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Characteristics of information transmission under uncertainty

Mariko Tanaka
Graduate School of Economics, University of Tokyo

Abstract

This paper utilizes a sender-receiver game involving a government and infinite heterogeneous agents to analyze the characteristics of information transmission in an environment where a true state does not exist and coordination among various players is required. It shows that a message conveyed by the government induces agents to consider public opinion not through direct communication, but through expectations concerning the government's action. It also shows that the need for coordination, self-interest, and altruism enable the government to convey a more precise and credible message by decreasing the incentive to misrepresent information, whereas a perfectly altruistic government would always convey a precise message.

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Contact: Mariko Tanaka - tana68@nifty.com.
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1. Introduction

Communication with markets is expected to smooth market reactions through announcing policy decisions as precisely as possible. Though disclosures are beneficial in conveying information, Morris and Shin (2002) pointed out that the public overreacts to signals under uncertainty owing to a coordination motive arising from a strategic complementarity in their actions. Hence, this paper analyzes optimal strategies of information transmission in the interaction between government and the public, in the spirit of Morris and Shin (2002).

The statements as a list of words issued by the government per se have no direct impact on the results, but may influence the consequences via public expectations. In this sense, we can regard policy announcements as cheap talk that "consists of costless, nonbinding, and nonverifiable messages which do not directly affect payoffs, but may have indirect effects on outcomes through changing the message receivers' beliefs (Gibbons, 1992)."

Stein (1989) characterized the Fed's announcement policy as cheap talk by adopting the concept of partition equilibria (Crawford and Sobel, 1982) where a message sender reports the partition his target lies in to the receiver. This paper also utilizes the same concept, but explicitly introduces infinite heterogeneous preferences of message receivers, the public, into a macro environment, where the true state does not exist and coordination between the government and the public is required. In such a setting, information transmission by the government can be "a focal point for the beliefs of the group as a whole" in Morris and Shin (2002). We will show that each agent considers actions of other agents, not through direct communication with the public, but through expectations about the action of the government, given the public's actions.

Alonso et al. (2008) studied vertical communication between two message senders and one receiver, who is also a decision-maker, as well as horizontal communication between two message senders, as opposed to this paper's assumption of one message sender and infinite receivers who all determine their own actions. We utilize Alonso et al.'s concepts of adaptation loss and coordination loss to compare vertical information transmissions in two types of government: a perfectly altruistic one, which completely reflects the public's utility, and one which does not. By examining both types of government, we find that communication attitudes depend on government's altruism as well as the need for coordination and self-interest.

This paper is organized as follows. The basic model is presented in Section 2. Section 3 describes the decision-making process of each agent. Section 4 analyzes the government's incentive to misrepresent its type. In Section 5, partition equilibria are characterized. Section 6 concludes the paper.

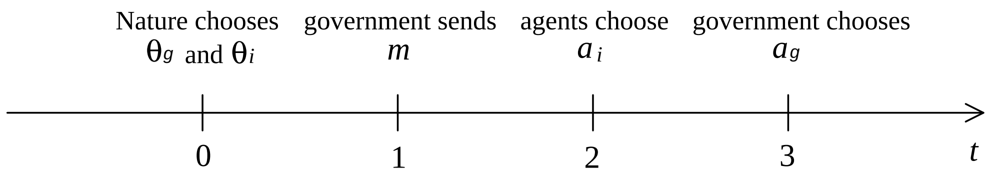

Figure 1 Timeline

2. The Model

There are two players: the public which is a continuum of heterogeneous agents, indexed by the unit interval $[0, 1]$, and the government. Nature chooses a target of government and a local condition of each agent, $\theta_g \in [0, 1]$ and $\theta_i \in [0, 1]$ at period 0. After government and agents both know their types, government costlessly conveys a message about its target, $m \in [0, 1]$, to agents at period 1. This communication has no real effect but may influence the outcome by altering the perception about the target among the public, that is, we consider a cheap talk game. Observing the message, each agent simultaneously determines the action a_i as a respective optimal solution at period 2. Finally, the government chooses the action a_g to maximize its utility at period 3. The game is depicted in Figure 1.

Each agent i derives utility from its local condition, $\theta_i \in [0, 1]$; its action, $a_i \in [0, 1]$; and the government's action, $a_g \in [0, 1]$: $U^i \equiv -(a_i - \theta_i)^2 - \delta(a_i - a_g)^2$, where the first term captures the adaptation loss that i's action does not perfectly coincide with its type, while the second one corresponds to the coordination loss that the micro action of each agent is not completely consistent with the macro action taken by the government.

The parameter $\delta \in (0, \infty)$ measures the importance of coordination relative to adaptation. Each agent i knows its type θ_i, but not that of the other agents or of the government. Similarly, the government knows its type θ_g but not that of each agent. It is common knowledge, however, that θ_g and $\{\theta_i\}_{i \in [0,1]}$ are uniformly distributed on $[0, 1]$. The draws of each are independent.

We consider two types of government: a perfectly altruistic one and an individualistically-oriented one. Both types of government maximize $U^g \equiv -\lambda(a_g - \theta_g)^2 + (1 - \lambda) \int_0^1 U^i di - (\epsilon - 1)(1 - \lambda) \int_0^1 (a_i - \theta_i)^2 di$. The parameter $\delta \in (0, \infty)$ that measures the importance of coordination relative to adaptation influences government's utility U^g via the public's utility $\int_0^1 U^i di$. The parameter $\lambda \in [0, 1]$ measures the government's bias towards its own interest, and the parameter ϵ denotes altruism of government, i.e., the degree to which the government takes account of the public's types.

If $\lambda = 1$, the government considers only self-interest. As λ decreases, the government becomes sensitive to the public's utility. If $\lambda = 0$, it does not take into account its interest, but whether it considers the public's types as well as the public's actions depends on the degree of altruism ϵ. If $\epsilon = 1$, the government is perfectly altruistic because it takes full account of the public's utility. As ϵ decreases, the government becomes more individualistic and enjoys higher utility because it does not need to consider the types of public.

For example, a perfectly individualistic government with $\epsilon = 0$ considers actions of the public in the same way as each agent considers the action of the government. On the other hand, a perfectly altruistic government with $\epsilon = 1$ has no conflict of interest with the public if $\lambda = 0$ and is unconcerned with the public's utility if $\lambda = 1$.

The first term corresponds to the adaptation loss that the government's action does not fit its type. The second term captures the average of individual utilities. The third term reflects conflict of interests between the government and the public. The following sections show that the decision-making process of both types of government is the same, but the communication attitudes of the two are different. All actions by agents $\{a_i\}_{i\in[0,1]}$ are taken simultaneously and are of equal size. The only difference among the agents is the respective agent type.

3. Decision Making

In this section, we characterize the decision-making process of two types of governments and the public, given the posterior beliefs over θ_g and $\{\theta_i\}_{i\in[0,1]}$. At period 3, the government chooses a_g after it observes the actions of the public to maximize $E[-\lambda(a_g-\theta_g)^2 - \epsilon(1-\lambda)\int_0^1 (a_i-\theta_i)^2 di - (1-\lambda)\delta \int_0^1 (a_i-a_g)^2 di | \theta_g, m, \{a_i\}_{i\in[0,1]}]$, where $\epsilon = 1$ if it is a perfectly altruistic government, and $\epsilon \neq 1$ otherwise. The equation that solves this problem is:

$$a_g = \frac{\lambda\theta_g + (1-\lambda)\delta\int_0^1 a_i di}{\lambda + (1-\lambda)\delta}, \tag{1}$$

which is independent of ϵ. Since we assume that the government takes actions of agents as given, it does not consider the second term of its objective function in its decision-making process. Hence, the optimal action of the government is independent of its degree of altruism.

At period 2, each agent i simultaneously chooses a_i after observing the message from the government to maximize $E[-(a_i-\theta_i)^2 - \delta(a_i-a_g)^2|\theta_i, m]$. Using equation (1), the action that solves this problem is:

$$a_i = \frac{\theta_i}{1+\delta} + \frac{\lambda\delta E[\theta_g|\theta_i, m]}{\{\lambda+(1-\lambda)\delta\}(1+\delta)} + \frac{(1-\lambda)\delta^2 E[\int_0^1 a_j dj|\theta_i, m]}{\{\lambda+(1-\lambda)\delta\}(1+\delta)}, \tag{2}$$

where $E[\theta_g|\theta_i, m]$ is the type of government that an agent i expects after observing the

Economics Bulletin, 2012, Vol. 32 No. 3 pp. 2629-2637

message, and $E[\int_0^1 a_j dj|\theta_i, m]$ is the average of individual actions expected by agent i.

We assume that $\int_0^1 a_i di = \int_0^1 E[\int_0^1 a_j dj|\theta_i, m]di$, implying that the collective action coincides with the average of collective actions expected by individuals. This assumption is a weak form of the rational expectations hypothesis proposed by Pesaran and Weale (2006), in that it does not require the rationality of each agent's expectation but allows for a considerable degree of heterogeneity at the individual level. Using this hypothesis, the actions of each agent and the government are as follows:

$$a_i = \frac{\theta_i}{1+\delta} + \frac{\lambda\delta E[\theta_g|\theta_i, m]}{\{\lambda + (1-\lambda)\delta\}(1+\delta)} + \frac{(1-\lambda)\delta^2}{(\lambda+\delta)(1+\delta)} E[\int_0^1 \theta_j dj|\theta_i, m] + \frac{\lambda(1-\lambda)\delta^3}{(\lambda+\delta)\{\lambda+(1-\lambda)\delta\}(1+\delta)} E[\int_0^1 E[\theta_g|\theta_j, m]dj|\theta_i, m], \quad (3)$$

$$a_g = \frac{\lambda\theta_g}{\lambda+(1-\lambda)\delta} + \frac{(1-\lambda)\delta}{\lambda+\delta}\int_0^1 \theta_i di + \frac{\lambda(1-\lambda)\delta^2}{(\lambda+\delta)\{\lambda+(1-\lambda)\delta\}}\int_0^1 E[\theta_g|\theta_i, m]di. \quad (4)$$

Both the government and agents take account of the expected and actual types of each other. Although horizontal communication among agents as in the case of decentralization in Alonso et al. (2008) does not occur, each agent considers the actions of other agents through expectations about the government's action. Since an agent has no power to alter the actions of infinite heterogeneous agents, its action is more influenced by other agents' actions in our model, compared to a setting where only two agents exist. This indirect effect of vertical communication does not appear even in the case of centralization in the Alonzo et al. model because the sole decision maker considers only the types of message senders. The next section shows that the two types of governments have different strategies in sending a message to affect the agents' expectations about the type of government, $E[\theta_g|\theta_i, m]$.

4. Incentive to misrepresent information

At period 1, the government sends a message $m \in [0, 1]$ to agents after observing the respective type. This section considers the government's incentive to misrepresent its type θ_g. If it can credibly send a wrong message to the public, the message may influence the outcome by altering the recognition about the target among agents. Let $g = E[\theta_g|\theta_i, m]$ be the agent i's expectation of θ_g under message m, and suppose that the government can simply choose any g. This implies that the government can credibly misrepresent its type and then induce the public to choose desirable actions for the government.

The government would like the public to have the posterior belief that maximizes its expected payoff: $g^* = argmax_g E[-\lambda(a_g - \theta_g)^2 - \epsilon(1-\lambda)\int_0^1 (a_i - \theta_i)^2 di - (1-\lambda)\delta\int_0^1 (a_i - a_g)^2 di|\theta_g]$, where a_i and a_g are given by equations (3) and (4). Solving this problem, we have:

$$g^* - \theta_g = \frac{(1-\epsilon)\{\lambda + (1-\lambda)\delta\}}{\lambda\delta + \epsilon\{\lambda + (1-\lambda)\delta\}}(\theta_g - \frac{1}{2}). \tag{5}$$

Since the coefficient of $(\theta_g - \frac{1}{2})$ is positive as long as $\epsilon \neq 1$, i.e., the government is not perfectly altruistic, the government exaggerates its type whenever $\theta_g \neq 1/2$. The coefficient is decreasing in δ, λ, and ϵ. Hence, the incentive to misrepresent information is increasing in $|\theta_g - 1/2|$ and decreasing in the need for coordination, δ, in the bias for government's interest, λ, and in altruism, ϵ. As the parameter δ increases, the government puts more weight on coordination and less on adaptation, while as the parameter λ increases, the government puts more weight on its own interest and less on the public's interest. As the parameter ϵ increases, the government's preference approaches towards that of the public.

The relationship between misrepresentation and the two parameters δ and λ is the opposite of the cases of centralization and decentralization, respectively, in Alonso et al. (2008). In their model, a message receiver coordinates the decisions between two message senders in the case of centralization, while in the case of decentralization, two agents send and receive a message to each other and choose optimal actions simultaneously. As δ in the case of centralization and λ in the case of decentralization increase, message senders exaggerate their types to induce the message receiver to choose the action closer to his type.

On the other hand, in our model, a message sender, i.e. the government, coordinates a macro decision by itself and micro decisions by heterogeneous infinite message receivers, i.e. agents. We show that both the government's self-interest and the need for coordination in the case of centralization mitigate misrepresentation of information by the government, not only because the message sender itself chooses the optimal action but also because there exists no true state of this macro environment.

If government is perfectly altruistic with $\epsilon = 1$, it has no incentive to misrepresent its type:

$$g^* = \theta_g. \tag{6}$$

Intuitively, as an infinitesimal individual action does not conflict with the government's interest, $-(a_g - \theta_g)^2$, the government regards its preference to be identical to that of agents.

In contrast, an individualistically-oriented government has an incentive to misrepresent its type as the interests of the government and the public conflict. As the parameter ϵ increases, the incentive to misrepresent its type decreases and converges to a perfectly altruistic case. In other words, more altruism incurs higher cost of manipulating public opinion and of conveying less precise messages to the public. As increasing altruism

Economics Bulletin, 2012, Vol. 32 No. 3 pp. 2629-2637

ϵ narrows the gap of interests between the government and the public, its effect on information transmission is consistent with a higher need for coordination δ. On the other hand, decreasing self-interest has the opposite effect because it induces the government to consider the public interest despite any conflict of interest with the public.

Regardless of such differences in strategies of cheap talk to the public, the actions by both types of governments deviate from their true types to minimize adaptation losses and coordination losses.

5. Cheap Talk Equilibria

This section analyzes multiple Bayesian Nash Equilibria according to Alonso et al. (2008) corresponding to a number of subintervals partitioning the interval $[0, 1]$, in which the government with $\epsilon \neq 1$ announces the subinterval its type belongs to. Such a strategy enables the government to convey a credible message to agents at little expense of precise information.

A communication equilibrium is characterized by the message rule for a government with $\epsilon \neq 1$, decision rules for agents and government, and belief functions for agents. The message rule specifies the probability of the message, given its type, $\mu(m|\theta_g)$; the decision rule for each agent is its action, given its type and message, $a_i(\theta_i, m)$, while for the government, given its type, message, and action of agents, $a_g(\theta_g, m, \{a_i\}_{i\in[0,1]})$; the belief function is the probability of the government's type, given the message, $p(\theta_g|m)$.

In the perfect Bayesian communication equilibria, the message rule is optimal for the government, given the decision rules; the decision rules are optimal, given belief functions; and the belief functions are derived from the message rule using Bayes's rule wherever possible:

(i) whenever $\mu(m|\theta_g) > 0$, $m \in argmax_m E[-\lambda(a_g - \theta_g)^2 - \epsilon(1-\lambda)\int_0^1 (a_i - \theta_i)^2 di - (1-\lambda)\delta \int_0^1 (a_i - a_g)^2 di|\theta_g]$, given the decision rules,

(ii) the decision rule for each agent i solves

for each agent i, $max_{a_i} E[-(a_i - \theta_i)^2 - \delta(a_i - a_g)^2|\theta_i, m]$, and

for government, $max_{a_g} E[-\lambda(a_g - \theta_g)^2 - \epsilon(1-\lambda)\int_0^1 (a_i - \theta_i)^2 di - (1-\lambda)\delta \int_0^1 (a_i - a_g)^2 di|\theta_g, m, \{a_i\}_{i\in[0,1]}]$, where $\epsilon \neq 1$.

(iii) the belief functions satisfy

$p(\theta_i|m) = \mu(m|\theta_g)/\int_p \mu(m|\theta_g)d\theta_g$, where $p = \{\theta_g : \mu(m|\theta_g) > 0\}$.

We partition $[0, 1]$ into $K + 1$ subintervals: $I^K \equiv (I_0, I_1, ..., I_K)$, where $I_0 = 0$ and I_K=1.

Proposition

If $\delta \in (0, \infty)$, then, for every positive integer K, there exists at least one equilibrium $(\mu(\cdot), a_i(\cdot), a_g(\cdot), p(\cdot))$, where

(i) $\mu(m|\theta_g)$ is uniform on $[I_{k-1}, I_k]$ if $\theta_g \in (I_{k-1}, I_k)$,
(ii) $p(\theta_g|m)$ is uniform on $[I_{k-1}, I_k]$ if $m \in (I_{k-1}, I_k)$,
(iii) Intervals are determined as follows:

$$I_{k+1} - I_k = I_k - I_{k-1} + \frac{4(1-\epsilon)\{\lambda + (1-\lambda)\delta\}}{\lambda\delta + \epsilon\{\lambda + (1-\lambda)\delta\}}(I_k - \frac{1}{2}) \text{ for k=1,...,K-1,}$$

(iv) $a_i(\theta_i, m)$ and $a_g(\theta_g, m, \{a_i\}_{i\in[0,1]})$ are given by equations (3) and (4).

Such partition equilibria do not exist for $\epsilon = 1$ because a perfectly altruistic government has no incentive to misrepresent its type. In the communication equilibria, the government can send a credible message to the public through a noisy signal. As the government's type θ_g deviates from the public opinion, 1/2, the incentive to misrepresent its type increases, inducing a wider subinterval.

6. Conclusion

This paper studies how cheap talk by government influences public behavior under uncertainty. The model analyzes the communication attitudes of two types of governments and characterizes partition equilibria in a macro environment consisting of infinite heterogeneous agents and the government.

The paper shows that a message by the government induces agents to consider other agents' actions through expectations about the government's action. It also shows that a perfectly altruistic government has no incentive to misrepresent its type, while an individualistically oriented government exaggerates its type. We find that the need for coordination, self-interest, and altruism enables an individualistic government to convey a credible message without sacrificing significant accuracy of information by decreasing the incentive to misrepresent information.

Appendix

If the public holds a posterior expectation g of θ_g, the expected payoff to the government is given by:

$$E[U^g|\theta_g, g] = E[-\lambda(a_g - \theta_g)^2 - \epsilon(1-\lambda)\int_0^1 (a_i - \theta_i)^2 di - (1-\lambda)\delta \int_0^1 (a_i - a_g)^2 di], \quad (7)$$

where a_i and a_g are given by equations (3) and (4), $g = E[\theta_g|\theta_i, m]$, and $\epsilon \neq 1$. Since $(\partial^2/\partial\theta_g\partial g)E[U^g|\theta_g, g] > 0$ and $(\partial^2/\partial\theta_g^2)E[U^g|\theta_g, g] < 0$, for any two different posterior expectations of the public, $\underline{g} < \overline{g}$, there exists at most one type of government that is indifferent between $\underline{g}$ and $\overline{g}$.

Suppose that contrary to the assertion of interval equilibria, there are two types $\underline{\theta_g} < \overline{\theta_g}$ such that $E[U^g|\underline{\theta_g}, \overline{g}] \geq E[U^g|\underline{\theta_g}, \underline{g}]$ and $E[U^g|\overline{\theta_g}, \underline{g}] > E[U^g|\overline{\theta_g}, \overline{g}]$. Since $E[U^g|\overline{\overline{\theta_g}}, \overline{g}] -$

$E[U^g|\overline{\theta_g}, \underline{g}] < E[U^g|\underline{\theta_g}, \overline{g}] - E[U^g|\underline{\theta_g}, \underline{g}]$ violates $(\partial^2/\partial\theta_g\partial g)E[U^g|\theta_g, g] > 0$, all equilibria with $\epsilon \neq 1$ must be interval equilibria.

We characterize the equilibria that induce a finite number of different actions. Let $m_k \in (I_{k-1}, I_k)$ be any message and $\overline{m}_k$ be the agent i's posterior belief of the expected value of θ_g after receiving m_k. In state I_k, the government must be indifferent between sending a message that induces a posterior $\overline{m}_k$ and a posterior $\overline{m}_{k+1}$: $E[U^g|I_k, \overline{m}_k] - E[U^g|I_k, \overline{m}_{k+1}] = 0$.

Using equation (7) and substituting $\overline{m}_k = \frac{I_{k-1}+I_k}{2}$, $\overline{m}_{k+1} = \frac{I_k+I_{k+1}}{2}$ and $E[\int_0^1 \theta_i di] = 1/2$, we obtain:

$$I_{k+1} - I_k = I_k - I_{k-1} + \frac{4(1-\epsilon)\{\lambda + (1-\lambda)\delta\}}{\lambda\delta + \epsilon\{\lambda + (1-\lambda)\delta\}}(I_k - \frac{1}{2}). \tag{8}$$

Using the boundary conditions $I_0 = 0$ and $I_K = 1$ to solve for the difference equation (8), we get

$$I_k = \frac{1}{2(x^K - y^K)}\{x^k(1+y^K) - y^k(1+x^K)\} + \frac{1}{2} \text{ for } 0 \leq k \leq K, \tag{9}$$

where the roots x and y which satisfy $xy = 1$ are given as follows:

$$x = 1 + \frac{2(1-\epsilon)\{\lambda + (1-\lambda)\delta\}}{\lambda\delta + \epsilon\{\lambda + (1-\lambda)\delta\}} + \sqrt{[\frac{2(1-\epsilon)\{\lambda + (1-\lambda)\delta\}}{\lambda\delta + \epsilon\{\lambda + (1-\lambda)\delta\}}]^2 - 1}, \text{ and}$$

$$y = 1 + \frac{2(1-\epsilon)\{\lambda + (1-\lambda)\delta\}}{\lambda\delta + \epsilon\{\lambda + (1-\lambda)\delta\}} - \sqrt{[\frac{2(1-\epsilon)\{\lambda + (1-\lambda)\delta\}}{\lambda\delta + \epsilon\{\lambda + (1-\lambda)\delta\}}]^2 - 1}.$$

Since $I_k + I_{K-k} = 1$, the intervals are symmetrically distributed around 1/2. If $\epsilon = 1$, there does not exist an interval equilibrium.

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