\tilde{a}_1, \tilde{a}_2)$ and for all states $\sigma \in \{A, B\}$, the following holds*

$$V(\hat{a}_1, \hat{a}_2|\sigma) + V(\tilde{a}_1, \tilde{a}_2|\sigma) \leq V(\min(\hat{a}_1, \tilde{a}_1), \min(\hat{a}_2, \tilde{a}_2)|\sigma) + V(\max(\hat{a}_1, \tilde{a}_1), \max(\hat{a}_2, \tilde{a}_2)|\sigma)$$

In our setting, the left and right sides of the equation above differ only in the case where $(\hat{a}_1, \hat{a}_2)$ and $(\tilde{a}_1, \tilde{a}_2)$ are either (A, B) or (B, A). Thus, supermodularity will hold if

$$2V(A, B|\sigma) \leq V(A, A|\sigma) + V(B, B|\sigma).$$

Noting that $2V(A, B|\sigma) = 0$ and $V(A, A|\sigma) + V(B, B|\sigma) = 1 + V^C$ for all σ, the payoff function is supermodular in cases where the value of coordinating, $V^C \geq -1$. V^C is modular when $V^C = -1$ and submodular when $V^C \leq -1$.

In the baseline model, agents must choose their actions simultaneously and without communication. However, before taking an action, each agent receives a dichotomous private signal, $s_i \in \{A, B\}$, which may be correlated with their partner's signal. With probability ρ the two individuals receive the same signal and thus have perfectly correlated signals. With probability $(1 - \rho)$ the two individuals receive independent signals. We assume that in each state σ, an individual receives signal σ with probability q.[8]

[7] For example, $\min(A, A) = \min(A, B) = A$ and $\min(B, B) = B$.

[8] Note that q will also be the probability that an individual who follows their signal correctly matches the state since $Pr(s_i = A \cap \sigma = A) + Pr(s_i = B \cap \sigma = B) = Pr(s_i = A|\sigma = A)Pr(\sigma = A) + Pr(s_i = B|\sigma = B)Pr(B) = q\pi + q(1 - \pi) = q$.

This implies that the the probability that both signals are equal to the true state is $\rho q + (1-\rho)q^2$, the probability that both signals are opposite to the true state is $\rho(1-q) + (1-\rho)(1-q)^2$, and the probability that only one signal matches the true state is equal to $2(1-\rho)q(1-q)$. In this last case, we assume that each agent is equally likely to have the signal that matches the state. We assume, throughout, that the signals are weakly positively correlated ($1 \geq \rho \geq 0$), and that signals are more informative than the initial prior (i.e., $q > \pi$).[9] We will refer to ρ as the level of **shared understanding** in our team, and refer to q as the **quality of the signal**.

2.1 An Example

As noted in the introduction, a simple example of our baseline example are two police officers arriving separately to a crime. Each officer receives reports over the radio about the situation and must quickly decide on which of two potential exits to cover. The quality of the signal relates to how easy it is that the officers can predict which exit the criminal will use. The level of shared understanding is likely to be related to two characteristics of the problem. First, shared understanding is likely to be influenced by the amount of shared information the two officers receive from dispatch. Second, shared understanding is likely to be related to their underlying training and the extent to which the officers cotton on to different components of the world.

Assumption 1 says that if both police officers arrive at the same exit as the criminal, the outcome is the same regardless of the exit. Assumption 2 says that both officers are equally capable of making the arrest if confronting the criminal alone but that this situation is strictly worse than coordinating on the correct door. Finally, Assumption 3 says that if both officers arrive at the exit without the criminal, the particular door does not matter.

The value of coordinating, V^C is the value of not catching the criminal and is normalized against the case where the two officers catch the criminal together and the case where one officer attempts to make the arrest alone. This normalization will depend on the risk posed by the criminal in making a solo arrest and the cost associated with letting the criminal leave the scene. In the supermodular case where $V^C \geq -1$, the criminal is dangerous and/or the criminal is likely to be caught by other police.

The key assumptions in our baseline model are that information is exogenous and that communication is either impossible or prohibitively expensive. We study alternative cases where team members must collect information and can communicate in section 3.

[9] This assumption puts some structure on the posteriors π_A and π_B that arise after receiving signals A and B. In particular, $q > \pi$ implies that $\pi_B < 0.5 < \pi < \pi_A$.

2.2 Equilibrium Team Play and the Value of Shared Understanding

We solve for Bayesian Nash Equilibrium (BNE) of this game, with the additional refinement that an equilibrium will never be played if it is universally Pareto dominated, i.e., Pareto dominated for all parameters satisfying the assumptions above.

Definition 2 *Define four sets of strategy profiles:*

- ***AA Unresponsive****, where both agents play A after all signals. Denote the team's payoff under this strategy* u^{AA}.
- ***AB Unresponsive****, where one agent plays A and one plays B, regardless of their signals. Denote the team's payoff under this strategy* u^{AB}.
- ***RR Responsive****, where both agents follow their signals. Denote the team's payoff under this strategy* u^{RR}.
- ***AR Partially Responsive****, where one agent follows his signal, while the other chooses A independent of his signal. Denote the team's payoff under this strategy* u^{AR}.

An equilibrium of each type is defined as a BNE in which a strategy profile of that type is part of the equilibrium.

We show in Appendix A.3 that any BNE that is not universally Pareto dominated is of one of these four types. Thus, we will consider equilibria of these types, only. The following proposition summarizes the existence conditions for each type of equilibrium. The proofs are, again, relegated to the appendix, as they are straightforwardly algebraic.

Proposition 1

1. *An* ***AA Unresponsive*** *equilibrium exists if and only if* $V^C \geq -(\frac{\pi}{1-\pi})(\frac{1-q}{q})$.
2. *An* ***AB Unresponsive*** *equilibrium exists if and only if* $V^C \leq -(\frac{\pi}{1-\pi})(\frac{q}{1-q})$.
3. *A* ***RR Responsive*** *equilibrium exists if and only if* $q \geq \frac{\pi}{1-\rho}$ ***or***
$$V^C \geq \left(\frac{q}{1-q}\right)\left(\frac{\pi - [(1-\rho)q+\rho]}{\pi - q(1-\rho)}\right).$$
4. *An* ***AR Partially Responsive*** *exists if and only if* $q \leq \frac{\pi}{1-\rho}$ ***and***
$$-\left(\frac{\pi}{1-\pi}\right)\left(\frac{q}{1-q}\right) \leq V^C \leq \left(\frac{q}{1-q}\right)\left(\frac{\pi - [(1-\rho)q+\rho]}{\pi - q(1-\rho)}\right).$$

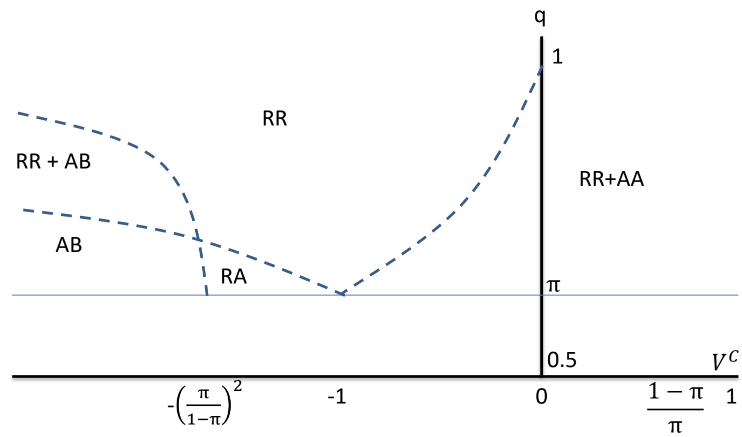

Figure 1: Agent Equilibria in The (V^C, q) Space with $\rho \in (0, 1)$.

Figure 1 graphically represents the equilibria in agent behavior that exists in the (V^C, q) space and with ρ fixed. AA and AB represent regions where the associated unresponsive equilibria exist, RR the regions where the responsive equilibrium exists, and RA where the partially responsive equilibrium exists.

Multiple equilibria can exist in two regions. When $V^C \geq -1$, both the Responsive and the AA unresponsive equilibria can exist. This comes from a coordination problem. If coordination is very important, player 1 wants to mix only in cases where player 2 is mixing. Similarly, both the Responsive and the AB unresponsive equilibria can exist when (i) V^C is very low and (ii) q is high enough that the Partially Responsive equilibrium does not exist.[10]

Whenever a unique equilibrium exists, it is (information-constrained) efficient, but when two sorts of equilibria exist it is possible to rank them from an efficiency standpoint, where one type of equilibrium will dominate for some subset of the parameter space and the other for the rest. Figure 1, a visual representation of Lemma 2 discussed in Appendix A.2, shows the efficient equilibrium for various parameter values. Note that in the case where V is supermodular, the responsive equilibrium is Pareto efficient

[10]When V^C is very low, all that matters is making sure that at least one player matches their action to the state, so clearly no one wants to deviate from the AB Unresponsive equilibrium. However, if player 1 knows that player 2 is playing the responsive equilibrium, and the signals are only weakly coordinated, player 1 can not effectively anti-coordinate by choosing the other action. In this case, the best move is to avoid missing the state by simply choosing whichever state player 1's signal indicates as most likely.

when the quality of the signal is high while the AA unresponsive equilibrium is efficient when the quality of the signal is low.

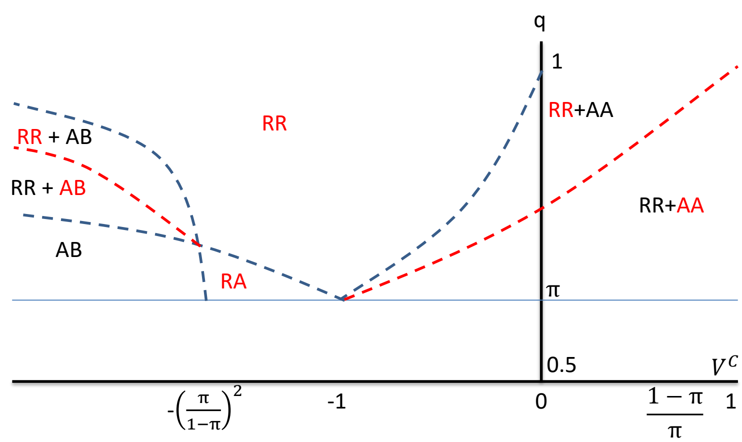

Figure 2: Efficient Strategies and Equilibria in The (V^C, q) Space with $\rho \in (0, 1)$.

While the level of shared understanding was held fixed in Figures 1 and 2, both figures make clear that there is a bifurcation in the set of potential equilibria at the point where V is modular and $V^C = -1$. At this value, there is no benefit or cost to coordinating actions relative to correctly choosing the state. Thus both players always follow their signal and shared understanding is irrelevant. The following proposition, which coincides with the result in Prat (2002), makes clear that shared understanding either increases or decreases the expected value of playing the responsive equilibrium when V is either supermodular or submodular.

Proposition 2 *Shared understandings affect payoffs only in the responsive equilibria, and in those equilibria, payoffs increase (decrease) with shared understandings if and only if $V^C > -1$ ($V^C < -1$).*

For the rest of the paper, we will concentrate on the supermodular case where the expected value of playing the responsive equilibrium is increasing in shared understanding. Here we note two things about this region. First, because the expected value of playing the responsive equilibrium is increasing in shared understanding, the region for which the AA equilibrium is Pareto efficient becomes smaller. This suggests that teams or firms who differ from one another in shared understanding may end up with very different procedures even when they receive signals with similar quality and have similar values of coordination. Second, because shared understanding works to reduce miscoordination, it has the most value in cases where signals are most likely to be different. Since fully informative signals will always be fully coordinated regardless of the shared level of understanding, the following proposition holds:

Proposition 3 *The value of shared understanding is decreasing in the quality of the signal.*

3 Managing Information

In this section, we explore how shared understanding interacts with information-related policies that are common in organizations. We begin by discussing how the level of shared understanding in an organization influences the relative cost and benefits of imposing rule-based decision-making on teams. We then explore how shared understanding interacts with direct communication that could be achieved if teams were forced to communicate in costly meetings. Finally, we analyze cases where teams must accumulate information through investment and explore how information-acquisition incentives change with shared understanding.

3.1 Rules

Consider an extreme sort of information policy, which we refer to as **Rules**, in which all discretion is taken from agents and their actions are completely pre-specified. We model this policy choice as a commitment before the game begins, and suppose it is chosen by a representative agent. If they decide to impose rules, perhaps at a cost, the agents' action sets are restricted in whichever way the planner decides. Otherwise, the game unfolds exactly as outlined in Section 2.

The use of rules is a weakly dominant strategy for the planner whenever an unresponsive equilibrium is efficient ($u^{AA} \geq u^{RR}$), while discretion is a weakly dominant strategy whenever a responsive equilibrium is efficient. Essentially, rules can be used to solve the agents' coordination problem when there are multiple equilibria. The value of rules is large when the team payoff from playing the unresponsive equilibrium exceeds the payoff from a response equilibrium by a large amount. The following proposition characterizes when that is the case.

Proposition 4 *The value of imposing rules increases as the prior strengthens or the value of maladaptive coordination increases, but it decreases as information quality improves or the teams shared understanding increases.*

We can use this proposition to understand what sorts of endeavors are likely to induce rulemaking. There are two sorts of reasons why rules might be valuable, one concerning payoffs and one concerning information. From a payoff perspective, managers will implement rules when the payoff from coordinating on the wrong thing is high enough, so a miss by both workers is not "too bad", relative to the risk of them failing to coordinate. Thus, very complementary tasks will be subjected to rules.

From the informational side, we expect to see rules when managers are very sure of the right thing to do, even before the information comes in, or where the information that is pending is poor. Of particular interest for our investigation of shared understandings, rules are also particularly attractive when the workers do not have a shared understanding of the world. Taken to the extreme, when agents have perfectly shared understandings of the world, there is never a reason to use rules. Rules solve the problem of failure to coordinate, but with perfectly shared understandings, that never happens. Rules and shared understandings are, therefore, substitutes, and a management would likely invest in one or the other, but not both. The same is true of informational quality, more generally.

3.2 Meetings

Consider a second information policy, where the team schedules a meeting in which they share their signals and make a plan before choosing their actions. If they are going to use a meeting policy, they must commit to it ex-ante (no emergency meetings) and each pay a cost m. In the absence of a meeting, we assume that the efficient equilibrium will be played, perhaps through the careful use of rules. If a meeting occurs, the agents can simply agree to a joint strategy at the meeting after jointly observing the signals.

After a meeting, agents can have one of three beliefs about the probability that the state is A, depending on the set of signals the agents received. Given our assumption that $V^C > -1$, however, the optimal choice after a meeting is either to play (A, A) or to play (B, B), and the (B, B) will be optimal if and only if both agents receive the B signal. The team's expected payoff of having a meetings u^M. Relative to simply playing the responsive equilibrium absent a meeting, this results in a net gain of

$$u^M - u^{RR} \equiv (1-\rho)[2q(1-q)(\pi + (1-\pi)V^c)] - m. \tag{1}$$

The gain from meetings, relative to simply following signals, comes from avoiding coordination problems when signals fail to align. This advantage, therefore, increases as the value of maladaptive coordination rises or when the prior is stronger, but decreases in the cost of the meeting and in the quality of the signal or completeness of the shared understanding.

Of course, for meetings to be attractive they have to outperform both the responsive equilibrium and the rules-based AA-unresponsive equilibrium. Since, other than the meeting cost, the payoff from meetings is simply the same as that from playing the responsive equilibrium, plus an additional coordination payoff when the signals do not match, similar factors drive the comparison between meetings and the AA-unresponsive strategy. The gain from meetings, relative to the AA-unresponsive payoff, increases in the quality of the signal and decreases in the value of maladaptive coordination, the strength of the prior, or the cost of the meeting. More interesting, and in contrast to the responsive equilibrium, the payoff from meetings decreases in the degree of shared understanding, since there is less information to share at them.

Overall, the manager will implement meetings when the payoff under meetings exceeds the payoff from the best alternative. Of course, when meetings are costless, they are always preferred, while when they are very costly they are never preferred. In fact, there will always been a unique cost of meetings m^*, which measures the attractiveness of meetings, where meetings are preferred for all $m < m^*$ and no meetings are preferred for all $m > m^*$. The following proposition summarizes how m^* varies with the other parameters of the model.

Proposition 5 *The threshold m that makes introducing a meeting optimal, m^*,*

1. *first increases in V^C and then decreases. It increases when the responsive equilibrium outperforms the AA-unresponsive equilibrium.*
2. *first increases in q and then decreases. It increases when then the AA-unresponsive equilibrium outperforms the responsive equilibrium.*
3. *first increases in π and then decreases. It increases when the responsive equilibrium outperforms the AA-unresponsive equilibrium.*
4. *decreases in ρ.*
5. *approaches zero as q or V^C approaches* 1.

As an alternative way of seeing when meetings are attractive, Figure 3 fixes m, π, and ρ, and lets V^C and q vary. Consistent with Proposition 5, meetings are most attractive for moderate q and V^C, when it is a "close call" between rules and discretion.

Taken together, our theory predicts that the value of meetings lie in a parameter zone that is "in between" the zones where the responsive equilibrium and rules are optimal. As such, we would predict that meetings are most valuable for intermediate signal qualities and for cases where there are intermediate payoffs to maladaptive coordination. Meetings and shared understanding are also substitutes and, as such, the value of a meeting is decreasing in shared understanding.

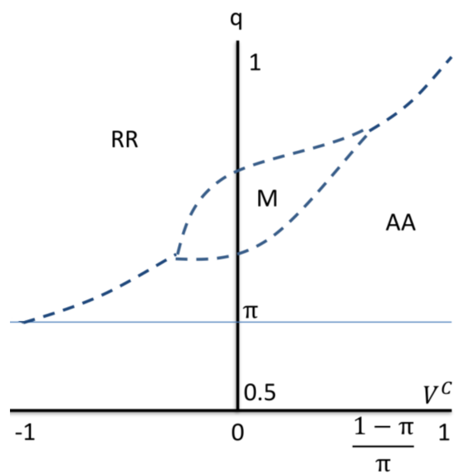

Figure 3: Meeting Policy (V^C, q) Space with $\rho \in (0, 1)$.

3.3 Investing in Information

In previous sections, we studied how teams may establish rules or hold meetings when both the quality of information and the level of shared understanding is given. This section explores how a team's incentive to accumulate information changes in response to changes in shared understanding. We highlight that information acquisition and shared understanding are substitutes and that a team will reduce investments in information in response to a greater shared understanding.

Consider a modified environment where the team must jointly decide on the amount of information they collect prior to the start of the game. Starting from any prior, π, assume that each individual in the team can invest in a signal that is correct with probability $\pi + I$ at cost cI^2, where $I \in [0, 1-\pi]$ and $c \geq 0$. We maintain the assumption that $V^C > -1$, as this is the region where both adaptation and coordination are important. In this region, if a team chooses to use rules, the team plays AA and has no value for information. It thus selects $I = 0$.

Information Acquisition in the Responsive Equilibrium: If a team chooses to play the responsive equilibrium, they jointly choose $I \in [0, 1-\pi]$ that maximizes the team's joint surplus

$$s^{RR}(\rho, \pi, c, V^C) \equiv \max_I 2\big(\alpha(I) + \beta(I)V^c\big) - 2cI^2, \tag{2}$$

where $\alpha(I) = \rho(\pi + I) + (1-\rho)[\pi + I]^2$ is the probability that the team matches on the correct state and $\beta(I) = \rho(1 - \pi - I) + (1-\rho)(1-\pi-I)^2$ is the probability that the team jointly coordinate on the wrong state.

In the interior case, the maximization yields

$$(3) \qquad I^{RR}(c,\rho,V^C) = \frac{[\rho(1-V^C) + 2(1-\rho)(\pi - (1-\pi)V^C)]}{2c - 2(1-\rho)(1+V^C)}.$$

This equation represents a maximum only when the second-order condition is negative, which occurs when $2c - 2(1-\rho)[1+V^C] > 0$. If the second-order condition is not satisfied, the value function is strictly increasing in I and the team prefers to be fully informed.

By taking the derivative of $I^{RR}(c,\rho,V^C)$ with respect to ρ it can be shown that I is decreasing in ρ and thus that the amount of information acquired by the team is decreasing in shared understanding.[11] In other words, information acquisition and shared understanding are substitutes. The intuition for this is straightforward. Without a shared understanding both team members must be informed in order to correctly coordinate on the correct state. Thus without a shared understanding, investing in information improves both coordination and adaptation. When the two parties have a shared understanding, by contrast, information improves only adaptation and is therefore less valuable.

Although investment in information is decreasing in ρ, the joint surplus of the team is always increasing in shared understanding. By the envelope theorem, $\frac{\partial s^{RR}(\rho,\pi,c,V^C)}{\partial \rho} = [(\pi + I^{RR}) - (\pi + I^{RR})^2][1+V^C] > 0$. So, the sign of the relationship between shared understanding and welfare is unchanged when information acquisition is endogenized, but the team "takes" some of the benefit as reduced information investment.

While the relationship between shared understandings and investment/welfare is monotonic, the relationship between shared understandings and the expected output of the team, $\left(\alpha(I^{RR}) + \beta(I^{RR})V^c\right)$, can be non-monotonic. We know from the exogenous-information analysis that absent investment adjustments, shared understanding leads to an increase in the expected output of the team when $V^C > -1$. However, the reduction in investment can be so extreme as to more than offset this direct increase. The net effect depends on the convexity of the cost of information. For high costs, the expected output of the team is increasing in ρ. For moderate moderate costs, output decreases up to some $\hat{\rho}$ and then increases. Finally, for low costs, the output of the team is decreasing in ρ. This fact may suggest that there is scope for a manager who only cares about outputs but not costs to influence the probability of successful coor-

[11] Taking the derivative of I with respect to ρ yields:

$$(4) \qquad \frac{\partial I^{RR}(c,\rho,0)}{\partial \rho} = \frac{(1-2\pi)(1+V^C) - 2(1+V^C)I^{RR}(c,\rho,V^C)}{2c - 2(1-\rho)(1+V^C)}.$$

This derivative is negative when the second-order condition is satisfied under the assumptions that $\pi > 1/2$, $V^C \in (-1,1]$, and $I \in [0, 1-\pi]$.

dination by influencing the level of shared understanding. We return to this issue below.

Meetings: We now study the incentive to gather information in the case of a meeting. As in the earlier section, meetings allow two individuals who receive opposing signals to coordinate on A. As before, we assume that the team chooses $I \in [0, 1-\pi]$ jointly and maximizes:

$$(5) \quad s^M(\rho, \pi, c, V^C, m) \equiv \max_I 2\big(\alpha(I) + \beta(I)V^C + \gamma(I)(\pi + (1-\pi)V^C)\big) - 2cI^2 - m,$$

where $\alpha(I)$ is the probability the team shares the correct signal, $\beta(I)$ is the probability the team shares the incorrect signal, and $\gamma(I) \equiv (1-\alpha(I)-\beta(I)) = 2(1-\rho)[\pi+I][1-\pi-I]$ is the probability of both team members receiving different signals.

In the interior case, the maximization yields

$$(6) \quad I^M(c, \rho, V^C) = \frac{[\rho(1-V^C) + 2(1-\rho)(\pi-(1-\pi)V^C) - 2(1-\rho)(2\pi-1)(\pi+(1-\pi)V^C)]}{2c - 2(1-\rho)[1+V^C] + 4(1-\rho)(\pi+(1-\pi)V^C)}.$$

As before, the solution to this equation is a maximum only when the second order condition is negative, which occurs only when $2c - 2(1-\rho)[1 - 2(\pi + (1-\pi)V^C)] > 0$. If the second-order condition is not satisfied, the value function is strictly increasing in I and the team prefers to be fully informed.

By comparing (3) and (6) and noting that in equation (6) the last term in the numerator is negative and the last term in the denominator is positive, teams acquire strictly less information when a meeting occurs than in the responsive equilibrium. This reduction in information acquisition is due to a meeting improving the outcome of teams where the two members receive different signals and reducing the coordination benefit of the two parties receiving more precise signals.

Unlike the responsive equilibrium, information acquisition is increasing in ρ.[12] In a meeting context, a shared understanding increases the likelihood that both parties receive the same incorrect signal and decreases the likelihood of mixed signals. As receiving the same incorrect signals is the worst possible signal event, team members prefer to acquire more information when shared understanding is high to reduce the probability of jointly being misinformed. In contrast to the responsive equilibrium case, $\frac{\partial s^m(\rho,\pi,c,V^C)}{\partial \rho} = [(\pi+I) - (\pi+I)^2][1 - V^C - 2] < 0$. Thus a team's joint surplus

[12]This can be seen by taking the derivative of I with respect to ρ:

$$(7) \quad \frac{\partial I^m(c,\rho,V^C)}{\partial \rho} = \frac{(1-2\pi)^2(1-V^C)}{D(\rho,V^C,\pi,c)} - \frac{2(1-2\pi)(1-V^C)}{D(\rho,V^C,\pi,c)} I^m(c,\rho,V^C),$$

where $D(\rho, V^C, \pi, c) = 2c - 2(1-\rho)[1+V^C] + 4(1-\rho)(\pi + (1-\pi)V^C)$ and $I^m(c, \rho, V^C)$ is the investment made by the team. Noting that the assumption $\pi > .5$ is equivalent to $1 - 2\pi < 0$, both terms are positive for $V^C \in [-1, 1)$.

is always decreasing in a shared understanding when a meeting will occur.

Finally, just as in the responsive equilibrium, there is not a monotonic relationship between ρ and the expected output of the team using a meeting: $\alpha(I) + \beta(I)V^C + (1 - \alpha(I) + \beta(I))(\pi + (1 - \pi)V^C)$. For high costs, the expected output of the team is decreasing in ρ, for moderate costs, the expected output of the team is decreasing up to some $\hat{\rho}$ and then increasing, and for low costs, the expected output of the team is strictly increasing in ρ.

4 Manager-Team Problems

In the last section, we explored how the possibility of rule-based systems, costly direct communication, and information acquisition interacted with a shared understanding. We saw that if a manager has fully aligned incentives, he will cultivate a shared understanding only in cases where both adaptation and coordination are important and where the cost of direct communication via a meeting is high. In this region of the parameter space, information acquisition was decreasing in shared understanding and thus, although the teams was better off with a high level of shared understanding, overall output of the team was lower.

In this section we explore how the manager may adjust the composition of the team when her objective function differs from that of the team. We assume that a manager has control over the composition of the team, and can thereby affect the level of shared understanding, but the manager does not control the actions of the team. We continue to concentrate on the case here $V^C > -1$ and where both adaptation and coordination are important.

4.1 Output-Based Managers

One way that a manager's preferences may diverge from those of the team is that she may care more about the team's output than she does about the costs incurred by team members.[13] In such cases, the manager may use the composition of the team to influence information acquisition or to either encourage or discourage meetings. We consider, here, the extreme case where the manager completely ignores the costs of information acquisition and meetings and only cares about the teams output. For exposition, let

$$o^{RR}(\rho, \pi, c, V^C) \equiv \alpha(I^{RR}(\rho, \pi, c, V^C)) + \beta(I^{RR}(\rho, \pi, c, V^C))V^C$$

[13]We see such output-based managers as common in large firms where hiring decisions fall to middle managers who have a vested interest in the performance of their team but where compensation is handled at a higher level of the hierarchy.

be the output-based manager's expected return if a team optimally plays the responsive equilibrium given the manager-selected level of shared understanding ρ, the prior π, the cost of acquiring information c, and the relative value of coordinating on the wrong action, V^C. Likewise, let

$$\begin{aligned} o^M(\rho, \pi, c, V^C) \;\; &\equiv \;\; \alpha(I^M(\rho, \pi, c, V^C)) + \beta(I^M(\rho, \pi, c, V^C))V^C \\ &\qquad + \gamma(I^M(\rho, \pi, c, V^C))(\pi + (1-\pi)V^C) \end{aligned}$$

be the manager's return if the team holds a meeting and plays optimally.[14] Finally, let

$$s^{AA}(\pi, V^C) = 2(\pi + (1-\pi)V^C)$$

be the expected value of a team that plays the AA-unresponsive equilibrium and let

$$o^{AA}(\pi, V^C) \equiv (\pi + (1-\pi)V^C)$$

be the manager's expected return if the team plays this equilibrium.

It will be useful to separate the rest of the discussion into the case where the team will never choose to have a meeting for any information cost and the case where meetings may occur. Recall that the expected value of the team decreases in ρ in the equilibrium with a meeting and increases in ρ in the responsive equilibrium. It follows that (i) the value of the responsive equilibrium relative to meetings is maximized at $\rho = 1$ and (ii) the value of a meeting relative to the other two policies is maximized at $\rho = 0$. Furthermore, when $\rho = 1$, the investment choices and expected output of a team are the same with or without the meeting.

Since meeting costs are assumed to be positive, the responsive equilibrium is always implementable by setting ρ to be very high. By contrast, the existence of meetings depends on both the meeting cost and the other parameters. Let $\overline{m}(\pi, V^C)$ be the meeting cost m such that

$$\max_c s^M(0, \pi, c, V^C, m) - s^{RR}(0, \pi, c, V^C) = 0.$$

The following lemma specifies $\overline{m}(\pi, V^C)$.

Lemma 1 *If the cost of meeting is such that* $m > \overline{m}(\pi, V^C)$*, where*

$$\overline{m}(\pi, V^C) \equiv 4\pi(1-\pi)\big[\pi + (1-\pi)V^C\big],$$

[14] As before, $\alpha(I) = \rho(\pi + I) + (1-\rho)[\pi + I]^2$ is the probability that the team matches on the correct state, $\beta(I) = \rho(1-\pi-I) + (1-\rho)(1-\pi-I)^2$ is the probability that the team jointly coordinate on the wrong state, and $\gamma(I) = (1 - \alpha(I) - \beta(I))$ is the probability that the signals of the team do not match.

then meetings never occur.

In the case where $m > \overline{m}(\pi, V^C)$ and meetings never occur, note first that the payoff to rules is equal to $o^{AA}(\pi, V^C)$, and this payoff is independent of ρ. Further, the responsive equilibrium with $\rho = 1$ outperforms rules, even for very low levels of information acquisition. This immediately implies that the manager will always prefer the responsive equilibrium to rules and she can always induce the team to select the responsive equilibrium over the AA-unresponsive equilibrium by setting ρ to be very high. It follows that the manager's objective is to maximize his surplus in the RR-responsive equilibrium subject to the constraint that the team may choose the AA-equilibrium.

For a given c, let $\hat{\rho}(c, \pi, V^C)$ be implicitly defined as follows:

Definition 3 *$\hat{\rho}(c, \pi, V^C)$ is the lowest level of shared understanding where a team will select the responsive equilibrium over a rule-based equilibrium if these are the only two policies available. If $s^{RR}(0, \pi, c, V^C) > s^{AA}(\pi, V^C)$, then $\hat{\rho}(c, \pi, V^C) = 0$. Otherwise, $\hat{\rho}(c, \pi, V^C)$ is the ρ that satisfies*

$$s^{RR}(\rho, \pi, c, V^C) = s^{AA}(\pi, V^C).$$

$\hat{\rho}(c, \pi, V^C)$ defines the cutoff point where the team is indifferent between the RR-responsive equilibrium and AA-unresponsive equilibrium. As such, we can now derive the optimal choices of the manager for varying costs of information collection. Recall that the relationship between share understanding and the expected output in the responsive equilibrium, $o^{RR}(\rho, \pi, c, V^C)$, is non-monotonic and can vary with c. When the cost of information is low, the expected output is decreasing in ρ and the managers will prefer to select the lowest level of shared understanding that is consistent with a responsive equilibrium. Thus, the optimal level of shared understanding will be $\hat{\rho}(c, \pi, V^C)$ defined above.

At the opposite extreme, when the cost of information is very high, the team's expected output is increasing in ρ since the team will collect very little information but shared understanding helps to avoid miscoordination. Thus, for high costs, the manager would prefer to select a team with maximal shared understanding.

At intermediate costs of information increases, the manager's payoff in the responsive equilibrium is convex in ρ with a single interior minimum.[15] As such, there will be a point where a team generates better outcomes under perfectly shared understanding

[15]Solving for the minimum is algebraically painful, but it is possible to bound the set of c's for which output is convex by identifying the c for which (i) expected output is strictly decreasing and (ii) expected output is strictly increasing. These can be found by finding the points where the slope of $\alpha(I^{RR}) + \beta(I^{RR})V^C$ is zero under perfectly shared understanding ($\rho = 1$) and no shared understanding ($\rho = 0$). For example,

than at the point where they are indifferent between rules and the responsive equilibrium. Let $\overline{c}(\pi, V^C)$ be the c such that $o^{RR}(\hat{\rho}(c, \pi, V^C), \pi, c, V^C) = o^{RR}(1, \pi, c, V^C)$ Then, for $c > \overline{c}(\pi, V^C)$, the manager prefers to maximize shared understanding in a team.

Figure 4 illustrates the decision the manager faces, in each of these cases. In Case 1, when information is cheap, the team will always play the responsive equilibrium and invest in information, so the manager can utilize a totally heterogeneous team ($\rho^* = 0$). In Case 2, with slightly higher costs, such a team would simply implement rules, so the manager chooses a team with higher levels of share understanding to induce the responsive equilibrium. In Case 4, for very high costs of information, the manager and team are aligned, and higher $\rho = 1$ is preferred by both. Case 3 illustrates the boundary case, where the manager is indifferent between implementing the Case 2 and Case 4 strategies.

The discussion above generates the following decision rule:

Proposition 6 *When $m > \overline{m}(\pi, V^C)$, a manager who cares only about the output of a team but not its costs will set ρ as follows:*

1. *if $c \leq \overline{c}(\pi, V^C)$ the manager sets $\rho^* = \hat{\rho}(c, \pi, V^C)$.*
2. *if $c > \overline{c}(\pi, V^C)$, the manager sets $\rho^* = 1$.*

This choice will always induce the team to play the responsive equilibrium.

Consider now the case where $m < \overline{m}(\pi, V^C)$, so that there exist costs and levels of shared understanding where the team may also hold a meeting. In order to induce the RR-equilibrium, the manager must now ensure that the team prefers the RR-equilibrium over both the AA-equilibrium and a meeting. Analogous to the analysis above, let $\hat{\hat{\rho}}(c, \pi, V^C)$ be implicitly defined as follows:

Definition 4 *$\hat{\hat{\rho}}(c, \pi, V^C)$ is the lowest level of shared understanding where a team will select the responsive equilibrium over the AA-equilibrium and an equilibrium involving meetings. If $s^{RR}(0, \pi, c, V^C) \geq \max\{s^{AA}(\pi, V^C), s^M(0, \pi, c, V^C, m)\}$, then*

when $V^C = 0$, it is the case that the manager's payoff is weakly decreasing in ρ when

$$c < \frac{2\left[(2\pi - 1) + \sqrt{(2\pi - 1)^2 - 3\pi(1 - \pi)}\right]}{3}.$$

This expression is equivalent to $c < \frac{1}{\sqrt{3}}$ in the case of $\pi = 1/2$. Likewise, the manager's payoff is weakly increasing in ρ when

$$c > \frac{1 + \pi}{1 - \pi}.$$

This expression is equivalent to $c > 3$ in the case of $\pi = 1/2$. Thus, an interior minimum will exist for $c \in \left[\frac{1}{\sqrt{3}}, 3\right]$ when $\pi = 1/2$.

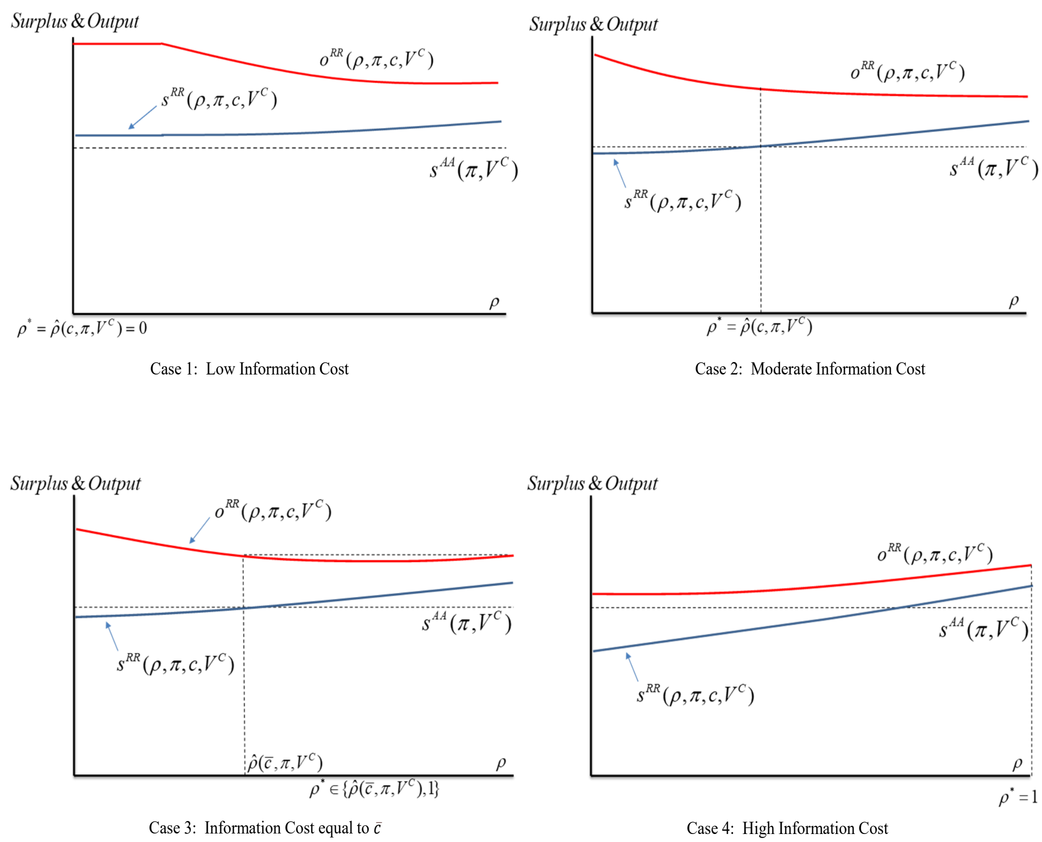

Figure 4: Manager's optimal choice of ρ as the cost of information increases in case where $m > \overline{m}(V^C)$. When information costs are low, the expected output of the team is falling in shared understanding and the manager hires for diversity (case 1) subject to the constraint that the team may choose to adopt a rule (case 2). For high costs, the preferences of the manager and team are aligned and the manager maximizes shared understanding (case 4). There is a cutoff cost of information where the manager switches between these strategies (case 3).

$\hat{\hat{\rho}}(c, \pi, V^C) = 0$. *Otherwise,* $\hat{\hat{\rho}}(c, \pi, V^C)$ *is the* ρ *that satisfies*

$$s^{RR}(\rho, \pi, c, V^C) = \max\{s^{AA}(\pi, V^C), s^M(\rho, \pi, c, V^C, m)\}.$$

For low costs, the probability of coordinating on the good state is higher in the responsive equilibrium than with a meeting due to the incentive to free ride on information acquisition in meetings.[16] As such, the manager will prefer to implement the RR equilibrium. Further, when the cost of information is low, the expected output of the manager is decreasing in ρ in the RR-equilibrium and the manager will prefer to select the lowest level of shared understanding that is consistent with a responsive equilibrium. The optimal level of shared understanding will therefore be $\hat{\hat{\rho}}(c, \pi, V^C)$ since he must prevent the team from both holding their own meeting or adopting a rule.

As the cost of information becomes larger, the output of the firm under the *RR*-equilibrium becomes convex in ρ and eventually becomes strictly increasing in ρ. As such, there will exist a cost where the manager will prefer to either (i) set $\rho = 1$ and induce the team to play the *RR* equilibrium or (ii) set $\rho = 0$ and induce the team to hold a meeting.

To distinguish between cases, it is useful to define two cost cutoffs. First, let $\bar{\bar{c}}(\pi, V^C)$ be the c such that $o^{RR}(\hat{\hat{\rho}}(c, \pi, V^C), \pi, c, V^C) = o^{RR}(1, \pi, c, V^C)$. This is the cost for which the manager is indifferent between implementing the *RR* equilibrium that maximizes information and the *RR* equilibrium with perfectly shared understandings. Further, let $\tilde{c}(\pi, V^C)$ be the cost of information such that $o^{RR}(\hat{\hat{\rho}}(c, \pi, V^C), \pi, c, V^C) = o^M(0, c, \pi, V^c)$. This is the cost for which the manager is indifferent between implementing the information-maximizing *RR*-equilibrium and a meeting.

If $\bar{\bar{c}}(\pi, V^C) < \tilde{c}(\pi, V^C)$, the managers optimal policy is divided into three parts. First, when costs of information acquisition are low, the manager selects the lowest level of shared understanding that is consistent with a responsive equilibrium. This level of shared understanding maximizes information acquisition for the firm. As costs rise, the output function becomes convex and there is eventually a cost where coordination concerns dominate information acquisition. As such, the manager has preferences that are aligned with the team and implements the *RR*-equilibrium with fully aligned incentives.

Finally, for very high information acquisition costs, the firm may not be able to induce high levels of information acquisition under the RR equilibrium. In this case, the manager may instead wish to induce direct communication between team members

[16] To see that information acquisiting is lower under a meeting, note that when c is small, the probability of coordinating on the good state is decreasing in ρ in the responsive equilibrium and increasing in ρ with meetings. As they are equal at $\rho = 1$, information acquisition is lower under a meeting for all possible ρ.

via a meeting to prevent miscoordination. Since shared understanding reduces the value of this direct communication, managers who wish to implement meetings will do so by hiring for diversity and setting $\rho = 0$. Let $c^M(\pi, V^C)$ be the cost of information acquisition such that $o^M(0, \pi, c, V^C) = o^{RR}(1, \pi, c, V^C)$. Then, the manager will always prefer a meeting for $c > c^M(\pi, V^C)$.

Figure 5 illustrates the managers decision in the case where $\overline{\overline{c}}(\pi, V^C) < \tilde{c}(\pi, V^C)$. In Case 1, information is cheap and it is optimal for the manager to implement the information-maximizing RR equilibrium. For moderately-high costs, the preferences of the manager and team are aligned and the manager maximizes shared understanding (Case 3). Finally, for very high costs, the manager hires for diversity and induces meetings (Case 4).

The following propositions summarize the optimal strategy of the manager:

Proposition 7 *When $m < \overline{m}(\pi, V^C)$ and $\overline{\overline{c}}(\pi, V^C) < \tilde{c}(\pi, V^C)$, a manager who cares only about the output of a team but not its costs will set ρ as follows:*

1. *if $c \leq \overline{\overline{c}}(\pi, V^C)$ the manager sets $\rho^* = \hat{\hat{\rho}}(c, \pi, V^C)$ and implements the responsive equilibrium.*
2. *if $c \in (\overline{\overline{c}}(\pi, V^C), c^M(\pi, V^C)]$, the manager sets $\rho^* = 1$ and implements the responsive equilibrium.*
3. *if $c > c^M(\pi, V^C)$, the manager sets $\rho^* = 0$ and implements an equilibrium with meetings.*

When m is very small or when the prior is very strong, it may be that $\overline{\overline{c}}(\pi, V^C) > \tilde{c}(\pi, V^C)$. In this case, there is no cost for which the manager wishes to induce a shared understanding in his team. As such, the manager will switch from inducing the information-maximizing RR-equilibrium for low costs of information and the equilibrium with meetings for high costs. The following proposition summarizes the optimal strategy of the manager in this alternative case:

Proposition 8 *When $m < \overline{m}(\pi, V^C)$ and $\overline{\overline{c}}(\pi, V^C) > \tilde{c}(\pi, V^C)$, a manager who cares only about the output of a team but not its costs will set ρ as follows:*

1. *if $c \leq \tilde{c}(\pi, V^C)$ the manager sets $\rho^* = \hat{\hat{\rho}}(c, \pi, V^C)$ and implements the responsive equilibrium.*
2. *if $c > \tilde{c}(\pi, V^C)$, the manager sets $\rho^* = 0$ and implements an equilibrium with meetings.*

Taken together, output-based managers may cultivate a shared understanding in their team when the cost of acquiring information is moderate. However, when (i) information costs are low or (ii) information costs are high and meeting costs aren't

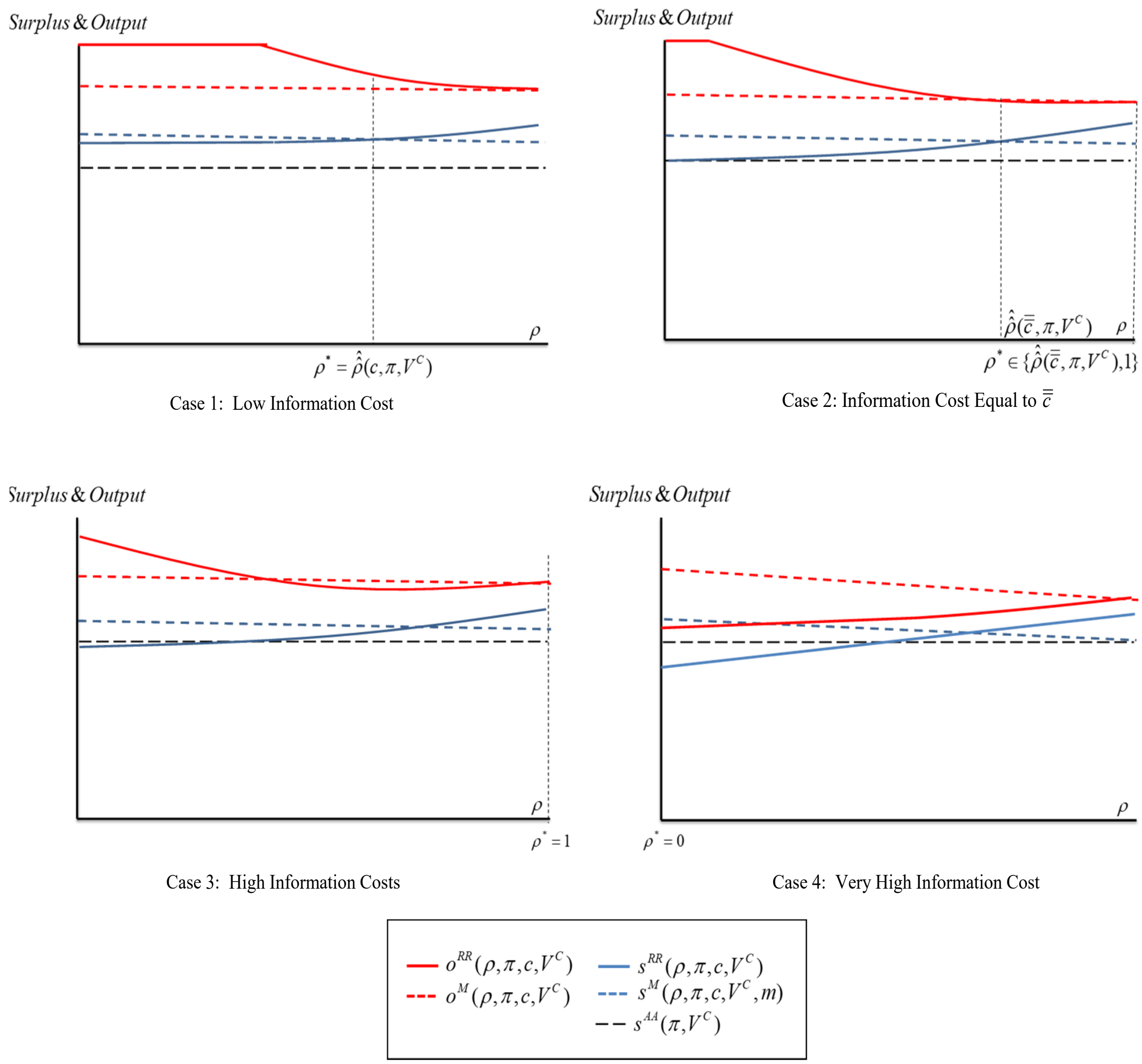

Figure 5: Manager's choice of ρ as the cost of information increases in case where $m < \overline{m}(\pi, V^C)$ and $\overline{c}(\pi, V^C) < \tilde{c}(\pi, V^C)$. When information costs are low, the manager seeks to encourage information acquisition in the RR equilibrium by reducing shared understanding subject to the constraint that the team may hold a meeting or adopt a rule (Case 1). For moderate costs, the preferences of the manager and team are aligned and the manager maximizes shared understanding (Case 3). There is a cutoff cost of information where the manager switches between these strategies (Case 2). Finally, for high costs, the manager hires for diversity and induces meetings (Case 4).

too high, an outcome-based manager will push for more diversity than is preferred by the team. When information costs are low, output-based managers may discourage a shared understanding in order to increase information acquisition. However, their ability to do so is constrained by the possibility that teams may move from a discretionary strategy to a rule-based strategy or one that involves a meeting. When information costs are high, the team may collect only a small amount of information regardless of the equilibrium played or the level of shared understanding. As such, an output-based manager may seek to minimize shared understanding in order to encourage meetings and to avoid echo chambers from emerging.

5 Conclusion and Discussion

We explored how managers might use shared understanding to improve decisions in environments where underlying teams face the twin goals of coordinating decisions and adapting to changing circumstances. We show that in our team-theoretic setting, a shared understanding improved the outcome of teams only when payoffs are supermodular and where getting the second person to align their actions with the first person is more valuable than getting the first person to choose the correct state, but where coordination is not so dominant a goal that it is better for the team to adopt a rule. When payoffs are submodular, teams are hurt by shared understanding since coordinating on the wrong state becomes more common.

We then considered the value of shared understanding in the supermodular case when team members also must exert effort to collect information and where it was possible to force the team to share information via a costly meeting. In the absence of a meeting, we showed that shared understanding is a substitute for information acquisition and that a team will optimally exert less effort as the level of shared understanding increases. Thus, while shared understanding improves the overall welfare of the team, there is a substitution away from information collection. When meetings are allowed, shared understanding reduces the overall welfare of a team that holds a meeting since there is no value in sharing the same signal. Thus, managers who wish to use meetings should hire for diversity to avoid echo chambers.

Finally, we considered the case of an output-based manager who cares only about the outcome of the group but not its input costs. This manager is responsible for hiring decisions and can therefore influence shared understanding, but cannot directly force the team to take a specific course of action. We show that an output-based manager may hire for diversity to encourage information acquisition when the cost of acquiring information is low. However, the level of shared understanding cannot be set too low or else the team will adopt rules or organize a meeting where there is an incentive to free ride on information collection. As costs increase, the preferences of the manager and team become aligned and a manager may maximize shared understanding to avoid miscoordination. Finally, when costs are high and the cost of meetings is low, the manager may again hire for diversity to encourage direct communication and the sharing of information.

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A Appendices: Additional Notation, Discussion of Other Equilibria, and Proofs

A.1 Additional Notation

The following notation is useful in discussing the additional equilibrium that exist in our environment and in the formal proofs below. Let π_s be the posterior probability that the state is A after observing signal s. Note that by Bayes' rule:

$$\pi_A = \frac{\pi q}{\pi q + (1-\pi)(1-q)},$$
$$\pi_B = \frac{\pi(1-q)}{\pi(1-q) + (1-\pi)q}.$$

Further, let $P_s^\sigma(e)$ represent the probability that the other player chooses action A when the state is σ, the player observes signal s, and the other party is playing strategy profile $e \in \{A, B, R, F\}$, where A is the strategy of always selecting A, B is the strategy of always selecting action B, R is the responsive strategy, and F is the strategy of always choosing an action that is opposite of one's signal (i.e., flipping the signal). Then the payoff to choosing A and B after signal j are:

$$U(A|s=j,e) = \pi_j[P_j^A(e)V^{FB} + (1-P_j^A(e))V^N] + (1-\pi_j)[P_j^B(e)V^C + (1-P_j^B(e))V^N],$$
$$U(B|s=j,e) = \pi_j[P_j^A(e)V^N + (1-P_j^A(e))V^C] + (1-\pi_j)[P_j^B(e)V^N + (1-P_j^B(e))V^{FB}].$$

Normalizing $V^{FB}=1$ and $V^N=0$, we can rewrite these utilities as:

$$\begin{aligned} U(A|s=j,e) &= \pi_j P_j^A(e) + (1-\pi_j)P_j^B(e)V^C, \\ U(B|s=j,e) &= \pi_j(1-P_j^A(e))V^C + (1-\pi_j)(1-P_j^B(e)). \end{aligned} \tag{8}$$

For a given ρ and q, note that:

$$\begin{aligned} P_A^A(R) &= \rho + (1-\rho)q, \\ P_A^B(R) &= \rho + (1-\rho)(1-q), \\ P_B^A(R) &= (1-\rho)q, \\ P_B^B(R) &= (1-\rho)(1-q), \end{aligned}$$

$$\begin{aligned} P_A^A(F) &= (1-\rho)(1-q), \\ P_A^B(F) &= (1-\rho)q, \\ P_B^A(F) &= \rho + (1-\rho)(1-q), \\ P_B^B(F) &= \rho + (1-\rho)q. \end{aligned}$$

Further, $P_s^\sigma(A)=1$ and $P_s^\sigma(B)=0$ for all states σ and signals s.

A.2 Proofs

Proof of Proposition 1: For an equilibrium to exist, it must be that both players prefer to play their candidate equilibrium action for each possible signal. We thus need to identify the set of conditions for which neither player has an incentive to deviate from their candidate strategy. We do this for each of the four strategy profiles separately:

- **AA Unresponsive**, where both players play A after all signals: for this to be an equilibrium, players must prefer to play A, after either signal, i.e., $U(A|s=j,A) > U(B|s=j,A)$ in (8). Replacing for $P_j^A(A) = P_j^B(A) = 1$, this requires that $\pi_j + (1-\pi_j)V^C > 0$, and the binding constraint occurs after the B signal (since $\pi_B < \pi_A$), so a necessary and sufficient condition for this equilibrium to exist is $V^C \geq -\frac{\pi_B}{1-\pi_B}$. Replacing for $\pi_B = \frac{\pi(1-q)}{\pi(1-q)+(1-\pi)q}$ yields

$$V^C \geq -\frac{\pi}{1-\pi}\frac{(1-q)}{q}. \tag{9}$$

This threshold is negative, increasing in q and decreasing in π, and given our assumption that $q > \pi$, it is minimized at -1 when $q = \pi$.

- **AB Unresponsive**, where one player plays A and one plays B, regardless of their signals: the player who plays A expects his partner to always play B, so he checks that $U(A|s = j, B) > U(B|s = j, B)$ when $P_j^A(B) = P_j^B(B) = 0$. This comparison reduces to $\pi_j V^C + (1-\pi_j) < 0$, which binds for π_B, if at all. Similarly, the player who plays B expects his partner to always play A, so equilibrium requires that $U(B|s = j, A) > U(A|s = j, A)$ when $P_j^A(A) = P_j^B(A) = 1$. Again, the comparison reduces to $\pi_j + (1 - \pi_j)V^C < 0$, which will bind for π_A, if at all. Finally, since $\pi > 1/2$ it's easy to check that the constraint for the player who plays B binds, if either does, so the necessary and sufficient condition for an equilibrium of this sort to exist is $V^C \leq -\frac{\pi_A}{1-\pi_A}$. Replacing for $\pi_A = \frac{\pi q}{\pi q+(1-\pi)(1-q)}$, allows us to again derive a condition on primitives,

$$V^C \leq -\frac{\pi}{1-\pi}\frac{q}{(1-q)}. \tag{10}$$

  This threshold is negative, decreasing in π and q, and given our assumption that $q > \pi$, it is maximized at -1 when $q = \pi = 1/2$. Since $q > \frac{1}{2}$, comparing this condition to (9) shows that there does not exist a V^C where both the AA Unresponsive equilibrium and the AB unresponsive equilibrium both exist.

- **Fully Responsive**, where both players follow their signals: in this equilibrium, a player expects his partner to play such that

$$\begin{aligned}
P_A^A(R) &= \rho + (1-\rho)q, \\
P_A^B(R) &= \rho + (1-\rho)(1-q), \\
P_B^B(R) &= (1-\rho)(1-q), \text{ and} \\
P_B^A(R) &= (1-\rho)q.
\end{aligned}$$

  The binding constraint is for the player to be willing to follow the equilibrium strategy after a signal B, when

$$\begin{aligned}
U(A|s = B, R) &= \pi_B[P_B^A(R)] + (1-\pi_B)[P_B^B(R)V^C], \text{ and} \\
U(B|s = B, R) &= \pi_B[(1-P_B^A(R))V^C] + (1-\pi_B)[(1-P_B^B(R))].
\end{aligned}$$

  Thus he is willing to follow his signal whenever

$$\pi_B(1-P_B^A(R))V^C + (1-\pi_B)(1-P_B^B(R)) \geq \pi_B P_B^A(R) + (1-\pi_B)P_B^B(R)V^C.$$

Gathering the V^C terms, this condition becomes

$$V^C[\pi_B(1-P_B^A(R)) - P_B^B(R)(1-\pi_B)] \geq \pi_B P_B^A(R) - (1-\pi_B)(1-P_B^B(R)),$$

or, after replacing for P_B^σ(R),

$$V^C[\pi_B(1-(1-\rho)q)-(1-\rho)(1-q)(1-\pi_B)] \geq \pi_B(1-\rho)q-(1-\pi_B)(1-(1-\rho)(1-q)).$$

Gathering the π_B terms on each side,

$$V^C[\pi_B(1-(1-\rho)q+(1-\rho)(1-q))-(1-\rho)(1-q)] \geq \pi_B[(1-\rho)q+(1-(1-\rho)(1-q))]-(1-(1-\rho)(1-q))$$

and simplifying

$$V^C[\pi_B(\rho q+(1-\rho)(1-q)+1-q)-(1-\rho)(1-q)] \geq \pi_B[2(1-\rho)q+\rho]-(\rho+(1-\rho)q).$$

The constant, on the right, is negative whenever $\pi_B < \frac{\rho+(1-\rho)q}{\rho+2(1-\rho)q} \in [0.5, 1]$. But $\pi_B < 1/2$, and so this condition is always satisfied and the constant on the right is always negative.

The coefficient on V^C, on the left, is positive whenever

$$\pi_B > \frac{(1-\rho)(1-q)}{(1-\rho)(1-q)+q\rho+1-q},$$

which holds for $q < \frac{\pi}{1-\rho}$. Thus, when $q \in (0.5, \frac{\pi}{1-\rho}]$, the condition becomes

$$V^C > \frac{\pi_B[2(1-\rho)q+\rho]-(\rho+(1-\rho)q)}{\pi_B[\rho q+(1-\rho)(1-q)+1-q]-(1-\rho)(1-q)},$$

where the RHS is negative. Label that cutoff V^{C^*}. Replacing for π_B, it simplifies to

$$V^{C^*} = \left(\frac{q}{1-q}\right)\frac{\pi-[(1-\rho)q+\rho]}{\pi-q(1-\rho)}. \tag{11}$$

For $q > \pi/(1-\rho)$ the condition is

$$V^C < \frac{\pi_B[2(1-\rho)q+\rho]-(\rho+(1-\rho)q)}{\pi_B[\rho q+(1-\rho)(1-q)+1-q]-(1-\rho)(1-q)},$$

but we can show that the RHS is positive and greater than 1, so the condition is always satisfied. The RHS is greater than 1 whenever

$$(\rho+(1-\rho)q)-\pi_B[2(1-\rho)q+\rho] > (1-\rho)(1-q)-\pi_B(\rho q+(1-\rho)(1-q)+1-q).$$

Collecting the π_B terms on the left, this becomes

$$\pi_B[\rho q + (1-\rho)(1-q) + 1 - q - [2(1-\rho)q + \rho]] > (1-\rho)(1-q) - (\rho + (1-\rho)q),$$

which simplifies to

$$\pi_B[2(1-\rho)(1-2q)] > (1-\rho)(1-2q) - \rho.$$

Since $q > \frac{1}{2}$, the coefficient on π_B on the left is negative, so when dividing the condition becomes

$$\pi_B < \frac{1}{2} + \frac{\rho}{2(1-\rho)(2q-1)},$$

which is always satisfied, since $\pi_B < \frac{1}{2}$ and $q > \frac{1}{2}$. Thus, whenever q is "large", the fully responsive equilibrium exists, and whenever q is "small", the fully responsive equilibrium exists as long at V^C is bigger V^{C^*}.

Finally, note that if the player is willing to play the responsive equilibrium after signal B, he is definitely willing to play the responsive equilibrium after signal A. When a player receives signal A, $U(A|s = A, R) = \pi_A P_A^A(R) + (1 - \pi_A(R))P_A^B(R)V^C$ and $U(B|s = A, R) = \pi_A(1-P_A^A(R))V^C + (1-\pi_A)(1-P_A^B(R))$. He is willing to follow his signal whenever

$$\pi_A P_A^A(R) + (1-\pi_A)P_A^B(R)V^C \geq \pi_A(1-P_A^A(R))V^C + (1-\pi_A)(1-P_A^B(R)),$$

or

$$(12)\quad \pi_A(1-P_B^B(R)) + (1-\pi_A)(1-P_B^A(R))V^C \geq \pi_A P_B^B(R)V^C + (1-\pi_A)P_B^A(R).$$

This condition is very similar to A.2, except it places a larger weight ($\pi_A > (1-\pi_B)$) on the larger term ($(1-P_B^B(R) > (1-P_B^A(R))V^C$) on the left and a larger weight on the smaller term ($P_B^B(R)V^C < P_B^A(R)$) on the right. So, if the player is willing to follow his signal after B, and $A.2$ is satisfied, this condition will be *a fortiori* satisfied and the player will definitely be willing to follow his signal after A.

Thus, the responsive equilibrium exists whenever $V^C \geq V^{C^*}$, where V^{C^*} is decreasing in q and increasing in ρ and we define $V^{C^*} = -\infty$ if $q > \frac{\pi}{1-\rho}$. In fact, V^{C^*} approaches $-\infty$ as $q \to \frac{\pi}{1-\rho} > 0$ from below.

- **A Partially Responsive** is an equilibrium where one player responds to his signal while the other player chooses A independent of his signal: The responsive agent is facing a problem similar to in the AA Unresponsive equilibrium. Paralleling the analysis there, equilibrium play by the responsive agent requires

$$(13) \qquad \pi_A + (1-\pi_A)V^C > 0 > \pi_B + (1-\pi_B)V^C$$

solving for V^C, and replacing for π_j this reduces to

$$(14) \qquad -\frac{\pi(1-q)}{(1-\pi)q} > V^C > -\frac{q\pi}{(1-q)(1-\pi)}.$$

The non-responsive agent is facing a problem similar to the responsive equilibrium. Since the maximizing choice is to follow the signal for $V^C > V^{C^*}$, we need $V^C \leq V^{C^*}$ to be in the partially-responsive equilibrium. Since $V^{C^*} \leq -1 < -\frac{\pi(1-q)}{(1-\pi)q}$, it's the non-responsive player's $V^C < V^{C^*}$ that will bind. Similarly, checking condition (12), when it is hardest to satisfy ($\rho = 1$) shows that it duplicates the responsive agent's constraint ($V^C > -\frac{q\pi}{(1-q)(1-\pi)}$) and any lower ρ makes the non-responsive player's choice after the A signal easier to support. Summing up, the partially responsive equilibrium requires $-\frac{q\pi}{(1-q)(1-\pi)} < V^C < V^{C^*}$. This range collapses and the partially responsive equilibrium does not exist if $V^{C^*} < -\frac{q\pi}{(1-q)(1-\pi)}$. Of course, this occurs whenever $q > \frac{\pi}{1-\rho}$, since $V^{C^*} = -\infty$, but it can also occur for finite, but sufficiently small, V^{C^*}, such as when q is just below $\frac{\pi}{1-\rho}$.

Proof of Proposition 2: Proposition two states that shared understandings affect payoffs only in the responsive equilibria, and in those equilibria, payoffs increase (decrease) with shared understandings if and only if $V^C > -1$ ($V^C < -1$).

The first part of this proposition, which states that shared understandings affects payoff only in the responsive equilibria, is shown directly in the proof of proposition 1. As seen there, shared understanding enters into each equation through the $P_s^\sigma(e)$ terms and these terms only depend on shared understanding when the other player is playing strategy R (or the dominated F strategy).

In the responsive equilibrium:

$$u^{RR} = \rho q + q^2(1-\rho) + [\rho(1-q) + (1-q)^2(1-\rho)]V^C.$$

Taking the derivative of this expression with respect to ρ yields:

$$q(1-q)[1+V^C],$$

Which is increasing when $V^C > -1$ and decreasing when $V^C < -1$. ■

Proof of Proposition 3: Shared understanding has value only in the RR Responsive equilibrium in the supermodular case where $V^C > -1$. Thus, we need to show that when $V^C > -1$, $\frac{d}{d\rho}u^{RR}$ is increasing in ρ in the relevant domain where $q > \pi > \frac{1}{2}$. As seen in the proof of Proposition 2,

$$\frac{du^{RR}}{d\rho} = q(1-q)[1+V^C].$$

Taking the derivative of this with respect to q yields:

$$\frac{du^{RR}}{d\rho dq} = [(1-2q)[1+V^C],$$

which is decreasing when $V^C > -1$ and $q > \frac{1}{2}$. ■

Proof of Proposition 4: $u^{AA} = \pi + (1-\pi)V^C$ and $u^{RR} = \rho q + (1-\rho)q^2 + [\rho(1-q) + (1-\rho)(1-q)^2]V^C$. The difference, $u^{AA} - u^{RR}$, can be directly shown to decrease in q and ρ and increase in V^C or π. ■

Proof of Proposition 5: In the main text, we noted that for meetings to be preferred over the responsive equilibrium, it must be the case that

$$m \leq 2q(1-q)(1-\rho)[\pi + (1-\pi)V^C].$$

For meetings to be preferred to the AA-unresponsive equilibrium, it must also be the case that

$$m \leq [(1-\pi)\alpha(q) - \pi\beta(q)](1-V^C),$$

where $\alpha(q) = \rho q + (1-\rho)q^2$ is the probability of coordinating on the correct state with the correct signal and $\beta(q) = \rho(1-q) + (1-\rho)(1-q)^2$ is the probability of coordinating on the wrong state.

We have defined m^* to be the m such that one of these constraints bind with equality. Thus, we simply need to see how the signs of these two constraints change in response to changes in the parameters. Let

$$\begin{aligned} B^{RR}(q,\pi,V^C,\rho) &= 2q(1-q)(1-\rho)[\pi + (1-\pi)V^C] \\ B^{AA}(q,\pi,V^C,\rho) &= [(1-\pi)\alpha(q) - \pi\beta(q)](1-V^C) \end{aligned}$$

be functions that represent the right-hand side of the two inequalities above. All the comparative statics in the paper arise from taking the derivative of these functions with respect to the parameters of interest:

1. $\frac{\partial B^{RR}}{\partial V^C} = (1-\rho)2q(1-q)(1-\pi) > 0$ and $\frac{\partial B^{AA}}{\partial V^C} = -[(1-\pi)\alpha(q) - \pi\beta(q)] < 0$. The

second inequality holds since $(1-\pi)\alpha(q) > \pi\beta(q)$. This is because $(1-\pi)\alpha(q)$ is increasing in q while $\pi\beta(q)$ is decreasing in q. It follows that the inequality is hardest to satisfy when $q=\pi$. When $q=\pi$, the inequality becomes

$$(1-\pi)[\rho\pi + (1-\rho)\pi^2] > \pi[\rho(1-\pi)] + (1-\rho)(1-\pi)^2$$

which reduces to $\pi > 1-\pi$. By the assumption that $\pi > \frac{1}{2}$, it follows that it is indeed the case that $(1-\pi)\alpha(q) > \pi\beta(q)$ and thus $\frac{\partial B^{AA}}{\partial V^C} < 0$. Thus statement (1) of Proposition 5 holds.

2. $\frac{\partial B^{RR}}{\partial q} = 2(1-2q)(1-\rho)[\pi + (1-\pi)V^C] < 0$, since $q > \frac{1}{2}$. Further, $\frac{\partial B^{AA}}{\partial q} = (1-V^C)\big[(1-\pi)[\rho + 2(1-\rho)q] + \pi[\rho + 2(1-\rho)(1-q)]\big] > 0$. Thus statement (2) of Proposition 5 holds.
3. $\frac{\partial B^{RR}}{\partial \pi} = 2q(1-\rho)(1-q)(1-V^C) > 0$, since we are focusing on cases where $V^C \geq -1$. Further, $\frac{\partial B^{AA}}{\partial \pi} = -(\alpha(q)+\beta(q))(1-V^C) < 0$. Thus statement (3) of Proposition 5 holds.
4. $\frac{\partial B^{RR}}{\partial \rho} = -[2q(1-q)(\pi+(1-\pi)V^C)] < 0$ and $\frac{\partial B^{AA}}{\partial \rho} = (1-V^C)[(1-2\pi)q(1-q)] < 0$. Thus statement (4) of Proposition 5 holds.
5. $lim_{q\to 1}B^{RR}(q,\pi,V^C,\rho) = 0$ and $lim_{V^C\to 1}B^{AA}(q,\pi,V^C,\rho) = 0$. Thus statement (5) of Proposition 5 holds.

■

Proof of Lemma 1: It must be the case that $\overline{m}(\pi, V^C)$ is the meeting cost beyond which the team surplus under meetings is always below that under the responsive equilibrium. Previously, we showed that $\frac{\partial s^{RR}(\rho,c,\pi,V^C)}{\partial \rho} > 0$ and $\frac{\partial s^{M}(\rho,c,\pi,V^C)}{\partial \rho} < 0$. Therefore, this means that, for a given meeting cost m, the maximum value of $s^M(\rho,c,\pi,V^C)$ is when $\rho = 0$ whereas the minimum value of $s^{RR}(\rho,c,\pi,V^C)$ is when $\rho=0$. As such, for a given meeting cost m, the difference $\Delta \equiv s^M(\rho,c,\pi,V^C) - s^{RR}(\rho,c,\pi,V^C)$ is the largest when $\rho = 0$.

Using the envelope theorem, the derivatives of $s^M(\rho,c,\pi,V^C)$ and $s^{RR}(\rho,c,\pi,V^C)$, respectively, with respect to c are given by

$$\frac{\partial s^M(\rho,c,\pi,V^C)}{\partial c} = -2\Big[I^M(\rho,c,\pi,V^C)\Big]^2 \quad \text{and} \quad \frac{\partial s^{RR}(\rho,c,\pi,V^C)}{\partial c} = -2\Big[I^{RR}(\rho,c,\pi,V^C)\Big]^2.$$

The derivative of $\Delta \equiv s^M(\rho,c,\pi,V^C) - s^{RR}(\rho,c,\pi,V^C)$ with respect to c is given by:

$$\frac{\partial \Delta}{\partial c} = \frac{\partial s^M(\rho,c,\pi,V^C)}{\partial c} - \frac{\partial s^{RR}(\rho,c,\pi,V^C)}{\partial c} = 2\Bigg[\Big(I^{RR}(\rho,c,\pi,V^C)\Big)^2 - \Big(I^M(\rho,c,\pi,V^C\Big)^2\Bigg].$$

Recall that we have $\frac{\partial I^{RR}(\rho,c,\pi,V^C)}{\partial \rho} < 0$, $\frac{\partial I^{M}(\rho,c,\pi,V^C)}{\partial \rho} > 0$ and that when $\rho = 1$ we have

$I^{RR}(1,c,\pi,V^C) = I^M(1,c,\pi,V^C)$. Then, this means that we have $I^{RR}(\rho,c,\pi,V^C) \geq I^M(\rho,c,\pi,V^C) \quad \forall\rho \in [0,1]$. As a result, we have $\frac{\partial\Delta}{\partial c} > 0 \; \forall\rho \in [0,1]$. This implies that Δ is maximized as $c \to \infty$. But as $c \to \infty$, we have $I^{RR} \to 0$ and $I^M \to 0$. As such, as $c \to \infty$ we have that

$$\Delta(0,c,\pi,V^C) \equiv s^M(0,c,\pi,V^C) - s^{RR}(0,c,\pi,V^C) = 4\pi(1-\pi)[\pi + (1-\pi)V^C] - m.$$

Setting the above to be equal to 0 yields

$$4\pi(1-\pi)[\pi + (1-\pi)V^C] - m = 0,$$

which gives us $\overline{m}(\pi,V^C) = 4\pi(1-\pi)[\pi + (1-\pi)V^C]$. ■

Proof of Proposition 6: The key question is how the manager's payoff in the responsive equilibrium varies with ρ, taking into account the effect on information investment. At the $I = 1-\pi$ boundary, information is perfect, and there's no effect from varying shared understandings. When information investment is in the interior, the effect of increasing shared understanding on the manager's payoff is given by

$$\frac{\partial o^{RR}}{\partial\rho} = (\pi+I)(1-\pi-I)(1+V^C) + \frac{\partial o^{RR}(\rho,\pi,c,V^C)}{\partial I^{RR}(\rho,\pi,c,V^C)}\frac{\partial I^{RR}(\rho,\pi,c,V^C)}{\partial\rho}, \tag{15}$$

where the first term is the direct increase in expected output that is due to a change in ρ and the second term is the indirect adjustment that the team makes when ρ is changed. Based on the analysis in section 3.3, $\frac{\partial o^{RR}(\rho,\pi,c,V^C)}{\partial I^{RR}(\rho,\pi,c,V^C)} > 0$ and $\frac{\partial I^{RR}(\rho,\pi,c,V^C)}{\partial\rho} < 0$. Thus, the second term is negative. Further, there exists a low valued c where $I^{RR}(\rho,\pi,c,V^C) = 1-\pi$ but where $\frac{\partial I^{RR}(\rho,\pi,c,V^C)}{\partial\rho}$ is negative. At this c, equation (15) is negative. Likewise, as $c \to \infty$, $\frac{\partial I^{RR}(\rho,\pi,c,V^C)}{\partial\rho} \to 0$ and $I^{RR}(\rho,\pi,c,V^C) \approx 0$. At this point, the expression is strictly positive. In between, the magnitude of the second term becomes smaller as c increases and thus, there exists a single cutoff c where the manager's payoff switches from decreasing with ρ to increasing with ρ.

Having characterized the shape of the manager's payoff, we have shown that there will exist a cost where the manager switches from minimizing shared understanding subject to the team choosing the RR equilibrium to maximizing shared understanding. In order to show that this switch point is unique,it is sufficient to show that the (negative) impact of c on output is decreasing in ρ. This is equivalent to showing that $\frac{\partial^2 o^{RR}}{\partial\rho dc}$ is positive. Taking the derivative of 15 with respect to c yields:

$$\frac{\partial^2 o^{RR}}{\partial\rho dc} = (1-2(\pi+I))(1+V^C)\frac{\partial I^{RR}(\rho,\pi,c,V^C)}{\partial c} + \frac{\partial o^{RR}(\rho,\pi,c,V^C)}{\partial I^{RR}(\rho,\pi,c,V^C)}\frac{\partial^2 I^{RR}(\rho,\pi,c,V^C)}{\partial\rho\partial\rho},$$

The first term is positive since $\pi > .5$ and information is decreasing in c. The second term is also positive since

$$\frac{\partial^2 I^{RR}(\rho,\pi,c,V^C)}{\partial\rho dc} = \frac{-2(1+V^c)\frac{\partial I^{RR}(\rho,\pi,c,V^C)}{\partial c} - 2\frac{\partial I^{RR}(\rho,\pi,c,V^C)}{\partial\rho}}{2c - 2(1-\rho)(1+V^C)}$$

and (i) both terms in the numerator are positive and (ii) the denominator is positive when teams are not fully informed.

Since the cross-derivative is positive, a manager who finds it optimal to maximize shared understanding for a given c will also wish to induce this shared understanding for all larger c. As such, the arguments in the text are sufficient to complete the proposition. ■

Proof of Proposition 7:

As discussed in the text, the expected output of a meeting is decreasing in ρ holding the amount of information fixed. However, information is increasing in ρ, Thus, the overall output of a meeting can be increasing, decreasing, or decreasing in ρ and then increasing.

Next note that output in the RR equilibrium is identical to the output in a meeting when $\rho = 1$. Thus, while a manager can never induce a meeting with $\rho = 1$, she can always induce the same output by setting $\rho = 1$ and having the team select the RR equilibrium. As such, it will never be optimal to implement a meeting when the overall output of a meeting is increasing in ρ since output will be dominated by implementing the RR equilibrium with $\rho = 1$. It follows that the only optimal policy that involves a meeting will be one where the manager chooses $\rho = 0$.

Given that the optimal policy with a meeting will always involve a $\rho = 0$, it remains only to identify the optimal policy as c increases. Identical to Proposition 6, output in the RR equilibiurm is decreasing in ρ for low c, decreasing and then increasing for moderate c, and increasing for high c. Thus, for low c, the manager wishes to select the lowest ρ subject to the team not choosing a meeting, this cutoff is $\hat{\hat{\rho}}(c,\pi,V^C)$. In the quadratic region, there will be a cost where the output for implementing the RR equilibrium at $\hat{\hat{\rho}}(c,\pi,V^C)$ will be the same as the payoff for choosing $\rho = 1$. This cost cutoff is $\bar{\bar{c}}(\pi,V^C)$. Note that, as shown in the proof for Proposition 6, since the (negative) impact of c on output is decreasing in ρ, the switch from $\hat{\hat{\rho}}(c,\pi,V^C)$ to $\rho = 1$ is unique, and the manager never switches back to $\hat{\hat{\rho}}(c,\pi,V^C)$.

Finally, there will be a cost where meetings are optimal. This cutoff is $c^M(\pi,V^C)$. Once c exceeds $c^M(\pi,V^C)$, the manager chooses meeting with $\rho = 0$ and never switches back to the RR equilibrium. In order to show that this switch is unique, it is sufficient to show that $\frac{\partial o^M(0,c,\pi,V^C)}{\partial c} > \frac{\partial o^{RR}(1,c,\pi,V^C)}{\partial c}$. Taking the derivative of

$o^{RR}(1, c, \pi, V^C)$ with respect to c yields:

$$\frac{\partial o^{RR}(1, c, \pi, V^C)}{\partial c} = -\frac{(1 - V^C)^2}{2c^2} = (1 - V^C) \cdot \frac{\partial I^{RR}(1, c, \pi, V^C)}{\partial c} < 0,$$

where

$$\frac{\partial I^{RR}(1, c, \pi, V^C)}{\partial c} = -\frac{1}{c} I^{RR}(1, c, \pi, V^C).$$

The derivative of $o^M(0, c, \pi, V^C)$ with respect to c is given by:[17]

$$\left\{2[\pi + I^M] - 2[1 - (\pi + I^M)]V^C - 2[\pi + (1 - \pi)V^C][2(\pi + I^M) - 1]\right\} \cdot \frac{\partial I^M}{\partial c},$$

where

$$\frac{\partial I^M(0, c, \pi, V^C)}{\partial c} = -\frac{1}{[c + (2\pi - 1)(1 - V^C)]} \cdot I^M(0, c, \pi, V^C).$$

observe that

$$\begin{aligned}
&1 - V^C > 2(\pi + I^M) - 2[1 - (\pi + I^M)]V^C - 2[\pi + (1 - \pi)V^C][2(\pi + I^M) - 1] \\
&\Leftrightarrow 1 - \left[2(\pi + I^M) - 1\right]V^C > 2(\pi + I^M) - 2[\pi + (1 - \pi)V^C][2(\pi + I^M) - 1] \\
&\Leftrightarrow -\left[2(\pi + I^M) - 1\right] - \left[2(\pi + I^M) - 1\right]V^C > -2[\pi + (1 - \pi)V^C][2(\pi + I^M) - 1] \\
&\Leftrightarrow -\left[2(\pi + I^M) - 1\right](1 + V^C) > -2[\pi + (1 - \pi)V^C][2(\pi + I^M) - 1] \\
&\Leftrightarrow 2[\pi + (1 - \pi)V^C] > 1 + V^C \\
&\Leftrightarrow 1 > V^C,
\end{aligned}$$

which is always satisfied, by our assumption that $V^C \leq 1$. In addition, since $\pi > \frac{1}{2}$ we also have that $I^M(0, c, \pi, V^C) < I^{RR}(1, c, \pi, V^C)$ and $\frac{\partial I^{RR}(1,c,\pi,V^C)}{\partial c} < \frac{\partial I^M(0,c,\pi,V^C)}{\partial c}$. As a result, it is indeed the case that $\frac{\partial o^M(0,c,\pi,V^C)}{\partial c} > \frac{\partial o^{RR}(1,c,\pi,V^C)}{\partial c}$. Lastly, since $\frac{\partial^2 o^{RR}}{\partial \rho dc} > 0$, then this means that $\frac{o^M(0,c,\pi,V^C)}{\partial c} > \frac{o^{RR}(\rho,c,\pi,V^C)}{\partial c}$ $\forall \rho \in [0, 1]$. That is, once c exceeds $c^M(\pi, V^C)$, the manager always chooses team meeting with $\rho = 0$ and never switches back to the RR equilibrium with $\hat{\hat{\rho}}(c, \pi, V^C)$. ■

Proof of Proposition 8:

As noted in the text, it can be the case that $c^M(\pi, V^C) < \tilde{c}(\pi, V^C) < \bar{\bar{c}}(\pi, V^C)$. As illustrated in Proposition 7, $o^M(\rho, c, \pi, V^C)$ is increasing in ρ for low values of c, convex in ρ for intermediate values of c, and decreasing in ρ for large values of c. When the cost of information c exceeds $\tilde{c}(\pi, V^C)$, the manager switches from the RR

[17] To reduce notation, I^M refers to $I^M(0, c, \pi, V^C)$ and $\frac{\partial I^M}{\partial c}$ refers to $\frac{\partial I^M(0,c,\pi,V^C)}{\partial c}$.

equilibrium with $\hat{\hat{\rho}}(c,\pi,V^C)$ to team meeting with $\rho = 0$. From Proposition 6 and 7, we showed that $\frac{\partial^2 o^{RR}}{\partial\rho dc} > 0$ and that $\frac{\partial o^M(0,c,\pi,V^C)}{\partial c} > \frac{\partial o^{RR}(1,c,\pi,V^C)}{\partial c}$, then this means that once the manager switches to the team meeting, the manager always chooses the team meeting with $\rho = 0$ for larger c and never switches back to the RR equilibrium. ■

Remark: In the main text, we argued that the case described in Proposition 8 is most likely to occur when π is small. To illustrate this, it is sufficient to show that

$$\frac{\partial o^{RR}(1,c,\pi,V^C)}{\partial\pi} - \frac{\partial o^M(0,c,\pi,V^C)}{\partial\pi} > 0.$$

First, note that

$$\frac{\partial o^{RR}(1,c,\pi,V^C)}{\partial\pi} = 1 - V^C \geq 0,$$

where the inequality is due to our assumption that $V^C \leq 1$. Next, we derive the derivative of the output with team meeting with respect to π, which is given by:

$$2\frac{\partial I^M}{\partial\pi}\cdot\left\{[\pi + I^M(0,c,\pi,V^C)] - [1-\pi-I^M(0,c,\pi,V^C)]V^C - [\pi+(1-\pi)V^C][2(\pi+I^M(0,c,\pi,V^C)) - 1]\right\}$$
$$+ 2(1-V^C)[\pi + I^M(0,c,\pi,V^C)][1-(\pi+I^M(0,c,\pi,V^C))],$$

where

$$\frac{\partial I^M(0,c,\pi,V^C)}{\partial\pi} = -\frac{4(1-V^C)(2\pi-1)}{\Big[2c+2(2\pi-1)(1-V^C)\Big]} - \frac{4(1-V^C)}{\Big[2c+2(2\pi-1)(1-V^C)\Big]}\cdot I^M(0,c,\pi,V^C) < 0.$$

In addition, we show that the expression in the bracket is positive.

$$\begin{aligned}
&2(\pi+I^M) - 2[1-(\pi+I^M)]V^C - 2[\pi+(1-\pi)V^C][2(\pi+I^M)-1] > 0\\
&\Leftrightarrow 2\pi(1-\pi) > I^M(0,c,\pi,V^C)(2\pi-1)\\
&\Leftrightarrow 2\pi(1-\pi) > \left[\frac{4\pi(1-\pi)(1-V^C)}{2c+2(2\pi-1)(1-V^C)}\right](2\pi-1)\\
&\Leftrightarrow c + (2\pi-1)(1-V^C) > (2\pi-1)(1-V^C)\\
&\Leftrightarrow c > 0,
\end{aligned}$$

which is always satisfied. Finally, since $(\pi + I^M(0,c,\pi,V^C)) \in (\frac{1}{2},1]$, then this implies that we have

$$2(1-V^C)[\pi+I^M(0,c,\pi,V^C)][1-\pi-I^M(0,c,\pi,V^C)] < 1-V^C.$$

As a result, it is always the case that the derivative of the team output under responsive equilibrium with respect to π is larger than that of team meeting.

Lemma 2 *1. An **AA Unresponsive** strategy yields payoff* $U_{AA} = \pi + (1-\pi)V^C$ *and is efficient iff*

$$V^C \geq \frac{\rho q + (1-\rho)q^2 - \pi}{(1-\pi) - [\rho(1-q) + (1-\rho)(1-q)^2]}.$$

2. *An **AB Unresponsive** strategy yields payoff* $U_{AB} = 0$*, and it is efficient iff* $V^C \leq -(\frac{q}{1-q})(\max\{\frac{\pi}{1-\pi}, \frac{\rho+(1-\rho)q}{\rho+(1-\rho)(1-q)}\})$.
3. *A **Partially Responsive** strategy yields payoff* $U_{AR} = \pi q + (1-\pi)(1-q)V^C$*, and it is efficient iff* $q \leq \frac{\pi}{1-\rho}$ ***and***

$$-(\frac{\pi}{1-\pi})(\frac{q}{1-q}) \leq V^C \leq (\frac{q}{1-q})(\frac{\pi - [(1-\rho)q + \rho]}{\pi - q(1-\rho)}).$$

4. *A **Responsive** strategy yields payoff* $U_{RR} = \rho q + (1-\rho)q^2 + (\rho(1-q) + (1-\rho)(1-q)^2)V^C$ *and is efficient everywhere else.*

Proof: To prove part 1 of this lemma, note that when the AA Unresponsive equilibrium exists, the RR equilibrium also exists. Thus, to identify the cases where it is efficient, we simply need to compare the payoffs in this equilibrium to the payoffs in the RR equilibrium.

In the AA Unresponsive equilibrium,

$$u^{AA} = \pi + (1-\pi)V^C$$

while the utility in the RR equilibrium is

$$u^{RR} = \rho q + (1-\rho)q^2 + \left[\rho(1-q) + (1-\rho)(1-q)^2\right]V^C.$$

It follows that the AA Unresponsive is efficient if

$$\pi + (1-\pi)V^C \geq \rho q + (1-\rho)q^2 + \left[\rho(1-q) + (1-\rho)(1-q)^2\right]V^C,$$

or, equivalently

$$V^C \geq \frac{\rho q + (1-\rho)q^2 - \pi}{(1-\pi) - \left[\rho(1-q) + (1-\rho)(1-q)^2\right]}.$$

When the AB Unresponsive equilibrium exists, the RR Responsive equilibrium also exists. Thus, to identify cases where the AB Unresponsive equilibrium is efficient, it is sufficient to find the region where the AB Unresponsive equilibrium exists and where it has a higher payoff than the RR equilibrium. The AB equilibrium always yields a payoff of zero. Thus, it has a higher utility to the RR equilibrium when

$$0 \geq \rho q + (1-\rho)q^2 + \left[\rho(1-q) + (1-\rho)(1-q)^2\right]V^C.$$

Rearranging, This occurs when

$$V^C \leq -\frac{q}{1-q}\frac{\rho + (1-\rho)q}{\rho + (1-\rho)(1-q)}.$$

As seen in Proposition 1, the AB equilibrium exists only if

$$V^C \leq -\frac{q}{1-q}\frac{\pi}{1-\pi}.$$

Putting these two constraints together yields the bound in part 2 of the lemma.

Finally, the Partially Responsive equilibrium is the unique equilibrium in its region. As such, it is efficient. Likewise, it can be shown that all other equilibria are dominated by one of the four equilibrium discussed (see Lemmas 3-8 in the supplementary appendix). Thus, the RR equilibrium is efficient in the remaining parts of the parameter space. ■

A.3 Dominated Equilibrium [Supplementary Appendix]

This supplementary appendix describe additional BNE that exist in our, but that are dominated by the four BNE that we concentrate on.

Lemma 3 *Define the* ***FF Responsive*** *strategy profile as one where both players play the action that is opposite to the signal. There exists a BNE where each player uses this strategy profile. However, it is dominated by the BNE where both players use the Responsive strategy profile.*

Proof: The FF Responsive equilibrium will exist if, when the other player is flipping their signals,

$$U(A|s=B,F) \geq U(B|s=B,F) \tag{16}$$

and

$$U(B|s=A,F) \geq U(A|s=A,F). \tag{17}$$

Equation (16) holds if:

$$\pi_B P_B^A(F) + (1-\pi_B)P_B^B(F)V^C \geq \pi_B(1-P_B^A(F))V^C + (1-\pi_B)(1-P_B^B(F)).$$

When the other player flips their signal:

$$\begin{aligned} P_B^A(F) &= \rho + (1-\rho)(1-q), \\ P_B^B(F) &= \rho + (1-\rho)q. \end{aligned}$$

Thus, when $\rho = 1$, equation (16) holds if:

$$\pi_B + (1-\pi_B)V^C \geq 0.$$

This is satisfied for $V^C \geq -\frac{\pi_B}{1-\pi_B}$ for any $q > 0.5$.

Equation 17 will be satisfied if and only if:

$$\pi_A(1-P_A^A(F))V^C + (1-\pi_A)(1-P_A^B(F)) \geq \pi_A P_A^A(F) + (1-\pi_A)P_A^B(F)V^C.$$

When the other player flips their signal:

$$\begin{aligned} P_A^A(F) &= (1-\rho)(1-q) \\ P_A^B(F) &= (1-\rho)q \end{aligned}$$

When $\rho = 1$, equation (17) holds if:

$$\pi_A V^C + (1 - \pi_A) \geq 0.$$

Thus, FF responsive is an equilibrium when shared understanding is very high and the value of coordination V^C is such that $V^C \geq -\frac{(1-\pi_A)}{\pi_A}$.

We now show that while the FF Responsive equilibrium exists, it is dominated by RR Responsive. In each state:

$$\begin{aligned} u^{FF} &= [\rho q + q^2(1-\rho)]V^C + [\rho(1-q) + (1-q)^2(1-\rho)] \\ u^{RR} &= [\rho q + q^2(1-\rho)] + [\rho(1-q) + (1-q)^2(1-\rho)]V^C \end{aligned}$$

Thus,

$$u^{RR} - u^{FF} = [1 - V^C]\big[[\rho q + q^2(1-\rho)] - [\rho(1-q) + (1-q)^2(1-\rho)]\big].$$

Noting that $q > \pi >= 0.5$, $[\rho q + q^2(1-\rho)] \geq [\rho(1-q) + (1-q)^2(1-\rho)]$ and $V^C \leq 1$, the difference is weakly positive. ■

Lemma 4 *Define the **BB Unresponsive** strategy profile as one where both players play the action B regardless of their signal. There exists a BNE where each player uses this strategy profile. However, it is dominated by the BNE where both players use the AA Unresponsive strategy profile.*

Proof: Let $V^C = 1$ and $\rho = 0$. Then,

$$\begin{aligned} U(B|s = j, B) &= 1, \\ U(A|s = j, B) &= 0, \end{aligned}$$

and $U(B|s = j, B) > U(A|s = j, B)$ for $q < 1$. By continuity, there exists a set of parameters for which the BB unresponsive strategy is part of a BNE. Specifically, it holds when V^C is such that $V^C \geq -\frac{(1-\pi_B)}{\pi_B}$.

To show that the BNE involving the BB unresponsive equilibrium is dominated by AA unresponsive, note that

$$\begin{aligned} u^{AA} &= \pi + (1-\pi)V^C \\ u^{BB} &= \pi V^C + (1-\pi), \end{aligned}$$

and that

$$u^{AA} - u^{BB} = (2\pi - 1)(1 - V^C) \geq 0$$

where the inequality follows from the assumption that $\pi > 0.5$, and $V^C \leq 1$. ■

Lemma 5 *Define the* ***RF Responsive*** *strategy profile as one where one player follows their signal and the other one plays the action that is opposite of the signal. There exists a BNE where each player uses this strategy profile. However, it is dominated by either the BNE where both players use the AA Responsive strategy profile or the BNE where both players use the AB Unresponsive strategy profile.*

Proof: For strategy R to be an agent's best response to the other agent playing F, the following two conditions must hold:

$$U(A|s = A, F) \geq U(B|s = A, F).$$

and

$$U(B|s = B, F) \geq U(A|s = B, F).$$

The first equation is equivalent to

$$\pi_A P_A^A(F) + (1 - \pi_A) P_A^B(F) V^C \geq \pi_A (1 - P_A^A(F)) V^C + (1 - \pi_A)(1 - P_A^B(F)),$$

where $P_A^A(F) = (1-\rho)(1-q)$ and $P_A^B(F) = (1-\rho)q$. Substituting $P_A^A(F)$ and $P_A^B(F)$ yields:

$$\pi_A(1-\rho)(1-q) + (1-\pi_A)(1-\rho)qV^C \geq \pi_A[1-(1-\rho)(1-q)]V^C + (1-\pi_A)[1-(1-\rho)q].$$

When $\rho = 1$, this condition becomes $\pi_A V^C + (1 - \pi_A) \leq 0$ and is satisfied when $V^C \leq -\frac{(1-\pi_A)}{\pi_A}$.

The second equation is equivalent to

$$\pi_B P_B^A(F) + (1 - \pi_B) P_B^B(F) V^C \leq \pi_B (1 - P_B^A(F)) V^C + (1 - \pi_B)(1 - P_B^B(F)),$$

where $P_B^A(F) = \rho + (1-\rho)(1-q)$ and $P_B^B(F) = \rho + (1-\rho)q$. Substitution of $P_B^A(F)$ and $P_B^B(F)$ gives

$$\begin{aligned}\pi_B[\rho + (1-\rho)(1-q)] + (1-\pi_B)[\rho + (1-\rho)q]V^C \quad &\leq \quad \pi_B[1 - \rho - (1-\rho)(1-q)]V^C \\ &\quad + (1-\pi_B)[1-\rho-(1-\rho)q]\end{aligned}$$

When $\rho = 1$, this condition becomes $\pi_B + (1-\pi_B)V^C \leq 0$, which is satisfied only when $V^C \leq -\frac{\pi_B}{1-\pi_B}$ Therefore, the binding constraint for strategy R to be optimal is $V^C \leq -\frac{\pi_B}{1-\pi_B}$, since $1-\pi_A < \pi_B$.

We now show that it is also possible for F to be a best response to the other agent playing R when $\rho = 1$ and $V^C \leq \min\left(-\frac{\pi_A}{1-\pi_A}, -\frac{(1-\pi_B)}{\pi_B}\right)$. For F to be a best response, it must be the case that

$$U(A|s = A, R) \leq U(B|s = A, R)$$

and

$$U(A|s = B, R) \geq U(B|s = B, R)$$

The first equation is equivalent to

$$\pi_A P_A^A(R) + (1-\pi_A)P_A^B(R)V^C \leq \pi_A(1-P_A^A(R))V^C + (1-\pi_A)(1-P_A^B(R))$$

where $P_A^A(R) = \rho + (1-\rho)q$ and $P_A^B(R) = \rho + (1-\rho)(1-q)$. This is equivalent to requiring that

$$\begin{aligned}\pi_A[\rho + (1-\rho)q] + (1-\pi_A)[\rho + (1-\rho)(1-q)]V^C \quad &\leq \quad \pi_A[1-\rho-(1-\rho)q]V^C \\ &+(1-\pi_A)[1-\rho-(1-\rho)(1-q)].\end{aligned}$$

When $\rho = 1$, the condition becomes $\pi_A + (1-\pi_A)V^C \leq 0$, where this is satisfied if $V^C \leq -\frac{\pi_A}{1-\pi_A}$.

The second equation is equivalent to

$$\pi_B P_B^A(R) + (1-\pi_B)P_B^B(R)V^C \geq \pi_B(1-P_B^A(R))V^C + (1-\pi_B)(1-P_B^B(R))$$

where $P_B^A(R) = (1-\rho)q$ and $P_B^B(R) = (1-\rho)(1-q)$. Substituting $P_B^A(R)$ and $P_B^B(R)$ yields:

$$\pi_B(1-\rho)q + (1-\pi_B)(1-\rho)(1-q)V^C \geq \pi_B[1-(1-\rho)q]V^C + (1-\pi_B)[1-(1-\rho)(1-q)].$$

When $\rho = 1$, this condition becomes $\pi_B V^C + (1-\pi_B) \leq 0$, which is satisfied when $V^C \leq -\frac{(1-\pi_B)}{\pi_B}$. Therefore, strategy F is a best response to the other agent playing strategy R if $V^C \leq -\frac{\pi_A}{1-\pi_A}$, since $\pi_A > 1-\pi_B$.

It follows from the four cases above that when $\rho = 1$, there exists a BNE where RF is the strategy profile employed by the two parties when $V^C \leq -\frac{\pi_A}{1-\pi_A}$, since $\pi_A > \pi_B$.

We now show that this PBE is always dominated by either the *AB Unresponsive* equilibrium or the *AA Unresponsive* equilibrium. The team's payoff in the AB unresponsive equilibrium is 0 while the payoff in the AA unresponsive equilibrium is given by

$$u^{AA} = \pi + (1-\pi)V^C.$$

Further, the team's payoff if the strategy profile *RF Responsive* is played is

$$u^{RF} = q(1-\rho)(1-q)(1+V^C).$$

Hence, we have that

$$u^{AA} - u^{RF} = V^C\big[(1-\pi) - (1-\rho)(1-q)q\big] + \big[\pi - (1-\rho)(1-q)q\big].$$

This difference is larger than 0 when V^C is such that

$$V^C \geq -\left(\frac{\pi - (1-\rho)(1-q)q}{(1-\pi) - (1-\rho)(1-q)q}\right)$$

where the expression on the right-hand side is smaller than -1.

The team's payoff when both agents play the *RF Responsive* strategy profile, u^{RF}, is smaller than 0, which is the team's payoff for *AB Unresponsive* equilibrium, when V^C is such that

$$(1-\rho)(1-q)(1+V^C)q \leq 0$$

which holds if $V^C \leq -1$. Therefore, we have shown that for all values of V^C, the *RF Unresponsive* equilibrium is either dominated by the *AA Unresponsive* equilibrium or the *AB Unresponsive* equilibrium. ■

Lemma 6 *Define the* ***BF Responsive*** *strategy profile as one where one player chooses action B and the other one plays the action that is opposite of the signal. This strategy profile does not form a part of a BNE since the player playing F always prefers to change strategy.*

Proof For F to be a best response to B it must be that

$$U(B|s=A,B) \geq U(A|s=A,B)$$

and

$$U(A|s=B,B) \geq U(B|s=A,B)$$

Noting that $U(B|s=A,B)=\pi_A V^C+(1-\pi_A)$ and $U(A|s=A,B)=0$, the first equation is equivalent to:

$$\pi_A V^C+(1-\pi_A)\geq 0 \Rightarrow V^C \geq -\frac{(1-\pi_A)}{\pi_A}$$

Likewise, the second equation is equivalent to:

$$0\geq \pi_B V^C+(1-\pi_B) \Rightarrow V^C \leq -\frac{(1-\pi_B)}{\pi_B}$$

Thus, for one player to play F, $V^C \in (-\infty, -\frac{(1-\pi_B)}{\pi_B}] \cap [-\frac{(1-\pi_A)}{\pi_A}, 1]$, which is not possible. Therefore, we have shown that there is no value of V^C for one of the agents to play F as a best response to the other agent playing B. ■

Lemma 7 *Define the* ***BR Responsive*** *strategy profile as one where one player chooses action B and the other one plays the action that corresponds to their signal. This strategy profile does not form a part of a BNE since the player playing B always prefers to change strategy.*

Proof: Consider first the agent who plays R. For the strategy R to be a best response to the other agent playing B, it has to be the case that

$$U(A|s=A,B)\geq U(B|s=A,B)$$

or, equivalently

$$\pi_A P_A^A(B)+(1-\pi_A)P_A^B(B)V^C \geq \pi_A(1-P_A^A(B))V^C+(1-\pi_A)(1-P_A^B(B))$$

where $P_A^\sigma(B)=0$. Therefore, the condition simplifies to $\pi_A V^C+1-\pi_A\leq 0$, which requires that $V^C\leq -\frac{(1-\pi_A)}{\pi_A}$. In addition, for the strategy R to be a best response to the other agent playing F, the following condition has to also hold:

$$U(A|s=B,B)\leq U(B|s=B,B)$$

which is equivalent to

$$\pi_B P_B^A(B)+(1-\pi_B)P_B^B(B)V^C \leq \pi_B(1-P_B^A(B))V^C+(1-\pi_B)(1-P_B^B(B))$$

where $P_B^\sigma(B)=0$. Therefore, the condition reduces to $\pi_B V^C+1-\pi_B\geq 0$, which requires that $V^C\geq -\frac{(1-\pi_B)}{\pi_B}$. In sum, for the strategy R to be a best response to the other agent playing B, V^C must be such that $V^C\in\left[-\frac{(1-\pi_B)}{\pi_B}, -\frac{(1-\pi_A)}{\pi_A}\right]$.

Now, consider the agent who plays the strategy B, given that the other agent is playing the strategy R. For the strategy B to be a best response to the other agent playing R, the following condition has to hold:

$$U(B|s = A, R) \geq U(A|s = A, R)$$

which is equivalent to

$$\pi_A(1 - P_A^A(R))V^C + (1 - \pi_A)(1 - P_A^B(R)) \geq \pi_A P_A^A(R) + (1 - \pi_A)P_A^B(R)V^C$$

where $P_A^A(R) = \rho + (1 - \rho)q$ and $P_A^B(R) = \rho + (1 - \rho)(1 - q)$. Therefore, substitution of $P_A^A(R)$ and $P_A^B(R)$ yields

$$\pi_A[1 - \rho - (1 - \rho)q]V^C + (1 - \pi_A)[1 - \rho - (1 - \rho)(1 - q)] \geq \pi_A[\rho + (1 - \rho)q] + (1 - \pi_A)[\rho + (1 - \rho)(1 - q)]V$$

Moving all the terms to the left hand side gives us:

$$\pi_A[1 - \rho - (1 - \rho)q]V^C + (1 - \pi_A)[1 - \rho - (1 - \rho)(1 - q)] - \pi_A[\rho + (1 - \rho)q] - (1 - \pi_A)[\rho + (1 - \rho)(1 - q)]V^C \geq 0.$$

Expanding the brackets yields:

$$\pi_A[1 - \rho - (1 - \rho)q]V^C + [1 - \rho - (1 - \rho)(1 - q)] + \pi_A[(1 - \rho)(1 - q) - (1 - \rho)] - \pi_A[\rho + (1 - \rho)q] - [\rho + (1 - \rho)(1 - q)]V^C + \pi_A[\rho + (1 - \rho)(1 - q)]V^C \geq 0$$

Collecting the $\pi_A V^C$ and π_A gives us:

$$\pi_A V^C\Big[1 - \rho - (1 - \rho)q + \rho + (1 - \rho)(1 - q)\Big] + \pi_A\Big[(1 - \rho)(1 - q) - (1 - \rho) - \rho - (1 - \rho)q\Big] + \Big[1 - \rho - (1 - \rho)(1 - q)\Big] - \Big[\rho + (1 - \rho)(1 - q)\Big]V^C \geq 0$$

Further simplification yields:

$$\pi_A V^C\Big[1 - (1 - \rho)q + (1 - \rho)(1 - q)\Big] + \pi_A\Big[- 1 - (1 - \rho)q + (1 - \rho)(1 - q)\Big] + \Big[1 - \rho - (1 - \rho)(1 - q)\Big] + \Big[- \rho - (1 - \rho)(1 - q)\Big]V^C \geq 0$$

$$\Rightarrow \pi_A(V^C - 1) + \pi_A\Big[(1 - \rho)(1 - q) - (1 - \rho)q\Big](V^C + 1) + 1 - \Big[\rho + (1 - \rho)(1 - q)\Big](V^C + 1) \geq 0$$

As an aside, note that π_A can be written as follows:

$$\pi_A = \frac{\pi q}{\pi q + (1-\pi)(1-q)} = \frac{\frac{\pi q}{1-q}}{1 + \frac{\pi}{1-q}(2q-1)}$$

Hence, by substituting π_A in the equation above, we obtain:

$$\left(\frac{1}{1+\frac{\pi}{1-q}(2q-1)}\right)\Bigg\{\frac{\pi q}{1-q}(V^C - 1) + \frac{\pi q}{1-q}\Big[(1-\rho)(1-q) - (1-\rho)q\Big](V^C+1) + \left(1 + \frac{\pi}{1-q}(2q-1)\right) - \left(1 + \frac{\pi}{1-q}(2q-1)\right)\Big[\rho + (1-\rho)(1-q)\Big](V^C+1)\Bigg\} \geq 0$$

Further simplification reduces the condition to

$$\left(\frac{1}{1+\frac{\pi}{1-q}(2q-1)}\right)\left[\frac{\pi}{1-q}\Big(V^C - (V^C+1)q\Big) + 1 - [1-q(1-\rho)](V^C+1)\right] \geq 0$$

Observe that the denominator is always strictly positive. Therefore, the overall sign of the above expression is determined by the sign of the numerator. We have to consider two cases, the first in which $V^C \leq -1$ and the second where $V^C > -1$. For the first case, observe that the coefficient on ρ is positive. Thus, the numerator is increasing in ρ. Therefore, for a given value of V^C, the largest possible value of the numerator is when $\rho = 1$. In this case, the numerator is equal to

$$-(1-\pi)V^C - \frac{\pi q}{1-q}$$

which is decreasing in V^C. Recall that, from above, $V^C \in \big[-\frac{(1-\pi_B)}{\pi_B}, -\frac{(1-\pi_A)}{\pi_A}\big]$ and so the smallest possible value of V^C is $-\frac{(1-\pi_B)}{\pi_B}$. When $V^C = -\frac{(1-\pi_B)}{\pi_B}$, the above expression is equal to:

$$\frac{q}{\pi(1-q)}[(1-\pi)^2 - \pi^2] < 0$$

where the inequality follows from the assumption that $\pi > \frac{1}{2}$.

Now, consider the second case in which $V^C > -1$. In this case, the coefficient on ρ is negative. Hence, the numerator is monotonically decreasing in ρ. Therefore, for a given value of V^C, the largest value of the numerator is when $\rho = 0$. When $\rho = 0$, the numerator is equal to:

$$\frac{\pi}{1-q}[V^C - q(V^C+1)] + 1 - (1-q)(V^C+1)$$

which simplifies to

$$V^C(\pi - (1-q)) + q\left(\frac{1-q-\pi}{1-q}\right).$$

Observe that this expression is increasing in V^C, since $\pi - (1-q) > 0$. Recall that the largest value for V^C is $-\frac{(1-\pi_A)}{\pi_A}$. When $V^C = -\frac{(1-\pi_A)}{\pi_A}$, the expression is equal to

$$-\left[\frac{(1-\pi)(1-q)}{\pi q}\right](\pi - (1-q)) + q\left[\frac{1-q-\pi}{\pi q}\right]$$

which is always negative, by that the assumption that $q > \pi > \frac{1}{2}$. Therefore, we have shown that for values of V^C that one agent has the incentive to play *Responsive R* strategy, the other player has the incentive to deviate from playing the *Unresponsive B* strategy when the signal is A. ■

Lemma 8 *Define the **AF Responsive** strategy profile as one where one player chooses action A and the other one plays the action opposite their signal. This strategy profile does not form a part of a BNE since the player playing F always prefers to change strategy.*

Proof: Consider the agent playing the strategy F. For playing strategy F to be a best response to the other agent playing A, it has to be the case that

$$U(A|s=A,A) \leq U(B|s=A,A)$$

and

$$U(A|s=B,A) \geq U(B|s=B,A).$$

The first equation is equivalent to

$$\pi_A P_A^A(A) + (1-\pi_A)P_A^B(A)V^C \leq \pi_A(1-P_A^A(A))V^C + (1-\pi_A)(1-P_A^B(A))$$

where $P_A^\sigma(A) = 1$. This simplifies to

$$\pi_A + (1-\pi_A)V^C \leq 0$$

which requires that $V^C \leq -\frac{\pi_A}{1-\pi_A}$. The second equation is equivalent to

$$\pi_B P_B^A(A) + (1-\pi_B)P_B^B(A)V^C \geq \pi_B(1-P_B^A(A))V^C + (1-\pi_B)(1-P_B^B(A))$$

where we again have $P_B^\sigma(A) = 1$. This condition can be simplified to

$$\pi_B + (1 - \pi_B)V^C \geq 0,$$

which requires that $V^C \geq -\frac{\pi_B}{1-\pi_B}$. Noting that $-\frac{\pi_B}{1-\pi_B} > -1 > -\frac{\pi_A}{1-\pi_A}$, both conditions cannot be met simultaneously and thus there does not exist parameters for which F is a best response to A.■