The Business, Entrepreneurship & Tax Law Review

Volume 6 | Issue 1 Article 4

2022

Genetically Engineered Food, Food Security, and Climate Change

Joanna K. Sax

Genetically Engineered Food, Food Security, and Climate Change

Professor Joanna K. Sax, JD PhD[*]

ABSTRACT

Malnutrition is the leading cause of death and disease worldwide. Climate change is an existential crisis. We need to feed people and address the role of agriculture in climate change – at the same time. This is problematic, as agriculture inherently creates issues that contributes to climate change. Utilizing science, through genetically engineered crops, is one way to close the harm gap between food security and climate change. This essay addresses the controversial issue of genetically engineered crops with the complicated issues of food security and climate change by analyzing three main issues: (1) how the science of genetically engineered crops can improve food security and lessen the impact of agriculture on climate change; (2) international regulation of genetically engineered crops; and (3) consumer misperception of risk as it relates to genetically engineered crops. In sum, this article tackles the complicated problem of genetically engineered food as it relates to food security and climate change. This essay is forward thinking as it promotes closing the divide between consumer misperception of risk and evidence-based assessment of risk to allow science to improve our food supply and decrease the impact on the planet.

* E. Donald Shapiro Professor of Law, California Western School of Law, San Diego, CA 92101; jsax@cwsl.edu; (619) 515-1555. Essay prepared for The Future of Food Conference hosted by the Business, Entrepreneurship & Tax Law Review at University of Missouri School of Law. The author wishes to thank the conference participants and editors of the journal.

I. INTRODUCTION

Addressing twin goals of increasing food security and decreasing the human impact on the climate requires highly technical solutions. The world's population is growing, and we need to feed more people by growing more crops in a more sustainable way. Malnutrition is the leading cause of death and disease worldwide.[1] Climate change is the existential crisis of our time.[2] Utilizing science, through the creation of genetically engineered crops, is one way to close the gap between food security and climate change.

Changing the genetic composition of crops is nothing new; humankind domesticated crops centuries ago, which included altering the DNA of plants even if humans did not understand the molecular changes at that time.[3] With more knowledge, humans learned new and different ways to domesticate and improve crops. In the 20th Century, seed manufacturers understood that changes at the molecular level could improve crops. Often, the seed manufacturers did not know the precise genetic changes they caused, but they understood the phenotypic changes, such as a better looking strawberry or green pepper. In sum, humans have consumed genetically modified crops for thousands of years.

In the last quarter of the 20th Century, new scientific understanding about genomes and improvements in genetic techniques paved the way for manipulating crop genomes in a way that had not previously been available. Scientists and seed manufacturers can now introduce foreign genetic sequences into a seed to give the resulting crop a new property, such as pest resistance. The original form of these techniques produced genetically modified organisms ("GMOs") because DNA from one organism was incorporated into another organism. Over the past 50 years, the understanding of plant genomes and the molecular techniques available increased such that scientists can manipulate DNA in ways that do not necessarily require the introduction of a foreign species' DNA, thus the more encompassing term of 'genetically engineered' is preferable, or at least more accurate. The long and the short of these developments is that scientists and seed manufacturers know much more about crop genomes and now have precise techniques to genetically modify crops. From a scientific perspective, these newer techniques do not pose any greater risk to human health as compared to the techniques used for centuries, *per se*, and they actually provide a way to improve crops that was not previously available.

Genetically engineered crops have an odd place in society. Some consumers inappropriately assign a high risk to food containing ingredients from genetically engineered crops and this is seen, for example, through calls for labeling laws. If a

---

1. Karen McVeigh, *Malnutrition Leading Cause of Death and Ill health Worldwide – Report*, THE GUARDIAN (May 12, 2020, 1:01 PM), https://www.theguardian.com/global-development/2020/may/12/malnutrition-leading-cause-of-death-and-ill-health-worldwide-report.

2. *See A Historic Commitment to Protecting the Environment and Addressing the Impacts of Climate Change*, OBAMA WHITE HOUSE ARCHIVES, https://obamawhitehouse.archives.gov/the-record/climate (last visited Feb. 02, 2022) ("President Obama believes that no challenge poses a greater threat to our children, our planet, and future generations than climate change[.]").

3. Tereza Sovoa et al., *Genome Editing with Engineered Nucleases in Economically Important Animals and Plants: State of the Art in the Research Pipeline*, 21 CURRENT ISSUES MOLECULAR BIOLOGY 41, 41 (2016) ("For thousands of years, the genetic basis of domesticated species has been changed by selecting the best progeny to improve desirable characteristics, such as yield and disease resistance, in subsequent generations.").

consumer wants to know that a food product is safe, that is certainly fair, but labeling something as genetically engineered, GMO, or even organic does not tell the consumer anything about safety. This misperception of risk is important to address because we need to use the science of genetically engineered crops to create more nutritious crops that can be grown in a more sustainable way – a goal that cannot be accomplished without the application of science.

This article tackles the controversial issue of genetically engineered crops with the complicated issues of food security and climate change. Part I describes the science of genetically engineered crops. This description is critical to understand what the science may be able to accomplish and to explain how scientists can assign evidence-based risk assessment. Part II addresses the international regulation of genetically engineered crops. Our food supply is global, but we do not have international standards for the regulation of genetically engineered crops, thus, the international system impacts the utilization of this technology. Part III explains that some consumers inappropriately assign a high risk and low benefit to genetically engineered crops. Consumer perception of risk is important because if consumers reject genetically engineered crops, then this creates a barrier to utilizing technology to solve the major interrelated problems of food security and climate change.

II. The Science of Genetically Engineered Crops

Decades of research supports the safety of genetic engineering techniques in our food supply.[4] When the molecular techniques were first applied to crops, scientists and regulators had concerns about unintended consequences.[5] An unintended consequence could include the increased expression of a toxin, for example.[6] To address this concern, a Coordinated Framework was created wherein the Environmental Protection Agency ("EPA"), Food and Drug Administration ("FDA"), and United States Department of Agriculture ("USDA") assumed overlapping jurisdiction for crops generated through genetic engineering techniques.[7] The administrative history of the Coordinated Framework is described elsewhere; however, for the purposes of this essay, what seemed like a good idea at the time has now become outdated, does not reflect our current scientific understanding, and likely contributes to consumer (mis)perception of the safety of genetically engineered crops as well as dis-incentivizes small biotechnology companies from creating niche products. This Part will proceed in two ways: (1) describe the science, and (2) provide examples of genetically engineered crops that might be more friendly to the climate and possibly address food security.

4. Nat'l Acads. of Scis., Eng'g, & Med., *Genetically Engineered Crops: Experiences and* Prospects, xiii (2016) (ebook) [hereinafter NAS Report].

5. Edward L. Rubin & Joanna K. Sax, *Administrative Guidance and Genetically Modified Food*, 60 Ariz. L. Rev. 539, 548 (2018).

6. Steven H. Strauss & Joanna K. Sax, *Ending Event-Based Regulation of GMO Crops*, 34 Nature Biotechnology 474, 475 (2016) ("A key early rationale for event-specific regulation was food safety. As originally constructed, the FDA's guidance report centered over unintended effects resulting from the gene insertion process.").

7. Coordinated Framework for Regulation of Biotechnology, 51 Fed. Reg. 23302, 23302 (June 26, 1986).

A. The science

Perhaps the first clarification required is the explanation that all of our crops are genetically modified; we do not grow nor eat wild-type varieties.[8] For thousands of years, humankind manipulated the DNA of our crops to obtain domesticated crop lines.[9] For centuries, this was done using techniques that are coined 'traditional' and include cross breeding, hybridization, irradiation, and chemical mutagenesis.[10] Irradiation, to choose one example, is the process by which seeds are exposed to forms of light that alter (or mutate) the DNA.[11] Seed manufacturers irradiate the seeds and then grow the plants to see what they get. Some seeds will not grow into plants, likely due to too much alteration to their DNA. Other seeds may grow into plants, but they may be deformed or produce toxins or have other deleterious characteristics. These seeds are weeded out through the manufacturing and commercialization processes.[12] Finally, perhaps one seed grows into a plant that has advantageous trait(s), such as a better-looking strawberry. Through our manufacturing and commercialization processes, these plants can be tested for deleterious events and if they pass these tests, then this new strawberry might be a good candidate for the marketplace. Now, the DNA sequence for the advantageous trait may never be known and the resulting strawberry plant may have many other mutations to the DNA, but through our commercialization processes, the strawberry can be determined as safe for consumption. This is how some crops are developed and used in the organic industry, for example.

Genetic engineering, unlike the mass mutagenic technique of irradiation, is more precise and the genetic changes are identified. Early techniques that produced the genetically modified organism, included the insertion of a genetic sequence from another species.[13] These sequences were known and could be tracked in the resulting seed. The concern at the time was that the insertion could disrupt another gene or cause increased expression of other genes; a concern that has not borne out with decades of research.[14] In any event, the changes were tracked, unlike the traditional techniques. Other molecular techniques now allow site directed

8. Rubin & Sax, *supra* note 5, at 543.

9. NAS REPORT, *supra* note 4, at 65.

10. *See, e.g.*, Frank Hartung & Joachim Schiemann, *Precise Plant Breeding Using New Genome Editing Techniques: Opportunities, Safety and Regulation in the EU*, 78 PLANT J. 742, 742 (2014) ("As a result, traditional plant breeding has been accomplished over the last 60 years by mutagenesis using chemical compounds or irradiation application, followed by screening of mutation for the desirable traits.").

11. *See* Liqiu Ma et al., *From Classical Radiation to Modern Radiation: Past, Present, and Future of Radiation Mutation Breeding*, 9 FRONTIERS IN PUB. HEALTH 1, 1–2 (2021).

12. Natalie Weber et al., *Crop Genome Plasticity and Its Relevance to Food and Feed Safety of Genetically Engineered Breeding Stacks*, 160 PLANT PHYSIOLOGY 1842, 1842–3 (2012) ("Although the genetic and biochemical bases for these traits are not usually well understood [for non-GE crops], conventional breeding has successfully stacked traits to create stable crop varieties that are considered safe and that, in most cases, were not subjected to safety assessments prior to commercialization." And "Despite this imprecision, plant breeding has a remarkable record of safety; no newly released variety has had any novel or previously unknown food or feed hazard [citation omitted].").

13. Frank Hartung & Joachim Schiemann, *supra* note 10, at 742 ("Since the mid 1990s, the classical repertoire of plant breeding techniques has been complemented by transgenic approaches to produce new plant varieties.")

14. Natalie Weber et al., *supra* note 12, at 1843.

mutagenesis, such that perhaps only a single base pair of the DNA is changed.[15] This highly precise technique is a more sophisticated mechanism compared to the older traditional techniques.

The manufacturing and commercialization processes are able to characterize the safety of genetically engineered crops in the same way that these processes are able to characterize the safety of traditionally modified crops.[16] Decades of research inform us that these molecular techniques do not pose additional safety risks as compared to traditional techniques.[17] The genetic engineering techniques do have their own issues, such as tracking, meaning that regulation that is specific to these techniques may be warranted, but the regulations need to reflect the evidence-based assessment of risk.[18]

B. Applying the science to address food security and climate change

The techniques employed via genetic engineering allow the improvement of crops; improvements that either cannot be done through traditional techniques or would be extremely difficult to obtain through traditional techniques. One well-known example is Golden Rice.[19] Rice is a staple crop in many impoverished areas of the world.[20] In these same areas, a deficiency in vitamin A also exists. This deficiency impacts children in particular, causing them to become essentially blind at dusk.[21] These children cannot see when daylight disappears. A way to address this malnutrition is to fortify the main food source so that children do not become blind at dusk.[22] Golden Rice is genetically engineered to contain beta-carotene, the precursor to Vitamin A.[23] If children eat Golden Rice, then they can obtain the needed nutrient so that they do not spend part of each day blind. No safety concerns exist with Golden Rice. The opposition to Golden Rice can be described as a non-scientific objection that has had the effect of allowing children to live with a debilitating condition.[24]

Another example of genetically engineered crops that can address food security are pest-resistant crops. Especially in poor countries, if a farm is devastated by a pest, the individuals in those communities will lack food to eat. As a related issue,

---

15. Khaoula Belhaj et al., *Plant Genome Editing Made Easy: Targeted Mutagenesis in Model and Crop Plants Using the CRSIP/Cas System*, 9 PLANT METHODS 39, 39 (2013) ("The ability to reprogram CRISPR/Cas endonuclease specificity using customizable small noncoding RNAs has set the stage for novel genome editing applications."); Tereza Sovoa et al., *supra* note 3, at 41.

16. Natalie Weber et al., *supra* note 12, at 1842–43.

17. Natalie Weber et al., *supra* note 12, at 1842–43; *see also*, Gregory Conko et al., *A Risk-Based Approach to the Regulation of Genetically Engineered Organisms*, 34 NATURE BIOTECHNOLOGY 493, 493–94 (2016).

18. Steven H. Strauss & Joanna K. Sax, *supra* note 6, at 475 ("In research, it is important to keep track of events as the effects and expression of independently inserted genes vary widely.").

19. ED REGIS, GOLDEN RICE, ix–xvii (Johns Hopkins Univ. Press, 2019) [hereinafter REGIS, GOLDEN RICE].

20. *Id.* at 13 ("For the world's poor, the ideal food to fortify is their default dietary staple, rice.").

21. *Id.* at 1 ("Their condition is called night blindness (nyclatopia) and it's one of the first indications of vitamin A deficiency.").

22. *Id.* at ix ("The 'gold' was in fact beta carotene, a substance that is converted into vitamin A in the human body, thus also known as provitamin A.").

23. *Id.*

24. *See, e.g.*, *id.* at x.

the promotion of organic farming techniques, especially in poor African nations, has a similar effect as banning genetically engineered crops.[25] Organic farming techniques may not allow for the use of some pesticides, which are needed to combat complete devastation of crops. The twofold problem – banning genetically engineered crops and promoting organic farming – may contribute to food security issues.

Pest-resistant genetically engineered crops have the ability to inherently fight off native pest species, potentially without the use of external pesticide application. One classic example of a pest-resistant crop is the Bt variety (e.g., Btcorn, Btcotton), which contains a portion of a bacteria genome that kills corn borer worms, which regularly impact crops.[26] Other genetic engineering techniques can give the crop an innate power to resist viral infections, such as plum pox.[27] The methodology of providing this innate protection can be accomplished in numerous ways, such as transfection or site-directed mutagenesis to favor a pest resistant gene.[28] Regardless of the technique used, the manufacturing and commercialization process allows scientists to test the safety of the resulting crops. Importantly, these techniques can be utilized to allow crops to survive serious infestations of pests, including viruses. And, as mentioned above, some of these types of crops simply cannot be obtained through traditional techniques.

Food security and climate change are inextricably linked.[29] As the climate changes, our agriculture system will also need to change. In addition, agriculture impacts climate change. For example, deforestation is part of agriculture, and this impacts climate change. With changes to our climate, pest infestation or water supply may be impacted, both of which will impact agriculture. Agriculture is not on the only contributor to climate change, but it is among the contributors. The question becomes, how to we grow more nutritious food in a more sustainable way? Genetically engineering crops are among those solutions.

Crops will die or senesce without enough water. Drought is a result of changes to our climate. Creating crops that are drought-tolerant, for example, allows crops to live even with less water.[30] The genes within a plant that tell it to die without enough water can be manipulated so that the signal to die is reduced.[31] Another example is the creation of pest-resistant crops, discussed above. By increasing the innate ability to fend off pests, less external application of pesticide is needed and crop yield can increase – a duo result that addresses climate change and food security. Delayed ripening is another example. If crops can be genetically engineered to delay ripening, then this increases the window of time to get the resulting crop to

---

25. *Cf.* Robert Paarlberg, *A Dubious Success: The NGO Campaign Against GMOs*, 5 GM CROPS & FOOD 223, 224 (2014).

26. Matthew Niederhuber, *Insecticidal Plants: The Tech and Safety of GM Bt Crops*, HARV. U.: SCI. NEWS (Aug. 10, 2015), http://sitn.hms.harvard.edu/flash/2015/insecticidal-plants.

27. *Honeysweet Plum Trees A Transgenic Answer to the Plum Pox Problem*, USDA AGRIC. RESEARCH SERV., https://www.ars.usda.gov/oc/br/plumpox/index (last modified Aug. 25, 2020) (providing answers to frequently asked questions).

28. *See, e.g.*, Ralph Scorza et al., *Genetic Rngineering of Plum Pox Virus Resistance: "HoneySweet" Plum–From Concept to Product*, PLANT CELL TISSUE ORGAN CULT, https://www.ars.usda.gov/ARSUserFiles/oc/br/plumpox/PCTOC2013.pdf.

29. *See* MARK LYNAS, SEEDS OF SCIENCE 33–49 (2018).

30. Honghong Hu and Lizhong Xiong, *Genetic Engineering and Breeding of Drought-Resistant Crops*, 65 ANN. REV. OF PLANT BIOLOGY 715, 716, 724–27, 731 (2014).

31. *See* Damiano Martignago, et al, *Drought Resistance by Engineering Plant Tissue-Specific Responses*, 10 FRONTIERS IN PLANT SCI. 1, 4 (2020).

market and more time for the crop to be consumed.[32] Rotting crops does not do anyone any good. Thus, this is another example that marries climate change and food security.

Genetic engineering of crops is often pitted against the organic farming practices, with the false notion that organic farming is the eco-friendly alternative to traditional farming practices.[33] This position assumes that everyone can afford the cost of organic products, an assumption that is not borne out by widespread malnutrition, especially in third-world countries. It is also a privileged position because it assumes that organic farming techniques can handle the risk of complete crop devastation in poor nations.[34] If a poor farmer in a poor nation has their crops invaded by a pest, the organic farming techniques are unlikely to handle the devastation, the crop is lost, and the farmer goes hungry. In reality, organic farming uses pesticides as well.[35] Organic farming has its own set of food supply and climate change issues. As proposed by others, marrying genetic engineering technology with organic farming practices might be among the solutions.[36] This idea is rejected by the Organic Farming Industry in the United States for what appear to be marketing and economic reasons.[37] This rejection is somewhat perplexing given that all crops grown by organic farmers are genetically modified via traditional techniques. In other words, organic farmers, just like all other farmers, are not growing wild-type varieties. Organic famers grow domesticated crops that are genetically modified.[38]

The larger issue is that we need to solve two problems: food security and human impact on climate change. We need solutions. Organic farming, for example, does not address food security in a large-scale manner.[39] The techniques of organic farming *may* provide some solutions to the human impact on climate change, but the

32. *See* Carmen Martin-Pizarro and David Posé, *Genome Editing as a Tool for Fruit Ripening Manipulation*, 9 FRONTIERS IN PLANT SCI. 1, 2 (2018).

33. *Cf.*, ORGANIC TRADE ASS'N, *Organic and GMOs*, https://ota.com/organic-101/organic-and-gmos (last visited Jan. 26, 2022) ("The use of genetically modified organisms (GMOs) is prohibited in organic products.").

34. Paarlberg, *supra* note 25, at 224 ("The single most powerful explanation for this continuing blockage of GMOs has been energetic NGO campaigns of disinformation, led and financed mostly by individuals from well-fed countries who do not need the technology themselves.").

35. *Organic Farming*, U.S. ENV'T PROTECTION AGENCY, https://www.epa.gov/agriculture/organic-farming (last updated Sept. 29, 2021) ("'Organically grown' food is food grown and processed using no synthetic fertilizers or pesticides. Pesticides derived from natural sources (such as biological pesticides) may be used in producing organically grown food.").

36. Amjad M. Husaini & Muhammed Sohail, *Time to Redefine Organic Agriculture: Can't GM Crops Be Certified as Organics?*, 9 FRONTIERS PLANT SCI. 1, 3 (2018) (explaining how these new breeding techniques are advantageous and promising for organic farmers).

37. *Organic and GMOs*, ORGANIC TRADE ASS'N, https://ota.com/organic-101/organic-and-gmos (last visited Jan. 26, 2022) ("The use of genetically modified organisms (GMOs) is prohibited in organic products.").

38. Martin M.Anderson, et al., *Feasibility of New Breeding Techniques for Organic Farming*, 7 TRENDS IN PLANT SCI. 426, 428 (2015) ("In nature, mutations happen spontaneously all the time and are the basis of evolution. They can result from internal mistakes in the functioning of the cellular machinery or from external factors, such as UV radiation from the sun or background radiation from the universe. Breeders have always made use of such mutations by exploiting the resulting diversity of traits, and have also accelerated the process by creating random mutations using radiation or mutagenic chemical treatment. Consequently, important traits have been selected for, including ease of harvesting, increased yield, and reduced toxicity. This holds true for all modern crop plants, including those used in organic farming." [internal citations omitted].).

39. *Id.* at 426 ("As a consequence, productivity is often lower in organic than in conventional agriculture, and several strategies have been suggested to close this yield gap between high- and low- performing conventional systems." [internal citations omitted].).

techniques will not have the widespread impact necessary, especially given the restriction of using genetically engineered crops.[40] This is not an anti-organic farming sentiment; it is a reality that we need to address agriculture in a large-scale manner. Genetically engineered crops, which provide more nutritious food in a more sustainable manner, are among the techniques that should be utilized to address food security and human impact on climate change.

III. THE INTERNATIONAL REGULATION OF GENETICALLY ENGINEERED CROPS

Our food system is complex and global. The patchwork of global regulations, regarding the sale and consumption of genetically engineered crops, impacts whether farmers will grow these crops. Farmers in an African nation, for example, may not grow pest resistant genetically engineered crops if they cannot export their crops to Europe. Farmers in the United States may not grow a particular type of genetically engineered crop if they cannot export their crop to China. Our supply chain is global, but different countries have different regulations regarding genetically engineered crops, and this creates a problem for utilizing the technology to solve food security and the human impact on climate change.

A. Regulation of genetically engineered food in the United States

The United States ("US") has a complicated interagency regulatory structure, but generally speaking, the US allows genetically engineered crops to be grown and consumed. The Coordinated Framework, originally established in 1986 and updated in 1992 provides that the FDA, USDA, and EPA oversee the regulation (or really deregulation) or genetically engineered crops and food.[41] Each agency has its own interests, although at times these interests overlap. The FDA cares about a safe food supply for human and animal consumption.[42] The USDA's interest is in the possibility of a negative consequence in agriculture, such as the development of a plant pest.[43] The EPA cares about the use of herbicides and pesticides, including the presence of an intrinsic pest protection system in a genetically engineered crop.[44] Depending on a particular crop, the manufacturer may have to move through one or more agencies to obtain de-regulation. In other words, a manufacturer seeks deregulation so that the manufacturer can grow and sell the crop without subsequent agency action.

The Coordinated Framework, at the time of its development, was a science-based approach. Decades of research since 1992 inform us that the Coordinated Framework is both underinclusive and overinclusive.[45] A large body of commentary

---

40. *Id.* ("A plea for merging organic agriculture and genetic engineering approaches has been previously published." [internal citation committed].).

41. Coordinated Framework for Regulation of Biotechnology, 51 Fed. Reg. at 23302; *The Unified Website for Biotechnology Regulation*, U.S. DEP'T OF AGRIC., https://usbiotechnologyregulation.mrp.usda.gov/biotechnologygov/about/about (last visited Jan. 26, 2022).

42. Federal Food, Drug and Cosmetics Act, 21 U.S.C. §§ 301–399i (2012).

43. Plant Protection Act, 7 U.S.C. §§ 7701–7786 (2012).

44. Federal Fungicide, Insecticide and Rodenticide Act, 7 U.S.C. §§ 136–136y (2012).

45. Conko et al., *supra* note 17, at 496.

has developed around the Coordinated Framework.[46] For simplicity the Coordinated Framework is underinclusive in that it might not capture newer techniques, such as CRISPR/CAS-9, which allows for a single base pair change.[47] This base pair change could be used to make an advantageous allele more prevalent. In other words, no new product is really developed, but the frequency of a particular protein may be increased. This type of change can be hard to track.[48] The Coordinated Framework does not squarely address this issue, for example. On the other end, the Coordinated Framework is overinclusive because: (1) we know much more about the genomes of crops, (2) their highly dynamic structure, and (3) the initial scientific concerns at the heart of the Coordinated Framework are now much better understood, such as the impact on the expression of endogenous toxins and can be addressed through the commercialization process. The lengthy and expensive de-regulation process is not needed to ensure a safe food supply in the same way that it was needed almost 40 years ago.

While the science of genetically engineered crops and the resulting food products are well understood, some consumers in the US have a different perception. The consumer perception is discussed more below, but to highlight how consumer resistance to genetically engineered crops is playing out in the US, a national labeling law now requires manufacturers to label food that contains genetically engineered material.[49] An interesting question is why is the labeling necessary? Is the label telling the consumer the information that they want to know? A recent study analyzing labeling found that consumers make associations with different labels, but that the labels do not actually tell the consumers what they want to know.[50] For example, the label 'natural' means something to consumers and they associate it with 'healthy' or 'safe.'[51] But, the label 'natural' has no regulatory definition and it does not tell consumers whether something is actually healthy or safe.[52] Similarly, consumers associated the label 'GMO' with being less healthy or safe, compared to the label 'natural.'[53] Even though the label, 'GMO,' does not actually tell the consumer whether something is actually healthy or safe.[54] The national labeling law is meant to create a nation-wide standard so that manufacturers are not subject to different state-by-state laws.[55] Additionally, labeling something with genetically

---

46. *See, e.g.*, *id.* at 494 (2016); Steven H. Strauss & Joanna K. Sax, *supra* note 6, at 475–76.

47. Khaoula Belhaj et al., *supra* note 15, at 39; Tereza Sovoa et al., *supra* note 3, at 41.

48. Strauss & Sax, *supra* note 6, at 475–6.

49. National Bioengineered Food Disclosure Standard, Pub. L. No. 114-216, 130 Stat. 834 (2016) (codified at 7 U.S.C. § 293(a)(1)); *see also Establishing the National Bioengineered Food Disclosure Standard*, U.S. DEP'T OF AGRIC., https://www.usda.gov/media/press-releases/2018/12/20/establishing-national-bioengineered-food-disclosure-standard (last visited Jan. 26, 2022).

50. Joanna K. Sax and Neal Doran, *Food Labeling and Consumer Associations with Health, Safety, and Environment*, 44 J. L., MED. & ETHICS 630, 635 (2016).

51. *Id.* ("Interesting, respondents associated food with the label 'natural' to be as healthy, safe, and environmentally friendly as other types of food labels, except those labeled GMO.")

52. *Id.* ("Given that the FDA has repeatedly refused requests to define this term, it has no precise regulatory definition.").

53. *Id.* 634–35.

54. *Id.* at 635 ("The response that GMO labeled food is less safe than food with other labels suggests a disconnect between respondent attitudes and the scientific consensus.").

55. Joe Hernandez, *GMO is Out, 'Bioengineered' is in, as New U.S. Food Labeling Rules Take Effect,* (Jan. 5, 2022), https://www.npr.org/2022/01/05/1070212871/usda-bioengineered-food-label-gmo#:~:text=The%20new%20term%20for%20foods,t%20possible%20through%20natural%20growth. ("Consumers will begin to see labels on some foods that say 'bioengineered' or 'derived from

engineered ingredients is not aversive, *per se*, so long as the information actually provides the information that consumers are seeking. Put differently, no objective reason exists not to inform consumers about any particular ingredient, but if consumers assign a subjective meaning – one that is not supported by the facts – then the labeling law is not helpful and can actually be hurtful.

Overall, the US regulatory framework allows for the growing and selling of genetically engineered crops. It is a heavily regulated system. Research suggests that consumers may assign a high risk to areas that are heavily regulated due to the impression that regulation is needed for safety reasons.[56] How governments regulate genetically engineered crops is likely a contributor to how consumers view ingredients from genetically engineered crops.

B. Regulation of genetically engineered food in the European Union

The European Union (EU) takes a different approach, as compared to the US. At the heart of the EU's approach to genetically engineered crops and the resulting food is the precautionary principle.[57] In short, the precautionary principle requires that the risks be fully understood prior to market entry.[58] This can serve as a barrier to market entry because scientific risk assessment does not generally reach zero.[59] The precautionary principle in this context is also problematic because it is not applied to traditional mutagenic techniques, so those crops and food made from those crops can freely enter the market. While each member state can make its own determination, most member states have not granted approval.[60] In addition, intense regulations exist for importing genetically engineered crops, which has the impact of deterring trade partners from growing genetically engineered crops.[61]

Interestingly, most animal feed in the EU is from genetically engineered crops, much of which is imported.[62] Instead, it is the crops and food for human consumption face the heavy hand of regulation in the EU.

---

bioengineering.' As the new federal standard takes hold and replaces the former patchwork of state-level requirements.").

56. *See* Peter M. Wiedemann & Holger Schutz, *The Precautionary Principle and Risk Perception: Experimental Studies in the EMF Area*, 113 ENV'T HEALTH PERSP. 402, 402–05 (2005).

57. *See, e.g., Future Brief: The Precautionary Principle: Decision-Making Under Uncertainty*, EUR. COMM'N, SCI. FOR ENV'T POL'Y, (Sept. 2017), https://ec.europa.eu/environment/integration/research/newsalert/pdf/precautionary_principle_decision_making_under_uncertainty_FB18_en.pdf.

58. *Id*. (citing the Communication on the Precautionary Principle from 2000: "Recourse to the precautionary principle presupposes that potentially dangerous effects deriving from a phenomenon, product or process have been identified, and that scientific evaluation does not allow the risk to be determined with sufficient certainty. The implementation of an approach based on the precautionary principle should start with a scientific evaluation, as complete as possible, and where possible, identifying at each stage the degree of scientific uncertainty.").

59. Frank Hartung & Joachim Schiemann, *supra* note 10, at 743–4.

60. *Genetically Modified Food in the European Union*, WIKIPEDIA, https://en.wikipedia.org/wiki/Genetically_modified_food_in_the_European_Union (last visited Jan. 26, 2022).

61. *See* John Davison, *GM Plants: Science, Politics and EC Regulations*, 178 PLANT SCI. 94, 94 (2010) ("The EU has the probably strictest regulations in the world for the presence of GMOs in food and feed. These require the labeling of food and feed where the level of approved GMO exceeds 0.9% of unintentional adventitious presence. For non-approved GMOs the threshold is 'zero' and thus requires that cargoes containing GMOs non-approved GMOs are returned to the port of origin or are destroyed.").

62. *No GMO from feed found in meat or eggs: EU agency*, REUTERS (Aug. 3, 2007, 5:01 AM), https://www.reuters.com/article/us-eu-gmo-food/no-gmo-from-feed-found-in-meat-or-eggs-eu-agency-

The EU's approach to genetically engineered crops has international consequences. Trade partners, including those in African nations, may not grow genetically engineered crops because they cannot trade with EU nations.[63] Given the international scope of our food systems, different regulatory structures in the US and the EU, for example, have wave effects that ripple to other countries, including developing countries. The lack of coordination and international regulations has consequences on the food supply and the impact of agriculture on climate change.

C. Regulation of genetically engineered food in China

China has a system for regulating the growing of a genetically engineered crop and a different system for the importing of genetically engineered crops.[64] To grow or import a genetically engineered crop, permission must be obtained from the Ministry of Agriculture (MOA).[65] To grow a crop, a manufacturer or farmer must obtain special licenses, a biosafety certificate, and several permits.[66] The foreign entity needs to seek approval from the MOA, which includes, but is not limited to, testing phases as well as documentation that the exporting country has permitted the same crop for the same intended uses to import raw materials for processing.[67]

As a major player in the international marketplace, the regulatory structure in China impacts whether foreign farmers will grow particular crops. In other words, if a farmer relies on exporting their crops to China, that farmer will want to know that their particular genetically engineered crop will receive approval from the MOA.

D. The food supply chain is global

The above very cursory descriptions of the regulation of the growing and trading of genetically engineered crops demonstrate that each country/region has its own set of regulations. To trade in the international marketplace, manufacturers and farmers must comply with the requirements of the EU, China, and the US. No central body governs the international regulation of genetically engineered food and each country/region may want information and regulatory approval that is different compared to one another. These separate and distinct systems in China, the EU, and the US create a patchwork system and may, arguably, decrease the application of the genetic engineering technology to be employed to address food security and the human impact on climate change.

The lack of a global regulatory system is not the only problem in realizing the full potential of genetically engineered crops. The consumer perception of risk related to genetically engineered crops impacts the marketplace as well. Research in other areas explains that consumers are more likely to assign a high risk to areas

---

idUSL0392209120070803 ("Around 90 percent of the EU's imports of GMO grain and oilseeds are used as animal feed.").

63. LYNAS, *supra* note 29, at 157.

64. Alice Yuen-Ting Wong and Albert Wai-Kit Chan, *Genetically Modified Foods in China and the United States: A Primer of Regulation and Intellectual Protection*, 5 FOOD SCI. AND HUMAN WELLNESS 124, 128 (2016).

65. *Id.*

66. *Id.*

67. *Id.* at 129.

that are heavily regulated because a consumer may believe that the area is highly regulated because the regulation is needed to decrease the danger of the regulated articles. Another possible source of consumer apprehension of genetically engineered crops may stem from marketing campaigns aimed to instill fear.[68] The consumer perception of risk is discussed in greater detail in the next section. Addressing the consumer perception of risk is likely critical to shoring up the international regulation of genetically engineered crops so that the major players in the supply chain can align and cooperate in the global supply chain.

IV. CONSUMER MISPERCEPTION OF RISK

The safety of food from the genetically engineered crops currently in the marketplace is not disputed; our food supply is safe for consumption.[69] Some consumers, however, assign a high-risk to food from genetically engineered crops – a perception not in line with the evidence-based assessment of risk. This misperception of risk can destroy our ability to use this technology to address food security and the human impact on climate change. Consumer misperception of risk is a tough problem to solve.

Consumer misperception of risk compared to evidence-based assessment of risk is not a new problem. This divide – consumers assigning a high risk while the evidence demonstrates a low risk – appears to be increasing. A salient example is the COVID-19 vaccine. Consumers are not getting vaccinated during the COVID-19 pandemic due to an inappropriate assignment of risk to the vaccine.[70] The evidence-based assessment of the risk of the vaccine is low; the risk of serious disease is high. This same issue exists with genetically engineered crops. Consumers assign a high risk to food with ingredients from genetically engineered crops, even though the evidence-based assessment of risk is low. This misperception of risk is spurred on by various influences, including anti-GMO campaigns and promoting organic food as safer.

At the legal regulatory level, we have deficits in our ability to implement policies designed to obtain the desired behavior. A large body of literature, broadly described as behavioral economics, addresses the problems of individuals responding in a particular way to a particular policy. More needs to be done than implementing sound policies. This article promotes an approach to closing the divide between consumer misperception of risk compared to evidence-based assessment of risk. The approach promoted herein allows consumers to have the tools to appropriately assign risk in the first place. In this way, our legal regulatory system is more likely to obtain the results it seeks.

Viewing this problem – the misperception of risk – at the decision-making level is not novel in and of itself; however, decision-making theories have not yet solved the precise problem addressed in this article. In other words, we can utilize what we know from decision-making theories related to risk perception to try to close the divide between consumer misperception of risk and evidence-based assessment of

---

68. *See, e.g.*, Yunhe Li et al., *Excessive Chinese Concerns over Genetically Engineered Food Safety are Unjustified*, 6 NATURE PLANTS 590, 590 (2020).
69. NAS REPORT, *supra* note 4.
70. Joanna K. Sax, *COVID-19 Vaccine Hesitancy and (Mis)perception of Risk,* 48 AM. J. L. & MED 54, 54-56 (2022).

risk. Two theories described herein – ambiguity aversion and affect heuristic – provide a framework to explore this problem at the root-cause level.

A. Ambiguity Aversion and perceptions of risk

Ambiguity Aversion, a theory pioneered by Daniel Ellsberg, explains that when people are presented with missing or conflicting information, they assign a high risk.[71] In an experiment, participants were presented with two choices: choose a red marble from an urn with a known ratio of black and red marbles or choose a red marble from an urn with an unknown ratio of marbles.[72] Participants favored the urn with the known ratio, even though there was a probability that the 'unknown' urn only contained red marbles.[73] This experiment supports the idea that people prefer a known risk, even if it might be a higher risk, compared to an unknown risk.[74] It also demonstrates that people are averse to missing information, i.e., the urn with the unknown ratio. Decades of research using the ambiguity aversion theory help us understand how people inappropriately assign risk when presented with missing or conflicting information.[75]

In a focus group study with Vaccine Hesitant Parents (VHPs), one study demonstrated that ambiguity aversion helps to explain vaccine hesitancy.[76] In these focus group studies, it was clear that VHPs inappropriately assign a high risk to the vaccine and a low risk to the vaccine preventable disease.[77] Their reasons included that they did not think their children were in a setting where they were at risk of getting the disease and that even if they did, they could take their child to the doctor for treatment.[78] They also assigned a high risk to the vaccine, noting that once the vaccine is given it cannot be undone; thus, they feared long-term side effects that could not be undone.[79] The evidence-based assessment of risk is that vaccines are low risk and high benefit and that the vaccine preventable disease is high risk. However, with purported missing or conflicting information, VHPs demonstrated an inability to appropriately assign risk.

Ambiguity aversion can also help us understand the anti-genetically engineered food sentiment. Consumers may be rejecting foods containing genetically engineered crops due to their receipt of conflicting or missing information about the

---

71. Daniel Ellsberg, *Risk, Ambiguity, and the Savage Axioms*, 75 Q. J. ECON. 643, 657 (1961).
72. *Id.*
73. *Id.*
74. *Id.* ("Responses from confessed violators indicate that the difference is not to be found in terms of the two factors commonly used to determine a choice situation, the relative desirability of the possible pay-offs and the relative likelihood of the events affecting them, but a third dimension of the problem of choice: the nature of one's information concerning the relative likelihood of events. What is at issue might be called the *ambiguity* of this information, a quality depending on the amount, type, reliability, and 'unanimity' of information, and giving rise to one's degree of 'confidence' in an estimate of relative likelihoods.").
75. *See, e.g.*, Colin Camerer & Martin Weber, *Recent Developments in Modeling Preferences: Uncertainty and Ambiguity*, 5 J. RISK & UNCERTAINTY 325, 333–41 (1992); Joanna K. Sax & Neal Doran, *Ambiguity and Consumer Perceptions of Risk in Various Areas of Biotechnology*, 42 J. CONSUMER POL'Y 47, 54–56 (2019) [hereinafter Sax & Doran (2019)].
76. Laura L. Blaisdell et al., *Unknown Risks: Parental Hesitation about Vaccination*, 36 MED. DECISION MAKING 479, 480 (2016).
77. *Id.* at 481-2.
78. *Id.* at 484 (Tables 4 & 5).
79. *Id.* at 483 (Table 3).

technology.[80] This conflicting and missing information is then the basis for their inappropriate assignment of risk. One study analyzed the role of missing and conflicting information in individuals'assessment of risk related to genetically engineered food.[81] This study found that individuals who were averse to ambiguous information were significantly more likely to assign a high risk to survey scenarios containing vignettes about genetically engineered food products.[82] In other words, it can be predicted who is more or less likely to inappropriately assign risk.[83] These data provide helpful information to test interventions to allow individuals to be more likely to appropriately assign risk. Finding effective interventions is difficult, but this article proposes that it should be a focus of future studies.

B. Affect Heuristic and perceptions of risk

The Affect Heuristic, a theory pioneered by Paul Slovic, explains that a 'faint whisper of emotion' impacts how individuals assign risk.[84] Decades of empirical research support the theoretical framework.[85] At a simplified level, individuals who experience feelings of fear or dread are more likely to assign a high risk and low benefit to a particular decision, regardless of the evidence-based assessment of risk.[86] Moreover, individuals who experience feelings of happiness or joy are more likely to assign a low risk and high benefit to a particular decision, regardless of the evidence-based assessment of risk.[87] One reason for this is that people do not want to replicate or re-experience feelings of fear or dread, so they reject a particular scenario by assigning a high risk.[88] Conversely, people want to replicate feelings of happiness or joy, so they do not reject a particular scenario by assigning a low risk.[89]

VHPs, described above under ambiguity aversion, might also be explained using the affect heuristic.[90] If parents experience feelings of fear or dread that their child will experience a side effect of a vaccine, such as autism (to be clear, there is no link between vaccines and autism), then the emotion of fear may underscore their

80. Sax and Doran, *supra* note 75, at 4.

81. *Id.* at 6–9.

82. *Id.* at 9.

83. *Id.* ("As hypothesized, we found that participants who showed an initial aversion to ambiguous information were significantly more likely to choose the response options that indicated a high assignment of risk, even when alternative choices had a high benefit or a likelihood of low risk.").

84. Paul Slovic, *Perception of Risk*, 236 Sci. 280, 280–85 (1987) [hereinafter Slovic (1987)]; Paul Slovic & Ellen Peters, *Risk Perception and Affect*, 15 CURRENT DIRECTIONS PSYCH. SCI. 322, 322 (2006) ("We shall focus this review on a 'faint whisper of emotion' called *affect*.").

85. *See, e.g.*, DANIEL KAHNEMAN, THINKING FAST AND SLOW 137–45 (2011) [hereinafter Kahneman (2011)] ("Paul Slovic probably knows more about the peculiarities of human judgment of risk than any other individual. His work offers a picture of Mr. and Ms. Citizen that is far from flattering: guided by emotion rather than by reason, easily swayed by trivial details, and inadequately sensitive to differences between low and negligibly low probabilities.").

86. Slovic, *supra* note 84, at 284–85; Slovic & Peters, *supra* note 84, at 322–23; Paul Slovic et al., *The Affect Heuristic*, 177 EUR. J. OPERATIONAL RES. 1333, 1334 (2007).

87. *See* Slovic & Peters, *supra* note 84, at 323–24.

88. *See* Ellen Peters et al., *Affect and Decision Making: A "Hot" Topic*, 19 J. BEHAV. DECISION MAKING 79, 83 (2006).

89. *See id.*

90. Joanna K. Sax, *Biotechnology and Consumer Decision-Making*, 47 SETON HALL L. REV. 433, 442 (2017) ("Both of these theories can operate at the same time, especially because they both apply to perceptions of risk.").

decision not to vaccinate; in other words, they inappropriately assign a high risk to the vaccine. The VHP cannot 'unsee' the false information regarding the link between vaccines and autism. They experience dread that they are hurting their child and decide not to vaccinate. This scenario suggests that both ambiguity aversion and affect could be driving the VHP's decision; a scenario that is recognized in the decision-making literature. In other words, decision-making is complicated and those that work in this field often collaborate because it may be that more than one theory is responsible for how people inappropriately assign risk under any given scenario.[91]

Affect may also help us understand the consumer rejection of genetically engineered crops.[92] False information linking genetically engineered crops to cancer (to be clear, there is no link between eating genetically engineered crops and cancer), elicits feelings of fear and dread.[93] The individual assigns a high risk and low benefit to genetically engineered crops – a risk assessment not in line with evidence-based assessment of risk. Effective marketing campaigns by anti-GMO groups use these emotions of fear and dread to sway consumers against genetically engineered crops.[94] We face a risk that the technology will be rejected by enough people and groups that it will be difficult to utilize genetic engineering techniques to address both food supply and the human impact on climate change.

C. Using decision-making theories to align consumer perception of risk with evidence-based assessment of risk

If consumers reject genetically engineered crops, our society loses a major tool to address food security and climate change. We can use the scientific techniques of genetic engineering to create more nutritious crops that can be grown more sustainably. Genetic engineering techniques are not the only solution to food security and climate change, but it is among the solutions. In order to deploy the molecular techniques, consumers need to be able to appropriately assign risk.

One goal of legal regulation is risk regulation. Thus, one approach is to regulate genetically engineered crops in a manner that reflects the evidence-based risk assessment; this works when people respond appropriately to the legal regulation. A large body of literature informs us that people do not always respond in the way that the policy seeks. A salient example is a vaccine mandate. Vaccines are safe and effective; thus, a vaccine mandate reflects the evidence-based risk assessment. However individuals reject vaccine mandates for various reasons, including but not limited to a misperception of the risk of the vaccine.[95] Similarly, with genetically engineered crops, a legal policy can reflect the evidence-based assessment of risk. Nonetheless we know that some consumers reject food made from genetically

---

91. Kahneman (2011), *supra* note 85 at 137–45.

92. *See, e.g.*, Edward Rozyman et al., *What Lies Beneath? Fear vs. Disgust as Affective Predictors of Absolutist Opposition to Genetically Modified Food and Other New Technologies*, 12 JUDGEMENT & DECISION MAKING 466, 472 (2017).

93. *See e.g.*, L.Z.G. Touyz, *Genetically Modified Foods, Cancer, and Diet: Myths and Reality*, 20 CURRENT ONCOLOGY e59, e60 (2013) ("The recent report claiming that GMFs are causally associated with cancer development in rats has been debunked by informed opinion[.]").

94. LYNAS, *supra* note 29, at 14–31.

95. Sax, *supra* note 70, at 86-90.

engineered crops, for various reasons, including but not limited to a misperception of the safety of genetically engineered crops.[96]

This essay utilizes well-studied decision-making theories, ambiguity aversion, and affect, to propose that these theories be utilized to align consumer perception of risk with an evidence-based assessment of risk such that consumers are more likely to respond to the legal regulation. These theories have not yet been used to answer the question posed herein: how do we close the divide between consumer misperception of the risk of food made from genetically engineered crops and evidence-based risk assessment. The idea is to address the risk perception prior to implementing a risk-based legal regulation. This idea shifts the conversation regarding the regulation of genetically engineered crops.

IV. CONCLUSION

No single solution exists to solve either the issue of food security or the human impact on climate change. Applying genetic engineering techniques with a goal or principle of alleviating food insecurity and addressing the human impact on climate change is among the approaches that should be utilized. The technology of genetically engineering our crops has promise, and the regulatory structures should reflect the evidence-based assessment of risk. Since our food supply is part of a global marketplace, streamlining international regulations will incentivize the use of this technology. The current patchwork system with differing views by nation-states makes this a difficult goal. On top of that is the consumer's misperception of risk regarding food containing genetically engineered crops. Some consumers inappropriately assign a high risk to food containing genetically engineered ingredients or to genetically engineered crops – a perception that is disconnected from the evidence-based assessment of risk. Even if the regulatory structures follow the science, consumer rejection will certainly impact the ability to utilize this technology to alleviate the issues of food security and climate change.

This essay seeks to explain the possible underlying reasons why some consumers inappropriately assign risk. Addressing risk perception through legal interventions may close the divide between consumer misperception of risk and evidence-based assessment of risk. Importantly, closing this divide allows the consumer to appropriately assign risk; it does not determine their final decision. A consumer may still prefer non-genetically engineered food, but that preference will not be based on an inappropriate assignment of risk. Our society faces complicated challenges, and we need to thoughtfully utilize our knowledge to solve these problems. One possible part of this solution is applying science to create more nutritious crops that can be grown more sustainably.

96. Joanna K. Sax, *The Problems with Decision-Making*, 56 TULSA L. REV. 39, 40-42 (2020).