Transparency and Costly Information Acquisition

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Abstract

I study the choice of economic transparency in a heterogeneous-information model where agents must pay a cost to observe the announcements of an information authority. The authority chooses transparency by selecting the number of signals regarding an aggregate state to make public, and agents respond by choosing how many of those signals to observe. I show that, when agents seek to coordinate their actions, the amount of information actually gathered by agents is non-monotonic in the transparency of the authority. The optimal degree of transparency is always interior and depends on the strength of complementarities in the economy. Transparency is distinguished from the precision of the authority's own information and the "quality" of its communications; increases in these are shown to be welfare improving under plausible conditions.

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1 Introduction

The United States Federal Reserve Bank (the Fed) communicates with the public about monetary policy in a much different way than it did twenty years ago. Today, the Fed makes explicit announcements regarding its target for the federal funds rate, releases a statement at the end of each Federal Open Market Committee (FOMC) meeting summarizing the rationale behind its decisions, and with some lag releases detailed minutes and other records of its internal deliberations. Additionally, the Chairman of the Fed has recently begun to hold regular press conferences after pre-specified FOMC meetings. All of these are innovations over the last two decades.

Despite the clear trend towards greater transparency in the conduct of US monetary policy, few would argue that these changes constitute a transformation towards total openness on behalf of the Fed. Over the same period, other central banks, notably those engaged in some form of inflation targeting, have come to reveal much more about their own forecasts and decision processes (but still not *everything*.) The changes in central bank communication, in the US and elsewhere, reflect a growing realization on the part of policy makers that a coherent communication strategy is an essential component of monetary policy as a whole. Yet, persistent differences in how banks communicate suggest there is little agreement on the proper communication strategy or on what factors should determine that choice.

The tempered move towards openness in the US, cross-country differences in transparency, and the fact that no central bank fully reveals its information, all indicate that policy-makers perceive tradeoffs in the choice to reveal more or less about their own views on the economy and their decision process. What might those tradeoffs be? The literature on the social value of public information (e.g. Morris and Shin, 2002; Angeletos and Pavan, 2007a) discusses one possibility, namely that agents might "over-coordinate" on public information. When public announcements are imprecise, excessive coordination may be harmful enough to warrant withholding the information altogether. In this literature, misalignments between the objectives of agents and policy-makers play a key role: agents over-coordinate on public information because an externality in preferences causes them to behave sub-optimally from a social perspective.

This paper offers an alternative account of why incomplete transparency may be a socially optimal policy, with emphasis on agent's own choices regarding the information they acquire. I propose a model of endogenous information acquisition in which agents' ability to coordinate depends on the communication policy of the information authority. In the model, the information authority must choose the extent of transparency, as measured by the number of (equally informative) signals it releases regarding an aggregate state in the economy. Agents choose the fraction of these signals they wish to observe, and pay a cost to do so. However, they cannot select which of the public signals to observe. Instead, they observe a random subset of all public signals. In this environment, increasing the number of signals made public has two opposing effects. On one hand, it increases the amount agents could potentially learn about the state. On the other, it increases the costs agents must pay to coordinate their information, since it increases the number of signals they must buy in order to acquire all public information.

This account of endogenous information choice provides a model of the tradeoff, to my knowledge first suggested by Morris and Shin (2007), between providing as much information as possible and ensuring common understanding among agents. I choose to focus on this tradeoff because I believe it captures the intuition that central banks often refrain from full disclosure in order to prevent "confusion" on the part of the public. In the language of Blinder (2007), too much communication, for example many speeches by different the members of the FOMC, may result in a "cacophony" of information, reducing the value of each individual signal. Similar concerns appear to be central in other public communication problems, from health policy to personal finance. The model proposed here provides a novel and succinct formalization of these ideas, which nevertheless constitutes a measured divergence from the previous literature on public information.

The endogenous information environment described above yields a number of results. First, I find that the degree of transparency of the authority has a non-monotonic impact on the amount of information acquired by agents. Revelation beyond a certain critical level causes agents to decrease the quantity of information they acquire. This results stems from the fact that agents with strategic complementarities in actions also find it more desirable to acquire information that they know that other agents will also acquire and act on. When the information authority in the economy releases a great deal of information - modeled as a large number of signals - agents rightfully anticipate that individual signals will not be observed by all agents, and therefore find the public information less valuable in their own decision problem. As a result, each agent is less inclined to purchase public information, which further decreases its value, and so on. As a consequence, too much information revelation results in less information acquisition, and lower utility overall.

Second, I find that the optimal degree of transparency is always interior: the authority always releases a positive but finite amount of information. Complete opacity is never optimal, since the first bit of information released by the authority improves agents' forecast of the state at the cost of an z small deviation from perfect coordination. Nor can full transparency be optimal: the desire to create common understanding among agents ensures that the authority never chooses to release more information than agents willingly acquire in equilibrium. The non-monotonicity in agents information acquisition means that doing so would result in lower overall information acquisition, with no corresponding benefit.

Third, I find that the optimal degree of transparency entails providing substantially less information than agents would willingly acquire if it were available. This result obtains because communication policy influences the costs of coordination faced by agents, despite the fact that the cost-per-signal acquired remains constant. When more signals are publicly available, agents must purchase more signals in order to ensure the same degree of coordination amongst themselves. In equilibrium they do so willingly, although they would prefer that the additional signals were not available. Additionally, I show that their choices are socially optimal given the communication policy.

The key parameter driving the results is the degree of strategic complementary in the economy. When agents and the authority perceive the same benefits to coordination, I find that stronger complementarities imply a lower degree of optimal transparency. Because stronger complementaries make lack of coordination more harmful, they also imply greater costs to providing communication beyond the optimal level. Furthermore, I find that when agents and the authority perceive different degrees of complementarity, it is the authority's preferences alone, and not those of agents, that drive the transparency choice.

Finally, the model of endogenous information allows me to distinguish transparency from two other aspects of communication that have often be conflated in earlier literature. Transparency, the "quantity of communication" undertaken by the authority, is distinct in the model from both quality of the information possessed by the authority itself, and from the quality of the authority's communication. While increases in transparency are not generically welfare improving, improvements in the authority's own information, and in the quality of its communication, are always beneficial under the baseline preferences. These distinctions may help to resolve some apparently counter-intuitive results in the earlier literature on transparency.

1.1 Literature

This paper is related to recent research on endogenous information acquisition, as well as a deep literature on global games and the social value of public information. The literature on endogenous information choice has centered primarily around rational inattention, introduced by Sims (2003). A range of authors (Mackowiak and Wiederholt, 2009; Woodford, 2009; Matejka, 2010) have argued that rational inattention can help to capture many qualitative features of the economy, including in firm-level pricing decisions. An alternative formulation of endogenous information acquisition has been proposed by Hellwig and Veldkamp (2009), who argue that multiplicity of information equilibria may become prevalent when agents face strategic complementarities in their actions. The process of information acquisition used in this paper nests that of Hellwig and Veldkamp (2009) and offers an approach to re-establishing uniqueness despite the presence of compelementarities; Myatt and Wallace (2010) suggest an alternative modification that also achieves uniqueness.

This paper is one of only two, to my knowledge, that study optimal communication policy in the context of endogenous information choice. Reis (2010), studies the question of when a policy maker should release its own private information about a coming change in regime, under a version rational inattention. Among other things, he finds that announcements made too early may be ignored by agents, and that optimal communication policy takes this into account. Reis (2010) and this paper share this theme; good communication policy requires public institutions take care to ensure that agents pay sufficient attention to their message.

My conclusions both complement and contrast with those from the literature on the social value of public information. Here, I concur with Morris and Shin (2002) that increases in transparency are not always welfare improving, while addressing certain critiques of their argument. Their results on transparency require a misalignment between the preferences of agents and those of the social planner, something Roca (2010) shows is absent in a particular new-Keynesian model with micro-founded preferences. The results on transparency here, however, do not rely on any misalignment between the preferences of agents and social welfare. Svensson (2006) argues that parameters values under which transparency may harmful in Morris and Shin (2002) are implausible: public information would need to be of incredibly low quality in order for the release of a signal to be harmful. Here, the qualitative results about transparency are robust to a wide range of parameters and, if anything, require the quality of public information to be sufficiently good. Finally, my results do not imply, as do those of Morris and Shin (2002), that the information authority should reveal as much information as possible, or nothing at all. Instead, optimal transparency is interior and varies continuously as a function of the various parameters in the model.

2 Model

2.1 Preferences

The economy consists of a continuum of expected utility-maximizing agents, indexed by i, and an information authority, G. Each agent chooses an action $p^i \in \mathbb{R}$, given their information. Agent i's preferences are given as minus a quadratic loss function, so that

$$-u^i(p^i|\theta, p, \bar{L}) = (1-\alpha)\left[p^i - \theta\right]^2 + \alpha(p^i - p)^2 \tag{1}$$

where θ represents an aggregate economic fundamental relevant to all agents and $p = \int_0^1 p^j dj$ gives the cross-sectional average action across agents. The degree of strategic complementarity in the agent's choice is measured by $\alpha \in [0, 1)$.

Under these preferences, agent i's optimal response function given her information is

$$p^{i^*} = (1-\alpha)E^i[\theta] + \alpha E^i[p] \tag{2}$$

where the notation $E^i[x]$ denotes expectations conditional on agent i's information set, $\mathcal{I}^i$.

Social welfare in the economy is measured by

$$-u^G(\{p^i\}, \theta) = (1-\alpha^*)\int_0^1 \left[p^i - \theta\right]^2 di + \alpha^* \int_0^1 (p^i - p)^2 di \tag{3}$$

In equation 3, the parameter $\alpha^* \in [0, 1)$ measures the degree of complementarity from the social planner's perspective, which may different from that perceived by agents.

The definition of the dispersion-loss term, $\int_0^1 (p^i - p)^2 di$, used here follows Angeletos and Pavan (2007a). Although it differs slightly from the definition used in Morris and Shin (2002), none of their computations depend on this choice. The alternative definitions, however, do have consequences whenever $\alpha^* > 0$. When $\alpha = \alpha^*$, this choice of preferences ensures agreement agents' and planner's preferred actions given information (Angeletos and Pavan, 2007a). In proposition 3, I establish that, whenever $\alpha = \alpha^*$, agents' individual information choices are socially optimal, as well. Consequently, when $\alpha = \alpha^*$, I will say that the agents' and planner's preferences are "aligned".

2.2 Information

2.2.1 The Communication Game

Before the realization of random variables, the information authority and agents choose information in a two stage game. In the first stage, the information authority selects its communication policy, which consists of selecting the degree of transparency. Transparency is measured by the quantity of public communication the authority promises to undertake. In the second stage, each agent i chooses her individual information allocation, which takes as given the information choice of other agents as well as the communication policy of the authority. Once communication policy and information allocations are made, uncertainty is realized, signals are observed, and agents choose their actions in an individually optimal manner given their information.

2.2.2 Authority's Information Choice

The authority receives a signal on the state of the economy of the form $g = \theta + \varepsilon$. Both the state, θ, and the error terms, ε, are assumed to be independent and normally distributed with mean zero and variances $\sigma_\theta^2 = 1$ and σ_ε^2 given exogenously. The information authority may share its information with the public by providing it with one or more signals, indexed by k, of the form

$$\begin{aligned} g_k &= g + \eta_k \\ &= \theta + \varepsilon + \eta_k \end{aligned} \tag{4}$$

The error in each signal is also assumed to be gaussian white noise, i.i.d. across signals, with exogenous variance σ_η^2. The only choice of the authority is its communication policy, which is given by K, the number of signals it wishes to make available for public observation. For future use, let $\mathbf{G}$ be the length-K random vector of signals released by the information authority with realizations G. I maintain the assumption that $\sigma_\varepsilon^2 = 0$ until section 6.

2.2.3 Agent's Information Choice

Given the authority's communication policy, each agent must choose how many of the public signals to observe, $N \leq K$, taking as given the information choices of other agents. To make these observations, agents must pay a utility cost of ΛN. I assume that agents cannot select precisely which of the K signals to observe, and instead observe a subset drawn randomly without replacement from among all of the signals released by the authority. This assumption is important; I discuss its relevance below and show how it may be substantially relaxed in section 7.

At the time of her action, the agent knows which signals she has observed, and the values those signals take, but has no information (beyond her priors) about the realizations of any other signals. To rigorously define agent i's information, let $\mathcal{G}^{\mathbf{i}}$ be a random K-vector of indicator variables. The k^{th} element of its realization, $\mathcal{G}^i_k$, is set to one if that signal is observed by agent i. Under these assumptions, the information set of agent i at the time of her action is denoted by $\mathcal{I}^i = \{G^i, \mathcal{G}^i\}$, where $G^i = \{g_k \in G; \mathcal{G}^i_k = 1\}$ is the set of signals observed by agent i. Implicitly, the set of values that are feasible for $\mathcal{I}^i$ depends both on the communication policy of the authority, and on the agent's information choice.

I assume that agents are bayesian, with priors the correspond to the unconditional distribution of all variables. Under these conditions, the inference of an agent observing N signals will give each signal equal weight and conditional expectations can be written

$$E[\theta|G^i] = a(N) \sum_{g_k \in G^i} g_k \tag{5}$$

where $a(N) = \frac{1}{N+\sigma^2_\eta}$.

The assumption that agents cannot select precisely which of the K signals to observe is strong. This assumption, and the assumption of Hellwig and Veldkamp (2009) that agents can *perfectly* select their preferred signals, can each be seen as special cases of a general model, in which agents "search" across signals with a limited ability to direct that search towards their most preferred signals. The current setup is analogous to an environment of "undirected" search, since agents can not influence which of the public signals they observe. Allowing for "perfectly directed" search introduces a large multiplicity of equilibria into the model, for precisely the reasons described by Hellwig and Veldkamp

(2009). However, I will show that, if search cannot be perfectly directed - if agents cannot be absolutely assured of sampling the signal they find most desirable - then uniqueness can be recovered, even for arbitrarily small deviations from perfectly directed search.

The crucial assumption or the results of this paper will prove to be that search across signals is imperfectly directed; completely undirected search is an extreme but analytically tractable special case. The presumption of imperfectly directed search is plausible for a number of reasons. First, agents may find it difficult or costly to determine which signals they would prefer: a force that is distinct from the cost of information acquisition per-se. Second, real agents must acquire information about a great deal of relevant variables in order to make all of their economic (and non-economic) decisions and almost always do so through "information aggregators," for example the New York Times or a Google search. These aggregators are separate entities, whose incentives may be different than their users and who may not know precisely what information their customers find most useful.

2.3 Definitions

In this section, I define concepts of equilibrium and efficiency, taking communication policy as given. Let $U^i(N^i, p^i(\mathcal{I}^i); p(G)) \equiv E[u^i] - \Lambda N^i$ be the unconditional expected utility of agent i as a function of her information allocation, N^i, and her pricing rule $p^i(\mathcal{I}^i)$, given the mapping of the authority's announcements to the aggregate action $p(G)$.

Definition 1. *Given communication policy, K, a pure strategy symmetric equilibrium consists of an information allocation, N^*, and a policy rule, $p^{i*}(\mathcal{I}^i)$, mapping information to actions, such that*

1. *Each agent's choice of information and policy rule maximize expected utility, taking other agents' actions as given:*

$$\{N^*, p^{i*}(\mathcal{I}^i)\} = \underset{N^i, p^i(\mathcal{I}^i)}{\operatorname{argmax}} \quad U^i(N^i, p^i(\mathcal{I}^i); p(G)) \quad \textit{subject to} \quad N^i \leq K \tag{6}$$

2. *The average action is given by $p(G) = \int_0^1 p^{i*}(\mathcal{I}^i) di$.*

The restriction to pure strategy equilibria simplifies notation, and will not exclude any equilibria under assumption 1, which I present shortly and maintain throughout the paper.

I now define a benchmark that will be helpful in evaluating the efficiency of the decentralized equilibria in the model.

Definition 2. *Given a communication policy, K, the socially optimal action plan consists of an i-common information allocation, N^o, and action rule, $p^o(\mathcal{I}^i)$, which satisfy*

$$\{N^o, p^{i^o}(\mathcal{I}^i)\} = \underset{N^i, p^i(\mathcal{I}^i)}{\text{argmax}} \;\; U^i(N^i, p^i(\mathcal{I}^i); p(G)) \quad \textit{subject to} \quad N^i \leq K \textit{ and } p(G) = \int_0^1 p^i(\mathcal{I}^i)di \tag{7}$$

The key difference between definitions 1 and 2 is that the former takes aggregate actions as given, while the latter imposes that aggregate actions are those induced by the planner's choice of $p^{i^o}(\mathcal{I}^i)$. I will later establish that the two definitions correspond when the equilibrium is unique and $\alpha = \alpha^*$.

The definition of the planner's *action plan* corresponds to the efficiency criterion used in Angeletos and Pavan (2007a), in that it considers efficiency given the constraint on information. This definition extends the previous definition, however, in that it incorporates the endogenous choice of information, rather than actions *given* information.

3 Equilibrium and Efficiency

The model is solved by optimizing sequentially, first choosing actions taking information as given, and then choosing the information allocation assuming that the use of that information is optimal.

3.1 Exogenous Information

In this section, I solve for the equilibria of the model taking the information choice of agents as given. I restrict myself to the space of linear equilibria, such that the mapping from signals to actions can be represented by a linear rule

$$p^{i^*} = \psi^{i^*} \sum_{g_k \in G^i} g_k \tag{8}$$

Aggregating equation 8 across agents implies a linear form for the aggregate price level

$$p = \psi^* \sum_{k=1}^{K} g_k \tag{9}$$

In appendix A, I iterate on equation 2 using a method of undetermined coefficients to solve for ψ^* and find that

$$\psi^* = \frac{1}{K + \frac{K/N-\alpha}{1-\alpha}\sigma_\eta^2} \tag{10}$$

Furthermore, the coefficients of the individual rule can be show to be given by

$$\psi^{i*} = \psi^* \frac{K}{N} = \frac{1}{N + \frac{1-\alpha N/K}{1-\alpha}\sigma_\eta^2} \tag{11}$$

Compare, now, the formulae for ψ^i* and the bayesian weights of an agents observing all N signals:

$$a(N) = \frac{1}{N + \sigma_\eta^2} \tag{12}$$

Inspection reveals that $\psi^{i*} \leq a(N)$, with strict inequality whenever $N < K$ and $\alpha > 0$. Moreover, the wedge between ψ^* and a grows with α, the strength of complementarity.

The wedge between ψ^* and a reflects the fact that agents seeking to coordinate actions will respond less to a given signal to the degree that it is not observed by all agents. As the ratio $\frac{N}{K}$ shrinks, and each signal is observed by a smaller fraction of agents, the announcements of the authority increasingly take on the characteristics of *private* information, in that the errors agents make in inferring the state are different for each agent.

3.2 Endogenous Information

In this section, I solve for the equilibrium information choice, assuming that information is used in the equilibrium manner. In appendix A.2, I show that, substituting in her optimal actions, the loss function of agent i (inclusive of information costs) can be written as

$$\begin{aligned} -E(u^i) = (1-\alpha)\left(\widetilde{\phi} a^i N - 1\right)^2 + (1-\alpha)\left(\widetilde{\phi} a^i N\right)^2 \frac{\sigma_\eta^2}{N} \\ + \alpha\left(\widetilde{\phi} a^i N - \widetilde{\psi} K\right)^2 + \alpha\left(\widetilde{\phi} a^i N - \widetilde{\psi} N\right)^2 \frac{\sigma_\eta^2}{N} + \Lambda N \end{aligned} \tag{13}$$

where $\tilde{x}$ represents a variable taken as given by agent i, $\widetilde{\psi} = \frac{1}{K + \frac{K/\tilde{N}-\alpha}{1-\alpha}\sigma_\eta^2}$, $\widetilde{\phi} = \frac{1+\frac{\sigma_\eta^2}{\tilde{N}}}{1+\frac{K/\tilde{N}-\alpha}{1-\alpha}\frac{\sigma_\eta^2}{K}}$, and $a^i = \frac{1}{N+\sigma_\eta^2}$.

3.2.1 Continuous Information

For analytical simplicity, I focus on a version of the model in which the information choices of the authority and agents can each be described by a continuous parameter, rather than the integers K and N. To do this, I divide each "unit" of information provided by the authority into a set of sub-units, and so on, *ad infinitum*.

To do this, fix exogenous parameters σ_G^2 and λ, which will correspond to the "quality" of the authority's communication and the cost of information in the continuous model. Now, consider a sequence of model parameters indexed by parameter $\bar{K} \to \infty$, in which the noise in each signal is given by $\sigma_\eta^2 = \bar{K}\sigma_G^2$ and the cost of a signal is given by $\Lambda = \frac{\lambda}{\bar{K}}$. As $\bar{K}$ grows, the precision and cost of a signal each become arbitrarily low.

The cost of information in each version of the model is invariant, in the sense that achieving a particular posterior variance on the state θ does not depend on $\bar{K}$. As an example, consider the cost of inferring the state with variance $\frac{\sigma_G^2}{1+\sigma_G^2}$ for a variety of $\bar{K}$. For any $\bar{K}$, doing so requires exactly $\bar{K}$ signals, since

$$E[\big(E(\theta|\{g_k; k=1,...,\bar{K}\}) - \theta\big)^2] = \frac{\sigma_\eta^2/\bar{K}}{1+\sigma_\eta^2/\bar{K}} = \frac{\sigma_G^2}{1+\sigma_G^2} \tag{14}$$

The cost of observing $\bar{K}$ signals is always $\Lambda\bar{K} = \lambda$, establishing the invariance.

With some simple rearrangement, agent i's loss function in 13 can rewritten in terms of σ_G^2 and only the ratios $\frac{K}{\bar{K}}$ and $\frac{N}{K}$. The limit of this function will be well defined, so long as the limits of these ratios are also well-defined and non-zero. We can now define two parameters to summarize information choices, each of which can take on a continuous (rational) value. Let $\kappa = \lim_{\bar{K}\to\infty} \frac{K}{\bar{K}}$, $\kappa \in [0,\infty)$, be the information authority's choice of transparency. Next, let $\nu = \lim_{\hat{K}\to\infty} \frac{N}{K}$ be agent i's information allocation. Since agents can only observe those signals released by the authority, $\nu \in [0,1]$. Finally, note that number of information units consumed by agent i is given by $\Gamma \equiv \frac{N}{\bar{K}} = \frac{N}{K}\frac{K}{\bar{K}}$, so that the cost of information can be written $c(\Gamma) = \lambda\Gamma$.

Taking limits, agent i's welfare can now be written

$$-E(u^i) = (1-\alpha)(\phi-1)^2 + (1-\alpha)\phi^2\frac{\sigma_G^2}{\kappa\nu} + \alpha(\phi-\tilde{\Psi})^2 + \alpha(\phi-\tilde{\Psi}\nu)^2\frac{\sigma_G^2}{\kappa\nu} + \lambda\kappa\nu \tag{15}$$

where $\phi = \tilde{\Psi}(1+\frac{\sigma_G^2}{\kappa\tilde{\nu}})(1+\frac{\sigma_G^2}{\kappa\nu})^{-1}$ and $\tilde{\Psi} = \left(1+\frac{1-\alpha\tilde{\nu}}{1-\alpha}\frac{\sigma_G^2}{\kappa\tilde{\nu}}\right)^{-1}$.

3.2.2 Equilibrium with Information Choice

Assumption 1. *Information costs are not too high:*

$$\lambda < \left(\frac{1-\alpha}{\sigma_G}\right)^2 \tag{16}$$

Assumption 1 is maintained throughout the remainder of the paper and is necessary to ensure that agents choose to acquire a non-zero quantity of information. It states that the costs of information should not be too high, relative to the precision of public information. When complementarities are high, the required costs of information required by the assumption are lower. This is natural, since in this case agents are more concerned with coordination than with the value of the state *per se*: agents can coordinate perfectly if none acquire any information about the state.

Proposition 1, proved in appendix A, establishes the characteristics of equilibrium information choice in the model. The proposition establishes that, under 1, the model has a unique equilibrium.

Proposition 1. *Suppose that assumption 1 holds. Then equilibrium information allocation is unique and is given by*

$$\nu^* = \begin{cases} 1 & \textit{if } \left(\frac{\sigma_G^2}{\lambda}\right)^{\frac{1}{2}} - \sigma_G^2 \geq \kappa \\ \hat{\nu} & \textit{otherwise} \end{cases} \tag{17}$$

where

$$\hat{\nu} = \frac{\left(\frac{\sigma_G^2}{\lambda}\right)^{\frac{1}{2}} - \frac{\sigma_G^2}{1-\alpha}}{\kappa - \frac{\alpha}{1-\alpha}\sigma_G^2} \tag{18}$$

The contrast between the uniqueness result here and the pervasive multiplicity in Hellwig and Veldkamp (2009) stems from the fact that, in that paper, agents may coordinate perfectly on the signals they wish to observe. From an agent's perspective, this creates a discontinuity in value between signals that are already observed by other agents (and therefore contain information about their actions as well as the state) and those that are not observed by others (and therefore only contain information about the state, and not others actions.)

Uniqueness in this case follows from the assumption that agents must randomize in selecting the signals that they observe.[1] As a result, all signals are observed with equal probability by other agents. Thus, an agent deciding whether to observe a marginal signal knows that all signals contain equal information about others actions: decreasing returns to additional observations arise only because agents update their beliefs less in response to new information once they are already observing a great deal of information. In section 7, I argue that uniqueness can be achieved when agents can choose to "oversample" a subset of signals, so long as they observe all signals with positive probability.

3.3 Transparency and Information Acquisition

How does communication policy affect equilibrium information acquisition? Proposition 2 establishes the important result that, whenever ν^* interior, an increase in the amount of transparency by the central bank actually decreases the amount of information acquired by agents.

Proposition 2. *Suppose $\alpha > 0$ and agents' equilibrium information choice is interior. Then information acquisition is decreasing in transparency:*

$$\frac{\partial \Gamma}{\partial \kappa} < 0 \tag{19}$$

Proof of Proposition 2. Recall that the total number of signals collected by agents i is given by $\Gamma = \kappa \nu^*$. Compute the derivative of Γ, for the case that $\nu^* = \hat{\nu}$:

$$\frac{\partial \Gamma}{\partial \kappa} = -\frac{\hat{\nu}}{\kappa} \frac{\frac{\alpha}{1-\alpha}\sigma_G^2}{\kappa(1+\sigma_\varepsilon^2) - \frac{\alpha}{1-\alpha}\sigma_G^2} \tag{20}$$

The denominator in the ration in equation 20 is positive whenever ν is interior and the numerators is positive by assumption, establishing the result. □

What is the mechanism behind this result? Consider what happens as the authority increases revelation, starting from a very low level. As long as agents attend to all public signals, increasing revelation increases the learning of all agents. At some point, however, the authority hits a threshold

[1] When signals are *a priori* identical, randomization is *an* equilibrium of model, even if randomization is not imposed as a constraint.

where agents no longer find it worthwhile to attend to all signals, even if they believe that other agents *do* observe all signals. When this happens, the equilibrium cannot entail agents observing all signals. However, since each agent now observes only a subset of all public signals, each signal become less valuable to other agents concerned with coordination. Therefore each agent is now less inclined to purchase an observation, and aggregate information acquisition is further reduced, to a level lower than that obtained under a policy of slightly less revelation.

Figure 1 plots consequences of greater transparency for aggregate information acquisition. The figure shows that the effect of endogenous choice of information can be substantial. When strategic complementarities are weak, information acquisition reach a maximum at $\hat{\kappa}$, and declines only slowly thereafter. When complementarities are strong, however, the effect described above creates a dramatic reduction in information acquisition, to less than half of its maximum value.

One economic interpretation of this result is that over-revelation on the part of the information authority, or central bank, may result in harmful "cacophony" (Blinder, 2007). The central bank may, in principle, wish to communicate more information to the public, but speaking with too many voices (sending too many signals) may overload agents' interest or capacity to process that information. When this happens, extra communication is not only unhelpful, it actually reduces knowledge about the state in the private sector, which responds to the cacophony by collecting *yet less* information from the public announcements than it otherwise would.

3.4 Efficiency of Equilibrium Information

Proposition 3. *Given any communication policy, when $\alpha = \alpha^*$, the equilibrium of the model is a socially optimal action plan.*

This proposition is proved in appendix B.2 by directly solving the planner's optimization problem. Angeletos and Pavan (2007b) establish that for the same preferences, $\alpha = \alpha^*$ implies that actions given information are efficient. Proposition 3 extends this result to the choice of information, for a case with a unique equilibrium. This proposition explains the choice to call $\alpha = \alpha^*$ the case of preference alignment.

When assumption 1 does not hold, the model may have two equilibria, each with different welfare implications. In that case, the statement of the proposition must be modified. Chahrour (2011) establishes that, under very general conditions, the socially optimal action plan is an equilibrium of the model, although other equilibria can (and often do) exist.

4 Optimal Transparency

Definition 3 formally states the information authority's problem. The information authority selects it communication policy in order to maximize social welfare.

Definition 3. *The information authority's optimal choice of transparency is denoted by the K that maximizes the social welfare of the resulting equilibrium allocations:*

$$K^* = \underset{K}{\operatorname{argmax}}\, U^i\left(N^*, p^{i^*}(\mathcal{I}^i); p(G)\right) \quad \textit{subject to} \quad p(G) = \int_0^1 p^{i^*}(\mathcal{I}^i)di;$$
$$N^*,\ p^{i^*}(\mathcal{I}) \ \textit{are equilibrium allocations given policy } K.$$

As before, this definition can be extended to the case of continuous choice. The social loss function, given equilibrium actions, can now be written

$$E[-u^G] = (1-\alpha)(\phi-1)^2 + (1-\alpha)\phi^2\frac{\sigma_G^2}{\kappa\nu} + \alpha\phi^2(1-\nu)^2\frac{\sigma_G^2}{\kappa\nu} + \alpha\,(1-\nu)\,\phi^2\frac{\sigma_G^2}{\kappa} + \lambda\kappa\nu \tag{21}$$

where $\phi = \psi^*$.

4.1 No-Waste Result

Lemma 1 establishes that, under an optimal communication policy, agents must attend to all signals released by the central bank. It is proved in appendix C.1.

Lemma 1. *The optimal choice of transparency must induce agents to select $\nu = 1$.*

The intuition for this result is as follows: if only a fraction of agents observe each signal, then each signal becomes less valuable for coordination, with no corresponding gain in the signal's informativeness about the state. Since the cost of each signal is constant, inducing this kind of dispersion in agent's information is always inefficient.

4.2 Optimal Degree of Transparency

Proposition 4. *When $\alpha = \alpha^*$ and $\left(\frac{\sigma_G^2}{\lambda}\right)^{\frac{1}{2}} - \frac{\sigma_G^2}{1-\alpha} > 0$, the optimal degree of transparency is given by*

$$\kappa^* = \sqrt{\frac{\sigma_G^2(1-\alpha)}{\lambda}} - \sigma_G^2 \tag{22}$$

Proposition 22 is prove in appendix C.2.

Figure 2 plots social welfare as a function of the precision of the information authority's communication, for two different degrees of complementarity. In both cases, incomplete information revelation is the optimal communication policy. The figure suggests that the optimal degree of revelation is decreasing in α. Taking the derivative of expression 22 with respect to the degree of complementarities establishes this result generally:

$$\frac{\partial \kappa^*}{\partial \alpha} = -\frac{1}{2}\left(\frac{\sigma_G^2}{\lambda(1-\alpha)}\right)^{\frac{1}{2}} < 0 \tag{23}$$

These results bear a *prima facie* resemblance to those of Morris and Shin (2002). On close inspection, however, some important differences emerge. First, the results in Morris and Shin (2002) are "bang-bang" in nature: the authority should either release its message at the highest possible precision or not at all. In contrast, the result here rationalize partial revelation, in which the authority communicates in a manner that is neither silent nor maximally transparent. Furthermore, if the authority were constrained to choose between full or partial revelation, they would indeed always prefer full revelation to silence.

A second important difference is the fact that results here are not the result of any sort of "mis-alignment" in preferences, the driving force behind the Morris and Shin (2002) result. Instead, this result stems from the nature of communication in the model, namely that communication policy can be fashioned so as to be conducive to coordination among agents, and that this is desirable. The economic intuition of the result here is quite distinct from previous literature: here, limited transparency serves to facilitate coordination in agent's information, while in the Morris and Shin (2002) strand of literature it serves to temper coordination in agent's actions.

Figure 3 highlights another important observation: the optimal degree of transparency is not that which maximizes equilibrium information acquisition. Instead, the optimal degree of transparency is substantially less this level. Let $\hat{\kappa}$ be defined as the κ which satisfies $\gamma^* = 1$. Solving this expression yields

$$\hat{\kappa} = \left(\frac{\sigma_G^2}{\lambda}\right)^{\frac{1}{2}} - \sigma_G^2 \tag{24}$$

Clearly $\kappa^* < \hat{\kappa}$ whenever α is between zero and one.

This result follows from the fact that, conditional on perfect coordination, higher complementaries decrease the social (and individual) value of learning about the state. To see this, consider the social welfare function, under the assumption that agents purchase all public information.

$$E[-u^G] = (1-\alpha)(\phi-1)^2 + (1-\alpha)\phi^2\frac{\sigma_G^2}{\kappa} + \lambda\kappa \tag{25}$$

Unsurprisingly, the terms related to coordination have completely dropped out. The remaining "fundamental" terms shrink as α increases, but the cost of each signal remain constant. As a result, the value of providing the public with more information is less, reducing the optimal degree of transparency.

Figure 4 provides additional intuition for this result. The figure plots the information cost paid by agent i as function of the correlation of her expectation of the state, conditional on the signals she observes, with "market expectations" which are assumed to rely on the full set of signals released by the information authority. As the figure shows, higher levels of revelation increase the cost of informational coordination for agents. Because of randomization, however, as agent i knows that any additional signals beyond κ^* released by the authority will be observed by some others, and therefore will choose to acquire that signal. Since agent i observes the signal, however, other agents also find it worthwhile. And so on. Thus, the incentives of individual agents to coordinate results in a "rat race" to acquire public information, even though all agents would prefer that the signals where withheld entirely by the authority.

4.3 Comparative Statics of Communication Quality

The quality of central bank's communication is integrally related to the ability of agents to coordinate their information and actions. Proposition 5 establishes that, when preferences are aligned, the information authority always prefers to communicate as precisely as possible.

Proposition 5. *When $\alpha = \alpha^*$, social welfare is improving with communication quality. That is*

$$\frac{\partial E[u^G]}{\partial \sigma_G^2} < 0 \tag{26}$$

Proof of proposition 5. By proposition 3, it is sufficient to show that welfare is decreasing in σ_G^2, given the choice of ν. Taking derivative of expression 21, we have that $\frac{\partial E[u^G]}{\partial \sigma_G^2} < 0$ if and only if

$$\left(1 - \frac{\phi}{\phi^*}\right) > \frac{1}{2}\left(\frac{1-\alpha^*\nu}{1-\alpha\nu}\right)\left(\frac{1-\alpha}{1-\alpha^*}\right) \tag{27}$$

where $\phi^* = \left(1 + \frac{1-\alpha^*\nu}{1-\alpha^*}\frac{\sigma_G^2}{\kappa\nu}\right)^{-1}$. But $\phi^* = \phi$ whenever $\alpha^* = \alpha$, so the inequality always holds given ν. $\square$

The central result of Morris and Shin (2002) is that a marginal increase in the precision of a public signal may be welfare-decreasing. Here, although full transparency is not optimal, increases in the precision of public signals as measured by σ_G^2 are welfare improving when $\alpha = \alpha^*$. Since $\alpha \neq \alpha^*$ in that paper, this may not be surprising. However, the result highlights the distinction in the model between precision of public announcements and transparency as measured by the quantity of public communication. Even when the central bank wishes to limit the quantity of information it provides, it still would like its communications to be a precise as possible: there is no such thing as constructive ambiguity under the baseline preferences. Later, I show this also true when transparency is chosen optimally.

5 Externalities in Preferences

Morris and Shin (2002) and the subsequent literature emphasize the link between preference misalignment (or externalities) and the optimal degree of transparency.[2] So far, I have focused on the case where preferences between agents and the social planner are aligned, and instead argued that the degree to which coordination is desirable (both socially and from the agents perspective) largely drives the choice of how precisely the information authority should speak about the aggregate state facing

[2]A short list of literature emphasizing the role of preference alignment includes Hellwig (2005); Angeletos and Pavan (2007a,b); Roca (2010).

the economy. Recall that in the exogenous information literature, when preferences are aligned, more precision of the public signal is always welfare increasing.

The first result of this section states that, when agents and the authority's preference are not aligned, the authority's perception of complementarities drives the choice of transparency.

Proposition 6. *The optimal degree of transparency is given by*

$$\kappa^* = \sqrt{\frac{\sigma_G^2(1-\alpha^*)}{\lambda}} - \sigma_G^2 \tag{28}$$

Two earlier observations drive this result. First, recall that range of transparency over which agents purchase all signals does not depend on α. This means that authority can induce "full acquisition" over the same range, regardless of the complementarities perceived by agents. Second, recall that in the case that $\nu = 1$, the equilibrium action coefficient is equal to the coefficient of inference, $\psi^i* = a(N)$, and does not depend on α. Thus, agent's actions are independent of α as long as $\nu = 1$. In this case, agent's complementarities effectively drop out of social welfare, leaving the authority to choose their policy according to the weights in the social welfare function.

This result depends on the assumption that agents have no private information. Since private information corresponds to the case where agents have different priors, it alternatively can be said to depend on the assumption of common priors. If agents did have access to private information about the state, then actions could be inefficient from a social perspective, and optimal communication may take that into account. To the extent that private information on the aggregate is relatively unimportant (or agents have similar priors), these results will provide a reasonably approximation of the true optimal degree of transparency.

Despite the strong result in proposition 6, private complementarity may have strong implications for the consequences of sub-optimal levels of transparency. Figure 5, compares social welfare for different degree of private complementarities, when $\alpha^* = .2$. When complementarities are low, "excessive" transparency has very small consequences for social welfare, since information acquisition is little affected by the extra revelation. However, when complementarities are strong, agents react to additional information by dramatically reducing their own acquisition of information and social welfare is greatly harmed by a relatively small amount of extra transparency.

Importantly, however, this wedge only appears once transparency exceeds the level $\hat{\kappa}$ at which agents purchase all public information. Recall that this level is independent of α. This means that, as long as $\alpha^* > 0$, the impact of small errors in the degree of transparency still depends only on α^*; α is only relevant in the range where information acquisition decreases with transparency.

Another natural question is whether preference alignment affects the welfare consequences of the quality communication? Recall that proposition 5 established that improvements in communication quality are always beneficial when preferences are aligned. An immediate implication of equation 27 is that communication is always welfare improving under optimal policy, regardless of alignment of preferences. This is true because optimal policy entails $\nu = 1$, and therefore, again, that $\phi = \phi^*$.

An open question is whether improvements in communication quality are always welfare improving, for any communication policy. There certainly exist cases where the inequality in 27 does not hold, but this expression takes information acquisition as given. Agents could shift attention so that improvements in σ_G^2 are beneficial in these cases as well.

6 Constraints on the Authority's Knowledge

One question that arises frequently in the literature on transparency is whether the degree of the information authority's knowledge about the state should impact the choice of transparency. In the model of Morris and Shin (2002), for example, a central bank which cannot provide a sufficiently precise message should withhold that message entirely. The present model, it turns out, provides an alternative rationalization for the idea that an information authority should release less information when the authority, itself, faces uncertainty about the realization of the state.

When σ_ε^2 is positive, the linear equilibrium pricing rule takes the same form as before, with the coefficient ψ now given by

$$\psi^* = \frac{1}{K\left(1 + \sigma_\varepsilon^2\right) + \frac{K/N - \alpha}{1-\alpha}\sigma_\eta^2} \tag{29}$$

The only difference with respect to equation 9 is the presence of the information authority's own uncertainty about the state. The natural result of this additional uncertainty, captured by equation 29, is that agents react less (in aggregate and individually) to the announcements of the authority.

The individual utility function is derived in appendix D. Limits can be taken in the same manner as before, allowing to derive equilibrium information choices as a function of the same continuous parameters.

Proposition 7. *Suppose that assumption 1 holds and $\sigma_\varepsilon^2 > 0$. Then equilibrium information allocation is unique and is given by*

$$\nu^* = \begin{cases} 1 & \textit{if } \left(\frac{\sigma_G^2}{\lambda}\right)^{\frac{1}{2}} - \sigma_G^2 \geq (1+\sigma_\varepsilon^2)\kappa \\ \hat{\nu} & \textit{otherwise} \end{cases} \tag{30}$$

where

$$\hat{\nu} = \frac{\left(\frac{\sigma_G^2}{\lambda}\right)^{\frac{1}{2}} - \frac{\sigma_G^2}{1-\alpha}}{\kappa(1+\sigma_\varepsilon^2) - \frac{\alpha}{1-\alpha}\sigma_G^2} \tag{31}$$

Expression 31 shows that agents choose to acquire less information, in the case that the information authority's own information is less informative about the state. Consider now the derivative

$$\frac{\partial \Gamma}{\partial \sigma_\varepsilon^2} = -\gamma^* \kappa (\sigma_\varepsilon^2)^{-2} \tag{32}$$

Expression 32 establish that, not surprisingly, equilibrium attention is decreasing in the precision of the central bank's communication policy. The expression also shows, however, that there is no independent interaction between complementarities and noise in the authority's own information. Figure 6 confirms this result, showing that equilibrium information acquisition is monotonically decreasing as the authority's information contains more error.

The consequences for optimal transparency are considered in proposition 8.

Proposition 8. *Suppose $\alpha = \alpha^*$, assumption 1 holds, and $\sigma_\varepsilon^2 > 0$. Then the optimal degree of transparency is given by*

$$\kappa^* = \frac{\sqrt{\frac{\sigma_G^2(1-\alpha)}{\lambda}} - \sigma_G^2}{1+\sigma_\varepsilon^2} \tag{33}$$

The proposition shows that optimal transparency with error is just a rescaling of the optimal level when the information authority's information is perfect. When the authority's information is less precise, optimal transparency decreases monotonically, with no separate role for the complementarity parameter, α. Figure 7 again shows these result graphically.

In both cases, complementarities do not independently change the optimal degree of revelation. This result derives from the fact that noise in the authority's own information is reproduced in all signals, and does not affect the coordination value of the various signals directly. For this reason, it is natural to suspect that improvements in the authority's information (decreases in σ_ε^2) are always welfare improving. Proposition 9 establishes this for the case of aligned preferences.

Proposition 9. *When $\alpha = \alpha^*$, social welfare is increasing in the precision of the authority's information. That is*

$$\frac{\partial E[-u^G]}{\partial \sigma_\varepsilon^2} > 0 \tag{34}$$

Proof. By proposition 3, it is sufficient to show this holds for a given choice of ν. The derivative of social loss with respect to σ_ε^2 is positive if and only if

$$\left(1 - \frac{\phi}{\phi^*}\right) > \frac{-1}{2\kappa} \tag{35}$$

where $\phi^* = \left(1 - \frac{1-\alpha^*\nu}{1-\alpha^*}\frac{\sigma_G^2}{\kappa\nu}\right)^{-1}$. Since $\phi = \phi^*$ whenever $\alpha = \alpha^*$, the proposition is established. □

Once again, the condition in equation 34 immediately implies that improvements in the information authority's information are welfare improving under optimal policy, since $\nu = 1$ implies that $\phi^* = \phi$, regardless of preference alignment.

7 Imperfectly-Directed Search

In this section, I plan to solve the model when search can be directed to varying degrees. This model should nest the current model of information choice, as well as that of Hellwig and Veldkamp (2009). I hope to show that uniqueness for interior values will hold as long as agents cannot perfectly coordinate the signals that they choose to observe.

As an example, consider where agent i can "direct" her search towards the set of $\tilde{N}$ signals that are "preferred" (over-sampled) by other agents: she can ensure that these signals receive relative weight of $\mu > 1$ with respect to the other signals in the search process. As she increases the number of signals she observes, these will be drawn disproportionately from the set of signals observed by other agents.

Since sampling is without replacement, however, this means that marginal signals will be increasingly likely to be drawn from the remaining group of signals, and thus less valuable from the perspective of coordination. This gradual decline in the coordination value of signals will hold as long as $\mu < \infty$, for it only in this case that agents can be assured of drawing signals from the "preferred" set as long as any remain, and assured of *not* selecting such signals subsequently.

8 Conclusions and Extensions

This paper offers an alternative explanation for why central banks often decline to provide as much information as possible about their own views on the economy. As in the previous literature on the social value of public information, this result depends heavily on the presence of strategic complementarities: without complementarities in actions, reducing the precision of the public signal can only harm social welfare. Yet, in contrast to most earlier literature on transparency, the result does not rely on any sort of misalignment in preferences from the agents' and social planner's perspective. Thus, the endogenous information model use here expands the variety of contexts in which incomplete information revelation by a public authority can be optimal.

Additionally, my results explain why the authority might resort to *partial* revelation, in contrast to previous conclusions that an information authority should either provide as much information as possible, or shut down the public signal entirely. Avoiding such "bang-bang" outcomes increases the plausibility of the results, as it accords more closely with the observation that central banks, as well as other public agencies, typically release substantial but limited amounts of information.

The tack taken here is a natural complement to the growing body of literature which focuses on the empirical consequences of endogenous acquisition of information. Since communication is fundamentally about the transfer of information, the introduction of information choice on the part of agents imposes new and relevant discipline on the study of optimal communication problems. One interesting direction for further research would be to study how costly information acquisition affects the ability of the information authority to commit to truthful communication, as issues of "cheap talk" are explicitly excluded from the current environment.

Observations of endogenous variables offers another potentially interesting extension of the current environment. Amador and Weill (2008) show that revelation of a public signal can have harmful effects on the ability of prices to aggregate private information. A conjecture is that when agents have a limited ability to process information, the importance of such an effect may be reduced, since agents can reallocate attention to the most informative signals available to them.

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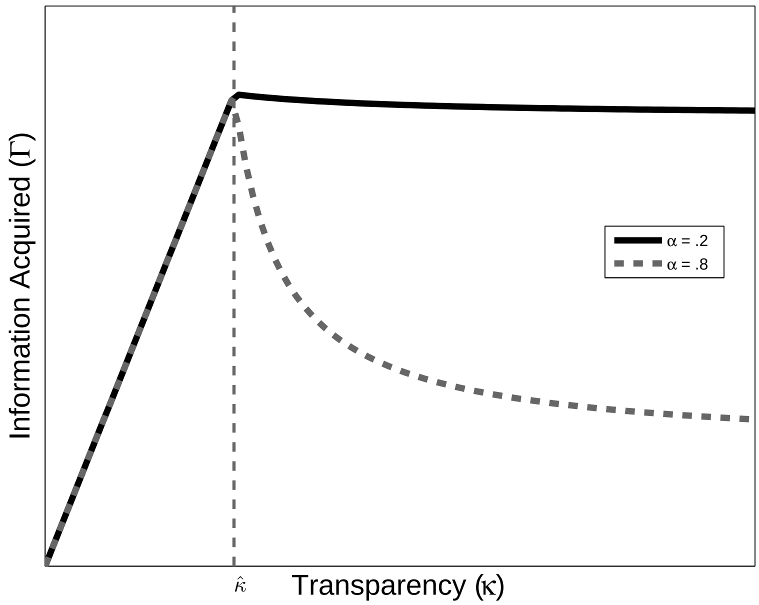

Figure 1: Information acquisition versus the degree of information release by the information authority, for different degrees of strategic complementarity. Information acquisition is decreasing for releases (transparency) greater that $\hat{\kappa}$.

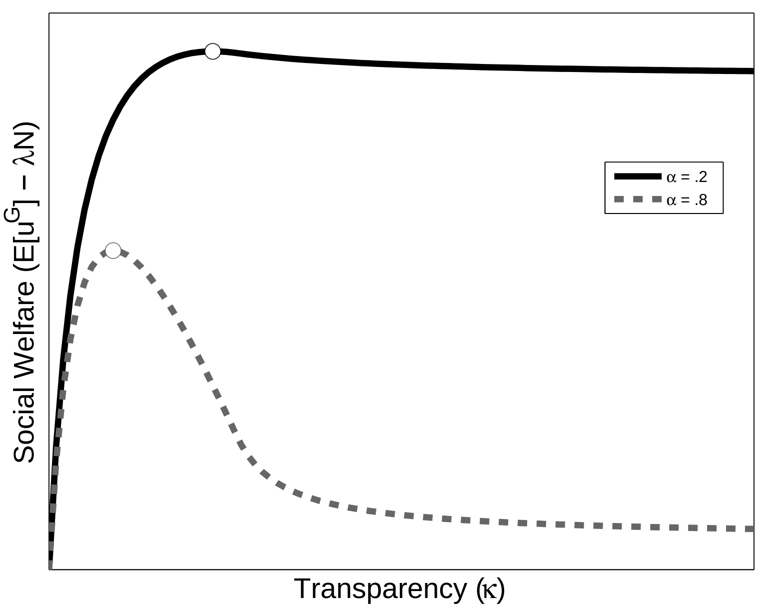

Figure 2: Social welfare as a function of the degree of transparency, for different degrees of strategic complementarity. The optimal degree of transparency is lower, when strategic complementarities are high ($\alpha = .8$).

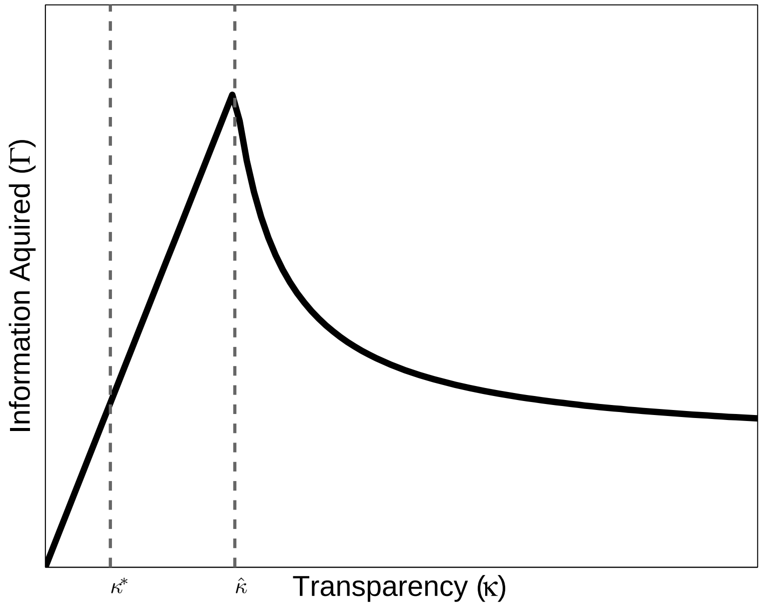

Figure 3: Information acquisition versus the degree of information release by the information authority, for the case of strong complementarities ($\alpha = .8$). The optimal degree of transparency, κ^*, does not "saturate" agents willingness to acquire information.

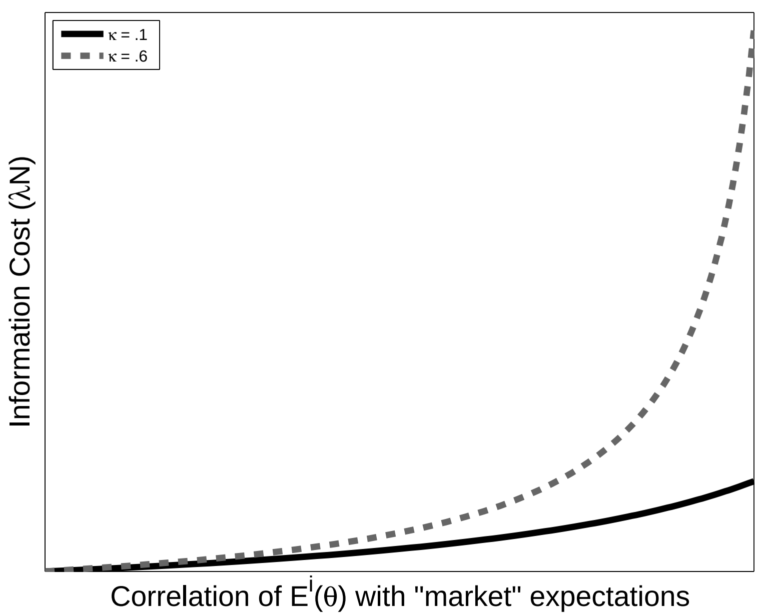

Figure 4: Information costs versus the degree of correlation with market information, for different degrees of transparency. When more information is released, increasing coordination with other agents is more costly.

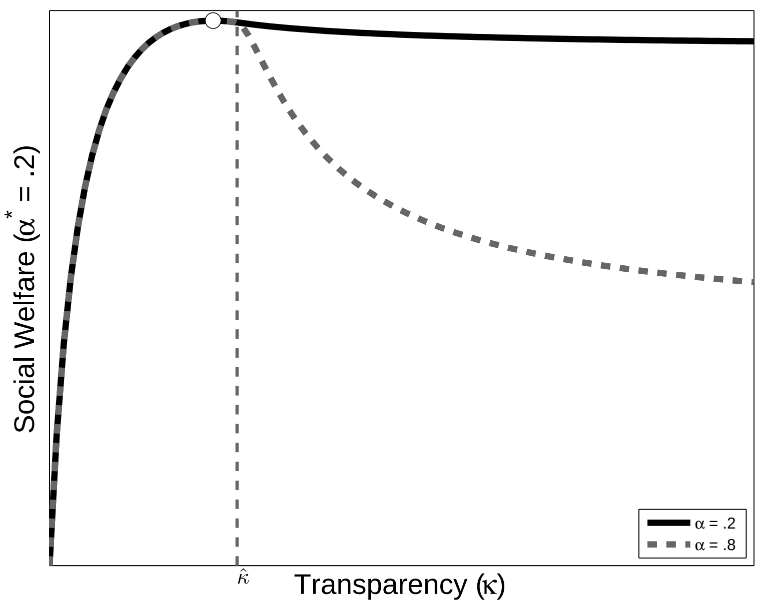

Figure 5: Social welfare as a function of the degree of transparency, when agent and planners preferences are misaligned. When $\alpha^* = .2$, high complementarities perceived by agents imply large losses to transparency greater than $\hat{\kappa}$.

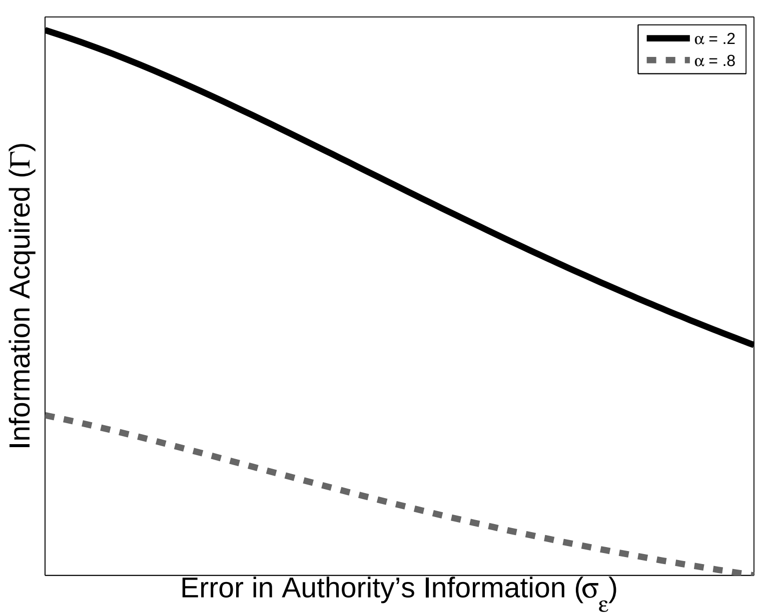

Figure 6: Information acquisition as a function of the error in the authority's own information. Information acquisition decreases monotonically as the authority's own information become less precise.

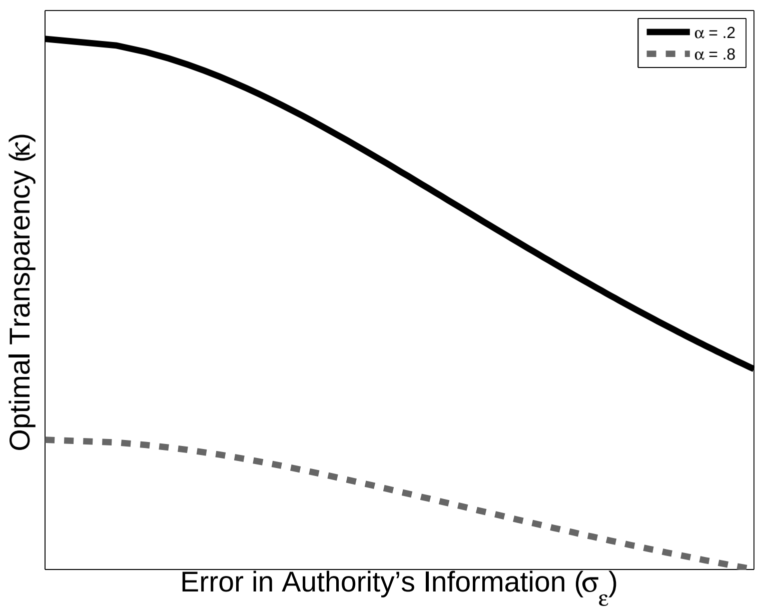

Figure 7: Optimal transparency as a function of the authority's own information. Transparency decreases monotonically as the authority's own information become less precise.

A Computing Equilibrium

A.1 Equilibrium Actions

In this section, I solve for the linear equilibrium coefficients of the agent's action rule using a method of undetermined coefficients, taking the information structure $N \leq K$ as given. I conjecture that the aggregate action rule takes the form given in equation 9, derive agent i's optimal response, and compute aggregate actions given the hypothesized rule. Equilibrium is a fixed point of the resulting mapping. The symbols $G, G^i, \mathcal{G}^i$, and $\mathcal{I}^i$ are all defined in the text in section 2.3. It helpful to further define $\mathcal{G}$ to be the K-vector of all ones.

Conditional on her observations, agent i's expectation of the state is given by

$$E(\theta|\mathcal{I}^i) = a \sum_{g_k \in G^i} g_k = a\mathcal{G}^i G' \tag{36}$$

where $a = \frac{1}{K+\sigma_\eta^2}$. Evaluating the agent first order condition in expression 2, we get agent i's choice of action as a function of her observations:

$$p^i = (1-\alpha)a\mathcal{G}^i G' + \alpha\psi\mathcal{G}^i G' + \alpha\psi(K-N)a\mathcal{G}^i G' \tag{37}$$

The last two terms in 37 correspond to the set of signals that are observed and unobserved by agent i respectively.

Integrating equation 37 across agents, the aggregate action is given by

$$\begin{aligned} p &= (1-\alpha)aE(\mathcal{G}^i)G' + \alpha\psi(1+a(K-N))E(\mathcal{G}^i)G' && (38) \\ &= ((1-\alpha)a + \alpha\psi(1+a(K-N)))\frac{N}{K}\sum_{g_k \in \mathbf{G}} g_k && (39) \end{aligned}$$

where I have used the fact that the draws of $\mathcal{G}^i$ are independent of the realizations of the signals, and that $E(\mathcal{G}^i) = \frac{N}{K}\mathcal{G}$. Equilibrium is then a fixed point of the expression

$$\psi = \frac{N}{K}((1-\alpha)a + \alpha\psi(1+a(K-N))) \tag{40}$$

The solution to this expression is

$$\psi^* = \frac{1}{K + \frac{K/N - \alpha}{1-\alpha}\sigma_\eta^2} \tag{41}$$

Individual i's responsiveness to each signal she observes is given by

$$\psi^i = \frac{K}{N}\psi = \frac{1}{N + \frac{1-\alpha N/K}{1-\alpha}\sigma_\eta^2} \tag{42}$$

A.2 Equilibrium Information

I now solve for agent i's choice of information, taking as given aggregate information and the equilibrium mapping of information to actions. Throughout, I denote the coefficients taken as given by agent i with a tilde, for example $\tilde{\psi}$. Agent i takes aggregate actions as given, so that $p = \widetilde{\psi} \sum_{k=1}^{N} g_k$, where

$$\widetilde{\psi} = \frac{1}{K + \frac{K/\tilde{N} - \alpha}{1-\alpha}\sigma_\eta^2} \tag{43}$$

Suppose that agent i selects to observe N signals and reacts to her information optimally according to the first order condition given by 2. Evaluating equation 39 and simplifying, her optimal action is

$$p^i = \widetilde{\phi} a^i \sum_{g_k \in G^i} g_k \tag{44}$$

where

$$\widetilde{\phi} = \frac{1 + \frac{\sigma_\eta^2}{\tilde{N}}}{1 + \frac{K/\tilde{N} - \alpha}{1-\alpha}\frac{\sigma_\eta^2}{K}}, a^i = \frac{1}{N + \sigma_\eta^2} \tag{45}$$

From here, compute the differences

$$p^i - \theta = \left(\widetilde{\phi} a^i N - 1\right)\theta + \sum_{g_k \in G^i} \widetilde{\phi} a^i \eta_k \tag{46}$$

$$p^i - p = \left(\widetilde{\phi} a^i N - \widetilde{\psi} K\right)\theta + \sum_{g_k \in G^i} \left(\widetilde{\phi} a^i - \widetilde{\psi}\right)\eta_k - \sum_{g_k \notin G^i} \widetilde{\psi}\eta_k \tag{47}$$

Computing the loss function (and dropping terms entirely beyond agent i's control) we have

$$\begin{aligned}-E(u^i) &= (1-\alpha)\left(\widetilde{\phi} a^i N - 1\right)^2 + (1-\alpha)\left(\widetilde{\phi} a^i N\right)^2 \frac{\sigma_\eta^2}{N} \\ &+ \alpha\left(\widetilde{\phi} a^i N - \widetilde{\psi} K\right)^2 + \alpha\left(\widetilde{\phi} a^i N - \widetilde{\psi} N\right)^2 \frac{\sigma_\eta^2}{N} + \Lambda N\end{aligned} \tag{48}$$

Equation 48 can be written in terms of the fractions $\frac{K}{K}$ and $\frac{N}{K}$, and is well defined in the limit, as long as κ and ν are. Taking these limits, individual i's welfare can be written

$$-E(u^i) = (1-\alpha)(\phi-1)^2 + (1-\alpha)\phi^2\frac{\sigma_G^2}{\kappa\nu} + \alpha(\phi-\tilde{\Psi})^2 + \alpha(\phi-\tilde{\Psi}\nu)^2\frac{\sigma_G^2}{\kappa\nu} + \lambda\kappa\nu \tag{49}$$

where $\phi = \tilde{\Psi}(1+\frac{\sigma_G^2}{\kappa\tilde{\nu}})(1+\frac{\sigma_G^2}{\kappa\nu})^{-1}$ and $\tilde{\Psi} = \left(1+\frac{1-\alpha\tilde{\nu}}{1-\alpha}\frac{\sigma_G^2}{\kappa\tilde{\nu}}\right)^{-1}$.

A.2.1 Agent Welfare is Convex on $(0, 1]$

Taking the derivative of 49 with respect to ν and simplifying substantially yields

$$\frac{\partial E(-u^i)}{\partial\nu} = \phi^2\frac{\sigma_G^2}{\kappa\nu^2} - 2\phi\nu^{-1}\left(1+\frac{\kappa\nu}{\sigma_G^2}\right)^{-1}\left(1+\frac{\sigma_G^2}{\kappa\tilde{\nu}}\right)\tilde{\Psi} + \lambda\kappa \tag{50}$$

Differentiating again, and simplifying, yields

$$\frac{\partial^2 E(-u^i)}{\partial\nu} = 2\phi B\nu^{-1}\left(\tilde{\Psi}\left(1+\frac{\sigma_G^2}{\kappa\tilde{\nu}}\right)\frac{2\kappa\nu}{c+\kappa\nu} - \phi\right) \tag{51}$$

This greater than zero, if the term in parenthesis is. Additional simplification shows that this term is

$$\tilde{\psi}\frac{\kappa\nu}{c+\kappa\nu} > 0 \tag{52}$$

whenever $\nu > 0$. And so utility is convex on $\nu \in (0, 1]$.

A.2.2 Interior Levels of Acquisition

A value of ν that sets expression 50 equal to zero is a unique solution to the agent's optimization problem.

$$\phi^2\frac{\sigma_G^2}{\kappa\nu^2} - 2\phi\nu^{-1}\left(1+\frac{\kappa\nu}{\sigma_G^2}\right)^{-1}\left(1+\frac{\sigma_G^2}{\kappa\tilde{\nu}}\right)\tilde{\Psi} + \lambda\kappa = 0 \tag{53}$$

In this case, equilibrium is a fixed point of expression 53, substituting ν for $\tilde{\nu}$. Making this substitution and simplifying yields:

$$-\phi^2\left(\frac{\sigma_G^2}{\kappa\nu^2}\right)+\lambda\kappa=0 \tag{54}$$

Solving the resulting expression for ν yields

$$\tilde{\nu}=\frac{\left(\frac{\sigma_G^2}{\lambda}\right)^{\frac{1}{2}}-\frac{\sigma_G^2}{1-\alpha}}{\kappa(1+\sigma_\varepsilon^2)-\frac{\alpha}{1-\alpha}\sigma_G^2} \tag{55}$$

A.2.3 No Information Acquisition

A.2.4 Total Information Acquisition

Full information acquisition ($\nu^*=1$) is an equilibrium if and only if the derivative of individual i's welfare (loss) is positive (negative) at $\nu=1$, when other agent's information is also full ($\tilde{\nu}=1$.) When $\tilde{\nu}=\nu=1$, we have that

$$\phi=\Psi=\frac{1}{1+\frac{\sigma_G^2}{\kappa}} \tag{56}$$

Setting the expression 50 greater than zero, and substituting 56

$$\phi^2 c/\kappa+\lambda\kappa<0 \tag{57}$$

Rearranging this condition yields

$$\kappa<\left(\frac{\sigma_G^2}{\lambda}\right)^{\frac{1}{2}}-\sigma_G^2 \tag{58}$$

Thus, $\nu^*=1$ is an equilibrium if and only if 58 holds.

B Efficiency

The social planner's problem is solved by minimizing the loss function assuming that all agents choose the same information and actions. For any given aggregate policy ϕ, and information choice ν, the loss function is given by

$$E[-u^G] = (1-\alpha)(\phi-1)^2 + (1-\alpha)\phi^2\frac{\sigma_G^2}{\kappa\nu} + \alpha\phi^2(1-\nu)^2\frac{\sigma_G^2}{\kappa\nu} + \alpha\,(1-\nu)\,\phi^2\frac{\sigma_G^2}{\kappa} + \lambda\kappa\nu$$
$$= (1-\alpha)(\phi-1)^2 + \phi^2\frac{\sigma_G^2}{\kappa\nu} - \alpha\phi^2\frac{\sigma_G^2}{\kappa} + \lambda\kappa\nu \tag{59}$$

B.1 Efficient Actions

Taking the first order condition of 59 with respect to ϕ, yields

$$(1-\alpha)(\phi-1) + \phi\frac{\sigma_G^2}{\kappa\nu} - \alpha\phi\frac{\sigma_G^2}{\kappa} = 0 \tag{60}$$

Solving this expression for ϕ gives

$$\phi^e = \left(1 + \frac{1-\alpha\nu}{1-\alpha}\frac{\sigma_G^2}{\kappa\nu}\right)^{-1} = \psi^* \tag{61}$$

B.2 Efficient Information

Substituting in optimal actions into expression 59, differentiating with respect to ν and setting to zero yields

$$-\phi^2\left(\frac{\sigma_G^2}{\kappa\nu^2}\right) + \lambda\kappa = 0 \tag{62}$$

which is the same as expression 54, establishing that planner's information choice and the agents' equilibrium information choice coincide.

C The Choice of Transparency

C.1 Proof of Lemma 1

Proof. The form of ν^* ensures that for any value of κ that implies $\nu^*(\kappa) < 1$, there exits another value of $\kappa' < \kappa$, such that $\nu^*(\kappa') = 1$ and $\kappa\nu^*(\kappa) = \kappa'\nu^*(\kappa')$. I want to show that social welfare is always under communication policy κ'. The welfare function in 59 is composed of three terms, those that refer to the "fundamental" portion of utility (multiplied by $(1-\alpha)$), those that refer to the "coordination motive" (multiplied by α), and the information costs. Under both policies, the information costs are equal. Furthermore, when $\nu = 1$, the second term is at its global minimum of zero. Finally, the first term is certain to lower under the $\nu = 1$ policy, because in that case $\phi = a$, the coefficient of optimal inference for the state. This implies that the first term is also at a global minimum for this policy. Thus, overall loss must be lower for the lower transparency ($\nu = 1$) policy. Furthermore this argument does not depend on the alignment of preferences (α need not equal α^*). $\square$

C.2 Optimal Transparency

Using the result of lemma 1, we can compute the optimal choice of κ assuming that $\nu = 1$. We can then confirm, ex post, that under that policy agents do choose $\nu = 1$. If this is so, then we have found the optimal level of transparency.

I seek to minimize

$$(1-\alpha)(\phi-1)^2 + (1-\alpha)\phi^2\frac{\sigma_G^2}{\kappa} + \lambda\kappa \tag{63}$$

where $\phi = \left(1 + \frac{\sigma_G^2}{\kappa}\right)^{-1}$. The first order condition is

$$2(\phi-1)\phi^2\frac{\sigma_G^2}{\kappa^2} + 2\phi^3\frac{c^2}{\kappa^3} - \phi^2\frac{\sigma_G^2}{\kappa}^2 + \frac{\lambda}{1-\alpha} = 0 \tag{64}$$

Solving this expression yields

$$\kappa^* = \left(\frac{\sigma_G^2(1-\alpha)}{\lambda}\right)^{\frac{1}{2}} - \sigma_G^2 \tag{65}$$

The solution for κ^* is clearly less than or equal $\hat{\kappa} = \left(\frac{\sigma_G^2}{\lambda}\right)^{\frac{1}{2}} - \sigma_G^2$, the maximum value of transparency for which agents choose $\nu = 1$.

D Constraints on Authority's Information

D.1 Equilibrium Actions

Following the same procedure as before, equilibrium coefficients (which again are efficient when $\alpha = \alpha^*$) can be computed

$$\psi^* = \frac{1}{K\left(1+\sigma_\varepsilon^2\right) + \frac{K/N-\alpha}{1-\alpha}\sigma_\eta^2} \tag{66}$$

D.2 Equilibrium Information

Individual i's welfare function can be written

(67)

Taking limits, this gives

(68)

Taking first order conditions and finding a fixed point gives the solution of equilibrium information acquisition, for interior levels.

D.3 Social Welfare

Social welfare can now be written

$$-E[u^G] = (1-\alpha^*)(\phi-1)^2 + (1-\alpha^*)\phi^2\frac{\sigma_G^2}{N} + (1-\alpha^*)\phi^2\sigma_\varepsilon^2$$
$$+\alpha^*(\phi-\phi)^2 + \alpha^*\phi^2\left(1-\frac{N}{K}\right)^2\frac{\sigma_G^2}{N} + \alpha^*\phi^2\left(1-\frac{N}{K}\right)\frac{\sigma_G^2}{K} + \Lambda N \tag{69}$$

Taking the appropriate limits and combining terms:

$$-E[u^G] = (1-\alpha^*)(\phi-1)^2 + (1-\alpha^*)\phi^2\sigma_\varepsilon^2 + \phi^2\frac{\sigma_G^2}{\kappa\nu} - \alpha^*\phi^2\frac{\sigma_G^2}{\kappa} + \lambda\kappa\nu \tag{70}$$

where $\phi = \psi^*$.

D.4 Choice of Transparency

Setting $\nu = 1$ and taking the derivative of 70 with respect to κ and setting to zero yields the optimal degree of transparency:

$$\kappa^* = \frac{\sqrt{\frac{\sigma_G^2(1-\alpha^*)}{\lambda}} - c}{1+\sigma_\varepsilon^2} \tag{71}$$