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Spinning the Facts against Genetically Engineered Foods?

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Abstract

A signaling game is developed in order to derive the equilibrium conditions under which special interest groups (SIGs) involved in the controversial debate over genetically engineered (GE) foods have the incentive to truthfully reveal their information or spin facts regarding the health impact of GE foods. Consumers can choose to inspect information provided by SIGs at a cost. The risk of spinning facts is much higher for pro-GE groups, because if it turns out that a certain GE food is unsafe, the penalty will be severe. However, anti-GE groups can still spin facts at low risk even if consumers choose to inspect. This helps explain why some pro-GE groups, particularly the biotech industry, tend to remain silent. Revealing information regarding the safety of GE foods could be counterproductive given pre-existing public skepticism. Consumers may not make "better" decisions with more information provided because more information increases their inspection costs. When it is costlier for consumers to inspect, it is more likely that anti-GE groups will continue to spin facts about the negative health impact of GE foods.

Keywords

Genetically Engineered Foods, Genetically Modified Organisms, GE Foods, GMOs, Non-GM, Biotech Crops, Bioengineered Foods, Health Economics, Signaling Game

1. Introduction

According to Food and Agriculture Organization (FAO) projections during the 2009 World Summit on Food Security, the world population will grow to 9.1 billion by 2050 and global food production will have to increase by 70 percent to meet increased demand (FAO, 2009). With more population, less land will be available for farming, and thus agricultural innovation and investment in new technology will be central to increasing global food production and food security. One of the major areas of research in agricultural innovation is the development of agricultural biotechnology that increases crop yield and crop resistance to pests, diseases, and extreme weather, thus reducing production costs and lowering food prices for consumers.

However, genetically engineered (GE) foods, which are also commonly referred to as genetically modified (GM) foods or bioengineered foods, have received broad opposition from the public, especially in developed countries. We use the term "GE" instead of the more common term "GM" in this paper, because genetic modification can occur naturally among plants such as in sweet potatoes which contain genes from the bacterium Agrobacterium (Kyndt et al., 2015) while genetic engineering is specifically an artificial process. In a 2010 consumer survey, Eurobarometer found that 59% of respondents from the EU-27 consider GE foods to be unsafe for human consumption. In 2003, the Japanese Ministry of Agriculture, Forestry and Fisheries (MAFF) conducted an internet survey of 600 consumers which found that 60% of respondents would not purchase GE foods even if these foods were priced cheaper than their non-GE equivalents. A 2015 Pew Research survey found that only 37% of US adults consider GE foods safe. In contrast, 88% of American Association for the Advancement of Science (AAAS) scientists considering GE foods generally safe (Funk & Lee, 2015). As of April 2020, over 64 countries require mandatory labeling of GE foods.

Major scientific organizations worldwide have made statements supporting the safety of GE foods (Green, 2014). Nicolia et al. (2014) reviewed over 1500 scientific papers on research conducted over the previous ten years and concluded that the scientific literature had not detected any significant health effects directly linked to the use of GE products. Panchin and Tuzhikov (2015) analyzed experimental data suggesting possible health hazards attributed to GE crops, but found no evidence of harm after correcting for multiple comparisons. Yet, opponents of GE foods argue that long-term health risks are still unknown based on available data. For example, one study concluded that:

"The results of most studies with GM foods indicate that they may cause some common toxic effects such as hepatic, pancreatic, renal, or reproductive effects and may alter the hematological, biochemical, and immunologic parameters. However, many years of research with animals and clinical trials are required for this assessment." (Dona & Arvanitoyannis, 2009: p. 164)

The public GE food debate is also intense, often involving a wide variety of claims made by various nongovernmental organizations. Graff, Hochman, and Zilberman argue that:

"Groups that stand to lose welfare from the introduction of biotech will, for instance, seek to provide consumers with bad news. Those who stand to gain will provide good news. Consumers weigh the evidence-filtered through the degree of trust and confidence they have in the group providing the evidence-to form their risk perceptions." (Graff, Hochman, & Zilberman, 2009: p. 41)

For example, on April 8, 2014, Collective-Evolution.com posted an article entitled "10 Scientific Studies Proving GMOs Can Be Harmful to Human Health" and listed ten concerns regarding the safety of GE foods (Walia, 2014):

1) Multiple toxins from GMOs detected in maternal and fetal blood. 2) DNA from genetically modified crops can be transferred into humans who eat them. 3) New study links GMOs to gluten disorders that affect 18 million Americans. 4) Study links genetically modified corn to rat tumors. 5) Glyphosate induces human breast cancer cells growth via estrogen receptors. 6) Glyphosate linked to birth defects. 7) Study links glyphosate to autism, Parkinson's and Alzheimer's. 8) Chronically ill humans have higher glyphosate levels than healthy humans. 9) Studies link GMO animal feed to severe stomach inflammation and enlarged uteri in pigs. 10) GMO risk assessment is based on very little scientific evidence in the sense that the testing methods recommended are not adequate to ensure safety.

In response, Katiraee (2015), through the Genetic Literacy Project (geneticliteracyproject.org), refuted each of the ten concerns and concluded that:

"Despite the title of the article, none of these studies proves or even persuasively suggests that GMOs can be harmful to human health. The majority are either obviously flawed or are not scientific studies. The current scientific consensus regarding GMOs remains unchanged: they are safe and do not pose a health risk to humans. However, a scientific consensus is subject to change if there is sufficient reproducible evidence that may impact it, but none of the studies reviewed here constitute such evidence." Katiraee (2015)

With conflicting and increasingly complex information originating from both the pro-GE and anti-GE sides, it is not surprising that many consumers choose not to base their sentiments regarding GE foods on scientific evidence. In a 2013 market study from the NPD Group (formerly called National Purchase Diary), over half of US consumers were found to be concerned about GMOs even though many were not able to accurately describe what they are (NPD Group, 2013).

In this paper we develop a signaling game that can help explain, for example, why there are far less advertisements by pro-GE SIGs who promote GE foods, such as large biotechnology corporations Monsanto and Dow Chemical Company. Under a wide range of assumptions, pro-GE groups' best strategy in this game is to reveal information truthfully. However, corporations such as Monsanto and Dow have been under public skepticism due to their "dark" history of political lobbying, cover-ups (Johnson, 2008), poisoning (Grunwald, 2002), etc. In this regard, even true messages they send could be counterproductive and keeping silent may be the best they can do.

The rest of this paper is organized as follows. First, we provide a brief review of the economic literature involving genetically engineered foods. Second, we describe the purpose of the upcoming analysis and discuss the overarching structure of the model. Next, we develop a signaling game to analyze the interaction among consumers, pro-GE special interest groups (SIGs) and anti-GE SIGs. We continue with a discussion of the resulting equilibria, which are summarized in a set of seven propositions that are derived in the **Appendix**. We follow up with further discussion and possible limitations. Finally, we provide conclusions and discuss the implications of our results.

2. Literature Review

Zilberman, Holland, and Trilnick summarize the issues surrounding the GE food debate as follows:

"GE has the potential to address some of the major challenges of our time, including food security, climate change adaptation, and environmental sustainability. It provides new tools and capacities to increase agricultural productivity, reduce its environmental footprint, feed growing populations in developing countries, and empower disadvantaged groups. At the same time, genetic engineering in agriculture has encountered fierce resistance by various ideological groups and powerful corporations and governments … This has led to a regulatory system that constrains the introduction of new varieties based on transgenic technologies, particularly in developing countries that would benefit most from them." (Zilberman, Holland, & Trilnick, 2018: p. 1)

The welfare of special interest groups (SIGs) including agricultural producers, food retailers, biotech innovators, agricultural input suppliers, and activist groups, is closely linked to the GE food debate. Several studies have attempted to ascertain the various causes of consumers' negative sentiment towards GE foods such as media bias, cognitive bias, and in-group bias. McCluskey, Kalaitzandonakes, and Swinnen (2015) found that consumers are more influenced by news that is bad rather than good. McFadden and Lusk (2015) suggest that consumers' adoption of new information is largely impacted by the extent to which it conforms to their prior belief. Another cause of consumers' negative sentiment could be due to "in-group" or "tribal" bias (Hewstone, Mark, & Hazel, 2002).

There is considerable controversy, uncertainty, and debate regarding methodological issues related to the existing economic literature that assesses GE foods (Falck-Zepeda, 2016). This has contributed to substantial media bias, which plays an especially important role in the public debate regarding GE foods (McCluskey & Swinnen, 2004). However, the media often gains from conflicts regardless of their outcome. Media organizations have the incentive to slant information toward consumers' preferences. Unfortunately, non-GE foods are more costly to produce than GE foods. Therefore, shifting consumer preferences towards non-GE ingredients will cause food prices to rise (Kalaitzandonakes, Lusk, & Magnier, 2018).

The controversy surrounding the use of GE foods has been around for a long time and is well documented (e.g. Schmitz, Moss, & Schmitz 2004; Moss, Schmitz, & Schmitz 2004; Moss, Schmitz, & Schmitz, 2008). As a result, over the first twenty years of this century, there has been a considerable amount of litigation involving GE foods. Much of this litigation has involved GE corn, although GE rice, canola, soybeans, and cotton have also had their share of legal battles (Moss, Schmitz, & Schmitz, 2006). For example, Aventis Crop Science introduced StarLink corn in the US at the turn of the twenty-first century and while it had been approved by the US Environmental Protection Agency (EPA) for livestock feed, it was not approved for human consumption. In 2000, evidence of the Cry9C protein used to create StarLink corn was found in Taco shells in Seattle and was also discovered commingled with approved corn in US elevators. Once Japan discovered the Cry9c protein in US corn shipments, it banned US corn imports for over a year and severely curtailed imports over the next several years. South Korea and other countries followed suit, also placing severe restrictions on StarLink corn imports and imposing stringent testing procedures. This StarLink corn event led to substantial economic losses to US farmers. A class-action lawsuit ensued, which eventually resulted in a settlement of $110 million in favor of US corn producers (Schmitz, Schmitz, & Moss, 2004; Schmitz & Moss, 2005).

In 2009, Syngenta introduced Agrisure Viptera and Agrisure Duracade seeds that contained the MIR162 GE trait. In spring 2011, MIR162 corn was planted over a wide area in North America. While MIR162 had been approved for human consumption in North America and several other countries, it had not yet been approved for consumption in China. When MIR162 was found commingled in a shipment of US corn, China imposed an embargo on North American corn imports from November 20, 2013 to December 14, 2014 (Schmitz, 2018). As of December 2019, North American corn exports to China still have not recovered. Several US lawsuits were filed against Syngenta in 2014, which were subsequently consolidated into two large class-action cases. On June 23, 2017, a Kansas City jury awarded $218 million to 440,000 US corn producers based on the grounds that Syngenta did foresee harm farm from the commingling of Viptera and non-Viptera corn in the grain handling system. In a separate case in Minneapolis filed by 22,000 Minnesota farmers, it was argued that Syngenta rushed Viptera to market without ensuring that all major markets had approved MIR162. On September 26, 2017 a settlement was reached in which Syngenta paid more than $1.4 billion in damages to US farmers (Schmitz, 2018).

In the United States, Vermont passed a law on July 1, 2016, requiring clear labeling on the packages of food items that contain GE ingredients. The Vermont law was superseded by a federal bill signed by President Obama on July 29, 2016. The federal bill established a "National Bioengineered Food Disclosure Standard" which charged the Agricultural Marketing Service (AMS) branch of the United States Department of Agriculture (USDA) to develop a national system for disclosing the presence of bioengineered material (Public Law 114-216, 2016). Implementation of the new USDA rules and regulations established by the US National Bioengineered Food Disclosure Standard began on January 1, 2020 (USDA AMS, 2018). The standard requires food manufacturers, importers, and certain retailers to ensure information regarding bioengineered foods are appropriately disclosed to US consumers (McFadden & Lusk, 2018). Unfortunately, imposing mandatory bioengineered food labeling increases the cost of food packaging and a portion of the increased costs associated with mandatory bioengineered food labeling will get passed on to consumers.

3. Model Description

In the following analysis, the media is viewed as the message deliverer, SIGs as message senders, and consumers as message receivers. Rasmusen (1993) assumes decision makers can choose to verify or investigate the actual state of the world at different costs. We generalize the concept of consumers' inspection costs to include both costs. Non-profit or non-governmental activist groups are viewed as SIGs because revenues for these activist groups originate from donors and grant makers, and thus they have the incentive to represent and serve their donors' interests with respect to controversial issues (Graff, Hochman, & Zilberman, 2009).

Consumers receive contradictory information about whether or not currently commercialized GE foods are safe for human consumption. Anti-GE SIGs claim that pro-GE groups twist science and alter truth, while pro-GE SIGs believe anti-GE groups base their statements on pseudoscience purposely misinforming consumers. Which side is more likely spinning facts? If consumers can discover the actual state of GE food safety if they choose to inspect the information provided by the SIGs at a certain cost, what are the restrictions on consumers' inspection costs as well as on SIGs' spin costs that would keep both parties from spinning facts? Finally, can SIGs manipulate consumers' inspection costs to their strategic advantage?

In order to address these questions, we use a signaling game to illustrate how SIGs strategically interact with consumers. We focus on the setting wherein SIGs are informed about the safety of GE foods and can influence consumers' purchase decisions by strategically sharing this information. We assume that consumers can discover the actual state of GE food safety if they choose to inspect the messages they receive at a certain cost. This may be a strong assumption, but it normally works strongly against SIGs spinning facts and thus serves as a prevention mechanism. The analysis shows that if consumers' inspection is costly, both parties could choose to spin facts in their best interests at the equilibrium. However, the pro-GE party faces a higher risk of incurring a net loss due to the exogenous penalty included in their spin costs. SIGs can indirectly influence consumers' inspection costs, and consumers may not be better informed about the safety of GE foods when there is an oversupply of information. The following analysis can be used by policy makers and industries to strengthen their position when attempting to educate the general public on the topic of GE foods. The policy implications of this analysis for the current GE food labeling law are also discussed.

4. Signaling Game

Signaling games are a class of games of incomplete information wherein one group of players is informed and the other group is not. The underlying assumption of a signaling game is that informed players will attempt to lie for strategic advantage and uninformed players will discount signals based on their beliefs. Signaling games have been extended to applications of lobbying, campaigning, and endorsing (see a review by Sloof, 2013: pp. 59-64). Bullock (2015) incorporated informed players' spin costs and uninformed players' inspection costs into a signaling game model to explain why making trade negotiations more transparent could result in more misinformation. We modify and extend Bullock's model to demonstrate the strategic interactions between consumers and SIGs involved in the GE food debate.

The first player is Nature (**Figure 1**). Nature does not refer to any living beings, but rather a random force drawing the actual state of the world or the fact in the game environment (Harrington, 2009). In this game, Nature moves first by determining whether or not a specific GE food has potential unknown health hazards to consumers. This fact is known only to SIGs. Previous literature, such as Austen-Smith and Wright (1992), incorporates the cost of information acquisition into the signal model to study message senders' incentive to acquire costly information, but they do not provide enough insights on how SIGs manipulate messages they have already acquired. Thus, we incorporate spin costs into our model because our focus is on whether or not SIGs will have the incentive to knowingly spin facts. We model three decision stages in the proposed game (**Figure 1**).

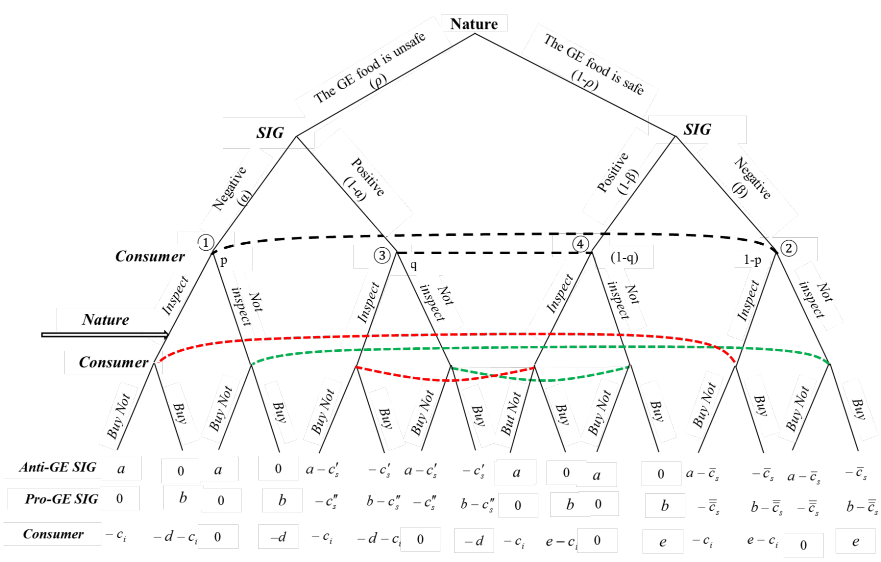

Figure 1. The signaling game between SIGs and consumers.

Stage I: Messages. Knowing the actual state of GE food safety $t \in \{t_1, t_2\}$, the groups choose whether or not to spin messages that they send to consumers. The message strategy for SIGs, conditional on having known the value of *t* from Nature, is a map,

$$\gamma_g : \{t_1, t_2\} \to [0,1],\ g = A, B, \tag{1}$$

in which t_1 = the GE food is unsafe, t_2 = the GE food is safe, A = anti-GE SIGs, and B = pro-GE SIGs, and $\gamma_g(t)$ = the probability that the special interest group G_g, knowing $t \in \{t_1, t_2\}$, sends a true or spun message to consumers. More specifically, we write

$$\gamma_g(t_1 \mid t = t_1) = \alpha \quad \text{and thus} \quad \gamma_g(t_2 \mid t = t_1) = 1 - \alpha, \tag{2}$$

which means if SIGs know the value of *t* being "the GE food is unsafe", the probability of SIGs choosing to signal negative messages about the GE food is α and the probability of choosing to signal positive messages is ($1-\alpha$). Similarly, we write

$$\gamma_g(t_1 \mid t = t_2) = \beta \quad \text{and thus} \quad \gamma_g(t_2 \mid t = t_2) = 1 - \beta, \tag{3}$$

which means if SIGs know that Nature has chosen "the GE food is safe", the probabilities of SIGs choosing to signal negative and positive messages about the GE food are β and ($1-\beta$), respectively.

Stage II: Consumer Inspection. Before having observed SIGs' messages, consumers have their prior beliefs: with probability ρ, consumers believe "the GE food is unsafe"; with probability ($1-\rho$), consumers believe "the GE food is safe". After having observed SIGs' messages $m_g \in \{t_1, t_2\}$, consumers update their beliefs: there is a probability of p that they are at position ①, ($1-p$) that they are at ②, q that they are at ③, and ($1-q$) that they are at ④ (**Figure 1**). In equilibrium, consumers' updated beliefs are consistent with SIGs' acting in their best interests and with Bayes' rule. In Bayesian terms, these beliefs can be expressed as

$$p = prob(t = t_1 \mid m_g = t_1) = \frac{\rho\alpha}{\rho\alpha + (1-\rho)\beta} \tag{4}$$

$$(1-p) = prob(t = t_2 \mid m_g = t_1) = \frac{(1-\rho)\beta}{\rho\alpha + (1-\rho)\beta} \tag{5}$$

$$q = prob(t = t_1 \mid m_g = t_2) = \frac{\rho(1-\alpha)}{\rho(1-\alpha) + (1-\rho)(1-\beta)} \tag{6}$$

$$(1-q) = prob(t = t_2 \mid m_g = t_2) = \frac{(1-\rho)(1-\beta)}{\rho(1-\alpha) + (1-\rho)(1-\beta)} \tag{7}$$

If SIGs signal only one type of message regardless of the value of *t*, then consumers will ignore these uninformative messages and just use their prior beliefs in deciding how to act. In this case, consumers' updated beliefs can be written as ($p = \rho, q$) or ($p, q = \rho$) which is essentially ($p = \rho, q = \rho$) since $p = \rho$ and $q = \rho$ can be mutually implied according to Bayes' rule. Under these updated beliefs, consumers decide whether or not to inspect (or verify the truthfulness of the messages provided by SIGs) before making their purchase decisions. A verification strategy for the consumer is a map

$$\delta : \{t_1, t_2\} \to [0,1] \tag{8}$$

in which $\delta(m_g)$ = the probability that the consumers C incur cost c_I to inspect the value of t, given the message m_g from SIGs. Let $c_i \in \{0, c_I\}$ denote the realization of consumers' mixed strategy, δ.

Stage III: Purchasing. If consumers choose to inspect, they will again update their beliefs about Nature's choice based on what their inspection reveals. Nature plays the next stage and represents consumers' newest updated beliefs. Based on these newest beliefs, consumers finally decide whether to buy the GE food or not. A purchasing strategy for consumers C is a map

$$\varepsilon : \{t_1, t_2\} \times \{\varnothing, t_1, t_2\} \to [0,1] \tag{9}$$

in which $\varepsilon(m_g, m_c)$ = the probability that consumers buy the GE food, having observed messages m_g from SIGs and learned m_c from their own inspection. $m_c \in \{\varnothing, t_1, t_2\}$ is what consumers learn after inspection. If consumers do not inspect ($c_I = 0$) we set $m_c \equiv \varnothing$.

After consumers make the purchase decision, consumers, anti-GE and pro-GE groups receive their respective payoffs. The payoff functions are assumed to be:

$$\Pi_{\text{anti-GE}} = \begin{cases} a - k & \text{if consumers do not buy the GE food} \\ -k & \text{otherwise} \end{cases} \tag{10}$$

$$\Pi_{\text{pro-GE}} = \begin{cases} b - k & \text{if consumers buy the GE food} \\ -k & \text{otherwise} \end{cases} \tag{11}$$

$$\Pi_{\text{consumers}} = \begin{cases} -d - c_i & \text{if consumers buy the GE food when } t = t_1 \\ e - c_i & \text{if consumers buy the GE food when } t = t_2 \\ -c_i & \text{if consumers do not buy} \end{cases} \tag{12}$$

where anti-GE SIGs get a if consumers do not buy the GE food but instead buy the non-GE equivalent, and 0 otherwise; pro-GE SIGs get b if consumers buy the GE food, and 0 otherwise. When these groups spin facts, they incur spin costs k, which will be specified in more detail shortly. If the value of t is that the GE food has potential health hazards (i.e., $t = t_1$), the payoff to consumers is $-d$ if they choose to buy the GE food. If the value of t is that the GE food is as safe as its non-GE equivalent (i.e., $t = t_2$), then the payoff to consumers is e. Consumers incur inspection costs, c_i, if they choose to inspect messages provided by SIGs.

We assume when the fact is "the GE food is unsafe", the spin costs, k, for anti-GE and pro-GE SIGs are c_s' and c_s'', respectively. When the fact is "the GE food is safe", the spin costs for anti-GE and pro-GE SIGs are $\overline{c}_s$ and $\overline{\overline{c}}_s$, respectively. Spin costs include the cost of commercial advertisements. Following Austen-Smith and Wright (1992), we also include a penalty associated with being caught twisting facts. This penalty term could be the cost of losing credibility, reputation, marketing opportunities, or litigation. A good example to explain this penalty term might be Volkswagen's "emissions gate" which caused significant losses to Volkswagen Group due to intentional cheating on emissions tests.

Finally, as discussed earlier, we assume that the probability that consumers discover the actual state of GE food safety is 1 if they choose to inspect. After inspection, they will buy the GE food if they discover that "the GE food is safe" and will not buy if "the GE food is unsafe". If consumers choose to not inspect, they will randomize their purchase decisions with some probabilities represented by prob (not buy if receive negative messages) = x, and thus prob (buy if receive negative messages) = $1 - x$; and prob (buy if receive positive messages) = y, and thus prob (not buy if receive positive messages) = $1 - y$. Under the above assumptions, the game can be simplified as in Figure 2 for the game between the anti-GE SIG and the consumer and as in Figure 3 for the game between the pro-GE SIG and the consumer.

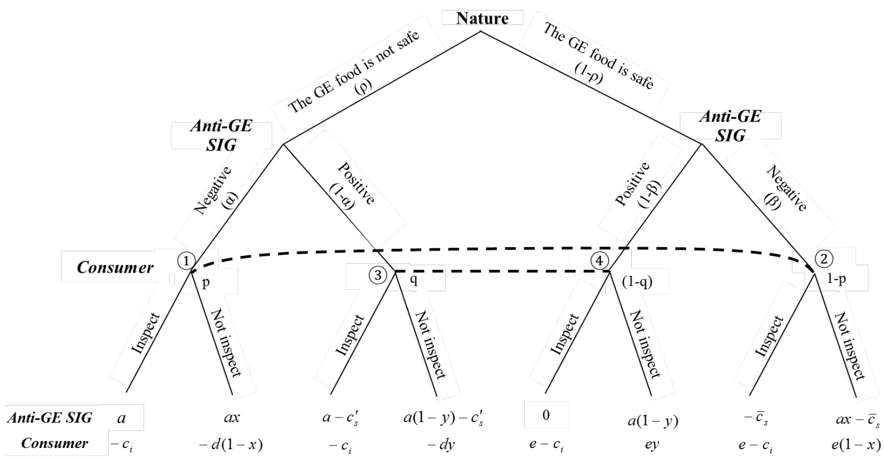

Figure 2. The simplified signaling game between anti-GE SIGs and consumers.

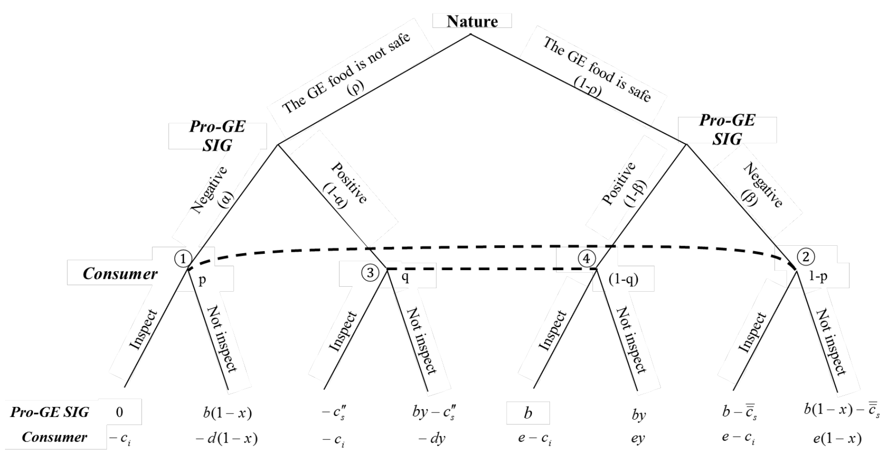

Figure 3. The simplified signaling game between pro-GE SIGs and consumer.

5. Equilibrium Results

The conditions supporting the equilibrium behavior are related to the payoffs to the players, the spin costs to SIGs, consumers' inspection costs, and consumers' updated beliefs after receiving messages provided by SIGs. It is worth noting that consumers' inspection decision rather than their purchase decision is based on these updated beliefs represented by p and q. In other words, consumers update their prior beliefs about the safety of GE foods conditional on having observed SIGs' actions. Then, they choose whether to check these messages or not, especially when they hear a message contradicting their prior beliefs. Their final purchase decision is based on what their inspection reveals.

Even though equilibria can be obtained where both SIGs spin facts in the opposite direction of their best interests, one of the necessary conditions to reach these equilibria is that their corresponding spin costs are sufficiently low (3*iii* and 4*iii* in **Table 1** for anti-GE groups and 2*III* and 4*III* in **Table 2** for pro-GE groups). This is improbable, in reality, because the spin costs for both pro-GE and anti-GE SIGs will generally be larger than their gain if they spin facts against their best interests. In other words, it is irrational for SIGs to spin facts in the opposite direction of their best interests. This implies, at the equilibrium, both groups will choose to either spin facts in their best interests or reveal information truthfully. Given this, the first proposition provides necessary and sufficient conditions for any group to reveal information truthfully.

For the game between SIGs and consumers, the conditions supporting the equilibrium, in which SIGs always reveal their information truthfully and consumers' updated (or posterior) beliefs are consistent with SIGs' strategy, are specified in the following seven propositions, which are derived in the **Appendix**.

Proposition **1.** If $c_i < \min\left[d(1-x), e(1-y)\right]$ implying that consumers' inspection costs are sufficiently low, then in equilibrium, consumers always inspect and SIGs reveal their information truthfully (1*iii* in **Table 1** and 1*III* in **Table 2**).

Proposition **2.** If $e(1-y) < c_i < d(1-x)$ in which $e(1-y) < d(1-x)$, meaning if it is too costly for consumers to inspect positive messages but is less costly to inspect negative messages, the anti-GE groups will reveal their information truthfully surely, while the pro-GE groups will do so only if their spin costs are large enough as specified by $c_s'' > b$ and $\bar{\bar{c}}_s > b(1-y)$.

Proposition **3.** If $d(1-x) < c_i < e(1-y)$ in which $d(1-x) < e(1-y)$ meaning if it is too costly for consumers to inspect negative messages but is less costly to inspect positive messages, the pro-GE groups will choose to reveal their information truthfully, while the anti-GE groups will do so only if their spin costs are high enough, $c_s' > a(1-x)$ and $\bar{c}_s > ax$.

Proposition **4.** If $c_i > \max\left(d(1-x), e(1-y)\right)$, meaning if it is too costly for consumers to inspect any type of messages, SIGs will reveal their information truthfully only if their spin costs are large enough (i.e., 4*iii* in **Table 1** and 4*III* in **Table 2**).

Table 1. Perfect Bayesian Nash Equilibrium (PBNE) conditions for the game between Anti-GE SIG and the consumer.

Consumers strategies	*i) Anti-GE SIG "always signal negative messages"; Consumer's beliefs* ($p = \rho$; q)	*ii) Anti-GE SIG "always signal positive messages"; Consumer's beliefs* (p; $q = \rho$)
1) "*Always inspect*"	1i): No PBNE	1ii): No PBNE
2) "*Inspect negative, not inspect positive*"	2i): No PBNE	2ii): No PBNE
3) "*Not inspect negative, inspect positive*"	3i): $d\rho + (e - e\rho - d\rho)x < c_i < e(1-\rho) - (e - e\rho - d\rho)y$, $c'_s > a(1-x)$, and $0 < \bar{c}_s < ax$	3ii): No PBNE
4) "*Always not inspect*"	4i): $c_i > \max\left[d\rho + (e - e\rho - d\rho)x, e(1-\rho) - (e - e\rho - d\rho)y\right]$ and $0 < \bar{c}_s < a(x+y-1)$ where $1 < (x+y) \le 2$	4ii): $c_i > \max\left[d\rho + (e - e\rho - d\rho)x, e(1-\rho) - (e - e\rho - d\rho)y\right]$, $0 < c'_s < a(1-x)$, and $\bar{c}_s > ax$
	iii) Anti-GE SIG "always signal facts from Nature"; Consumer's beliefs ($p = 1$; $q = 0$)	*iv) Anti-GE SIG "always signaling messages opposite to the fact from Nature"; Consumer's beliefs* ($p = 0$; $q = 1$)
	1iii): $c_i < \min\left(d(1-x), e(1-y)\right)$	1iv): No PBNE
	2iii): $e(1-y) < c_i < d(1-x)$	2iv): No PBNE
	3iii): $d(1-x) < c_i < e(1-y)$; $c'_s > a(1-x)$, and $\bar{c}_s > ax$	3iv): $ex < c_i < dy$; $0 < c'_s < a(1-x)$, and $0 < \bar{c}_s < ax$
	4iii): $c_i > \max\left(d(1-x), e(1-y)\right)$; $c'_s > a(1-x-y)$ when $0 < (x+y) \le 1$ *or* $\bar{c}_s > a(x+y-1)$ when $1 < (x+y) \le 2$	4iv): No PBNE

Table 2. Perfect Bayesian Nash Equilibrium (PBNE) conditions for the game between Pro-GE SIG and the consumer.

Consumers strategies	*I) Pro-GE SIG "always signal negative messages"; Consumer's beliefs* ($p = \rho$; q)	*II) Pro-GE SIG "always signal positive messages"; Consumer's beliefs* (p; $q = \rho$)
1) "*Always inspect*"	1I): No PBNE	1II): No PBNE
2) "*Inspect negative, not inspect positive*"	2I): $e(1-\rho) - (e - e\rho - d\rho)y < c_i < d\rho + (e - e\rho - d\rho)x$, $c''_s > by$, and $0 < \bar{c}_s < b(1-y)$	2II): $e(1-\rho) - (e - e\rho - d\rho)y < c_i < d\rho + (e - e\rho - d\rho)x$, $0 < c''_s < by$, and $\bar{c}_s > b(1-y)$
3) "*Not inspect negative, inspect positive*"	3I): No PBNE	3II): No PBNE
4) "*Always not inspect*"	4I): No PBNE	4II): $c_i > \max\left[e(1-\rho) - (e - e\rho - d\rho)y, d\rho + (e - e\rho - d\rho)x\right]$ $0 < c''_s < b(x+y-1)$ where $1 < (x+y) \le 2$
	III) Pro-GE SIG "always signal facts from Nature"; Consumer's beliefs ($p = 1$; $q = 0$)	*IV) Pro-GE SIG "always signal messages opposite to the fact from Nature"; Consumer's beliefs* ($p = 0$; $q = 1$)
	1III): $c_i < \min\left(d(1-x), e(\ -y)\right)$	1IV): No PBNE
	2III): $e(1-y) < c_i < d(1-x)$; $c''_s > by$, and $\bar{\bar{c}}_s > b(1-y)$	2IV): $dy < c_i < ex$ $0 < c''_s < by$ and $0 < \bar{\bar{c}}_s < b(1-y)$
	3III): $d(1-x) < c_i < e(1-y)$;	3IV): No PBNE
	4III): $c_i > \max\left(d(1-x), e(1-y)\right)$; $\bar{\bar{c}}_s > b(1-x-y)$ when $0 < (x+y) \le 1$ *or* $c''_s > b(x+y-1)$ when $1 < (x+y) \le 2$	4IV): No PBNE

Next, we consider the conditions supporting the equilibria in which both SIGs signal messages in their best interests regardless of what the actual state of GE food safety reveals, and consumers use their prior beliefs to decide their best strategy. Here, consumers' updated beliefs, ($p=\rho; q=\rho$), can be interpreted as consumers believing that the probability of GE food being unsafe is still ρ regardless of what messages she receives. The condition supporting such an equilibrium is provided below.

***Proposition* 5.** If $\left(d\rho+\left(e-e\rho-d\rho\right)x\right)<c_i<\left(e\left(1-\rho\right)-\left(e-e\rho-d\rho\right)y\right)$ meaning if it is too costly for consumers to inspect negative messages while it is less costly to inspect positive messages, anti-GE SIGs will always signal negative messages when their spin cost associated with being caught lying is low, $\overline{c}_s<ax$, and meanwhile, it is "irrational" to spin against their best interests, $c'_s>a\left(1-x\right)$. However, given this strategy, spinning facts through signaling uninformative positive messages is not optimal to pro-GE SIGs.

***Proposition* 6.** If $\left(e\left(1-\rho\right)-\left(e-e\rho-d\rho\right)y\right)<c_i<\left(d\rho+\left(e-e\rho-d\rho\right)x\right)$ meaning if it is too costly for consumers to inspect positive messages while it is less costly to inspect negative messages, pro-GE SIGs will always signal positive messages when the cost of being caught spinning facts in their best interests is low, $c''_s<by$, and it is irrational for them to spin facts against their own best interests, $\overline{\overline{c}}_s>b\left(1-y\right)$. Given this strategy, spinning fact through signaling uninformative negative messages is not optimal to anti-GE SIGs.

***Proposition* 7.** If $c_i>\max\left[d\rho+\left(e-e\rho-d\rho\right)x,e\left(1-\rho\right)-\left(e-e\rho-d\rho\right)y\right]$ meaning if it is too costly for consumers to inspect any messages (equivalent to not inspect both messages), both groups will signal messages in their best interests as long as the cost of being caught lying is low: $\overline{c}_s<a\left(x+y-1\right)$ for anti-GE groups and $c''_s<b\left(x+y-1\right)$ for pro-GE groups.

The above equilibria and their supporting conditions can also be interpreted in the following way. There are basically two ways to ensure that both SIGs always reveal their information truthfully: one is to lower consumers' inspection costs so that they will at least inspect the negative messages from anti-GE SIGs (1*iii* and 2*iii* in Table 1) and at least inspect the positive messages from pro-GE SIGs (1*III* and 3*III* in Table 2); the other is to make sure that SIGs' cost of spinning facts are high enough.

We focus on the "revealing information truthfully" equilibrium conditions regarding spin costs, $\overline{c}_s$ for anti-GE groups and c''_s for pro-GE groups (consumers' inspection costs will be discussed later in the next section). In a debate related to human food consumption, it is naturally easier to restrain pro-GE groups' actions because it would be highly risky to spread positive messages about GE foods if the fact is that the consumption of GE foods poses hazards to human health (i.e., $t=t_1$). Knowingly spinning facts and claiming "the GE food is safe" could not only destroy pro-GE groups credibility, but also lead to litigation. However, it is difficult to impose a high spin cost on anti-GE groups because their supporting objectives—conventional or organic foods—are already accepted by the public. Even if the GE food is fully believed to be as safe as its conventional counterparts by the public sometime in the future, it is hard to punish SIGs for spinning facts at that time.

There is another equilibrium in which both sides could choose to spin facts in their best interests. The conditions on SIGs to reach this equilibrium indicate that their cost of spinning would have to be sufficiently low at certain levels as specified in propositions 5 to 7. The question here again is whether it is easier for one side than the other to meet such conditions. As discussed above, it is generally harder to impose a high spin cost on anti-GE groups. Therefore, it is naturally easier for anti-GE groups to encounter a low spin cost.

The equilibrium conditions are also related to consumers' purchase decisions when consumers do not inspect, which are the values of x and y representing the influence power of SIGs' messages. A higher value of x indicates that it is easier for anti-GE groups to reach the equilibrium wherein they will always signal negative messages. In addition, a higher value of y indicates that it is easier for pro-GE groups to reach the equilibrium wherein they will always signal positive messages. Yet, this does not change the fact that pro-GE groups' cost of spinning facts could be fatal even if consumers completely follow their message (i.e., $y = 1$ while $c_s'' > by$).

6. Further Discussion and Limitations

The SIGs' strategies are dependent on consumers' strategies which are determined by consumers' inspection costs. Can SIGs influence consumers' inspection costs? We assume consumers' inspection costs can be expressed through a function of the time needed to learn about each piece of information. Thus, we can write consumers' inspection costs as $c_i = f(s)$, where s represents the time needed to inspect a piece of information. When the supply of information increases, the time spent on each piece of information is reduced and thus consumers' inspection costs become higher. This works strongly in favor of anti-GE SIGs because when it is too costly for consumers to inspect any messages, these groups will always signal negative messages as long as their spin cost is low $\left(\overline{c}_s < a(x+y-1)\right)$. As discussed previously, it is relatively easier for anti-GE SIGs to obtain such low spin costs.

We have limited our discussion to a specific setting under which consumers first inspect messages from SIGs before they make purchase decisions. However, there are two other groups that might never choose to inspect and always believe that GE foods are unsafe or safe. SIGs would most likely choose to strengthen their loyal consumer base by sending messages that conform to consumers' prior beliefs, and meanwhile, they would try to convince the other group of consumers who are uncertain about the safety of GE foods. The question is how much weight SIGs would place on the group of consumers who are uncertain about the safety of GE foods and may find out the true state through inspections.

Another limitation is the extent to which SIGs would have an interest in spinning facts. In our model, we assume that SIGs maximize their payoff functions which are simplified to be only dependent on two parameters: consumers' purchase decisions and their own spin costs. Thus, SIGs will choose to spin facts if it is profitable for them to do so. There could be other factors that may influence SIGs' strategies.

7. Conclusions and Implications

Improving food security with a quickly growing global population is of great importance to all governments, especially in poorer countries. GE foods that provide higher yields at a lower cost are currently available on the market for certain types of food, but not for all. For example, GE wheat is not commercially available while GE corn is. These existing GE foods have not been scientifically proven to be unsafe compared to their conventional counterparts, and therefore improve food security. However, anti-GE sentiment reduces expansion of existing GE food and inhibits further development of more affordable GE foods in food insecure countries. For example, the Zambian Government rejected a donation of GE food from the United States for nearly three million of its people facing famine in 2002 due to unfounded safety concerns (BBC News, 2002). For this reason, it is important that consumers are properly educated with respect to the current state of science as it relates to GE food safety and the possible ulterior motive of SIGs involved in the debate.

SIGs can choose to spin facts in their best interests in order to influence consumers' purchase decisions. Yet, they will be worried about losing their reputation or even getting into costly litigation if their statements are found to be false. Our framework imposed two major assumptions. One is that consumers choose whether to verify messages they receive from SIGs before they make their purchase decisions. The other assumption is that if consumers choose to inspect, they will discover the current state of GE food safety. Under these assumptions, we explored SIGs' best strategies in the heated GE food debate.

The results indicate that both SIGs could choose to spin facts when their messages are costly for consumers to inspect. However, it is much riskier for pro-GE groups to spin facts in their best interests, because it could be detrimental for them to distort facts if they are found to be incorrect. If they lose consumers' trust or become involved in litigation, they lose the opportunity to introduce new products or may be forced out of business. Revealing information truthfully is more likely their optimal strategy. Moreover, under the above framework, current GE labeling laws may serve as a negative message to consumers' which helps reinforce anti-GE SIGs' positions.

Previous studies have shown that consumers' inspection costs increase when there is an oversupply of information. If consumers' inspection costs are too high, they will stop inspecting and will just let their prior biases guide their decisions. Too much information may overwhelm consumers, but it may do more good than harm to reduce consumers' inspection costs by providing more information based on scientific evidence. Therefore, interdisciplinary researchers should collaborate to simplify the dissemination of scientific evidence to the general public. Some critics claim that science performed using industry funding is more likely to result in a pro-GE outcome, while publicly funded science independent of biotech companies is more likely to result in more neutral or even moderately anti-GE outcomes (Hilbeck et al., 2015). To ensure neutrality, more public funds should be made accessible to independent researchers to test plausible hypotheses regarding GE food safety.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Appendix: Mathematical Derivations of Propositions

In this game, SIGs have four possible strategies:

1) Always signal negative messages about GE food regardless of the fact;

2) Always signal positive messages about GE food regardless of the fact;

3) Signaling the same messages as the fact from Nature;

4) Signaling messages opposite to the fact.

In 1), SIGs' messages are entirely uninformative given that its strategy is to signal the same message regardless of the truth. Given that SIGs' first possible strategy is to always signal negative messages, consumers believe that SIGs' messages are independent of the truth, and thus consumers will ignore the messages and just use their prior beliefs in deciding their strategies. In other words, consumers' updated beliefs are the same as their prior belief: $p = \rho$. Under these beliefs, their expected payoff from inspecting, denoted by E^I, is

$$E^I = (-c_i)\rho + (e - c_i)(1-\rho) = e(1-\rho) - c_i \tag{A1}$$

and their expected payoff from not inspecting, denoted by E^{NI}, is

$$E^{NI} = -d(1-x)\rho + e(1-x)(1-\rho) = (-d\rho + e - e\rho)(1-x) \tag{A2}$$

Therefore, when consumers receive negative messages from SIGs, their best response is to inspect if $c_i < d\rho + (e - e\rho - d\rho)x$, and to not inspect if $c_i > d\rho + (e - e\rho - d\rho)x$.

Next, to complete consumers' strategy, we need to determine their best response to positive signals from SIGs. Consumers cannot update their beliefs because they do not observe positive messages due to anti-GE SIG's "always signaling negative messages" strategy, but they believe there is a probability q that they are at ③ and $(1-q)$ at ④. If they receive positive messages from SIG, their payoff from inspecting is

$$E^I = (-c_i)q + (e - c_i)(1-q) = e(1-q) - c_i \tag{A3}$$

and their payoff from not inspecting is

$$E^{NI} = (-dy)q + ey(1-q) = (e - eq - dq)y \tag{A4}$$

Therefore, when consumers receive positive messages from SIGs, their best response is to inspect if $e(1-q) - c_i > (e - eq - dq)y$ which is equivalent to $c_i < e(1-q) - (e - eq - dq)y$, and to not inspect if $c_i > e(1-q) - (e - eq - dq)y$. In response to SIG's first possible strategy "always signaling negative messages", there will be four possible strategies for consumers (**Table A1**):

SIGs second possible strategy, "always signal positive messages", is also uninformative to consumers, and thus when consumers receive positive messages from SIGs, their updated beliefs can be express as (p; $q = \rho$). Under these beliefs, consumers' expected payoff from inspecting when they receive positive messages from SIGs is

$$E^I = (-c_i)\rho + (e - c_i)(1-\rho) = e(1-\rho) - c_i \tag{A5}$$

Table A1. Four possible consumer responses to "Always Signal Negative Messages".

Consumers' possible strategies under beliefs $(p = \rho; q)$	Conditions
1) "*Always inspect*"	$c_i < \min\left(d\rho + (e - e\rho - d\rho)x, e(1-q) - (e - eq - dq)y\right)$
2) "*Inspect negative, not inspect positive*"	$e(1-q) - (e - eq - dq)y < c_i < d\rho + (e - e\rho - d\rho)x$
3) "*Not inspect negative, inspect positive*"	$d\rho + (e - e\rho - d\rho)x < c_i < e(1-q) - (e - eq - dq)y$
4) "*Always not inspect*"	$c_i > \max\left(d\rho + (e - e\rho - d\rho)x, e(1-q) - (e - eq - dq)y\right)$

and their expected payoff from not inspecting is

$$E^{NI} = -dy\rho + ey(1-\rho) = y(e - e\rho - d\rho) \tag{A6}$$

Therefore, when consumers receive positive messages from anti-GE SIGs, their best response is to inspect if $e(1-\rho) - c_i > (1-\rho)ey - \rho dy$, which is equivalent to $c_i < e(1-\rho)(1-y) + \rho dy$, and to not inspect if $c_i > e(1-\rho)(1-y) + \rho dy$.

Next, to complete consumers' strategy, we need to determine their best response to negative messages from anti-GE SIGs. Consumers cannot update their beliefs because they do not observe negative messages given anti-GE SIG's "always signal positive messages" strategy. However, they believe that there is a probability p that they are at ① and 1-p at ②. Based on these beliefs, their payoff from inspecting is

$$E^{I} = (-c_i)p + (e - c_i)(1-p) = e(1-p) - c_i \tag{A7}$$

and their payoff from not inspecting is

$$E^{NI} = -d(1-x)p + e(1-x)(1-p) = (1-x)(e - ep - dp) \tag{A8}$$

Therefore, when consumers receive negative messages from anti-GE SIGs, their best response is to inspect if $e(1-p) - c_i > (1-x)(e - ep - dp)$, which is equivalent to $c_i < e(1-p) - (1-x)(e - ep - dp)$; and to not inspect if $c_i > e(1-p) - (1-x)(e - ep - dp)$.

Again, there will be four possible strategies for consumers (**Table A2**).

SIGs' third and fourth possible strategies are informative to consumers, and thus consumers' beliefs are determined by Bayes' rule and the SIGs' strategies. Consumers' updated beliefs are ($p = 1; q = 0$) when SIGs play the third strategy, while ($p = 0; q = 1$) when SIGs play the fourth strategy (**Table A3**).

It remains to check if anti-GE SIGs have an incentive to deviate from their strategy given consumers' possible strategies. We first consider anti-GE SIG's first possible pure strategy "always signal negative messages". Consumers' strategies (1) and (2) can be excluded, because if consumers' best response to negative messages from the anti-GE SIG is to inspect, then "always signal negative messages" is no longer optimal for the anti-GE SIG, because when consumers choose to inspect negative messages they receive, the anti-GE SIG receives a payoff of zero by sending positive messages while it gets ($-\overline{c}_s$) by sending negative messages.

Table A2. Four possible consumer responses to "Always Signal Positive Messages".

Consumers' possible strategies under beliefs (p; $q = \rho$)	Conditions
1) "*Always inspect*"	$c_i < \min\left(e(1-\rho)(1-y)+\rho dy, e(1-p)-(1-x)(e-ep-dp)\right)$
2) "*Inspect negative, not inspect positive*"	$e(1-\rho)(1-y)+\rho dy < c_i < e(1-p)-(1-x)(e-ep-dp)$
3) "*Not inspect negative, inspect positive*"	$e(1-p)-(1-x)(e-ep-dp) < c_i < e(1-\rho)(1-y)+\rho dy$
4) "*Always not inspect*"	$c_i > \max\left(e(1-\rho)(1-y)+\rho dy, e(1-p)-(1-x)(e-ep-dp)\right)$

Table A3. Consumers' updated beliefs when SIGs play different strategies.

Consumers' possible strategies	Under beliefs ($p = 1$; $q = 0$)	Under beliefs ($p = 0$; $q = 1$)
1) "*Always inspect*"	$c_i < \min\left(d(1-x), e(1-y)\right)$	$c_i < \min(dy, ex)$
2) "*Inspect negative, not inspect positive*"	$e(1-y) < c_i < d(1-x)$	$dy < c_i < ex$
3) "*Not inspect negative, inspect positive*"	$d(1-x) < c_i < e(1-y)$	$ex < c_i < dy$
4) "*Always not inspect*"	$c_i > \max\left(d(1-x), e(1-y)\right)$	$c_i < \max(dy, ex)$

There is an incentive for anti-GE SIGs to signal positive messages when the truth is "the GE food is safe". Thus, anti-GE SIGs will have the incentive to signal positive messages when they know Nature has chosen "the GE food is safe". Therefore, there is no perfect Bayesian Nash equilibrium (PBNE) in which anti-GE SIGs play "always signal negative messages" as long as consumers always inspect when they receive negative messages.

Therefore, there is only one PBNE, which could be either (3) or (4). That is, if $d\rho+(e-e\rho-d\rho)x < c_i < e(1-q)-(e-eq-dq)y$ for $q=\dfrac{\rho(1-\alpha)}{\rho(1-\alpha)+(1-\rho)(1-\beta)}$; $c_s' > a(1-x)$; and $\overline{c_s} < ax$ are all satisfied, then the PBNE is for anti-GE SIGs to always send a negative signal and consumers to either: a) not inspect if they receive negative messages; or b) to inspect if they receive positive messages. On the other hand, if $c_i > \max\left(e\rho+(e-e\rho-d\rho)x, e(1-q)-(e-eq-dq)y\right)$ for any $q=\dfrac{\rho(1-\alpha)}{\rho(1-\alpha)+(1-\rho)(1-\beta)}$; $0 < c_s' < a$; and $\overline{c}_s < a(x+y-1)$ in which $1<(x+y)\le 2$ are all satisfied, the PBNE is for anti-GE SIGs to always send a negative signal and consumers to not inspect regardless of what messages they receive. Hence, when consumers' inspection costs reach a certain level related to their prior belief, they would choose not to inspect negative messages, but to inspect positive messages from anti-GE SIGs. However, according to anti-GE SIG's best strategy profile, consumers will never receive positive messages. It should also be noted that if consumers' inspection cost is high enough so that $c_i > \max\left(d\rho+(e-e\rho-d\rho)x, e(1-q)-(e-eq-dq)y\right)$, it is no longer optimal for them to inspect any messages from anti-GE SIGs regardless of what message they receive.

It remains to check if pro-GE SIGs have the incentive to deviate from the strategy "always signal positive messages" given consumers' possible strategies. Cases (1) and (2), in which consumers will inspect negative messages, can be excluded because the anti-GE SIGs will have the incentive to deviate from this second strategy when the fact from Nature is "the GE food is unsafe". For instance, given consumers' first possible strategy "always inspect" and the fact from Nature "the GE food is unsafe", anti-GE SIGs receive *a* by sending negative messages while they receive ($a-c_s'$) by sending positive messages. There is an incentive for the anti-GE SIGs to signal negative messages when the truth is "the GE food is unsafe".

With respect to consumers' third strategy "not inspect if receive negative messages, inspect if receive positive messages", in order for the anti-GE SIG's "always signal positive messages" to be the optimal response, it must be the case that $ax<a-c_s'$ and $ax-\overline{c}_s<0$, which is equivalent to $c_s'<a(1-x)$ and $\overline{c}_s>ax$. Thus, if $e(1-p)-(1-x)(e-ep-dp)<c_i<e(1-\rho)(1-y)+\rho dy$, $ax<a-c_s'$, and $ax-\overline{c}_s<0$, the perfect Nash Equilibrium is for pro-GE SIGs to always send positive messages and consumers to either: a) not inspect if they receive negative messages; or b) inspect if they receive positive messages. On the other hand, if $c_i>\max\left(e(1-\rho)(1-y)+\rho dy, e(1-p)-(1-x)(e-ep-dp)\right)$, $c_s'<a(1-y-x)$, and $\overline{c}_s>a(x+y-1)$, the perfect Nash equilibrium is for pro-GE SIGs to always send positive messages and consumers to not inspect regardless of what messages they receive.

The Perfect Nash Equilibrium requires $c_s'<a(1-x-y)$ and $\overline{c}_s>a(x+y-1)$. However, these two conditions cannot exist simultaneously: $\overline{c}_s>a(x+y-1)$ and the prerequisite $0<\overline{c}_s<a$ indicate $x+y>1$ which means $c_s'<a(1-x-y)<0$. Therefore, there is no Perfect Nash Equilibrium in (3).

The anti-GE SIG's third possible strategy (signaling facts from Nature), would be informative for consumers, and thus consumers' beliefs are determined by Bayes' rule and the anti-GE SIG's strategy. Given anti-SIG's strategy, consumers' beliefs are ($p=1; q=0$), meaning if anti-GE SIGs signal negative messages, then consumers will believe that the fact from Nature is "the GE food is unsafe", and if anti-GE SIGs signal positive messages, then the fact is "the GE food is good". Consumers' best response to these beliefs is to not inspect regardless of what anti-GE SIG's signal. Given consumers' best response, we still need to check if anti-GE SIGs have any incentive to deviate from their third possible strategy. If $(1-y)>ax-\overline{c}_s$, anti-GE SIGs will always signal negative messages if consumers do not inspect. So, if the truth is "the GE food is safe", anti-GE SIGs have the incentive to signal negative messages, deviating from their third possible strategy. Therefore, there is no perfect Bayesian Nash equilibrium when anti-GE SIGs play ($s=0$ if $g=0$, $s=1$ if $g=1$).

The anti-GE SIG's fourth possible strategy (always signal messages opposite to the fact from Nature), is also informative. In this case, consumers' beliefs are ($p=0; q=1$). The requirements for anti-GE SIGs to not deviate from "always signal negative messages" are $c_s' > a(1-x-y)$ and $\overline{c}_s < a(x+y-1)$. Since $0<\overline{c}_s<a$, then $1<(x+y)\le 2$. $c_s' > a(1-x-y)$, in which $a(1-x-y)<0$, will always be satisfied, and thus anti-GE SIGs will signal messages opposite to the fact from Nature only if $0<c_s'<a$.