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Idiosyncratic Information and Vague Communication

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This study explores why, at critical moments, governments may withhold vital information from the public. We explain this phenomenon by what we call idiosyncratic events, or events independent of the information receiver's state-contingent payoff functions. Idiosyncratic events often influence the receiver's belief on the sender's performance. If such events are correlated with the events determining the payoff functions, the sender may withhold information so as to improve his image. This result may be applied to the manipulation of information regarding a number of recent real-world phenomena, including the Fukushima nuclear accident in 2011 and the ongoing outbreak of COVID-19.

INTRODUCTION

While the world is still struggling to understand and control the new coronavirus that struck in early 2020, it has already been suggested that in many different countries, governments have sought to control and manipulate information flows concerning the disease for political, economic, or public-safety reasons.[1] This follows many cases of information withholding relating to such issues as whistle-blowing, product defect, and "post-reality" and "post-fact" politics.[2] A slightly older and more thoroughly documented example is the 2011 Fukushima nuclear accident, during which the Japanese government was harshly criticized by foreign observers for withholding vital information during the first several weeks after the accident.[3] On the first day of the accident, people were informed that a bad accident had occurred at the nuclear plant. However, it took many months before they were told more precisely how bad the accident was. In these cases, and in many other crises, the following question arises: why is vital information withheld?

Facing this reality, the present study explains vague communication by what we call idiosyncratic information, defined as information on events independent of an information receiver's state-contingent payoff function; we call this an idiosyncratic event. We extract game-theoretic features from the Fukushima accident and build a cheap-talk game (Crawford and Sobel 1982) to explain not only the Fukushima accident but also various cases of vague communication by means of idiosyncratic information.

In the Fukushima accident, the possibility of losing the public's trust appears to have been important for the government. It is reported that by setting the evacuation range within the 20-kilometer radius of the Fukushima plant, the then prime minister, Naoto Kan, expressed that it would be desirable from a safety viewpoint to set a much larger evacuation area. However, he was reportedly concerned that if the evacuation range were extended to a 50- or 100-kilometer radius, the government might not be able to carry out the evacuation, thereby losing the people's trust in the government's crisis management capability.[4]

We describe this trust by means of the idiosyncratic events that are correlated to the nonidiosyncratic events determining the receiver's state-contingent payoff function. If they are correlated with each other, it is reasonable to assume that an information receiver holds beliefs on not only nonidiosyncratic but also idiosyncratic events. Like the public's trust, beliefs on idiosyncratic events are often concerned with an information receiver's evaluation on the information sender. If so, there is no surprise that the informed agent is concerned with the uninformed agent's belief on idiosyncratic belief. A quintessential example is what Mr. Kan referred to as the public's trust.

Our main finding is that, due to the correlation between idiosyncratic and nonidiosyncratic events, an information sender may withhold its private information so as to influence the receiver's idiosyncratic belief in the sender's own favor. In short, idiosyncratic information makes communication vague.

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[1] This may have seriously worsened the outbreak, for it is often said that an early detection is highly important to containing an infectious disease (Hanage 2020). See Dorn (2020) and Shear, Fink, and Weiland (2020) for the Chinese and US cases, respectively.
[2] On the whistle-blower case leading to President Trump's impeachment, see Liptak, Leblanc, and Mang (2019); on a recent product safety issue, see Gates (2019) and Hamby (2020); on "post-reality" and "post-fact" politics, see Holmes (2016) and Collingson (2019).
[3] Tabuchi and Bradsher (2011).
[4] Funabashi (2012a).

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If, more specifically, the information sender has too strong an idiosyncratic concern, communication with the receiver may become vague. If the idiosyncratic concern is not too strong and not too weak, there is a unique partially informative equilibrium. This is because if the idiosyncratic concern is too strong, the sender's optimal choice is to maximize its idiosyncratic interest, in which case information would be completely hidden. If, in contrast, the idiosyncratic concern is sufficiently weak, the optimal choice is to maximize the public's payoff, in which case information would be fully revealed. In between, a partially informative equilibrium exists that is a unique informative perfect Bayesian equilibrium.

The second result addresses why the most serious state is mixed with less serious states but not with the least serious one. We demonstrate that this occurs if the receiver's prior trust in the sender is high. This is because if a sufficiently high trust is already established, the sender has relatively little to gain in terms of reputation for trustworthiness by deviating to tell that the accident is the least serious. We demonstrate that the Fukushima accident may be explained as such an equilibrium.

The third result is that the lower the public's prior trust, the more likely the sender pools all but the most serious accident. This is because if only a very low trust is built, the sender in the most serious accident could expect little trust gain by deviating from truth telling. The 1979 Three Mile Island accident as well as a series of accidents in Japan during the latter half of the 20th century may be described by this type of equilibrium.

Different idiosyncratic concerns may motivate different information senders, which may explain vague communication in various contexts. For a manufacturer of a risky product, for example, customers' beliefs on product safety can be nonidiosyncratic, which determines their expected payoffs. At the same time, the market's evaluation on the company's profit/business prospect may be idiosyncratic. Many cover-up cases on product defect may result from this type of idiosyncratic motive. Information flows relating to the current outbreak of coronavirus may be given a similar explanation by the government's concern on public health (nonidiosyncratic) and its political concern (idiosyncratic).

A completely different type of application may be found in monetary policy. It is often said that while monetary policy was thought of as rather discretionary in the last century, independence and transparency have become important for modern central banks. Despite this, however, central banks face strong pressures from political leaders, as well as the general public, to keep the economy performing well or, at least, as though performing well. If these pressures constitute a serious idiosyncratic concern for a central bank, our model predicts that the central bank may create a noise in the market.[5] This is consistent with Lustenberger and Rossi (2020), who obtain empirical evidence showing that the central bank creates noises in the market.

Our research question is, as is noted above, why vital information may be withheld during an undesirable event like a nuclear accident. This question necessitates a model in which the information sender does not have any action bias ex ante; this feature is important in forming a benchmark model in which undesirable information may be hidden. We address the question by highlighting the idiosyncratic concern, which is a type of reputational concern in the literature on reputational cheap talk. In our model, a sender does not have any ex ante action bias. That is, the fully revealing messaging strategy is a unique optimal strategy for the sender if, as in Kamenica and Gentzkow (2011), the sender could precommit to a messaging strategy ex ante. At the same time, the sender has a single objective function by which we may compare strategy choices between ex ante and ex post naturally. Ottaviani and Sorensen (2006) and Pavesi and Scotti (2014) work with models in which the ex ante choice of a messaging strategy is indeterminate. Sobel (1985), Benabou and Laroque (1992), Trueman (1994), Morris (2001), and Morgan and Stocken (2003) work with models in which an information sender has multiple personalities with different objective functions. Although, in our model, the sender does not have any ex ante action bias, reputational concerns prevent the sender from full revelation.

Outside of the literature on reputational cheap talk, our study is related to Levy and Razin (2007) in assuming that information is biased through the existence of multidimensional states of nature. It is also related to Kőszegi (2006), who works with a model free from an ex ante bias by focusing on the case in which the ex post optimal strategy of the sender coincides with that of the receiver. In order to address the withholding of vital information, the present study works with a model that incorporates a conflict of interest between the sender and the receiver in the choice of an ex post optimal strategy.

In what follows, we will review the Fukushima accident and then build our model to capture the accident. After characterizing perfect Bayesian equilibria with different flows of information, we relate them to various types of nuclear accidents as well as to other types of real-world incidences. We then conclude.

FUKUSHIMA ACCIDENT

Around 2:45 p.m., March 11, 2011, an earthquake of magnitude 9.0 occurred off the coast of the Tohoku area of Japan. The earthquake caused a huge tsunami, which arrived in the coastal area by 3:15 p.m. The Fukushima Daiichi nuclear power plant was overwhelmed by the tsunami, which inundated the main buildings and stopped the electric power supply. The plant had six nuclear reactors, which were set in individual buildings.

In the type of nuclear reactor used at Fukushima, water is boiled by heat from nuclear fission that takes place in nuclear fuel rods. Because of the high heat, each reactor must constantly be cooled by water, which

[5] See Stein (1989) for an early study relating a central bank's imprecise announcement to cheap talk.

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is impossible without an electric power supply. Even if the fuel rods become no longer usable for a nuclear reactor, the used rods must be cooled down in a water pool for a number of years before they can be removed safely.

At the time of the earthquake, reactors 1 through 3 of the six reactors were active. The tsunami stopped the electric power supply, which made it impossible to cool the active reactors and the pool containing used fuel rods. The overheating reactors melted down and, at the same time, produced a large volume of hydrogen gas. The accumulated hydrogen gas caused the explosions of the buildings that contained the active reactors and the used nuclear fuel rods. It was more than a month before the further deterioration of the reactors was no longer an immediate threat.

The accident is classified at level 7, the highest on the international nuclear and radiological event scale.[6] During the first month of the accident, as is discussed in the Introduction, the government provided very little information to the public.

Extreme Danger

Before beginning our analysis, it is important to explain how dangerous the situation was immediately following the Fukushima accident and in what ways vital pieces of information were withheld by the government. From the very beginning of the accident, the country was facing a catastrophic situation. After leaving the prime minister's office, Mr. Kan (2014a, 18) writes

> "[the] chairman of the Atomic Energy Commission of Japan, pointed out to me that, in the worst-case scenario, people within a radius of 155 miles would have to be evacuated, and they would not be able to return home for ten, twenty, or thirty years. The Tokyo metropolitan area, home to 50 million people and almost half of the entire population of Japan, is within this 155-mile zone."

In the end, this worst scenario did not come to pass largely due to sheer luck, according to Mr. Kan, who attributes this to "*Kami no gokago*" (God's divine protection).[7]

What may have prompted this description may be explained in a program by the national broadcasting company, NHK (2014). That program reported that the Fukushima plant was in fact in a catastrophic state during the first week. The earthquake and accident occurred on March 11. It was known that, without power supply, the water that cooled the spent nuclear fuel rods would evaporate in 14 days; in addition, engineers feared the possibility that the pool in which the fuel rods were stored was damaged so that water might have leaked out within the first several days. Because they could not find a way either to add water or to restart the power supply, officials in both the Japanese and the American governments thought they were facing an imminent danger of nuclear explosions caused by overheated, spent fuel rods. If such explosions had occurred, it would have become impossible to work on the three nuclear reactors, and this could have led to massive explosions. One of the reactors used plutonium fuel, which is far more dangerous than uranium fuel. It was later discovered that the pool in which the spent fuel rods were kept continued to hold water only because of a fortuitous coincidence. A nearby pool that normally would have been empty happened to have been filled with water, and the water in this nearby pool had unexpectedly flowed into, and filled, the pool holding the spent fuel rods. If the second pool had not been filled with water, what Mr. Kan feared would have become a reality.[8]

Disturbed Flows of Information

From the beginning of the accident, the government sent a clear message informing the public that an accident had occurred and was not under control. As the situation developed, however, the public was given very little information besides that initial message.

For example, people had no idea about the worst-case scenario that concerned Mr. Kan. His choice of the evacuation range discussed in the Introduction was another example.

From the beginning of the accident, moreover, both the government and the power company avoided using the term "meltdown." On the second day of the accident, a spokesman for the Nuclear Safety Commission acknowledged the possibility that nuclear fuel was melting down. Receiving a complaint from the prime minister's office, the commission replaced its spokesman within a few hours. After that single occasion, the term "meltdown" was avoided for a long time, although it was later discovered that all the Fukushima Daiichi reactors melted down a few hours after the accident.[9]

SPEEDI data was also another type of information withheld. SPEEDI is the acronym for the System for Prediction of Environmental Emergency Dose Information. It is designed to track the spread of radioactive materials in the case of a nuclear accident. These data were not made available for the Japanese public until March 23, but the U.S. military forces were provided with data within a few days of March 11 (Onishi and Fackler 2011).

Big Surprise

It appears that the tsunami and the Fukushima accident were a big surprise for the Japanese government. Although, prior to the earthquake, scientists had warned of the possibility of a tsunami, pointing out that

[6] See the Intermediate Report by Investigation Committee on the Accident at the Fukushima Nuclear Power Stations of Tokyo Electric Power Company.

[7] This expression appears in a Japanese version of Kan (2014a); see (Kan, 2014b). Also see Funabashi (2012b, Loc 6189).

[8] Funabashi (2012b, Loc 6189).

[9] Funabashi (2012b, Loc 6483).

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TABLE 1. Variables

$\theta=(\omega,c)$	Vector of natural and human causes of accident, called a state of nature.
Θ	Set of states of nature.
$p^o_\Theta(\Theta)$	Ex ante subjective probability with which the state of nature, θ, occurs.
c	Capability of the sender.
$C=\{0,1\}$	Set of capabilities. If $c=1$, the government is capable of handing the accident; if $c=0$, it is not.
$p^o_c(c)$	The public's ex ante subjective probability distribution on c.
t^o	The receiver's ex ante trust of the sender.
$E_{pc}(c)=t$	Expected capability of the sender, representing the receiver's trust t of the sender.
ω	Fundamental state of nature.
$\Omega=\{1,2\}$	Set of fundamental states of nature.
$s=\omega-c$	Scale of accident. If $s=s_2$, the accident is worst; if $s=s_1$, it is bad; if $s=s_0$, it is normal.
k	Importance of the idiosyncratic concern for the sender.
h	Importance of the nonidiosyncratic concern for the sender.
m	Message that the sender sends to the receiver.
$q(\cdot\|\theta)$	Messaging rule, the probability distribution that governs the way in which a message is sent, given the state of nature, θ.
q	Messaging strategy, a collection of messaging rules for all states of nature, $q(\cdot\|\theta)$ with $\theta\in\Theta$.
x	The receiver's self-protection effort against the accident.
$x(p_s)$	The receiver's optimal self-protection effort, contingent on his nonidiosyncratic belief p_s.
$p_s(\cdot\|m)$	Ex post nonidiosyncratic belief (the receiver's ex post probability belief on the scales of accident, s, contingent on the sender's message m).
$p_c(\cdot\|m)$	Ex post idiosyncratic belief (the receiver's ex post belief on the capability of the sender, contingent on the sender's message m).

an earthquake of a similar size occurred in 869 AD in the same region (see Shishikura et al. 2007), the operator of the Fukushima plant, the Tokyo Electric Power Company (TEPCO), had completely discounted the possibility that such a tsunami might cause a nuclear accident on the scale of the Fukushima accident.

This is evidenced by the 1990 Nuclear Safety Commission guideline, the "Safety Guideline for the Plants Operating Light Water Electric Generators." Guideline 27 in that publication states, "It is unnecessary to take into account a long-term loss of all AC power supply (blackout) because the restart of power cables and the repair of emergency alternating-current electricity generators can be expected" (translated by the authors). Emergency diesel electric generators were placed in the basement of the Fukushima facility. As soon as the tsunami hit the plant, most of the emergency generators were submerged in sea water or swept away by the tsunami; most electric facilities, pumps, fuel tanks, and emergency batteries were severely damaged. This made it impossible to cool the nuclear reactors and the spent fuel rods, which resulted in the meltdown of the reactors and the explosions of the building containing the reactors.

MODEL

We focus on a game between an information sender and an information receiver (Ms. Sender and Mr. Receiver). As is noted at the outset, people were informed of a bad accident during an early stage of the Fukushima accident; the extremely bad state of the accident was acknowledged much later by the government. Building the simplest possible framework, this study explains such partial withholding of information by the correlation between nonidiosyncratic and idiosyncratic events. Table 1 summarizes the major variables.

As is discussed in the Introduction, we define nonidiosyncratic events, $s\in S$, as events affecting the receiver's state-contingent payoff, $u(s,x)$, which depends on the receiver's action, $x\geq 0$. In order to capture the partial revelation of information of nonidiosyncratic events, we need at least three nonidiosyncratic events, $S=\{0,1,2\}$, where states 0, 1, and 2 may be thought of as normal, bad, and the worst events. Idiosyncratic events, $c\in C$, are those that do not affect the payoff function, $u(s,x)$, but are correlated to the nonidiosyncratic events, s. Assume that there are only two idiosyncratic events, $C=\{0,1\}$.

In the context of the Fukushima accident, we may interpret s as the scale of the accident and c as the government's capability to handle the accident. In order to characterize the correlation between s and c, it is convenient to introduce a *fundamental state of nature*, $\omega\in\Omega=\{1,2\}$ that, together with the government's capability, c, determines an accident scale, $s=\omega-c\in S$.

This is based on our observation that an extreme accident usually has multiple causes. In the Fukushima accident, the fundamental state of nature, ω, captures *beyond-human factors*, including the tsunami, whereas c can be thought of as representing *human factors*, including the government's capability. If, for example, $\omega=2$ and $c=0$, the beyond-human factor, ω, is large, whereas the government's capability, c, is low, in which case the accident scale is the worst, $s=2$. While this interpretation is natural in the context of nuclear accidents, the correlation between s and c may be directly assumed in order to interpret the model in different contexts. Although beyond-human and human factors may appear to be distinguished by physical features, a

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more economically established criterion is the Hand rule, which is cost based.[10]

Denote as $\mathbf{p}_S$ the information receiver's belief on nonidiosyncratic events, s. The receiver determines his action, x, so as to maximize his expected payoff, $E_{\mathbf{p}_S}(u(s,x))$, where $E_{\mathbf{p}}$ denotes the operator taking an expected value with respect to probability distribution, $\mathbf{p}$. The receiver's *optimal action* is

$$x(\mathbf{p}_S) = \arg\max_x E_{\mathbf{p}_S}(u(s,x)). \tag{1}$$

In the context of the Fukushima accident, x is the receiver's self-protective effort. We adopt the following specific form for a payoff function.

$$u(s,x) = -\left[(2s-x)^2 + \psi s\right] - x^2. \tag{2}$$

This implies that the larger s, the smaller u; thus, we call $s=0$, 1, and 2 normal, bad, and the worst events, respectively, for the receiver. The first term, $(2s-x)^2+\psi s$, may be thought of as representing the receiver's damage from the accident, which can be reduced by choosing $0<x<2s$; the second term, x^2, represents the cost of self-protection effort. With no self-protection effort ($x=0$), the damage from the accident, $4s^2+\psi s$, increases in the scale of accident.[11]

Denote as $\mathbf{p}_C$ the information receiver's belief on idiosyncratic events, c. This belief, $\mathbf{p}_C$, determines the receiver's evaluation on the sender, $t=t(\mathbf{p}_C)$. In the context of the Fukushima context, $t=t(\mathbf{p}_C)$ may be thought of as the public's trust in the government. We assume that this evaluation is assumed to be equal to the expected value of idiosyncratic events,

$$t(\mathbf{p}_C) = E_{\mathbf{p}_C}(c). \tag{3}$$

Because $c=0,1$, Equation 3 guarantees t is increasing in $\mathbf{p}_C(1)$. In modeling the Fukushima accident, we assume a single information receiver with a state-contingent payoff function, $u(s,x)$, and the evaluation of idiosyncratic belief, $t(\mathbf{p}_C)$. As we discuss later, it is possible to think of the case in which $u(s,x)$ and $t(\mathbf{p}_C)$ are held by two different individuals, each of whom knows the other receiver's belief.

We use the term *ex ante* to refer to the state before the events become known and *ex post* to refer to the state after the events. It may be shown that the model has no *ex ante* bias under the following assumption. Under this assumption, it may be shown that there is no ex ante action bias. Since $s=\omega-c$, we may think of $\Theta = C\times\Omega$ as the *state space* in our model. Denote as $\mathbf{p}_\Theta$ a probability distribution on Θ. The receiver initially holds a prior belief on, $\mathbf{p}^o_\Theta$. This gives rise to his prior beliefs on nonidiosyncratic and idiosyncratic events, $\mathbf{p}^o_S$ and $\mathbf{p}^o_C$, the latter of which determines the receiver's prior evaluation of the sender, $t^o = t(\mathbf{p}^o_C)$.[12] Once nonidiosyncratic and idiosyncratic events, s and c, are realized, they are known to the sender. With this knowledge, the sender will select a message m to convey information on the events, by which the receiver will update his belief. Denote as $\mathbf{p}_S(\cdot|m)$ and $\mathbf{p}_C(\cdot|m)$, respectively, the updated beliefs on nonidiosyncratic and idiosyncratic events when the receiver receives message m.

The sender's payoff is determined by a weighted sum of the receiver's payoff, u, and his evaluation of the sender, t. Because the sender knows the realized events, s and c, her ex post payoff when she sends message m is

$$v = hu(s,x(\mathbf{p}_S(\cdot|m)) + kt(\mathbf{p}_C(\cdot|m)). \tag{4}$$

In this expression, the first term on the right-hand side (hu) may be called a nonidiosyncratic term, which depends on the receiver's nonidiosyncratic belief, $\mathbf{p}_S(\cdot|m)$. The second term (kt) may be called an idiosyncratic term, which depends on the receiver's idiosyncratic belief, $\mathbf{p}_C(\cdot|m)$. Parameters $h\geq 0$ and $k\geq 0$, respectively, capture the strength of the sender's nonidiosyncratic and idiosyncratic concerns.

In what follows, we will characterize an equilibrium in the above model by means of the information receiver's prior evaluation of the sender, t^o, and the sender's relative idiosyncratic concern, k/h. In our game, the sender, observing state θ, selects a message, m, with a probability $\mathbf{q}(m|\theta)$. This probability is specified by a probability measure $\mathbf{q}(\cdot|\theta)$ on the space of messages, M (*message space*), and is called a *messaging rule.* The sender chooses her messaging rule $\mathbf{q}(\cdot|\theta)$ in the following manner: (1) Without knowing the realized state of nature, θ, the receiver holds a prior belief on the state of nature, $\mathbf{p}^o_\Theta$. Once a message m is received, the receiver updates this belief by the Bayes rule to form a posterior belief, $\mathbf{p}_\Theta(\cdot|m)$, which determines the receiver's posterior beliefs on accident scale, $\mathbf{p}_S(\cdot|m)$, and on the sender's capability, $\mathbf{p}_C(\cdot|m)$. (2) The receiver will choose his action x based on the posterior belief on accident scale, $\mathbf{p}_S$, $x=x(\mathbf{p}_S(\cdot|m))$. (3) The sender believes that the receiver holds the posterior belief, $\mathbf{p}_\Theta(\cdot|m)$.

In this updating process, the receiver does not know the realized state of nature, θ, but knows that the collection of messaging rules from which the sender selects a message in each possible state of nature. We call this collection, $\mathbf{q}=\{\mathbf{q}(\cdot|\theta):\theta\in\Theta\}$, a *messaging strategy.* Knowing a message m and a messaging strategy $\mathbf{q}$, the receiver updates his prior belief by the *Bayes rule.* To define this, let

$$\Theta(s) = \{\theta\in\Theta:\theta=(\omega,c),\omega-c=s\} \tag{5}$$

[10] This criterion is based on the cost-benefit analysis. If the social benefit from investing in accident avoidance is larger than its cost, the accident is attributed to a human mistake; if not it is considered to be an act of God. See Posner (2014).

[11] This payoff function is adopted so as to guarantee that the larger scale of accident the nonelite expects, the larger the optimal self-protection effort—that is, for all s, $\arg\max_x u(s,x)=s$.

[12] Note that the terms "prior" and "posterior" refer to the states before and after, respectively, the nonelite receives a message from the elite whereas the terms *ex ante* and *ex post* refer to those before and after, respectively, an accident occurs.

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and

$$\Theta_c = \{\, \theta \in \Theta : \theta = (\omega,\, \mathrm{c}), \omega \in \Omega \}. \tag{6}$$

By the Bayes rule, the *Bayes updated beliefs* are given as follows:

$$\mathbf{p}_S^{\mathbf{q}}(s|m) = \frac{\sum_{\theta \in \Theta(s)} \mathbf{q}(m|\theta)\mathbf{p}_\Theta^o(\theta)}{\sum_{\theta \in \Theta} \mathbf{q}(m|\theta)\mathbf{p}_\Theta^o(\theta)} \tag{7}$$

and

$$\mathbf{p}_C^{\mathbf{q}}(c|m) = \frac{\sum_{\theta \in \Theta_c} \mathbf{q}(m|\theta)\mathbf{p}_\Theta^o(\theta)}{\sum_{\theta \in \Theta} \mathbf{q}(m|\theta)\mathbf{p}_\Theta^o(\theta)}. \tag{8}$$

With these updated beliefs, the sender chooses her optimal messaging rule for the realized state of nature, θ,

$$\mathbf{q}(\cdot|\theta) = \arg\max_{\mathbf{q}'(\cdot|\theta)} E_{\mathbf{q}'(\cdot|\theta)}(v^{\mathbf{q}}(s_i, m)), \tag{9}$$

where

$$v^{\mathbf{q}}(s_i, m) = hu(s_i, x(\mathbf{p}^{\mathbf{q}}{}_S(\cdot|m)) + kt(\mathbf{p}^{\mathbf{q}}{}_C(\cdot|m)), \tag{10}$$

$s(\theta) = \omega - c$ and $(c, \omega) = \theta$.

A *perfect Bayesian equilibrium* is defined as a messaging strategy $\mathbf{q}$ satisfying (9) with the receiver's state-contingent payoff, $v^{\mathbf{q}}(s_i, m)$, determined by the receiver's updates beliefs, $\mathbf{p}_S^{\mathbf{q}}(\cdot|m)$ and $\mathbf{p}_C^{\mathbf{q}}(\cdot|m)$, $m \in M$, such that if $\sum_\Theta \mathbf{q}(m|\theta)\mathbf{p}_\Theta^o(\theta)\, d\theta > 0$, $\mathbf{p}_S^{\mathbf{q}}(\cdot|m)$ and $\mathbf{p}_C^{\mathbf{q}}(\cdot|m)$ are Bayes-consistent (*or satisfy* Equations 7 and 8). In our model, there is an equilibrium in which the space of accident scales S is partitioned and in which the receiver can identify for sure the element of the partition to which the realized state of nature belongs. We call such an equilibrium a pure-messaging strategy equilibrium.

Three types of pure-messaging strategies can be thought of:

Single-state-revealing Messaging Strategy: This is a messaging strategy in which the receiver either knows or does not know that a particular state of an accident, s, is realized. That is, a messaging strategy, $\mathbf{q}$, is s-revealing if the following is satisfied:

(i) There is $m \in M$ such that $\mathbf{q}(m|\theta) = 1$ for any $\theta \in \Theta(s)$.

(ii) Let $\{s', s''\} = S \setminus \{s\}$. There is $m \in M$ such that $\mathbf{q}(m|\theta) = 1$ for any $\theta \in \Theta(s') \cup \Theta(s'')$ and $\mathbf{q}(m|\theta) = 0$ for any $\theta \in \Theta(s)$.

Totally Uninformative Messaging Strategy: This is a messaging strategy that conveys no information on the scale of the accident, s. That is, a messaging strategy, $\mathbf{q}$, is totally uninformative if the following is satisfied:

(i) There is $m \in M$ such that $\mathbf{q}(m|\theta) = 1$ for any $\theta \in \Theta(s)$ and $s \in S$.

Fully Revealing Messaging Strategy: This is a messaging strategy from which the receiver can identify the exact scale of an accident no matter which state is realized. That is, a messaging strategy, $\mathbf{q}$, is fully revealing if the following is satisfied:

(i) For each $s \in S$, there is $m \in M$ such that $\mathbf{q}(m|\theta) = 1$ for any $\theta \in \Theta(s)$.

(ii) If $\mathbf{q}(m|\theta) = 1$ and $\theta \in \Theta(s)$, $\mathbf{q}(m|\theta') = 0$ for $\theta' \in \Theta(s')$ and $s' \neq s$.

The basic insight that this study reveals is as follows:

Proposition 1 *If an information sender's idiosyncratic concern is too strong relative to her nonidiosyncratic concern (or if k/h is sufficiently large), communication with the receiver becomes vague.*

An intuition behind this proposition may be explained by focusing on the cases of $h = 0$. If $k > h = 0$, the sender chooses a message purely for her own benefit. Then, she chooses a message that conveys the least serious accident has occurred no matter which state is realized, thereby establishing a totally uninformative equilibrium. (If, instead, $h > k = 0$, the sender's objective function is perfectly aligned with that of the receiver, in which case the sender's optimal choice is to fully reveal information.)

EQUILIBRIA

As is discussed in the previous section, the government sent at the beginning of the Fukushima accident a clear message that a bad accident had occurred. However, the public was not informed of how bad the accident was. This state may be captured by the s_0-revealing messaging strategy together with s_2 being the realized event. Here, we characterize this strategy as well as other types of messaging strategies in equilibrium.

Theorem 1 *An s_0-revealing pure-messaging strategy is in a perfect Bayesian equilibrium if and only if*

$$\frac{k}{h} \leq \frac{3 - 2t^o}{(1-t^o)(2-t^o)}. \tag{11}$$

Proof. Only if part: Suppose that an s_0-revealing pure-messaging strategy $\mathbf{q}$ is in a perfect Bayesian equilibrium. For a realized state s_i, there is m_i such that $\mathbf{q}(m_i|\theta) = 1$ and $\theta \in \Theta(s_i)$. Receiving m_1, the receiver will form updated beliefs, $\mathbf{p}_C^{\mathbf{q}}(1|m_1) = \frac{t^o}{2-t^o}$, $\mathbf{p}_S^{\mathbf{q}}(1|m_1) = \frac{1}{2-t^o}$ and $\mathbf{p}_S^{\mathbf{q}}(2|m_1) = \frac{1-t^o}{2-t^o}$. This implies $x\left(\mathbf{p}_S^{\mathbf{q}}(\cdot|m_1)\right) = \frac{3-2t^o}{2-t^o}$. Then, the sender's payoff will be

$$v^{\mathbf{q}}(s_1, m_1) = -h\frac{\left(6 - 8t^o + 3(t^o)^2\right)}{(2-t^o)^2} + k\frac{t^o}{2-t^o}. \tag{12}$$

Let $m_0 \in M$ be such that $\mathbf{q}(m_0|\theta) = 1$ and $\theta \in \Theta(s_0)$. Receiving this message, m_0, the receiver will form updated beliefs, $\mathbf{p}_C^{\mathbf{q}}(1|m_0) = 1$ and $\mathbf{p}_S^{\mathbf{q}}(0|m_0) = 1$. Since this implies $x\left(p_S^{\mathbf{q}}(\cdot|m)\right) = 1$,

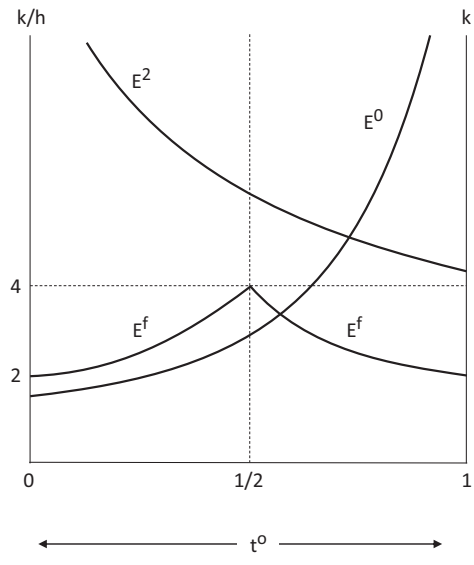
$$v^{\mathbf{q}}(s_1, m_0) = -4h + k. \tag{13}$$

Thus, $v^{\mathbf{q}}(s_1, m_1) > v^{\mathbf{q}}(s_1, m_0)$ if and only if Equation 11 holds.

If part: Let be an s_0-revealing pure-messaging strategy. Then, for each $s_i \in S$, there is m_i such that $\mathbf{q}(m_i|\theta) = 1$

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FIGURE 1. Perfect Bayesian Equilibria



and $\theta \in \Theta(s_i)$. For m such that $\sum_{\Theta} \mathbf{q}(m|\theta)\mathbf{p}^o_\Theta(\theta)\mathrm{d}\theta = 0$, choose $\left(\mathbf{p}^{\mathbf{q}}_S(\cdot|m), \mathbf{p}^{\mathbf{q}}_C(\cdot|m)\right) = \left(\mathbf{p}^{\mathbf{q}}_S(\cdot|m_1), \mathbf{p}^{\mathbf{q}}_C(\cdot|m_1)\right)$. Then, by Equation 10, $v^{\mathbf{q}}(s_i, m_i) \geq v^{\mathbf{q}}(s_i, m)$, which implies Equation 9.

Theorem 2 *An s_2-revealing messaging strategy is in a perfect Bayesian equilibrium if and only if*

$$\frac{k}{h} \leq \frac{(2t^o+1)^2}{t^o(1+t^o)}. \tag{14}$$

Theorem 3 *A fully informative messaging strategy is a perfect Bayesian equilibrium if and only if*

$$\frac{k}{h} \leq min\left\{\frac{2}{t^o}, \frac{2}{1-t^o}\right\}.^{13} \tag{15}$$

In Figure 1, we illustrate the region of parameters in which each type of equilibrium emerges. Curves E^0, E^2, and E^f, respectively, illustrate the boundaries of Equations 11, 14, and 15. If the idiosyncratic concern is sufficiently strong relative to the nonidiosyncratic concern (i.e., if k/h is sufficiently large), by the above theorems, information is withheld completely.[14] Theorems 1 and 2 show that a partially informative equilibrium, either s_0-revealing or s_2-revealing, is uniquely determined between above curve E^f and below (the higher of) curves E^0 and E^2.

[13] A fully revealing equilibrium in this sense requires only that the accident scales, s, are fully separated from each other. In this respect, it is somewhat nonstandard; the standard sense of full revelation requires all the information that the sender possess is conveyed (θ = (c, w)).

[14] There are equilibria that are not outcome equivalent to those in our study. However, they can be eliminated by the neologism proof refinement (Farrel 1993).

In order to explain the role of prior trust t^o, we focus on the idiosyncratic term $(t(\mathbf{p}_C))$ in the sender's payoff function, given in Equation 4. For this purpose, we first calculate the conditional probabilities on the sender's capability, C,

$$\begin{aligned} &\mathbf{p}^o_C(1|s_2) = 0; \\ &\mathbf{p}^o_C(1|s_1) = \mathbf{p}^o_C(1); \\ &\mathbf{p}^o_C(1|s_0) = 1. \end{aligned} \tag{16}$$

In our model, the sender's idiosyncratic term satisfies $t(\mathbf{p}_C) = E_{\mathbf{p}_C}(c) = \mathbf{p}_C(1)$. When s_2 is realized, by Equation 16, the sender's idiosyncratic gain from understating the accident scale by one level is

$$\begin{aligned} G_2 &= t\left(\mathbf{p}^o_C(\cdot|s_1)\right) - t\left(\mathbf{p}^o_C(\cdot|s_2)\right) \\ &= t^o > 0. \end{aligned} \tag{17}$$

When s_1 is realized, it is

$$\begin{aligned} G_1 &= t\left(\mathbf{p}^o_C(\cdot|s_0)\right) - t\left(\mathbf{p}^o_C(\cdot|s_1)\right) \\ &= 1 - t^o > 0. \end{aligned} \tag{18}$$

Gains $G_2 > 0$ and $G_1 > 0$, respectively, capture the sender's "idiosyncratic gains" from telling a lie in the case in which states s_2 and s_1 are realized. In order for the fully revealing equilibrium to be supported, those idiosyncratic gains must be smaller than the "nonidiosyncratic costs" of misguiding the receiver (i.e., a reduction in u). Curve E^f shows the upper bound for k/h, supporting this equilibrium.

As Equation 17 shows, the larger t^o, the larger the "idiosyncratic gain" in event s_2 from understating the accident scale. This is reflected in the downward-sloping part of curve E^f—that is, the region of k/h supporting the fully revealing equilibrium becomes narrower as t^o increases. As Equation 18 shows, the smaller t^o, the larger the "idiosyncratic gain" in state s_1 from understating the accident scale. This is reflected in the upward-sloping part of E^f; the region of k/h supporting the fully revealing equilibrium becomes narrower as t^o decreases. This explains why curve E^f is single peaked.

The s_0-revealing and s_2-revealing equilibria can be explained in a similar manner. If s_2 is realized in the s_2-revealing equilibrium, we may prove that the sender's "idiosyncratic gain" from understating the accident scale is

$$\begin{aligned} G_{s_2} &= t\left(\mathbf{p}^o_C(\cdot|s_0 \cup s_1)\right) - t\left(\mathbf{p}^o_C(\cdot|s_2)\right) \\ &= \frac{2t^o}{1+t^o} - 0. \end{aligned} \tag{19}$$

In contrast, if either s_1 or s_2 is realized in the s_0-revealing equilibrium, the sender's "idiosyncratic gain" is

$$\begin{aligned} G_{\{s_1,s_2\}} &= t\left(\mathbf{p}^o_C(\cdot|s_0)\right) - t\left(\mathbf{p}^o_C(\cdot|s_1 \cup s_2)\right) \\ &= 1 - \frac{t^o}{2-t^o}. \end{aligned} \tag{20}$$

The s_0-revealing and s_1-revealing equilibria can be supported if the "idiosyncratic gains" are smaller than the "nonidiosyncratic costs" of misguiding the receiver. Curves E^2 and E^0 show the upper bounds for

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k/h supporting these two equilibria, respectively. Equation 19 shows that as t^o approaches 0, the "idiosyncratic gain" from understating the accident scale in event s_2 in the s_2-revealing equilibrium approaches 0. This is behind the downward-sloping curve E^2, which shows that the region of k/h supporting the s_2-revealing equilibrium becomes wider and wider to infinity as t^o decreases to 0. In contrast, Equation 20 shows that if t^o approaches 1, the "idiosyncratic gain" from the understatement in event $\{s_1, s_2\}$ in the s_0-revealing equilibrium approaches 0. This is reflected in the upward-sloping part of E^0, which shows that the region of k/h supporting the s_0-revealing equilibrium becomes wider and wider to infinity as t^o increases to 1. This explains why curve E^0 is upward-sloping.[15]

Our main result, summarized below, gives complete characterizations for unique informative and uninformative equilibria. In order to state the result, we say that an equilibrium is informative if it is not totally uninformative and that it is uninformative if it is not fully revealing.

Proposition 2 Let $t^o \neq 1/2$, $A = \frac{(2t^o+1)^2}{t^o(1+t^o)}$, $B = \frac{3-2t^o}{(1-t^o)(2-t^o)}$, *and* $C = \min\left\{\frac{2}{t^o}, \frac{2}{1-t^o}\right\}$.[16]

1. *An s_0-revealing messaging strategy is a unique informative (pure-messaging) perfect Bayesian equilibrium if and only if*

$$A < \frac{k}{h} \leq B. \tag{21}$$

2. *An s_2-revealing messaging strategy is a unique informative (pure-messaging) perfect Bayesian equilibrium if and only if*

$$\max\{C, B\} < \frac{k}{h} \leq A. \tag{22}$$

   a. *A totally uninformative messaging strategy equilibrium is a unique uninformative equilibrium if and only if* $\frac{k}{h} > \max\{A, B\}$.

Proof. If $t^o \neq 1/2$, an s_1-revealing equilibrium does not exist for any value of k/h; this follows from the single crossing property. (In order to make a formal proof, let $\mathbf{q}$ be an s_1-revealing pure-messaging rule. There are $m \in M$ and $m_1 \in M$ such that $\mathbf{q}(m|\theta) = 1$ for any $\theta \in \Theta(s_0) \cup \Theta(s_2)$ and $\mathbf{q}(m_1|\theta) = 1$ for any $\theta \in \Theta(s_1)$. If $t_0 \neq 1/2$, $x\left(\mathbf{p}_S^{\mathbf{q}}(\cdot|m)\right) \neq x\left(\mathbf{p}_S^{\mathbf{q}}(\cdot|m_1)\right)$. Let $x\left(\mathbf{p}_S^{\mathbf{q}}(\cdot|m)\right) > x\left(\mathbf{p}_S^{\mathbf{q}}(\cdot|m_1)\right)$. By the definition of an equilibrium,

$$h\left\{u\left(s, x\left(\mathbf{p}_S^{\mathbf{q}}(\cdot|m)\right)\right) - u\left(s_0, x\left(\mathbf{p}_S^{\mathbf{q}}(\cdot|m_1)\right)\right)\right\} \geq k\left\{t\left(\mathbf{p}_C^{\mathbf{q}}(\cdot|m_1)\right) - t\left(\mathbf{p}_C^{\mathbf{q}}(\cdot|m)\right)\right\}$$

for $s = s_0$. Since $u_{12} > 0$, this must hold with strict inequality for all $s > s_0$. This contradicts

$$h\left\{u\left(s_1, x\left(\mathbf{p}_S^{\mathbf{q}}(\cdot|m)\right)\right) - u\left(s_1, x\left(\mathbf{p}_S^{\mathbf{q}}(\cdot|m_1)\right)\right)\right\} \geq k\left\{t\left(\mathbf{p}_C^{\mathbf{q}}(\cdot|m_1)\right) - t\left(\mathbf{p}_C^{\mathbf{q}}(\cdot|m)\right)\right\}$$

The case of $x\left(\mathbf{p}_S^{\mathbf{q}}(\cdot|m)\right) < x\left(\mathbf{p}_S^{\mathbf{q}}(\cdot|m_1)\right)$ can be proved in much the same way.

REAL-WORLD APPLICATIONS

Our model captures two major determinants for the pattern of communication: a receiver's prior observation on the sender's idiosyncratic characteristic, t^o, and the relative intensity between idiosyncratic and non-idiosyncratic concerns of the sender, k/h.

Since the middle of the last century, organizations and institutions with private information have been asked to align their decision criteria closer and closer with those of information receivers. As is explained with Equation 4, this may be thought of as a general consensus to reduce $k/h \geq 0$. This change has taken place in many parts of society; it is reflected in the tightening of disclosure requirements in the government, the increasing emphasis on corporate social responsibility in the private sector, and the tendency towards independence (from the government) of central banks. Although this change has contributed to rendering information more transparent, the information sender's decision criterion has not yet been aligned completely to that of the receiver (that is, k/h is still unignorable). The Fukushima accident may be explained in this context.

Various Types of Nuclear Accidents

A. s_0*-revealing type:*

In the s_0-revealing equilibrium, only the least damaging event (s_0) is revealed. This occurs when the information receiver's idiosyncratic evaluation of the sender (t^o) is sufficiently high at the same time that the sender's idiosyncratic concern (k/h) is not too small and not too large. As is shown below, this theoretical prediction is consistent with the Fukushima accident.

Two important changes occurred in Japan from the last century to this century. The first is the significant increase in people's trust in the government's capability in handling nuclear power, (t^o). During the latter half of the 20th century, people's trust in the government's capability in handling nuclear energy generation (t^o) was low. This reflects the country's disastrous defeat in the WWII and the nuclear bombing of Hiroshima and Nagasaki at the end of the war.

This atmosphere changed during the 2000s. According to Iwai and Shishido (2015, 177), the percentage of people who worried about the danger of nuclear power plants decreased from 68% in 1999 to 56% in 2009. They explain, "The reasons for feeling safe . . . included 40% of people saying Japan has a satisfactory history in nuclear power generation, 36% saying Japan's nuclear power generation is safe, 33% saying that they trust the

[15] In the s_0-revealing equilibrium, it may be demonstrated that the nonidiosyncratic cost of insufficient self-protection from overstating safety when s_1 is realized, $v^{\mathbf{q}}(s_1, m_1) - v^{\mathbf{q}}(s_1, m_0)$, is increasing in t_0. Together with the above explanations, this explains the upward sloping shape of E^0. In much the same way as this, we may explain that E^2 is downward sloping.

[16] If $t^o = 1/2$, there is an s_1-revealing equilibrium regardless of k/h. In this equilibrium, both players receive the equilibrium payoffs that are equal to those in a totally uninformative equilibrium.

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government." The Cabinet Bureau (2012) reports that in 2009 60% of people were in favor of increasing Japan's reliance on nuclear energy. This shows that t^o was much higher around the time of the Fukushima accident than before.[17]

Another important change is the Japanese government's policy reversal on nuclear accidents from secrecy to transparency, or a reduction in k/h. In 2001, Japan adopted the Information Disclosure Law. Perhaps prompted by this law, in March 2007, the government took the initiative to reveal 20 relatively minor accidents that took place between 1978 and 2006 and had been hidden completely.[18]

On one hand, this change has made k/h be too low to support the totally uninformative equilibrium after 2007. In fact, the two subsequent minor accidents before the 2011 Fukushima accident were fully revealed. One is the Kashiwazaki-Kariwa nuclear power plant accident (level-0) caused by the 6.8-magnitude earthquake on that day in the Niigata region on July 16, 2007. The other is at the Fukushima Daiichi plant on June 17, 2010. The 2007 accident was quickly reported throughout the world (Fackler 2007); the 2010 accident was immediately acknowledged by the operator of the plant (TEPCO 2010).

On the other hand, the reduction in k/h was not sufficient to support the fully informative equilibrium, as is suggested by the Fukushima accident. Looking at the recent coronavirus outbreak, moreover, international observers continue to hold the view that, even today, the Japanese government is inclined to withhold vital information from the public (Dooley, Rich, and Inoue 2020).

All these facts support that the Fukushima accident was in the s_0-revealing equilibrium. Another possible s_0-revealing equilibrium is the Chernobyl accident in 1986. Although the Soviet government initially tried to hide the accident, it was soon publicly acknowledged. This reflects President Gorbachev's glasnost (openness) policy, which reduced k/h significantly. At the same time, President Gorbachev was receiving rather high public trust for his perestroika (reform), which suggests that t^o was relatively high (Higginbotham 2019).

B. s_2*-revealing type:*

In the s_2-revealing equilibria, only the most damaging event (s_2) is revealed. This occurs when the information receiver's idiosyncratic evaluation of the sender (t^o) is low. The Three Mile Island accident and the series of accidents at Japanese nuclear plants between the 1970s through the middle of the 2000s may be described by this equilibrium.

Within 30 minutes of the accident, the station manager at the Three Mile Island plant announced a general emergency. The accident was severe (level 5), which can be identified with s_2.

In the nuclear industry at the time, a highly secretive atmosphere was surrounding less severe accidents and problems. For example, a *CNN* article (Cooke 2011) points out "[i]n most countries, the global community has few ways of knowing what really goes on inside nuclear reactors because the industry is shrouded in secrecy." This is clearly evidenced by the halted construction of the William H. Zimmer Power Station in 1982. Since a very early stage of construction, according to a *Cincinnati Magazine* article (Keiger, 1983), the Zimmer Station had suffered from serious structural flaws, which had been ignored by early investigations. In the end, those flaws were found to be unfixable, and the construction was halted after a large sum of investments. These facts, together with the Three Mile Island accident, suggest that the information flows in the nuclear industry at that time can be described by an s_2-revealing messaging strategy.

During the late 1970s, the American public's trust in the government (t^o) was extremely low. The accident occurred right after the anti-Vietnam War movements, as symbolized by the Kent State shooting by the Ohio National Guard in 1970, the Watergate scandal during the period 1972 through 1974, and the loss of the Vietnam War in 1975 (Dalton 2005).

At the same time, the government intended to align its decision criterion with that of the public—that is, to reduce k/h. This is evidenced by the Freedom of Information Act of 1966. This law contributed to the revelation of various pieces of classified information; under this law, for example, the classified information on two major nuclear accidents in the 1950s was made public (Grober and Glasser 2020; Lewis 2019). In the 1970s, moreover, several whistle-blowers started to reveal less serious nuclear safety problems in the US, some of which had existed since the 1950s (Burnham 1976; New York Times 1979). Those whistle-blower cases as well as the Zimmer incidence evidence that k/h was not low enough to support a fully informative equilibrium during the late 1970s. All of these facts are consistent with the view that the U.S. nuclear industry was in the s_2-revealing equilibrium.

In Japan, as is noted above, 20 nuclear accidents were completely hidden between 1978 through 2006. During the same period, eight relatively serious nuclear accidents were reported immediately. The most severe was the 1999 Tokaimura accident, in which two workers died (level 4). There were one level-3 accident in 1997, four level-2 accidents, one level-1 accident in 1995, and one level-0+ accident in 2004, in which five workers died. The 20 less serious accidents were completely hidden, in addition.

[17] The public's high assessment on the government capability itself may be attributable to an informational bias that existed long before the Fukushima accident. Recently, it has been reported that in 2007 and 2009, the IAEA informed TEPCO and the government that "a magnitude-8.3 earthquake off the coast of Fukushima could lead to tsunami of around 15 meters, . . . , inundating the buildings." The IAEA further reports that TEPCO, as well as the government, failed to take a necessary measure against such a tsunami (Kyodo News, May 25, 2015; see also Muccury [*Guardian*, June 11, 2015]). At the time of the accident, the public was unaware of these facts and generally under the impression that both the government and TEPCO were skillfully managing the power plant. In order to explain this, we may incorporate a state in which nothing occurs.

[18] For a list of those accidents, see Japan Bar Association (2007).

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This state of the Japanese nuclear industry may be described by an s_2-revealing messaging strategy if we reinterpret s_0 as the state in which nothing occurs. The eight major accidents that were publicly acknowledged at the time of accident may be thought of as s_2. In contrast, the 20 hidden (and less serious) accidents were s_1. The state in which the government told nothing about these 20 accidents may be described by $\{s_0, s_1\}$.

As is noted above, people's trust in the government's capability in handling nuclear power (t^o) was rather low at that time. It was known that the 1973 Mihama plant accident was hidden and made public in 1976 by a whistle-blower.[19] People were thus well aware that minor accidents could occur and be hidden by the government and the industry; in other words, they were aware that they were in $\{s_0, s_1\}$ when no accident was reported. Until (and even after) the Fukushima accident, it had been one of the most important energy policies for the Japanese government to promote nuclear power generation.[20] Given this goal, it was highly important for the government to prove its capability in handling nuclear energy—that is, the government idiosyncratic concern on people's trust was high (k/h was high). At the same time, people's scrutiny over the government's performance was tight, and their demand for the government's aligning with its decision criterion to the public concern was strong (k/h was not too high). All these facts support that the Japanese nuclear industry was in the s_2-revealing equilibrium in the latter half of the 20th century.

C. Totally Uninformative Type:

During the first half of the twentieth century, it was often thought that a government could determine what was good for the public, in particular, during an emergency. During WWI, for example, President Wilson pushed the Sedition Act that prohibited people from acting against the government's war efforts. According to Barry (2017), this led public health officials to lie about the spread of Spanish flu, which worsened the outbreak. During the Cold War, a similar atmosphere prevailed in countries engaging in nuclear development, thereby suppressing information on accidents and safety issues.

One example is the Kyshtym accident. It took place in 1957 in Ural and is rated as level 6, next to Chernobyl and Fukushima. While local residents were affected, information was kept secret by the government until 1989 (Milne and Perera 1989). In the Western world, the accident was first reported by a dissident scientist Medvedev (1976), although details of the accident are still unknown (Lewis 2019). This state may be described by a totally uninformative messaging rule by interpreting, again, s_0 as event in which nothing occurs.

Proposition 2 shows that this messaging strategy is the unique uninformative equilibrium if, given a level of prior trust, t^o, $0 < t^o < 1$, k/h is sufficiently high. In those days, many people exiled from the Soviet Union, which suggests that the public's trust in the government could be rather low, $t^o << 1$. At the same time, trust was not too low, $t^o >> 0$, as is evidenced by the fact that the presidency of Nikita Khrushchev was based on the popularity of his policy on consumer and heavy industry (Breslauer 1982). He was, however, ousted in 1964 due to the loss of popularity for his handling of the Cuba crisis. This suggests that for the Soviet political leaders back then, the public's trust was a must for holding onto power—that is, k/h was high.

A similar totally uninformative equilibrium explains the nuclear accident in 1959 at the Santa Susana Field Laboratory near Los Angeles. Grober and Glasser (2020) explain that although it could be the worst nuclear accident in U.S. history, it was completely kept secret before a local TV network *KNBC* reported the accident in 1979. Information on the 1957 Windscale accident in England was withheld in a similar manner.[21] In the 1970s, several whistle-blowers started to reveal less serious nuclear safety problems in the U.S., some of which had existed since the 1950s. This suggests that minor problems were likely to have existed in the Soviet Union as well, if not publicly reported. This further supports the view that these early accidents can be described by the totally uninformative equilibrium.

Idiosyncratic Profit or Business Concern

A profit or business mandate is another type of idiosyncratic concern that may lead a private corporation or organization to withhold information vital for the safety or wellness of their customers, clients, and the community where the entity is located. A recent example relates to the two crashes of Boeing 737 MAX in 2018 and 2019. A major cause of the accidents was the malfunction of a flight sensor that led the computerized flight control to trigger a wrong flight path, which the pilots could not correct in time (Gates 2019).

A recent *New York Times* report points out that a 2009 Boeing 737 NG crash near the Amsterdam airport may have been caused by a similar autocontrol problem (Hamby 2020). According to the report, if information gathered through the accident investigation had been fully revealed at that time, the 2018 and 2019 crashes might never have occurred. Although the cause of the accident was attributed to pilots' errors by the Dutch investigators, "[d]ecisions by Boeing, including risky design choices and faulty safety assessments, also contributed to the accident . . . but the Dutch Safety Board either excluded or played down criticisms of the manufacturer in its final report after pushback from a team of Americans that included Boeing and federal safety officials."

[19] See Kono (2011); the author is a long-term lower diet member and is currently the Defense Minister of Japan.

[20] See the Atomic Energy Basic Act of 1955, which seeks to "secure energy resources in the future." For an English translation, see http://www.japaneselawtranslation.go.jp/law/detail/?vm=04&re=01&id=2233.

[21] Dwyer (2007).

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The report explains that during landing, in the 2009 accident, one of the two key flight sensors malfunctioned. This sensor sent data that contradicted the other sensor, which the pilots did recognize correctly. Because, however, Boeing's pilots' manual did not explain that these sensors were assigned to different tasks, the pilots may not have realized, until too late, that the autothrottle was controlled by the malfunctioning sensor. Although this possibility was pointed out at that time, it was not included in the report.

This state may be captured by an s_0-revealing messaging strategy. That is, the state in which no mechanical failure exists can be identified with s_0, that in which a mechanical failure is correctable by pilots with s_1, and that in which a mechanical failure is not correctable by pilots with s_2. Although the accident investigation concluded that s_1 was realized, it was mixed with s_2 to constitute $\{s_1,s_2\}$, which is pointed out by independent research.

Our model allows for the agent that holds an idiosyncratic belief to be different from one who holds a nonidiosyncratic belief. Airline companies form their nonidiosyncratic beliefs on the safety of an airplane (p_S) through their own evaluation of safety designs and safety records and, when choosing an airplane, they calculate their expected safety (payoffs for airlines) by those beliefs. At the same time, the market (general public) forms an idiosyncratic belief on the company's business or profit prospects $(\mathbf{p}_C)$, which gives rise to an idiosyncratic concern for the company (t). Our result shows that if a company has established too high a reputation as an airplane manufacturer (too high t^o) and if the business concern is too important for the manufacturer (too high k/h), vital information on the safety of an airplane may be withheld, thereby resulting in the s_0-revealing equilibrium.

There have been many similar incidences. For example, in 2009, leading cigarette companies were found to have lied to hide the danger of smoking" (Bartz 2009). Another example relates to the Minamata disease, a severe neurological disease caused by the release of methylmercury from the Chisso Corporation's chemical factory from 1932 to 1968. It affected more than two thousand people; it is well known that the company hid its failure to take proper safety precautions (Halloran 1973). Information withholding in these and many similar incidences of product defects and wrong production procedures can be explained by the idiosyncratic business concern that dominated the nonidiosyncratic safety concern of a company.[22]

Monetary Interventions

One application of our results is on monetary policy.[23] Until some 30 years ago, the central bank conducted its discretionary policy by "catching the market by surprise." Since then, the independence and transparency in policy of a central bank have been emphasized more and more. Despite this, however, the discretionary aspect of monetary policy still remains.

In order to explain the process of noise creation, think of the following three possible economic states. In the worst state (s_2), it is desirable for the central bank to intervene in the markets for long-term economic variables. In the best state (s_0), no central bank intervention is necessary; in this case, the bank just controls the flow of short-term funds. There is a mildly bad state in which it is desirable for the central bank to intervene in the markets for middle-term economic variables (s_1).

These states may be thought of as nonidiosyncratic events, which determine the private sector's nonidiosyncratic payoff function, $u(s,x)$. These events may be correlated to events that are concerned with the central bank's performance, which can be represented by a broad range of variables such as the past performance of the economy, that of monetary policy, the central bank governor's public relations skill, and so on. These variables may be thought of as idiosyncratic events, c.

The private sector holds its own future outlook, or a nonidiosyncratic belief, $(\mathbf{p}_S)$. It bases its own action on this outlook, $x(\mathbf{p}_S)$, and obtains its payoff, $u(s,x(\mathbf{p}_S))$. Politicians, as well as the general public, observe the central bank's performance and form their evaluations represented by $t(\mathbf{p}_C)$. The central bank may be concerned with the private sector's nonidiosyncratic payoff, $u(s,x(\mathbf{p}_S))$, and the evaluation of politicians and the general public, $t(\mathbf{p}_C)$.

In these circumstances, the model predicts that the larger t^o, the more likely the bank would mix s_1 and s_2. At the same time, it would reveal s_0. In other words, the central bank would create no noise in the market for short-term funds, whereas it would create a noise in the markets for middle- and long-term economic variables in states s_1 and s_2.

In contrast, the smaller t^o, the more likely the bank would mix s_1 with s_0. At the same time, it would reveal s_2. In other words, the central bank would create no noise in state s_2, or on long-term economic variables, whereas it would create a noise in the markets for short- and middle-term economic variables, thereby mixing s_0 and s_1.

These predictions of our model are consistent with Lustenberger and Rossi (2020). They investigate the effects of different types of central bank messages on the accuracy of private sector economists' forecasts on one short-term variable (short-term interest rate) and three longer-term economic variables (the yield on 10-year government bonds, the CPI inflation rate and the real GDP growth rate); as messaging devices, they adopt a number of central bank speeches, an index of central bank transparency, and the frequency of governor changes. Their estimations are based on a sample set covering 73 central banks in four major geographical regions: Western economies, Asia Pacific, Eastern Europe, and Latin America.

As is summarized in Table 2, a short-term noise (on short-term interest rate) is not created in the

[22] These results show that a private company's idiosyncratic profit or business concern could be a major factor to reduce the quality of market (Yano 2009).

[23] We are grateful to a referee of this journal for suggesting that our theory may be applied to information flows between central banks and the public.

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TABLE 2. Region-Wise Forecast Errors

		Short-term effects	⟷		Long-term effects
	Variable	Interest rate (Short-term)	Inflation (CPI)	Yields (10-year bonds)	Growth (Real GDP)
Western economies	Speech		++	++	
	Transparency			---	
	Turnover				
Asia Pacific	Speech		+++		
	Transparency				
	Turnover	++			
Eastern Europe	Speech				
	Transparency				
	Turnover	+			
Latin America	Speech			L[1]	
	Transparency		+	L[1]	
	Turnover	+		L[1]	

Note: Source: A Summary of Region-Wise Estimation Results (Lustenberger and Rossi 2020, Table 3). The variables are defined as follows: Speech is made up of central bank speeches as collected by the Bank for International Settlements, compiled by Lustenberger and Rossi (2020). Transparency is a comprehensive measure of central bank transparency presented by Dincer and Eichengreen (2014) and updated by Lustenberger and Rossi (2020). Turnover is actual turnover of the central bank's governor in a year, as described by Dreher, Sturm, and de Haan (2010). The symbols are defined as follows: +++ (- - -) indicates that the coefficient is positive (negative) and significant at the 99% level, ++ (- -) indicates the coefficient is positive (negative) and significant at the 95 % level, and + (-) indicates the coefficient is positive (negative) and significant at the 90 % level.
[1]Estimates not available.

Western economies, but it is in each of the other three regions. In contrast, a long-term noise (on returns on 10-year bonds) is created in the Western economies but not in the other three regions. These are consistent with the predictions of our model, provided that the public's trust in central bank is higher in the Western economies than in the rest of the regions.

Unfortunately, Lustenberger and Rossi (2020) do not include an independent variable that perfectly fits the image of a middle-term economic variable. Because, however, the CPI inflation rate reflects both short-term and long-term expectations on an economy than 10-year bonds, it may be interpreted as a middle-term economic variable. Under this interpretation, the results of Lustenberger and Rossi (2020) fit with our model's predictions for all the regions but Eastern Europe. That is, in the Western economies, where t^o can be assumed to be relatively high, noise is created in both s_1 and s_2. In the Asia Pacific and Latin American regions, where t^o may be assumed to be relatively low, noise is created in both s_1 and s_0.

CONCLUDING REMARKS

This study has shown that vague communication may be explained by the information sender's idiosyncratic concern. This may explain various real-world incidences, including a number of nuclear accidents, cover-ups of defective products, and even noises created by central banks.

Although it is too early to make a definitive analysis, our theory is also applicable to the 2020 coronavirus outbreaks. It is reported that in many countries, information flows on coronavirus outbreaks have been disturbed by various idiosyncratic concerns. In Italy, it is reported that national political leaders were too concerned about their economies at very early stages before the virus spread in respective countries. For that reason, the messages from leaders were not serious enough to convey the seriousness of the disease, which underprepared the public (see Horowitz, Bubola, and Povoledo 2020). A similar view is expressed on the Spanish outbreak (Ward 2020). This may be explained by the correlation between events relating to the nonidiosyncratic public safety (seriousness of the disease) and those relating to the idiosyncratic economic performance. A similar explanation may apply to the outbreaks in the UK and U.S. The Chinese government might have been concerned with its public image (Yang, Liu, Liu, and Yu 2020).

Post-reality politics may also be explained in our context. "Alternative facts" may appeal to a particular group of voters, whereas it may be completely idiosyncratic for other groups. If a political leader's message is interpreted in different ways by different groups of voters, post-reality politics may work.

In the report of the Independent Investigation Commission on the Fukushima Nuclear Accident (IICFNA 2014), the late Professor Koichi Kitazawa, the chairman of the IICFNA, perceives the Fukushima accident as a

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serious communication failure.[24] He urges, "it is essential that the government learns from the Fukushima accident—during which, at times, there were debilitating communication problems" (Kitazawa 2014).[25] He then continues, "Japan must work hard on constructing an organizational infrastructure to allow unfettered information sharing in times of crisis."[26] Our study shows that one way to build such an organizational infrastructure is to enhance a conscious effort to align the information sender's decision criterion with that of the receiver by reducing the sender's idiosyncratic concern. This effort may be assisted by introducing rules and proper systems of governance.

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[24] See Fukushima Genpatsu Jiko Dokuritsu Kensho Iinkai (2012) and the English version of the report (IICFNA 2014). The IICFNA is the civilian-led commission organized by the Rebuild Japan Initiative Foundation (RJIF). At least two more investigation commissions investigated the Fukushima accident. They were formed by the statutory law and the Japanese government.

[25] Koichi Kitazawa (1943–2014) was the president of Tokyo City University. Earlier, he served as the Executive Director of Japan Science and Technology Agency (JST).

[26] These quotations are not included in Kitazawa (2012) that appears in the Japanese version of the IICFNA report; see Fukushima Genpatsu Jiko Dokuritsu Kensho Iinkai 2012).

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