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# Endogenous Alleviation of Overreaction Problem by Aggregate Information Announcement*

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**Abstract**

It is well-known that agents overreact to public information in markets characterized by strategic complementarities. We propose a simple and implementable manner of alleviating overreaction problem. Extending the model of Morris and Shin (2002) to a multi-region economy, we show that, under an aggregate information announcement, each agent converts purely public information into imperfect public information endogenously. This makes the agents' beliefs dispersed and alleviates the overreaction problem. Moreover, we compare the welfare effect of the aggregate information announcement with that of separate one. We find that there exist plausible situations where the aggregate information announcement is better than the separate information announcement despite degraded quality.

*Keywords*: Aggregate information; Social welfare; Transparency; Disclosure; Beauty contest *JEL classification*: C72, D82, D83, and E58

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# 1 Introduction

This paper investigates *how* public information should be disclosed. In recent years, the welfare effect of public information has been vigorously discussed. Most studies discuss the problem of *whether* public information should be released. The authorities in these works disseminate public information *as it is*. That is, the manner of disclosure is identical.

Owing to the many important studies on this subject, we know what to expect when the authorities release information to the public as it is. However, we know little regarding the differential effects of disclosing public information in different manners. We extend the well-known model of Morris and Shin (2002), and present a simple and welfare-improving manner of public information dissemination.

Disseminating public information sometimes decreases social welfare. By modeling the Keynesian beauty contest, Morris and Shin (2002) show that decreases in social welfare may occur when agents have strategic complementarities and heterogeneous beliefs. Suppose that agents decide their behavior after receiving two types of available information regarding economic fundamentals: private information, which is independent among agents, and public information, which is perfectly correlated among agents. Each signal represents information regarding economic fundamentals. However, public information plays another role in a market with strategic complementarities. Public information is perfectly correlated among agents; that is, all agents know the realized value of signals received by others. This means that the agents can use public information to anticipate not only fundamentals but also others' expectations and hence, their behavior. Moreover, all agents are aware that they all have the same public information. This makes their behavior dependent on higher order expectations, which are, in other words, agents' expectations regarding others' expectations of others' expectations, and so on, of fundamentals.

As a result, in a market with strategic complementarities, agents' behavior depends more strongly on public information than on their expectations of fundamentals under Bayes' rule. In other words, agents overreact to public information. If the action that reflects fundamentals alone is socially desirable, the disclosure of public information may worsen social welfare because of agents' overreaction. Morris and Shin (2002) conclude that, in their Keynesian beauty contest model, the authorities should not release public information unless it is sufficiently accurate.

Most studies in the literature investigate *whether* public information should be released in various payoff structures. We call this issue the *whether-to problem.* In their seminal paper, Morris and Shin (2002) model the Keynesian beauty contest, which can be regarded as a stock market, and find that public information dissemination may worsen social welfare. A number of studies consider the whether-to problem. To cite representative examples, Angeletos and Pavan (2004) consider the payoffs with investment externalities. Hellwig (2005) does so in a monopolistic competition market. Angeletos and Pavan (2004) and Hellwig (2005) conclude that public information disclosure always improves social welfare. Angeletos and Pavan (2007) investigate a more general market environment. They find that the welfare effect of public information depends on the relationship between the overall precision of information regarding underlying fundamentals and the correlation of information among agents.[1]

The aforementioned studies assume that the authorities release public information in an unchanged form. In other words, they do not consider how to conduct their announcement policies. We call this issue the *how-to* problem. In contrast to the whether-to problem, few studies address the how-to problem.

Morris and Shin (2007) give us a clue of this notion. They investigate the situation where each agent receives a "club signal" that is available to only a subset of the population. Combining the contributions of Morris and Shin (2007) and Angeletos and Pavan (2007), we can guess that the welfare effects of information crucially depend on the tradeoff between the overall precision of information regarding the unknown fundamentals and the degree of information correlation among agents. The key to the how-to problem is to find the implementable manners of alleviating the overreaction problem.

To the best of our knowledge, only three papers consider the how-to problem explic-

[1]There are other streams of literature on public announcement. One stream is to endogenize information acquisition, for instance, Hellwig and Veldkamp (2009), Colombo and Femminis (2008), and Myatt and Wallace (2012). Another is to apply to business cycles (Hellwig 2002, Amato and Shin 2003, Ui 2003, Adam 2007, Angeletos and La'O 2008, Angeletos and Pavan 2009, Lorenzoni 2009, Mackowiak and Wiederholt 2009, etc.), financial markets (Allen et al., 2006), policy intervention(James and Lawler, 2011), and government credibility (Chen et al., 2012).

itly.[2] Cornand and Heinemann (2008) study the optimal dissemination range of public announcements. They conclude that public information should be disseminated to only some of the agents. Myatt and Wallace (2010) and Arato and Nakamura (2011) analyze the welfare effect of an ambiguous announcement by assuming that the authorities can mix private noise into public information. Myatt and Wallace (2010) focus on a Lucas-Phelps island-economy, and Arato and Nakamura (2011) use the beauty contest payoff structure. They show that in each economy, there exists an appropriately ambiguous announcement policy. This means that mixing private noise into public information can help improve social welfare.

These three papers use different methods of public information dissemination. In each method, the authorities can partially avoid excess coordination among agents, thereby improving social welfare. We think that these studies extend the literature from a *whether-to* problem to a *how-to* one explicitly.

However, it is somewhat difficult for the authorities to implement their proposed announcement policies. The manner of Morris and Shin (2007) that introduce semi-public information cannot exclude communication among groups. In the partial announcement policy proposed by Cornand and Heinemann (2008), it is difficult for the authorities to prevent agents who receive authorities' announcement from sharing it with agents who do not receive it. In the ambiguous announcement policy proposed by Myatt and Wallace (2010) and Arato and Nakamura (2011), it is difficult for the authorities to discern their manner of speech and realize the appropriate level of ambiguity.

In this paper, we will propose a simple and realistic means of disclosing public information in order to avoid excess coordination, or equivalently, overreaction to the actions of other agents. Suppose that the economy consists of several regions with local fundamentals and that there is a single government. In this economy, the authorities could choose one of three alternatives to disclose public information. The first is the *separate information announcement* (hereafter, SIA) policy, which means that the authorities release public signals regarding each region's fundamentals separately. The second is the *aggre-*

[2] Dewan and Myatt (2008, 2012) study the effect of communication clarity in the political science literature of leadership.

*gate information announcement* (hereafter, AIA) policy, which means that the authorities release only one public signal regarding fundamentals in the whole economy. The third is the *no-announcement* (hereafter, NA) policy, which means the authorities do not release public information.[3] We show that the SIA policy has the identical welfare implication as in Morris and Shin (2002), and that the AIA policy can be more desirable than both SIA and NA policies.

Aggregate information is more degraded information regarding economic fundamentals than separate information, because, if an agent has separate information, he can easily create aggregate information by a simple sum of each value. However, if the agent has only aggregate information, he cannot obtain information regarding the local fundamentals. Hence, AIA has a negative welfare effect on the precision of information regarding economic fundamentals. Despite this negative effect, AIA can improve social welfare for the following reason. Aggregate information itself is useless in estimating local fundamentals. The agents have to extract information regarding the fundamentals of their region from aggregate public information, by using their private information regarding the fundamentals of the foreign region. Hence, the information obtained from this extraction is dispersed among agents. In other words, by this information extraction, the agents mix private noise into public information endogenously. AIA makes agents' beliefs more dispersed than SIA does. Therefore, AIA can alleviate the overreaction problem, and it has a positive effect on social welfare. If this positive effect dominates the negative one, then social welfare can be improved.

The AIA policy proposed in this paper has several advantages compared to the policies in existing studies. First, the methods of information dissemination in existing papers require the authorities to possess some aforementioned specialized skills. However, the AIA policy is simple and concrete, so it does not require the authorities to possess any special skills.

[3] Although we may regard this situation as one country consisting of multiple sectors, another realistic example of the situation that we consider is the EU. The EU consists of several countries and a single central bank, the European Central Bank (ECB). In this case, SIA means that the ECB announces each region's fundamentals (for example, productivities, GDPs, or money stocks of each country) of all countries in the EU. AIA means that the ECB announces only the fundamentals of the whole economy (for example, aggregate GDP or aggregate money stock in the EU).

Second, from a technical point of view, existing studies considering the how-to problem do not use *purely* public information. In other words, the information released by the authorities is not perfectly correlated among all agents. However, in this paper, all public information conducted by the authorities is released as purely public information following the traditional definition.

Third, in contrast to the club signal proposed by Morris and Shin (2007) and the partial announcement policy proposed by Cornand and Heinemann (2008), AIA policy releases identical (purely) public information to all agents. Hence, we do not need to consider the case in which public information is shared with other agents.

Finally, agents' beliefs in AIA are dispersed endogenously. Our dependent logic for improving welfare is similar to the ambiguous announcement proposed by Myatt and Wallace (2010) and Arato and Nakamura (2011). However, their authorities make agents' beliefs dispersed exogenously. On the other hand, under the AIA policy, agents mix private noise into public information in person, not the authorities. Hence, the authorities need not speak ambiguously in order to mix appropriate levels of private noise into public information.

This paper is related to two discussions. One is the discussion among Morris and Shin (2002), Svensson (2006), and Morris et al. (2006). Svensson (2006) claims that the range of the parameters where NA is prefered in Morris and Shin (2002) is unrealistic; that is, a *pro*-transparency policy is desirable. We show that, in contrast to the claim by Svensson (2006), the AIA policy, that is, a kind of *con*-transparency policy, can be more appropriate even when the precision of public information is more accurate than that of private information.

The other is the discussion among currency-attack literature in the field of global games.[4] Heinemann and Illing (2002) and Lindner (2006) consider a relationship between currency attacks and transparent policy, and show that transparency may avoid currency attacks. In particular, Lindner (2006) uses a similar idea to our announcement policy. He finds that the SIA policy makes multiple equilibria less likely than the AIA policy. His

[4]See Morris and Shin (1998, 2001).

conclusion, though, differs from ours due to the difference of frameworks. His research attention is on the elimination of multiple equilibria, but ours is on the welfare-effect of transparency in a unique equilibrium.

## 2 The model

We examine a two-region economy, $k \in \{1, 2\}$.[5] Each region has one measure of agents. Each agent living in region $k$ is indexed by $ik \in [0, 1]$. Agent $ik$ chooses an action $a_{ik} \in \mathbb{R}$. We write $a_k$ for the action profile over all agents in region $k$.

As in Morris and Shin (2002), agent $ik$ has the Keynesian beauty contest payoff structure:

$$u_{ik}(a_k, \theta_k) = -(1-r)(a_{ik} - \theta_k)^2 - r(L_{ik} - L_k), \tag{1}$$

where $\theta_k$ is the state (or fundamentals) of the region $k$, $r \in [0, 1]$ is a constant, and

$$L_{ik} \equiv \int_0^1 (a_{jk} - a_{ik})^2 dj, \qquad L_k \equiv \int_0^1 L_{jk} dj.$$

The first component of the payoff is a standard quadratic loss in the distance between the underlying state $\theta_k$ and the agent's action $a_{ik}$. The second term represents Keynes' beauty contest. The loss is increasing in the distance between $ik$'s action and the average action of the whole population in his home region.[6] Each agent maximizes his expected payoff. Then, agent $ik$'s best response function is

$$a_{ik} = (1-r)E_{ik}(\theta_k) + rE_{ik}(\bar{a}_k), \tag{3}$$

where $E_{ik}$ represents agent $ik$'s expectation operator conditional on his available informa-

[5]We discuss a multi-region economy in Section 6.

[6]For simplicity, we assume that the states of each region are all independent. However, we think that the generality will hold. For instance, we can define the payoff as

$$u_{ik}(a_k, \theta_k) = -(1-r)\{a_{ik} - (\theta + \theta_k)\}^2 - r(L_{ik} - L), \tag{2}$$

where $\theta$ is a global condition. Then, the results in this paper hold.

tion and $\bar{a}_k \equiv \int_0^1 a_{jk} dj$ represents the average action of all agents in region $k$. From (3), we can understand $r$ as the strength of the motive to coordinate in this economy.[7]

Here, we define social welfare as the simple (normalized) sum of all agents:

$$\begin{aligned} W(a|\theta) &\equiv \frac{1}{2(1-r)} \sum\nolimits_{k=1}^{2} \int_0^1 u_{ik} di \\ &= -\frac{1}{2} \sum\nolimits_{k=1}^{2} \int_0^1 (a_{ik} - \theta_k)^2 di. \end{aligned} \tag{4}$$

Note that the beauty contest terms disappear at the social level. Then, the socially optimal action is

$$a_{ik,opt} = E_{ik}(\theta_k). \tag{5}$$

(5) says that the action reflecting only the fundamentals is socially optimal. This means that an individual motive to coordinate is socially inefficient.

Comparing (3) with (5), we know that there may be a conflict between individual decisions and the socially optimal solution in this economy.

# 3 Information Structure

## 3.1 Private information

For simplicity, we assume that the agents have an improper prior distribution of the fundamentals; that is, $\theta_k$, $k \in \{1, 2\}$, is distributed uniformly on the real line. Agents receive two private signals regarding each region:

$$x_{ik} = \theta_k + \epsilon_{ik} \text{ with } \epsilon_{ik} \sim N(0, 1/\beta), \quad \text{and} \tag{6}$$

$$z_{ik} = \theta_\ell + \kappa_{ik} \text{ with } \kappa_{ik} \sim N(0, 1/\gamma). \tag{7}$$

[7] Note that, in our model, agents are not concerned with the foreign fundamentals. This assumption is unrealistic in the global financial market. However, our result holds from a qualitative standpoint. Moreover, this assumption makes analysis clear and simple.

where $x_{ik}$ is the signal regarding $ik$'s home region, and $z_{ik}$ is the one regarding the foreign region $\ell \neq k$. $\beta$ and $\gamma$ represent the information precision regarding $ik$'s home and foreign region, respectively.

### 3.2 Public information

The authorities also receive two signals regarding each region: for each $k \in \{1, 2\}$,

$$y_k = \theta_k + \eta_k, \text{ with } \eta_k \sim N(0, 1/\alpha). \tag{8}$$

$\alpha$ is the precision of the authorities' information regarding each region.[8] Moreover, we define $y \equiv y_1 + y_2$ and call it *aggregate information*. We assume that all error terms are i.i.d.. Figure 1 shows our two-region economy.

[Inserte Figure 1 here.]

## 4 Announcement Policies

To maximize social welfare, the authorities can release their signals in various ways. Here, we assume that the authorities can choose an announcement policy from three alternatives. The first is the SIA policy, where the authorities announce $y_1$ and $y_2$ separately. The second is the AIA policy, where the authorities disclose only $y$. The third is the NA policy where the authorities release no information. In our model, the NA policy corresponds to the case of $\alpha = 0$ in the above two policies.

In the next section, we compare the social welfare effect under these three announcement policies and determine the most preferred announcement policy.

[8] For simplicity, we consider the case where the authorities' information precision regarding each region is the same.

### 4.1 Separate information announcement

First, we discuss SIA. Assume that the authorities release $y_1$ and $y_2$ separately. Hence, each agent observes four signals, $\{x_{ik}, z_{ik}, y_1, y_2\}$. Remember that each agent is only concerned with his own state. Hence, under this policy, agents use only two signals, $x_{ik}$ and $y_k$, because all error terms are i.i.d..

By Bayesian updating, agent $ik$'s expectation of fundamentals in his home region is

$$E_{ik}(\theta_k) = E(\theta_k | x_{ik}, y_k) = \frac{\alpha y_k + \beta x_{ik}}{\alpha + \beta}. \tag{9}$$

This value corresponds to the socially-optimal action. However, (3) corresponds to the individual-optimal action. Hence, we need the agent's expectation of the average behavior.

Agents determine their behavior on the basis of the information available to them. Therefore, if an agent knows the signal values of other agents, he can use the signal to not only estimate the fundamentals but also predict the behavior of the other agents. $y_k$ is perfectly correlated information. This means that all agents know the exact signal value of the other agents and use it to predict their behavior. Moreover, all agents know that the others have the same signal. This fact generates higher-order expectations among agents. Morris and Shin (2002) show this effect of public information and point out the overreaction to public information theoretically.

All error terms have normal distribution and the payoff is quadratic, and we use the method of undetermined coefficients. Then, all results are identical to those of Morris and Shin (2002), and we can borrow them.

**Result 1** (Morris and Shin (2002))**.** *The equilibrium action under SIA policy is*

$$a_{ik} = \frac{(1-r)^{-1}\alpha y_k + \beta x_{ik}}{(1-r)^{-1}\alpha + \beta}, \tag{10}$$

*and social welfare is*

$$W_S(\alpha; \beta, \gamma) = \frac{(1-r)^{-2}\alpha + \beta}{[(1-r)^{-1}\alpha + \beta]^2}. \tag{11}$$

*Assume that* $r \geq 1/2$*. Then, NA is preferred if* $\alpha < \alpha_S$*, where* $\alpha_S = (2r-1)\beta$.

Note that the equilibrium action puts more weight on public information than the socially optimal one does. The reason is that agents use public information to estimate fundamentals as well as the average action of the other agents. In other words, agents overreact to public information, and hence, some social welfare losses arise. However, if the precision of public information is high enough, the positive effect of accurate estimation dominates the negative one of over reaction to public information. $\alpha_S$ represents the threshold of these two effects.

Figure 2 shows the welfare effect of $\alpha$, given $\beta$ and $\gamma$, under SIA policy. When $\alpha$ approaches infinity, social welfare can reach the first-best level. We can easily verify $\lim_{\alpha\to\infty} W_S(\alpha) = -\beta^{-1}$ and $\alpha_S = (2r-1)\beta$, which is the threshold value of whether to release information under this policy. That is, if $\alpha$ is bigger than $\alpha_S$, the authorities can better improve social welfare by using SIA policy than by using NA policy.

[Insert Figure 2 here.]

## 4.2 Aggregate information announcement

Next, we discuss AIA, where the authorities disclose only $y$. Under this policy, agent $ik$ receives three signals, $\{x_{ik}, z_{ik}, y\}$. Note that $y$ includes the information about two states, but the agent who receives $y$ cannot know the disaggregated data regarding each state; that is, he does not know $y_1$ and $y_2$. Therefore, agents who want to know information regarding their home state from the authorities' announcement have to pick it out from $y$ by using their received private information regarding the foreign state.

Using $y$ and $z_{ik}$, they can extract the signal regarding $\theta_k$:

$$\begin{aligned} y_{ik} \equiv y - z_{ik} &= (\theta_k + \theta_\ell + \eta_k + \eta_\ell) - (\theta_\ell + \kappa_{ik}) \\ &= \theta_k + \eta_k + \eta_\ell - \kappa_{ik} \end{aligned}$$

Define $\psi_k$ as the precision of $y_{ik}$ and $\rho$ as the correlation of $y_{ik}$ among agents, where

$$\psi_k = \alpha\gamma/(\alpha + 2\gamma) \quad \text{and} \quad \rho = 2\gamma/(\alpha + 2\gamma).$$

$y_{ik}$ is the information regarding $\theta_k$ but is degraded compared to $y_k$; $\psi_k < \alpha$. Note that $y_{ik}$ contains private noise, so it is no longer a purely public signal.

**Lemma 1.** *AIA has an effect of converting purely public information into imperfect correlated information by individual estimation.*

The authorities in Myatt and Wallace (2010) and Arato and Nakamura (2011) alleviate the overreaction problem using an ambiguous announcement. Ambiguous announcement means that the authorities can release imperfect correlated information exogenously.[9] On the other hand, the authorities in our model release traditional defined public information. Then, agents transform public information from a perfectly correlated signal into an imperfectly correlated one. That is to say, we present a simple and endogenous mechanism of alleviation of agents' behavior. Moreover, the property of perfect correlation of AIA avoid the criticism of the communication problem among groups or agents discussed in Morris and Shin (2007) and Cornand and Heinemann (2008).

From Bayes' rule, the estimation of economic fundamentals regarding the home region, and hence the socially optimal action, is

$$E_{ik}(\theta_k) = E(\theta_k | x_{ik}, z_{ik}, y) = \frac{\psi_k y_{ik} + \beta x_{ik}}{\psi_k + \beta}. \tag{12}$$

Using (3) and the method of undetermined coefficient, we obtain the individual optimal action and social welfare.

**Proposition 1.** *The equilibrium action under AIA policy is*

$$a_{ik} = \frac{\psi_k (1 - r\rho)^{-1} (y - z_{ik}) + \beta x_{ik}}{\psi_k (1 - r\rho)^{-1} + \beta}. \tag{13}$$

[9] Note that the authorities in Myatt and Wallace (2010) and Arato and Nakamura (2011) can choose the proper level of correlation to maximize welfare.

*From* (4)*, we have*

$$W_A(\alpha;\beta,\gamma) = -\frac{\psi_k(1-r\rho)^{-2}+\beta}{[\psi_k(1-r\rho)^{-1}+\beta]^2}. \tag{14}$$

*Proof.* See Appendix A. □

[Insert Figure 3 here.]

Figure 3 shows the welfare effect of $\alpha$, given $\beta$ and $\gamma$, under AIA policy. We can easily obtain $\lim_{\alpha\to\infty} W_A(\alpha) = -(\beta+\gamma)^{-1}$, which is lower than that of the SIA policy. This means that AIA cannot attain the first-best welfare. Aggregate information itself cannot be divided to each state's information. Therefore, even if the authorities know the true value of a state, social welfare cannot attain the first-best allocation.

The threshold value of whether to release aggregate information is

$$\alpha_A = (2r-1)\beta\frac{2\gamma}{\beta+\gamma} = \alpha_S\frac{2\gamma}{\beta+\gamma} \tag{15}$$

That is, if $\alpha$ is bigger than $\alpha_A$, AIA can improve welfare compared to its level in the NA policy. Note that if $\gamma < \beta$, then $\alpha_A$ is strictly smaller than $\alpha_S$. This means that the range of $\alpha$ where NA is preferred to AIA is smaller than that of $\alpha$ where NA is preferred to SIA. Below, we assume that $\gamma < \beta$.[10]

# 5 SIA or AIA as a Preferred Announcement policy

Assume that the authorities are welfare maximizers. Hence, they compare the welfare level of SIA with that of AIA and choose the most preferred one. From (11) and (14), we have the following results.

**Proposition 2.** *Suppose that* $r \geq 3/7$*. Then there exists a threshold of* $\alpha_C$*, and*

[10]This assumption implies that agents have more accurate beliefs about the fundamentals of their home region than about those of foreign regions. It is realistic.

1. *when $\alpha \in [0, \alpha_C)$, the authorities should disclose aggregate information, and*
2. *when $\alpha \in [\alpha_C, \infty)$, the authorities should disclose separate information.*

*Moreover, if $r < 3/7$, then the authorities should disclose separate information in any $\alpha$.*

*Proof.* See Appendix B. □

[Insert Figure 4 here.]

[Insert Figure 5 here.]

If the authorities choose NA, then the welfare is $\lim_{\alpha\to 0} W(\alpha) = -1/\beta$. We can think of this value as the reservation welfare. However, when $r \leq 1/2$, $W_S$ and $W_A$ are always greater than $-1/\beta$. Hence, NA is never chosen by the authorities. On the other hand, when $r > 1/2$, welfare levels of SIA and AIA fall below $-1/\beta$ in the range of small $\alpha$.[11] That is, the authorities can improve welfare by choosing NA in this range.

Given $r > 1/2$, AIA is the most preferred policy if and only if

$$W_A(\alpha) \geq \max\{W_S(\alpha), \lim_{\alpha\to 0} W(\alpha)\}. \tag{16}$$

The case is similar when NA or SIA is the most preferred policy. To compare the three announcement policies, we combine Figures 2 and 3 to obtain Figure 4. The answer to the optimal announcement policy problem is shown more formally in the following proposition.

**Proposition 3.** *Suppose that $r \geq 1/2$ and $\gamma < \beta$ and that the authorities can choose from three announcement policies.*[12] *Then, there is a unique $\alpha_c \in (\alpha_A, \infty)$ and the preferred policy rule is as follows:*

[11] $r > 1/2$ corresponds to the situation that NA can be chosen in Morris and Shin (2002).

[12] If $\gamma = \beta$, $\alpha_A$ is equal to $\alpha_S$. If $\gamma > \beta$, then $\alpha_A$ is bigger than $\alpha_S$. In these two cases, the authorities never choose AIA. Note also that the range of $\alpha$ when AIA is the most preferred becomes wider as $\gamma$ becomes smaller.

1. *When* $\alpha \in [0, \alpha_A)$*, the authorities should not disclose their information.*

2. *When* $\alpha \in [\alpha_A, \alpha_c)$*, the authorities should disclose aggregate information.*

3. *When* $\alpha \in [\alpha_c, \infty)$*, the authorities should disclose separate information.*

*Proof.* See Appendix B. □

The intuition of Proposition 3 can be obtained by considering a tradeoff between the precision and the correlation of signals. Because under the AIA policy each agent mixes private noise into public signal, there are two differences between the AIA and the SIA policy. First, the AIA policy has a welfare-disadvantage by degradation of information precision. Each agent can estimate the value of fundamentals more accurately under the SIA policy than the AIA policy because the information that each agent receives from the authorities under the SIA policy is more precise than under the AIA policy ($\alpha > \psi_k$); hence, this effect of the AIA policy decreases social welfare. Second, the AIA policy has a welfare-advantage because of the weakening of signal correlation among agents. Note that a correlated signal can be used as a focal point regarding others' action. The information that each agent receives from the authorities under the SIA policy is more correlated among agents than under the AIA policy. Hence, in a zero-sum game with strategic complementarities, each agent reacts more excessively to the information that he receives from the authorities under the SIA policy than under the AIA policy ($(1-r)^{-1} > (1-r\rho)^{-1}$). This effect of the AIA policy increases social welfare. Taken together, if the public signal is highly precise (part 3), the advantage of the AIA policy is small; hence, the SIA policy is preferred. If the public signal is precise to some extent (part 2), the advantage exceeds the disadvantage; hence the AIA policy is preferred. Note that the NA policy has a similar advantage and disadvantage over the AIA policy. If the public signal is sufficiently imprecise (part 1), the disadvantage of the AIA policy will exceed the advantage; hence, the NA policy is preferred.

# 6 Discussions

## 6.1 Advantages of AIA over the proposed policies in existing studies

The AIA policy has some advantages over the policies proposed in existing studies. The method of information dissemination in existing papers requires the authorities to possess some special skills. However, the method we proposed is simple and concrete, so it does not require the authorities to possess any special skill. First, in contrast to the partial announcement policy proposed by Cornand and Heinemann (2008), the AIA policy releases identical public information to all agents. Hence, we do not need to consider the case in which public information is shared with other agents. Second, although in this paper, the mechanism for improving welfare by making the agents' beliefs more dispersed is similar to the ambiguous announcement policy proposed by Arato and Nakamura (2011) and Myatt and Wallace (2010), under the AIA policy, the agents mix private noise into public information endogenously, not the authorities. Hence, the authorities need not speak ambiguously in order to mix appropriate levels of private noise into public information.

## 6.2 Is AIA desirable under realistic parameter values?

Our conclusions are related to the discussion between Svensson (2006) and Morris et al. (2006). Svensson (2006) posited the issue of parameter adequacy. He claimed that the range of the parameters where NA is preferred in Morris and Shin (2002) is unrealistic, because the authorities have less-precise information in this range than in the private sector; that is, $\alpha < \beta$. Usually, we can assume that the authorities have better information than that of the private sector; that is, $\alpha > \beta$. Hence, Svensson (2006) said that "Morris and Shin (2002) is actually pro-transparency, not con."

Morris et al. (2006), in a reply to Svensson (2006), basically accept Svensson's comment. However, they additionally suggest that if there is a correlation between private information and public information, the adequacy of their opaque announcement policy would hold. That is, they show that there can be information structures in which a con-transparency policy could increase welfare in realistic ranges of parameters.

A reasonable question is "can AIA be desirable under $\alpha > \beta$?" The answer is "yes." From Proposition 3, AIA is desirable in $\alpha \in [\alpha_A, \alpha_C]$. Assume that $r$ is near 1 and $\beta > \gamma$. Then, $\alpha_C$ is larger than $\alpha_S$ and $\alpha_S \approx \beta$. These imply that $\alpha_C > \beta$. This means that there are situations in which the authorities should disclose aggregate information, even if $\alpha > \beta$.

### 6.3 Robustness

Our results are robust in an increasing number of states. Assume that there are $m \in \mathbb{N}$ states in the economy and that other assumptions still hold. Needless to say, in SIA, all results are identical to Morris and Shin (2002). In AIA, an agent has to estimate his home state by using the available private signals regarding foreign fundamentals. Note that, for each $k \in \{1, \ldots, m\}$

$$y = y_1 + \cdots + y_m \quad \text{and} \quad z_{ik\ell} = \theta_\ell + \kappa_{ik\ell} \quad \text{for } \ell \neq k,$$

where $z_{ik\ell}$ represents private information regarding $\theta_\ell$ received by agent $ik$ and $\kappa_{ik\ell}$ represents the error term of $z_{ik\ell}$. Hence, the obtained signal of $ik$'s state is

$$y_{ik} = y - \sum_{\ell \neq k} z_{ik\ell}.$$

Because all error terms are independent, we can use the reproductivity of normal distributions. Hence,

$$y_{ik} = \theta_k + \hat{\eta} + \hat{\kappa}_{ik},$$

where $\hat{\eta} = \sum_{\ell=1}^{m} \eta_\ell$ and $\hat{\kappa}_{ik} = \sum_{\ell \neq k} \kappa_{ik\ell}$. Hence, the results obtained in the previous section still hold qualitatively, as long as the authorities release aggregate information regarding the whole economy.[13]

[13] Note that if we think about a multi-region economy as comprising more than two regions, we can consider other announcement policies, such as a partial AIA policy. For instance, the authorities aggregate only two of three signals. As conjectured from the result of Arato and Nakamura (2011), the partial AIA policy would be preferred in some situations. However, numerical analysis is needed for a more detailed

# 7 Conclusion

We extend the model of Morris and Shin (2002) to a multi-region economy and compare the welfare under three announcement policies: SIA, AIA and NA. We find that agents endogenously transform aggregate public information from perfectly correlated information into imperfectly correlated information, thereby reducing agents' overreaction to public information. Hence, the AIA policy can improve social welfare.

This paper has two main contributions. First, we presented an endogenous mechanism of disseminating imperfectly correlated information. Second, we proposed a simple welfare-improving announcement policy rule.

The AIA policy has some advantages over the policies proposed by existing works, from the implementation point of view. First, even if the authorities can improve social welfare using the NA policy, in reality, it is difficult for the authorities not to make announcements regarding routine information. Moreover, social welfare under the AIA policy dominates the welfare level under the NA policy if the precision of the information in the foreign region is lower than in the home region. Second, in contrast to the announcement policies proposed by studies such as the partial announcement policy proposed by Cornand and Heinemann (2008) and the ambiguous announcement policy proposed by Myatt and Wallace (2010) and Arato and Nakamura (2011), the AIA policy is simple, and therefore, it does not depend on the authorities' policy management ability.

# Appendix A: Proof of Proposition 1

The equilibrium action exists, is unique, and is linear. The proofs are the same as in this standard literature.[14] Here, we show the derivation of (13).

The available information of each agent is $\{x_{ik}, z_{ik}, y\}$. Note that $y$ has information regarding $\theta_k$ and $\theta_\ell$. The agent can extract the information regarding $\theta_k$ and $\theta_\ell$ from $y$ by $y - z_{ik}$ and $y - x_{ik}$. Define $y_{ik} \equiv y - z_{ik}$ and $y_{i\ell} \equiv y - x_{ik}$. Using Bayesian updating, the expected values of the economic fundamentals regarding the agent's home and foreign

analysis; hence, it is the aim of future research.

[14] See Morris and Shin (2002) and footnote 5 in Angeletos and Pavan (2007).

regions are

$$E_{ik}(\theta_k) \equiv E(\theta_k | x_{ik}, z_{ik}, y) = \frac{\psi_k y_{ik} + \beta x_{ik}}{\psi_k + \beta}, \text{ and } E_{ik}(\theta_\ell) \equiv E(\theta_\ell | x_{ik}, z_{ik}, y) = \frac{\psi_\ell y_{i\ell} + \gamma z_{ik}}{\psi_\ell + \gamma}, \tag{17}$$

where $\psi_k = \alpha\gamma/(\alpha + 2\gamma)$ and $\psi_\ell = \alpha\beta/(\alpha + 2\beta)$ represent the precisions of $y_{ik}$ and $y_{i\ell}$, respectively.

All error terms are distributed normally and are independent, and the payoffs are quadratic. Therefore, we can use the method of undetermined coefficient. Assume that the linear equilibrium is

$$a_{ik} = (1-\mu)x_{ik} + \mu y_{ik} = (1-\mu)x_{ik} + \mu(y - z_{ik}), \tag{18}$$

where $\mu \in [0, 1]$ is constant. Then, the average action in region $k$ is

$$\bar{a}_k = (1-\mu)\theta_k + \mu(y - \theta_\ell) \tag{19}$$

where $\int x_{ik} di = \theta_k$ and $\int z_{ik} di = \theta_\ell$.

From the first-order condition (3) and average action in region $k$ (19), we have

$$\begin{aligned} a_{ik} &= (1-r)E_{ik}(\theta_k) + rE_{ik}(\bar{a}_k) \\ &= (1-r)E_{ik}(\theta_k) + r\left\{(1-\mu)E_{ik}(\theta_k) + \mu[y - E_{ik}(\theta_\ell)]\right\} \end{aligned} \tag{20}$$

Substituting (17) into (20) and using $\rho \equiv 2\gamma/(\alpha + 2\gamma)$, which is interpreted as the correlation between $y_{ik}$ and $y_{jk}$, $j \neq i$, we have

$$\begin{aligned} a_{ik} &= (1-r)\frac{\psi_k y_{ik} + \beta x_{ik}}{\psi_k + \beta} + r\left\{(1-\mu)\frac{\psi_k y_{ik} + \beta x_{ik}}{\psi_k + \beta} + \mu\left(y - \frac{\psi_\ell y_{i\ell} + \gamma z_{ik}}{\psi_\ell + \gamma}\right)\right\} \\ &= \left\{(1-r\mu)\frac{\beta}{\psi_k + \beta} + r\mu\frac{\psi_\ell}{\psi_\ell + \gamma}\right\} x_{ik} + \left\{(1-r\mu)\frac{\psi_k}{\psi_k + \beta} + r\mu\frac{\gamma}{\psi_\ell + \gamma}\right\}(y - z_{ik}) \\ &= \frac{\beta - r\rho\beta\mu}{\psi_k + \beta}x_{ik} + \frac{\psi_k + r\rho\beta\mu}{\psi_k + \beta}(y - z_{ik}) \end{aligned} \tag{21}$$

Each coefficient of equation (21) must equal the ones in equation (18). Picking up the coefficient of $y - z_{ik}$ in each equation and comparing them, we obtain

$$\mu = \frac{\psi_k + r\rho\beta\mu}{\psi_k + \beta} \quad \Leftrightarrow \quad \mu = \frac{\psi_k(1-r\rho)^{-1}}{\psi_k(1-r\rho)^{-1} + \beta}.$$

Hence,

$$a_{ik} = \frac{\psi_k(1-r\rho)^{-1}(y - z_{ik}) + \beta x_{ik}}{\psi_k(1-r\rho)^{-1} + \beta}. \tag{13}$$

*Q.E.D.*

## Appendix B: Proofs of Proposition 2 and 3

First, we prove Proposition 3.

1. $\alpha \in [0, \alpha_A)$

   From the discussion in subsections 3.1 and 3.2, it is clear that if and only if $\alpha \in [0, \alpha_A)$, the authorities should not disclose their information.

2. $\alpha \in [\alpha_A, \alpha_S)$

   When $\alpha \in [\alpha_A, \alpha_S)$,

$$W_S \leq -\beta^{-1}, \text{ with equality iff } \alpha = \alpha_S$$
$$W_A \geq -\beta^{-1}, \text{ with equality iff } \alpha = \alpha_A.$$

   Hence, $W_S < W_A$.

3. $\alpha \in [\alpha_S, \infty)$

$$\begin{aligned} W_S - W_A &= -\frac{(1-r)^{-2}\alpha + \beta}{[(1-r)^{-1}\alpha + \beta]^2} - \left( -\frac{\psi_k(1-r\rho)^{-2} + \beta}{[\psi_k(1-r\rho)^{-1} + \beta]^2} \right) \\ &= \frac{\alpha F(\alpha; \beta, \gamma, r)}{[(1-r)^{-1}\alpha + \beta]^2 \, [\psi_k(1-r\rho)^{-1} + \beta]^2}, \end{aligned}$$

where

$$F(\alpha;\beta,\gamma,r) = (\beta+\gamma)\alpha^3 + [\gamma^2 + (4-6r)\beta\gamma + (1-2r)\beta^2]\alpha^2$$
$$+ (1-r)\beta\gamma[3(1-r)\gamma + (3-7r)\beta]\alpha + 2(1-r)^2(1-2r)\beta^2\gamma^2.$$

Because $\alpha/\{[(1-r)^{-1}\alpha+\beta]^2[\psi_k(1-r\rho)^{-1}+\beta]^2\} > 0$, the sign of $W_S - W_A$ is identical to that of $F(\alpha)$.

$F(\alpha_S) = (2r-1)r^2\beta^2\gamma(\gamma-\beta) < 0$, $\lim_{\alpha\to\infty} F(\alpha) = \infty$, and the fact that $F(\alpha)$ is continuous and third-order imply that the equation of $F(\alpha) = 0$ has one or three solutions in the range of $\alpha \in (\alpha_S, \infty)$ (Fact1).

$$F'(\alpha) = 3(\beta+\gamma)\alpha^2 + 2[\gamma^2 + (4-6r)\beta\gamma + (1-2r)\gamma^2]\alpha$$
$$+ (1-r)\beta\gamma[3(1-r)\gamma + (3-7r)\beta] \tag{22}$$

and

$$F''(\alpha) = 6(\beta+\gamma)\alpha + 2[\gamma^2 + (4-6r)\beta\gamma + (1-2r)\beta^2].$$

Therefore, $F''(\alpha)$ is increasing in $\alpha$ and

$$F''(\alpha_S) = 2[\gamma^2 + \beta\gamma + (4r-2)\beta^2] > 0.$$

Hence, $F''(\alpha) > 0$ in $\alpha \in [\alpha_S, \infty)$ so that $F'(\alpha)$ is increasing in $\alpha \in [\alpha_S, \infty)$. This implies that $F(\alpha) = 0$ has at most two solutions in the range of $\alpha \in (\alpha_S, \infty)$ (Fact 2).

Facts 1 and 2 imply that $F(\alpha) = 0$ has a unique solution in the range of $\alpha \in (\alpha_S, \infty)$.

We define the solution as $\alpha_C$. Because $F(\alpha_S) < 0$ and $\lim_{\alpha\to\infty} F(\alpha) = \infty$,

$$F(\alpha)\begin{cases} < 0 \\ = 0 \\ > 0 \end{cases}, \quad \text{if} \begin{cases} \alpha_S \leq \quad \alpha < \alpha_C \\ \qquad\quad \alpha = \alpha_C \\ \alpha_C < \quad \alpha \end{cases} \cdot$$

Hence, from 1, 2, and 3,

$$\max\{W_N, W_A, W_S\} = \begin{cases} W_N \\ W_A \\ W_S \end{cases} \quad \text{if } \alpha \in \begin{cases} [0, \alpha_A) \\ [\alpha_A, \alpha_C) \\ [\alpha_C, \infty) \end{cases},$$

where $W_N \equiv -\beta^{-1}$ represents the welfare level in the NA policy.

*Q.E.D.*

Next we prove Proposition 2. It is sufficient to show that $F'(0) < 0$. From (22), we have

$$F'(0) < 0 \quad \Leftrightarrow \quad r > 3/7 + \frac{12/7}{7\,[(\beta/\gamma) + (3/7)]}, \tag{23}$$

where $r \to 1$ ($r \to 3/7$) as $\beta/\gamma$ goes to 0 ($\infty$). This means that if $1 > r > 3/7$, there exists a region where the welfare level of AIA is greater than that of SIA.

*Q.E.D.*

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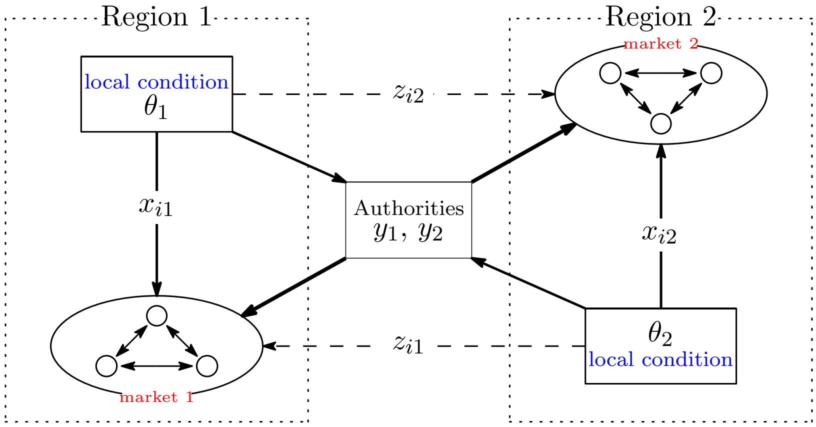


Figure 1: Two-region economy

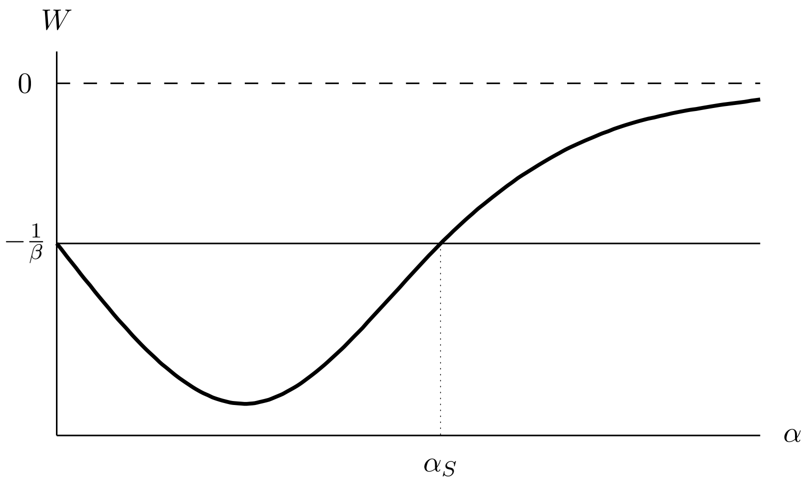


Figure 2: Separate Announcement Policy

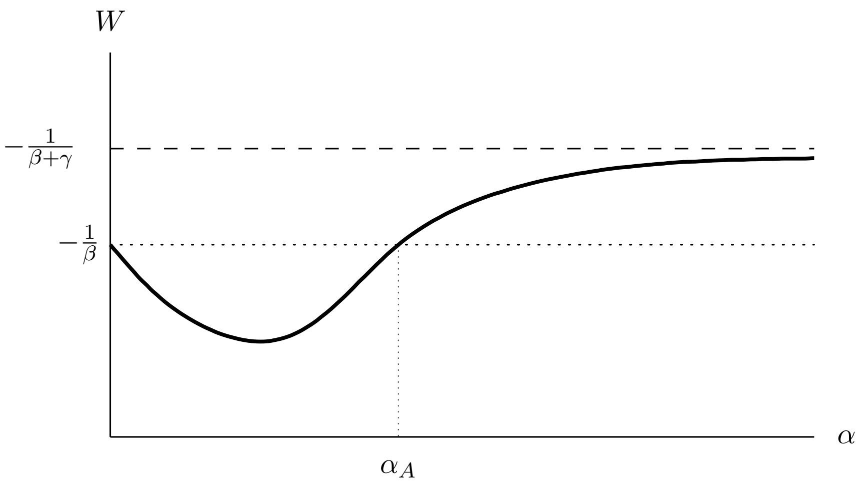


Figure 3: Aggregate Announcement Policy

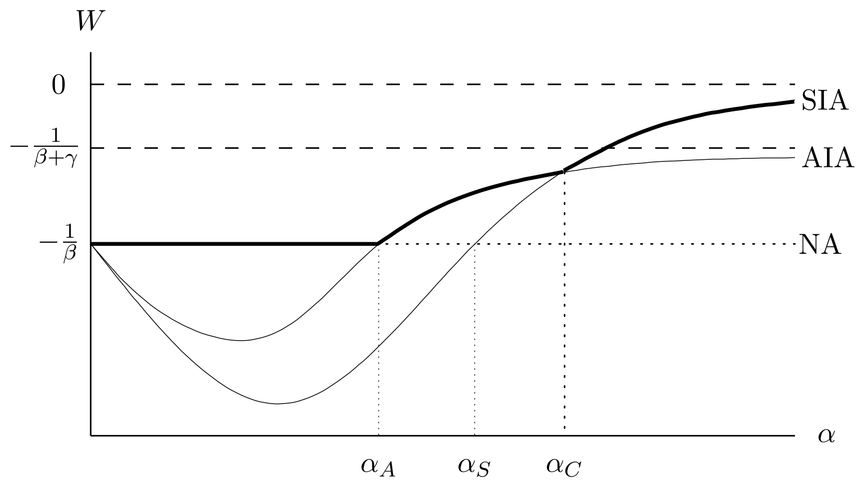


Figure 4: Preferred Announcement Policy: $1 > r > 1/2$

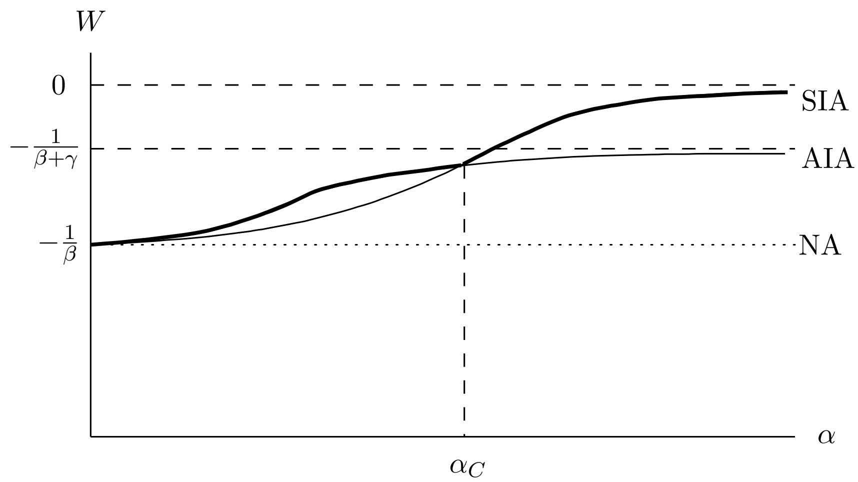


Figure 5: Preferred Announcement Policy: $1/2 \geq r > 3/7$

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