

# THE LAW AND POLICY OF AVIAN INFLUENZA: A COMING SHIFT

*Lukas Schnepel*<sup>†</sup>

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## ABSTRACT

*This paper argues that the prevailing law and policy framework is inadequate for managing current outbreaks of avian influenza and that reform is needed. Specifically, it examines the National Poultry Improvement Plan, arguing that a mass vaccination program for commercial poultry is warranted in light of the mounting social and economic costs of managing avian influenza under the status quo approach. In making this argument, this article discusses the poultry industry, avian influenza, federal regulations, and possible solutions. It illustrates why the status quo is insufficient and makes recommendations for reform, including a mass vaccination program for commercial poultry and increased investments in gene editing technology.*

## I. INTRODUCTION

From 2022 to 2023, nearly 40 million domesticated poultry were exterminated in the United States.<sup>1</sup> This was in response to an outbreak of a highly

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<sup>†</sup> I am a JD candidate at the University of Iowa, class of 2024, and a summer associate at Koley Jessen in Omaha.

1. Denise Chow & Evan Bush, The Avian Flu is Hammering U.S. Poultry Farmers, Leaving Experts to Ask: What has Changed?, NBC News (Jan. 18, 2023, 2:57 PM),

pathogenic avian influenza of the H5N1 strain (avian influenza or HPAI) which has been ravaging wild and domesticated bird populations alike throughout the United States since early 2022.<sup>2</sup> This makes it the deadliest avian influenza outbreak in United States history and one which threatens the physical and economic well-being of all Americans.<sup>3</sup> This article argues that the current policy framework is less effective against avian influenza than other diseases and that new ideas are needed.

Avian influenza is far from a novel phenomenon, having been recorded and studied as early as 1878 but referred to as “fowl plague.”<sup>4</sup> By the early 1980s, researchers had discarded the notion of fowl plague and adopted the term “highly pathogenic avian influenza” (HPAI) as more scientifically appropriate.<sup>5</sup> Importantly, HPAI is defined in veterinary medicine as “any influenza virus [for avian species] that results in not less than 75% mortality within 8 days [of inoculation].”<sup>6</sup> “Low pathogenic avian influenza” (LPAI) is simply avian influenza which is not lethal enough to be considered HPAI.<sup>7</sup> Outbreaks of HPAI and LPAI have historically been managed without a major impact on the American food production system and typically come and go within a broadly defined “flu season”

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<https://www.nbcnews.com/science/science-news/avian-bird-flu-egg-prices-rcna66273>  
[<https://perma.cc/6EEK-FLPP>].

2. *H5N1 Bird Flu Detections Across the United States (Backyard and Commercial)*, CTRS. FOR DISEASE CONTROL AND PREVENTION (May 31, 2023), <https://www.cdc.gov/flu/avianflu/data-map-commercial.html> [<https://perma.cc/JFD2-7NLF>] (“[Avian influenza] ...viruses have been detected in U.S. wild aquatic birds, commercial poultry and backyard or hobbyist flocks beginning in January 2022. These are the first detections of [these] viruses in the U.S. since 2016.”).

3. Bill Chappell, *What We Know About the Deadliest U.S. Bird Flu Outbreak in History*, NAT’L PUB. RADIO (Dec. 2, 2022, 5:00 AM), <https://www.npr.org/2022/12/02/1140076426/what-we-know-about-the-deadliest-u-s-bird-flu-outbreak-in-history> [<https://perma.cc/5Y49-N28F>].

4. D.J. Alexander & I.H. Brown, *History of Highly Pathogenic Avian Influenza*, 28 REV. SCI. TECH. OFF. INT. EPIZ. 19, 20 (2009), <https://doc.woah.org/dyn/portal/digidoc.xhtml?statelessToken=USHi9N-71EDqawTHVX0wYrVCjSIZ8B8vx8qFYu3Ngcw=&actionMethod=dyn%2Fportal%2Fdigidoc.xhtml%3AdownloadAttachment.openStateless> [<https://perma.cc/QZ7A-XF6S>]; Jim Mertens, *THIS WEEK: Avian Flu Likely to get Worse Before it Gets Better*, WQAD8 (Mar. 27, 2022, 10:00 AM) <https://www.wqad.com/article/news/local/this-week/avian-flu-mike-naig-iowa-secretary-of-agriculture-outbreak-2022/526-5bd2bc4f-6596-44cf-a832-a4de1b69007d> [<https://perma.cc/VHZ3-PPFU>].

5. Alexander & Brown, *supra note 4* at 23.

6. *Id.*

7. *Id.* at 25.

that is generally associated with migratory bird movements.<sup>8</sup> The strain of avian influenza that the United States has been grappling with since early 2022 is different, namely, in that it appears to be an endemic, not seasonal, form of HPAI.<sup>9</sup> This could pose unique challenges to managing avian influenza with respect to avian and human health, as well as economic impacts.<sup>10</sup>

This article argues that state and federal laws are insufficient in addressing avian influenza as it currently exists within the United States and that law and policy should be changed. These arguments are articulated across three sections. Part II provides important background information on the poultry industry and the impact of avian influenza on the economy and human health.<sup>11</sup> Part III analyzes federal law, specifically, the National Poultry Improvement Plan.<sup>12</sup> Part IV shows why the law falls short in responding to the current situation with avian influenza.<sup>13</sup> Part V offers several recommendations for reform that include implementation of a mass vaccination program for avian influenza in commercial poultry and investing in gene editing technologies.<sup>14</sup> This article contributes to the literature by rendering a novel analysis of state and federal law with respect to avian influenza in the United States. It also makes the first call in the academic legal literature for immediate policy changes to provide for a mass vaccination program of commercial poultry.

## II. BACKGROUND

This section provides the background information necessary to understand avian influenza and its impacts on human health and the economy. It also provides useful background information necessary to understand the American poultry industries. Overall, this section argues that the poultry industry is valuable to the country, which makes it worth protecting as a matter of public policy. It argues further that because avian influenza poses a serious threat to this industry as well as human health, policymakers should seriously consider reform.

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8. Mertens, *supra* note 4.

9. *Id.*

10. See Chris Clayton, *Avian Influenza Spread Wider and Wider*, DTN (Feb. 27, 2023, 7:01 AM), <https://www.dtnpf.com/agriculture/web/ag/news/article/2023/02/27/expert-current-highly-pathogenic-flu> [<https://perma.cc/X4GH-X5SD>] (describing the unique challenges posed by the 2022-2023 outbreak compared to past outbreaks).

11. See *infra* Part II.

12. See *infra* Part III.

13. See *infra* Part IV.

14. See *infra* Part V.

### A. The American Poultry Industry

Poultry farming can be defined as the “raising of birds domestically or commercially, primarily for meat and eggs but also for feathers.”<sup>15</sup> “Chickens, turkeys, ducks, and geese are of primary importance [in poultry farming, but] guinea fowl and squabs” are also raised commercially.<sup>16</sup> The poultry sector is important, and poultry production is big business on global, national, and state levels.<sup>17</sup> Domestic and international consumers rely on it to provide the market with large quantities of affordable poultry products like meat and eggs.<sup>18</sup> Additionally, various industries rely on it to provide useful inputs to other goods, such as “fertilizer, biodiesel, animal feed, electricity, biogas, bone powder, . . . biodegradable plastics[,] . . . [and] gelatin.”<sup>19</sup> Other examples of poultry byproducts include manure, which can be used or sold by farmers as fertilizer,<sup>20</sup> and feathers—such as duck down—which can be used in apparel and fashion.<sup>21</sup>

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15. Wesley Patterson Garrigus, *Poultry Farming*, ENCYCLOPEDIA BRITANNICA (May 16, 2023), <https://www.britannica.com/topic/poultry-farming> [<https://perma.cc/C9W4-THFW>].

16. *Id.*

17. See generally A. Mottet & G. Tempio, *Global Poultry Production: Current State and Future Outlook and Challenges*, 73(2) WORLD’S POULTRY SCI. J. 245 (2017) (detailing how the poultry sector makes important contributions to food security and is poised for relatively high levels of growth on the global level); R. Prabakaran et al., *Diversified Poultry Production: An Overview*, 8(2) J. OF ENTOMOLOGY AND ZOOLOGY STUD. 211 (2020), <https://www.entomoljournal.com/archives/2020/vol8issue2/PartD/9-1-228-430.pdf> [<https://perma.cc/WH5S-VCYJ>] (showing that the global poultry industry has grown substantially in recent decades, especially in developing countries like India); *U.S. Poultry Industry Provides 2 Million Jobs and \$556 Billion in Economic Impact*, UNITED EGG PRODUCERS (Nov. 2, 2022), <https://unitedegg.com/u-s-poultry-industry-provides-2-million-jobs-and-556-billion-in-economic-impact/> [<https://perma.cc/AN92-3HPX>] (discussing the American poultry sector); *Value-Added Agriculture - Poultry*, IOWA AREA DEV. GRP. (June 4, 2023, 10:17 PM), <https://www.iadg.com/iowa-advantages/value-added-agriculture-poultry/> [<https://perma.cc/Z5BL-KJQT>] (discussing the Iowa poultry sector).

18. See Mottet & Tempio, *supra* note 17.

19. Alireza Seidavi et al., *Poultry Byproducts in BYPRODUCTS FROM AGRICULTURE AND FISHERIES: ADDING VALUE FOR FOOD, FEED, PHARMA, AND FUELS* (Benjamin K. Simpson et al. eds. 2019).

20. *Gateway to Poultry Production and Products*, FOOD AND AG. ORG. OF THE UNITED NATIONS (June 4, 2023, 10:15 PM), <https://www.fao.org/poultry-production-products/products-processing/en/#:~:text=Demand%20for%20poultry%20meat%20and%20eggs%20is%20expected,slightly%20higher%20in%20developing%20than%20in%20developed%20regions> [<https://perma.cc/D7X6-K6FX>].

21. *Id.*

Additionally, with respect to egg production, liquid egg products create eggshells as a byproduct, which can be used as an input to animal feed.<sup>22</sup>

The American poultry industry has undergone transformational changes since the turn of the 20th century.<sup>23</sup> A good illustration of this exists in the broiler industry.<sup>24</sup> In the early 1900s, the industry consisted mainly of “backyard flocks” that were raised and used by individual households for eggs and meat.<sup>25</sup> It was not until as late as 1930 when the “broiler chicken” was developed, and it was not until the 1950s when the broiler became the primary source of chicken meat in the United States.<sup>26</sup> It was also in the 1950s when vertical integration led to single enterprises operating as “[f]eed mills, hatcheries, farms, and processors.”<sup>27</sup> After the 1970s, the industry modernized by adopting improved nutritional strategies, disease management, mechanization, and improved genetics.<sup>28</sup> A similar trajectory of modernization and development can be observed in the egg and turkey industries.<sup>29</sup> This technological and operational modernization has caused the American poultry industry to become highly efficient, to the point where a broiler can be raised to market weight in five weeks, and a hen can lay 300 eggs per year, as opposed to 100 eggs over four months in the early to mid-20<sup>th</sup> century.<sup>30</sup>

This industrywide evolution caused the American poultry sector to become the world’s largest producer of poultry meat and the second largest producer of eggs.<sup>31</sup> The year 2022 marked a record for broiler production; the industry turned

22. *Id.*

23. Sarah Mock, *From Farm to Factory: The Unstoppable Rise of American Chicken*, THE GUARDIAN (Aug. 17, 2020, 2:30 AM), <https://www.theguardian.com/environment/2020/aug/17/from-farm-to-factory-the-unstoppable-rise-of-american-chicken> [https://perma.cc/4NML-SVXC].

24. *Id.*

25. *U.S. Chicken Industry History*, NAT. CHICKEN COUNCIL (June 4, 2023, 10:34 PM), <https://www.nationalchickencouncil.org/about-the-industry/history/> [https://perma.cc/W8MX-KNT7].

26. *See id.* (explaining that broilers are specifically raised for meat).

27. *Id.*

28. *Id.*

29. *See History of Commercial Egg Production*, AM. EGG BD., THE INCREDIBLE EGG (June 4, 2023, 10:01 PM), <https://www.incredibleegg.org/about-us/us-egg-farming-history> [https://perma.cc/3P2P-7L73]; *See Raising America’s Turkeys*, NAT’L TURKEY FED’N (June 24, 2023, 12:36 AM), <https://www.eatturkey.org/raising-turkeys/> [https://perma.cc/77VU-ZWPZ].

30. Garrigus, *supra* note 15.

31. *Poultry & Eggs*, U.S. DEPT. OF AGRIC. ECON. RSCH. SERV. (Jan. 18, 2023), <https://www.ers.usda.gov/topics/animal-products/poultry-eggs> [https://perma.cc/MCY6-ER3K]; *Eggs - Production (Tonnes)*, OUR WORLD IN DATA (June 4, 2023, 10:37 PM),

out a remarkable 46.201 billion pounds of meat.<sup>32</sup> Exports alone totaled 7.278 billion pounds.<sup>33</sup> For eggs, 2022 production totaled 7.719 billion dozen eggs, of which 226.5 million dozen eggs were exports.<sup>34</sup> For turkey, 2022 production was 5.222 billion pounds with 408.4 million pounds exported.<sup>35</sup>

The importance and scale of the American poultry industry are anticipated to increase as demand for poultry products is expected to grow on the global level across all regions and income levels.<sup>36</sup> Because the world population continues to grow, poultry products are a relatively cheap source of animal protein; poultry is a leaner source of protein than beef and pork and there are little to no religious or cultural prohibitions on the consumption of poultry.<sup>37</sup> While this growth and concentration may make the American poultry industry more susceptible to disease risk, it also makes safeguarding the American poultry industry critically important—not just to our own well-being, but for the health and prosperity of the world.

### *B. Impact of Avian Influenza on the Economy*

The 2022–2023 outbreak of avian influenza has wreaked havoc on state economies and on American consumers.<sup>38</sup> The most obvious impact on consumers has been the sharp increase in egg prices, which is far in excess of the overall inflation rate.<sup>39</sup> While the annual inflation rate for “all items” was 6.4% between January 2022 and January 2023, the rate for eggs was 70.1%.<sup>40</sup> Agriculture market experts suggest that this dramatic spike in egg prices was caused primarily by avian influenza.<sup>41</sup> Additionally, avian influenza has caused prices for chicken to increase

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<https://ourworldindata.org/grapher/egg-production-thousand-tonnes?tab=table>  
[<https://perma.cc/AX8U-KGGE>].

32. U.S. DEPT. OF AGRIC. ECON. RSCH. SERV., LIVESTOCK, DAIRY, AND POULTRY OUTLOOK: FEBRUARY 2023 24 (Feb. 14, 2023), <https://www.ers.usda.gov/webdocs/outlooks/105840/ldp-m-344.pdf?v=3258.5> [<https://perma.cc/UBH3-7FP8>].

33. *Id.* at 26.

34. *Id.* at 28, 30.

35. *Id.*

36. *Id.*

37. *Id.*

38. See CONSUMER PRICE INDEX- JANUARY 2023, U.S. DEPT. OF LAB., BUREAU OF LAB. STAT. (2023), [https://www.bls.gov/news.release/archives/cpi\\_02142023.pdf](https://www.bls.gov/news.release/archives/cpi_02142023.pdf) [<https://perma.cc/5JC3-RED5>] (reporting annual inflation).

39. *Id.* (reporting annual egg price inflation).

40. *Id.*

41. Greg Iacurci, *Egg Prices Rose 60% in 2022. One Farm Group Claims It's a "Collusive Scheme by Suppliers*, CNBC (Jan. 24, 2023, 10:46 AM),

by 14.5% over the course of a year.<sup>42</sup> The result has been an increase in poultry prices even as the inflation rate drops.<sup>43</sup> Impacts on consumers can be especially rough in areas that rely on food imported from out of state; for example, egg prices in Hawaii were recently reported at an average price of \$9.73 per dozen.<sup>44</sup> Moreover, eggs and chicken have historically been the two lowest-cost animal protein sources for consumers.<sup>45</sup> This renders low-income consumers especially vulnerable to the economic impacts of avian influenza.

These high consumer prices are no consolation to poultry producers.<sup>46</sup> Because an instance of avian influenza at a production facility results in depopulation, a producer who experiences such an outbreak will also experience sunk costs with respect to the time and money that they have invested in the infected flock.<sup>47</sup> Such costs include all expenses attributable to the infected flock, including the cost of the birds, feed, and water.<sup>48</sup> Moreover, there are the lost future revenues attributable to the infected flock.<sup>49</sup> Finally, there are emotional impacts on producers who experience such an outbreak in their flock.<sup>50</sup> Research on Dutch dairy producers who had to cull their herds in response to the 2001 outbreak of Foot and Mouth Disease suggests that they experienced serious mental health

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<https://www.cnbc.com/2023/01/23/high-egg-prices-due-to-a-collusive-scheme-by-suppliers-group-claims.html> [<https://perma.cc/DK4B-STEP>].

42. Greg Iacurci, *Why Egg Prices Are Surging – But Chicken Prices Are Falling: It’s an “Act of God” Event, Says Trade Strategist*, CNBC (Nov. 14, 2022, 8:56 AM), <https://www.cnbc.com/2022/11/11/why-egg-prices-are-surging-but-chicken-prices-are-falling.html> [<https://perma.cc/L4WR-TG4A>].

43. Kenny Torrella, *Why Egg Prices Keep Going Up While Inflation is Going Down*, VOX (Jan. 12, 2023, 4:00 PM), <https://www.vox.com/future-perfect/2022/11/22/23472207/bird-flu-vaccine-turkey-prices-chickens-hens-cull-depopulation> [<https://perma.cc/GN26-788D>].

44. Kelly Tyko, *Why High Egg Prices Remain at Unappetizing Levels*, AXIOS (Jan. 22, 2023), <https://www.axios.com/2023/01/22/egg-shortage-high-prices-bird-flu> [<https://perma.cc/5HKY-XFSY>].

45. U.S. DEPT. OF AGRIC. ECON. RSCH. SERV., *supra* note 32.

46. *Avian Flu Cases Harm Producers, Poultry Prices*, FARM PROGRESS (Nov. 18, 2022), <https://www.farmprogress.com/poultry-news/avian-flu-cases-harm-producers-poultry-prices> [<https://perma.cc/45WK-LXYS>].

47. *Id.*

48. *Id.*

49. *Id.*

50. Jada M. Thompson & Amy D. Hagerman, *Stress and Resiliency Among Confined Animal Producers*, CHOICES (June 11, 2023, 3:56 PM) <https://www.choicesmagazine.org/choices-magazine/theme-articles/farm-stress/stress-and-resiliency-among-confined-animal-producers> [<https://perma.cc/VJ9P-6MSG>].

impacts, including stress, marginalization, and depression.<sup>51</sup> Even producers who do not experience an avian influenza outbreak may still suffer from the psychological impact of avian influenza as a constant, invisible threat.<sup>52</sup>

Past avian influenza outbreaks suggest that the disease threatens economies at the community, sectoral, and national levels.<sup>53</sup> Local agrarian communities that depend on poultry both for commercial and domestic purposes can be devastated by avian influenza, as was the case when Vietnam contended with avian influenza in the early 2000s.<sup>54</sup> Particular states are also economically vulnerable to avian influenza.<sup>55</sup> The 2015 avian influenza outbreak demonstrated that Iowa's economy is particularly fragile to the impacts of the disease because Iowa producers were more heavily impacted than producers in any other state.<sup>56</sup> One reason for this is that Iowa is located within the "Mississippi Flyway," a popular route for migratory birds which often carry the disease.<sup>57</sup> Meanwhile, entire economic sectors, such as tourism, can face headwinds as people try to avoid areas experiencing outbreaks.<sup>58</sup> Even national economies can feel the effects of avian influenza—it is argued that Vietnam experienced a 0.1 to 0.2 percent decline in GDP during the above-mentioned outbreaks.<sup>59</sup>

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51. E.H. Van Haaften et al., *The Psychological Impact of the Foot and Mouth Disease Crisis on Dutch Dairy Farmers*, 51 WAGENINGEN J. LIFE SCIS. 339, 339–49 (2004), <https://www.sciencedirect.com/science/article/pii/S1573521404800010> [<https://perma.cc/YM27-C7BP>].

52. See Kirsti Marohn, *As Avian Flu Cases Slow, Farmers Struggle with Mental Illness*, MINN. PUB. RADIO NEWS (May 24, 2022, 4:00 AM), <https://www.mprnews.org/story/2022/05/24/as-avian-flu-cases-slow-farmers-struggle-with-mental-stress> [<https://perma.cc/QM3R-FGNU>].

53. MILAN BRAHMBHATT, AVIAN AND HUMAN PANDEMIC INFLUENZA- ECONOMIC AND SOCIAL IMPACTS (June 4, 2023, 10:34 PM), <https://www.worldbank.org/content/dam/Worldbank/document/HDN/Health/AHI-SocioImpacts.pdf> [<https://perma.cc/C9SM-TZBM>].

54. *Id.*

55. Bryan Richards, *Distribution of Highly Pathogenic Avian Influenza in North America, 2021/2022*, U.S. GEOLOGICAL SURV., NAT'L WILDLIFE HEALTH CTR. (Nov. 27, 2022), <https://www.usgs.gov/centers/nwhc/science/distribution-highly-pathogenic-avian-influenza-north-america-20212022#overview> [<https://perma.cc/6FAZ-T23U>].

56. MARO IBARBURU ET AL., ECONOMIC IMPORTANCE OF THE IOWA EGG INDUSTRY 3 (2019), <https://www.iadg.com/webres/File/Industry%20Reports/19IAEggIndReport.pdf> [<https://perma.cc/6928-XQ5D>].

57. Jared Strong, *Iowa Birds Account for 43% of Avian Flu Victims*, IOWA CAPITAL DISPATCH (Mar. 28, 2022, 5:04 PM), <https://iowacapitaldispatch.com/2022/03/28/iowa-birds-account-for-43-of-avian-flu-victims/> [<https://perma.cc/FR8S-DH55>].

58. BRAHMBHATT, *supra* note 53.

59. *Id.* at 2.



Should avian influenza become transmissible between humans in such a way that causes a human pandemic, the economic impacts could be much more severe. Asian economic models from the region's 2006 avian influenza outbreak paint a bleak picture.<sup>60</sup> Even a relatively conservative economic model which assumes a "relatively mild pandemic" of avian influenza that lasts only four quarters, predicted that GDP in Asia would decline 2.6%.<sup>61</sup> An avian influenza pandemic that spread throughout the world, however, could cause global GDP to decline 4 to 5 percent.<sup>62</sup> In short, an avian influenza pandemic amongst humans would make the current avian influenza impacts seem trivial.

### *C. Impact of Avian Influenza on Human Health*

The threat of avian influenza goes beyond financial impacts.<sup>63</sup> There is a material risk that avian influenza could spread to humans in such a way that it creates a new pandemic.<sup>64</sup> So far, instances of poultry to human transmission of avian influenza have been rare.<sup>65</sup> However, when such a transmission does occur, it can result in a range of health outcomes from mild illness to death.<sup>66</sup> Human-to-human transmission of avian influenza has also occurred in a small number of instances.<sup>67</sup> Case fatality rates for humans infected with avian influenza

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60. BRIAN PEARCE, ECONOMIC BRIEFING: AVIAN FLU (2006), <https://www.iata.org/en/iata-repository/publications/economic-reports/impact-of-avian-flu/> [<https://perma.cc/85JY-4FJC>].

61. *Id.*

62. *Id.*

63. *Avian Influenza*, WORLD ORG. FOR ANIMAL HEALTH (June 4, 2023, 10:49 PM) <https://www.woah.org/en/disease/avian-influenza/#:~:text=Impact%20on%20animal%20health%2C%20including%20wild%20birds&text=Often%20considered%20mainly%20as%20vectors,the%20biodiversity%20of%20our%20ecosystems> [<https://perma.cc/DVS4-TK3F>] (explaining that avian influenza has the potential to impact international trade, tourism, biodiversity, and human health).

64. Arnold S. Monto, *The Threat of an Avian Influenza Pandemic*, 352(4) N. ENG. J. MED. 323–25 (2005); Charles J. Russell & Robert G. Webster, *The Genesis of a Pandemic Influenza Virus*, 123(3) CELL. 368–71 (2005), [https://www.cell.com/cell/fulltext/S0092-8674\(05\)01094-9?\\_returnURL=https%3A%2F%2Flinkinghub.elsevier.com%2Fretrieve%2Fpii%2FS0092867405010949%3Fshowall%3Dtrue](https://www.cell.com/cell/fulltext/S0092-8674(05)01094-9?_returnURL=https%3A%2F%2Flinkinghub.elsevier.com%2Fretrieve%2Fpii%2FS0092867405010949%3Fshowall%3Dtrue) [<https://perma.cc/4W7Z-HJY8>].

65. *Bird Flu Virus Infections in People*, CTRS. FOR DISEASE CONTROL AND PREVENTION (May 4, 2022), <https://www.cdc.gov/flu/avianflu/avian-in-humans.htm#:~:text=Although%20avian%20influenza%20A%20viruses%20usually%20do%20not,person%E2%80%99s%20eyes%2C%20nose%20or%20mouth%2C%20or%20is%20inhaled> [<https://perma.cc/JTY3-46X5>].

66. *Id.*

67. *Id.*

are extremely high for both LPAI and HPAI, generally registering at or above 40%.<sup>68</sup> Among infants and young children, the case fatality rate could be as high as 89%, with death occurring on average between nine and ten days following onset of the disease.<sup>69</sup>

The true threat in this story is the possibility that avian influenza mutates during human-to-human transmission such that it becomes capable of being transmitted as efficiently as other viruses, such as COVID.<sup>70</sup> If this occurs, the result could be millions of deaths worldwide and many more cases where people suffer adverse health consequences short of death.<sup>71</sup> Unfortunately, we are currently seeing spread of avian influenza from mammals to mammals, such as in mink, bears, skunks, and otters.<sup>72</sup> This could suggest that the virus is capable of mutating so that it would spread more efficiently amongst humans because of the similarities present between the respiratory tracts of humans and other mammals, although this has not yet been established conclusively.<sup>73</sup> Ultimately though, at least one epidemiologist suggests that avian influenza is “near the top of the list in terms of viruses that have [human] pandemic potential.”<sup>74</sup>

Indeed, it appears that the 2022–2023 outbreak of avian influenza is different from past outbreaks in important ways.<sup>75</sup> Specifically, the strains of avian influenza currently circulating are different because “the virus seems better adapted to infecting wild birds . . . it’s able to spread in parts of the world and during times of the year not seen before . . . [and] it’s able to persist longer [into the summer months].”<sup>76</sup>

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68. *Reported Human Infections with Avian Influenza A Viruses*, CTRS. FOR DISEASE CONTROL AND PREVENTION (Apr. 17, 2023), <https://www.cdc.gov/flu/avianflu/reported-human-infections.htm> [<https://perma.cc/C6BL-3J67>].

69. Niti Mittal & Bikash Medhi, *The Bird Flu: A New Emerging Pandemic Threat and its Pharmacological Intervention*, 1(2) INT’L J. HEALTH SCIS. 277–83 (2007) (showing that between 2003 and 2007, 172 human deaths were recorded out of 291 cases worldwide).

70. Zeynep Tufekci, *An Even Deadlier Pandemic Could Soon Be Here*, N.Y. TIMES (Feb. 3, 2023), <https://www.nytimes.com/2023/02/03/opinion/bird-flu-h5n1-pandemic.html>; Keren Landman & Benji Jones, *Can You Get the Bird Flu?*, VOX (Feb. 6, 2023, 9:23 AM), <https://www.vox.com/science-and-health/23572561/bird-avian-flu-influenza-h5n1-pandemic-eggs> [<https://perma.cc/29YY-H577>].

71. Tufekci, *supra* note 70; Landman & Jones, *supra* note 70.

72. Tufekci, *supra* note 70; Landman & Jones, *supra* note 70.

73. Tufekci, *supra* note 70; Landman & Jones, *supra* note 70.

74. Landman & Jones, *supra* note 70.

75. Elisabeth Mahase, *H5N1: Do We Need to Worry About the Latest Bird Flu Outbreaks?*, 380 BMJ 401 (2023).

76. *Id.*

Overall, the risks to human health posed by avian influenza are uncertain but potentially devastating.<sup>77</sup> The lessons of past pandemics teach us that animal viruses and their mutations have the capacity to become transmissible among humans.<sup>78</sup> The COVID pandemic taught us that viruses have the capacity to disrupt society in ways that we have yet to fully comprehend.<sup>79</sup> One difference between avian influenza and COVID, however, is that avian influenza seems to have a far deadlier potential.<sup>80</sup> Another difference, on the bright side, is that we are still able to act in prevention of an avian influenza pandemic in order to stop it from occurring in the first place.<sup>81</sup>

### III. AVIAN INFLUENZA UNDER FEDERAL LAW: THE NATIONAL POULTRY IMPROVEMENT PLAN

Federal law contemplates a response to avian influenza largely through the National Poultry Improvement Plan (NPIP).<sup>82</sup> The NPIP is a creation of the Code of Federal Regulations, and more specifically, the USDA's Animal and Plant Health Inspection Service (APHIS).<sup>83</sup> The USDA's authority to promulgate the regulations comprising the NPIP derive from various federal statutes.<sup>84</sup> At first blush, one would assume that the lengthy NPIP regulations would serve as a robust

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77. *Id.*

78. *Id.* (noting that the 2009 "swine flu" virus, the 1968 and 1957 influenza pandemics, and potentially the 1918 pandemic originated from animal influenzas).

79. See *The COVID Decade: Understanding the Long-Term Societal Impacts of COVID-19*, THE BRITISH ACAD. (2021) <https://www.thebritishacademy.ac.uk/publications/covid-decade-understanding-the-long-term-societal-impacts-of-covid-19/> [<https://perma.cc/X5FU-SDHM>].

80. See *infra*, note 162 and accompanying text.

81. See generally *Prevention and Antiviral Treatment of Bird Flu Viruses in People*, CTRS. FOR DISEASE CONTROL AND PREVENTION (Oct. 31, 2022), <https://www.cdc.gov/flu/avianflu/prevention.htm> [<https://perma.cc/5YZE-5VPH>].

82. See 9 C.F.R. §§ 145–47 (2023) (comprising the entirety of the NPIP).

83. See *USDA Updates the National Poultry Improvement Plan*, U.S. DEPT. OF AGRIC. ANIMAL AND PLANT HEALTH INSPECTION SERV. (Oct. 1, 2020), [https://www.aphis.usda.gov/aphis/newsroom/stakeholder-info/sa\\_by\\_date/sa-2020/sa-10/npip-update](https://www.aphis.usda.gov/aphis/newsroom/stakeholder-info/sa_by_date/sa-2020/sa-10/npip-update) [<https://perma.cc/RN3G-KH53>] (demonstrating how the APHIS engages in notice and comment rulemaking with respect to the NPIP).

84. See 7 U.S.C. § 8308 (2023) (providing that the United States Secretary of Agriculture has the power to "detect, control, or eradicate" animal diseases, pay indemnities, and that the Secretary shall continue to finance the NPIP).

mechanism by which the federal government can surveil and manage outbreaks of avian influenza.<sup>85</sup> However, this is not the case.<sup>86</sup>

The NPIP began in the 1930s with the purpose of addressing the pullorum disease which was common amongst poultry, particularly chickens.<sup>87</sup> Although participation has always been voluntary, the NPIP succeeded in virtually eliminating pullorum by the 1970s.<sup>88</sup> Today, the NPIP is a framework by which several poultry diseases, including pullorum, fowl typhoid, avian influenza, and others, are tested and monitored.<sup>89</sup>

Overall, the NPIP attempts to manage infectious diseases by incentivizing producers to prove that their flocks are free from disease and to take steps to ensure they remain free from disease.<sup>90</sup> The NPIP is overseen by the federal government and is administered by state agencies.<sup>91</sup> The program operates on an entirely voluntary basis, meaning that there is no legal requirement for producers to comply with its terms.<sup>92</sup> Rather, producers may choose to qualify for NPIP certification in order to obtain various benefits.<sup>93</sup> Despite the voluntary nature of the NPIP, it has proven effective in managing and eradicating various poultry diseases in the United States.<sup>94</sup>

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85. See 9 C.F.R. §§ 145–47 (containing the NPIP).

86. See *USDA Updates the National Poultry Improvement Plan*, *supra* note 83 (providing that the NPIP is an optional program); see *infra* note 117 (arguing that the NPIP is not effective against current strains of avian influenza).

87. *National Poultry Improvement Plan (NPIP)*, U.S. DEPT. OF AGRIC. ANIMAL AND PLANT HEALTH INSPECTION SERV. (June 2, 2020), <https://www.aphis.usda.gov/aphis/ourfocus/animalhealth/nvap/NVAP-Reference-Guide/Poultry/National-Poultry-Improvement-Plan> [<https://perma.cc/3YE5-5CSL>].

88. Zac Williams, *History and Importance of the National Poultry Improvement Plan: Protecting Poultry Since 1935*, CHICKEN WHISPERER (June 4, 2023, 10:12 PM), <https://www.chickenwhisperermagazine.com/the-chicken-movement/history-and-importance-of-the-national-poultry-improvement-planprotecting-poultry-since-1935> [<https://perma.cc/B6U6-LDF5>].

89. *NPIP History*, NAT'L POULTRY IMPROVEMENT PLAN (June 4, 2023, 10:35 PM), <https://www.poultryimprovement.org/default.cfm?CFID=24815152&CFTOKEN=f3fbf6267000c4e4-45114287-FF2B-10E3-7C51B01F09396862> [<https://perma.cc/ST49-TTKH>].

90. See *id.*

91. *USDA Updates the National Poultry Improvement Plan*, *supra* note 83.

92. *Id.*

93. *Id.*

94. R.G. MAIN ET AL., CASE STUDY: IS IT TIME FOR AN NPIP LIKE PROGRAM FOR THE US PORK INDUSTRY? 5 (2019), [https://www.researchgate.net/publication/333990909\\_Case\\_Study\\_Is\\_it\\_Time\\_for\\_an\\_NPIP\\_like\\_Program\\_for\\_the\\_US\\_Pork\\_Industry](https://www.researchgate.net/publication/333990909_Case_Study_Is_it_Time_for_an_NPIP_like_Program_for_the_US_Pork_Industry) [<https://perma.cc/N65K-K854>].

More specifically, NPIP certification is on a disease-by-disease basis—both flocks and large geographic areas, such as states, may be certified.<sup>95</sup> Certification distinguishes between “clean” and “monitored.”<sup>96</sup> For example, a producer’s flocks may be certified for pullorum but not avian influenza, or the state of Iowa could be certified as monitored for avian influenza but clean for pullorum.<sup>97</sup> Moreover, NPIP certification requirements vary based on whether the certification is sought for a flock or for a slaughter plant, the species of the flock for which certification is sought, whether the flock produces eggs, and whether the flock exists solely as a hatchery to produce additional birds for use in other flocks.<sup>98</sup> An illustration of how the NPIP operates can be seen in certain requirements for certification. To illustrate this, a hatchery seeking certification for a breeder flock will have to comply with the following requirements:

Be audited at least annually by an official state agency.<sup>99</sup>

Undergo testing for the disease for which certification is sought.<sup>100</sup>

For avian influenza certification, a sample of 30 poultry per flock must test negative for avian influenza every 90 days; testing must be conducted through officially recognized methods such as enzyme-linked immunosorbent assay tests.<sup>101</sup>

Tests which yield positive results for various diseases must be reported to the Official State Agency.<sup>102</sup>

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95. See, e.g., 9 C.F.R. § 146.24 (2023) (providing the conditions for a state to be considered “monitored” for avian influenza in chickens); 9 C.F.R. § 146.44 (2023) (providing the same for turkeys); *Pullorum-Typhoid Clean States*, NAT’L POULTRY IMPROVEMENT PLAN (June 4, 2023, 10:35 PM), <https://www.poultryimprovement.org/cleanStates.cfm> [<https://perma.cc/FVB5-H885>] (showing a map of jurisdictions certified as clean for pullorum).

96. MAIN ET AL., *supra* note 94, at 3–14.

97. See 9 C.F.R. § 146.24; 9 C.F.R. § 146.44.

98. See 9 C.F.R. § 146 Subpart A (2023) (describing different requirements for flocks and slaughter plants); 9 C.F.R. § 146 Subparts B–D (2023) (providing requirements for “egg layer flocks,” “chicken slaughter plants,” and “turkey slaughter plants”). Compare 9 C.F.R. § 145 (2023) (providing requirements for “breeding poultry”), with 9 C.F.R. § 146 (2023) (providing requirements for “commercial poultry”).

99. 9 C.F.R. § 145.12 (2023).

100. See 9 C.F.R. § 145.14 (2023).

101. 9 C.F.R. § 145.14(d) (2023); 9 C.F.R. § 145.93(c) (2023).

102. See, e.g., 9 C.F.R. § 145.15 (2023); 9 C.F.R. § 145.23(b)(2)(i), (3)(iv)(v) (2023); 9 C.F.R. § 145.33 (b)(2)(i) (2023).

Overall, the requirements are technical and complex, but they are designed to ensure that poultry are free of disease at the source and remain free from disease throughout their journey from hatchery to farm to slaughterhouse to table.<sup>103</sup> The requirements seal off flocks from one another, test them to prove lack of disease, and monitor them continuously.<sup>104</sup> Participants institute thorough biosecurity measures to reduce the risk that foreign vectors of disease are introduced within a flock.<sup>105</sup> On the whole, the NPIP certification requires producers to adopt commercially reasonable best practices for ensuring that poultry are free from infectious diseases.<sup>106</sup>

There are two primary reasons why the NPIP has been successful in improving the health of American poultry.<sup>107</sup> First, NPIP offers a powerful indemnification incentive to producers.<sup>108</sup> The indemnification aspect of NPIP is particularly relevant because it provides that when an NPIP participant experiences losses as a result of a disease outbreak, such as from a resulting quarantine, extermination, and disinfection routine, the federal government will indemnify the producer for most of the associated financial loss.<sup>109</sup> Formally, this indemnification is 100% of the affected flock's value for NPIP certified flocks, compared to the 25% indemnity the USDA provides for non-NPIP flocks.<sup>110</sup> Nonetheless, many producers argue that calculation of flock value under the NPIP is insufficient.<sup>111</sup>

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103. See *National Poultry Improvement Plan (NPIP)*, *supra* note 87.

104. See generally *Poultry Biosecurity*, IOWA STATE UNIV. COLL. OF VETERINARY MED., THE CTR. FOR FOOD SEC. AND PUB. HEALTH (June 4, 2023, 10:17 PM), <https://poultrybiosecurity.org/#Training> [<https://perma.cc/3AKZ-WBEE>] (describing broadly the requirements for NPIP certification by flocks); U.S. DEP'T OF AGRIC. & THE CTR. FOR FOOD SEC. AND PUB. HEALTH, CHECKLIST FOR SELF-ASSESSMENT OF IMPLEMENTING POULTRY BIOSECURITY (2018), <https://poultrybiosecurity.org/files/Self-Assessment-Checklist-for-Enhanced-Poultry-Biosecurity.pdf> [<https://perma.cc/AY38-HJEC>].

105. See *id.*

106. See *id.*

107. *Pullorum-Typhoid Clean States*, *supra* note 95.

108. *Id.*

109. Jeremy Chartier, *NPIP Certification: Why it Matters When Buying Chicks*, BACKYARD POULTRY (Mar. 15, 2019), <https://backyardpoultry.iamcountryside.com/feed-health/npip-certification-why-it-matters-when-buying-chicks/#:~:text=If%20the%20USDA%20or%20state%20veterinarian%20has%20to,whereas%20non-NPIP%20members%20only%20receive%20around%2025%25%20indemnification> [<https://perma.cc/T9GY-TWV2>].

110. *Id.*

111. See 9 C.F.R. § 53.3 (2023).

Second, over time, downstream purchasers of poultry products, especially foreign purchasers, have made NPIP participation a contractual requirement.<sup>112</sup> Today, producers who seek to export their poultry products generally must become NPIP certified.<sup>113</sup> Thus, a producer may seek to become NPIP certified because participation will simultaneously improve the quality of the poultry output, increase potential commercial opportunities for the producer, and offer an equivalent to insurance.<sup>114</sup> This has caused participation in NPIP to be near universal among commercial poultry producers.<sup>115</sup> The result is that the NPIP has been credited with enabling American producers to maintain exports even throughout the 2022–2023 avian influenza outbreak.<sup>116</sup>

When one considers the history of the NPIP within our current context, however, it becomes clear that the NPIP alone will not be sufficient to contain what has become an ever more aggressive and endemic strain of avian influenza.<sup>117</sup> Despite the fact that the NPIP is nearly universally adopted, has had extraordinary success in virtually eliminating many diseases, and that it has imposed significant precautionary measures on the production process, we are continuing to struggle in managing outbreaks of avian influenza.<sup>118</sup> This is evidence that a different approach must be pursued.<sup>119</sup> While the NPIP is geared toward eradicating and preventing disease outbreaks, the current iteration of avian influenza is endemic and cannot be eradicated or prevented.<sup>120</sup>

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112. *Pullorum-Typhoid Clean States*, *supra* note 95.

113. *Id.*

114. Rodger K. Main et al., *Overview of the National Poultry Improvement Plan (NPIP)*, IOWA STATE UNIV. DIGIT. PRESS (June 4, 2023, 10:18 PM), <https://iastate.pressbooks.pub/usporkindustry/chapter/overview-of-the-national-poultry-improvement-plan-npip/> [<https://perma.cc/4U8M-L2ZB>].

115. *Id.*

116. *Id.*

117. See JOHANNA A. HARVEY ET AL., *THE CHANGING DYNAMICS OF HIGHLY PATHOGENIC AVIAN INFLUENZA H5N1: NEXT STEPS FOR MANAGEMENT & SCIENCE IN NORTH AMERICA* (2022), [https://www.researchgate.net/publication/366080370\\_The\\_Changing\\_Dynamics\\_of\\_Highly\\_Pathogenic\\_Avian\\_Influenza\\_H5N1\\_Next\\_Steps\\_for\\_Management\\_Science\\_in\\_North\\_America](https://www.researchgate.net/publication/366080370_The_Changing_Dynamics_of_Highly_Pathogenic_Avian_Influenza_H5N1_Next_Steps_for_Management_Science_in_North_America) [<https://perma.cc/LJM4-6FU7>].

118. Bernt Nelson, *High Path Avian Influenza Update - What's Next?*, AM. FARM BUREAU FED'N (May 5, 2023), <https://www.fb.org/market-intel/high-path-avian-influenza-update-whats-next> [<https://perma.cc/RS2K-B67H>] (noting that the USDA is continuing to rely on “reactive” measures to what is becoming a “long-term problem”).

119. *See id.*

120. *Id.*; Tom Polansek, *Bird Flu Spreads to New Countries, Threatens Non-Stop ‘War’ on Poultry*, REUTERS (Feb. 15, 2023, 1:31 PM), <https://www.reuters.com/world/bird-flu-spreads-new-countries-threatens-non-stop-war-poultry-2023-02-15/> [<https://perma.cc/6AZ6-GG67>].

#### IV. INTERIM CONCLUSION: OVERALL, THE LAW FALLS SHORT ON AVIAN INFLUENZA

The NPIP, through state and federal law, incentivizes producers to make herculean efforts to combat animal infectious diseases; this has led to widespread adoption of rigorous biosecurity practices. However, the United States, at the time of this writing, is entering its second consecutive year of dealing with a particularly severe outbreak of avian influenza.<sup>121</sup> This section explains why the prevailing legal framework is inadequate for addressing avian influenza as it now exists. It argues that while the NPIP is geared toward disease eradication through biosecurity practices, avian influenza has become epidemic and more aggressive to where eradication is not possible. Therefore, a new approach is needed.

Federal law falls short on the issue of avian influenza because on one hand, the NPIP has been administered to its fullest extent with participation being near universal among large commercial breeders, while on the other hand, avian influenza is seemingly here to stay, with cases continuing over one year after the latest outbreak began in early 2022.<sup>122</sup> If even sophisticated, well-funded commercial flock owners in full compliance with the NPIP's rigorous biosecurity requirements cannot prevent avian influenza from infecting their flocks, then perhaps the virus has become too powerful for the NPIP to contain.

Consider the history and purpose of the NPIP: the NPIP was intended to, and had tremendous success in, preventing and eradicating various avian diseases from the American poultry industry.<sup>123</sup> The NPIP was designed to eliminate poultry disease by incentivizing producers to adopt certain best practices and to prove freedom from disease through periodic testing.<sup>124</sup> Some diseases, such as Pullorum, are entirely eradicable through adoption of these best practices.<sup>125</sup> Other diseases, such as certain poultry diseases present in foreign jurisdictions, are similarly preventable through such best practices.<sup>126</sup>

For many years, the NPIP was rather effective at addressing avian influenza.<sup>127</sup> Because past outbreaks of the disease were generally seasonal and low pathogenic, the NPIP served its purpose by reducing infections and addressing them when they occurred so as to allow the disease to run its course, much in the

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121. See Nelson, *supra* note 118.

122. See *Poultry Biosecurity*, *supra* note 104; *infra* note 133.

123. Nelson, *supra* note 118.

124. *Pullorum-Typhoid Clean States*, *supra* note 95.

125. Williams, *supra* note 88.

126. Chow & Bush, *supra* note 1.

127. See *supra* notes 87-89 and accompanying text.



way that simple influenza in humans often runs its course in a seasonal fashion, but perhaps avian influenza has changed.<sup>128</sup> Many experts argue that the disease has become more virulent and is now no longer a foreign disease that comes and goes at times, but that is now an endemic disease that will continue in perpetuity.<sup>129</sup> Indeed, avian influenza may have become too strong for the NPIP to constrain, such that best practices encouraged by the NPIP are no longer sufficient to prevent or eradicate avian influenza.<sup>130</sup> Such is the experience of many producers, who take every precaution and even go beyond the NPIP regulations, only to witness avian influenza annihilate their flocks.<sup>131</sup>

Imagine if society had never developed a vaccine for COVID-19, and it continued to fight the disease simply through testing and preventative health protocols. The result would have been a society far more susceptible and far more inundated with the disease. This is the situation we are currently experiencing with avian influenza, except that avian influenza represents a far greater potential threat to human and animal health than COVID-19.<sup>132</sup>

Meanwhile, the economic costs of this outbreak are continuing to mount, yet there is no end in sight to it, despite the industry taking more than reasonable precautions.<sup>133</sup> It should be emphasized that, in terms of costs, the 2022–2023 avian influenza outbreak has cost our society in excess of \$2 billion in direct costs: \$661 million in direct government spending and over \$1 billion in costs to the

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128. See *supra* notes 10, 68 and accompanying text.

129. See *supra* notes 10, 105, 108 and accompanying text.

130. See discussion *infra* Section V.1 (discussing expert endorsements of poultry vaccination as a potential alternative to current practices).

131. See *infra* note 133 (discussing the extensive precautions taken by producers to prevent what is becoming an ever more uncontrollable disease).

132. Compare Mahase, *supra* note 75 (providing avian influenza fatality rates of 50% or higher), with WHO Coronavirus (COVID-19) Dashboard, WORLD HEALTH ORG. (June 4, 2023, 10:48 PM), <https://covid19.who.int/> [<https://perma.cc/P67H-EBJU>] (providing a COVID fatality rate of about 1% as of May 3, 2023, given 765,222,932 reported cases and 6,921,614 deaths worldwide).

133. See Donnelle Eller, *Bird Flu Outbreak has Slowed in 2023, but Iowa Poultry Producers Remain Fearful*, DES MOINES REG. (Apr. 10, 2023, 6:01 AM), <https://www.desmoinesregister.com/story/money/agriculture/2023/04/10/iowa-bird-flu-2023-outbreak-has-slowed-egg-prices-expected-rise/70076233007/> [<https://perma.cc/66JN-S95Q>] (detailing how although less severe than in 2022, detections of avian influenza persist in 2023 to a worrying extent). Some producers have even turned to creative home remedies to preventing avian influenza infections, such as using lasers and drones to disburse migratory birds that might be carrying the virus. *Id.*

industry.<sup>134</sup> Additionally, increases in food prices for consumers and psychological impacts on producers contribute to produce a very high total social cost.<sup>135</sup> Economic costs would grow exponentially should avian influenza become transmissible among humans in such a way that causes a new pandemic.<sup>136</sup>

Ultimately, law and policy reform could be an effective means by which our society can reduce the costs of navigating avian influenza under the status quo. Federal and state policymakers must be willing to supplement the NPIP with measures that go further in combatting avian influenza. This article makes two recommendations. The primary recommendation is to adopt an avian influenza vaccination program for commercial poultry. Additionally, it recommends additional funding for research on potential applications of gene editing technology in agriculture.

## V. RECOMMENDATIONS

This section provides multiple recommendations for reforming federal policy to be more impactful in mitigating the avian influenza disease. Specifically, this section recommends that the federal government pursue a mass vaccination program for commercial poultry and invest more heavily in gene editing technologies. However, the core policy recommendation that this section puts forth, and the one which could make a significant difference in the fight against avian influenza, is that policymakers should be doing as much as possible to lay the groundwork for eventual mass vaccination of poultry.

### *A. Pursue Mass Vaccination of Commercial Poultry*

The United States should establish a mass vaccination program for commercial poultry as soon as possible. Vaccines are the best way for policymakers to respond to avian influenza going forward; state and federal governments must coordinate a plan to begin mass vaccination of poultry as soon as commercially and technically possible.<sup>137</sup> This is because vaccination could

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134. Josh Funk, *Bird Flu Costs Accumulate as Avian Influenza Outbreak Enters Second Year*, USA TODAY (Feb. 18, 2023, 2:06 PM), <https://www.usatoday.com/story/news/health/2023/02/18/bird-flu-outbreak-costs-billions/11290771002/> [<https://perma.cc/X9YH-SFS3>].

135. *Id.*

136. See BRAHMBHATT, *supra* note 53.

137. See Jianzhong Shi et al., *Alarming Situation of H5 and H7 Avian Influenza and Effective Control Strategies*, EMERGING MICROBES & INFECTIONS, Dec. 12, 2022, at 1, 1, <https://pubmed.ncbi.nlm.nih.gov/36458831/> [<https://perma.cc/6EXU-5E9Y>] (“we recommend that any unnecessary obstacles to vaccination strategies should be removed immediately”).

prove to be an effective supplement to the NPIP in combating the ever more virulent avian influenza.<sup>138</sup>

There is a growing trend amongst experts that signals openness to poultry vaccination as a method of better controlling outbreaks of avian influenza.<sup>139</sup> For example, the World Health Organization’s chief scientist has recently called for the development of vaccines for animal influenza strains—avian influenza is the primary concern.<sup>140</sup> One avian influenza expert recently stated that, “we should be vaccinating the poultry population of the United States against [avian influenza] . . . [to] prevent the inevitable transmission to humans.”<sup>141</sup> In agreement, an expert

138. In other words, the NPIP is consistent with best practice and must be continued. *But see* Xianying Zeng et al., *Vaccination of Poultry Successfully Eliminated Human Infection with H7N9 Virus in China*, 61 *SCI. CHINA LIFE SCIS.* 1465, 1465–73 (2018), <https://link.springer.com/article/10.1007/s11427-018-9420-1> [<https://perma.cc/NEN4-D5LA>] (reporting that poultry vaccination “eliminated human infection with H7N9 virus” and decreased the virus isolation rate in poultry by 93.3% in China in 2013); Jon Cohen, *Bird Shots*, *SCI.* (Apr. 6, 2023), <https://www.science.org/content/article/bird-shots-vaccinating-poultry-best-defense-deadly-bird-flu> [<https://perma.cc/H8XW-LMAH>] (attributing poultry vaccination to entirely eliminating the disease from Mexico in 1995).

139. *See infra* notes 160–61; Jiahao Zhang et al., *H9N2 Avian Influenza Viruses: Challenges and the Way Forward*, 4(2) *LANCET MICROBE* e70, e70 (2023) (Discussing how Chinese poultry vaccination likely prevented the spread of avian influenza to humans and stating that “[w]e strongly advise that more attention be given to . . . develop[ing] universal H9N2 vaccines”); *High Pathogenicity Avian Influenza Vaccination Strategies to Prevent and Control HPAI, Removing Unnecessary Barriers for Usage*, *INT’L ALL. FOR BIOLOGICAL STANDARDIZATION* (June 4, 2023, 10:16 PM), <https://hpa-paris-2022.iabs.org/> [<https://perma.cc/SX82-CX6X>] (focusing on “removing unnecessary barriers for usage” of vaccination); David E. Swayne, *Impact of Vaccines and Vaccination on Global Control of Avian Influenza*, 56 *AVIAN DISEASES* 818, 818 (2012), <https://pubmed.ncbi.nlm.nih.gov/23402099/> [<https://perma.cc/Y6RV-C29G>] (“Clinical disease and mortality have been prevented in chickens, human cases have been reduced, and rural livelihoods and food security have been maintained by using vaccines during HPAI outbreaks. . . . vaccination can be added as an additional tool within a wider control strategy when immediate eradication is not feasible”); David E. Swayne et al., *Success Factors for Avian Influenza Vaccine Use in Poultry and Potential Impact at the Wild Bird-Agricultural Interface*, 11 *ECOHEALTH* 94, 94 (2014), <https://link.springer.com/article/10.1007/s10393-013-0861-3> [<https://perma.cc/8DUS-JXQF>].

140. Natalie Grover, *Develop Vaccines for All Animal Influenza Strain, Says Incoming WHO Chief Scientist*, *REUTERS* (Feb. 21, 2023, 2:05 AM), <https://www.reuters.com/business/healthcare-pharmaceuticals/develop-vaccines-all-animal-influenza-strain-says-incoming-who-chief-scientist-2023-02-20/> [<https://perma.cc/G8VD-T56H>].

141. Sheryl Gay Stolberg & Emily Anthes, *U.S. Considers Vaccinating Chickens as Bird Flu Kills Millions of Them*, *N.Y. TIMES* (Mar. 6, 2023), [https://www.spokesman.com/stories/2023/mar/06/us-considers-vaccinating-chickens-as-bird-](https://www.spokesman.com/stories/2023/mar/06/us-considers-vaccinating-chickens-as-bird)

on virology also recently stated that vaccination would be effective in lowering exposures and viral evolution that could result in the virus making a jump to humans.<sup>142</sup> Overall, there is strong support in the academic literature for vaccinating poultry against avian influenza.<sup>143</sup>

Countries have seen success with vaccinating poultry during past outbreaks of avian influenza.<sup>144</sup> Additionally, commercial poultry vaccination is currently occurring in some places, which serves at least to demonstrate that a vaccination program would be technically feasible in the United States.<sup>145</sup> For example, Mexico authorized the use of poultry vaccines for avian influenza on an emergency basis in 2023 and has thus far administered roughly 170 million doses.<sup>146</sup> China, the world's biggest producer of eggs, has been vaccinating for avian influenza since 2004.<sup>147</sup> Egypt has been vaccinating since 2006.<sup>148</sup> Vietnam "routinely" vaccinates for avian influenza.<sup>149</sup> Vaccines for avian influenza are also available in Italy and Indonesia.<sup>150</sup> Ecuador recently announced plans to begin vaccinating poultry after a case where avian influenza made the jump to humans.<sup>151</sup> The

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flu-kill/. This statement was made by Robert G. Webster of St. Jude Children's Research Hospital.

142. *Id.* This statement was made by Anice C. Lowen of Emory University.

143. *See infra* notes 160–62; *See also* H. Chen, *Avian Influenza Vaccination: The Experience in China*, 28 *REVUE SCIENTIFIQUE ET TECHNIQUE* 267, 271 (2009) ("[t]he vaccination strategy has been effective . . . in reducing the incidence of H5N1 in poultry and . . . human[s]").

144. *See infra* notes 160–62 (discussing Chinese and Mexican successes with poultry vaccination for avian influenza); *see also* Hualan Chen & Zhigao Bu, *Development and Application of Avian Influenza Vaccines in China*, 333 *CURRENT TOPICS MICROBIOLOGY AND IMMUNOLOGY* 153 (2009) (providing that "Over 30 billion doses of these vaccines have been used in China and other countries, including Vietnam, Mongolia, and Egypt, and have played an important role in H5N1 avian influenza control in these countries").

145. *See* Nelson, *supra* note 118.

146. *Factbox: Bird Flu Vaccination Policies by Country*, REUTERS (Feb. 17, 2023, 2:34 AM), <https://www.reuters.com/business/healthcare-pharmaceuticals/bird-flu-vaccination-policies-by-country-2023-02-17/> [<https://perma.cc/XM3D-PWDQ>] [hereinafter *Factbox: Bird Flu Vaccination*].

147. *Id.*

148. *Id.*

149. Stolberg & Anthes, *supra* note 141.

150. Jen Christensen, *US Government is Testing Avian Flu Vaccines for Birds, but Ending the Historic Outbreak Isn't That Simple*, CNN (May 5, 2023), <https://www.msn.com/en-us/health/other/us-government-is-testing-avian-flu-vaccines-for-birds-but-ending-the-historic-outbreak-isn-t-that-simple/ar-AA1aMzaT> [<https://perma.cc/VRE5-LYPF>].

151. Global Ag Media, *Once-Shunned Vaccines Now Under Consideration Amidst Avian Influenza Spread*, THE POULTRY SITE (Feb. 23, 2023),

European Union is harmonizing vaccine regulations and anticipates large scale vaccinations will begin in France by September 2023.<sup>152</sup>

Moreover, the United States is closer to rolling out avian influenza vaccines than one might assume. While the United States has avian influenza vaccine in its “national veterinary stockpile” and has been researching vaccines since 2015, it has not yet employed them.<sup>153</sup> Nonetheless, a mass vaccination program is currently being contemplated by vaccine manufacturers and by the USDA.<sup>154</sup> The USDA is currently testing three vaccine candidates, which include two private sector vaccines and one produced in-house by the USDA’s Agriculture Research Service.<sup>155</sup> While data on these trials is anticipated to be released at the time of this article’s writing, it could still take up to three years for a viable vaccine to be rolled out (unless emergency measures are invoked).<sup>156</sup> The best-case scenario contemplated by the USDA is 18 months.<sup>157</sup> All of this demonstrates that the United States is in a position which makes mass vaccination for avian influenza feasible within a relatively short time frame.

The largest barrier to such a program, however, is that it would be in direct violation of certain trade agreements.<sup>158</sup> One reason why vaccination could

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<https://www.thepoultrysite.com/news/2023/02/bird-flu-alarm-drives-world-towards-once-shunned-vaccines> [<https://perma.cc/V3PY-FFZW>].

152. *Factbox: Bird Flu Vaccination*, *supra* note 146.

153. *Id.*

154. John Hult, *Brookings Company Looks to Build Bird Flu Vaccine*, ARGUS LEADER (April 28, 2023, 10:54 AM), <https://www.argusleader.com/story/news/2023/04/28/brookings-company-looks-to-build-bird-flu-vaccine/70163386007/> [<https://perma.cc/5NL3-6R78>]; Dan Flynn, *USDA Orders Vaccine Trials for Bird Flu Outbreaks*, FOOD SAFETY NEWS (April 19, 2023), <https://www.foodsafetynews.com/2023/04/usda-orders-vaccine-trials-for-bird-flu-outbreaks/> [<https://perma.cc/G4SP-S7TD>].

155. Flynn, *supra* note 154. The private sector vaccines are being produced by Zoetis and Merck Animal Health, respectively.

156. *Id.*

157. *Fact Sheet: USDA Continues Partner Engagement to Mitigate Highly Pathogenic Avian Influenza for 2023 Season*, U.S. DEP’T OF AGRIC. (Apr. 14, 2023), <https://www.usda.gov/media/press-releases/2023/04/14/fact-sheet-usda-continues-partner-engagement-mitigate-highly> [<https://perma.cc/YYB2-92EF>] [hereinafter *Fact Sheet: USDA Continues Partner Engagement*].

158. *See, e.g., Importing Live Poultry into the United States*, U.S. DEP’T OF AGRIC. (Sept. 23, 2022), [https://www.aphis.usda.gov/aphis/ourfocus/animalhealth/animal-and-animal-product-import-information/live-animal-imports/sa\\_avian/importing-live-poultry/ct\\_live\\_poultry](https://www.aphis.usda.gov/aphis/ourfocus/animalhealth/animal-and-animal-product-import-information/live-animal-imports/sa_avian/importing-live-poultry/ct_live_poultry) [<https://perma.cc/9QF6-6ALD>] (providing that the United States requires imported live poultry to *not* be vaccinated for avian influenza). This requirement makes it easier to detect whether a particular animal is positive as testing currently produces a positive result in response to the presence of antibodies, whether these antibodies come from a

complicate poultry export is because trading partners want assurance that imported poultry is free of avian influenza—vaccinations would make that more difficult to demonstrate.<sup>159</sup> This is because current surveillance testing programs rely on serology testing that is based on the presence of antibodies in blood.<sup>160</sup> These tests cannot distinguish between antibodies resulting from natural infection and antibodies resulting from vaccination.<sup>161</sup> Therefore, individual sets of trading partners would need to negotiate as to whether assurances of freedom from avian influenza are sufficient under the testing circumstances then prevailing.<sup>162</sup>

This has caused the broiler industry, which exports roughly 10% of its production, to oppose vaccination, at least for the time being.<sup>163</sup> On the other hand, the turkey industry—which relies much less on exports—sees it the other way because vaccination is a much simpler prospect where production is destined for domestic consumption.<sup>164</sup> Medgene, a South Dakota based animal vaccine company, has publicly suggested that it may be wise to begin vaccinating turkeys.<sup>165</sup> This would allow the safety, efficacy, and economic efficiency of a mass vaccination program to be tested in practice before it is introduced to the poultry industry at large.<sup>166</sup>

Some experts urge a conservative approach to vaccination too.<sup>167</sup> One expert stated that there is a risk that inadequate vaccination could lead to additional viral

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vaccine or from a naturally occurring infection. Philip Gruber, *Trade Bans Limit Appeal of Avian Influenza Vaccines*, LANCASTER FARMING (Oct. 9, 2022), [https://www.lancasterfarming.com/farming-news/poultry/trade-bans-limit-appeal-of-avian-influenza-vaccines/article\\_f15bd71a-465e-11ed-b669-eb49223f2c47.html](https://www.lancasterfarming.com/farming-news/poultry/trade-bans-limit-appeal-of-avian-influenza-vaccines/article_f15bd71a-465e-11ed-b669-eb49223f2c47.html) [https://perma.cc/5MBQ-ENK4].

159. Stolberg & Anthes, *supra* note 141; *see also supra* note 117.

160. Megan Lighty et al., *Vaccination for Highly Pathogenic Avian Influenza (HPAI)*, PENNSTATE EXTENSION (Apr. 3, 2023), <https://extension.psu.edu/vaccination-for-highly-pathogenic-avian-influenza-hpai> [https://perma.cc/KD4W-NDG3].

161. *Id.*

162. *Id.*

163. Christensen, *supra* note 150; *Turkey by the Numbers*, NAT'L TURKEY FED'N (June 4, 2023, 10:09 PM), <https://www.eatturkey.org/turkeystats/#:~:text=In%202021%2C%20U.S.%20consumption%20of%20turkey%20was%205.1,turkey%20producer%20and%20largest%20exporter%20of%20turkey%20products> [https://perma.cc/T7EN-2RJK] (suggesting that roughly 90% of American turkey production is consumed domestically).

164. Christensen, *supra* note 150.

165. Hult, *supra* note 154.

166. *Id.*

167. Stolberg & Anthes, *supra* note 141.

shedding, and ultimately, more cases of avian influenza.<sup>168</sup> Another expert warns that vaccination is not “a silver bullet,” and that vaccinations do not necessarily prevent infection.<sup>169</sup> Furthermore, an ineffective vaccine could produce additional mutations in the virus with unclear results.<sup>170</sup>

However, this article argues that the benefits to vaccinating poultry for avian influenza outweigh the potential risks and complications. First, it is important to note that instituting a vaccination program may reduce the risk of the virus mutating into a form which is transmissible to humans.<sup>171</sup> Another important benefit of vaccinating commercial poultry may be that much of our response to outbreaks of avian influenza could become more efficient and more humane.<sup>172</sup> Consider the poultry death toll from the 2022–2023 avian influenza outbreak in the United States in which roughly 58 million birds were exterminated.<sup>173</sup> Most of these birds died not from avian influenza per se but from the mass culling that occurs in an effort to contain the virus. Were we to vaccinate poultry en masse, much of this culling would be unnecessary because birds would either not get the virus in the first place or could merely be quarantined to allow the virus to run its course within an immunized flock. Thus, although current disease management practices would not be eliminated, they could be reduced.

Additionally, a mass vaccination program may be more economically efficient than our current approach. Presently, the poultry industry is subjected to testing and culling protocols by which tens of millions of birds have been recently exterminated. This results in sunk investment costs and lost profits for producers who raise large commercial flocks only to have to destroy them. Indemnification is inadequate, however, as farmers’ costs tend to be far in excess of indemnification payments in the event of mandatory culling.<sup>174</sup> Moreover, indemnification only

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168. Christensen, *supra* note 150.

169. *Id.*

170. Giovanni Cattoli et al., *Evidence for Differing Evolutionary Dynamics of A/H5N1 Viruses Among Countries Applying or Not Applying Avian Influenza Vaccination in Poultry*, 29 *VACCINE* 9368, 9371 (2011), [https://damanhour.edu.eg/pdf/researches/Cattoli\\_Evi\\_differing\\_evolution\\_dyn\\_H5N1\\_poultry\\_Vaccine\\_Nov2011.pdf](https://damanhour.edu.eg/pdf/researches/Cattoli_Evi_differing_evolution_dyn_H5N1_poultry_Vaccine_Nov2011.pdf) [<https://perma.cc/2LZS-KJPD>].

171. See Zeng et al., *supra* note 138 (finding this to be the case in China).

172. See Adam Minter, *Want to Control Bird Flu? Vaccinate the Chickens!*, *MINT* (Feb. 26, 2023, 6:53 PM), <https://www.livemint.com/science/health/want-to-control-bird-flu-vaccinate-the-chickens-11677417446006.html> [<https://perma.cc/JX6F-SNYE>].

173. See generally *Fact Sheet: USDA Continues Partner Engagement*, *supra* note 157.

174. Philip Gruber, *Duck Farmers Question Officials on Avian Influenza*, *LANCASTERONLINE* (Apr. 13, 2023), [https://lancasteronline.com/news/local/duck-farmers-question-officials-on-avian-influenza/article\\_e17e352d-46ea-5ac4-b533-1c68340bdfdc.html](https://lancasteronline.com/news/local/duck-farmers-question-officials-on-avian-influenza/article_e17e352d-46ea-5ac4-b533-1c68340bdfdc.html)

shifts these costs, more or less, to the taxpayer.<sup>175</sup> If all poultry were vaccinated, however, society may be able to forgo large-scale testing and culling, and instead could test and cull in a much more limited fashion when faced with actual outbreaks of the disease.

An avian influenza vaccine, on the other hand, “can be as low as a few cents per dose.”<sup>176</sup> If the entire American chicken population was inoculated with customary two-dose series at a cost of even \$0.05 per dose,<sup>177</sup> the cost of the vaccines alone would be \$51 million. Naturally, there would be a variety of other costs—labor, equipment, and opportunity costs to name a few. However, avian influenza has cost the United States at least \$1 billion since 2022; this means that investing in vaccines could be more economically efficient, especially since the disease has become endemic.<sup>178</sup>

Overall, given the current impacts of avian influenza on markets, and the risk to human health, the complications that could arise from a mass vaccination program seem worth navigating. Most of these complications could be resolved at the negotiating table because many trading partners are becoming increasingly open to the prospect of vaccinating poultry for avian influenza. Additionally, vaccination could begin with poultry destined for domestic consumption to prevent export disruptions. Therefore, the federal government should accelerate its poultry vaccine efforts with respect to avian influenza and should strive to introduce vaccines into American poultry production as soon as possible.

### *B. Invest in Innovative Technologies Like Gene Editing*

Genome editing (gene editing) “is a method that lets scientists change the DNA of many organisms, including plants, bacteria, and animals. Editing DNA

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[<https://perma.cc/S6WF-HDF7>] (describing that a duckling may cost \$1.20 and be worth \$7.00 at market prices, while the USDA indemnity payment is only \$0.90).

175. *See id.* This is because indemnification comes from the USDA, which is ultimately financed through government spending.

176. Stolberg & Anthes, *supra* note 141.

177. *Id.* (stating that an avian influenza vaccination is generally completed across two doses); M. Shahbandeh, *Total Number of All Chickens in the U.S. 2000-2022*, STATISTA (Apr. 12, 2023), <https://www.statista.com/statistics/196028/total-number-of-all-chickens-in-the-us-since-2000/#:~:text=In%202020%2C%20the%20number%20of%20all%20chickens,in%20the%20United%20States%20total%20around%20518.3%20million> [<https://perma.cc/W5UC-9872>] (stating that the 2022 chicken population hovered around 513 million).

178. Funk, *supra* note 134.



can lead to changes in physical traits, like eye color, and disease risk.”<sup>179</sup> Gene editing is accomplished through the use of technologies like Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR), which was successfully used in recent years to cure mice of an inherited disease.<sup>180</sup> CRISPR, and other gene editing technologies, have a variety of useful applications for farm animals and have been used to design physically superior breeds of farm animals.<sup>181</sup> For instance, Japanese scientists created a red sea bream that carries 17% more muscle than current breeds, even on an identical diet.<sup>182</sup>

CRISPR is particularly relevant with respect to avian influenza because it is a potential means by which poultry could be bred to withstand or be immune to the disease.<sup>183</sup> It is feasible that poultry genetics could be manipulated to improve immune responses or even to render them immune to avian influenza.<sup>184</sup> This has already been done with certain species, such as when scientists successfully gene-edited a variety of pig that was resistant to Porcine Reproductive and Respiratory Syndrome Virus.<sup>185</sup> CRISPR is also significant to avian influenza because it is helpful for the development of new tests and vaccines for the disease.<sup>186</sup>

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179. *What is Genome Editing*, NAT’L HUM. GENOME RSCH. INST. (Aug. 15, 2019), <https://www.genome.gov/about-genomics/policy-issues/what-is-Genome-Editing> [https://perma.cc/44SS-KZHM].

180. Sharon Begley, *CRISPR Cures Inherited Disorder in Mice*, SCI. AM. (Oct. 9, 2018), <https://www.scientificamerican.com/article/crispr-cures-inherited-disorder-in-mice/>.

181. Jessica Hamzelou, *How CRISPR is Making Farmed Animals Bigger, Stronger, and Healthier*, MIT TECH. REV. (Jan. 20, 2023), <https://www.technologyreview.com/2023/01/20/1067125/crispr-farmed-animals-bigger-stronger-healthier/#:~:text=Using%20CRISPR%20to%20target%20the,the%20same%20amount%20of%20food> [https://perma.cc/6AQ8-9N7G].

182. *Id.*

183. See Jenny-Helena Söllner et al., *Genome Editing Strategies to Protect Livestock from Viral Infections*, VIRUSES, Oct. 4, 2021, at 1, <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8539128/> [https://perma.cc/D232-2QJ7].

184. See Hicham Sid & Benjamin Schusser, *Applications of Gene Editing in Chickens: A New Era is on the Horizon*, FRONTIERS GENETICS, Oct. 9, 2018, at 1, <https://www.frontiersin.org/articles/10.3389/fgene.2018.00456/full> [https://perma.cc/DZZ4-P4LL]; Sudeepta K. Panda & Mike J. McGrew, *Genome Editing of Avian Species: Implications for Animal Use and Welfare*, 56 LAB’Y ANIMALS 50 (2022), <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8918865/> [https://perma.cc/H9DL-7UMU]; see also Söllner, *supra* note 183, at 2 (“other strategies to supplement biosecurity and traditional breeding must be developed to protect animals and their producers from infectious disease outbreaks. A promising approach could be . . . CRISPR”).

185. Söllner, *supra* note 183.

186. *Id.* at 14.

Investing in CRISPR is smart because the technology is easy to use, efficient, and cheap.<sup>187</sup> CRISPR could produce breakthroughs in our understanding and management of avian influenza and a host of other issues, such as human diseases, plant agriculture, bioenergy, and conservation of endangered species.<sup>188</sup> To ameliorate the long-run costs of responding to avian influenza through draconian detect-and-cull methods is worth the short-run investment in additional CRISPR research.<sup>189</sup> Therefore, the state and federal governments should cooperate in applying CRISPR to the design of commercial poultry.

## VI. CONCLUSION

Overall, this article conducted an analysis of federal and state laws pertaining to avian influenza, offered critiques of the existing legal framework, and proposed recommendations for reform which could allow the law to better respond to an increasingly severe situation with avian influenza in the continental United States. Its primary conclusion is that policymakers must quickly introduce poultry vaccinations for avian influenza because existing legal frameworks focus on eradication, which is no longer possible because the disease is now endemic.

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187. Gus R. McFarlane et al., *On-Farm Livestock Genome Editing Using Cutting Edge Reproductive Technologies*, FRONTIERS SUSTAINABLE FOOD SYS., Nov. 15, 2019, at 1, <https://www.frontiersin.org/articles/10.3389/fsufs.2019.00106/full> [<https://perma.cc/FC3T-B8LN>].

188. Jennifer A. Doudna, *What is CRISPR: The Ultimate Guide to CRISPR Mechanisms, Applications, Methods & More*, SYNTHGO (June 4, 2023, 10:20 PM), <https://www.synthego.com/learn/crispr> [<https://perma.cc/5SG8-R9WD>].

189. *Id.* (describing CRISPR research as inexpensive); see HARVEY, *supra* note 117; see also Fong Yang Looi et al., *Creating Disease Resistant Chickens: A Viable Solution to Avian Influenza?*, VIRUSES, Oct. 15, 2018, at 1, <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6213529/> [<https://perma.cc/9LTZ-YPV6>]; E. M. Abdelwhab & Hafez M. Hafez, *Insight into Alternative Approaches for Control of Avian Influenza in Poultry, with Emphasis on Highly Pathogenic H5N1*, VIRUSES, Nov. 19, 2012, at 1, <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3509689/> [<https://perma.cc/FJ43-W5CD>] (describing the viability of gene-based interventions for addressing avian influenza).