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Theme Overview: Economic Consequences of Highly Pathogenic Avian Influenza

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Articles in this theme

- **Local Economies and Highly Pathogenic Avian Influenza**
- **Proactive Risk Assessments to Improve Business Continuity**
- **The Impact of Highly Pathogenic Avian Influenza on Table Egg Prices**
- **Regionalization of Highly Pathogenic Avian Influenza**
- **Government Spending to Control Highly Pathogenic Avian Influenza**

In a New York Times interview done in October 2015 with an Iowa turkey farmer, the arrival of highly pathogenic avian influenza (HPAI) was described as “when they went to bed one night, their turkeys were healthy; the next morning, almost 100 were dead and hundreds more were gasping for breath. Thousands of birds died in days” (McKenna, 2016). This farmer was one of 211 commercial poultry farmers and 21 backyard poultry farmers with confirmed detections across 15 states that experienced the worst avian health disaster in U.S. history. Previous avian health emergencies, such as the 2002-2003 exotic Newcastle disease (END) outbreak or the 2004 HPAI outbreak, were isolated to a limited geographic region. This outbreak was different. Wild bird surveillance programs identified strains of HPAI in the Pacific Flyway in December 2014, shortly after HPAI was identified in British Columbia in November 2014. HPAI strains H5N2, H5N8, and an isolated case of H5N1 were identified in wild birds, backyard poultry, and commercial poultry farms in Oregon, Washington, California, and Idaho between December 2014 and February 2015. All of these states are in the Pacific Migratory Flyway. Then, the HPAI-H5N2 strain was identified in the Mississippi and Central Flyways starting in March 2015; however, the most expansive damage in terms of birds infected occurred in Minnesota and Iowa. The last infected farm was confirmed on June 17, 2015 in Iowa, although response efforts to eliminate virus on farms continued well into the fall. Response plans in development since the early 2000s were deployed in a combined State-Federal response effort that resulted in the identification and depopulation of 7.5 million turkeys, 42.1 million egg layers as well as ducks and other specialty birds.

This themed set of articles explores the economic consequences of the 2015 HPAI outbreak, and how expectations based on economic research for avian influenza disease response planning played out in reality. The issue brings together animal health economics expertise from government and academia, drawing from research done in the heat of the outbreak and post-outbreak analysis on lessons learned.

The articles range from the national level, to the regional level, and down to the local level cutting across topics of public decision making and resource allocation, regionalization and trade, business continuity and permits, price formation of poultry products, and costs of local response and cleanup. Johnson, Seeger, and Marsh provide observations of HPAI activities in the local economy and summarize response and cleanup cost information for Minnesota and Iowa. Thompson and Pendell use a business continuity framework to examine product movement and permitting during the HPAI outbreak. Huang, Hagerman, and Bessler investigate the daily shell egg price movements in the Midwest, Northeast, Southcentral, and Southeast regions of the United States, and examine impacts of the 2015 HPAI incident on egg layers in the Midwest on these egg prices. Seitzinger and Paarlberg explore implementation of regionalization, its design, and implications for response strategies. Johannson, Preston and Seitzinger examine U.S. taxpayer costs against the benefit of avoided economic losses to domestic producers in response to HPAI. Each paper provides economic insights from the HPAI events based on empirical assessment from actual data or calibrated simulations. As in any significant economic event such as HPAI, necessary adjustments were made to mitigate losses and costs, lessons were learned, and new questions are in need of answers.

For more information

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Local Economies and Highly Pathogenic Avian Influenza

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JEL Classifications: Q10, R1
Keywords: Highly Pathogenic Avian Influenza, Local Economies, Disasters, Disease Mitigation

Economic shifts, regulatory change, and disasters always produce winners and losers. Whether or not these changes are good for the local economy, disasters both burden and provide opportunities for individual people, businesses, or groups—local and non-local. Disasters interrupt the stock and flow of resources for firm inputs, distort firm outputs, and alter service consumption patterns in local economies. Consequently, firm income changes are often followed by a redistribution of funds within the local area. Disasters also involve government planning and response, as well as aid for local communities. The 2014-2015 highly pathogenic avian influenza (HPAI) outbreak was the largest animal health disaster in the United States, involving the removal and disposal of nearly 50 million birds. An initial assessment of the local consequences suggests the outcomes from the HPAI outbreak resulted in fewer jobs, lower output, lower value-added, and decreased local, state, and Federal tax receipts (DIS, 2015a). Infected farms directly impacted by the disaster, and the non-infected farms not directly impacted by the disaster, realized different outcomes and consequences. Total social costs of the HPAI outbreak also included government investment for planning, surveillance, biosecurity, and stockpiling for preparation, response, cleanup, and indemnification.

Approximately $879 million was spent on the 2014-2015 HPAI outbreak and Fall planning activities according to data from USDA's Animal and Plant Health Inspection Service (APHIS). This is equivalent to 1.82% of the total poultry production value, including egg values (USDA-NASS, 2014). Approximately $200 million of the total mitigation expenditures were indemnity payments (USA Today, 2015) to farmers, growers, and companies, $610 million to response activities on premises according to USDA-APHIS, $34 million on Fall planning costs, and the remaining $35 million likely applied to overtime, travel, and supplies for Veterinary Services’ employees. Given the likelihood of future HPAI outbreaks and if HPAI becomes endemic in wild birds (USDA-APHIS, 2016d), it is prudent to move forward with an understanding of the likely outcomes on the local economy and the economic agents involved for mitigating and planning for future events.

Disasters and the Local Economy

Small, rural, and local economies face both losses and costs because of livestock disease disasters such as HPAI. Table 1 provides a general overview of the types of losses and costs relevant to the 2014-2015 HPAI outbreak.

Along with economic losses and costs, disasters induce other outcomes, such as altered competition between firms, changes in the demand for inputs, and increased prices of services for mitigation and cleanup. Altered competition evolves from the direct impacts of the disease on some farms but not on others. This also includes the effect of non-local firms entering the locality in response to increases in the demand for labor, natural resources, and equipment. In the long run, these impacts—coupled with the occurrence of disease outbreaks in small, rural economies—modify income distribution and resource allocation that can further compound economic losses.

Different outcomes and consequences may be realized by infected premises and non-infected premises. Output prices can rise, making non-infected producers better off—though price fluctuations can be mitigated to some extent by contracts. Not only are infected producers worse off, but if prices increase as a result of these events at the retail level, then consumers can pay more for products. On the other hand, if prices decrease because of export bans on livestock or livestock products, then consumers can pay less for products. State and Federal governments bear many of the economic consequences for stockpiling, response, clean up, and disposal, while some businesses and services, local and non-local, can realize a temporary windfall. Examples of selected changes in the flow of funds to the local economy are shown in Figure 1.

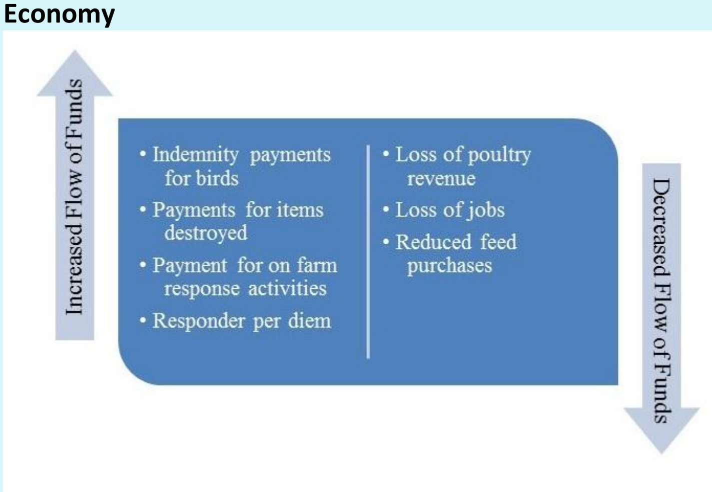
Observations from HPAI 2014-2015

Local economies experienced a major influx of State and Federal responders and contractors, as well as goods and services immediately after HPAI events. Long distances between outbreak locations in rural

Table 1: **Economic Losses and Costs to a Local Economy**

Term	Definition	HPAI Examples
Direct Losses	Direct losses in physical output and assets	Loss of livestock, reduction in egg and poultry output
Indirect Losses	Indirect losses are those that follow from the physical damages	Transportation and commuter disruptions, loss of local tax revenues, reduced tourism
Ex Post Costs	Mitigation expenditures undertaken during recovery period	Response, clean up, and recovery: personal protective equipment, organic material, equipment rental, labor, food, lodging, other services
Market Impacts	Changes in commodity prices for inputs, outputs, and assets	Changes in revenue of poultry and poultry products to firms and prices paid by consumers
Ex-Ante Costs	Mitigation expenditures undertaken before the disaster occurs	Preventative investment, stockpiling, biosecurity, and surveillance

Figure 1: **Examples of Changes in Flow of Funds for a Local Economy**



areas, increased competition, and demand for goods limited the availability of selected local inputs or services. Additionally, simultaneous HPAI events compounded and intensified response efforts, created bottlenecks, and increased costs. The major local response actions and constraints include the following:

Renting Vehicles and Hotels

Responders immediately needed transportation and lodging. Some responders realized additional search costs locating vehicles and transaction costs due to rental service representatives not always being available. Responders were housed in rural locations with limited hotel room options. Not surprisingly, the more scarce the number of rooms and the higher the willingness to pay for a room, the higher the price—the average increase was about 45%. Price-discrimination worsened in areas near resort locations during summer months. While some Incident Command Posts were established in hotels for convenience, others had technological issues, such as restricted internet and printing services, which forced them to drive to other locations to accomplish tasks, increasing costs.

Purchasing Federal and Disinfecting Vehicles

Federal employees were required to use specific purchase credit cards for selected items; however, local vendors in some locations were not equipped to accept those cards. Responders cleaned and disinfected vehicles at local car washes. If a car wash did not accept a purchase card, for example, responders were forced to locate another option or use their own funds, potentially increasing risk and costs.

Labor

Animal disease outbreaks require an immediate demand for labor. Response efforts for the 2014-2015 HPAI outbreak required 1,220 deployments of Federal employees, as well as, numerous state employees, producers, and other labor to respond to the emergency situation. However, crews trained to operate foaming units were in short supply and had a low likelihood of being located in rural areas where infection occurred. To request more labor, the Resource Ordering and Status System (ROSS), which "tracks tactical, logistical, service, and support resources mobilized by the incident dispatch community" (FAMIT, 2016) was activated. Filling labor requests using this system could be time consuming. In addition, the Federal government requires medical clearances for occupational activities related to emergency disease response. These requirements apply to all Federal employees, both temporary and permanent, as well as contractors, and in turn can further delay labor availability and increase ex-post costs. Nevertheless, this system serves an important purpose, such as helping to avoid the long-term costs of hiring responders not meeting labor qualifications or with pre-existing medical conditions.

Locating Equipment

The stock and flow of rental equipment such as skid steers, loaders, dump trucks, and roll-off dumpsters also experienced changes. These changes were at times seasonal, especially during the warmer weather months, as disease response activities competed for identical resources with crews from the construction industry. During winter months, supplies like heaters, generators, and warming tents could be scarce.

Specialized equipment was also difficult to source. Thermometers used to examine compost efficacy were special order items since they were manufactured outside of the United States. Although proactive measures were taken in planning, preparation, and stockpiling for an HPAI event, the magnitude of the 2014-2015 events exceeded the capacity of the stockpile for certain items. The prolonged 2014-2015 HPAI outbreak weakened distributor inventories, especially for foam depopulation equipment and CO2 carts, and compelled upstream manufacturers to place these items on back order.

Water Limitations for Depopulation by Foaming

Foam depopulation was the most cost-effective measure of HPAI containment due to relatively low labor requirements and speed of depopulation (USDA-APHIS, 2015a), but high water consumption requirements for these machines at times challenged limited water sources and well recharge rates. During summer months, water usage was directed away from crop irrigation resulting in indirect losses. These factors induced transportation of water from other sources in plastic water tanks, but freezing conditions during winter rendered plastic tanks impractical.

Carbon Dioxide Use in Depopulation

When environmental and water supply factors precluded foaming depopulation, responders use carbon dioxide depopulation methods. However, CO2 canisters could not always be locally sourced and suppliers were hesitant to expose canisters to virus, presenting a constraint in meeting HPAI containment goals. Although these needs were recognized during planning and preparation exercises, the size of the 2014-2015 HPAI outbreak exceeded the stockpile capacity for certain items and created further logistical problems. Simultaneous infections in areas with substantial physical distances between flocks increased the demand and scope of these resources. In response, APHIS has evaluated National Veterinary Services' strategy and is reviewing the acquisition of additional equipment which would be staged closer to high-risk geographic areas, which could decrease response time (USDA-APHIS, 2016d).

Disposal by Composting and Landfilling

Disposal methods differed based on flock size and space, but composting and landfilling were used most frequently (USDA-APHIS, 2015a). Reductions in the supply of organic materials for composting grew as the outbreak continued, driving up ex-post costs. In certain places, disposal by landfill was available near concentrated outbreak areas, but sometimes it was hours away from the infected premises. Even with investments in planning and preparation for disposal, agreements with landfills to accept infected birds took time to negotiate. Ex-post HPAI costs increased as a result.

Facilities Cleaning and Disinfection

After disposal, organic materials were removed and barn surfaces cleaned and disinfected. Heating at 100-120 degrees Fahrenheit for seven days was the most cost-effective disinfection method. The average cost of cleaning and disinfection for commercial egg layers was $8 million, compared to just $170,000 for average turkey grow-out farms (USDA-APHIS, 2016b). This cost difference is attributed to infrastructure and production characteristics of layer farms having more barns and birds, as well as, cleaning and disinfecting layer cages is more labor intensive, in comparison to farms raising birds on the floor.

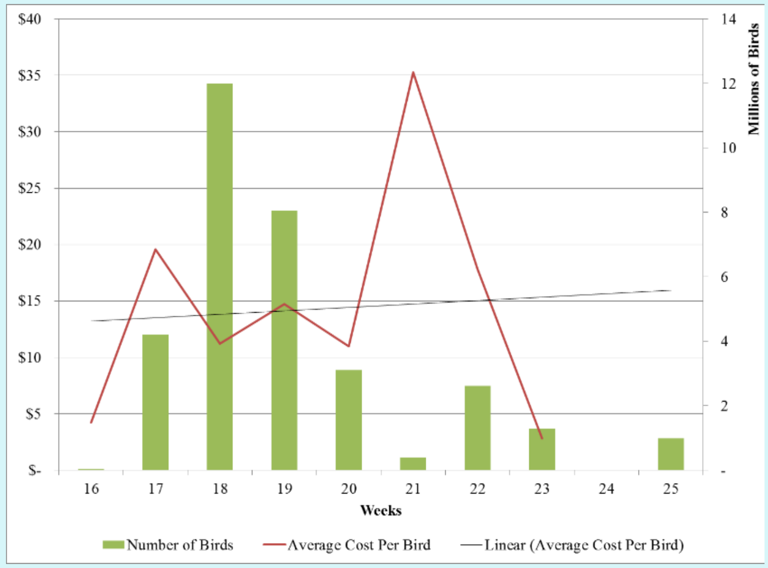
Comparing Costs in Iowa and Minnesota

The two States hardest hit by the HPAI outbreaks were Iowa and Minnesota, with a loss of 32 million birds in Iowa (95% chickens) and 9 million birds in Minnesota (54% turkeys). Iowa accounted for 66% of the total birds lost in the United States, or 1.6% of the total production value of chickens (USDA-NASS, 2015). Decision Innovation Solutions (DIS) (2015b) reported 8,444 fewer jobs, $1.2 million in lower output, and $426.9 million in lower value-added in Iowa. Similarly, Minnesota accounted for 19% of the total birds lost in the United States, or 2.09% of the total production value of turkeys (USDA-NASS, 2015; USDA-NASS, 2014; USDA-APHIS, 2015c). Every 100 poultry jobs lost translated into direct loss of an estimated $27.3 million in poultry processing output (UMN Extension, 2015). These initial results are based on modeling exercises using standard impact analysis with economic multipliers to estimate losses, and are not the actual costs incurred during the outbreak.

Response Activity Cost

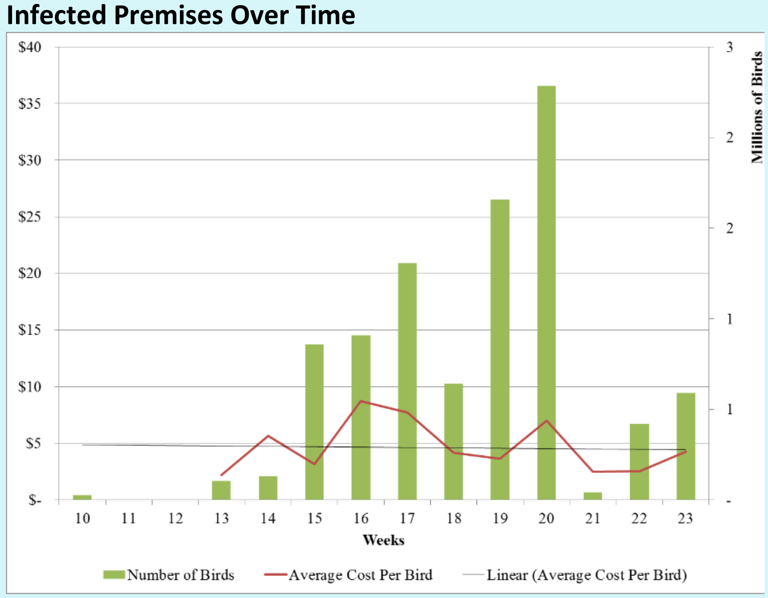
The trend in the cost of response activities on premises and number of birds depopulated by week serve as a proxy for the demand of supplies, labor, and equipment in the local and surrounding communities. In Iowa, bird losses reach a peak of about 12 million in week 18 (Figure 2). In Minnesota (Figure 3), bird losses reach a peak of over 2.5 million in week 20. The average cost-per-bird for depopulation, disposal, and cleaning and disinfection activities exhibits more variation and increases over time in Iowa relative to Minnesota. The average cost-per-bird was $4.63 in Minnesota and $14.47 in Iowa. This totaled $463 million for Iowa and $42 million for Minnesota. The lower cost in Minnesota could be attributed to the operation type, as well as, lower demand for—and easier access to—equipment and labor. Limited availability of labor and other inputs drove up logistics costs and became constraining for responders working to depopulate quickly after disease detection to help contain disease spread. Also, it is cheaper to clean floor bird facilities as opposed to multi-vertical layer cages, and the majority of operations affected in Minnesota were turkeys. In January 2016, APHIS released the flat rate payments for virus elimination in preparation for future outbreaks in order to expedite payments to infected producers and improve efficiency in HPAI disease response. Those were $1.15, $3.55, and $6.45 per bird for broilers, turkeys, and layers, respectively (USDA-APHIS, 2016b). Flat rates, implemented in the January 2016 outbreak in Indiana, provided an incentive to producers to be efficient in completing virus elimination activities while environmental testing on site ensured the effectiveness of virus elimination activities on infected premises.

Figure 2: **Iowa Cost-per-bird for Response Activities on Infected Premises Over Time**



Source: USDA, APHIS, unpublished data.

Figure 3: **Minnesota Cost-per-bird for Response Activities on Infected Premises Over Time**



Source: USDA, APHIS, unpublished data.

Responder Hotel Cost

The demand for hotel rooms changed in response areas as the outbreak spread, which resulted in increased nightly hotel rates. The average rate in Minnesota (USGSA, 2015) started at per-diem early in the outbreak, and then increased over time to remain over per-diem. Rates in Iowa started at per diem, fluctuated and were over per-diem a majority of the time as well, but the increase over time was small. While a lodging waiver was approved to increase the nightly hotel rate above original per-diem rates, the original rates for 2015 were exceeded more often as the outbreak progressed. Some responders experienced consistent rates at per-diem, or slightly higher, during their deployment. In extreme cases, responders experienced some 15 different hotel rates during a 25-night deployment, with only two of those nights at per-diem and 23 over per-diem. The average nightly hotel rate in Iowa was $121.07 and in Minnesota was $118.87. Overall, the average hotel rate increased about 45% in Iowa and Minnesota.

Discussion: Winners and Losers

The HPAI outbreak of 2014-2015 produced both winners and losers. The large influx of government responders and private contractors affected local communities in ways that were both expected and unforeseen. Subsequent changes in supply and demand altered the normal flow of goods and services within the afflicted economies, resulting in the redistribution of income between members of local municipalities as well as to others outside the local economy. Some realized benefits to their business (such as, hotels, restaurants, local supply, and equipment rental stores) while others realized costs and losses (such as, poultry producers, feed distributors, and processing plants). However, most recognized just how challenging HPAI could be, especially in small communities.

Small companies in the businesses of renting equipment or contracting experienced a much greater demand for equipment, even in nearby localities where the outbreak did not occur. There is some evidence that truck transportation output declined because of decreased demand for poultry production (DIS, 2015a). However, demand for truck transportation also increased due to disease mitigation. Whether or not the increased demand for truck transportation or temporary rental price hikes benefitted businesses in the long-run is an empirical question. In the short-run at least, it was apparent that business' income changed during the outbreak.

The HPAI outbreak also affected input producers for the livestock industry. Feeds and other poultry production related goods were superfluous during the downtime in poultry production in control areas, leading to declines in output for animal food manufacturing and grain farming businesses (DIS, 2015a).

Consequences were clearly realized by the poultry producers themselves. Although contracts in the poultry sector tend to reduce price volatility, changes in revenue and capital were immediate for some poultry producers who were very close to sending products to market, including export markets. Their revenue from selling products on the open market was lost, and their expenses changed from providing food, water, care, and housing to poultry during disease response and cleanup. Producers were provided indemnification and cost recovery for response and cleanup, but this is not intended to cover all the economic costs. USDA-APHIS does not provide funds to cover production or income losses incurred during downtime or other business disruptions (USDA-APHIS, 2016a).

Expediting depopulation, cleaning, and disinfection in order to be cleared to restock poultry was a priority. Producers wanted to get back into business as soon as possible in order to smooth income effects of production downtime. As a result, producers incurred up-front expenses for cleaning activities for which they would possibly be reimbursed for in the near future. However, processing these payments from State and Federal governments required approval and time. To expedite the payments for virus elimination in future outbreaks USDA-APHIS developed the flat rates described above. Although indemnity and flat rate payments greatly helped to alleviate mitigation costs, HPAI created many substantial economic losses for those directly involved.

Lessons Learned

Preventative investments in planning and preparation, industry contracts, and instruments such as government price lists and per-diem agreements worked to mitigate response and cleanup risk and costs. Other strategic solutions include equipment staging, stockpiling and storage, labor acquisition and procurement plans. “Acquiring additional supplies to close [the] gap…between current supplies on hand and the projected needs of a worst-case scenario” has been an important planning step for mitigating future events (USDA-APHIS, 2015b). Nevertheless, strategic responses to disasters need continual improvement and updating, including enhancing risk management, flexible regulatory policy, and effective reorganizing.

Risk-based instruments such as livestock insurance for diseases have been proposed in the past. This topic, and writing continuity of business insurance policies for situations like HPAI, remains an open question for future research and discussion. During the 2014-2015 HPAI outbreak, no other non-government entities provided payments to producers besides APHIS, with the exception of some poultry companies and producers cost-sharing in the form of time, resources (such as, personal protective equipment), and expenses (such as, non-reimbursed time and utilities). In unique situations, the State provided a limited number of premises with indemnity or reimbursement for resources used in response activities.

Resource constraints have already caused difficulties in responding to a single disease outbreak in multiple states. The risk of another concurrent outbreak in other species occurring in different areas of the nation could further stress resources. Producers, consumers, and state and Federal governments need to respond cohesively to each emergency and allocate resources in the most effective manner. Some, but not all states have sufficient resources to respond to animal disease outbreaks, depending on the size of the outbreak. The larger the outbreak, the more reliant states are on Federal resources for response efforts. The Federal government has recently evaluated and increased its resources dedicated to emergency response by revising third-party logistics contracts to “provide surge personnel and equipment to support states without sufficient resources (depopulation, decontamination, and disposal)” (USDA-APHIS, 2016c).

Several other observations are important. It is imperative to keep in mind the role of public health as well as animal health in all animal disease outbreaks, especially for potentially zoonotic diseases such as HPAI. Increasing the population density with response personnel stretches public health resources thin in rural communities, and stress on responders and ground-level workers certainly is real and important to acknowledge. Finally, tracking expenses in an effective manner for economic cost assessment is important for both State and Federal agencies to successfully assess the outcomes of disease events. The experience has also highlighted what would be useful to know in the future. For example, little is known about the impact of market structure and contracts, as well as economies of scale and scope, on response costs. Additional specific areas that would be helpful to know include the impact of changing indemnity payment policies—such as a change to split payments, changing disease response policies—such as virus elimination flat rates, and changes in applications for unemployment benefits in states with infected sites balanced with the increased demand for local labor for disease response activities.

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Proactive Risk Assessments to Improve Business Continuity

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In December 2014, highly pathogenic avian influenza (HPAI) was discovered in U.S. poultry, eventually affecting more than 48 million birds by July 2015. The outbreak heavily affected Midwest poultry, specifically Iowa and Minnesota. The majority of affected operations were turkey operations but the vast majority of affected birds were layer hens (67%), or chickens that lay eggs to be consumed as either table eggs or further processed egg products (USDA-APHIS, 2015). During the outbreak, animal health officials used a permitting process to aid in business continuity and to alleviate some of the physical and economic stress of the outbreak. These permits allowed movement of products and animals on and off non-infected premises that were located within control areas, typically a ten-kilometer radius area surrounding infected premises, reducing potential costs associated with the outbreak.

Business continuity planning provides a way for the various stakeholders, such as producers, industry, and government, to prepare for unplanned events that could negatively impact business operations (Zsidisin, Melnyk, and Ragatz, 2005). This pre-planning provides guidelines on how to reduce business disruptions during an animal disease outbreak (Hennessey et al., 2010), especially when the disease management strategies are considered economic “wicked problems”, or those that are difficult to solve for various, contradictory reasons (Miller and Parent, 2012). Plans must account for risk of disease spread, disease exposure rates, and unintended consequences of allowing movement within and outside control areas. These unintended consequences are those effects that are not intended with the disease management strategy including spread of disease to a non-infected premise that increases the cost and longevity of an outbreak. If the risks associated with movement were such that the benefits of movement outweigh potential unintended consequences, then product movement could occur.

For the egg layer industry, these unintended consequences could affect multiple groups along the supply chain. First, contract and independent producers could be affected through losses in income and additional costs of egg and egg product disposal that are prohibited from moving outside the control area. Second, processors and integrators could be impacted through processing disruptions and retail shortages. Third, due to an egg shortage, consumers could be affected through higher price for eggs and egg products. Finally, government stakeholders, at all levels, could be affected through the cost of indemnity and disease control as well as eradication measures. Planning and developing management strategies for disease outbreaks can potentially alleviate some of these business strains as evidenced by the recent outbreak of HPAI in the U.S. poultry industry.

Secure Egg Supply Plans

Business continuity planning for the U.S. egg industry began in 2006 when personnel at the U.S. Department of Agriculture's Animal and Plant Health Inspection Service’s (USDA-APHIS) along with other federal and state agencies, academia, and industry formed the Egg Sector Working Group to assess the risk of spread of HPAI associated with movement of various poultry products. Issues identified by the Egg Sector Working Group are addressed through a series of proactive risk assessments for poultry products which analyze the disease spread risk of movement of products and farm inputs within and from outside of a control area. This working group was instrumental in developing the Secure Egg Supply plans to help support business continuity in the egg industry (Hennessey et al., 2010). These proactive risk assessments are useful in preparing and planning for a permitting process in the event of an outbreak to be readily applied, as opposed to reactive risk assessments being estimated after an outbreak occurs slowing down the permitting process.

The risk assessments follow the World Organization for Animal Health (OIE) standards and guidelines that were introduced to address the Agreement on Sanitary and Phytosanitary Measures by the World Trade Organization (OIE, 2013a; 2013b). These risk assessments include an entry assessment, exposure assessment, consequence assessment, and risk estimation. Entry and exposure assessments estimate the disease spread risks associated with product movement inside and outside of control areas, and have been completed for seven egg commodities (USDA-APHIS, 2013). The seven egg commodities include: pasteurized liquid eggs, non-pasteurized liquid eggs, washed and sanitized shell eggs, nest run shell eggs, hatching eggs, day-old chicks, and egg shells and inedible eggs.

With any highly infectious disease outbreak, there is the potential risk of increased disease exposure by allowing movement from the control area. The movement of shell eggs from monitored premises have been assessed to pose relatively low additional risk for disease spread over a baseline scenario of movement restrictions, where movement is not allowed within the control area (USDA-APHIS, 2010). However, any potential increase in the spread of disease could result in increased depopulation and disposal costs, other direct costs to producers, a reduced supply of sellable eggs and increase in retail prices, increased indemnity payments by the government, and restocking costs once this is allowed. Consequence assessments should account for these decisions made during an outbreak, and the proactive risk assessments address these management decisions, which are then incorporated into the economic consequences.

To date, the entry and exposure risk assessments have focused on evaluating the likelihood of susceptible poultry becoming exposed via movement of poultry products. These assessments are publicly available as the Secure Egg Supply Plans (USDA-APHIS, 2013). These assessments' disease management recommendations were incorporated in the decision making process by state and federal agencies when managing the most recent HPAI outbreak, providing a framework for disease management strategies. The final step for risk assessment is the risk estimation, which will integrate the results from the entry, exposure, and consequence assessments.

The consequence assessment, or a benefit-cost analysis, for business continuity is being developed. To assess the benefits and costs of allowing movement of products and farm inputs during a HPAI outbreak, animal health officials need to consider multiple decision factors including:

1) the likelihood of susceptible poultry becoming exposed due to the movement,
2) the likely economic and social consequences of exposure, and
3) the economic and social impacts of stopping product movements.

This economic portion of the consequence assessment will be incorporated with the entry and exposure assessments to provide a final risk estimate for business continuity.

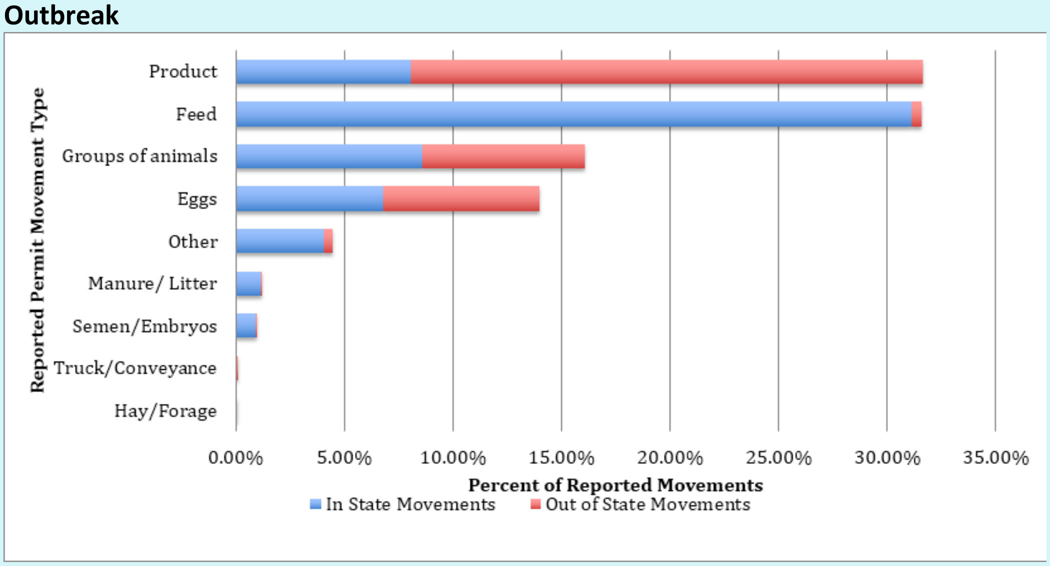
Movements In/Out of Control Area

To manage the spread of a disease, pre-defined control areas are established around infected, detected premises. The control area is defined as the area in which disease management protocols dictate movement within and outside for a specified radius, commonly 10-15 kilometers (USDA-APHIS, 2015b). These control areas almost always include non-infected premises as well. Non-infected premises within the control area are at the center of business continuity discussions, as these premises under stop movement orders are prohibited from moving products on or off farm during a disease outbreak due to geographic location. Products requiring movement permits include egg products produced on farm as well as feed and farm inputs moving onto these premises from outside the control area.

According to the Secure Egg Supply Plans, premises that increase their biosecurity measures to include key points of protection such as truck washing for movement both onto and off of premises, personal protective equipment used by farm workers that are site specific, proper disposal of waste and euthanized birds, and disease monitoring can apply for movement permits. These permits require premises to test negative for HPAI prior to any movement, with continued testing to ensure a disease free premises. For example, nest run shell eggs must have two negative avian influenza polymerase chain reaction (PCR) pools per house and a holding period of two days, or a period when products are stored until allowed to move, where one of the samples must be taken on or after the second day (USDA-APHIS, 2013). When these requirements are met, premises may request movement permits that sanction selected movements.

All permits must go through state animal health agencies. The typical process for permits is to submit a request, review of the request, approval or denial of the request, and finally movement. The request could be for single or multiple movements for a specified period of time. All permits must be recorded by the state agencies and should be approved by the receiving state for both interstate and intrastate movements. The majority of states use USDA's Emergency Management Response System (EMRS) for data entry and those that do not, eventually recorded their permits into this central system. All steps should be recorded in EMRS accurately and in a timely manner. All permits are reviewed, and if movement stipulations are not consistently met, permits may be revoked.

Figure 1: **Movement Types into and out of Control Areas for the 2014-2015 HPAI Outbreak**



Source: USDA-EMRS, 2016

During the 2015 U.S. HPAI outbreak, approximately 7,800 permits were awarded accounting for approximately 20,000 movements as reported in EMRS in April 2016. These permits were issued for individual and multiple intra and interstate movements. Not all movements were consistently recorded in EMRS. The reported permits mainly included movement of feed, farm products, and live animals as shown in Figure 1. It should be noted that semen/embryo movement is considered high risk for potential disease spread. Currently, there are no permitting guidelines for secure movement. All movements of any products are at the discretion of state health officials. Of the permitted movements reported, 61% of all movements were in-state movements. The proportion of movements varies with the individual item type. For example 98% of all feed movements originated in the same state as the destination premises. Non-essential movements were restricted during the outbreak. However, with the permitting process, essential movements were allowed, which provided a reduction in business disruption as a result of the HPAI outbreak.

Business Continuity and the Benefits and Costs of the Permitting Process

The value of issuing permits is very important for business continuity. Valuing the permitting process is multifaceted, needing to account for both the potential change in disease spread and market changes for an accurate counterfactual assessment. The outlays of an outbreak under stop movement orders as a disease management strategy are costly when accounting for costs of management and losses in potential revenue. During an outbreak in which stop movement orders are in place, producers that are not infected, but that fall within a control area, face capacity constraints for egg storage. Storage on a typical egg layer farm (100,000–110,000 layers) is three to four days for eggs produced (USDA-NASS, 2014). Once storage is over capacity, and if the eggs cannot move from premises to either a processor or a breaker facility, they must be properly disposed. During the outbreak there is the possibility that farms are unable to properly dispose of eggs and egg products if disposal volume is beyond operating capacity. If disposal cannot be executed on farms, alternative disposal methods must be arranged, potentially taxing waste facilities already managing depopulation disposal from infected premises. Movement permits reduce the need for egg disposal, decreasing these additional costs to producers as well as lessening the burden on waste management facilities.

Potential Benefits to Producers with Business Continuity

Most importantly for producers, the permitting process leads to a reduction in revenue disruption with permitted movement of eggs off premises. Eggs that are destroyed due to storage limitations represent forgone revenue. During the most recent outbreak there were shortages of eggs, driven by depopulation of infected premises, which would have been exacerbated without a permitting process. Figure 2 shows the changes in U.S. egg supply as well as the changes in average price paid for Grade A, large white eggs (USDA-NASS, 2016; U.S. Department of Labor-BLS, 2016). Producers located in the control areas that were able to move product, with movement permits, captured the increase in egg prices due to the supply shortages.

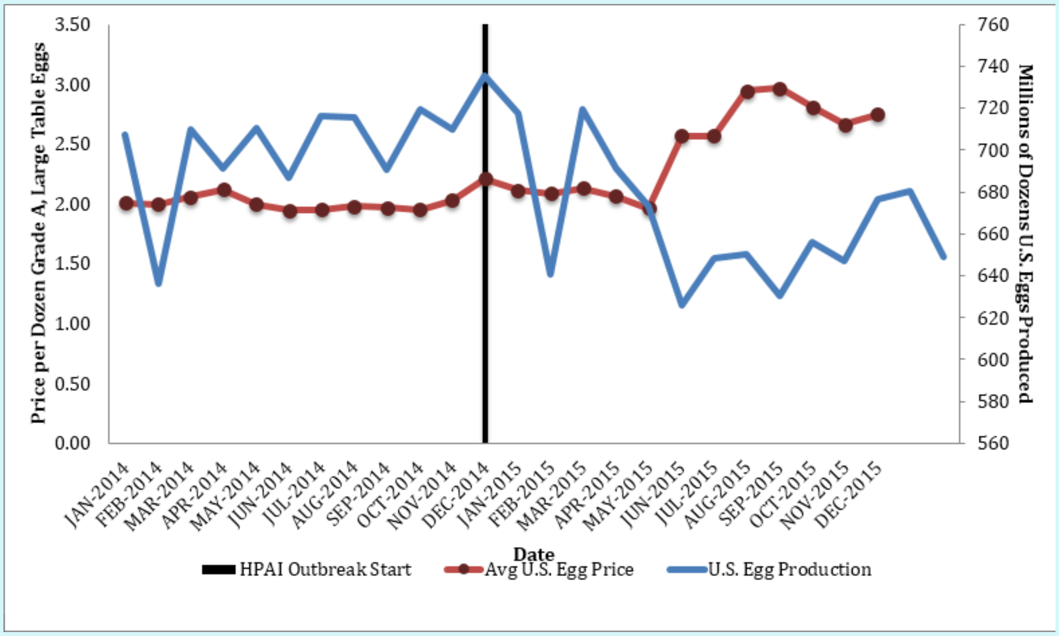
Potential Benefits to Processors with Business Continuity

Permitting allowed processors to better meet demand for individual consumers and further processing customers, reducing processor potential losses. While processers make the decision where eggs should be diverted—either table eggs for individual consumption or further processing—based on the relative value, the shortages in eggs increased the prices for both products (USDA-AMS, 2015). Reducing the loss in supply allowed processors to manage stocks of eggs during the outbreak so as to lessen their loss in revenue due to egg shortages.

Potential Benefits to Consumers with Business Continuity

Consumers benefit from permitting processes through continued supply of eggs. The reduction in stocks of eggs caused a dramatic increase in the price of table eggs. The national price for Grade A, large table eggs in July 2015 was $2.57, a 32% increase over July 2014 table egg prices (Figure 2) (U.S. Department of Labor-BLS, 2016). Without a permitting process, there would have been fewer eggs in the supply chain. It is reasonable to conclude that these table egg prices would have been higher and caused a greater burden to consumers.

Figure 2: **U.S. Egg Production Quantities and National Average Prices from July 2014 – December 2015**



Source: USDA-NASS, 2016; U.S. Department of Labor-BLS, 2016

Potential Direct Costs with Business Continuity

Potential losses are not solely reductions in potential revenue, there are also direct and indirect costs associated with a disease outbreak. The commonly discussed direct costs include those associated with appraisal, cleaning and disposal, euthanasia, indemnification, quarantine, and surveillance (Pendell et al., 2015). However, there are additional direct costs associated with obtaining movement permits. For a premises to be approved for a movement permit, the operation must ensure a certain level of biosecurity during the outbreak. This requirement includes adding additional personnel, truck washes, personal protective equipment for all people entering the premises, and baits and traps for potential disease vectors. The federal, state, and local government also have additional administrative, testing, and monitoring costs associated with movement permits.

Potential Indirect Costs with Business Continuity

There are indirect costs that also need to be considered during an outbreak, for example, increased use of water or excess demand for landfills. The increased use of resources could result in negative environmental externalities—for example, reduction in available water—for local communities. With a permitting process, the direct costs are still incurred to ensure all measures are being taken to reduce the risk of HPAI spread. However, permits can help in reducing some of the burden for disposal that would be incurred if the control area were managed using only stop movement orders. Business continuity does not reduce all the costs associated with an outbreak, but it does provide a source of revenue to producers to meet their financial obligations.

Potential Government Costs with Business Continuity

The final stakeholder in managing disease outbreaks is the government. In response to the 2015 HPAI outbreak, the USDA spent approximately $1 billion for controlling and eradicating the disease outbreak and recovery (USDA-OC, 2015). There were costs associated with testing, disease management, movement permit review, veterinary services, monitoring, and surveillance. The USDA paid nearly $200 million in indemnity to producers or bird owners to compensate for their losses and aid recovery (USDA-OC, 2015). Costs associated with mandated disease management practices, including cleaning and disinfecting for affected farms were reimbursed to producers.

The USDA created a National Permitting Unit to oversee and provide a central point of contact for all permitting data and additional review. The costs for movement permits included a management system (EMRS), labor in the field, and the National Permitting Unit. Each permit had to be approved by an acting supervisor in the field, filed appropriately, and approved by respective state agencies, which all represent additional costs associated with business continuity.

Lessons Learned in Managing Future Risks

The U.S. poultry industry was greatly affected by HPAI during the 2015 outbreak. There were more than 48 million birds affected, of which 32 million were layer birds. For future outbreaks, the lessons learned through the 2015 HPAI outbreak are invaluable for supporting the planning and preparation of the permitting process. On-going training will help prepare states and personnel with the proper procedures and reporting practices.

This outbreak was unique in that instead of completing risk assessments on a case-by-case ad hoc basis for animals and products in the control areas, premises that incorporated the Secure Egg Supply Plan changes were allowed to apply for permits to move either product or essential material in and out of the control area. By implementing additional biosecurity measures as outlined in the Secure Egg Supply plans, this ensured that the best disease management practices were in place, reducing the risk for disease spread and better controlling movement. State animal health authorities issued approximately 7,800 movement permits. The majority of these permits were issued to move feed onto farms or to move products out of the control area. By allowing movement, there was likely a reduction in the price increase to consumers, foregone revenue to producers, and potential indemnity payments by the USDA. However, there were producer costs associated with this management strategy including increased biosecurity, which should be applied with or without permits, as well as the government cost of the permitting process. These costs have not been quantified and is an area for extended research.

Permitting movement during a highly pathogenic disease outbreak can provide a reduction in potential negative effects, examples of which are discussed above. The costs associated with controlling and eradicating a disease affect producers, processors, consumers, and government. Completing proactive risk assessments helps with disease outbreak preparation and planning, such that permits may be issued sooner in the process than if the risk assessments were created reactively. In support of these risk assessments, current ongoing work in business continuity is quantifying the impacts of business continuity on these participants and the market. The consequence assessment together with the entry and exposure assessments will create a complete risk estimation for business continuity. Research extensions applicable to future outbreaks or different commodities could include trade implications of a permitting process. Trading partners could choose to accept or ban products originating from a specific region or the entire country if they do not agree with allowing movement from a control area. These trade implications also help to create a holistic understating of the implications of business continuity.

Finally, the use of business continuity and the lessons learned in the poultry industry during the 2014-2015 HPAI outbreak can be applied to other industries and for potential future outbreaks and in motivating proactive assessments for planning and preparation.

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The Impact of Highly Pathogenic Avian Influenza on Table Egg Prices

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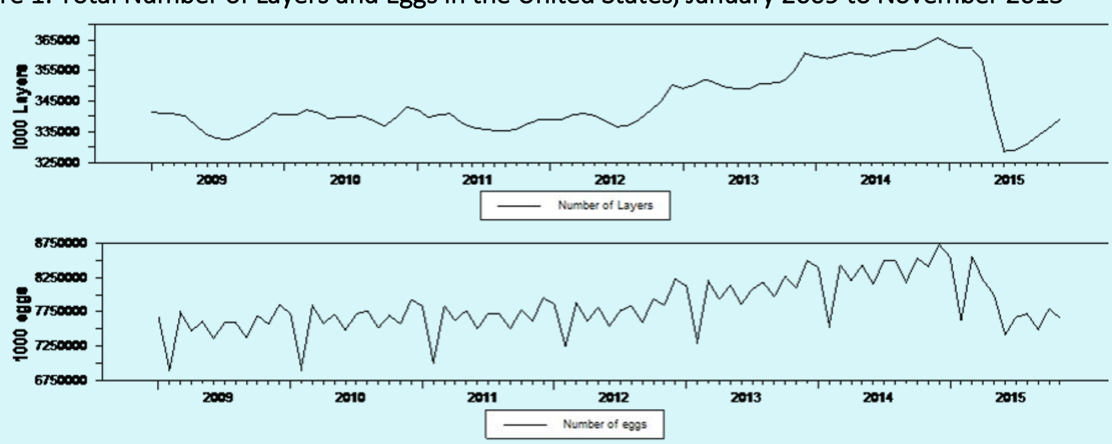
JEL Classifications: Q1, Q13, C52, C53
Keywords: Egg Price, Highly Pathogenic Avian Influenza, Information Structural Break, Price Discovery, Price Forecasting

The 2014-2015 HPAI Outbreak

The 2015 highly pathogenic avian influenza (HPAI) outbreak was the largest animal health emergency in U.S. history. Two strains of HPAI (H5N2 and H5N8) were found in wild birds and domestic poultry, affecting 21 states. The greatest production impact occurred as a result of HPAI-H5N2, which infected poultry in Iowa and Minnesota. Iowa in particular has dense pockets of egg-laying farms and produced more table eggs than any other state in 2014 (U.S. Poultry, 2015).

The large decrease in laying-hen inventory in April 2015 reflects the period of heaviest depopulation of layer farms in the Midwest (Figure 1). Movement restrictions were established that prohibited birds, table eggs, or individual pasteurized eggs from infected premises from moving off-farm or entering commerce. Eggs from some infected premises had managed movements that permitted controlled liquid egg pasteurization, under the authority of State Animal Health Officials and USDA officials. Controlled or managed movement restrictions were also placed on non-infected poultry premises within a 10km control area around each infected flock—presumptive and confirmed—for egg and bird movements. The bird and egg movements from non-infected premises were approved by state and USDA response officials as part of the Secure Poultry Supply plans developed prior to the HPAI outbreak.

Figure 1: Total Number of Layers and Eggs in the United States, January 2009 to November 2015



Source: USDA-AMS, 2015

In addition to the decrease in eggs produced because of bird mortalities, bilateral trade sanctions limited the international demand for U.S. poultry products from the affected areas. These trade sanctions varied geographically, ranging from national trade sanctions put in place by a small number of countries to more common state and control zone trade sanctions. The United States exports a relatively small percentage of its annual egg production but lost over 10% of the national laying-hen inventory to the HPAI outbreak.

In aggregate, the 2015 HPAI outbreak restricted the supply of eggs on the market, leading to the highest egg prices observed in more than 30 years, after adjusting for inflation. The worst of the HPAI outbreak was restricted to the Midwest, but the impact of the price effects were seen across the country.

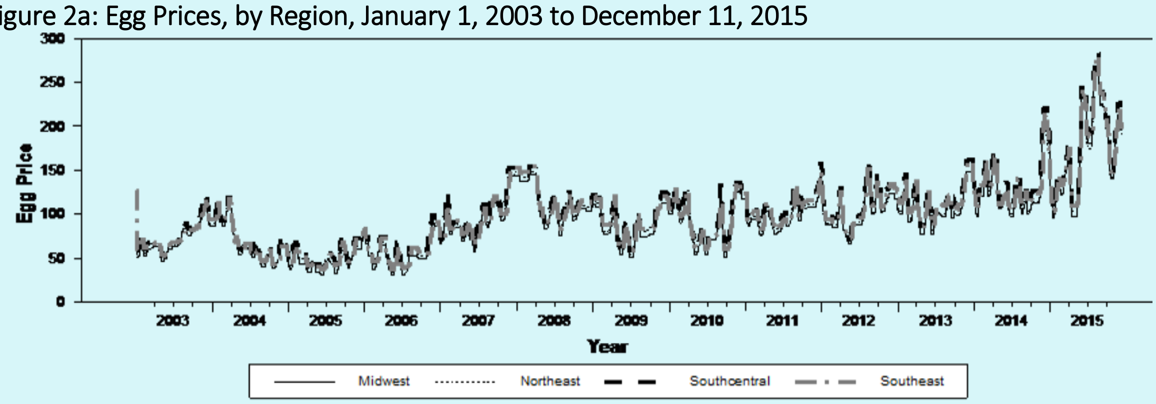
What Happened to the Cost of My Omelet?

Sometimes a disaster like HPAI happens that can drastically change the price of something you buy regularly. This is particularly true for our industries that have concentrated production and relatively few producers, such as the egg industry, and when consumers don't greatly reduce how much they buy when prices go up. How does an industry respond to the resulting high prices? The egg production companies that are not infected with the disease respond by increasing production in other regions, but they might not increase production right away. The situation may have to reach a certain level of impact before the producers from other regions are motivated to change their behavior. These are "break points" or "break dates", beyond which egg producing and consumer region relationships start to shift around in response to market signals. In response to expanding egg production, the price of your omelet goes back down. What about the price of your omelet next month, or next year? Understanding how egg supplies and prices will change in future months allows egg producing companies to plan how many chicks they will hatch that will lay eggs in the future, and it allows companies that trade internationally to negotiate terms and plan shipments. So new price information from each region in the face of a disaster like HPAI triggers a chain reaction of decisions, all of which eventually determine the cost of your omelet.

Structure of the Egg Industry, Price Formation, and Price Forecasting

Using USDA-designated regions, Figure 2a plots the egg price series in the Midwest, Northeast, Southcentral, and Southeast regions of the United States from January 1, 2003, to December 11, 2015.

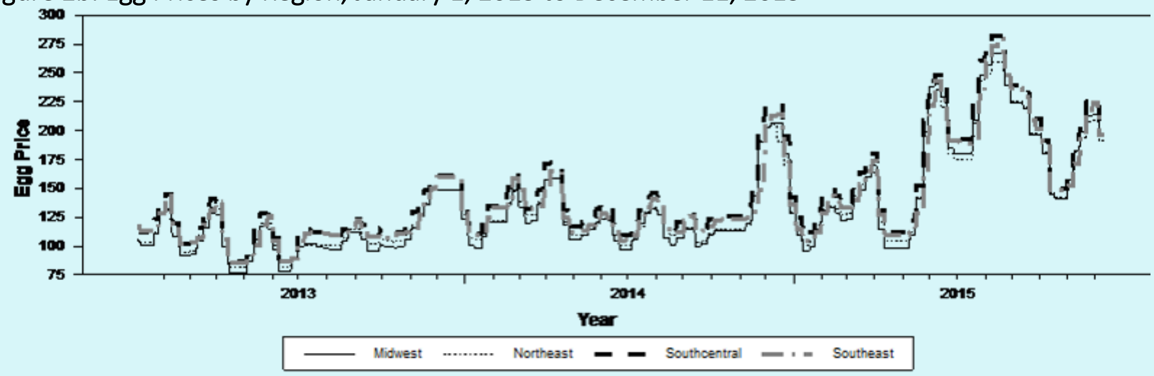
Figure 2a: Egg Prices, by Region, January 1, 2003 to December 11, 2015



Source: USDA-AMS, 2015

Figure 2b focuses on the period just before and just after the HPAI outbreak. In these two figures, all four regional price series align. The volatilities of the four egg prices series increased at the end of 2014.

Figure 2b: Egg Prices by Region, January 1, 2013 to December 11, 2015



Source: USDA-AMS, 2015

How much did HPAI in the Midwest Impact Egg Prices Nationally?

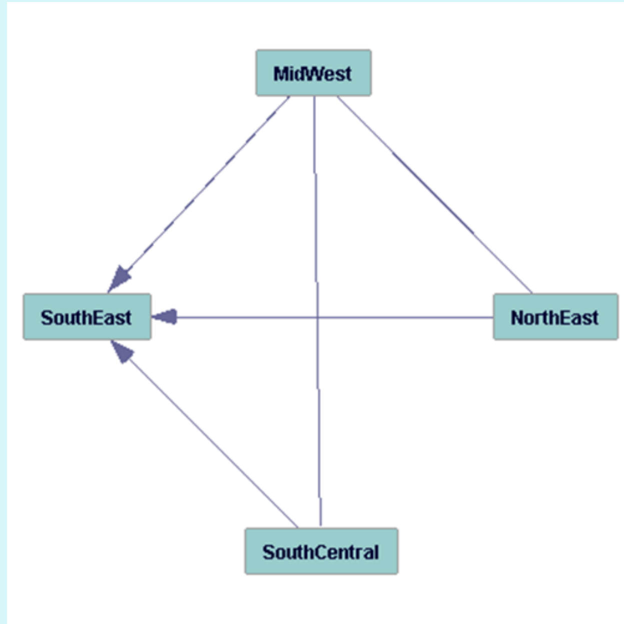
The decline in egg prices that began in late 2014 suggests that there were one or more unexpected shifts—so-called, structural breaks, by economists—in the egg price series since that time. According to USDA's Animal and Plant Health Inspection Service (APHIS) stakeholder announcements, the first case of the HPAI-H5N2 virus in a U.S. commercial layer flock was confirmed in Jefferson County, Wisconsin, on April 13, 2015; about 200,000 egg-laying hens were depopulated on that farm. In Iowa, the top egg-producing state in the United States, the first case of HPAI in a large flock of egg-laying hens—4.2 million birds—in Osceola County was confirmed as infected by USDA's National Veterinary Services Laboratory on April 20, 2015 (USDA-APHIS, 2015). This incident was closely followed by HPAI infections on nine more laying-hen farms in Iowa in late April. After the Osceola flock confirmation in Mexico, one of the United States' top egg shipment destinations, expanded its import ban to include live birds and eggs from Iowa. The price information flows among the four egg price series shown in Figures 2a and 2b may have changed in mid to late April. Rigorous statistical analysis found one break point in the egg price series in the Midwest, Northeast, and Southcentral regions and two break points in the egg price series in the Southeast region. Furthermore, prices from all four regions had a common break date of April 17, 2015. The Southeast region had one other break on August 15 2014. The break point on April 17, 2015, aligns with the timeline of movement restrictions on the first HPAI-H5N2 presumptive positive layer flock in the Midwest.

This finding might mean that when HPAI caused significant damage in the Midwest, the disease shock caused a shift in national egg prices. The Midwest is a major egg producing region. It is expected that a large HPAI event in that region could have consequences across the national egg industry, and the April 2015 break aligns with the timeline of disease spread. Perhaps the more interesting questions are how this break affected price discovery relationships across regions and what this meant for making egg price forecasts after the event.

Egg Price Discovery before the 2015 HPAI Event

Price discovery identifies the relative importance of new information arising from markets separated by space, time or form, as is the case for the U.S. table egg market. Based on advanced statistical techniques (Appendix), Figure 3 distills how price discovery might have occurred prior to the 2015 HPAI event. The Southeast price was influenced by price information that originated from the Midwest, Southcentral, and Northeast regions; however, price information generated in the Southeast region had no return influence on those three markets. Additional statistical analysis shows that information flowed from the Midwest region to the Southcentral region, but no relationship was found between the Midwest and the Northeast regions. The price in the Southcentral region performed as an information transmitter, and both the Midwest and the Northeast regions seemed to be information sources. This result makes sense, as states with the highest numbers of egg layers in 2014—1st Iowa, 2nd Ohio, 3rd Indiana, and 4th Pennsylvania—were in the Midwest region (U.S. Poultry, 2015). The Northeast region has a major human population and, therefore, is a prime area of egg consumption.

Figure 3: Estimated Price Shocks on Regional Egg Prices, August 21, 2014 to April 17, 2015



Note: Based on directed acyclic graph analysis.

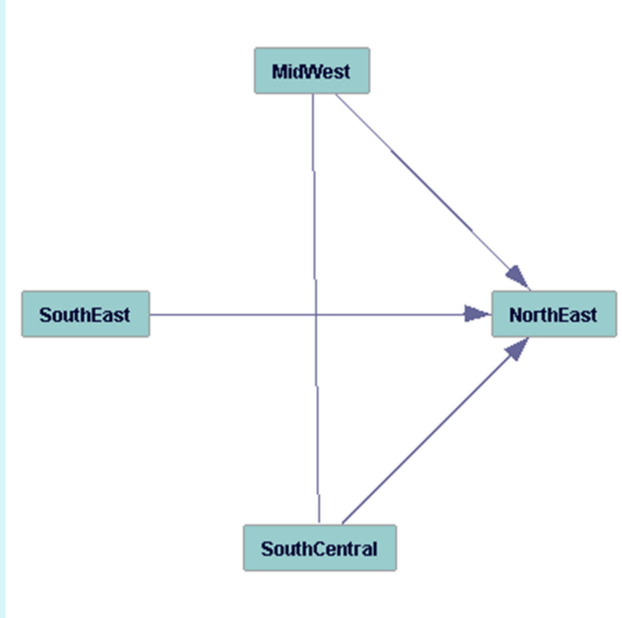
How did egg price discovery change after the 2015 HPAI event?

In comparison to the pre-HPAI relationships shown in Figure 3, Figure 4 shows the flow of market information within these four regions after HPAI infection was discovered in the Midwest in April 2015 until the December 2015. During this period, the shocks from the Midwest were driving egg prices in the Northeast, as was price information originating in the Southcentral and Southeast regions where egg producers might have absorbed the demand for eggs that the Midwest could not meet. There is only one undirected line in Figure 4—between the Midwest and the Northeast. This result makes sense given how HPAI-H5N2 affected the supply of eggs in the Midwest because of the disease and depopulation deaths of presumptive positive laying hens.

The Southcentral region was found to be an information transmitter, and both the Midwest and Southeast regions seem to be information sources. In the Southeastern region, Georgia and Florida are the largest egg producers, and in the Southcentral region, Texas is the largest egg producer (U.S. Poultry, 2015). The Northeast region has the highest human population and, therefore, accounts for the highest egg consumption, and would receive price effects from supply shocks resulting from HPAI.

In terms of relative importance of each region of the United States on egg price uncertainty 21 days ahead—about one month of business days— before the HPAI event information, production or consumption shocks arising in the Midwest, accounted for about 67% of its price uncertainty. New information—production or consumption shocks—from the Northeast accounted for about 17% of the Midwest price uncertainty—at 21 business days ahead—and less than 3% each for information arising from the Southeast and about 13% from the Southcentral regions. So clearly before the event, the Midwest was highly responsible for much of the new information and uncertainty in egg prices. After the event, things change. The Midwest continued to account for about 64% of new price information in the Midwest, but now the Northeast and Southcentral account for less than 3% of the price uncertainty in the Midwest and the Southeast jumps up to more than 33%. After the event the Southeast region has a much greater say in price information in the Midwest than it had before the HPAI event.

Figure 4: Estimated Price Shocks on Regional Egg Prices, April 18, 2015 to December 11, 2015



Note: Based on directed acyclic graph analysis.

A similar pattern exists for other regions. The Northeast as a last example, saw 4% contribution of new information from the Southeast region on price in the Northeast region before the event—at the 21-day horizon—but saw this number jump to over 32% after the event. Again the Southeast region became a major contributor to new price information in the Northeast region after the HPAI event, along with the Midwest, which accounted for about 13% of the new price information in the Northeast before the event and 64% after the event.

Finally, the Southeast region accounted for less than 15% of new price information from 1 to 21 days before the event; whereas after the event, the Southeast region accounted for from over 90% (at two days or less ahead) to over 32% of its price uncertainty at 21 days ahead. This suggests that clearly the Southeast region became a more self-reliant region after the event.

Lessons Learned

Despite the catastrophic HPAI outbreak event in the Midwest in the spring of 2015, markets did adjust, resulting in changes in prices and price discovery across major producing and consuming regions in the United States. Of course producers and wholesalers understood the firm level aspects of this adjustment in real time, as they were actually working to negotiate price, to secure and unload product. What is possibly not known is how the aggregate data fit into an overall pattern of discovery. What regions turn out to be centers of price discovery? What regions offer no new information for other regions, but use new information arising in other regions? The bottom line here is markets work; old patterns of discovery disappear, as new patterns arise. The market is able to adapt. Even with contracts, people need eggs and inter-regional trade will have price implications across time and space.

The large HPAI outbreak in the Midwest did enough damage to cause a shift in national egg prices, which affected egg producers and egg consumers across the country, as shown by the common break point found on April 17, 2015 for the four regional prices. The HPAI-H5N2 virus was detected in commercial egg laying farms around this break date.

Two general conclusions can be made. First, economic events in one region of the country in egg production or egg demand can affect egg prices and ultimately egg production and egg consumption in other regions, particularly if the event occurs in a region with a high concentration of national production. Prior to HPAI, the Midwest region, a major egg producer, and the Northeast region, a major egg consumer, are the sources of price information in the United States. However, after the outbreak the Southeast region emerged as another source of price information. The Southeast region contains a few states with dense areas of layer farms. Interestingly, the Midwest region's influence on the Southeast region's price uncertainty was reduced after the event. That is to say, after the event, the Southeast region appeared to be more self-reliant and have greater price influence in other regions.

The HPAI event of April 2015 changed the price communication structure of the four U.S. regions and had implications for the Northeast consumption region and the Southeast and Midwest production regions. The Midwest region was not particularly influential on Northeast egg prices before the event, but after the event it became the dominant source of price uncertainty. It will be interesting to see, as the Midwest fully recovers to previous egg layer inventory levels, if these price relationships between the Midwest, Southeast, and Northeast regions remain the same or return to pre-HPAI status.

The second general conclusion is that developing forecasts to plan and budget for the future using short-term prices, i.e., less than a month, for one region should account for what is happening in the other regions. Local prices may not suffice. Regional communication around the time of the HPAI event showed up clearly in price forecasts. The interdependence among the four regional prices should not be ignored in forecasting prices.

Appendix on Statistical Techniques for Price Discovery

1. Measuring Structural Breaks

Hall, Osborn and Sakkas (2013 and 2015) proposed two new information criteria, called the modified Bayesian and Hannan-Quninn criteria. See:

Hall A. R., D. R. Osborn, and N. Sakkas. 2013. "Inference on Structural Breaks Using Information Criteria." *Manchester School* 81(3): 54–81.

Hall A. R., D. R. Osborn, and N. Sakkas. 2015. "The Asymptotic Behaviour of the Residual Sum of Squares in Models with Multiple Break Points." Working paper, University of Manchester.

2. Causal Relationships Among Price Series

A directed acyclic graph (DAG) on contemporaneous price shocks presents the contemporaneous causal relationship among these four price series. A DAG is a directed graph with no directed cycles, which is formed by a collection of variables and directed lines. The assumptions behind the validity are given in Spirtes, Glymour and Scheines (2000) and further analysis is presented in Lai and Bessler (2015). See:

Lai, P., and D.A. Bessler. 2015. "Price Discovery Between Carbonated Soft Drink Manufactures and Retailers: A Disaggregate Analysis with PC and LiNGAM Algorithms." *Journal of Applied Economics* 18(1):173-98.

Spirtes, Peter, Clark Glymour, and Richard Scheines (2001), *Causation, Prediction, and Search.* Cambridge, MA: The MIT Press, 2nd edition.

3. Probability Forecasting Systems

Dawid (1984 and 1985) provides the formal mathematics on probability forecasting systems. See:

Dawid, A.P. 1984. "Statistical theory: A Prequential Approach." *Journal of Royal Statistical Society* 147: 278-297.

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Regionalization of the 2014 and 2015 Highly Pathogenic Avian Influenza Outbreaks

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JEL Classifications: Q11, Q13, Q17, Q18
Keywords: Regionalization, Trade, Highly Pathogenic Avian Influenza

Livestock disease trade restrictions were typically implemented at a national level prior to recent trade negotiations. Internationally negotiated sanitary agreements formalized the concept of regionalization where nations could be subdivided into disease-free and affected zones. The underlying assumption was that regionalization in conjunction with other control measures is a preferred strategy in the event of a disease outbreak because export losses often drive the loss in economic welfare. Regionalization allows exports from disease-free regions to continue. Analyses of potential highly pathogenic avian influenza (HPAI) outbreaks by Paarlberg et al., (2007) and the Livestock Marketing Information Center (LMIC) report by Johnson *et al.,* (2014) do find such benefits.

Most analyses of regionalization rely on hypothetical outbreaks. In 2014 and 2015 the United States experienced outbreaks of two strains of HPAI. A total of 49.6 million birds, mostly turkeys and layers, were depopulated and both national and regional trade restrictions were imposed. The importer response to these outbreaks expanded the application of regionalization beyond previous experiences both in a geographic sense as well as using product differentiation. The economic analyses surrounding the 2014 and 2015 HPAI events provide lessons about future regionalization plans that enhance the understanding of the market and economic welfare effects of a disease outbreak and have implications for outbreak response.

Regionalization Observed—and Modeled—during the 2014-2015 HPAI Event

In late 2014 and early 2015, H5N2 and H5N8 strains of highly pathogenic avian influenza appeared in commercial and backyard poultry flocks in British Columbia and the U.S. west coast. Initial epidemiological modeling for an HPAI event in the Pacific Northwest suggested a moderate commercial outbreak with geographic spread within Washington, Oregon, and California. An economic model was used to estimate the impacts of control strategies. For example, simulated control strategies assumed the removal of two million birds from existing national supplies which translated into small percentage production shocks of -0.2% or less for national broiler meat, turkey meat, and egg supplies. Consumers in the United States were assumed to react to price changes but not change their preference structure consistent with the results presented in Beach *et al*., 2008.

About the Use of Economic Models to Measure Regional Impacts

The 2014 and 2015 HPAI economic analyses utilized an updated version of a U.S. agricultural sector model presented in Paarlberg *et al.,* (2008) modified to split poultry into chicken meat and turkey meat. This revision is presented in the LMIC bulletin by Johnson *et al*., (2014). This quarterly model developed from the USDA annual baseline determines percentage changes from the baseline that result from a disease event. The HPAI analyses relied on a baseline updated in the spring of 2014 which was prior to the HPAI outbreaks. The major difference with more recent baseline values is that the baseline used did not include the rapid increase in U.S. egg and egg product exports that were occurring immediately prior to the HPAI outbreaks.

Scenarios analyzing the impacts of HPAI events on prices, quantities, and measures of economic welfare consist of assumptions about output reductions due to disease for poultry and egg products, control measures like movement restrictions, and reductions in poultry and egg product exports. Output reductions are product and region specific. Outbreaks in different flyways affect the extent of egg, turkey, or broiler depopulations very differently depending on regional production patterns. The output reductions assumed early in the HPAI event are from epidemiological modeling. Once the HPAI outbreak ended, actual depopulation could be analyzed. Control measures vary by region since they are linked to the density of production. Export reductions depend on the pattern of regional depopulation and trade partner response. Some trade partners ban imports of all poultry and egg products from the United States, but most trade partners limit imports from infected states, counties, or control zones. Trade restrictions can also be specific to the degree of processing. Export reductions analyzed are based on notifications by importing nations and the share of U.S. exports shipped to the trade partner. Reductions in product outputs and reductions in exports inserted into the model calculate estimated changes in prices and quantities. Those changes are used to determine changes in economic welfare.

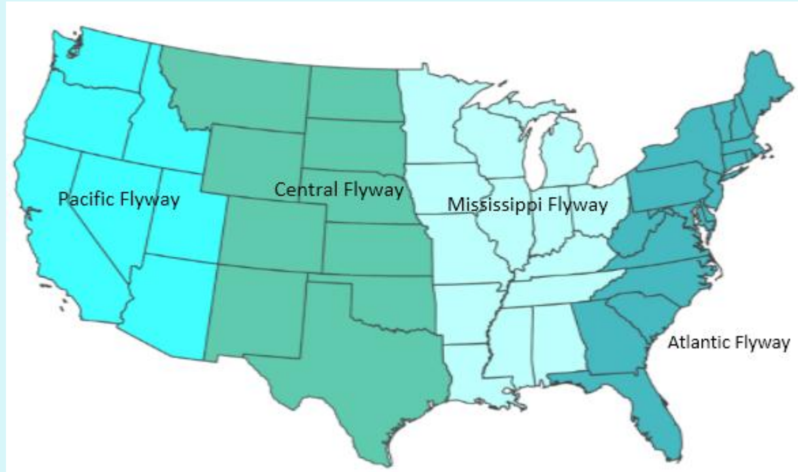
Early Regionalization Scenario—December 2014

Because the responses of trading partners were not completely known, the initial assumption was that trading partners would react in a manner similar to their response to the Canadian outbreak immediately preceding the U.S. outbreak. That response signaled a greater willingness to regionalize outbreak related trade restrictions. The U.S. scenario assumed major trading partners—Canada and Mexico—would accept a state-level regionalization strategy as would eight other countries imposing restrictions. Korea was assumed to ban all U.S. exports for three months based on analyses by Johnson *et al*., (2012; 2104). In order to reflect state-level regionalization restrictions, the share a state contributes to national trade was assumed to be the same as its production's share of total U.S. production. This translated into three-month reductions of 1.8% of total U.S. broiler meat exports, 0.3% of U.S. egg exports, and less than 0.1% reduction for U.S. turkey meat exports.

The willingness of importing countries to regionalize affected state's trade previously rested on the assumption that the affected area would be quarantined from the rest of the United States. In 2013, Washington, Oregon, and California combined represented about 8% of U.S. egg production, but contained over 15% of the U.S. human population. For turkey meat, California represented 5% of 2013 U.S. turkey production with over 12% of the U.S. human population. Although state-specific trade data are not available, these numbers suggest each of the states is a net importer of these products. Because the three states involved in this simulation are deficit areas of poultry and poultry products within the United States, they were assumed to continue receiving product from the remainder of the United States when estimating the economic impacts rather than being isolated.

Estimated returns to the U.S. livestock and feed sector over the 2015–2017 years simulated fell by $376.8 million under this Pacific Flyway outbreak scenario. When there is no regionalization, import bans by trading partners against the states in the Pacific, Mississippi, and Atlantic Flyways (Figure 1) result in an estimated loss to the U.S. feed and livestock sector of nearly $2.2 billion. The estimated small decline in returns shows the benefits regionalization can have in mitigating impacts of disease outbreaks.

Figure 1: U.S. Flyways



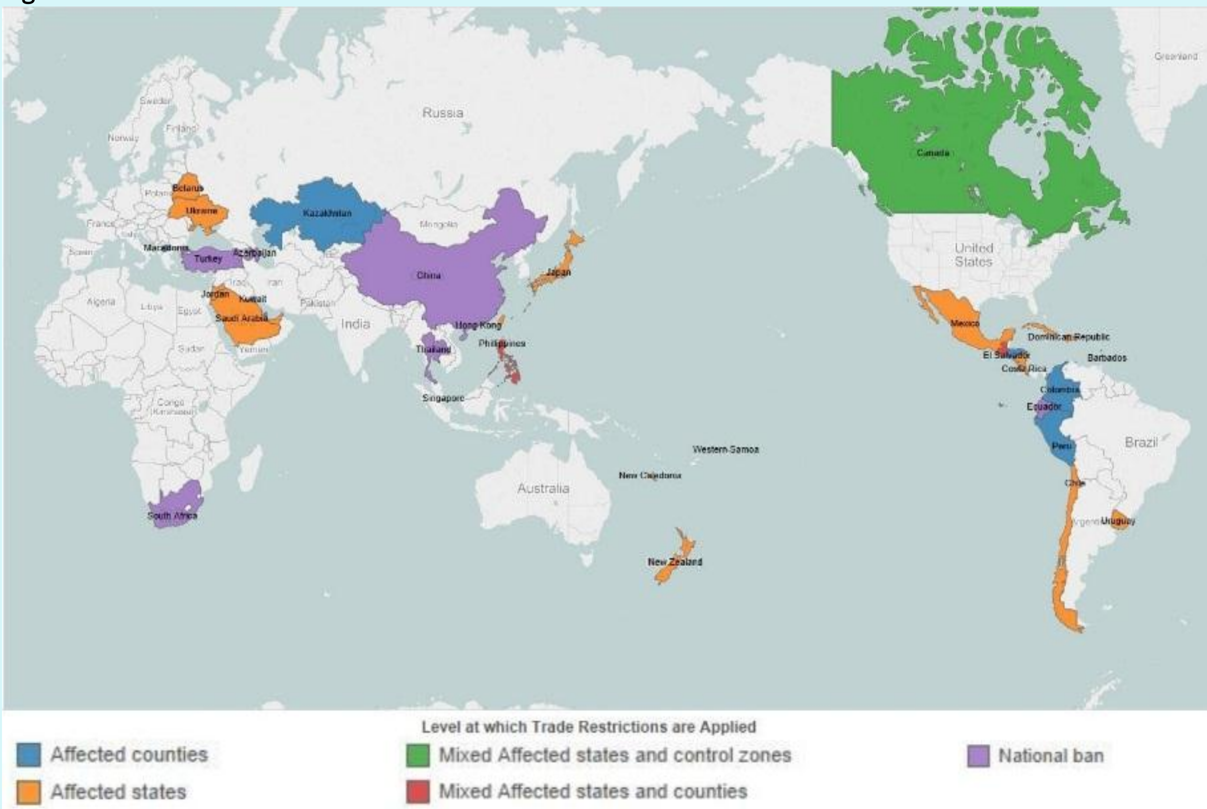
Revisiting the Regionalization Scenario as HPAI Spread East

A second strain of HPAI (H5N2) was discovered in the Mississippi Flyway in early 2015, but did not spread extensively until March. Unlike the earlier cases in 2014, the 2015 HPAI cases were concentrated in states that are major turkey and egg production regions—Minnesota and Iowa. Iowa alone represented over 16% of 2013 egg production with about 1% of the human population. Minnesota accounted for over 15% of 2013 U.S. turkey meat production but had under 2% of the U.S. population. Such levels of production represent the potential for marked disruptions in supplies to other states. Volumes of eggs and turkey meat that might be confined to those states were in excess of what local residents could consume. For this scenario, the production reductions due to HPAI combined with permitted movements of lower risk product from the affected states exceeded the historic levels of exports from the affected states. In contrast, if surplus product had been “trapped” in the affected area, the analysis would have proceeded with the affected area isolated from market developments in the remainder of the country.

The economic scenario was expanded to recognize that the large geographic spread of the HPAI incidents in the Mississippi Flyway would also result in expanded trade sanctions by trade partners. The estimated economic impacts for HPAI scenarios affecting both the Pacific and the Mississippi Flyways were based on domestic production impacts due to the disease of approximately 7% reductions in the quarterly U.S. supply of eggs and turkeys during the second quarter of 2015. The export shocks applied in the model were a 49% embargo on U.S. exports of turkey, an 18 to 21% embargo on broiler meat exports, and a 16 to 20% embargo on all egg and egg product exports each lasting 6 months. These export shocks were reduced to half of those percentages for an additional three months. These simulated embargoes recognized the large number of countries that limited trade restrictions to the affected states’ production (Figure 2).

Losses to the livestock and feed grains’ sectors in the United States for the 2015–2017 period simulated by the model under this outbreak scenario were estimated to be $1.2 billion to $1.4 billion. These changes in economic welfare for producers reflect the interaction between production losses and export declines which have opposing effects on price and the value of birds depopulated.

Figure 2: HPAI Trade Restriction Announcements



Note: Level at which Embargoes were applied to imports of U.S. poultry and poultry products, April 28, 2015

A Retrospective Regionalization Scenario

With the last cases of HPAI concluding in summer 2015, a third estimation of the economic impacts due to HPAI was undertaken using the production shocks derived from the total numbers of turkeys, layers, and pullets actually depopulated in 2015. As the larger outbreak progressed in the Midwest, importing countries adopted more focused regionalization schemes, some even going down to control areas. These were combined with product differentiation where processed products—originating in the infected areas and deemed to be of lower risk for HPAI spread—still flowed outside of the affected areas under permitted movements. The trade shocks used in the model resulted from the pattern of observed trade embargoes related to the HPAI outbreak in quarters one and two of 2015. In quarter three, export restrictions were half those imposed for quarter two and in quarter four of 2015, restrictions were half the quarter three export reductions to recognize the actual four month length of the outbreak and the further tightening pattern of regionalization applied.

The model estimates for eggs show that trade restrictions offset the production shock in the first quarter of 2015 causing wholesale prices to decline by less than 1%. By the second quarter, however, the larger production shocks were sufficient to outweigh the trade restrictions with egg prices increasing sharply. These higher prices from the output loss gave improved returns to the egg sector as higher returns to producers with eggs dominated lost returns to producers with infected birds (Table 1). In the

Table 1: Economic Impact Estimates for 2014/2015 U.S. HPAI Outbreak

Changes in Returns to:	Absolute Change from Base (Million Dollars)	Change from Base (Percent)
Red Meat Processing	1.1	
Eggs and Layers	52.6	26.7
Broilers	-275.7	-1.5
Turkeys	-214.2	-6.8
Dairy Cattle and Milk	-2.1	
Beef Cattle	74.8	0.1
Swine	21.5	
Lambs and Sheep	0.4	
	-372.7	
Crops	2.3	
Soybean Processing	-712.1	
Land Values	-150.8	
Value Added	-180.1	
Total Welfare Producers	-1043.1	

third quarter of 2015, exports continued to be weak and egg production losses smaller, so sector returns declined.

For turkeys, first quarter 2015 production losses were lower than exports lost, so the turkey price fell slightly. In the second quarter, this relationship switched, leading to a small increase in turkey prices. In subsequent quarters, lost exports dominated the production loss, so turkey prices fell. Lower prices and lost output meant grower returns were lower. Output losses for broilers were less than 1%, but with exports down by up to 21% and exports representing 23% of production, prices fell slightly. As a result, returns to producers fell below the quarterly, no outbreak, baseline levels.

Reduced feed demand in the poultry sectors meant lower returns to crop producers of less than 1%. Returns to land owners adjusted slowly but also fell slightly. Lower feed costs benefitted cattle and swine producers with their returns up above baseline returns. For the feed and livestock sector, estimated losses in returns attributed to the outbreak, shown in Table 1 at $1.0 billion, were $200 million to $400 million less than the economic impact cited above. The series of analyses performed at various points of time during an actual HPAI event lead to several lessons and observations regarding regionalization of an HPAI outbreak.

Lesson 1: Net Importing Regions are Easier to Regionalize, Net Exporting Regions are More Difficult

Regionalization is relatively easy to implement for net importing regions as shown in the Pacific Flyway scenario because any production loss is balanced by increased imports by the state or region. This is similar to the observation that trade policy instruments to defend price support operations are easier to implement for importing nations than for exporting nations. This is the situation for the cases in Washington, Oregon, and California in late 2014.

In contrast, net exporting states fall into two categories: net exporters of small amounts of product and net exporters of larger amounts of product. If state production and consumption are close to equal and the net exporting states regionalized do not represent a large share of imports by the rest of the nation, then regionalization is similar to imposing a no-trade solution assuming low risk products are not allowed to leave the affected region under permitting. Therefore, regionalization would not be as disruptive to implement in this first category.

However, in a net exporting region with larger quantities of exports, regionalization can alter the pattern of economic welfare changes because it delinks prices. Prices for product trapped inside a region will fall to clear markets. Thus, consumers inside a region experience a gain in consumer surplus. Producers experience a loss in economic welfare beyond that associated with depopulation due to reduced income on remaining production. If exports of consumer-ready products are prohibited and consumers cannot fully consume the embargoed product, production facilities will respond with reduced shifts and production, and products which cannot be marketed may be destroyed. Given the spatial location of plants, market power may increase. Outside the region, poultry and egg product supplies are reduced, so prices increase. Price increases lead to lost consumer surplus but enhanced returns to producers in these unaffected regions. Even though lower risk products could be shipped from affected areas during the 2015 outbreak, supply disruptions for eggs led to large price increases and, in some instances, restrictions on the number of eggs purchased by consumers. If product had been trapped inside the affected states, even greater supply disruptions would have occurred.

Depending on the size of the embargoed region for net exporting regions with larger quantities of exports, contestability of the market outside of the embargoed region may be reduced which further increases price. If net exports by these regions are large relative to production and consumption is relatively small, then regionalization should be drawn more tightly around outbreak control zone areas rather than at more distant state boundaries. Or they should be augmented by permitted movement of low-risk product from the infected states to mitigate outbreak losses to producers. In situations like that seen in 2015, where states accounting for large shares of national production, such as Minnesota and Iowa, experience a disease outbreak, tighter control zones cause less supply disruption. Yet, the benefits of tighter control zones must be balanced against the risks of further disease spread beyond the zones.

Lesson 2: Regionalization at State or Control Zone Levels Increase the Need for State Level Consumption and Interstate Trade Data

Evaluating state-based regionalization requires knowing state-level trade flows. Limitations on the availability of state-level trade data hindered the analyses. Monthly production data is limited to key producing states. If outbreaks occur in other states, the only production data that may be available are those in the Census of Agriculture which is collected every five years. Data on state consumption of poultry products is also limited. In these analyses of HPAI events the assumption used is that per capita consumption is uniform across the United States, so population estimates can be used to infer state consumption levels. Consequently, state-based regionalization analyses rely on these assumptions and ignore differences in state consumption.

Control zones established at the sub-state level are virtually impossible to evaluate with the data currently available. County level production numbers are occasionally available from NASS state reports but coverage varies greatly by state due to confidentiality issues. Poultry product consumption values necessary to determine county flows must be generated from national per capita consumption and county population estimates.

Lesson 3: Reductions in the Economic Impact of Livestock Disease due to Regionalization affects the Mix of Disease Control Responses

The potential for regionalization linked to geography and product differentiation to reduce livestock disease outbreaks' economic impact raises additional questions about the mix of disease control strategies applied to outbreaks of highly infectious diseases. If the overall economic impacts of disease are reduced by regionalization, the government expense and mix of response strategies could be reconsidered to determine the new optimal combinations of disease control strategies to be applied. For example, additional costs are incurred for surveillance to support regionalization and for administration of permitted movements of negligible risk product even though the outbreak size may not decrease. Regionalization does not uniformly lower economic impacts, so while many economic impacts are lowered, others are increased. Critical to implementation of regionalization is being able to understand and evaluate shifts in economic welfare as well as the total impact. Such shifts must be considered given the resources available to implement a regionalization strategy.

Additional Lessons from the 2014 and 2015 Events

Earlier analyses of regionalization assumed that regionalization would embargo supplies inside the region while allowing exports to international trading partners to continue. Regionalization as implemented in the 2014 and 2015 HPAI event in the United States suggests a more nuanced approach with lessons for future events and economic impact assessments for other diseases. One lesson is the role the net trade position of the affected region plays. Net importing regions are easier to regionalize. For excess supply regions, allowing negligible risk products to flow outside a regionalized area mitigates the economic damage which might occur in an area, provided international trading partners accept these permitted movements rather than insist on full isolation of the affected region.

A second lesson is the importance of understanding how regionalization decisions alter price movements within and outside the region and consequently the impacts on economic welfare. Regionalization increases the need for state-level data in order to more accurately determine its benefits in reducing the economic impact of livestock disease outbreaks. These benefits can then be weighed against disease control responses and the associated costs which may alter the mix of disease control strategies.

Appendix

Meat demand elasticities, a measure of how quantities demanded change with price, were updated from earlier published versions of the model. Elasticities for beef and pork are based on Tonsor *et al.*, (2010). The broiler meat elasticity is an average of the values reported by Muth *et al.*, (2006). The demand elasticity for turkey meat is constructed from elasticities reported for poultry and that used for broilers. The lamb meat elasticity is from Paarlberg and Lee (1998). The demand elasticity for eggs is the original value from Huang (1996). Elasticity of substitution values between the livestock intermediate inputs and capital for the poultry products and milk were reduced to lower the implied supply elasticities in order to give price changes consistent with those observed since the original model construction.

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Government Spending to Control Highly Pathogenic Avian Influenza

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JEL Classifications: Q11, H59
Keywords: Cost-benefit Analysis, Highly Pathogenic Avian Influenza, Government Spending, Epidemiological Model

Since first being detected in the United States in the Pacific Northwest in December 2014, highly pathogenic avian influenza (HPAI) spread across 21 states, affecting 211 commercial and 21 backyard poultry flocks. The last case of the HPAI event of 2015—the spring of 2015 outbreak—was identified in June 2015. To stem the widespread outbreak, the lead federal agency, the U.S. Department of Agriculture's (USDA) Animal and Plant Health Inspection Service (APHIS), worked with farmers, state and local agencies, and private contractors to depopulate 7.5 million turkeys and 42.1 million egg-layer and pullet chickens. Overall, federal expenditures on the outbreak totaled about $879 million, including roughly $610 million for depopulation, cleaning, and disinfection, together with indemnification at 100% of the fair market value of the birds totaling $200 million. The remainder was overtime, travel, supplies and fall planning costs.

Did the costs of these government efforts result in net social welfare benefits to the U.S. economy? In general, to answer that question, policy analysis will examine measures of consumer surplus and producer surplus. For example, the Office of Management and Budget's Circular A-4 describes the cost of a policy as being "the net reduction in the total surplus (consumer plus producer) is a real cost to society." Consumer surplus is the difference between the amounts consumers would be willing to pay for a good versus the prices they actually pay. Producer surplus measures the net gain that producers receive for producing and selling a good.

However, in the case of HPAI, while changes in consumer surplus can be estimated, we consider only changes in producer surplus in evaluating the domestic benefits of addressing HPAI. Why is that? Although consumers are the ultimate beneficiaries of efforts to reduce losses from animal diseases, including only domestic consumer benefits in a benefit-cost assessment results in counterintuitive and potentially counterproductive results for purposes of HPAI policy evaluation. In particular, because the United States is a net exporter of poultry products, especially broilers, bans by our trading partners on importation of U.S. poultry products benefit U.S. consumers due to larger domestic supplies and lower U.S. prices. But U.S. producers are made worse off by trade losses, and the U.S. economy as a whole suffers even though U.S. consumers receive a windfall benefit from lower prices and higher consumption. Thus, we compare producer benefits to the costs for depopulation, cleaning, disinfection, and indemnification for the spring 2015 HPAI outbreak.

How do we measure the benefits of government efforts to control the spread of HPAI? Absent such a response, simulation modeling suggests that HPAI outbreaks would have been even more widespread and costly. This is because a key component to disease response is early identification of infected birds and immediate depopulation of those flocks to limit potential spread to nearby farms. Without government resources to help producers quickly identify infected animals, to provide indemnification of the flock, and to assist with cleaning and disposal costs, it is likely that producers would not self-identify their farms as being infected as urgently or might attempt to continue moving birds. In those cases, modeling suggests a wider spread of the disease, additional lost production, and likely additional loss of export markets for poultry products in general.

To estimate the impacts of HPAI on agricultural producers and markets, an epidemiological model of disease spread was combined with a quarterly economic model of the U.S. livestock and feed economy. In tandem, the models simulated the economic impacts of the spring 2015 outbreak and alternative response scenarios for the period from December 2014, when HPAI was first confirmed, through December 2017, when markets are expected to return to their pre-outbreak forecasts.

Incorporating Epidemiological Model Outputs into Economic Analyses

The conceptual model provided by InterSpread Plus v.5 (Stevenson et al., 2013) was used as the framework for developing a U.S. national scale model of HPAI. This HPAI disease spread model simulates the daily path outbreaks might take through the U.S. poultry population under alternative control measures. Different detection and surveillance options as well as depopulation, disposal, cleaning, and disinfection methods are combined into individual "scenarios", and each scenario is run through the model repeatedly to capture a range of uncertainty in how the disease and the control measures might behave. The outputs of running these scenarios include the number of birds that die, their location, and the length of the outbreak for each scenario. This output is then fed into a quarterly economic model of the U.S. livestock and feed sectors (Paarlberg et al., 2008) to reflect the disease impact, or shock, to poultry and poultry products production and international trade. The economic model is then run to estimate how market prices for all livestock and feed will change as a result of the outbreak and how these price changes affect the supply and use of livestock, their products, and their feeds.

Estimated net losses to U.S. livestock and feed producers and processors due to the spring 2015 HPAI outbreak were $712.1 million (Table 1). Estimated declines in land values and value-added were $330.9 million. Adding those together, the estimated impact on the U.S. livestock and feed sector was $1.04 billion in losses. Assuming no government eradication and control efforts, epidemiological models coupled with economic modeling suggest producer losses from the spring 2015 HPAI outbreak could have ranged from $1.96 billion to $3.18 billion. Based on that modeling, government led efforts limited producer losses that otherwise would have occurred by between $920 million to $2.14 billion, with a midpoint of $1.53 billion. Thus, considering only the reduction in economic losses to domestic producers, the estimated net benefit of approximately $879 million in federal spending on disease control and eradication was between −$120 million to $1.10 billion, with a midpoint of $490 million. In other words, over most of the range of simulated impacts, the estimated benefits of avoided losses from government led efforts exceeded actual federal outlays on those efforts leaving room for additional response expenditures by state and local governments.

Table 1: Spring 2015 Outbreak Modeling Scenarios

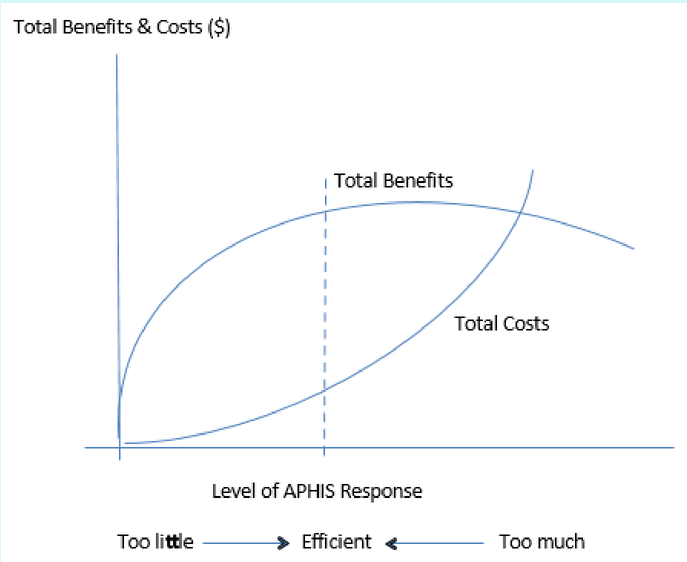
Sector	Simulation of No Federal Response		Actual Outbreak
	Lower Bound	Upper Bound	
		Million	
Eggs and Layers	16	-66	53
Broilers	-570	-919	-276
Turkeys	-267	-337	-214
Dairy Cattle and Milk	-6	-10	-2
Beef Cattle	136	217	75
Swine	41	67	22
Lambs and Sheep	1	1	0
Crops	-648	-1,029	-373
Soybean Processing	0	0	2
Red Meat Processing	2	4	1
Total Welfare Producers	**-1,294**	**-2,073**	**-712**
Land Values	-272	-435	-151
Value Added	-394	-675	-180
Total Producer Impact	**-1,960**	**-3,183**	**-1,043**

Source: USDA-APHIS

Were Governmental Efforts Appropriate?

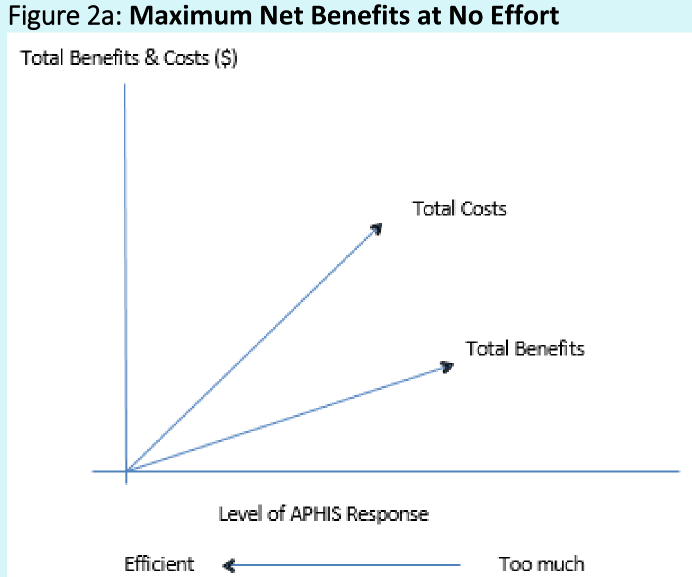
While simulations of the economic impacts of the spring 2015 outbreak indicate positive net benefits to producers relative to taxpayer costs, the results do not tell us whether the federal, state, and local responses should have been more aggressive or less aggressive. From a planning perspective, marginal costs equal to marginal benefits will occur when the total cost curve measuring disease control and eradication efforts is furthest below the total benefits curve (Figure 1). We would say that at levels of effort below that point, net benefits of control—total benefits minus total costs—could be increased by increasing government efforts. Conversely, at levels of government effort past that point, net societal benefits could still be positive, but could be increased by lower levels of efforts. Under our framework, optimal effort would occur when an additional dollar spent on disease detection and eradication generates an additional dollar of prevented losses to agricultural producers. From the perspective of taxpayer cost versus producer benefit, this represents the optimal level of government efforts.

Figure 1: **Maximum Net Benefits when Distance Between Total Benefits and Total Costs is Greatest**



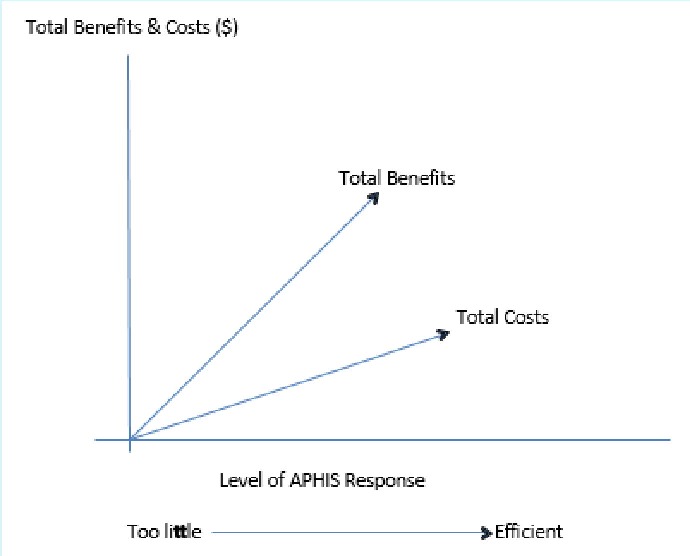
The coordinated effort is essentially the expected costs to government authorities to adopt a particular control and prevention strategy for a disease event or season, such as during the spring or fall and winter migration of wild ducks and geese from Canada to Mexico and back. That is to say, we model this response as a strategy that would be adopted throughout the course of a disease event or in preparation for a potential disease event. We do not model government effort as a sequential activity where at some point in time it would make sense for governmental agencies to move from a control strategy of expending government resources to a non-control strategy of withdrawing government efforts. There may be some control strategies that have activities that are contingent on the extent of a particular outbreak, however. For example, consider the case when the outbreak is particularly virulent, or the benefit curve was to shift upwards. In those cases, USDA-APHIS as a coordinating agency would likely argue for a new strategy that addressed that new total benefit function.

Figure 2a: **Maximum Net Benefits at No Effort**



Note that there are additional considerations that do not show up in this depiction. Equity concerns may exist in limiting indemnification and offsetting cleaning and disinfection services for some producers, but not all producers—see the discussion on tipping points below. That approach would particularly be true if the policy were changed without notice and could impair efficient notification by producers of future infections to the agency. The role of uncertainty regarding disease spread is not explicitly

Figure 2b: **Maximum Net Benefits at Maximum Effort**



addressed in this framework. However, solving the epidemiological model for multiple repetitions takes into account the role that chance plays in disease spread. Inserting the results of multiple repetitions of the epidemiological model into the economic model produces a range of estimates reflecting uncertainty about the spread of disease among farms and across time.

Two special cases exist from the earlier depiction (Figures 2a and 2b). Figure 2a, exhibits the case when there is no level of effort that generates positive net benefits. That is, you will always be spending more to limit losses than you actually do to reduce losses. As a result, no efforts should be undertaken.

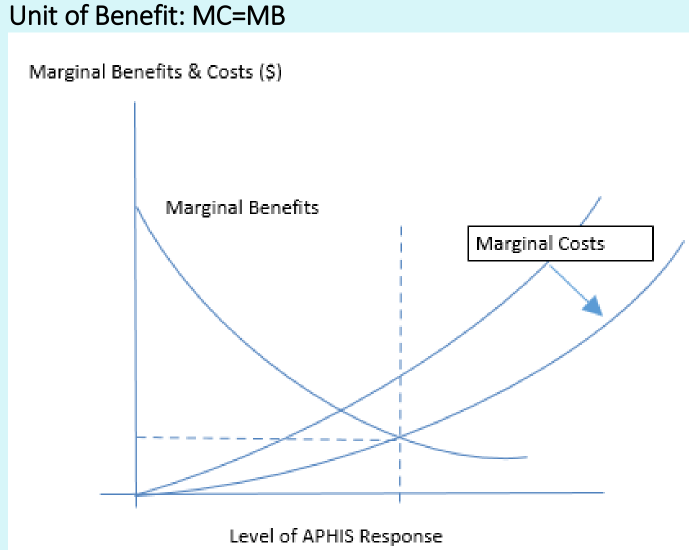
While we argue against including economic measures of domestic consumer welfare in terms of assessment of U.S. HPAI control efforts, we recognize that avian diseases do have the potential to spread to humans if allowed to spread without any control actions. Therefore, it is unlikely that the United States will ever allow a "no action" approach, since potential human health risks, however remote a possibility, require USDA intervention. Moreover, the Department of Health and Human Services (HHS) or the Department of Homeland Security (DHS) would likely become more involved if USDA were to stop control actions. In other words, zero federal spending and zero avoided loss from that spending is unlikely to be realized.

Similarly, federal, state, and local government agencies are responsible for protecting the health, quality, and marketability of the nation's animals. If government did not act in a manner consistent with that mission, public confidence in U.S. animal health and food safety would decline. Similarly, the international reputation that facilitates trade between the U.S. and our export markets would be tarnished and trade regionalization efforts, included permitted movement of low risk product, would be limited as a result. The costs of those would far outweigh any potential savings on scaled back efforts to control HPAI in the U.S. poultry sector.

Alternatively, in figure 2b, in the case when total benefits always exceed total costs, the response should always be at the maximum amount since you are always generating more benefits than you are spending. A case could be envisioned, such as bovine spongiform encephalopathy (BSE), when the costs of eradication are very high, but the uncertainty to human health drives the benefit function to a much higher level justifying maximum efforts.

Are there ways to more efficiently use the budgetary resources to lower the costs of the current aggressive responses? Additional more aggressive efforts are also more efficient if the marginal costs of the government efforts

Figure 3: Maximum Net Benefits also Occur when the Cost of Achieving Another Unit of Benefit is Equal to Another Unit of Benefit: MC=MB



become lower (Figure 3). This can be thought of as contracting for services ahead of time so that scarcity values—temporal price discrimination—do not drive up response costs. While it is likely that those more aggressive efforts would be more costly, it is also clear that some of those costs are mitigated by pre-planning and pre-determination of cleaning and disposal rates, relative to the spring 2015 case (USDA, 2016). While such preparatory effort entails additional federal costs, simulating alternative scenarios allows us to shed light on the effectiveness of those efforts in terms of disease spread and the resulting costs to producers and taxpayers.

Preparations for Future Outbreaks

Following the devastating losses from the spring 2015 outbreak, federal, state, and local governments engaged in extensive planning efforts with industry, and international partners in preparation for a potential reoccurrence of the disease (USDA, 2016). To aid in planning, USDA, APHIS examined the potential impacts of alternative control strategies assuming a widespread outbreak involving multiple states and production sectors (USDA, 2015). The analysis modeled the epidemiologic and economic effects of alternative strategies varying factors influencing disease spread and control: (a) depopulation capacity and time required for cleaning and disinfection (C&D); (b) detection and reporting of disease by poultry producers; and (c) biosecurity.

Simulations were conducted assuming widespread introduction of HPAI into the domestic poultry population at 20 geographically dispersed sites over a 50-day period. Under the spring 2015 simulations, net benefits to disease response efforts of approximately $500 million were generated when the spread of the disease affected approximately 50 million birds. However, in the fall 2015 preparedness and planning scenarios, APHIS simulated an outbreak roughly three times larger than the outbreak in the spring 2015.

Epidemiologic results showed that the greatest reductions in the number of birds requiring depopulation would be achieved by combining the best depopulation capacity seen during the spring 2015 outbreak with the best disposal capacity together with improved producer reporting and improved biosecurity. Those changes together would decrease the median number of farms infected to about 350 with 27 million birds affected compared to more than 2,500 farms and 183 million birds affected in the baseline scenario assuming average depopulation and disposal capacity observed during the spring 2015 outbreak. Moreover, doubling depopulation and disposal capacity would result in a further 20% reduction in the overall number of birds requiring depopulation.

The fall 2015 simulation exercise showed potential economic losses to the livestock and feed sectors of up to $6.2 billion. For a response similar to the spring 2015 outbreak, economic impacts for the median scenarios indicate producer losses of $3.3 billion, or a benefit of roughly $2.9 billion. Given these scenarios consider an outbreak that is three times larger than the spring 2015 outbreak, costs of response could approach $3 billion for such a scenario. Producer losses can be lowered by an additional 40%, to $2.1 billion, with improved depopulation and disposal capacity coupled with improved producer reporting and biosecurity, an overall benefit of $4.1 billion. Doubling depopulation and disposal capacity would result in further reductions in producer losses down to $1.3 billion, a benefit of $4.9 billion.

In sum, fall 2015 simulations suggest that benefits of up to $3 billion are available under efforts similar to spring 2015 and as much as $5 billion under more aggressive response efforts, depending on our trading partners' responses to our disease control efforts. A scenario in which vaccines are deployed could substantially increase the potential loss to agricultural producers if Asian markets fully embargo U.S. exports of poultry meat rather than taking the regionalization approach some did in the spring 2015 outbreak. Modeling of HPAI vaccination tentatively indicate that in densely populated poultry areas benefits of vaccination in terms of disease reduction, lower depopulation and virus elimination costs, and reduced consumer reaction to disease control efforts may outweigh the additional costs of implementing vaccination and wider regional, as opposed to state level, exporter bans. Because we can only conjecture the reactions of our trading partners as well as uncertainty around the costs of a vaccination program, it is difficult to build a decision tree that would account for all possible scenarios leading to a decision whether to trigger the deployment of vaccines. Thus, the more viable option is to establish a framework for decision making that accounts for the extent of actual disease spread, costs and success of control efforts, and likely reactions of trading partners.

However, based on paying for virus elimination through a flat rate system which compensates producers equal amounts per type of bird, the increased speed of response, and the expanded capacity for depopulation, the response costs per affected bird is expected to be lower in a future outbreak (USDA, 2016). Therefore, the increased government efforts described above for responding to a larger potential outbreak as well as industry biosecurity efforts should result in higher net welfare benefits.

Is there a Social Tipping Point?

Arguably, there may be a "tipping point" beyond which further federal efforts to stem the spread of HPAI should cease, at least in terms of measurement of economic costs and benefits to society. In other words, is there a point at which the actual costs of addressing an HPAI outbreak exceed the actual benefits to society, as would be the case beyond the point which the total benefits and total costs curves intersect in Figure 1? While measuring costs of government disease control efforts as they are incurred is a fairly straightforward exercise, the measurement of actual benefits during an outbreak with precision is difficult given uncertainties about the level of epidemic spread and the trade response. In the midst of an HPAI outbreak, it is unlikely the benefits could be known in order to judge the marginal benefits of additional actions. Given that disease spread is a process that depends, to some degree, on nothing explainable other than pure chance, uncertainty about further disease spread surrounds the outcome of any decision to continue federal intervention.

Furthermore, a number of consequences would result from changing government efforts to address HPAI in the middle of an outbreak. A key to understanding this issue is how the government response is viewed by our global trading partners, as discussed above. In the case of a response to HPAI that is interpreted as the disease becoming endemic to the United States, it is likely that we would lose more of our trading partners. Our trading partners likely would respond negatively to any reduction in HPAI control efforts. Nationwide trade embargoes likely would replace any regionalized trade restrictions put in place by our trading partners, leading to sharp drops in exports. Additionally, there are economic arguments that suggest allowing the global reputation of the United States to suffer in the wake of a "no action" scenario would far outweigh the current budgetary outlays envisioned for government actions on HPAI.

In addition, changing government efforts, such as by limiting indemnities or cleanup costs after a certain point, could present moral hazard issues in addition to raising equity and fairness issues among farmers hit by HPAI. For example, suppose farmers whose flocks were infected before a tipping point was reached received indemnity payments and coverage of disposal, cleaning, and disinfection costs, but farmers whose flocks were infected afterward received less assistance. That could *encourage* producers to report HPAI infection earlier. However, if federal funds are only forthcoming to producers hit by HPAI prior to the tipping point, then producers with a high probability of getting hit could face conflicting incentives in pursuing biosecurity efforts. Such a policy for HPAI response would have similar spillover effects for other animal diseases as well.

The more useful approach in the short term or in the midst of an outbreak is to evaluate the expected costs and benefits of alternative control strategies, as previously discussed. Strategies with positive expected net benefits are worth pursuing on economic grounds, while strategies with expected costs exceeding benefits should generally be avoided.

For More Information

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