Welfare Effects of Public Information

Stephen Morris
(Yale University)
Hyun Song Shin
(London School of Economics)

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Deutsche Bundesbank, Wilhelm-Epstein-Strasse 14, 60431 Frankfurt am Main,
P.O.B. 10 06 02, 60006 Frankfurt am Main, Federal Republic of Germany

Telephone (0 69) 95 66-1
Telex within Germany 4 1 227, telex from abroad 4 14 431, fax (0 69) 5 60 10 71
Internet: http://www.bundesbank.de

Please address all orders in writing to: Deutsche Bundesbank,
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Summary

What are the welfare effects of enhanced disclosures of public information ? Is it always the case, that frequent and timely publication of economic statistics by government agencies and the central bank are desirable ? This question has become one of several interlinked strands of debate on the desirability of transparency in hte conduct of monetary policy. Here we put to the test the presumption that greater disclosures of public information is always welfare enhancing. We examine the impact of public information in a setting where a principal provides public information to private sector agents. The principal's interest is in inducing the agents to take actions that are appropriate to the fundamentals. The agents, too, are motivated to take actions appropriate to the underlying state, but they also have a coordination motive arising from a strategic complementarity in their actions. When there is perfect information concerning the underlying state, there is no conflict of interest between the principal and the agents. However, when there is imperfect information, the welfare effects of increased public disclosures is more equivocal.

Zusammenfassung

Welche Wohlfahrtseffekte hat eine größere Publizität öffentlicher Informationen? Ist die häufige und zeitnahe Veröffentlichung von Wirtschaftsstatistiken durch Regierungsstellen und die Zentralbank immer wünschenswert? Diese Frage zieht sich wie ein roter Faden durch die Diskussion über das Thema, inwieweit Transparenz bei der Durchführung der Geldpolitik wünschenswert ist. Wir prüfen die These, dass eine verbesserte Publizität öffentlicher Informationen stets wohlfahrtssteigernd ist. Wir wollen im Rahmen eines Modells, bei dem der Prinzipal (Zentralbank) Informationen an die Akteure im privaten Sektor gibt herausfinden, wie öffentliche Informationen wirken. Der Informationsgeber möchte bewirken, dass die Akteure den wirtschaftlichen Grunddaten entsprechend handeln. Die Akteure sind ihrerseits auch daran interessiert, ihr Handeln an den grundlegenden Bedingungen zu orientieren, aber sie sind auch auf Koordination bedacht, da sich ihre Handlungen aus strategischen Gründen gegenseitig ergänzen müssen. Bei vollkommener Information über die Grundbedingungen besteht kein Interessenkonflikt zwischen Informationsgeber und Akteuren. Bei unvollkommener Information hingegen sind die Wohlfahrtseffekte einer größeren Publizität öffentlicher Informationen weniger eindeutig.

Table of Contents

Welfare Effects of Public Information*

1. Introduction

What are the welfare effects of enhanced disclosures of public information? Is it always the case that frequent and timely publication of economic statistics by government agencies and the central bank are desirable? This question has become one of several interlinked strands of debate on the desirability of transparency in the conduct of monetary policy.

Much of this debate makes appeal to broad notions of transparency in terms of the political accountability of the policy making process (see, for instance, the debate between Buiter (1999) and Issing (1999) on the European Central Bank). We shall focus on a more narrowly defined question. When the central bank or government agency has discretion over how much information to make available publicly, is it always desirable to disclose as much information as is feasible? Often, this question is posed in the context of whether central banks should make available the forecasts generated by their internal models, and some recent papers have discussed the merits of public disclosure in the context of models of macro policy games between central banks and the private sector (for instance, Geraats (2000) and Tarkka and Mayes (2000)). A broader discussion of the issue of transparency is given in Winker (2000).

Here, we put to the test the presumption that greater disclosures of public information is always welfare enhancing. When economic agents have other sources of information, and have a material interest in the behaviour of other agents in the economy, the effect of public information is subtle and sometimes can appear to be disproportionate relative to a naive reading. Financial markets are prone

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to react to announcements by public officials which merely state the obvious, or reaffirm widely known policy stances. However, such reactions can be understood in terms of the strategic interactions between the private sector agents themselves. Even if the face value of the announcement tells the agent nothing new about the underlying fundamentals, the public nature of the disclosure means that this information is now in the public domain, and hence has an influence on the agent's beliefs about the actions and beliefs of others in the economy. When the interactions between economic agents are strong, news about the prospective actions of others will be an important determinant in one's own behaviour. Morris and Shin (2000, section 3) outline the impact of public information that arise in simple incomplete information games when agents have noisy signals of the underlying state (so-called 'global games'). In what follows, we will develop these results further. Hellwig (2000) has also examined the impact of public information in global games.

To the extent that public information has an impact beyond its simple face value, any noise or imprecision will have a similarly large impact. By its nature, economic statistics are imperfect measurements of sometimes imprecise concepts, and no government agency or central bank can guarantee flawless information. The price reactions in the financial markets to the publication of statistics such as the U.S. non-farm payroll data and the various purchasing managers' indices illustrate well the impact of public information. Sometimes, the damage done by the "noise" in official statistics can be significant. For instance, the flaws in the U.K.'s earnings data supplied by its Office of National Statistics has been credited with provoking unjustifiably tight credit conditions in the U.K. in the spring and summer of 1998[1].

We examine the impact of public information in a setting where a principal (such as a central bank) provides public information to private sector agents. The principal's interest is in inducing the agents to take actions that are approriate to the underlying state of fundamentals. The agents, too, are motivated to take actions appropriate to the underlying state, but they also have a coordination motive arising from a strategic complementarity in their actions. When there is perfect information concerning the underlying state, there is no conflict of interest between the principal and the agents. The unique equilibrium in the game between the agents also minimizes the principal's loss function. However, when there is imperfect information, the welfare effects of increased public disclosures is more equivocal. In particular,

- when the agents have no private information - so that the only source of information for the agents is the public disclosures - then greater precision

[1]See, for instance, "Garbage in garbage out" *Economist magazine*, October 15th 1998.

of the public information always makes the principal better off.

- However, if the agents have access to some private information, it is not always the case that greater precision of public information is desirable. Over some ranges, increased precision of public information is detrimental to the principal's goals. Specifically, the greater the precision of the agents' *private* information, the greater is the danger posed by increased provision of public information in making the principal worse off.

This latter result is especially troubling in the highly sensitized world of today's financial markets populated with Fed watchers (and watchers of other central banks and their personalities), economic analysts, and other commentators of the economic scene. Our second bullet point above suggests that these private sources of information may actually *crowd out* the public information by rendering the public information detrimental to the policy makers' goals. The possibility exists that the hightened sensitivities of the market magnifies any noise in the public information to such a large extent that public information ends up by causing more harm than good. If the public body anticipates this effect, then the consequence of the heightened sensitivities of the market is to push the public body into reducing the precision of the public signal. In effect, private and public information end up being *substitutes*, rather than complements.

The challenge for central banks and other public organizations is to strike the appropriate balance between providing sufficiently accurate signals to the private sector so as to allow it to pursue its goals, but to recognize the inherent limitations of any set of economic statistics and to guard against the potential damage done by the imperfections in the data. This is a difficult balancing act at the best of times, but this task is likely to become even harder as more central banks begin to exercise independence over monetary policy and the private sector market participants react to this by stepping up their surveillance of central banks' activities and pronouncements. The intense spotlight directed towards the European Central Bank by the press and private sector market participants illustrates the difficulty faced by policy makers.

We begin with the model. After establishing the benchmark cases, the main results are presented in section 4.

2. Model

A principal faces the problem of inducing two agents to undertake actions appropriate to the underlying state of the economy θ. In particular, the principal's payoff is given by

$$W = -\left(\frac{a_1 + a_2}{2} - \theta\right)^2 \tag{2.1}$$

where $a_i \in \mathbb{R}$ is the action undertaken by investor i. Thus, at state θ, the principal would like average action $\frac{1}{2}(a_1 + a_2)$ to be as close as possible to θ. In contrast, the payoff functions of agents 1 and 2 are given respectively by

$$\begin{cases} u_1 = -(a_1 - \theta)^2 - \rho(a_2 - a_1)^2 \\ \\ u_2 = -(a_2 - \theta)^2 - \rho(a_2 - a_1)^2 \end{cases} \tag{2.2}$$

where ρ is a positive constant. The agents' payoffs consist of a squared loss function (the first term) plus an interactions term in which higher action by one agent increases the attractiveness of a higher action for the other.

The principal is a central bank or government fiscal authority who has the aim of keeping the aggregate economic activity close to some appropriate level, where this appropriate level is defined in terms of the *average* action being set equal to the state θ. The agents, on the other hand, have two motivations. On the one hand, each agent would like his *individual* action to be as close to the state θ, but he is also influenced by the complementarity of actions between the two agents. The higher is the action of one agent, the higher is the desired action of the other agent relative to some state of fundamentals. During a property boom, for instance, the incentives of property developers (and their bankers) will be determined by the buoyancy of the market as well as their perception of the underlying fundamentals of the economy. The parameter ρ determines the relative strength of the coordination motive in the two agents' actions.

Although the agents' payoff functions differ from the principal's, provided that the agents have perfect information concerning θ, there is no conflict of interest. The optimal level of investment for the principal can be obtained as the unique equilibrium of the game between the two agents. To see this, note that the best reply relations are:

$$\begin{cases} a_1 = \frac{1}{1+\rho}\theta + \frac{\rho}{1+\rho}a_2 \\ \\ a_2 = \frac{1}{1+\rho}\theta + \frac{\rho}{1+\rho}a_1 \end{cases} \tag{2.3}$$

which yield the equilibrium:

$$a_1 = a_2 = \theta, \tag{2.4}$$

which also maximizes the principal's payoff W. In this sense, provided that there is perfect information concerning θ, there is no conflict of interest between the principal and the agents.

2.1. Public Information Benchmark

Consider now the case where information is not perfect. The state θ is drawn from an (improper) uniform prior over the real line, but the agents observe a *public signal*

$$y = \theta + \eta \tag{2.5}$$

where η is normally distributed, independent of θ, with mean zero and variance σ_η^2. The signal y is 'public' in the sense that the actual realization of y is common knowledge to both agents. The agents choose their actions after observing the realization of y. The expected payoffs of the agents at the time of decision are then given by

$$\begin{cases} \mathrm{E}\left(u_1 | y\right) = -\mathrm{E}\left(\left(a_1 - \theta\right)^2 \middle| y\right) - \rho \mathrm{E}\left(\left(a_2 - a_1\right)^2 \middle| y\right) \\ \mathrm{E}\left(u_2 | y\right) = -\mathrm{E}\left(\left(a_2 - \theta\right)^2 \middle| y\right) - \rho \mathrm{E}\left(\left(a_2 - a_1\right)^2 \middle| y\right) \end{cases} \tag{2.6}$$

Conditional on y, both agents believe that θ is distributed normally with mean y and variance σ_η^2. Hence, the best reply relations are

$$\begin{cases} a_1\left(y\right) = \frac{1}{1+\rho}\mathrm{E}\left(\theta | y\right) + \frac{\rho}{1+\rho}\mathrm{E}\left(a_2 | y\right) \\ a_2\left(y\right) = \frac{1}{1+\rho}\mathrm{E}\left(\theta | y\right) + \frac{\rho}{1+\rho}\mathrm{E}\left(a_1 | y\right) \end{cases} \tag{2.7}$$

where $a_i\left(y\right)$ denotes the action taken by agent i as a function of y. We have already noted that $\mathrm{E}(\theta | y) = y$. Also, since the strategies of both agents are measurable with respect to y, we have $\mathrm{E}(a_i | y) = a_i\left(y\right)$, so that in the unique equilibrium,

$$a_1\left(y\right) = a_2\left(y\right) = y \tag{2.8}$$

and the expected payoff for the principal at θ is

$$\begin{aligned} \mathrm{E}\left(W | \theta\right) &= -\mathrm{E}\left[\left(y - \theta\right)^2 \middle| \theta\right] \\ &= -\sigma_\eta^2 \end{aligned}$$

Thus, the principal's objective would be best served by reducing the noise in the signal y. The smaller the noise in the public signal, the higher is the principal's expected payoff. In this respect, greater "transparency" in the dissemination of information to the agents is in the interests of the principal. We will now contrast this with the general case in which agents have private information as well as public information.

3. Private and Public Information

Consider now the case where, in addition to the public signal given by y, agent i observes the realization of a *private signal*:

$$x_i = \theta + \varepsilon_i \tag{3.1}$$

where ε_i is a normally distributed noise term with zero mean and variance σ_ε^2, independent of θ and η, with $\mathrm{E}(\varepsilon_1 \varepsilon_2) = 0$. The private signal of one investor is not observable by the other. This is the sense in which these signals are private.

As before, the investors' decisions are made after observing the respective realizations of their private signals as well as the realization of the public signal. Denote by

$$a_i \left(\mathcal{I}_i \right) \tag{3.2}$$

the decision by investor i as a function of the information set $\mathcal{I}_i$ available to investor i. The information set $\mathcal{I}_i$ consists of the pair:

$$(y, x_i)$$

that captures all the information available to investor i at the time of decision. The notation in (3.2) makes explicit that the *strategy* of investor i in the imperfect information game is a function that maps the information $\mathcal{I}_i$ to the action a_i. For any given strategy, a_i is therefore a random variable that is measurable on the partition generated by $\mathcal{I}_i$.

3.1. Equilibrium

Let us now analyse the equilibrium of the imperfect information game. For any random variable z, let us denote by

$$\mathrm{E}\left(z \left| \mathcal{I}_i \right. \right)$$

the expectation of z conditional on the information set $\mathcal{I}_i$. For investor 1 with information set $\mathcal{I}_1$, the problem is to choose a_1 so as to maximize expected utility:

$$-\mathrm{E}\left((a_1 - \theta)^2 \left| \mathcal{I}_1 \right. \right) - \rho \mathrm{E}\left((a_2 - a_1)^2 \left| \mathcal{I}_1 \right. \right) \tag{3.3}$$

Under imperfect information, investor 1 must make inferences concerning the random variables θ and a_2. The first is determined by Nature, but the second is generated by the strategy of investor 2. The first order condition for (3.3) and the analogous problem for investor 2 yields the pair of equations:

$$\left\{ \begin{array}{l} a_1 \left(\mathcal{I}_1 \right) = \frac{1}{1+\rho} \mathrm{E}\left(\theta \left| \mathcal{I}_1 \right. \right) + \frac{\rho}{1+\rho} \mathrm{E}\left(a_2 \left| \mathcal{I}_1 \right. \right) \\ \\ a_2 \left(\mathcal{I}_2 \right) = \frac{1}{1+\rho} \mathrm{E}\left(\theta \left| \mathcal{I}_2 \right. \right) + \frac{\rho}{1+\rho} \mathrm{E}\left(a_1 \left| \mathcal{I}_2 \right. \right) \end{array} \right. \tag{3.4}$$

Both a_1 and a_2 are random variables that are measurable with respect to the appropriate information sets $\mathcal{I}_1$ and $\mathcal{I}_2$. However, the information available to the two investors cannot be ranked in terms of their information content, so that the equilibrium actions will not be common knowledge.

By repeated substitutions using the two equations in (3.4), we have

$$\begin{aligned}(1+\rho)\,a_1(\mathcal{I}_1) &= \mathrm{E}(\theta\,|\mathcal{I}_1) + \rho\mathrm{E}(\overbrace{\tfrac{1}{1+\rho}\mathrm{E}(\theta\,|\mathcal{I}_2) + \tfrac{\rho}{1+\rho}\mathrm{E}(a_1\,|\mathcal{I}_2)}^{a_2}\,|\mathcal{I}_1) \\ &= \mathrm{E}(\theta\,|\mathcal{I}_1) + \tfrac{\rho}{1+\rho}\mathrm{E}\left(\mathrm{E}(\theta\,|\mathcal{I}_2)\middle|\,\mathcal{I}_1\right) + \tfrac{\rho^2}{1+\rho}\mathrm{E}\left(\mathrm{E}(a_1\,|\mathcal{I}_2)\middle|\,\mathcal{I}_1\right) \\ &= \mathrm{E}(\theta\,|\mathcal{I}_1) + \tfrac{\rho}{1+\rho}\mathrm{E}\left(\mathrm{E}(\theta\,|\mathcal{I}_2)\middle|\,\mathcal{I}_1\right) + \left(\tfrac{\rho}{1+\rho}\right)^2\mathrm{E}\left(\mathrm{E}\left(\mathrm{E}(\theta\,|\mathcal{I}_1)\middle|\,\mathcal{I}_2\right)\middle|\,\mathcal{I}_1\right) \\ &\quad + \tfrac{\rho^3}{(1+\rho)^2}\mathrm{E}\left(\mathrm{E}\left(\mathrm{E}(a_2\,|\mathcal{I}_1)\middle|\,\mathcal{I}_2\right)\middle|\,\mathcal{I}_1\right)\end{aligned}$$

and so on. The terms involving nested expectations cannot be reduced in the way we were able to for the case with public information alone, since the partitions generated by $\mathcal{I}_1$ and $\mathcal{I}_2$ are not identical. Instead, they must be analysed by keeping track of the higher order expectations of the agents - i.e. of what one agent believes about the other agent's beliefs. In order to proceed with less notational baggage, let us indicate the conditioning information set by means of a subscript on the expectations operator, so that

$$\mathrm{E}_i(\cdot) \equiv \mathrm{E}(\cdot\,|\mathcal{I}_i) \tag{3.5}$$

and define the iterated expectations operator:

$$\mathrm{E}_1^k(\cdot) \equiv \overbrace{\mathrm{E}_1(\mathrm{E}_2(\mathrm{E}_1(\cdots(\cdot)\cdots)))}^{k \text{ times}} \tag{3.6}$$

with $\mathrm{E}_2^k(\cdot)$ defined analogously for agent 2. Thus, $\mathrm{E}_1^k(z)$ is 1's expectation of 2's expectation of 1's expectation $\cdots$ (k times) of z. Using this notation, the iterated substitution of the equations in (3.4) yields the following characterization of the equilibrium strategy for 1.

$$(1+\rho)\,a_1 = \sum_{k=1}^{N}\left(\tfrac{\rho}{1+\rho}\right)^{k-1}\mathrm{E}_1^k(\theta) + \rho\left(\tfrac{\rho}{1+\rho}\right)^N\mathrm{E}_1^{N+1}(z) \tag{3.7}$$

where $z = a_1$ if N is even, and $z = a_2$ if N is odd. We shall confine our attention to equilibria where $(\rho/(1+\rho))^N\mathrm{E}_1^{N+1}(z)$ converges to zero as $N \to \infty$. Since

$\frac{\rho}{1+\rho} < 1$, a sufficient condition for this is that the sequence $\left\{ \mathrm{E}_1^N(z) \right\}$ be bounded. The equilibrium strategies are then given by the pair of series

$$\begin{cases} a_1 = \frac{1}{1+\rho} \sum_{k=1}^{\infty} \left(\frac{\rho}{1+\rho} \right)^{k-1} \mathrm{E}_1^k(\theta) \\ \\ a_2 = \frac{1}{1+\rho} \sum_{k=1}^{\infty} \left(\frac{\rho}{1+\rho} \right)^{k-1} \mathrm{E}_2^k(\theta) \end{cases} \tag{3.8}$$

We will now proceed to solve for these expressions explicitly.

3.2. Higher Order Expectations

Let us denote by α the precision of the public information, and denote by β the precision of the private information, where

$$\begin{cases} \alpha = \dfrac{1}{\sigma_\eta^2} \\ \beta = \dfrac{1}{\sigma_\varepsilon^2} \end{cases} \tag{3.9}$$

Then, based on both private and public information, the expected value of θ is:

$$\mathrm{E}_i(\theta) = \frac{\alpha y + \beta x_i}{\alpha + \beta} \tag{3.10}$$

What about investor 1's expectation of investor 2's expected value of θ? This iterated expectation is given by

$$\begin{aligned} \mathrm{E}_1(\mathrm{E}_2(\theta)) &= \mathrm{E}_1\left(\frac{\alpha y + \beta x_2}{\alpha + \beta} \right) \\ &= \frac{\alpha y + \beta \mathrm{E}_1(x_2)}{\alpha + \beta} \\ &= \frac{\alpha y + \beta \mathrm{E}_1(\theta + \varepsilon_2)}{\alpha + \beta} \\ &= \frac{\alpha y + \beta \mathrm{E}_1(\theta)}{\alpha + \beta} \\ &= \frac{\alpha y + \beta \left(\frac{\alpha y + \beta x_1}{\alpha + \beta} \right)}{\alpha + \beta} \\ &= \frac{\left((\alpha + \beta)^2 - \beta^2 \right) y + \beta^2 x_1}{(\alpha + \beta)^2} \end{aligned} \tag{3.11}$$

In the second line of this derivation, we have made use of the fact that y can be pulled outside the expectations operator $\mathrm{E}_i(\cdot)$ of both players, since y is a public signal, and hence belongs to both information sets. More generally, we have the following lemma.

Lemma 3.1. $E_1^k(\theta) = \left(1-\mu^k\right) y + \mu^k x_1$, *where* $\mu = \beta/(\alpha+\beta)$.

The proof is by induction on k. We know from (3.10) that the lemma holds for $k=1$. Suppose that it holds for $k-1$. Then,

$$\begin{aligned}
\mathrm{E}_1^k(\theta) &= \mathrm{E}_1\left(\mathrm{E}_2^{k-1}(\theta)\right) \\
&= \mathrm{E}_1\left(\left(1-\mu^{k-1}\right) y + \mu^{k-1} x_2\right) \\
&= \left(1-\mu^{k-1}\right) y + \mu^{k-1}\mathrm{E}_1(x_2) \\
&= \left(1-\mu^{k-1}\right) y + \mu^{k-1}\mathrm{E}_1(\theta+\varepsilon_2) \\
&= \left(1-\mu^{k-1}\right) y + \mu^{k-1}\mathrm{E}_1(\theta) \\
&= \left(1-\mu^{k-1}\right) y + \mu^{k-1}\left((1-\mu) y + \mu x_1\right) \\
&= \left(1-\mu^{k}\right) y + \mu^{k} x_1
\end{aligned}$$

which proves lemma 3.1. For the purpose of deriving the equilibrium strategy, it is more useful to work with the following expression for $\mathrm{E}_1^k(\theta)$.

$$\begin{aligned}
\mathrm{E}_1^k(\theta) &= \left(1-\mu^k\right) y + \mu^k x_1 \\
&= \mathrm{E}_1(\theta) - \mathrm{E}_1(\theta) + \left(1-\mu^k\right) y + \mu^k x_1 \\
&= \mathrm{E}_1(\theta) + \left(\mu-\mu^k\right)(y-x_1) \qquad (3.12)
\end{aligned}$$

Substituting (3.12) into (3.8), and introducing the constant

$$r \equiv \frac{\rho}{1+\rho}$$

we can derive the equilibrium strategy of agent i by noting that

$$\begin{aligned}
(1+\rho)\, a_i &= \left[\mathrm{E}_i(\theta) + \mu(y-x_i)\right]\sum_{k=1}^{\infty}\left(\tfrac{\rho}{1+\rho}\right)^{k-1} - (y-x_i)\sum_{k=1}^{\infty}\left(\tfrac{\rho}{1+\rho}\right)^{k-1}\mu^k \\
&= \frac{\mathrm{E}_i(\theta)}{1-r} + \mu(y-x_i)\left[\frac{1}{1-r} - \frac{1}{1-\mu r}\right]
\end{aligned}$$

so that

$$a_i = \mathrm{E}_i(\theta) + (y-x_i)\frac{r\mu(1-\mu)}{1-\mu r} \qquad (3.13)$$

Let us pause here to interpret (3.13). When we compare this expression with the complete information benchmark given by (2.4) and the public information benchmark given by (2.8), the first term in (3.13) is exactly analogous with its counterpart terms in (2.4) and (2.8). The new element introduced by the combination of private and public information is the second term in (3.13). It gives the public signal added weight in the choice of a_i beyond its role in determining the conditional expectated value of θ. Conversely, the private signal x_i is given a diminished role relative to its role in determining $\mathrm{E}_i(\theta)$. This second term disappears when $r = 0$ - that is, when the coordination motive of the two agents is removed. It also disappears when either μ is zero or one. Thus, if either the public information overwhelms the private information (so that $\mu = 0$), or the private information overwhelms the public information ($\mu = 1$), then the second term disappears. However, if both sources of information are present, the second term remains as a non-trivial influence in the equilibrium strategy.

3.3. Simpler Solution Method

The equilibrium strategy is linear in the signals x_i and y, as can be seen in (3.13). Indeed, if we were content to confine attention at the outset to equilibria in linear strategies only, a simpler solution method suggests itself[2]. We could begin by postulating that the equilibrium strategy takes the form

$$a_i = c_0 y + c_1 x_i$$

for constants c_0 and c_1, and then substitute into the payoff function of both players. The coefficients c_0 and c_1 can then be obtained by matching coefficients in the equivalent linear expressions that result from the players' first order conditions. Note that this method of solution would be applicable for a wider range of payoff functions than the one examined in this paper. For instance, when there are more than two players, the tractability of the linear solution method would be unaffected, whereas tracking higher order beliefs would be more cumbersome.

Having solved for the equilibrium strategy in terms of the fundamentals, we can now turn to the main business - of analysing the welfare effect of public information

4. Welfare Effect of Public Information

Let us now address the following question. How is the principal's payoff affected by the precisions of the agents' signals? In particular, will the principal's payoff

[2] We are grateful to Frank Heinemann for pointing this out to us.

be increasing in the precision α of the public signal? Using the fact that

$$\begin{cases} x_i = \theta + \varepsilon_i \\ y = \theta + \eta \\ \mu = \beta / (\alpha + \beta) \end{cases}$$

we can solve for the equilibrium strategies in terms of the basic random variables θ, y and $\{\varepsilon_i\}$.

$$a_i = \theta + \frac{\eta\alpha}{\alpha+\beta}\left[1 + \frac{r\beta}{\alpha+\beta(1-r)}\right] + \frac{\varepsilon_i\beta}{\alpha+\beta}\left[1 - \frac{r\alpha}{\alpha+\beta(1-r)}\right] \tag{4.1}$$

If the two expressions in the square brackets were both equal to 1, the two types of noise (private and public) would be given weights that are commensurate with their precision. That is, η would be given weight equal to its relative precision $\alpha/(\alpha+\beta)$ while ε_i would be given weight equal to its relative precision $\beta/(\alpha+\beta)$. However, the weights in (4.1) deviate from this. The noise in the public signal is given relatively more weight, and the noise in the private signal is given relatively less weight. This feature reflects the coordination motive of the agents, and reflects the disproportionate influence of the public signal in influencing the agents' actions. The magnitude of this effect is greater when r (equal to $\rho/(1+\rho)$) is large.

What effect does this have on the principal's expected payoff? The expected payoff of the principal at θ is given by

$$-E\left[\left(\frac{a_1+a_2}{2} - \theta\right)^2 \middle| \theta\right]$$

which is

$$\begin{aligned} & -\left(\tfrac{\alpha}{\alpha+\beta}\right)^2\left(1+\tfrac{r\beta}{\alpha+\beta(1-r)}\right)^2 \mathrm{E}\left(\eta^2\right) - \left(\tfrac{\beta}{\alpha+\beta}\right)^2\left(1-\tfrac{r\alpha}{\alpha+\beta(1-r)}\right)^2 \tfrac{\mathrm{E}\left(\varepsilon_1^2\right)+\mathrm{E}\left(\varepsilon_2^2\right)}{4} \\ = & -\frac{\alpha}{(\alpha+\beta)^2}\left[1+\frac{r\beta}{\alpha+\beta(1-r)}\right]^2 - \frac{\beta}{2(\alpha+\beta)^2}\left[1-\frac{r\alpha}{\alpha+\beta(1-r)}\right]^2 \end{aligned} \tag{4.2}$$

By examining (4.2), we can answer the comparative statics questions concerning the effect of increased precision of private and public information.

4.1. Better Private Information is Always Good

The principal is always made better off by an increase in the precision of the private information of the two agents. We can see this by differentiating (4.2) with respect to β, the precision of the private signals. We have:

$$\frac{\partial \mathrm{E}(W|\theta)}{\partial \beta} = \frac{(1-r)(r+3)\alpha + (1-r)^3 \beta}{2(\alpha + (1-r)\beta)^3} > 0 \tag{4.3}$$

Thus, increased precision of private information enhances the principal's payoff unambiguously.

4.2. Better Public Information is Not Always Good

The same cannot be said of the effect of increased precision of the public signal. The derivative of (4.2) with respect to α is:

$$\frac{\partial \mathrm{E}(W|\theta)}{\partial \alpha} = \frac{\alpha - r(1-r)\beta}{(\alpha + (1-r)\beta)^3} \tag{4.4}$$

so that

$$\frac{\partial \mathrm{E}(W|\theta)}{\partial \alpha} \geq 0 \quad \text{if and only if} \quad \frac{\beta}{\alpha} \leq \frac{1}{r(1-r)} \tag{4.5}$$

In other words, increased precision of public information is beneficial only when the private information of the agents is not very precise. If the agents have access to very precise information (so that β is high), then any increase in the precision of the public information will be harmful. Thus, as a rule of thumb, when the private sector agents are already very well informed, the official sector would be well advised not to make public any more information, unless they could be confident that they can provide public information of great precision. If we suppose (as is reasonable) that increasing the precision of public information is costly for the principal, then corner solutions at $\alpha = 0$ may be common. In particular, note that

$$\left.\frac{\partial \mathrm{E}(W|\theta)}{\partial \alpha}\right|_{\alpha=0} = \frac{-r}{(1-r)^2 \beta^2} < 0$$

Even if greater precision of public information can be obtained relatively cheaply, there may be technical constraints in achieving precision beyond some upper bound. For instance, the principal may be restricted to choosing α from some given interval $[0, \bar{\alpha}]$. In this case, even if the choice of α entails no costs, we will see a "bang-bang" solution to the choice of optimal α. Depending on the precision of the private information β, the official sector will either provide no public information at all (i.e. set $\alpha = 0$), or provide the maximum feasible amount of public information (i.e. set $\alpha = \bar{\alpha}$). The better informed is the private sector, the higher is the hurdle rate of precision of public information that would make it welfare enhancing.

Figure 4.1 illustrates the indifference curves for the principal in (α, β)-space. The curves are the set of points that satisfy $\mathrm{E}(W|\theta) = C$, for three values of C. As can be seen from figure 4.1, when $\beta > \alpha/r\,(1-r)$, the principal's indifference curves are upward sloping, indicating that the principal's payoff is decreasing in the precision of public information.

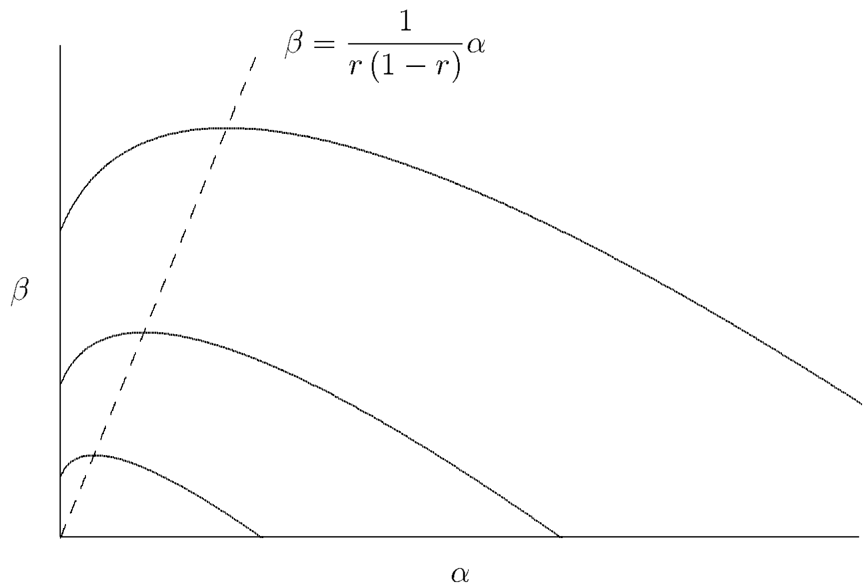

Figure 4.1: Indifference Curves for Principal

What is the intuition for this result? Equation (3.13) shows well the added impact of public information in determining the actions of the agents. In addition to its role in forming the conditional expectation of θ, there is an additional (positive) term involving the public signal y, while there is a corresponding negative term involving the private signal x_i. Thus, the agents "overreact" to the public signal while suppressing the information content of the private signal. Thus, the impact of the noise η in the public signal is given more of an impact in the agents' decisions than it deserves.

The results of this paper may also be useful in the related literature on the strategic effects in macroeconomic forecasting. Ottaviani and Sorensen (2000) note that the strategies of professional forecasters may be influenced in subtle ways by the incentives at work. Both excessive conformity and excessive differentiation can arise, depending on the payoffs faced by the forecasters. See also Lamont (1995) and Keane and Runkle (1998).

5. Concluding Remarks

Public information has attributes that make it a double-edged instrument for policy makers. The strategic interactions between agents means that its impact is larger than could be justified by the face value of its content. Thus, although public information is extremely effective in influencing actions, the danger arises from the fact that it is *too effective* at doing so. Agents overreact to public information, and thereby magnifies any noise which inevitably creep in. Although disclosure policy has been examined in some fields of microeconomics, it is still in its early stages in macroeconomics. We hope that our paper may make a contribution to this important research.

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