How to Disclose Public Information, Separately or Aggregately?*

Hiroki Arato†

Faculty of Urban Liberal Arts, Tokyo Metropolitan University

Tomoya Nakamura‡

Financial Services Agency (FSA Institute), Government of Japan

Abstract

We investigate *how* public information should be disclosed by the authorities in a multi-region economy characterized by strategic complementarities. In particular, we compare three announcement policies: a separate information announcement policy, which discloses information regarding each region: an aggregate information announcement policy, which discloses information regarding the whole economy: and a no announcement policy. The quality of aggregate information is more degraded than that of separate information. However, under the aggregate information announcement policy, each agent converts purely public information into imperfect public information. This makes the agents' beliefs more dispersed and alleviates their overreaction. We show that the aggregate information announcement policy can be better than the separate one in plausible situations.

Keywords: Aggregate information; Social welfare; Transparency; Disclosure; Beauty contest

JEL classification: C72, D82, D83, and E58

*We would like to thank Junichiro Ishida, Ryuichiro Ishikawa, Makoto Saito, Tadashi Sekiguchi, Akihisa Shibata, and Etsuro Shioji; participants of the Japanese Economic Association Spring Meeting 2011 at Kumamoto Gakuen University; and seminar participants at Hitotsubashi University and Fukuoka University for their helpful comments. Arato is also grateful to financial support by Grant-in-Aid for Research Activity Start-up (22830058). The views expressed in this paper are those of the authors and do not necessarily reflect the views of the Financial Services Agency or the FSA Institute.

†E-mail address: arato@tmu.ac.jp

‡E-mail address: tomoya.nakamura@fsa.go.jp

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 seek to elucidate this issue in the present.

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 the agents decide on 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; that is, an agent's expectation about others' expectations of the others' expectations of $\cdots$ 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, the 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 the 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 or not* 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 dissemination always improves social welfare. Angeletos and Pavan (2007) investigate a more general market environment. They parameterize the cases in which public information improves welfare.[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.

To the best of our knowledge, only three papers consider the how-to problem. 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. Arato and Nakamura (2011) and Myatt and Wallace (2010) analyze the welfare effect of an ambiguous announcement by assuming that the authorities can mix private noise into public information. Arato and Nakamura (2011) use the beauty contest payoff structure and Myatt and Wallace (2010) focus on a Lucas-Phelps island-economy. 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 either 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. However, their proposed announcement policies are somewhat unrealistic and difficult to implement. 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 with agents who do not receive authorities' announcement. In the ambiguous announcement

[1]There are other streams of literature on public announcement. One stream is to endogenize information acquisition, for instance, Dewan and Myatt (2008), Hellwig and Veldkamp (2009), and Colombo and Femminis (2008). 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.) and financial markets (Allen et al., 2006).

policy proposed by Arato and Nakamura (2011) and Myatt and Wallace (2010), 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 *aggregate 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.[2] 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 is separate information, because, if the agent has separate information, he can easily create aggregate information by a simple sum of each value. However, if he 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. This makes their beliefs more dispersed than SIA does. Therefore, AIA can alleviate the overreac-

[2] Although we may regard this situation as one country consisting 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).

tion 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. The methods of information dissemination in existing papers require the authorities to possess some aforementioned unrealistic skills. However, the AIA policy is simple and concrete, so it does not require the authorities to possess any special skills.[3] First, in contrast to the partial announcement policy proposed by Cornand and Heinemann (2008), 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 the mechanism for improving welfare in this paper, that is, making the agents' beliefs more dispersed, is similar to the ambiguous announcement proposed by Arato and Nakamura (2011) and Myatt and Wallace (2010), under the AIA policy, the agent mix private noise into public information endogenously, not the authorities. Hence, the authorities need not to speak ambiguously in order to mix appropriate levels of private noise into public information.

This paper is also related to 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.

2 The model

We examine a two-region economy, $k \in \{1, 2\}$.[4] 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

[3]From a technical point of view, existing studies considering the how-to problem do not use *purely* public information. That is, all agents do not receive identical information from the authorities. However, in this paper, all public information conducted by the authorities is released as purely public information following the traditional definition.

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

payoff structure:

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

where θ_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 θ_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.[5] 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 the agent ik's expectation operator conditional on his available information 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.[6]

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

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

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

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

[5] For simplicity, we assume that the states of each region are independent from each other. 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 θ is a global condition. Then, the results in this paper hold.

[6] 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.

(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, θ_k, $k \in \{1, 2\}$, is distributed uniformly on the real line. Agents receive two private signals regarding each region:

$$x_{ik} = \theta_k + \epsilon_{ik} \text{ with } \epsilon_{ik} \sim N(0, 1/\beta), \quad \text{and} \quad z_{ik} = \theta_{-k} + \kappa_{ik} \text{ with } \kappa_{ik} \sim N(0, 1/\gamma). \tag{6}$$

where x_{ik} is the signal regarding his home region, and z_{ik} is the one regarding the foreign region. β and γ represent the information precision regarding his home and foreign region, respectively.

3.2 Public information

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

$$y_k = \theta_k + \eta_k, \text{ with } \eta_k \sim N(0, 1/\alpha). \tag{7}$$

α is the precision of the authorities' information regarding each region.[7] Moreover, we define $y \equiv y_1 + y_2$ and call it *aggregate information*. We assume that all error terms are i.i.d..

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.

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

4 Announcement Policies

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, the agent ik's expectation of fundamentals in his home region is

$$E_{ik}(\theta_k) = E(\theta | x_{ik}, y_k) = \frac{\alpha y_k + \beta x_{ik}}{\alpha + \beta}. \tag{8}$$

This value corresponds to socially optimal action. However, (3) corresponds to individual optimal action. Hence, we need the agent 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 with Morris and Shin (2002) and we can borrow them.

Result 1 (Morris and Shin (2002))**.** *Assume that $r \geq 1/2$. The equilibrium action under AIA policy is*

$$a_{ik} = \frac{(1-r)^{-1}\alpha y_k + \beta x_{ik}}{(1-r)^{-1}\alpha + \beta}, \tag{9}$$

and social welfare is

$$W_S(\alpha; \beta, \gamma) = \frac{(1-r)^{-2}\alpha + \beta}{[(1-r)^{-1}\alpha + \beta]^2}. \tag{10}$$

NA is preferred if $\alpha < \alpha_S$, where $\alpha_S = (2r-1)\beta$.

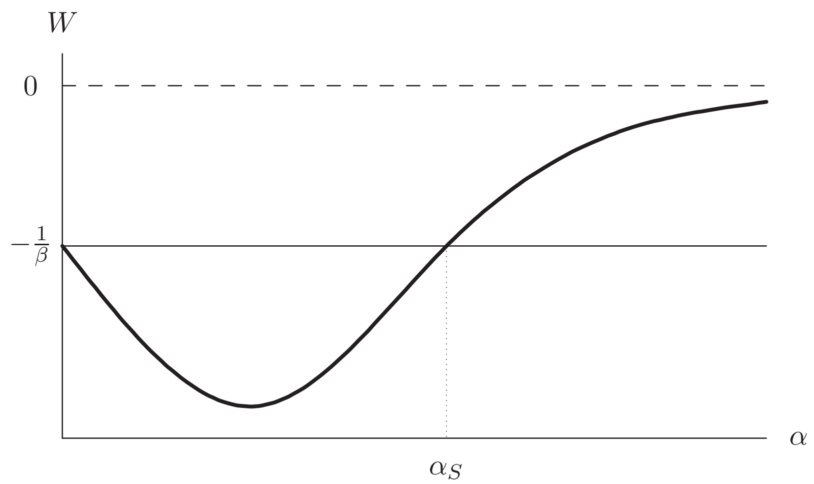

Figure 1: Separate Announcement Policy

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. α_S represents the threshold of these two effects.

Figure 1 shows the welfare effect of α, given β and γ, under SIA policy. When α 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 α is bigger than α_S, the authorities can better improve social welfare by using SIA policy than by using NA policy.

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 θ_k:

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

Define ψ as the precision of y_{ik} and ρ as the correlation of y_{ik} among agents, where

$$\psi = \frac{\alpha\gamma}{\alpha + 2\gamma} \quad \text{and} \quad \rho = \frac{2\gamma}{\alpha + 2\gamma}.$$

y_{ik} is the information regarding θ_k but is degraded compared to y_k; $\psi < \alpha$. Note that y_{ik} contains private noise, so it is no longer a purely public signal. That is, AIA converts purely public information into imperfect correlated information by individual estimation.

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

$$E_{ik}(\theta_k) = E_{ik}(\theta | x_{ik}, z_{ik}, y) = \frac{\psi y_{ik} + \beta x_{ik}}{\psi + \beta}. \tag{11}$$

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

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

$$a_{ik} = \frac{\psi(1 - r\rho)^{-1}(y - z_{ik}) + \beta x_{ik}}{\psi(1 - r\rho)^{-1} + \beta}. \tag{12}$$

From (4)*, we have*

$$W_A(\alpha; \beta, \gamma) = -\frac{\psi(1 - r\rho)^{-2} + \beta}{[\psi(1 - r\rho)^{-1} + \beta]^2}. \tag{13}$$

Proof. See Appendix A. □

Figure 2 shows the welfare effect of α, given β and γ, under AIA policy. We can easily obtain $\lim_{\alpha \to \infty} W_A(\alpha) = -(\beta + \gamma)^{-1}$, which is lower than that of 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, the social welfare cannot attain the first-best allocation.

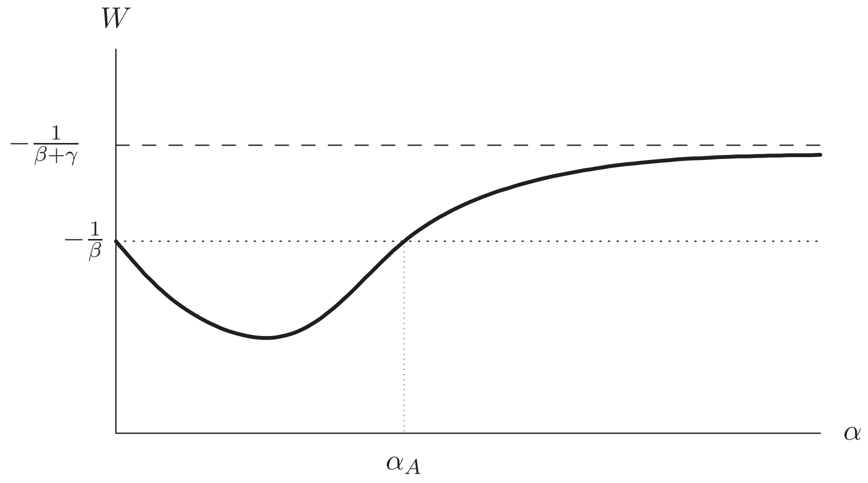

Figure 2: Aggregate Announcement Policy

The threshold value of whether to release aggregate information is

$$\alpha_A = (2r-1)\beta\frac{2\gamma}{\beta+\gamma} = \alpha_S\frac{2\gamma}{\beta+\gamma} \tag{14}$$

That is, if α is bigger than α_A, the authorities can better improve welfare compared to its level the NA policy. Note that if $\gamma < \beta$, then α_A is strictly smaller than α_S. This means that the range of α where NA is more preferred than AIA is smaller than that of α where NA is more preferred than SIA. Below, we assume that $\gamma < \beta$.[8]

5 SIA or AIA as a Preferred Announcement policy

Assume that the authorities are welfare maximizers. Hence, they compare the welfare levels under the three policies and choose the most preferred one. If the authorities choose NA, then the welfare is $\lim_{\alpha\to 0} W(\alpha) = -\frac{1}{\beta}$. We can think of this value as the reservation welfare. AIA is the most preferred policy if and only if

$$W_A(\alpha) \geq \max\{W_S(\alpha), \lim_{\alpha\to 0} W(\alpha)\}. \tag{15}$$

The case is similar when NA or SIA is the most preferred policy. To compare the three announcement policies, we combine Figure 1 and 2 and obtain

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

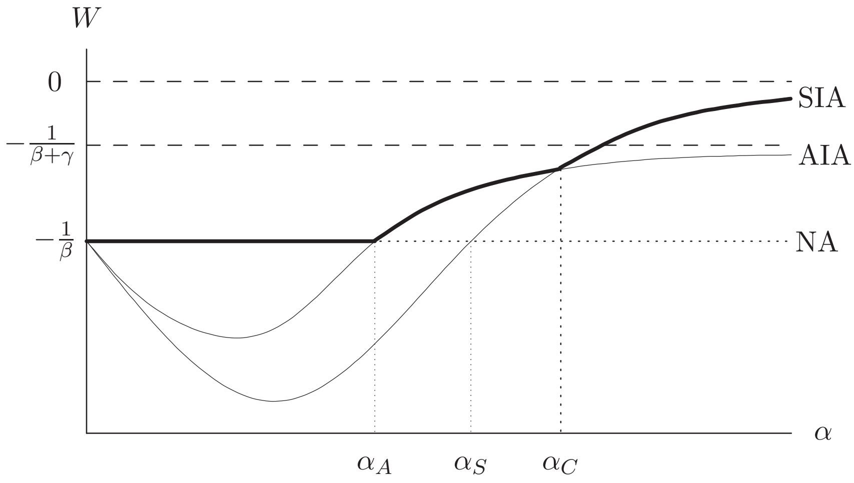

Figure 3: Preferred Announcement Policy

Figure 3. The answer to the optimal announcement policy problem is shown more formally in the following proposition.

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

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.*

Proposition 2 is our main conclusion.[9] The intuition can be obtained by considering the tradeoff between SIA and AIA. SIA is more precise information regarding fundamentals than is AIA, $\alpha > \psi$. Hence, if α is precise enough, the welfare comes closer to first best. In this sense, SIA is the preferred policy when α is large enough. However, this economy has strategic complementarity, and the agent is motivated to coordinate with the other agents. Therefore, if the signal has correlation, the agents use the signal

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

as the information regarding average action. However, in AIA, the agent's private estimation from y and z_{ik} makes the correlation weaker than that in SIA. Hence the agents' beliefs are dispersed and the overreaction problem is alleviated, $(1-r)^{-1} > (1-r\rho)^{-1}$. This means that AIA is preferred if α is small to some extent. Finally, if α is small enough, then the positive welfare effect from the reduced overreaction are dominated by the negative effect from information degradation. Then, NA is preferred by the authorities.

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 agent 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 a lower information precision 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), a reply to Svensson (2006), basically accept Svensson's comment. However, they additionally suggest that if there exists 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 naturally arising question is "can AIA be desirable under $\alpha > \beta$?" The answer is "yes." From Proposition 2, AIA is desirable in $\alpha \in [\alpha_A, \alpha_C]$. Assume that r is near to 1 and $\beta > \gamma$. Then, α_C is larger than α_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 private signals regarding foreign fundamentals available to him. Note that, for each $k \in \{1, \ldots, m\}$

$$y = y_1 + \cdots + y_m \quad \text{and} \quad z_{ikl} = \theta_l + \kappa_{ikl} \quad \text{for } l \neq k,$$

where z_{ikl} represents private information regarding θ_l received by agent ik and κ_{ikl} represents the error term of z_{ikl}. Hence, the obtained signal of his state is

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

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.[10]

[10] Note that if we think about a multi-region economy as comprising more than two regions, we can consider other announcement policies such as partially 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 analysis; hence, it is an aim of future research.

7 Conclusion

This paper investigate how public information should be disclosed, although most of studies focus on whether it should be disclosed. 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 who receive aggregate information convert purely public information into imperfectly correlated information endogenously, thereby reducing agents' overreaction to public information. Hence, the AIA policy can improve social welfare.

The AIA policy we proposed 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 information precision of the foreign region is lower than that of 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 we proposed 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 poofs are the same as in this standard literature.[11] Here, we show the derivation of (12).

The available information of each agent is $\{x_{ik}, z_{ik}, y\}$. Note that y has information regarding θ_k. The agent can extract the information regarding θ_k from y by $y - z_{ik}$. Define $y_{ik} \equiv y - z_{ik}$. Using Bayesian updating, the estimation of the economic fundamentals regarding the agent's home region is

$$E(\theta_k|x_{ik}, z_{ik}, y) = \frac{\psi_k y_{ik} + \beta x_{ik}}{\psi_k + \beta} \quad \text{and} \quad E(\theta_\ell|x_{ik}, z_{ik}, y) = \frac{\psi_\ell y_{i\ell} + \gamma z_{ik}}{\psi_\ell + \gamma}, \tag{16}$$

where $\psi_k = \frac{\alpha\gamma}{\alpha+2\gamma}$ and $\psi_\ell = \frac{\alpha\beta}{\alpha+2\beta}$ are the precision of y_{ik} and $y_{i\ell}$, respectively.

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

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

$$\begin{aligned} a_{ik} &= (1-\mu)x_{ik} + \mu y_{ik} & (17)\\ &= (1-\mu)x_{ik} + \mu(y - z_{ik}), & (18) \end{aligned}$$

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

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

From the first-order condition (3), we have

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

Define the correlation of y_{ik} as $\rho \equiv \frac{2\gamma}{\alpha+2\gamma}$.

Substituting each expected value, we have

$$a_{ik} = \frac{\psi(1-r\rho)^{-1}(y - z_{ik}) + \beta x_{ik}}{\psi(1-r\rho)^{-1} + \beta}. \tag{21}$$

Q.E.D.

Appendix B: Proof of Proposition 2

Proof:

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

   From the discussion in 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 $\alpha \in [\alpha_A, \alpha_S)$,

   $$\begin{aligned} W_S &\le -\beta^{-1}, \text{ with equality iff } \alpha = \alpha_S \\ W_A &\ge -\beta^{-1}, \text{ with equality iff } \alpha = \alpha_A. \end{aligned}$$

   Hence, $W_S < W_A$.

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

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

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 $\frac{\alpha}{[(1-r)^{-1}\alpha+\beta]^2[\psi(1-r\rho)^{-1}+\beta]^2} > 0$, 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).

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

and

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

Therefore, $F''(\alpha)$ is increasing in α 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 α_C. Because $F(\alpha_S) < 0$ and $\lim_{\alpha\to\infty} F(\alpha) = \infty$,

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

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.

References

Adam, K. (2007) "Optimal Monetary Policy with Imperfect Common Knowledge," *Journal of Monetary Economics*, **54**, pp. 267–301.

Allen, F., S. Morris and H. S. Pavan (2006) "Beauty Contests and Iterated Expectations in Asset Markets," *Review of Financial Studies* **19**(3), pp. 719–752.

Angeletos, G.-M. and J. La'O (2008) "Dispersed Information over the Business Cycle: Optimal Fiscal and Monetary Policy," mimeo.

Angeletos, G.-M. and A. Pavan (2004) "Transparency of information and coordination in economies with investment complementarities," *American Economic Review*, **94**(2), pp. 91–98.

Angeletos, G.-M. and A. Pavan (2007) "Efficient use of information and social value of information," *Econometrica*, **75**(4), pp. 1103–1142.

Angeletos, G.-M. and A. Pavan (2009) "Policy with Dispersed Information," *Journal of the European Economic Association*, **7**(1), pp. 11–60.

Amato, J.D. and H. S. Shin (2003) "Public and Private Information in Monetary Policy Models," Discussion Paper, Bank of International Settlements and LSE.

Arato, H. and T. Nakamura (2011) "The benefit of mixing private noise into public information in beauty contest games," *The B.E. Journal of Theoretical Economics*, **11**(1) (Contributions), article 8.

Colombo, L. and G. Femminis (2008) "Social value of information with costly information acquisition," *Economics Letters*, **100**(4), pp. 196–199.

Cornand, C. and F. Heinemann (2008) “Optimal degree of public information dissemination,” *Economic Journal*, **118**, pp. 718–742.

Dewan, T. and D. P. Myatt (2008) “The Qualities of Leadership: Direction, Communication, and Obfuscation,” *American Political Science Review*, **102**(3), pp. 351–368.

Hellwig, C. (2002) “Public Announcements, Adjustment Delays and the Business Cycle,” Working Paper, UCLA.

Hellwig, C. (2005) “Heterogeneous information and the welfare effects of public information disclosures,” working paper, UCLA.

Hellwig, C. and L. Veldkamp (2009) “Knowing What Others Know: Coordination Motives in Information Acquisition,” *Review of Economic Studies*, **76**(1), pp. 223–251.

Keynes, J. (1936) “*The General Theory of Employment, Interest and Money*,” Cambridge: Macmillan Cambridge University Press.

Lorenzoni, G. (2009) “Optimal Monetary Policy with Uncertain Fundamentals and Dispersed Information,” *Review of Economic Studies*, **77**(1), pp. 305–338.

Mackowiak, B. and M. Wiederholt (2009) “Optimal Sticky Prices under Rational Inattention,” *American Economic Review*, **99**(3), pp. 769–803.

Morris, S. and H. S. Shin (2002) “Social Value of Public Information,” *American Economic Review*, **92**(5), pp. 1521–1534.

Morris, S. and H. S. Shin (2005) “Central Bank Transparency and the Signal Value of Price,” *Brookings Papers of Economic Activity,* **2**, pp. 1–66.

Morris, S., H. S. Shin, and H. Tong (2006) “Social Value of Public Information: Morris and Shin (2002) Is Actually Pro-Transparency, Not Con: Reply,” *American Economic Review*, **96**(1), pp. 453–455.

Myatt, D. P. and C. Wallace (2010) “On the sources and value of information: public announcements and macroeconomic performance,” mimeo.

Svensson, L. E. (2006) “Social Value of Public Information: Comment: Morris and Shin (2002) Is Actutually Pro-transparency, Not Con,” *American Economic Review*, **96**(1), pp. 453–455.

Ui, T. (2003) "A Note on the Lucas Model: Iterated Expectations and the Neutrality of Money," Working Paper, Yokohama National University.

Vives, X. (2008) "*Information and Learning in Markets: The Impact of Market Microstructure*," Princeton University Press.