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Information Aggregation and Countervailing Biases in Organizations

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Information Aggregation and Countervailing Biases in Organizations*

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Abstract

A decision maker relies on an agent for decision-relevant information. We consider two dimensions of biases—one over projects (project bias) often assumed in cheap talk models à la Crawford and Sobel (1982) and the other over the outside option (pandering bias) scrutinized in Che, Dessein and Kartik (2013). The two biases counteract each other. This effect is more significant as payoffs to different projects are more highly negatively correlated. As a result, a larger project bias can facilitate cheap talk communications and benefit the players. Due to this correlation-driven countervailing biases, the comparison between veto-based delegation and non-delegation is not trivial.

Keyword: Bias, Cheap Talk, Correlation, Outside Option.

JEL Codes: D82, D83.

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1 Introduction

A decision maker (DM) (e.g., an executive director or a senior manager) often relies on a more informed agent (e.g., an expert or a local manager) for decision-relevant information. As frequently observed in organizations, information aggregation is prevented due to conflicts of interest. We consider two dimensions of conflicts of interest—the first over multiple projects (project bias) and the second over whether to choose the outside option of no project (pandering bias). Each one alone hurts information aggregation in decision making (Crawford & Sobel, 1982, hereafter CS; Che, Dessein, & Kartik, 2013, hereafter CDK). However, we find that a correlation in the payoffs to different projects also affects information aggregation. The more highly negative the correlation is, the greater extent to which the project bias counteracts the pandering bias. As a consequence, this effect of countervailing biases results in aggregation of more information in decision making, which benefits the players.

We study a model with discrete choices including an outside option. The DM can choose either project 1 or project 2, or he can choose the outside option of no project. The DM incurs the entire cost of implementing a project. The agent has perfect and private information on the state, which determines the benefits (except for costs) of each project to the players. There are four states, (High, High), (High, Low), (Low, High), and (Low, Low). If the state is (High, High), both projects yield large benefits. If the state is (High, Low), project 1 yields large benefits while project 2 yields small benefits. If the state is (Low, High), project 2 yields large benefits while project 1 yields small benefits. After observing the state, the agent sends a cheap talk message to the DM. Thereafter, the DM makes his choice. Ex-ante, the players may have different preferences over projects (a project bias). The DM is ex-ante biased toward project 1 in the sense that the DM expects a larger benefit from project 1 than project 2 based on the common prior. The agent's ex-ante bias may be in the same or different direction from the DM. Because of his bias toward project 1, the DM tends to select the outside option with a smaller probability when project 1 rather than project 2 is recommended. As a result, in order to avoid the outside option, the agent may be tempted to recommend project 1 even if project 2 yields larger benefits to both players. This is a version of the pandering bias first identified by CDK.

The project bias counteracts the pandering bias in affecting information transmission and welfare (Chiba & Leong, 2015).[1] We find that this countervailing effect is stronger as the correlation between the two projects' benefits is more highly negative.[2] Consider the case that the state is almost certainly either (High, Low) or (Low, High). If their ex-ante biases are in different directions, i.e., the DM's ex-ante bias is toward project 1 while the agent's ex-ante bias is toward project 2, the agent has a small incentive to hide information. To see this, note that in state (High, Low), the agent may want to induce project 2 by hiding this information; but revealing this information helps decrease the probability of the DM selecting the outside option. In state (Low, High), revealing this information increases the probability of the DM selecting the outside option; but the agent prefers project 2. Hence, in either state, the agent is willing to reveal his information. But if both players are ex-ante biased toward project 1, both of project and pandering biases cause the agent to hide (Low, High) and always report (High, Low) to the DM.

By contrast, suppose the correlation is highly positive in the sense that the state is almost certainly either (High, High) or (Low, Low). In either state, the DM selects between project 1 and the outside option. Thus, the agent has no incentive to reveal (Low, Low), leading the DM to select the outside option, regardless of the level of project bias. Due to the positive correlation, the project bias is too weak to counteract the pandering bias.

Next, we compare two mechanisms—veto-based delegation and non-delegation (communication). Under veto-based delegation, the agent is delegated to select a project. The DM implements the selected project or vetoes it. Under non-delegation, as in the basic model, the agent only sends a non-binding recommendation of a project to the DM. We find that when the project bias is large, veto-based delegation can result in aggregation of more information in decision making and hence benefit the both players. Veto-based delegation is better than non-delegation in a larger parametric space as the correlation between projects' benefits is more highly positive. In other words, non-delegation can be efficient as the correlation is more highly negative. This finding is related to our main result. The negative correlation causes the project and pandering biases counteract each other, and hence we can secure information aggregation without relying on a delegation mechanism.

[1] In Chiba & Leong (2015), the DM chooses one of two projects or the outside option of no project. One project succeeds, and another project fails (i.e., the correlation is -1). The larger project bias can lead to more information transmission.

[2] The correlation is zero in CDK while it depends on a pair of projects in CS.

The remainder of the article is organized as follows. Section 2 reviews related literature. Section 3 defines a model with discrete projects and an outside option and presents the effect of correlation in project payoffs on communications. This section also introduces examples of a negagtive (or positive) correlation in the payoffs to different projects. Section 4 compares two delegation mechanisms. Section 5 concludes. Proofs are in the appendix.

2 Related Literature

This article is closely related to cheap talk models in CDK and CS. In CDK, the economics of pandering is discussed where the agent sometimes biases his recommendation toward what CDK call the DM's conditionally better looking project. The agent has the incentive to distort information to prevent the DM from choosing the outside option. The more valuable the option, the higher the incentive. Unlike CDK, we allow correlation among projects, which makes information aggregation non-monotonic in project bias holding pandering bias fixed.

CS considered only a project bias, while we consider two dimensions of biases as explained. Consequently, two papers are significantly different from each other—CS showed a monotonic relationship between the project bias and information transmission whereas we show a non-monotonic relationship between them.

Chiba and Leong (2013 and 2015) also studied cheap talk communications in the presence of countervailing biases. Chiba and Leong (2013) added an outside option to a uniform quadratic case in CS. Chiba and Leong (2015) considered a model with two projects and an outside option where the payoffs to the two projects are perfectly negatively correlated–one project succeeds and the other project fails. The both papers showed non-monotonicity between information aggregation and project bias. However, their models, the former including continuos projects and the latter including only two states for two projects, do not allow the examination of the effect of correlation on information aggregation. Hence, their models do not well explain why the project bias counteracts the pandering bias. On the other hand, our model with two projects and four states allows the full range of possible payoff correlations, enabling us to show the effect of correlation on the non-monotonicity result.

On countervailing biases in cheap talk models, Chakraborty and Harbaugh (2007 and 2010) are also relevant to this paper. In their models, there are multiple dimensional projects and states, and the DM selects the amount of each dimension of project. The project bias is given by the disagreement on the amount of each dimension of project. They explored conditions in which the negative effect of the project bias on information aggregation can be counteracted. Charkraborty and Harbaugh (2007) showed that if both players' payoff functions are supermodular, the players can agree on the comparative ranking over projects however huge the project bias is. Hence, there is an equilibrium in which the agent transmits comparative ranking over projects to the DM. In Chakraborty and Harbaugh (2010), the agent has state-independent linear preferences—the agent wants to induce as large an project as possible in each dimension of project. They showed that if the DM's payoff function is quasi-convex, there can construct an informative equilibrium in which the agent partitions the multiple-dimensional state space into multiple regions so that the agent is indifferent among the DM's responses in all regions of the partition.

On the non-monotonicity between information aggregation and the project bias, Caillaud and Tirole (2007), Che and Kartik (2009), Landier, Sraer and David Thesmar (2009), Hori (2007), and Itoh and Morita (2017) are relevant. In Caillaud and Tirole (2007), the agent persuades the DM to accept his proposal of an project by sending a report. Landier, Sraer, and Thesmar (2009) studied a costly signaling model with an informed manager and an uninformed worker. The manager selects the suboptimal project for the firm, in order to motivate the agent to do his best for the implementation of the project. Their model is close to our model under veto-based delegation model when the correlation is negative. Che and Kartik (2009), Hori (2007), and Itoh and Morita (2017) studied models of information acquisition and disclosure while we focus on cheap talk models.

Our model is also comparable with communication games including veto stages in which an outside option–vetoing a proposal—can be chosen. In Matthews (1989) and Shimizu (2013, 2017), the DM makes a proposal according to the message received from the agent, and the agent can either accept it or veto it. Hence, unlike our paper, they allowed the agent instead of the DM to choose an outside option. In models of legislative procedures with a closed rule by Gilligan and Krehbiel (1987), and Krishna and Morgan (2001), the agent recommends an project, and the DM decides whether to authorize the recommended project or veto it. Unlike our veto-based delegation game, their models do not involve countervailing biases or correlation.

Blume and Board (2013) also used a cheap talk model with an outside option in their extended model. However, their main focus is different from ours. In their model, players are language constrained at different levels, and hence different people use language in different ways.

3 Model

3.1 Setup

Our terminology is from CDK and CS unless stated otherwise. An organization has identified two potential projects—project 1 and 2. The organization can carry out a project, $P \in \{1,2\}$, or no project (the outside option), $P = \varnothing$.

The organization has two key players, an uninformed decision maker (DM) and an informed agent (A). The agent has information—he observes a two dimensional state of the world $\theta = (\theta_1, \theta_2)$ such that

$$\theta = \begin{cases} (1,l) & \text{w.p. } \frac{1-\rho}{4} \\ (1,1) & \text{w.p. } \frac{1+\rho}{4} \\ (l,l) & \text{w.p. } \frac{1+\rho}{4} \\ (l,1) & \text{w.p. } \frac{1-\rho}{4} \end{cases} \tag{1}$$

where $l \in (0,1)$ and $\rho \in (-1,1)$.

Both players are risk-neutral, and seek to maximize payoffs. If the DM selects a project, both players' payoffs depend on the state, the project and a cost of implementing a project. On the other hand, if the DM selects the outside option, each player's payoff (or his *expected* payoff) is zero. The payoff of player $j \in \{DM, A\}$ is denoted $U^j\left(a, \theta, c_j\right)$ where:

$$U^j\left(P, \theta, c_j\right) = \begin{cases} \theta_1 - c_j & \text{if } P = 1 \\ b_j \theta_2 - c_j & \text{if } P = 2 \\ 0 & \text{if } P = \varnothing \end{cases} \tag{2}$$

where $b_{DM} \in (l,1)$, $b_A \in (l, 1/l)$ and $c_A = 0$. c_{DM} is drawn from a uniform distribution with support $[0,1]$.

The project set, the distributions of θ and c_{DM}, and the parameters ρ, c_A, b_{DM} and b_A are common knowledge. c_{DM} is observed publicly right before the DM's decision making. θ is only observable to the agent. Before the DM chooses P, the agent sends a cheap talk message $m \in M$ to the DM, where M is any large set.

The timeline is:

Step 1. Nature chooses the state θ, which is privately and perfectly observed by the agent.

Step 2. The agent sends a cheap talk message m. The DM observes this message without noise.

Step 3. The DM's project cost c_{DM} is determined and publicly observed.

Step 4. The DM decides whether to implement a project $P \in \{1, 2\}$ or the outside option of no project $P = \varnothing$.

Step 5. Both players' payoffs are realized. The game ends.

The solution concept is Perfect Bayesian equilibrium (PBE). The agent's strategy is a function $q(m|\theta)$ associating each state θ with a message distribution used by the agent in that state. The DM's strategy is a function $P(m, c_{DM})$ associating the agent's message m and the DM's cost c_{DM} with the DM's decision P. The DM's belief is a function $\mu(\theta|m)$, where $\mu(\theta|m) \geq 0$ and $\int_{\theta \in \{1,l\}^2} \mu(\theta|m) = 1$, that gives the DM's posterior as a function of m by Bayes' rule.

The major ingredients in this model are two dimensions of biases—project bias and pandering bias—and a correlation between the two projects' benefits.

Project bias—This bias is about the difference in preferences over projects. Our project bias is comparable to "the preference similarity parameter" (b) in CS. We assume $b_{DM} \in (l, 1)$ and $b_A \in (l, 1/l)$. First, $b_{DM} < 1$ means that the DM is ex-ante biased toward project 1. Next, $b_{DM} > l$ means that the DM does not always prefer project 1 to project 2: at least in $\theta = (l, 1)$, the DM prefers project 2 to project 1. Interpretations are similar for the agent: the agent is ex-ante biased toward project 1 or project 2; but, regardless of his ex-ante bias, the agent does not prefer the same project in every state θ. We refer to $|b_{DM} - b_S|$ as the level of project bias.

Pandering bias—This bias is related to the difference in a preference for the outside option of no project. Our pandering bias is comparable to "pandering" in CDK. c_j is interpreted as player j's cost which he incurs when an project is implemented. For simplicity, we assume $c_A = 0$. We also assume that c_{DM} is drawn from a uniform distribution with support $[0, 1]$. (If we assume c_{DM} is fixed and commonly known or privately observed by the DM instead, the non-monotonicity result remains unchanged.) Hence, as assumed in CDK, the agent never finds the outside option optimal while the DM may prefer the outside option to any other project in some state.

Correlation—ρ is the correlation coefficient between θ_1 and θ_2. In addition, for the both players, ρ is the correlation coefficient between the two projects' benefits.[3] Although the setup is not exactly the same, $\rho = 0$ is assumed in a model with multiple projects and continuum states of CDK, and $\rho = -1$ is assumed in a model with two states and two projects of Chiba and Leong (2015) (see Figure 1). ρ depends on which pair of projects we compare in a uniform quadratic example of CS (i.e., there are continuum projects and continuum states).

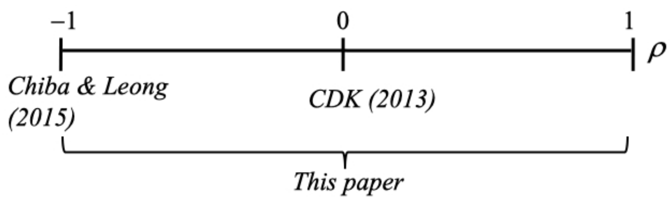

Figure 1: Correlations in models

We would like to explain why we do not use a setup directly comparable to the current literature such as CDK and CS.

Discrete states—We consider four states for two projects. This is different from CDK, who assumed continuum states and discrete projects, CS, who assumed continuum states and continuum projects, or Chiba and Leong (2015), who assumed two states and two projects. We think our assumption of four states and two projects helps clearly understand the effect of correlation between the two projects' benefits on information transmission. In addition, our setup allows to single out one parameter, ρ, which affects the correlation of the two projects' benefits for both players, but which does not affect a mean or a variance of a project for any player.

Continuum project costs—In CDK's model of pandering, the project cost is predetermined and publicly known. Precisely speaking, they did not consider the project cost. Instead, they considered different payoffs from selecting the outside option for different players: a positive payoff for the principal while zero payoff for the agent. On the other hand, we are going to analyze interaction between the pandering bias

[3] For each player $j \in \{DM, A\}$, a correlation coefficient of the two projects' benefits $cor\left(r\theta_1, b_j\theta_2\right)$ is ρ. But regardless of ρ, unconditional means of project 1 and project 2 are $E\left[\theta_1\right] = \frac{1+l}{2}$ and $E\left[b_j\theta_2\right] = \frac{b_j(1+l)}{2}$, and their unconditional variances are $Var\left[\theta_1\right] = \frac{(1-l)^2}{2}$ and $Var\left[b_j\theta_2\right] = \frac{{b_j}^2(1-l)^2}{2}$.

and the project bias. Intuitions are explained clearly if we assume continuum project costs while the fixed cost assumption does not change our main result. The assumption of continuum project costs is borrowed from Landier, Sraer and Thesmar (2009).

3.2 Results

The *project* and *pandering biases* can counteract each other in affecting information transmission and welfare. More importantly, we will show that this countervailing effect is driven by the correlation in project benefits. As the correlation coefficient ρ is closer to -1, *the project bias* generates a stronger force which works in the opposite direction of the pandering bias. As a result, the larger project bias can facilitate information transmission and improve welfare.

Our first result corresponds to CDK's Lemma 1 (CDK, p. 57). The agent always prefers an project to the outside option and he chooses his message to maximize the probability that his preferred project is chosen, whichever project that is. Hence the agent either reveals only which project he prefers or no information at all. The agent needs at most two messages.

Lemma 1 *Every PBE is outcome-equivalent to a PBE in which the agent's strategy consists of at most two messages.*

In light of this lemma, we assume a binary message set, $M = \{1, 2\}$, for simplicity. Without loss of generality, we focus on equilibria in which the agent's strategy satisfies:

$$q\left(1|\theta = (1, l)\right) \geq q\left(1|\theta = (l, 1)\right). \tag{3}$$

That is, the agent sends $m = 1$ in $\theta = (1, l)$ more frequently than in $\theta = (l, 1)$. The interpretation is that the agent recommends project 1 more frequently when project 1 is better than project 2 for both players than in the opposite situation.

The next lemma modifies CDK's Lemma 2 in their discrete project and continuous state model (CDK, pp. 57-58) for our discrete state and discrete project model.

Lemma 2 *In any PBE, for some* $m \in \{1, 2\}$*, if*

$$\min\left\{q\left(m|\theta = (1, l)\right), q\left(m|\theta = (l, 1)\right)\right\} > 0 \tag{4}$$

holds, then, at least one of:

$$q\left(m|\theta = (1, l)\right) = q\left(m|\theta = (1, 1)\right) = q\left(m|\theta = (l, l)\right) \tag{5}$$

or

$$q\left(m|\theta=(1,1)\right)=q\left(m|\theta=(l,l)\right)=q\left(m|\theta=(l,1)\right) \tag{6}$$

holds. If

$$q\left(m|\theta=(1,l)\right)=q\left(m|\theta=(l,1)\right) \tag{7}$$

holds, then, both of (5) and (6) hold.

For any two states θ and θ', we say that the agent *pools* θ and θ' if $q\left(m|\theta\right)>0$ and $q\left(m|\theta'\right)>0$ for some m. Moreover, the agent *fully pools* θ and θ' if $q\left(m|\theta\right)=q\left(m|\theta'\right)$. Lemma 2 says that if the agent pools $\theta=(1,l)$ and $\theta=(l,1)$, then, $\theta=(1,1)$ and $\theta=(l,l)$ should be fully pooled with at least one of $\theta=(1,l)$ and $\theta=(l,1)$. If the agent fully pools $\theta=(1,l)$ and $\theta=(l,1)$, he fully pools all the states.

Without loss of generality, we assume that the agent sends $m=1$ if he fully pools all states. We define types of equilibria using terminology borrowed from CDK.

Definition 1 *(1) In a truthful equilibrium (T),* $q\left(1|\theta=\theta'\right)=1$ *for* $\theta'\in\{(1,l),(1,1),(l,l)\}$ *and* $q\left(1|\theta=(l,1)\right)=0$*; and* $P\left(m,c_{DM}\right)\in\{m,\varnothing\}$ *for any* m.

(2) In a pandering-toward-1 equilibrium (P1), $q\left(1|\theta=\theta'\right)=1$ *for* $\theta'\in\{(1,l),(1,1),(l,l)\}$ *and* $q\left(1|\theta=(l,1)\right)\in(0,1)$*; and* $P\left(m,c_{DM}\right)\in\{m,\varnothing\}$ *for any* m.

(3) In a pandering-toward-2 equilibrium (P2), $q\left(1|\theta=(1,l)\right)=1$, $q\left(1|\theta=\theta'\right)\in(0,1)$ *for* $\theta'\in\{(1,1),(l,l)\}$ *and* $q\left(1|\theta=(l,1)\right)=0$*; and* $P\left(m,c_{DM}\right)\in\{m,\varnothing\}$ *for any* m.

(4) In a pandering-toward-2 equilibrium′ (P2′), $q\left(1|\theta=(1,l)\right)=1$ *and* $q\left(1|\theta=\theta'\right)=0$ for $\theta'\in\{(1,1),(l,l),(l,1)\}$*; and* $P\left(m,c_{DM}\right)\in\{m,\varnothing\}$ *for any* m.

(5) In a zero equilibrium (Z), $q\left(1|\theta=\theta'\right)=1$ *for any* θ'*; and* $P\left(m,c_{DM}\right)\in\{1,\varnothing\}$ *for any* m.

In a zero equilibrium (Z), the agent does not reveal any information. The other equilibria are *partition equilibria* in which the agent partitions the state space into two parts and reveals which partition the state θ belongs to. See Figure 2.

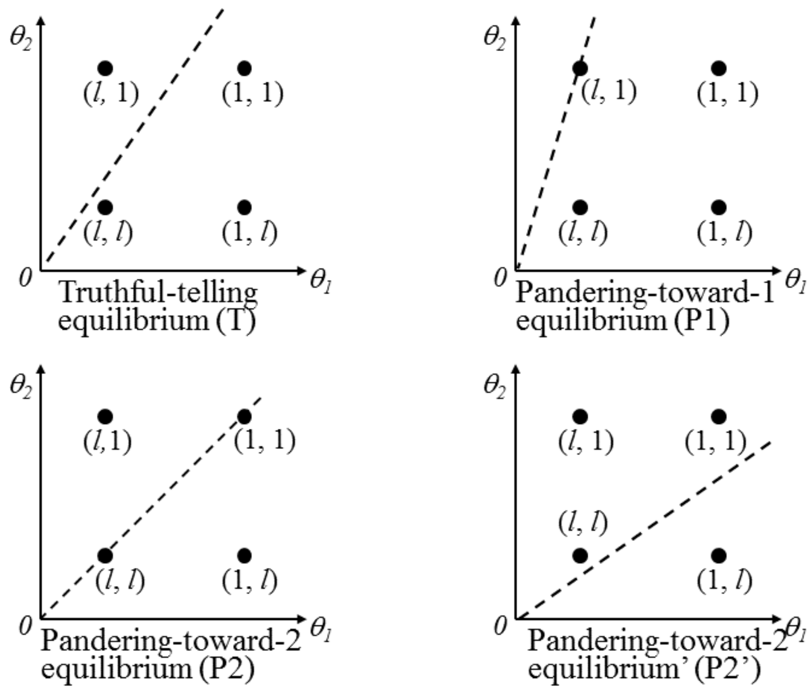

Figure 2: Information partitions in different types of equilibria

We sometimes call the first four equilibria (T, P1, P2, P2′) *informative equilibria.* We interpret equilibrium messages in either of two ways, suggestion of ranking between the two projects or recommendation of a project. In an informative equilibrium, the agent can induce whatever project he wants: he induces project 1 (project 2) by sending $m = 1$ ($m = 2$) with a positive probability. In a zero equilibrium, there is no information transmission, and the agent can only induce project 1 or the outside option whatever message he sends. Based on the first interpretation, in a truthful equilibrium, the agent always reveals the true ranking for the DM. Based on the second interpretation, the agent recommends either project depending on the state in an informative equilibrium while the agent always recommends project 1 in a zero equilibrium.

The next lemma provides characterization of all equilibria for fixed parameters and the welfare comparison among them.

Lemma 3 *For any fixed parameters, there exist at most two types of equilibria, an inform-*

ative equilibrium (T, P1, P2, or P2′) and a zero equilibrium (Z). A zero equilibrium always exists. If an informative equilibrium exists, it makes both players better off than a zero equilibrium.

In light of Lemma 3, we will focus on the most informative equilibrium for any fixed parameters. The next result gives comparative statics across parameters based on the most informative equilibrium.

Proposition 1 *Let* $B(\rho,l) := \frac{2+(1+\rho)l}{3+\rho}$, $D(b_{DM},\rho,l) := 1 + \frac{2(l+1)(1-b_{DM})^2}{\rho b_{DM}(b_{DM}+1)(1-l)+(3+5l-(5+3l)b_{DM})b_{DM}}$, *and* $d(\rho,l) := 1 - \frac{(1-\rho)(1-l)}{l+l\rho+2}$. *Then, for any fixed* b_{DM}, ρ, *and* l,

(1) A truthful equilibrium (T) exists for $b_A \in \left[\frac{B(\rho,l)\cdot l}{b_{DM}}, \frac{B(\rho,l)}{b_{DM}}\right]$,

(2) A pandering-toward-1 equilibrium (P1) exists for $b_A \in \left(\frac{l+l^2}{2b_{DM}}, \frac{B(\rho,l)\cdot l}{b_{DM}}\right)$,

(3) A pandering-toward-2 equilibrium (P2) exists for

$$\begin{cases} b_A \in \left(\frac{B(\rho,l)}{b_{DM}}, D(b_{DM},\rho,l)\right) & \text{if } b_{DM} < d(\rho,l), \\ b_A \in \left(\frac{B(\rho,l)}{b_{DM}}, \frac{1}{b_{DM}\cdot B(\rho,l)}\right) & \text{if } b_{DM} \geq d(\rho,l), \end{cases}$$

(4) A pandering-toward-2 equilibrium′ (P2′) exists for $b_A \in \left[\frac{1}{b_{DM}\cdot B(\rho,l)}, \frac{1}{l}\right)$ *if* $b_{DM} \geq d(\rho,l)$,

(5) The only equilibrium is a zero equilibrium (Z) otherwise.

Furthermore, the DM's ex-ante expected payoff is not monotonic in $|b_A - b_{DM}|$ *if* $b_{DM} < \sqrt{B(\rho,l)\cdot l}$.

Lemma 3 and Proposition 1 are closely related to the main result in Chiba and Leong (2015). Figure 3 describes the most informative equilibrium for different values of b_{DM} and b_A given $l = 0.5$ and $\rho = -0.4$. From the definitions, the following relation holds:

$$D(b_{DM},\rho,l) < \frac{1}{B(\rho,l)b_{DM}} \quad \text{iff } b_{DM} < d(\rho,l).$$

For $b_{DM} < d(\rho,l)$, line $D(b_{DM},\rho,l)$ separates areas for P2 and Z, respectively. For $b_{DM} \geq d(\rho,l)$, line $\frac{1}{b_{DM}\cdot B(\rho,l)}$ separates areas for P2 and P2′, respectively. Interestingly, for smaller b_{DM}, informative equilibria (T, P1, P2, or P2′) exist in a narrower range of b_A. Moreover, if b_{DM} is so small that $b_{DM} < \sqrt{B(\rho,l)\cdot l}$, the truthful equilibrium (T) exists only for $b_A > b_{DM}$.

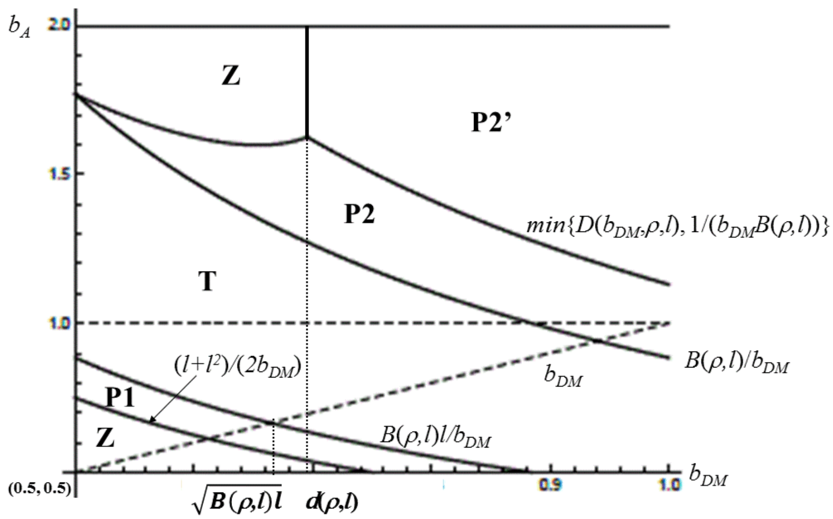

Figure 3: The most informative equilibrium ($l = 0.5$ & $\rho = -0.4$)

Figures 4 and 5 show the ex-ante expected payoff of the DM and the agent, respectively, for different levels of b_A given $l = 0.5$, $\rho = -0.4$ and $b_{DM} = 0.6$, i.e., $b_{DM} < \min\left\{\sqrt{B(\rho,l)\cdot l}, d(\rho,l)\right\}$. For both players' payoffs, there is a jump at $b_A = D(b_{DM},\rho,l)$, below which a pandering-toward-2 equilibrium (P2) exists and above which only a zero equilibrium (Z) exists.

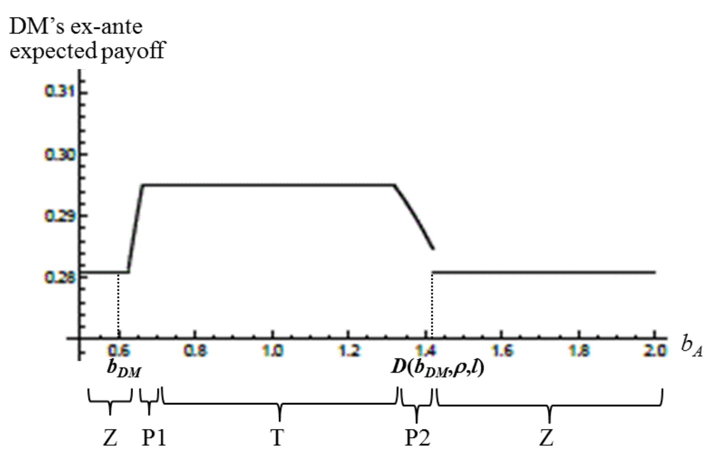

Figure 4: DM's ex-ante expected payoff in the most informative equilibrium ($b_{DM} = 0.6$, $l = 0.5$, & $\rho = -0.4$)

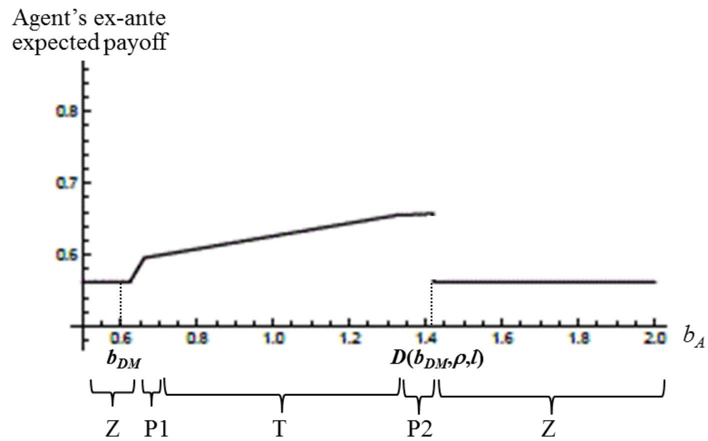

Figure 5: Agent's ex-ante expected payoff in the most informative equilibrium (b_{DM} = 0.6, l = 0.5, & ρ = −0.4)

To understand the intuition of this result, we sketch the proof. Let $E\left[\theta_i|m=j\right]$ denote the DM's updated belief on θ_i when the agent sends message $m=j$, where $i,j \in \{1,2\}$. In an informative equilibrium, the DM should agree with the project ranking (or a recommendation) suggested by the agent. The next two conditions should hold.

$$E\left[\theta_1|m=1\right] \geq b_{DM} \cdot E\left[\theta_2|m=1\right] \tag{8}$$

and:

$$b_{DM} \cdot E\left[\theta_2|m=2\right] \;\; \geq E\left[\theta_1|m=2\right] \tag{9}$$

(8) means that when the agent sends $m=1$ (i.e., suggestion that project 1 be better than project 2), the DM also prefers project 1 to project 2. (9) means that when the agent sends $m=2$, the DM also prefers project 2 to project 1. Due to the DM's ex-ante bias to project 1, (8) holds in every type of equilibrium while (9) may not. If (8) and (9) hold, the DM implements a recommended project if the cost is below the expected benefit from the project. That is, the DM selects $P=1$ if $m=1$ and $E\left[\theta_1|m=1\right] \geq c_{DM}$; he selects $P=2$ if $m=2$ and $b_{DM} \cdot E\left[\theta_2|m=2\right] \geq c_{DM}$; and he selects $P=\varnothing$ otherwise.

On the other hand, in an informative equilibrium, the agent should also be incentivized to reveal information. Hence, for a truthful equilibrium (T) to exist, in addition to (8) and (9), the next two conditions should also hold:

$$\underbrace{\underbrace{\theta_1}_{\substack{\text{Agent's payoff}\\ \text{from project 1}}} \cdot \underbrace{E\left[\theta_1|m=1\right]}_{\substack{\text{Probability that}\\ \text{project 1 is implemented}}}}_{\text{Agent's expected payoft from sending m=1}} \geq \underbrace{\underbrace{b_A \cdot \theta_2}_{\substack{\text{Agent's benefit}\\ \text{from project 2}}} \cdot \underbrace{b_{DM} \cdot E\left[\theta_2|m=2\right]}_{\substack{\text{Probability that}\\ \text{project 2 is implemented}}}}_{\text{Agent's expected payoft from sending m=2}} \tag{10}$$

given $\theta \in \{(1,l), (1,1), (l,l)\}$ and:

$$\underbrace{\underbrace{b_A \cdot \theta_2}_{\substack{\text{Agent's payoff}\\ \text{from project 2}}} \cdot \underbrace{b_{DM} \cdot E\left[\theta_2|m=2\right]}_{\substack{\text{Probability that}\\ \text{project 2 is selected}}}}_{\text{Agent's expected payoft from sending m=2}} \geq \underbrace{\underbrace{\theta_1}_{\substack{\text{Agent's payoff}\\ \text{from project 1}}} \cdot \underbrace{E\left[\theta_1|m=1\right]}_{\substack{\text{Probability that}\\ \text{project 1 is selected}}}}_{\text{Agent's expected payoft from sending m=1}} \tag{11}$$

given $\theta = (l,1)$. (10) means that the agent wants to induce project 1 (i.e., he sends $m = 1$) given θ. (11) means that the agent wants to induce project 2 (i.e., he sends $m = 2$) given θ.

In a truthful equilibrium (T), the DM's consistent beliefs are:

$$E\left[\theta_1|m=1\right] = \tfrac{2+(1+\rho)l}{3+\rho} = B(\rho,l), E\left[\theta_2|m=1\right] = \tfrac{2l+(1+\rho)}{3+\rho},$$
$$E\left[\theta_1|m=2\right] = l, \text{ and } E\left[\theta_2|m=2\right] = 1.$$

To verify the existence, we check whether (8)-(11) hold based on these beliefs. Similarly we check the existence of the other types of equilibria. We can also show that there are not multiple informative equilibria.

According to (8)-(11), smaller b_{DM} (i.e., the DM's ex-ante bias to project 1 is stronger) leads to a stronger pandering bias in the following sense. The agent is more incentivized to recommend project 1 because recommending project 2 leads to a smaller probability of project implementation. In addition, for smaller b_{DM}, a ranking that project 2 is better than project 1 is less agreeable to the DM.

Hence, focusing on small b_{DM}, we explain how the project bias can offset the pandering bias. First consider $b_A < 1$. The agent is also ex-ante biased toward project 1, and the pandering bias also incentivizes the agent to recommend project 1. Especially for $b_A < \frac{l+l^2}{2b_{DM}}$, (10) does not hold even when $\theta = (l,1)$ (i.e., project 2 is better than project 1). There is no informative equilibrium.

Next consider $b_A > 1$. The agent is biased toward project 2, which reduces the incentive to recommend project 1, especially given $\theta = (l, 1)$. An informative equilibrium still exists for relatively large $b_A > 1$. But as we gradually increase b_A, eventually the agent wants to recommend project 2 given $\theta = (1, 1)$ and $\theta = (l, l)$ as well. A truthful equilibrium does not exist any more. Then, the agent mixes two messages given $\theta = (1, 1)$ or $\theta = (l, l)$ so that (10) holds with equality. For further larger b_A, the agent recommends project 2 more frequently, which decreases $E[\theta_2|m = 2]$. The consequence depends on the level of b_{DM}. For $b_{DM} < d(\rho, l)$, if $b_A > D(b_{DM}, \rho, l)$, there is no way to make (9) and (10) hold together given $\theta = (1, 1)$ or $\theta = (l, l)$, and hence there is no informative equilibrium. There is discontinuity at $b_A = D(b_{DM}, \rho, l)$ for the level of information transmission. But for $b_{DM} \geq d(\rho, l)$, the agent can gradually increase recommendation of project 2 making conditions (8)-(11) hold given each state.

Next, we explain the welfare implication. Let $V^{DM,T}(\rho, b_A, b_{DM}, l)$ denote the DM's ex-ante expected payoffs in a truthful equilibrium (T). The ex-ante expected payoff in other types of equilibria are denoted similarly. For any type of equilibrium $X \in \{T, P1, P2, P2', Z\}$, the DM's ex-ante expected payoff is given by:

$$\begin{aligned} V^{DM,X}(\rho, b_A, b_{DM}, l) &= \Pr(m=1) \int_0^{E[\theta_1|m=1]} (E[\theta_1|m=1] - c) \cdot dc \\ &\quad + \Pr(m=2) \int_0^{b_{DM}E[\theta_2|m=2]} (b_{DM}E[\theta_2|m=2] - c) \cdot dc \\ &= \Pr(m=1) \frac{E[\theta_1|m=1]^2}{2} + \Pr(m=2) \frac{b_{DM}^2 E[\theta_2|m=2]^2}{2} \end{aligned}$$

For example:

$$\begin{aligned} V^{DM,T}(\rho, b_A, b_{DM}, l) &= \frac{(2+(1+\rho)l)^2}{8(3+\rho)} + \frac{(1-\rho)b_{DM}^2}{8} \\ V^{DM,P2'}(\rho, b_A, b_{DM}, l) &= \frac{1-\rho}{8} + \frac{(2+(1+\rho)l)^2 b_{DM}^2}{8(3+\rho)} \\ V^{DM,Z}(\rho, b_A, b_{DM}, l) &= \frac{(1+l)^2}{8} \end{aligned}$$

$V^{DM,P1}(\rho, b_A, b_{DM}, l)$ and $V^{DM,P2}(\rho, b_A, b_{DM}, l)$ depend on all parameters. (See the appendix.) For any fixed parameters, the informative equilibrium is better than the zero equilibrium for the DM.

To compare the payoffs across parameters, the next observations are important. Fix ρ and l, then,

(1) T, P1, P2, and Z exist for small b_{DM} while only T, P2, and P2′ exist (i.e., Z does not exist) for large b_{DM} .

(2) For any b_{DM}, $V^{DM,T}(\rho, b_A, b_{DM}, l) > V^{DM,Z}(\rho, b_A, b_{DM}, l)$ regardless of b_A.
(3) $V^{DM,T}(\rho, b_A, b_{DM}, l) - U^{DM,Z}(\rho, b_A, b_{DM}, l)$ strictly increases with b_{DM}.
(4) But as $b_{DM} \searrow l$, $V^{DM,T}(\rho, b_A, b_{DM}, l) - U^{DM,Z}(\rho, b_A, b_{DM}, l) \searrow \frac{(1-\rho)(1-l)^2}{8(3+\rho)}$.
(5) For any b_{DM}, $V^{DM,T}(\rho, b_A, b_{DM}, l) > U^{DM,P2'}(\rho, b_A, b_{DM}, l)$ regardless of b_A.
(6) $V^{DM,T}(\rho, b_A, b_{DM}, l) - U^{DM,P2'}(\rho, b_A, b_{DM}, l)$ strictly decreases with b_{DM}.
(7) And as $b_{DM} \nearrow 1$, $V^{DM,T}(\rho, b_A, b_{DM}, l) - U^{DM,P2'}(\rho, b_A, b_{DM}, l) \searrow 0$

Due to these observations, we conclude that for $b_{DM} < \sqrt{B(\rho, l) \cdot l}$, the truthful equilibrium (T) exists only for $b_A > b_{DM}$, and hence the DM's ex-ante expected payoff is not monotonic in $|b_A - b_{DM}|$. Moreover, given ρ and l, considering different levels of b_A has significant effect on the DM's payoff for small b_{DM} while it does not for large b_{DM}. Hence, it is reasonable to focus on the non-monotonicity given $b_A < \sqrt{B(\rho, l) \cdot l}$.

The similar argument applies to the agent's ex-ante expected payoff.

Corollary 1 *For any fixed b_A, ρ, and l, the agent's ex-ante expected payoff is not monotonic in $|b_A - b_{DM}|$ if $b_A < \sqrt{B(\rho, l) \cdot l}$.*

Let $V^{A,T}(\rho, b_A, b_{DM}, l)$ denote the agent's ex-ante expected payoffs in a type X equilibrium for $X \in \{T, P1, P2, P2', Z\}$. Since the agent does not incur a cost of implementing a project, his expected payoff is given by:

$$\begin{aligned} V^{A,X} &= \Pr(m=1) \int_0^{E[\theta_1|m=1]} E[\theta_1|m=1]\, dc \\ &\quad + \Pr(m=2) \int_0^{b_{DM}E[\theta_2|m=2]} b_A E[\theta_2|m=2]\, dc \\ &= \Pr(m=1) E[\theta_1|m=1]^2 + \Pr(m=2) b_{DM} b_A E[\theta_2|m=2]^2 \end{aligned}$$

For example:

$$\begin{aligned} V^{A,T} &= \frac{(2+(1+\rho)l)^2}{4(3+\rho)} + \frac{(1-\rho)b_{DM}b_A}{4} \\ V^{A,P2\prime} &= \frac{1-\rho}{4} + \frac{(2+(1+\rho)l)^2 b_{DM} b_A}{4(3+\rho)} \\ V^{A,Z} &= \frac{(1+l)^2}{4} \end{aligned}$$

We omit remaining details for the agent's ex-ante expected payoffs.

Finally, we present our main claim that the non-monotonicity between information aggregation and the project bias is significant as the correlation is closer to -1.

Proposition 2 *Fix l. Then, $\sqrt{B(\rho, l) \cdot l}$ strictly decreases with ρ. Furthermore, fix l and b_{DM}. Then,*

(1) $V^{DM,T}(\rho, b_A, b_{DM}, l) - V^{DM,Z}(\rho, b_A, b_{DM}, l)$ *strictly decreases with* ρ.
(2) $V^{DM,T}(\rho, b_A, b_{DM}, l) > V^{DM,Z}(\rho, b_A, b_{DM}, l)$ *for any* ρ.
(3) $V^{DM,P2'}(\rho, b_A, b_{DM}, l) - V^{DM,Z}(\rho, b_A, b_{DM}, l)$ *strictly decreases with* ρ
(4) $V^{DM,P2'}(\rho, b_A, b_{DM}, l) > V^{DM,Z}(\rho, b_A, b_{DM}, l)$ *only for small* ρ.

As mentioned above, if $b_{DM} < \sqrt{B(\rho, l) \cdot l}$, information transmission is not monotonic in $|b_A - b_{DM}|$. According to the first part of Proposition 2, the non-monotonicity is more frequently observed as the correlation is more highly negative. Figure 6 compares the most informative equilibrium and cutoff $\sqrt{B(\rho, l) \cdot l}$ for $l = 0.5$ and various ρ.

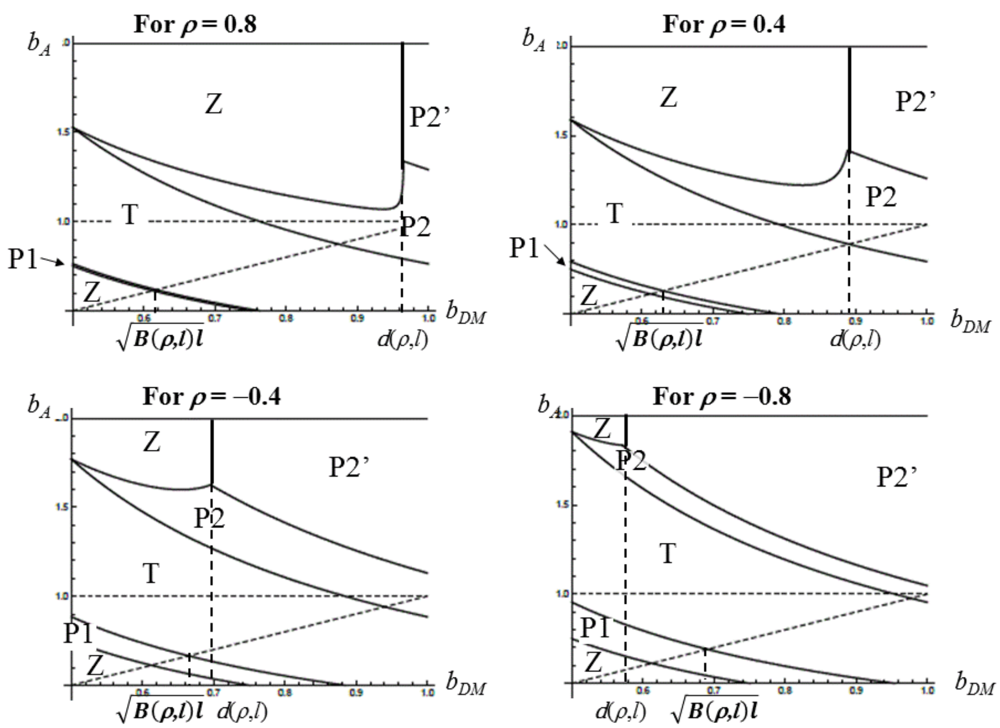

Figure 6: The most informative equilibrium ($l = 0.5$ & various ρ)

According to the second part of Proposition 2, the non-monotonicity of information transmission has more significant effect on at least the DM's ex-ante expected payoff. Figures 7 and 8 compare the ex-ante expected payoffs of the DM and the agent, respectively, for $l = 0.5$ and various ρ.

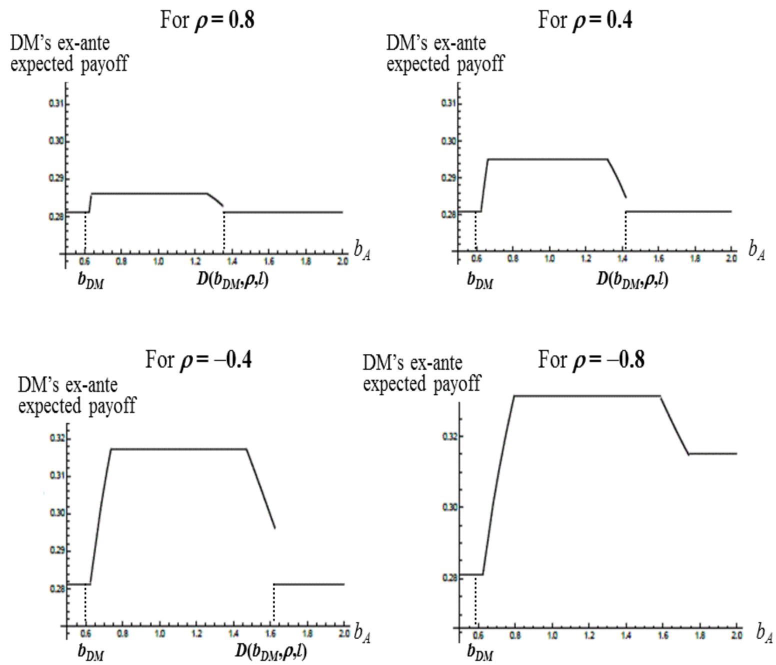

Figure 7: DM's ex-ante expected payoff in the most informative equilibrium (b_{DM} = 0.6, l = 0.5, & various ρ)

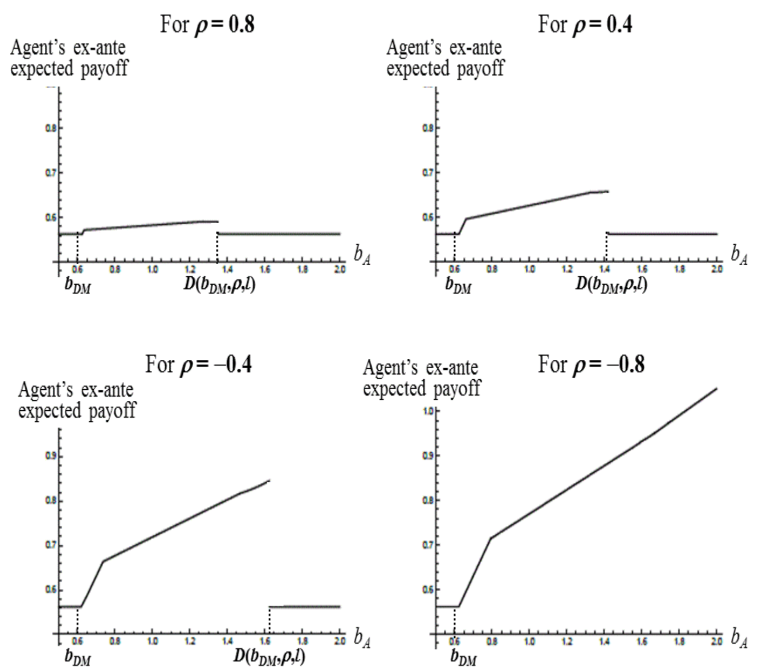

Figure 8: Agent's ex-ante expected payoff in the most informative equilibrium (b_{DM} = 0.6, l = 0.5, & various ρ)

3.3 Examples of Negative/Positive Correlations

Here are examples of a negative (or positive) correlation in the payoffs to different options.

An investor decides to invest in one industry or to not invest in any industry at all. If the available option is between the airline and oil industries, we can expect negative correlation in payoffs to the two options.[4] But between the airline and hotel industries, a positive correlation can be assumed because both industries complement each other.

If the available option is between two renewable energies such as wind power and solar power, there is a positive correlation because government regulations are to boost/suppress the market as a whole.[5] If it is between non-renewable energy such as oil energy and renewable energy, we expect a negative correlation.

If we compare payoffs from different products, Mac OS X and Macbook have a positive correlation[6] while Mac OS X and Windows operation system may have a negative correlation.

4 Veto-Based Delegation

The DM is a principal who controls the resources of the organization and makes a decision. Aggregation of the agent's information in decision making is of the principal's interest. To investigate the optimal organizational structure, we discuss two mechanisms: *non-delegation* (*communication*) (*Nd*) and *veto-based delegation* (*Vd*).[7]

Delegation is associated with *a loss of control.* However, *a loss of information* is inevitable if an uninformed principal (DM) possesses decision-making authority. Milgrom and Roberts's "delegation principle" implies that the power to make decisions should belong to an informed agent, such as the divisional managers in the context

[4]"Over the past 50 trading sessions, there has been a strong inverse correlation between the airline index and oil prices." See <https://www.reuters.com/article/us-usa-airlines-stocks/rising-oil-prices-help-ground-u-s-airline-stocks-could-make-them-cheap-idUSKCN1IM24C>

[5]There is a positive correlation between wind and solar powers since 2009. See <https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=7110436>. From 2002 to 2012, the average annual growth rates for wind and solar powers are 26.1% and 50.1%, respectively. See <http://www.energies-renouvelables.org/observ-er/html/inventaire/pdf/15e-inventaire-Chap01-Eng.pdf>.

[6]Apple gets a 30% commission on software bought through the Mac App Store. <https://discussions.apple.com/thread/7032123>.

[7]We do not consider *full delegation* because it is not easily comparable with *no delegation* in our model (that the DM incurs the entire cost of implementing a project).

of our case study above (Milgrom & Roberts, 1992). Under what circumstances will delegation benefit the DM?

Under *Nd*, the players play the game in Section 3. Hence, the timeline is:

Step 1. Nature chooses the state θ, which is privately and perfectly observed by the agent.

Step 2. The agent sends a cheap talk message m. The principal (DM) observes this message without noise.

Step 3. The principal's project cost is determined and publicly observed.

Step 4. The principal decides whether to implement a project $P \in \{1, 2\}$ or the outside option of no project $P = \varnothing$.

Step 5. Both players' payoffs are realized. The game ends.

Under *Vd*, the agent is authorized to choose between projects, but the principal can veto the agent's choice in favor of the outside option. The timeline changes accordingly. Steps 4 under *Nd* is changed to Step 4':

Step 4'. The principal chooses $P \in \{m, \varnothing\}$.

As in Section 3, we assume a binary message set, $M = \{1, 2\}$. m^d denotes the agent's message. $q^d(\theta)$ denotes the probability that the agent sends $m^d \in \{1, 2\}$. $P^d(c, m^d)$ denotes the principal's strategy. $\mu^d(m^d)$ is the principal's posterior belief. We focus on equilibria in which the agent's strategy satisfies (3) in Section 3.

Also, *a truthful equilibrium (T), a pandering-toward-1 equilibrium (P1), a pandering-toward-2 equilibrium (P2), a pandering-toward-2 equilibrium' (P2'), and a zero equilibrium (Z)* are defined for both delegation mechanisms.

See section 3 for results under *Nd*. Under *Vd*, conditions (8) and (9) are not necessary any more. That is, the agent does not need to persuade the principal (DM) to agree to the agent's project ranking.

Remark 1 *Fixing ρ and b_{DM} and l, veto-based delegation (Vd) improves information transmission than non-delegation (Nd) for a large project bias $|b_A - b_{DM}|$.*

Figure 9 shows the existence of each type of equilibrium given $l = 0.5$ and $\rho = -0.4$ under veto-based delegation (Vd). Fix b_{DM} small enough that $b_{DM} < d(\rho, l)$. Then, for $b_A > D(b_{DM}, \rho, l)$, there will be information aggregation under Vd while there is no informative equilibrium under Nd. The improvement is described by "(Z)→P2" and "(Z)→P2′" in Figure 9.

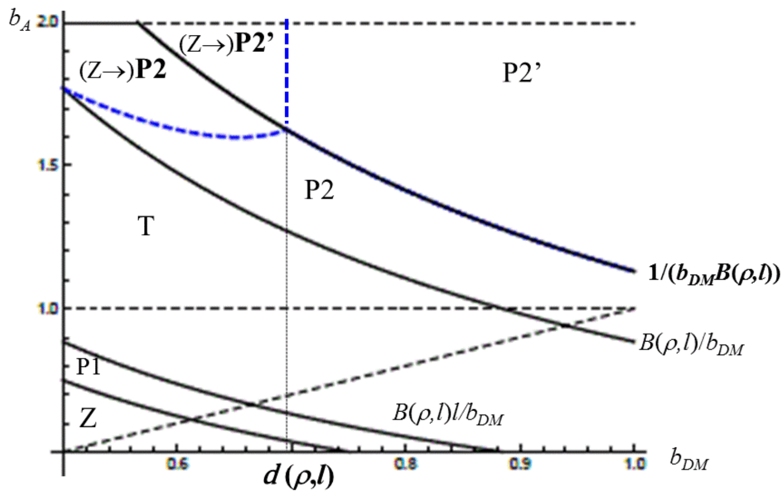

Figure 9: The most informative equilibrium under veto-based delegation (Vd) ($l = 0.5$ & $\rho = -0.4$) Its improvement on the most informative equilibrium under no-delegation (Nd) is described by (Z→)P2 or (Z→)P2'.

Remark 2 *Fix l. Then, $d(\rho, l)$ strictly increases with ρ. Thus, veto-based delegation (Vd) improves both players' expected payoffs on no-delegation (Nd) for a larger parametric space of b_{DM} as ρ increases.*

The first part of this remark is obvious from the functional form of $d(\rho, l)$. Hence, veto-based delegation (Vd) improves information transmission on no-delegation (Nd) for a larger set of parameters. Figure 10 shows types of equilibria under veto-based delegation (Vd) and how information aggregation is improved for various ρ fixing

$l = 0.5$.

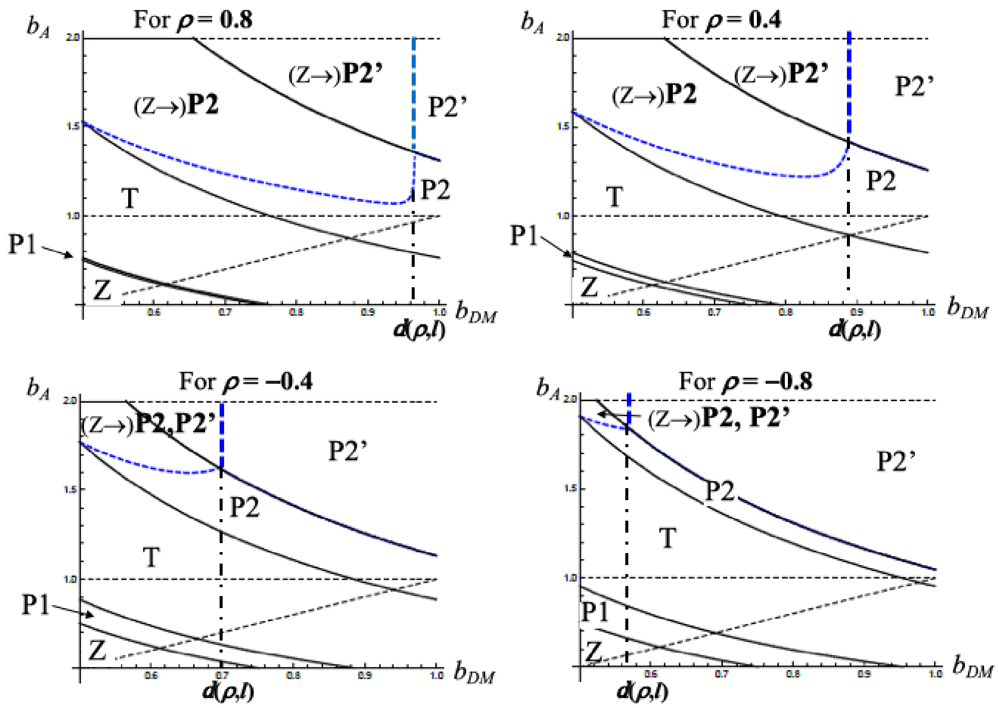

Figure 10: Equilibrium under Vd, Improvement on Nd ($l = 0.5$ & various ρ)

Although we omit details, more information transmission caused by delegation always benefits the agent. This is not always true for the DM. But we find that at least for b_A near and above $D(b_{DM}, \rho, l)$, more information transmission caused by delegation benefits the DM as well. Recall that under *Nd*, for any fixed $b_{DM} < d(\rho, l)$, there is discontinuity at $b_A = D(b_{DM}, \rho, l)$ for the level of information transmission. We can show that this continuity causes sudden drop of the DM's ex-ante expected payoffs. First, we find:

$$V^{DM,P2}(\rho, b_A, b_{DM}, l) - V^{DM,Z}(\rho, b_A, b_{DM}, l) > 0 \text{ at } b_A = D(b_{DM}, \rho, l)$$

In addition, with respect to b_A, $V^{DM,Z}(\rho, b_A, b_{DM}, l)$ is constant while $V^{DM,P2}(\rho, b_A, b_{DM}, l)$ is continuous. Therefore, there is $\epsilon > 0$ such that

$$V^{DM,P2}(\rho, b_A, b_{DM}, l) - V^{DM,Z}(\rho, b_A, b_{DM}, l) > 0 \text{ for } b_A \in (D(b_{DM}, \rho, l), D(b_{DM}, \rho, l) + \epsilon),$$

i.e., veto-based delegation (*Vd*) improves the DM's ex-ante expected payoff on no-delegation at least for $b_A \in (D(b_{DM}, \rho, l), D(b_{DM}, \rho, l) + \epsilon)$. Thus, the second part of this remark holds.

There is a larger room for improvement as the correlation is closer to 1. In other words, non-delegation can be efficient as project payoffs are negatively correlated to each other. This can be related to the observation in Section 3 that the negative correlation causes the project and pandering biases counteract each other.

This result is not implied by the current literature. Dessein (2002) worked on CS's model with continuous projects and states. When the DM vetoes the agent's recommendation, some default project is implemented. He showed that given a reasonable default project, *veto-based delegation* mechanism strictly dominates *non-delegation* if and only if the project bias is small. Mylovanov (2008) suggested that with the optimal choice of the default project, *Vd* can replicate any optimal outcome for the principal, which is realized under *Nd* for large bias. (See also Melumad & Shibano, 1994.)

On the other hand, CDK compared different delegation regimes based on comparative statics with respect to the principal's payoff for the outside option. They claimed that when communication is influential (pandering incentive is not so strong as to prevent communication), delegation is weakly preferred to communications by the principal:

"(Their) Theorem 5 is stronger than the delegation result in the Crawford and Sobel (1982) cheap-talk model. For that model, Dessein (2002) has shown that delegation is generally preferred to communication only if the conflict of interest is sufficiently small, rather than whenever communication is influential. By contrast, in the current model, delegation is (weakly) preferred by the DM whenever communication can be influential. In Crawford and Sobel (1982), the analogous result only holds under certain assumptions such as the "uniform-quadratic" specification." (CDK, pp. 68)

In our model, even when communication is not influential, delegation can be strictly preferred to communication by the DM.

5 Conclusion

The presence of the outside option makes biases between the players two-dimensional, consisting of project and pandering biases. We have shown that the correlation in project payoffs affects the interaction between the two biases. As the correlation is more highly negative, the project bias has a larger countervailing effect on the pandering bias. As a result, the project bias has non-monotonic relationship with information transmission and hence the DM's ex-ante expected payoffs.

We have also studied delegation in the presence of the two biases. On the contrary to the current literature, the veto-based delegation improves information aggregation in decision making when the project bias is large. As the correlation in project payoffs is more highly positive, this improvement is observed in a larger parametric space.

Our future studies include endogenizing pandering bias (cf. Rantakari 2012). Second, it is also interesting to investigate the optimal delegation mechanism (cf. Holmström, 1977 & 1984; Melumad & Shibano, 1991; Alonso & Matouschek, 2008) in the presence of countervailing biases. Third, Gilligan and Krehbiel (1987), Krishna and Morgan (2001), and Martin (1997) studied models with multiple agents (and a principal) and demonstrated that a closed rule (veto based delegation with a fixed default decision) dominates an open rule (communication) if and only if the *bias* is small. It is not clear whether the same conclusion holds in the presence of countervailing biases between multiple agents and the principal.

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Appendix A: Proofs for Section 3

A.1 Proof of Lemmas 1 and 2.

Given $\theta = (\theta_1, \theta_2)$, the agent's expected payoff by sending arbitrary message m' is:

$$\begin{aligned}&\theta_1 \cdot \Pr\left(\text{DM implements project 1 given } m = m'\right)\\&+ (b_A \cdot \theta_2) \cdot \Pr\left(\text{DM implements project 2 given } m = m'\right).\end{aligned}$$

If the agent wants to induce project 1 given some θ, the agent prefers a message which induces the DM to select project 1 with the highest probability. Multiple messages which induce project 1 survive only if these messages induce project 1 with the same probability. The argument is similar for the case when the agent wants to induce project 2. Hence, every equilibrium outcome is replicated by an equilibrium in which there used the same number of messages as the number of equilibrium projects. We need at most two messages. If only one project is induced on the equilibrium path, we only need one message.

Next, suppose $m = m_1$ ($m = m_2$) induces the DM to select project 1 (project 2) with a positive probability. The agent partially or fully pools $\theta = (1, l)$ and $\theta = (l, 1)$ in either of the two cases. First, $m = m_2$ is not dominated given $\theta = (1, l)$. Second, $m = m_1$ is not dominated given $\theta = (l, 1)$. In the first case:

$$\begin{aligned} & \underbrace{1 \cdot \Pr\left(\text{DM implements project 1 given } m = m_1\right)}_{\text{The agent's expected payoff if he sends } m=m_1} \\ \leq \quad & \underbrace{(b_A \cdot l) \cdot \Pr\left(\text{DM implements project 2 given } m = m_2\right)}_{\text{The agent's expected payoff if he sends } m=m_2}. \end{aligned}$$

Hence, $m = m_2$ is dominant for the agent given $\theta = (l, l)$ and $\theta = (1, 1)$. Similarly in the second case, $m = m_1$ is dominant for the agent given $\theta = (l, l)$ and $\theta = (1, 1)$. Thus, in either case, $\theta = (l, l)$ and $\theta = (1, 1)$ are pooled with either or both of $\theta = (1, l)$ and $\theta = (l, 1)$.

A.2 Proof of Lemma 3.

As discussed in Section 3, whether (8) through (11) hold based on the DM's expectations determines the type of informative equilibrium. We can show that multiple types of informative equilibria do not exist together. The second sentence follows from the property of cheap talk models: there always exists an equilibrium where no information is revealed (a babbling equilibrium). In this model, without information, the DM never implements project 2. Thus, a zero equilibrium always exists.

Welfare comparison is trivial. If there is an informative equilibrium, both players prefer project 2 to project 1 given at least one state. However, in a zero equilibrium, only project 1 is implemented. Both players should be better off in an informative equilibrium than in a zero equilibrium.

A.3 Proof of Proposition 1.

In *a truthful equilibrium (T)*,

$$\theta = \begin{cases} (1,l) & \text{w.p. } \frac{1-\rho}{4} & \rightarrow m=1 \\ (1,1) & \text{w.p. } \frac{1+\rho}{4} & \rightarrow m=1 \\ (l,l) & \text{w.p. } \frac{1+\rho}{4} & \rightarrow m=1 \\ (l,1) & \text{w.p. } \frac{1-\rho}{4} & \rightarrow m=2 \end{cases}$$

Then, the DM's expectation is

$$E\left[\theta_1|m=1\right] = \frac{\frac{1}{2}\cdot 1+\frac{1+\rho}{4}l}{\frac{3+\rho}{4}} = \frac{2+(1+\rho)l}{3+\rho}, E\left[\theta_2|m=1\right] = \frac{2l+(1+\rho)}{3+\rho},$$
$$E\left[\theta_1|m=2\right] = l \text{ and } E\left[\theta_2|m=2\right] = 1.$$

Hence, (8) and (9) hold. How about (10) and (11)? Given $\theta = (l,1)$, the agent should prefer project 2:

$$(1\cdot b_A)\cdot(1\cdot b_{DM}) \geq l\cdot\frac{2+(1+\rho)l}{3+\rho} \quad \Leftrightarrow b_A b_{DM} \geq l\cdot\frac{2+(1+\rho)l}{3+\rho} = l\cdot B\left(\rho,l\right)$$

Given $\theta=(1,1)$ or (l,l), the agent should prefer project 1:

$$1\cdot\frac{2+(1+\rho)l}{3+\rho} \geq (1\cdot b_A)\cdot(1\cdot b_{DM}) \quad \Leftrightarrow b_A b_{DM} \leq \frac{2+(1+\rho)l}{3+\rho} = B\left(\rho,l\right)$$

Similarly, in *P1*,

$$\theta = \begin{cases} (1,l) & \text{w.p. } \frac{1-\rho}{4} & \rightarrow m=1 \\ (1,1) & \text{w.p. } \frac{1+\rho}{4} & \rightarrow m=1 \\ (l,l) & \text{w.p. } \frac{1+\rho}{4} & \rightarrow m=1 \\ (l,1) & \text{w.p. } \frac{1-\rho}{4} & \rightarrow m=1 \text{ w.p. } q, m=2 \text{ w.p. } 1-q \end{cases}$$

Then, DM's expectation is

$$E\left[\theta_1|m=1\right] = \frac{2+(1+\rho+q(1-\rho))l}{3+\rho+q(1-\rho)}, E\left[\theta_2|m=1\right] = \frac{2l+(1+\rho+q(1-\rho))}{3+\rho+q(1-\rho)},$$
$$E\left[\theta_1|m=2\right] = l \text{ and } E\left[\theta_2|m=2\right] = 1.$$

Hence, (8) and (9) hold. How about (10) and (11)? Given $\theta = (l,1)$, the agent should be indifferent:

$$(1 \cdot b_A) \cdot (1 \cdot b_{DM}) = l \cdot \frac{2+(1+\rho+q(1-\rho))l}{3+\rho+q(1-\rho)} \quad \Leftrightarrow q = \frac{(2+(1+\rho)l)l-b^S b^R(3+\rho)}{(1-\rho)\left(b^S b^R - l^2\right)}$$

$q = 1$ iff $b_{DM} b_A = \frac{(1+l)l}{2}$.

In *P2*,

$$\theta = \begin{cases} (1,l) & \text{w.p. } \frac{1-\rho}{4} & \rightarrow m = 1 \\ (1,1) & \text{w.p. } \frac{1+\rho}{4} & \rightarrow m = 1 \text{ w.p. } q, m = 2 \text{ w.p. } 1-q \\ (l,l) & \text{w.p. } \frac{1+\rho}{4} & \rightarrow m = 1 \text{ w.p. } q, m = 2 \text{ w.p. } 1-q \\ (l,1) & \text{w.p. } \frac{1-\rho}{4} & \rightarrow m = 2 \end{cases}$$

Then, the DM's expectation is

$$E\left[\theta_1 | m = 1\right] = \frac{1-\rho+q(1+\rho)(1+l)}{1-\rho+2q(1+\rho)}, E\left[\theta_2 | m = 1\right] = \frac{(1-\rho)l+q(1+\rho)(1+l)}{1-\rho+2q(1+\rho)},$$
$$E\left[\theta_1 | m = 2\right] = \frac{(1-\rho)l+(1-q)(1+\rho)(1+l)}{1-\rho+2(1-q)(1+\rho)} \text{ and } E\left[\theta_2 | m = 2\right] = \frac{1-\rho+(1-q)(1+\rho)(1+l)}{1-\rho+2(1-q)(1+\rho)}.$$

(8) holds. But (9) holds only if

$$\begin{aligned} & b_{DM} \cdot E\left[\theta_2 | m = 2\right] \geq E\left[\theta_1 | m = 2\right] \\ & \Leftrightarrow q \geq \overline{q}\left(b_{DM}, \rho, l\right) := 1 - \frac{(b_{DM}-l)\cdot(1-\rho)}{(1-b_{DM})(1+\rho)(1+l)} \end{aligned}$$

How about (10) and (11)? Given $\theta = (1,1)$, the agent should be indifferent:

$$\begin{aligned} & E\left[\theta_1 | m = 1\right] = b_A b_{DM} E\left[\theta_2 | m = 2\right] \\ & \Leftrightarrow \frac{1-\rho+q(1+\rho)(1+l)}{1-\rho+2q(1+\rho)} = b_A b_{DM} \frac{1-\rho+(1-q)(1+\rho)(1+l)}{1-\rho+2(1-q)(1+\rho)} \\ & \Rightarrow q = \widetilde{q}\left(b_A, b_{DM}, \rho, l\right) \end{aligned}$$

$b_A = \frac{B(\rho,l)}{b_{DM}}$ if $q = 0$. We can also show that if $b_A > D\left(b_{DM}, \rho, l\right)$, then, $\widetilde{q}\left(b_A, b_{DM}, \rho, l\right) < \overline{q}$. That is, for q satisfying $E\left[\theta_1 | m = 1\right] = b_A b_{DM} E\left[\theta_2 | m = 2\right]$, (9) does not hold.

We find $D\left(\rho, l, b_{DM}\right)$ plugging $q = \overline{q}\left(b_{DM}, l, \rho\right)$ into $\frac{1-\rho+q(1+\rho)(1+l)}{1-\rho+2q(1+\rho)} = b_{DM} b_A \frac{1-\rho+(1-q)(1+\rho)(1+l)}{1-\rho+2(1-q)(1+\rho)}$. We can also show that It means $q\left(b_A, b_{DM}, l, \rho\right) < \overline{q} \Leftrightarrow b_A > D\left(\rho, l, b_{DM}\right)$ (too frequent $m = 2$ if the agent's bias b_A is large)

$$D\left(b_{DM}, \rho, l\right) < \frac{B(\rho,l)}{b_{DM}} \quad \text{iff } b_{DM} < d\left(\rho, l\right) = 1 - \frac{(1-\rho)(1-l)}{l+l\rho+2} \text{ (i.e., } \overline{q}\left(b_{DM}, \rho, l\right) > 0\text{).}$$