Analysis of An African Swine Fever Outbreak in the United States: Implications on National and Iowa Agriculture

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Abstract

This paper estimates the economic impact of an outbreak of African Swine Fever on U.S. agriculture. The immediate impact of such an outbreak would be the closure of international markets to U.S. pork. This is true because even countries that have the disease will prohibit importation of pork from other countries with the disease. The paper evaluates two scenarios. The first scenario, called the "all-years" scenario, assumes that the disease spreads to feral swine and that the U.S. is unable to eliminate the disease over the ten-year projection period. The second scenario, the "2-years" scenario, assumes that the U.S. is successful in controlling the disease and that the country reenters export markets within two years. In both scenarios, the immediate impact is a reduction in U.S. live hog prices of 40% to 50%. This price reduction is needed to clear the market of surplus pork that would otherwise have been exported. In the "all-years" scenario, the U.S. pork industry downsizes after about five years of losses, and it remains at lower output levels for the remainder of the period. Impacts on other meats and feed grains markets are presented for both scenarios as well as on broader economic variables such jobs and value added. The anima disease outbreak results in large employment losses. In the "2-years" scenario, the industry faces a period of large financial losses but is back in the export markets before significant downsizing begins. Pork industry revenue losses add up to $15 billion in the "2-years" scenario and a little over $50 billion in the "all-years" scenario. Nationwide employment losses at the end of ten years in the "all-years" scenario equal 140,000 jobs. Iowa job losses in the "all-years" scenario are 22,000 by year ten. There are almost no job losses at the end of ten years for the "2-years" scenario.

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1. Introduction

African Swine Fever (ASF) is a highly contagious and deadly viral animal disease that causes up to 100% fatality in pigs and wild boars according to the Animal Production and Health Division of the Food and Agriculture Organization of the United Nations (FAO, 2021). It has also been labeled as one of the diseases that causes more if not the most economic damages to the swine value chain at a global level (Boklund et al. 2009, Sanchez-Vizcaino et al. 2012). A myriad of factors is behind this reputation including the high fatality rate for infected animals, its transboundary spread through wild animals and human activities (Costard et al. 2013), consumer´s concerns, costs of controlling the disease (Fernandez-Carrion et al. 2016), and trade restrictions imposed as a result of outbreaks (Costard et al. 2009, Halasa et al. 2016).

A recent and ongoing outbreak has affected several countries in Asia including China, Vietnam, Cambodia, South Korea, North Korea, India, Indonesia, Myanmar, Mongolia, and the Philippines, among others (Figure 1). The first case was discovered in China in August 2018, and, despite the culling of millions of pigs, the disease has spread very quickly across the continent. [3] While no cases have been detected in the United States, the disease is currently also present in 9 countries in Europe and 23 countries in Africa, and there is a risk that it will spread to other parts of the world.

This outbreak has resulted in the loss of millions of animals both due to the disease and from culling, burning, and burial. With solid data being scarce and underreporting, some experts estimate a reduction in the pig herd size of China in the order of 30%-50% or higher in 2019, with expected reductions in production of 25% , and an additional decline in production between 10-15% in 2020.[4] Because there is no cure or vaccine for the disease, the economic effects are large and far-reaching.[5] Imports from countries where ASF is present are prohibited and the loss of pigs results in devastating losses to producers (Halasa et al. 2016).

[3] Since the beginning in 2018, cases of ASF were detected in 32 Provinces/Autonomous Regions/Municipalities/Special Administrative Regions, including 10 outbreaks reported in the first 5 months of 2021.

[4] https://www.reuters.com/article/us-china-economy-output-pork/chinas-2019-pork-output-plunges-to-16-year-low-as-disease-culls-herd-idUSKBN1ZG08H.
https://www.bbc.com/news/business-50833054

[5] As of the time of this writing there have been announcements that an effective vaccine has been developed but that it will take time and significant resources in order for it to be widely available and used (https://www.bloomberg.com/news/articles/2020-01-31/promising-african-swine-fever-vaccine-no-panacea-scientists-say)

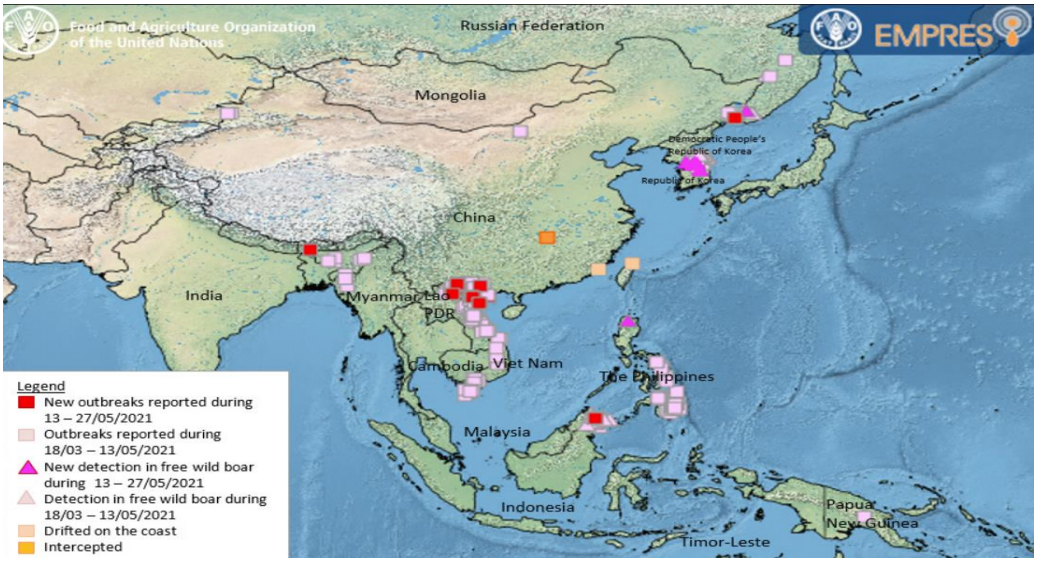

Figure 1. ASF Outbreak in Asia
Source: United Nations Food and Agriculture Organization (FAO), (accessed June 14th, 2021).
http://www.fao.org/ag/againfo/programmes/en/empres/ASF/situation_update.html

The U.S. is currently free of the disease (eradicated in 1978). The USDA's assessment of the likelihood of an outbreak in the U.S. through legal importation of live pigs and swine products and by-products indicates it is negligible to low with low uncertainty (moderate uncertainty for swine products and by-products). However, the likelihood of the disease entering the U.S. through illegal entry of swine products and by-products is high with low uncertainty (negligible to low with moderate uncertainty for illegal entry of live pigs) (USDA APHIS:VS). Jurado et al. (2019) estimate the risk of entry of ASF into the U.S. if pork is smuggled in air passenger luggage. They find that the risk is high especially from China, Hong Kong and Russia with five U.S. airports accounting for over 90% of the risk.

Given the potentially devastating impact of this disease, the USDA has been actively working to safeguard against the entry of ASF into the country including surveillance and testing, monitoring cargo and travelers from affected countries, collaborating with and urging producers to follow strict on-farm protocols and best practices, and restricting pork imports from affected countries. In addition to the adverse effects on producers (loss of export markets and profits) outlined above, an outbreak in the U.S. would result in potentially enormous costs related to slaughtering infected domestic and wild herds and restricting the movement of animals between states. The effects are likely going to be spread to other animal products. In addition, changes in the size and composition of the domestic animal industry can also be expected to affect the feed

markets and in particular the market for corn and soybean meal. The latter market can be expected to be particularly affected because of the heavy use of soybean meal in swine production.

Various economic impacts of animal disease outbreaks in different countries have been estimated in previous work using different methodologies. While a lot of attention has been paid to outbreaks of foot and mouth disease (Schroeder et al. 2015; Elbakidze et al. 2009; Pendell et al. 2007; Paarlberg, Lee, and Seitnzinger, 2003; Hagerman et al. 2012), ASF has attracted much less attention. Additionally, the aforementioned work analyzes different control strategies for FMD outbreaks of different regions, geographic spread, and control strategies focusing on the cattle industry.

Although most previous studies analyze the direct costs of controlling the disease on the pork industry (e.g,. Fasina et al. 2012; Saatkamp, Berentsen and Horst, 2000), other studies have also looked at costs associated with the loss of export markets (Mangen, Burrell and Mourits, 2004; Fernandez-Carrion et al. 2016). However, these studies either do not consider changes in market equilibrium for the affected commodities or the interactions of the markets with other agricultural products such as competing meats and grains used for feed (or both). Broader economic impacts outside the agricultural sector and the labor markets are also absent in the works mentioned so far. Halasa et al. (2016) analyze the effects of a contained short-lived outbreak and trade restrictions in Denmark, which, according to the authors, still lead to substantial economic losses. The authors do not estimate changes in domestic equilibrium prices or the wider economic impacts that result from the disappearance of export markets.

The purpose of this paper is to examine the market (for selected commodities) and economy-wide impacts of the elimination of U.S. pork exports due to a hypothetic outbreak of ASF in the United States. We first establish a baseline scenario, which represents the status quo (no ASF disease exists). Then we consider two scenarios, one where we assume that all U.S. exports are eliminated over the ten years of the projection period (2020 to 2029) and another where the export market recovers after two years of zero pork exports. In the first case, a ten-year projection period allows time for the industry to reach a new equilibrium where the industry shrinks (producers making losses exit the market) and pork is sold only in the domestic market. The scenarios are compared to the baseline to estimate the impact of this downsizing on the U.S. economy. While the directional impacts on variables such as the domestic pork price and production of an ASF outbreak can be predicted from standard economic theory, a numeric model is needed to quantify

the expected magnitude of these changes. Quantitative models are also helpful for identifying spillovers that may occur in related markets (namely, corn and soybean meal), as wells as broader economic impacts such as changes in value added and employment as conducted in this study.

Our study updates and extends a study by Hayes et al. (2011) (the only antecedent we are aware of for the U.S.), which uses a previous version of the same system of agricultural models to examine the costs to the livestock industry associated with the loss of export markets for pork and beef (separately) due to a foreign animal disease (foot and mouth disease). The size and reliance of export markets by the pork industry was much smaller in the Hayes et al. 2011 study, implying a more muted effect had an outbreak occurred. We also consider different paths of trade recovery and extend the analysis of the economy-wide impacts including effects on the labor market, through the use of a well-known input-output model (IMPLAN). We include the economic impacts on the state of Iowa agriculture given the state's position as the country's number one producer and exporter of pork.

The paper is organized as follows. We provide an overview of the methodology including descriptions of the models used for the analysis. Then, we present the results of the two scenarios in terms of the impact on select U.S. agricultural commodities as well as on the national and Iowa economies. Finally, we offer conclusions and some policy implications.

2. Methodology

We quantify the impacts on selected U.S. agricultural markets as well as on the national and state economies through the use of a combination of interrelated models: a global agricultural modeling system and an input-output model for the U.S., namely the CARD agricultural modeling system and the IMPLAN model, respectively.[6] The CARD agricultural model system provides the impact on U.S. and global agricultural commodities in terms of supply, utilization, and prices. The IMPLAN input-output model provides industry-level impacts in terms of changes in employment, labor income, industrial output, and value added. Both models capture the interlinkages between sectors, which is important given that, in the interrelations involved in the

[6] CARD stands for the Center for Agricultural and Rural Development at Iowa State University, and IMPLAN stands for IMpact Analysis for PLANing.

supply and demand for agricultural products, factors that disrupt the market for one commodity are likely to affect others.

CARD Agricultural Modeling System

The CARD model is a system of econometric, partial equilibrium, non-spatial models of global agriculture, widely used in policy and market analysis (Carriquiry et al. 2020, Dumortier et al. 2021). The models cover all major temperate crops, sugar, biofuels, dairy, and livestock and meat products for all major producing and consuming countries. The key drivers in the model are supply and demand equations for all the modeled commodities in all the modeled countries. Extensive market linkages exist in the modeling system, reflecting derived demand for feed in livestock and dairy sectors, competition for land in production, and consumer substitution possibilities for close substitutes such as vegetable oils and meat types (Figure 2). The interlinked models are used to generate ten-year baseline projections for agricultural markets and for policy analysis based on the baseline projections.

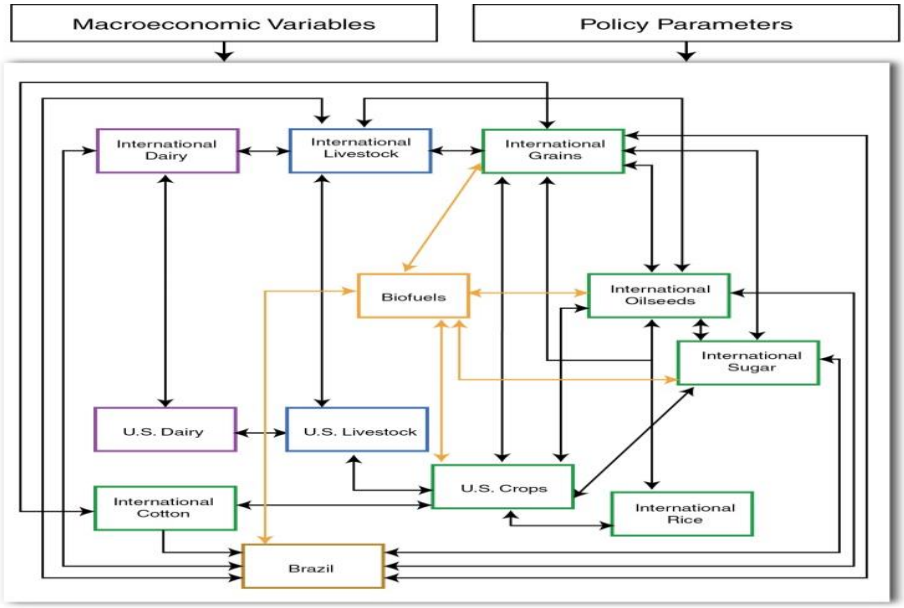

Figure 2: CARD Model Interactions

The modeled commodities are listed in Table 1, but not all commodities are covered in all countries. A total of 61 countries and regional aggregates are included in the full model. For more

details on the full CARD modeling system, see Meyers *et. al.* 2010. For this study, we focus on pork, beef, broilers, corn, soybeans, and soybean meal, although we run the entire agricultural modeling system including all commodities. Thus, the equilibrium conditions reported reflect the broader interactions.

Table 1. Commodity Coverage in CARD's Deterministic Model of U.S. Markets

Crops	Crop-based products	Livestock and poultry	Animal-based products
Corn	Ethanol	Beef cattle	Beef
Wheat	Biodiesel	Dairy cattle	Pork
Soybeans	Sugar	Hogs	Chicken
Upland cotton	High-fructose corn syrup	Chickens	Turkey
Long-grain rice	Distillers grains	Turkeys	Fluid milk
Short/medium grain rice	Corn gluten feed		American cheese
Sorghum	Corn gluten meal		Other cheese
Barley	Corn oil		Nonfat dry milk
Oats	Corn stover		Butter
Sunflowerseed	Soybean meal and oil		Evaporated milk
Peanuts	Sunflower meal and oil		Ice cream
Canola	Canola meal and oil		Eggs
Hay	Peanut meal and oil		
Sugar beets	Cottonseed		
Sugarcane	Cottonseed meal and oil		
Switchgrass			

Model parameters are derived from a combination of econometric estimation from time series data, prior information based on economic theory, technical relationships, and the literature. For example, corn feed and residual use is a function of feed and livestock prices, an index of grain-consuming animals, and the quantities of competing feeds consumed. The equation is constructed to ensure that corn feed and residual use change proportionally with livestock and poultry production. Given this modeled structure and parameters, econometric estimation is used to derive the responsiveness of corn feed use with respect to corn and soybean meal prices and a weighted index of livestock prices.

The modeling system captures the biological, technical, and economic relations among key variables within a particular commodity and across commodities. The model is based on historical

data analysis, current academic research, and a reliance on accepted economic, agronomic, and biological relationships in agricultural production and markets. Specifically, the model attempts to explicitly capture the extensive linkages that exist in agricultural markets such as the derived demand for feed in livestock and dairy sectors, competition for land in production, and consumer substitution possibilities for sets of close substitutes.

The model includes detailed policy variable coverage. In particular, agricultural and trade policies for each commodity in a country are included in the sub-models to the extent that they affect the supply and demand decisions of the economic agents. These include taxes on exports and imports, tariffs, tariff rate quotas, export subsidies, intervention prices, other domestic support instruments, and set-aside rates. For the baseline analysis, existing agricultural and trade policy variables are extended at current levels through the outlook period.

Given that the ASF scenarios are implemented in the U.S., we also provide a brief description of the U.S. agricultural sub-model. Within the CARD modeling system, the United States model covers 16 crops, 20 crop products, 5 types of livestock and poultry, and 12 animal-based products. Modeled commodities account for approximately two-thirds of U.S. crop receipts and 96 percent of livestock and poultry sector receipts. For almost all commodities, the U.S. model estimates production, consumption and prices. For example, for corn, the model includes corn planted area, harvested area, and yields per acre at a regional level. Domestic corn consumption is divided into feed and residual, ethanol, high-fructose corn syrup, seed, and other food and industrial uses at the national level. The model estimates corn prices by the equilibrium condition that total supply (production plus imports and beginning stocks) must equal total demand (domestic consumption plus exports and ending stocks). U.S. exports must be consistent with net trade by all the other countries in the world model.

Data for commodity supply and utilization are obtained from the Production, Supply and Distribution (PSD) online database of the U.S. Department of Agriculture (USDA), the F.O. Lichts online database, the Food and Agriculture Organization (FAO) of the United Nations (FAOSTAT Online), the European Commission Directorate General for Energy and Transport, and Brazilian Sugarcane Industry Association **(**UNICA), among others. Macroeconomic data such as gross domestic product (GDP), GDP deflator, population, and exchange rate are exogenous variables that drive the projections of the model. They are from the International Monetary Fund and IHS Markit.

For this analysis, the agricultural models are first run in a business-as-usual mode, which we label the "base case" or "baseline". Then the modeling system is modified to simulate a scenario in which the U.S. pork exports are eliminated over the ten-year projection period because of ASF (called the "all-years" scenario) and another scenario in which U.S. exports are eliminated for two years only (called the "2-years" scenario). After the changes, the modeling system is run again, and a new global agricultural market equilibrium is obtained for each of the scenarios. The new equilibrium for the first scenario (zero pork exports for ten years) is labeled the "all years" scenario. The equilibrium for the second scenario (zero pork exports for the first two projected years) is labeled the "two years" scenario. By comparing the scenarios against the base case, we estimate the impacts of the ASF outbreak on domestic (U.S.) agricultural markets and on global markets. Output from the CARD model is then used as input into the IMPLAN model to obtain the ASF impacts on the national and Iowa economies in terms of national industry output, value added, labor income, and employment.

For each commodity, the market equilibrium for time period *t* is obtained through the use of the following identity equating supply and demand:

(1) $$\boldsymbol{BS_t + Prod_t + Imp_t \equiv Cons_t + ES_t + Exp_t}$$

where $\boldsymbol{BS_t}$ and $\boldsymbol{ES_t}$ represent beginning and ending stocks, respectively. $\boldsymbol{Prod_t}$ denotes production, and $\boldsymbol{Cons_t}$ stands for consumption in year *t*. $\boldsymbol{Exp_t}$ and $\boldsymbol{Imp_t}$ represent exports and imports in year *t*, respectively. The system of models solves for a vector of prices per time period *t* for which the identity presented in Equation (1) holds. Grouping terms as domestic supply $\boldsymbol{S_t(p(k)) = Prod_t + BS_t}$, domestic demand $\boldsymbol{D_t(p(k)) = Cons_t + ES_t}$, and net exports $\boldsymbol{NE_t(p(k), k) = Exp_t - Imp_t}$, where we make explicit that the equilibrium price will depend on the sanitary status of the country with $\boldsymbol{k = 0}$ indicating absence of ASF and $\boldsymbol{k = 1}$ indicating presence of the disease, respectively. Thus, the equation above can be rewritten as

(2) $$\boldsymbol{NE_t(p(k), k) = S_t(p(k)) - D_t(p(k))}\ .$$

Note that the sanitary status affects domestic production and consumption through prices but enters both the net export component through prices and by itself. This reflects the fact that non-price trade barriers including prohibitions from other countries can affect the net demand for U.S. exports. It is worth emphasizing that we model net exports as the rest of the world's excess demand (or the demand for U.S. products from the rest of the world). For the case of a net exporter as is

the U.S. for pork (and many other agricultural products), we have $\boldsymbol{NE_t(p(k), k) \geq 0}$ with strict equality in the case where the disease is present. In this line, a trade barrier as a result of the appearance of ASF in the U.S. would result in

$$\boldsymbol{NE_t(p(0), 0) > NE_t(p(1), 1)} \tag{3}$$

with $NE_t(p(1), 1) = 0$ if trade with the U.S. is prohibited due to the presence of the disease.[7]

In equilibrium, and with the presence of the trade prohibition attributed to ASF, we need $S_t\big(p(1)\big) - D_t\big(p(1)\big) = NE_t(p(1), 1) = 0$, which implies $S_t\big(p(1)\big) = D_t\big(p(1)\big)$, that is domestic supply is fully used in the local market.

With upward sloping supply curves and downward sloping demand curves, Equation (3) necessarily means that $p(1) < p(0)$. Intuitively, as excess demand from the rest of the world is reduced in response to an outbreak of ASF in the U.S., the domestic price needs to be reduced in order for the market to be in equilibrium.[8] While standard economic theory tells us the expected directional changes in equilibrium prices, quantity demanded and quantity supplied, the magnitude of these changes and the effects on other commodity markets are an empirical question.

IMPLAN Model

The IMPLAN input-output model is an inter-industrial accounting system that produces input-output accounts by region (Figure 3). It is populated with data that are updated annually and is used to estimate the economic impacts of changes in regional production. Input-output models are price-static models that rely on economic characteristics of the recent past to project near-term outcomes. Modifications were made to the national model to more adequately reflect the crop and animal production sectors measured for this analysis.

[7] While imports are not prohibited in the presence of ASF and conceptually we could have negative net exports, in practice this is not a relevant situation to consider as lower domestic prices will prevent imports.

[8] In the case of a marginal reduction in export market access, comparative statics indicate

$$\frac{\partial p(t)}{\partial t} = -\frac{\frac{\partial NE(p(k),k)}{\partial p}}{\left[\frac{\partial NE(p(k),k)}{\partial p} + \frac{\partial D(p(k))}{\partial p} - \frac{\partial S(p(k))}{\partial p}\right]} < 0$$

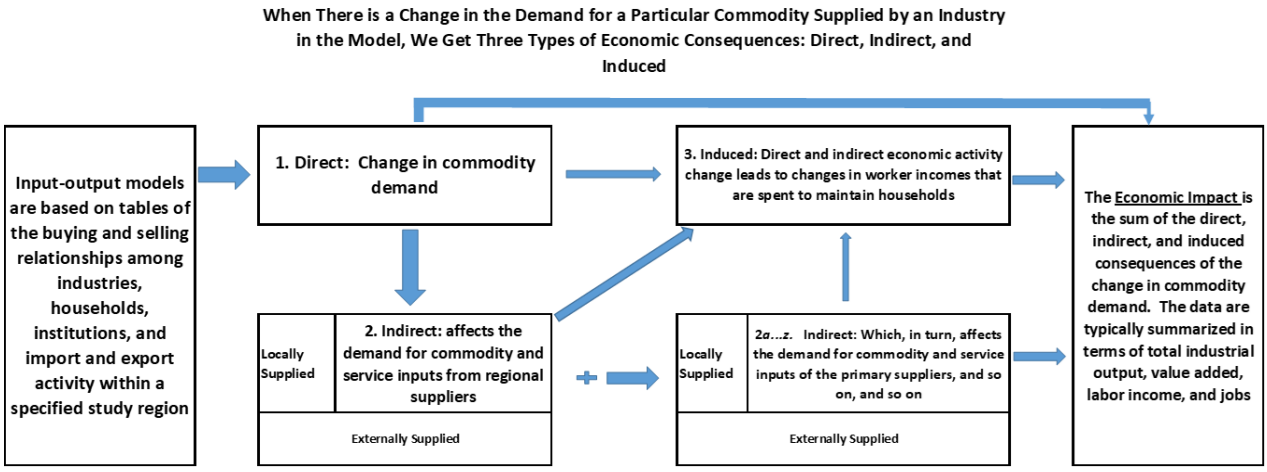

Figure 3: IMPLAN Model Outline

The IMPLAN model translates percentage changes in the quantities produced of the targeted commodities into standard economic impact summarizations. The current national model is modified to explicitly include the agricultural and manufactured commodities specified in this report. Percentage changes in output in the relevant commodity sectors generated by the CARD modeling system are used to shock the model and produce multiplied-through impacts in terms of the direct effects on a particular industry or commodity, the indirect effects upon supply chains, and the induced effects caused by changes in labor income and household consumption. These effects are reported in terms of industrial output changes, value added changes (which is analogous to GDP), labor income consequences, and job impacts.

To determine the economic impacts of an ASF outbreak in the U.S., the IMPLAN model generated results for both the U.S. and the Iowa economies. IMPLAN is a fixed-price and fixed-relationships model designed mainly to provide short-term projections based on changes in commodity outputs. For this analysis, changes in key commodities – corn, soybeans, soybean meal, pork, beef, and broilers – are "shocked" in the model to discern the expected job, labor income, value added, and the total output consequences of those changes. As the input-output model contains fixed, initial supply sector coefficients, the model had to be adjusted to eliminate double counting. Accordingly, upstream linkages in all of the modeled sectors were set to zero with one-another so that all of the effects modeled were unique to that sector and did not include coincidental effects in the other five sectors modeled.

The method of adjustment for all six commodities is to compare the difference over the measurement periods of the scenarios against the baseline projection. These quantity changes are then divided by the production quantities in 2019/2020, the year of no impacts, to yield a percentage change to apply to the industrial output values that exist in the model for each commodity. These change values become the "shocks" to the sectors evaluated. All financial values are expressed in expected 2020 constant amounts.

3. Results of the Swine Fever Scenarios

This section provides the results for both the elimination of U.S. pork exports for all the years of the projection period ("all-years" scenario) and for only two years ("2-years" scenario). It presents the direct impacts on the supply, demand, trade, and prices of selected commodities before moving to the broader economic implications. Results from the CARD modeling system are expressed in terms of deviations of the scenarios from the baseline for pork, beef, corn, soybeans, and soybean meal. Impacts on the national and Iowa economies from the IMPLAN model are presented as the difference in levels of jobs, labor income, value added, and output between the baseline and the scenarios for each year of the ten-year projection period.

Impact on U.S. Agricultural Commodities

Pork

As anticipated and as the figures below indicate, the trade restrictions in response to the animal disease outbreak result in lower domestic prices, production, and farm revenues, while increasing domestic consumption of pork. More detailed results in terms of percent changes for the scenarios relative to the baseline are presented in Appendix 1.

As shown in Figures 4 and 5, hog prices (Barrows and Gilts, National Base) decrease in both the "all-years" scenario and the "2-years" scenario when compared to the baseline. The hog prices fall by approximately 47% in the first year of the outbreak under both scenarios. However, prices gradually recover over time, following distinct paths depending on the scenario. Clearly the sooner the restrictions are lifted, the sooner prices recover to baseline levels. (Figure 5). Prices eventually stabilize and are 1.8% lower than the baseline by the end of the ten-year projection period in the

scenario in which pork exports continue to remain at zero. These lower prices are compatible with normal profits under a decline in feed costs as corn and soybean meal prices decline given that the livestock sector shrinks (see section of beef below). Prices return to baseline levels by the end of the projection when the trade restriction is short lived. The lower prices observed during the period of analysis are needed to both entice domestic buyers to increase consumption beyond baseline levels and absorb the excess supply generated by the trade restriction, and to signal to farmers to reduce production.

Inertias and long cycles in animal production result in output adjusting gradually over time in response to even sharp changes in prices (Figure 6). In the "2-years" scenario, production initially falls as farmers react to economic losses, but it starts to recover as soon as exports are reopened and producers are able to obtain international prices. However, as Figure 6 shows, production only reaches levels similar to those of the baseline about 3 or 4 years after export markets are again available. For the case of the "all-years" scenario production continues adjusting downwards because producers exit the market as the industry keeps looking to return to normal profits. The contraction of the pork industry is evident in Figure 6, which highlights the fact that ASF would have a devastating effect on pork producers especially in the all-years scenario where production declines by almost 30% by the end of the projection period even as margins return to baseline levels. The "2-years" scenario also shows a very small contraction in the industry in the long term given that exports eventually return to normal levels. Thus, a smaller percentage of hog producers exit the market in the "2-years" scenario relative to the "all-years" scenario.

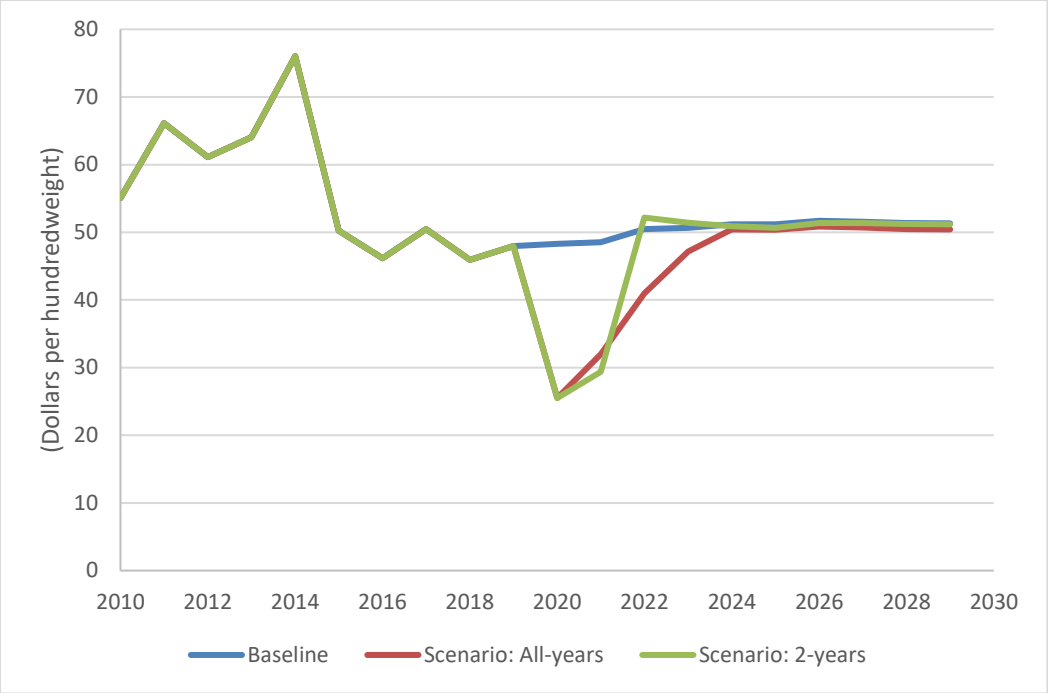

Figure 4. Impact of ASF on U.S. Live Hog Prices (Levels, Barrows & Gilts, National Base)

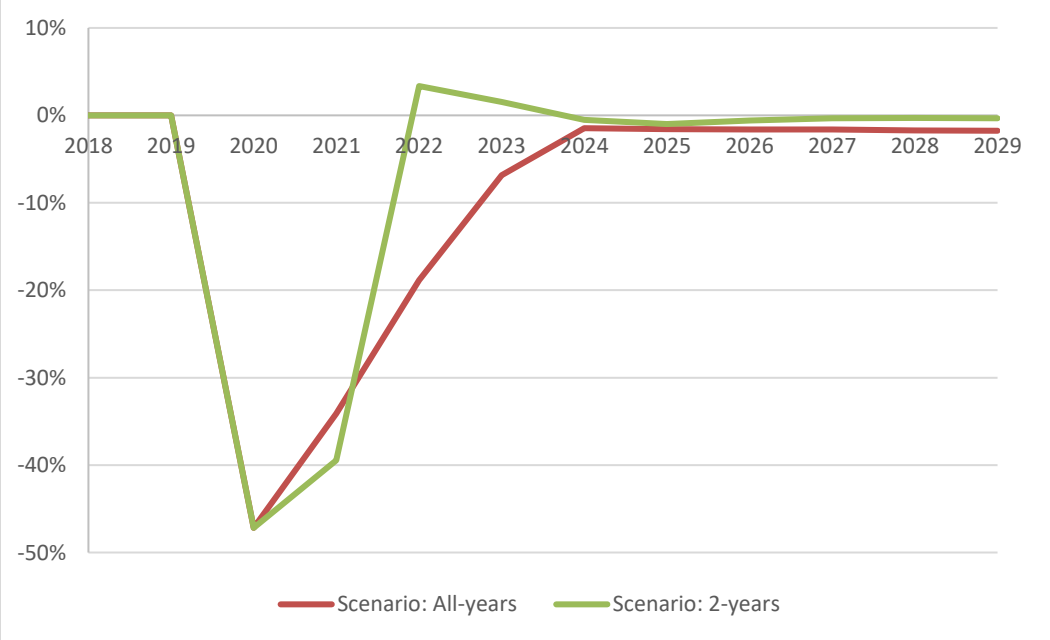

Figure 5. Impact of ASF on U.S. Live Hog Prices (Percent Change from Baseline, Barrows & Gilts, National Base)

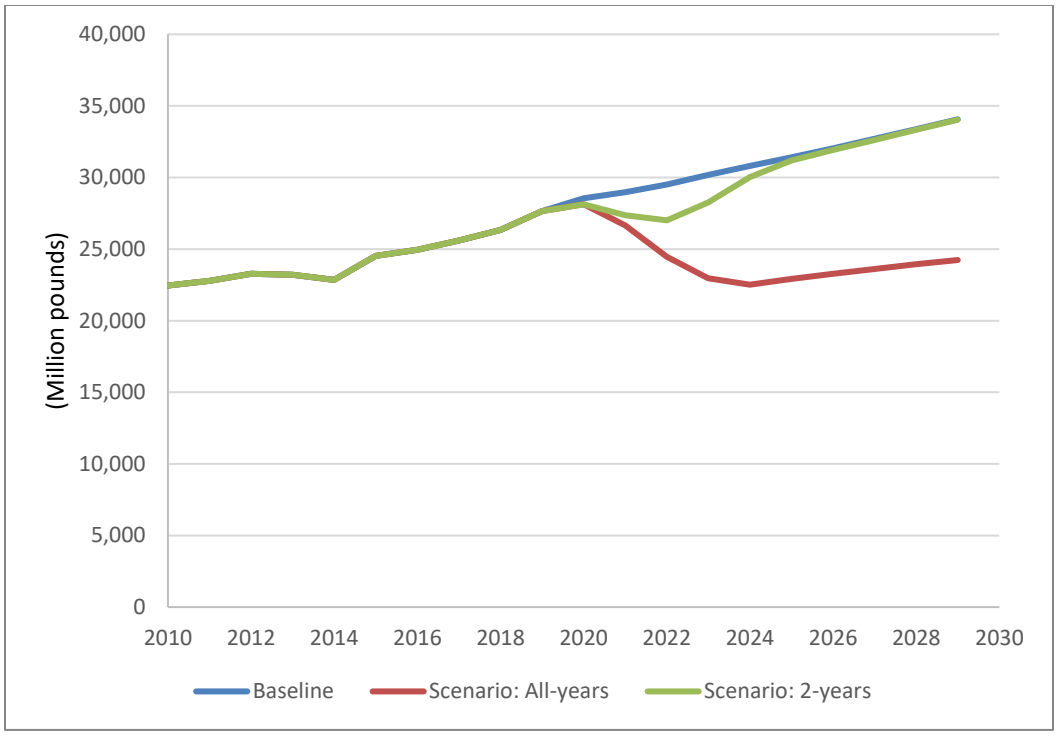

Figure 6. Impact of ASF on U.S. Pork Production (Levels)

Lower prices and quantities sold lead to a decline in the pork industries revenue. Figure 6, which compares pork revenues between the baseline and the two scenarios, shows that the pork revenues fall dramatically in the first few years and, while they do start to increase in subsequent years, the revenues reach baseline levels only in the last three years of the projection period in the case of the "2-years" scenario. Revenues remain well below the baseline in the all-years scenario and never return to pre-outbreak levels. Over the ten-year period, revenue losses in total revenue add up to $15 billion in the "2-years" scenario and a little over $50 billion in the "all-years" scenario.

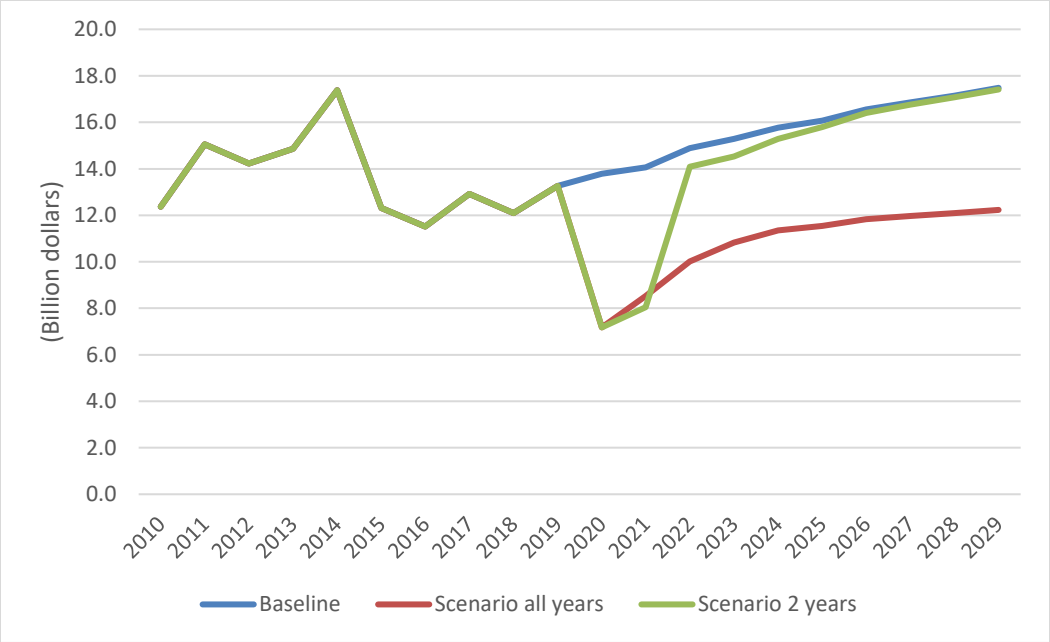

Figure 7. Impact of ASF on U.S. Pork Revenue

Beef

As is evident in Figure 8, cattle prices (Nebraska Direct Steers, 1,100 – 1,300 pounds) in both scenarios initially decline because meat consumers substitute toward the less expensive pork. Cattle prices start to recover over the projection period after the pork industry adjusts to the outbreak in the long run. As in the case of hog prices, Figure 8 shows that cattle prices eventually return to slightly above baseline levels (less than 1% higher, on average, relative to the baseline). While the magnitudes and paths of the price changes (relative to the baseline) are similar in both scenarios, the prices recover faster in the "2-years" scenario than in the "all-years" scenario after the initial drop because pork exports start to recover in the third year of the projection period. In the "2-years" scenario, cattle prices go back to baseline levels by the end of the projection period.

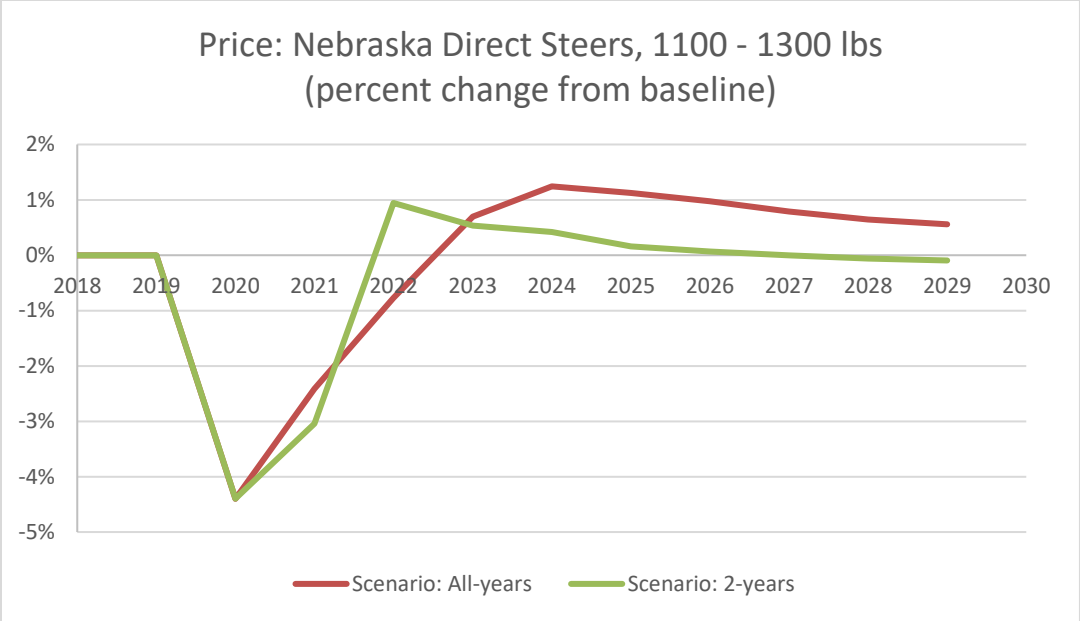

Figure 8. Impact of ASF on U.S. Live Cattle Prices (Percent Change from Baseline, Nebraska Direct Steers, 1100-1300 lb)

Beef production in both scenarios does not deviate very much from baseline levels (Table 2). However, production of beef does initially decline slightly relative to the baseline in response to the lower prices resulting from the fall in domestic use before recovering back to close to baseline levels. There is stronger demand for beef from the international market (as pork supply declines) especially in the first few years and this demand helps mitigate the reduction in prices in the earlier years and the faster recovery of prices over the projection period. The stronger international demand for beef combined with strong domestic competition from pork lead to an expansion of net exports and a reduction in domestic consumption of beef.

The story with poultry is slightly different (Table 3). The model is indicating that lower pork exports from the US creates a shortage of meats in the international market, and there is an enhanced substitution towards broilers relative to beef. In this line, the stronger export demand leads to (besides larger exports) higher prices for broilers and lower domestic consumption in the first few years of the projection or both scenarios. As in the case of beef, supply and utilization variables, and prices tend to return to baseline levels as time goes by for the 2-years scenario. The effects on price also tend to decrease towards the end of the projection for the "All-years" scenario as production has time to respond to better economics (higher prices and lower feed costs). With domestic prices inching towards the baseline, so does domestic consumption by the end of the projection period.

Table 2. Impact on the U.S beef market over time expressed a percent relative to the baseline

BEEF	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**
Change from baseline						(percent)					
Price (1100 - 1300 #, Nebraska Direct Steers)											
Scenario: All-years	0.00%	-4.40%	-2.41%	-0.77%	0.70%	1.24%	1.13%	0.97%	0.79%	0.64%	0.56%
Scenario: 2-years	0.00%	-4.40%	-3.05%	0.94%	0.53%	0.42%	0.16%	0.07%	0.00%	-0.06%	-0.10%
Production											
Scenario: All-years	0.00%	0.31%	-0.39%	-0.23%	-0.19%	-0.11%	-0.09%	-0.10%	-0.08%	-0.03%	0.02%
Scenario: 2-years	0.00%	0.31%	-0.33%	-0.43%	0.07%	-0.07%	-0.12%	-0.15%	-0.15%	-0.14%	-0.14%
Consumption											
Scenario: All-years	0.00%	-5.63%	-4.48%	-2.57%	-1.15%	-0.39%	-0.21%	-0.12%	-0.06%	0.00%	0.05%
Scenario: 2-years	0.00%	-5.63%	-5.12%	-0.09%	0.23%	-0.01%	-0.13%	-0.14%	-0.11%	-0.09%	-0.09%
Net Exports											
Scenario: All-years	0.00%	79.06%	39.90%	28.35%	14.85%	7.67%	5.11%	2.94%	2.31%	1.83%	1.74%
Scenario: 2-years	0.00%	79.07%	46.97%	-1.79%	2.73%	0.64%	1.61%	1.13%	0.71%	0.52%	0.54%

Table 3. Impact on the U.S broiler market over time expressed a percent relative to the baseline

Broiler	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**
Change from baseline						(percent)					
12 City Wholesale											
Scenario: All-years	0.00%	0.96%	0.33%	0.55%	0.76%	0.78%	0.63%	0.61%	0.59%	0.56%	0.55%
Scenario: 2-years	0.00%	0.97%	0.28%	-0.16%	-0.19%	-0.22%	-0.25%	-0.20%	-0.21%	-0.24%	-0.26%
Production											
Scenario: All-years	0.00%	0.18%	0.39%	0.60%	0.80%	0.96%	1.03%	1.08%	1.13%	1.20%	1.26%
Scenario: 2-years	0.00%	0.17%	0.32%	0.30%	0.21%	0.12%	0.06%	0.04%	0.04%	0.05%	0.05%
Consumption											
Scenario: All-years	0.00%	-1.63%	-0.98%	-0.64%	-0.39%	-0.25%	-0.19%	-0.18%	-0.18%	-0.17%	-0.17%
Scenario: 2-years	0.00%	-1.64%	-1.13%	0.15%	0.13%	0.09%	0.05%	0.02%	0.02%	0.02%	0.02%
Net Exports											
Scenario: All-years	0.00%	8.87%	7.06%	6.36%	6.26%	6.28%	6.26%	6.27%	6.39%	6.51%	6.64%
Scenario: 2-years	0.00%	8.85%	7.35%	0.99%	0.61%	0.25%	0.09%	0.14%	0.14%	0.14%	0.14%

Corn

Table 4 compares the results for the all-years scenario and the 2-years scenario relative to the baseline for the U.S. corn market. As the table shows, corn prices do not change very much between the baseline and the two scenarios. However, they are slightly lower in the scenarios relative to the baseline. The change in corn prices is small due offsetting effects. While, on the one hand, ASF in the U.S. leads to a lower domestic demand for feed, in particular from the pork sector, the international demand becomes stronger as it needs to (at least partially) cover the global excess demand for animal protein that occurs as the U.S. is not allowed to trade pork. Additional corn from the U.S. is needed to feed these animals elsewhere. These offsetting effects are clearly evident in Table 4. Production decreases in response to the lower prices in both scenarios, although the decrease in production is relatively muted, which is consistent with the smaller change in prices over the projection period when compared to the baseline.

Soybeans and Soybean Meal

Tables 5 and 6 present the impact of an ASF outbreak on the markets for soybeans and soybean meal. The outbreak (and ensuing trade restrictions) lowers the price of soybeans in the all-years scenario relative to the baseline, thus decreasing soybean production by about 0.5% by the end of the projection period. Production also declines at the beginning in the 2-years scenario but by a smaller percentage than the all-years scenario and remains close to baseline levels towards the end of the projection period. The offsetting forces between domestic demand and international demand described for corn above are also present in the markets for soybeans and soybean meal. In short lower domestic demand is partially offset by international demand for protein meal to replace the reduced supplies of U.S. pork in international markets, which results in lower prices and production of the oilseed and its byproduct.

The decline in prices is more pronounced in particular in the case of soybeans and soybean meal relative to corn. This is because pork is the product where the shock originates and the one more severely hit by the trade restriction. Pork production accounts for a particularly important proportion of the demand for soybeans for feed, the main use of soybeans. This proportion is higher than in the demand of corn for feed. Additionally, the demand for corn has a broader base (beyond feed) relative to soybeans including fuel and industrial used, and food uses.

Table 4. Impact on the U.S corn market over time expressed a percent relative to the baseline

CORN	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Change from baseline						(percent)					
Price											
Scenario: All-years	0.00%	-1.17%	-0.68%	-0.85%	-0.62%	-0.62%	-0.55%	-0.56%	-0.56%	-0.57%	-0.51%
Scenario: 2-years	0.00%	-1.12%	-0.11%	-0.34%	0.03%	-0.21%	-0.17%	-0.26%	-0.26%	-0.28%	-0.31%
Production											
Scenario: All-years	0.00%	-0.42%	-0.63%	-0.47%	-0.44%	-0.34%	-0.32%	-0.29%	-0.28%	-0.27%	-0.25%
Scenario: 2-years	0.00%	-0.41%	-0.39%	-0.14%	-0.15%	-0.10%	-0.19%	-0.19%	-0.23%	-0.23%	-0.25%
Consumption											
Scenario: All-years	0.00%	-1.32%	-1.90%	-2.20%	-2.38%	-2.41%	-2.46%	-2.51%	-2.59%	-2.66%	-2.68%
Scenario: 2-years	0.00%	-1.22%	-0.81%	-0.52%	-0.29%	-0.11%	-0.11%	-0.11%	-0.12%	-0.13%	-0.14%
Net Exports											
Scenario: All-years	0.00%	6.35%	9.38%	13.82%	15.55%	16.04%	15.16%	14.52%	14.31%	14.14%	13.40%
Scenario: 2-years	0.00%	5.87%	3.63%	2.66%	1.23%	-0.37%	-0.62%	-0.86%	-0.88%	-0.89%	-0.80%

Table 5. Impact on the U.S soybeans market over time expressed a percent relative to the baseline

SOYBEANS	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Change from baseline						(percent)					
Price											
Scenario: All-years	0.00%	-1.03%	-1.10%	-1.12%	-1.16%	-1.05%	-1.08%	-1.08%	-1.19%	-1.19%	-1.18%
Scenario: 2-years	0.00%	-0.92%	-0.49%	-0.12%	-0.03%	-0.01%	-0.11%	-0.14%	-0.17%	-0.17%	-0.19%
Production											
Scenario: All-years	0.00%	0.05%	-0.09%	-0.25%	-0.32%	-0.39%	-0.40%	-0.44%	-0.47%	-0.51%	-0.52%
Scenario: 2-years	0.00%	0.07%	-0.07%	-0.07%	0.04%	0.04%	0.08%	0.06%	0.07%	0.07%	0.08%
Consumption											
Scenario: All-years	0.00%	-0.12%	-0.30%	-0.47%	-0.57%	-0.62%	-0.64%	-0.67%	-0.72%	-0.75%	-0.76%
Scenario: 2-years	0.00%	-0.08%	-0.22%	-0.18%	-0.07%	-0.04%	-0.02%	-0.03%	-0.03%	-0.03%	-0.03%
Net Exports											
Scenario: All-years	0.00%	0.09%	0.13%	0.02%	-0.03%	-0.08%	-0.10%	-0.13%	-0.17%	-0.19%	-0.15%
Scenario: 2-years	0.00%	0.10%	0.18%	0.15%	0.19%	0.15%	0.20%	0.19%	0.20%	0.20%	0.21%

Table 6. Impact on the U.S soybean meal market over time expressed a percent relative to the baseline

SOYBEAN MEAL	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**
Change from baseline						(percent)					
Price											
Scenario: All-years	0.00%	-2.72%	-3.72%	-4.51%	-5.00%	-5.05%	-5.24%	-5.45%	-6.00%	-6.34%	-6.64%
Scenario: 2-years	0.00%	-2.34%	-2.19%	-1.19%	-0.53%	-0.37%	-0.51%	-0.64%	-0.76%	-0.79%	-0.85%
Production											
Scenario: All-years	0.00%	-0.16%	-0.35%	-0.52%	-0.62%	-0.66%	-0.68%	-0.72%	-0.76%	-0.80%	-0.82%
Scenario: 2-years	0.00%	-0.12%	-0.25%	-0.19%	-0.08%	-0.05%	-0.03%	-0.04%	-0.05%	-0.05%	-0.05%
Consumption											
Scenario: All-years	0.00%	-3.22%	-5.68%	-7.73%	-8.54%	-8.52%	-8.56%	-8.67%	-8.72%	-8.83%	-8.98%
Scenario: 2-years	0.00%	-2.57%	-2.45%	-2.01%	-0.81%	-0.27%	-0.13%	-0.12%	-0.10%	-0.12%	-0.15%
Net Exports											
Scenario: All-years	0.00%	10.57%	17.46%	22.34%	24.43%	24.09%	24.56%	25.18%	25.73%	26.71%	28.37%
Scenario: 2-years	0.00%	8.47%	7.09%	5.60%	2.25%	0.65%	0.29%	0.20%	0.15%	0.19%	0.33%

The demand for soybean oil partially disciplines the soybean price decline. As less soybeans are produced and crushed due to the lower prices and crushing margins, the supply of soybean oil falters (results not shown). This creates an excess demand for soybean oil, which leads to higher prices for this commodity as it tries to increase production. However, additional soybean crushing is needed to increase production of soybean oil, which, by the joint production technology, leads to higher supplies of soybean meal. While disciplining the decline in soybean prices, the induced additional soybean crushing puts downward pressure on the price of soybean meal.

Impact on the U.S. National Economy and the State of Iowa Economy

To isolate the Iowa (state) results from the U.S. (national) results, two IMPLAN models were built and run. The percentage allocation of the commodity output changes over time for Iowa are based on Iowa's direct output in each of the commodities analyzed as a share of the U.S. values contained in the IMPLAN model. An exception, however, is made for the Iowa share of broilers. As Iowa's poultry industry is overwhelmingly dominated by laying hens and egg production, with comparatively small levels of broiler production, we use the percentage of farm broiler chicken inventories in Iowa compared to the nation from the 2017 Agricultural Census.

From each model, for the U.S. and for Iowa, two distinct impact summaries are generated, one considering the "all-years" scenario and the other considering the "2-years" scenario. Separate impacts are compiled for each commodity – corn, soybeans, soybean meal, pork, beef, and broilers – and the unique, non-duplicative effects are then summed.[9] The tables below display the annual value of the total economic impacts as deviations between the scenarios and the baseline for each year through 2028/2029 expressed as reductions or gains in the values for the commodities in the IMPLAN model. The total values reported are the sum of all direct (producer or processor level), indirect (the supplying sectors), and the induced (household spending) amounts. Values are reported for jobs (full and part-time), labor income (the value of all wages and salaries plus employer-provided benefits), value added (includes labor income plus returns to investors and indirect tax payments), and total output (the sales value of production). Detailed results separating direct, indirect, and induced effects for the U.S and Iowa are included in Appendix 2 and 3, respectively.

[9] Detailed tables are provided for all commodities combined for each scenario in Appendix 2.

Table 7 shows that, for the U.S., in the all-years scenario, job losses grow from 6,380 in the first year, 2020/2021, to 142,485 by 2028/2029. Value added, which is analogous to gross domestic product, is reduced by $563.6 million in the first year, but declines to $11.1 billion by the last year when all multiplied-through consequences are summed.

In the "2-years" scenario (Table 8), job losses are 6,201 in the first year, climb to 39,542 in losses by 2022/2023, and then fall to 220 jobs by the last year. Value added is reduced by $544.45 million in the first year, grows to a $2.99 billion reduction by 2022/2023, and then turns to a positive $25.64 million in 2028/2029.

Table 7. Total Annual U.S. Economic Impacts in the "All-Years" Scenario

Impact Year	Jobs	Labor Income	Value Added	Output
	Thousands		Millions	
20/21	-6.4	($318)	($564)	($1,026)
21/22	-40.8	($1,743)	($3,134)	($6,100)
22/23	-79.7	($3,435)	($6,182)	($11,823)
23/24	-112.4	($4,849)	($8,728)	($16,616)
24/25	-127.0	($5,479)	($9,865)	($18,678)
25/26	-129.1	($5,565)	($10,023)	($18,924)
26/27	-132.9	($5,730)	($10,322)	($19,479)
27/28	-137.7	($5,941)	($10,702)	($20,182)
28/29	-142.5	($6,149)	($11,078)	($20,853)

Table 8. Total Annual U.S. Economic Impacts in the "2-Years" Scenario

Impact Year	Jobs	Labor Income	Value Added	Output
	Thousands		Millions	
20/21	-6.2	($307)	($544)	($975)
21/22	-27.2	($1,146)	($2,067)	($3,981)
22/23	-39.5	($1,657)	($2,989)	($5,717)
23/24	-26.0	($1,100)	($1,986)	($3,587)
24/25	-9.4	($374)	($681)	($1,157)
25/26	-1.9	($52)	($100)	($110)
26/27	-0.8	($3)	($11)	$29
27/28	-0.6	$0	($4)	$34
28/29	-0.2	$17	$26	$95

For Iowa (Table 9), in the all-years scenario, job losses grow from 1,100 in year one to 22,076 by the last year. Value added is reduced by $93.00 million in year one and losses grow to $1.78 billion by 2028/2029.

In the "2-years" scenario for Iowa, initial year job losses of 1,089 grow to 5,862 by 2022/2023 before recovering to just 63 jobs lost by 2028/2029. Value added reduces by $91.65 million in year one, grows to $470.6 million in the third year, and then recovers to a negative $2.95 million in the last year.

Table 9. Total Annual Iowa Economic Impacts in the "All-Years" Scenario

Impact Year	Jobs	Labor Income	Value Added	Output
	Thousands		Millions	
20/21	-1.1	($46)	($93)	($242)
21/22	-5.6	($224)	($451)	($1,149)
22/23	-11.8	($471)	($948)	($2,388)
23/24	-16.9	($677)	($1,360)	($3,421)
24/25	-19.4	($776)	($1,560)	($3,919)
25/26	-19.8	($795)	($1,597)	($4,014)
26/27	-20.5	($820)	($1,648)	($4,142)
27/28	-21.3	($852)	($1,713)	($4,306)
28/29	-22.1	($886)	($1,779)	($4,473)

Table 10. Total Annual Iowa Economic Impacts in the 2-Years Scenario

Impact Year	Jobs	Labor Income	Value Added	Output
	Thousands		Millions	
20/21	-1.1	($46)	($92)	($237)
21/22	-3.9	($156)	($314)	($801)
22/23	-5.9	($234)	($471)	($1,190)
23/24	-4.4	($176)	($354)	($882)
24/25	-1.7	($67)	($135)	($332)
25/26	-0.4	($15)	($30)	($70)
26/27	-0.2	($5)	($10)	($22)
27/28	-0.1	($4)	($7)	($15)
28/29	-0.1	($1)	($3)	($4)

4. Conclusion and Policy Implications

The U.S. is a major exporter of pork. U.S. pork exports accounted for about 30% of world pork exports at 3 million metric tons, carcass weight equivalent (second only to the European Union) in 2019 and 2020 (USDA, 2020). Additionally, the U.S. saw significant increases in pork exports to China because of the ASF in Asia. Therefore, an outbreak of swine fever in the U.S. would result in a significant reduction is U.S. pork exports and a loss in export markets. This study aims to quantify the impacts of an ASF outbreak in the U.S. pig herd both in terms of domestic agricultural markets and in terms of economic impacts. We highlight the effect of the outbreak in Iowa, the largest producer and exporter of pork in the U.S.

We find that the inability of the U.S. to export pork leads to a flood of pork in the domestic market putting downward pressure on prices and affecting the profits of hog producers. Loss of pork export markets because of ASF creates an oversupply of meat on the domestic market with significant price reductions throughout the marketing system. Live hog prices fall to encourage the U.S. consumer to eat more pork. The availability of inexpensive pork in the U.S. domestic market leads to price reductions in competing proteins. Consumers in the rest of the world who are suddenly cut off from imported pork will necessarily reduce consumption of pork and turn towards domestic proteins or to other meat imports both from the U.S. and from other exporting countries. The U.S. loses market shares and its status as a major exporter of pork for a significant amount of time after the first outbreak. As the U.S. meat sectors adjust to lower demand, feed-grain use falls and economic activity and employment in the U.S. livestock sector and its affiliated industries suffer. Second-round impacts include a reduction in the U.S. trade balance and in rural employment.

Results show that the costs associated with an ASF outbreak are large and require risk mitigation and safeguards. Policies in the form of insurance against drastic price reductions could be explored in this regard, and would be worth to analyze them in future research.

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APPENDIX 1
IMPACT OF THE AFRICAN SWINE FEVER OUTBREAK IN THE U.S.

A.1. Impact on U.S. Agricultural Commodities

PORK	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**
Change from baseline						*(percent)*					
Price (Barrows & Gilts, Natl. Base)											
Scenario: All-years	0.00%	-47.20%	-34.10%	-18.80%	-6.86%	-1.47%	-1.58%	-1.62%	-1.63%	-1.71%	-1.76%
Scenario: 2-years	0.00%	-47.20%	-39.50%	3.35%	1.53%	-0.53%	-1.00%	-0.57%	-0.34%	-0.30%	-0.32%
Production											
Scenario: All-years	0.00%	-1.45%	-8.04%	-17.10%	-24.00%	-26.90%	-27.00%	-27.30%	-27.80%	-28.30%	-28.80%
Scenario: 2-years	0.00%	-1.45%	-5.54%	-8.43%	-6.42%	-2.55%	-0.67%	-0.31%	-0.22%	-0.15%	-0.09%
Consumption											
Scenario: All-years	0.00%	25.54%	17.83%	9.53%	3.13%	0.09%	-0.41%	-0.57%	-0.55%	-0.61%	-0.69%
Scenario: 2-years	0.00%	25.54%	20.91%	-1.07%	-1.34%	-0.64%	-0.02%	0.08%	0.01%	-0.03%	-0.03%
Net Exports											
Scenario: All-years*	0.00%	-100.0%	-100.0%	-100.0%	-100.0%	-100.0%	-100.0%	-100.0%	-100.0%	-100.0%	-100.0%
Scenario: 2-years	0.00%	-100.0%	-100.0%	-26.5%	-18.8%	-7.3%	-2.3%	-1.3%	-0.7%	-0.3%	-0.1%
Revenue						*(billion dollars)*					
Scenario: All-years	0	-6.61	-5.54	-4.87	-4.46	-4.42	-4.53	-4.71	-4.88	-5.06	-5.26
Scenario: 2-years	0	-6.61	-6.02	-0.8	-0.76	-0.48	-0.27	-0.15	-0.09	-0.08	-0.07

A.2. National Impacts by Year for All Commodities Scenario

Total Annual U.S. Economic Impacts in the All Years Scenario

All Commodities 20/21

Impact Type	Jobs	Labor Income	Value Added	Output
Direct	(2,988)	$ (130,347,676)	$ (250,775,293)	$ (449,213,155)
Indirect	(1,598)	$ (85,822,902)	$ (133,421,372)	$ (255,792,482)
Induced	(1,794)	$ (101,623,832)	$ (179,439,190)	$ (321,230,249)
Total	(6,380)	$ (317,794,408)	$ (563,635,854)	$ (1,026,235,887)

All Commodities 21/22

Impact Type	Jobs	Labor Income	Value Added	Output
Direct	(23,476)	$ (741,105,343)	$ (1,429,175,325)	$ (2,697,109,331)
Indirect	(7,458)	$ (444,284,833)	$ (720,729,414)	$ (1,641,351,975)
Induced	(9,837)	$ (557,356,039)	$ (983,885,195)	$ (1,761,225,395)
Total	(40,772)	$ (1,742,746,216)	$ (3,133,789,933)	$ (6,099,686,705)

All Commodities 22/23

Impact Type	Jobs	Labor Income	Value Added	Output
Direct	(46,798)	$ (1,518,465,519)	$ (2,915,884,736)	$ (5,266,412,971)
Indirect	(13,492)	$ (817,950,396)	$ (1,327,311,635)	$ (3,085,357,402)
Induced	(19,390)	$ (1,098,584,933)	$ (1,939,200,654)	$ (3,471,261,910)
Total	(79,680)	$ (3,435,000,850)	$ (6,182,397,022)	$ (11,823,032,295)

All Commodities 23/24

Impact Type	Jobs	Labor Income	Value Added	Output
Direct	(66,305)	$ (2,159,799,135)	$ (4,142,667,737)	$ (7,404,461,832)
Indirect	(18,717)	$ (1,138,716,467)	$ (1,847,822,974)	$ (4,311,046,545)
Induced	(27,375)	$ (1,550,972,442)	$ (2,737,721,302)	$ (4,900,640,446)
Total	(112,398)	$ (4,849,488,047)	$ (8,728,212,009)	$ (16,616,148,840)

All Commodities 24/25

Impact Type	Jobs	Labor Income	Value Added	Output
Direct	(75,338)	$ (2,462,374,320)	$ (4,721,980,489)	$ (8,352,435,682)
Indirect	(20,734)	$ (1,264,159,066)	$ (2,049,830,560)	$ (4,788,950,014)
Induced	(30,927)	$ (1,752,245,634)	$ (3,092,947,337)	$ (5,536,485,278)
Total	(127,001)	$ (5,478,779,024)	$ (9,864,758,382)	$ (18,677,870,992)

All Commodities 25/26

Impact Type	Jobs	Labor Income	Value Added	Output
Direct	(76,748)	$ (2,511,379,332)	$ (4,816,939,461)	$ (8,483,914,816)
Indirect	(20,899)	$ (1,273,984,387)	$ (2,064,050,295)	$ (4,816,263,224)
Induced	(31,416)	$ (1,779,917,226)	$ (3,141,764,480)	$ (5,623,857,163)
Total	(129,065)	$ (5,565,280,949)	$ (10,022,754,233)	$ (18,924,035,222)

All Commodities 26/27

Impact Type	Jobs	Labor Income	Value Added	Output
Direct	(79,103)	$ (2,588,880,233)	$ (4,967,217,592)	$ (8,745,541,261)
Indirect	(21,473)	$ (1,308,662,202)	$ (2,119,594,212)	$ (4,943,056,598)
Induced	(32,347)	$ (1,832,669,409)	$ (3,234,865,452)	$ (5,790,504,832)
Total	(132,925)	$ (5,730,211,848)	$ (10,321,677,252)	$ (19,479,102,710)

All Commodities 27/28

Impact Type	Jobs	Labor Income	Value Added	Output
Direct	(81,980)	$ (2,687,439,571)	$ (5,157,598,007)	$ (9,073,506,153)
Indirect	(22,218)	$ (1,353,341,812)	$ (2,190,942,616)	$ (5,104,729,263)
Induced	(33,536)	$ (1,900,025,249)	$ (3,353,746,480)	$ (6,003,300,953)
Total	(137,735)	$ (5,940,806,637)	$ (10,702,287,099)	$ (20,181,536,388)

All Commodities 28/29

Impact Type	Jobs	Labor Income	Value Added	Output
Direct	(84,886)	$ (2,788,535,599)	$ (5,352,369,180)	$ (9,390,137,754)
Indirect	(22,888)	$ (1,393,705,580)	$ (2,254,967,833)	$ (5,249,256,824)
Induced	(34,710)	$ (1,966,547,437)	$ (3,471,147,082)	$ (6,213,442,905)
Total	(142,485)	$ (6,148,788,621)	$ (11,078,484,090)	$ (20,852,837,503)

Total Annual U.S. Economic Impacts in the Two Year Only Scenario

All Commodities 20/21

Impact Type	Jobs	Labor Income	Value Added	Output
Direct	(2,952)	$ (127,668,769)	$ (244,228,413)	$ (421,326,999)
Indirect	(1,514)	$ (81,446,549)	$ (126,637,707)	$ (243,255,993)
Induced	(1,735)	$ (98,307,464)	$ (173,581,826)	$ (310,743,714)
Total	(6,201)	$ (307,422,781)	$ (544,447,946)	$ (975,326,706)

All Commodities 21/22

Impact Type	Jobs	Labor Income	Value Added	Output
Direct	(16,107)	$ (502,337,773)	$ (970,649,613)	$ (1,793,013,059)
Indirect	(4,611)	$ (277,172,980)	$ (449,260,218)	$ (1,030,138,358)
Induced	(6,469)	$ (366,534,456)	$ (646,981,588)	$ (1,158,119,658)
Total	(27,188)	$ (1,146,045,216)	$ (2,066,891,418)	$ (3,981,271,074)

All Commodities 22/23

Impact Type	Jobs	Labor Income	Value Added	Output
Direct	(24,022)	$ (745,319,619)	$ (1,431,822,348)	$ (2,567,338,941)
Indirect	(6,168)	$ (381,421,018)	$ (621,823,931)	$ (1,475,450,395)
Induced	(9,351)	$ (529,815,230)	$ (935,161,945)	$ (1,673,957,802)
Total	(39,542)	$ (1,656,555,877)	$ (2,988,808,223)	$ (5,716,747,137)

All Commodities 23/24

Impact Type	Jobs	Labor Income	Value Added	Output
Direct	(16,401)	$ (534,672,123)	$ (1,017,843,029)	$ (1,628,034,521)
Indirect	(3,341)	$ (213,729,985)	$ (346,872,386)	$ (846,905,615)
Induced	(6,212)	$ (351,934,223)	$ (621,119,966)	$ (1,111,784,408)
Total	(25,954)	$ (1,100,336,336)	$ (1,985,835,379)	$ (3,586,724,544)

All Commodities 24/25

Impact Type	Jobs	Labor Income	Value Added	Output
Direct	(6,594)	$ (204,152,194)	$ (388,579,681)	$ (556,893,669)
Indirect	(669)	$ (49,947,047)	$ (81,415,142)	$ (222,606,651)
Induced	(2,110)	$ (119,513,109)	$ (210,856,975)	$ (377,395,065)
Total	(9,374)	$ (373,612,353)	$ (680,851,796)	$ (1,156,895,385)

All Commodities 25/26

Impact Type	Jobs	Labor Income	Value Added	Output
Direct	(1,903)	$ (46,244,221)	$ (87,057,684)	$ (74,587,539)
Indirect	279	$ 10,680,545	$ 16,675,788	$ 17,336,153
Induced	(296)	$ (16,745,317)	$ (29,490,579)	$ (52,757,913)
Total	(1,920)	$ (52,308,994)	$ (99,872,474)	$ (110,009,300)

All Commodities 26/27

Impact Type	Jobs	Labor Income	Value Added	Output
Direct	(1,103)	$ (18,862,778)	$ (35,916,000)	$ (10,533,113)
Indirect	366	$ 16,921,347	$ 26,531,397	$ 42,698,282
Induced	(17)	$ (933,249)	$ (1,588,757)	$ (2,816,663)
Total	(754)	$ (2,874,681)	$ (10,973,359)	$ 29,348,507

All Commodities 27/28

Impact Type	Jobs	Labor Income	Value Added	Output
Direct	(944)	$ (14,001,309)	$ (26,646,283)	$ (3,638,756)
Indirect	304	$ 14,184,318	$ 22,243,967	$ 37,111,160
Induced	1	$ 69,125	$ 170,399	$ 327,555
Total	(638)	$ 252,133	$ (4,231,916)	$ 33,799,959

All Commodities 28/29

Impact Type	Jobs	Labor Income	Value Added	Output
Direct	(688)	$ (7,148,236)	$ (13,761,384)	$ 21,905,295
Indirect	373	$ 18,692,206	$ 29,798,548	$ 56,284,046
Induced	95	$ 5,410,401	$ 9,600,638	$ 17,209,028
Total	(220)	$ 16,954,371	$ 25,637,803	$ 95,398,369

A.3. Iowa Impacts by Year for All Commodities by Scenario

Total Annual Iowa Economic Impacts in the All Years Scenario

All Commodities 20/21

Impact Type	Jobs	Labor Income	Value Added	Output
Direct	(609)	$ (21,266,107)	$ (49,141,155)	$ (147,930,584)
Indirect	(295)	$ (16,684,093)	$ (28,413,739)	$ (66,231,588)
Induced	(196)	$ (8,437,457)	$ (15,445,956)	$ (27,806,023)
Total	(1,100)	$ (46,387,658)	$ (93,000,851)	$ (241,968,195)

All Commodities 21/22

Impact Type	Jobs	Labor Income	Value Added	Output
Direct	(3,391)	$ (107,568,672)	$ (248,715,993)	$ (705,612,586)
Indirect	(1,265)	$ (75,858,297)	$ (127,822,341)	$ (309,352,124)
Induced	(947)	$ (40,789,880)	$ (74,666,134)	$ (134,418,797)
Total	(5,603)	$ (224,216,855)	$ (451,204,466)	$ (1,149,383,507)

All Commodities 22/23

Impact Type	Jobs	Labor Income	Value Added	Output
Direct	(7,172)	$ (228,613,149)	$ (526,538,530)	$ (1,463,246,321)
Indirect	(2,605)	$ (157,098,109)	$ (264,460,500)	$ (642,513,413)
Induced	(1,992)	$ (85,774,716)	$ (157,010,181)	$ (282,660,549)
Total	(11,768)	$ (471,485,987)	$ (948,009,209)	$ (2,388,420,284)

All Commodities 23/24

Impact Type	Jobs	Labor Income	Value Added	Output
Direct	(10,293)	$ (328,254,673)	$ (755,195,247)	$ (2,092,701,113)
Indirect	(3,743)	$ (225,521,712)	$ (379,738,111)	$ (922,342,911)
Induced	(2,860)	$ (123,148,536)	$ (225,423,156)	$ (405,822,035)
Total	(16,894)	$ (676,924,938)	$ (1,360,356,513)	$ (3,420,866,059)

All Commodities 24/25

Impact Type	Jobs	Labor Income	Value Added	Output
Direct	(11,801)	$ (376,671,825)	$ (866,335,840)	$ (2,396,749,645)
Indirect	(4,286)	$ (258,280,012)	$ (434,879,071)	$ (1,056,474,093)
Induced	(3,279)	$ (141,200,594)	$ (258,467,221)	$ (465,310,331)
Total	(19,364)	$ (776,152,451)	$ (1,559,682,132)	$ (3,918,534,069)

All Commodities 25/26

Impact Type	Jobs	Labor Income	Value Added	Output
Direct	(12,073)	$ (385,482,463)	$ (886,523,435)	$ (2,454,408,560)
Indirect	(4,399)	$ (264,855,004)	$ (446,031,441)	$ (1,082,999,270)
Induced	(3,358)	$ (144,621,520)	$ (264,729,553)	$ (476,583,976)
Total	(19,829)	$ (794,959,008)	$ (1,597,284,429)	$ (4,013,991,806)

All Commodities 26/27

Impact Type	Jobs	Labor Income	Value Added	Output
Direct	(12,448)	$ (397,528,417)	$ (914,344,602)	$ (2,532,994,070)
Indirect	(4,540)	$ (273,329,752)	$ (460,320,764)	$ (1,117,516,532)
Induced	(3,464)	$ (149,184,881)	$ (273,082,791)	$ (491,622,030)
Total	(20,452)	$ (820,043,070)	$ (1,647,748,158)	$ (4,142,132,633)

All Commodities 27/28

Impact Type	Jobs	Labor Income	Value Added	Output
Direct	(12,930)	$ (413,084,908)	$ (950,123,090)	$ (2,633,177,822)
Indirect	(4,724)	$ (284,257,641)	$ (478,761,923)	$ (1,161,988,365)
Induced	(3,601)	$ (155,074,240)	$ (283,863,396)	$ (511,029,905)
Total	(21,254)	$ (852,416,811)	$ (1,712,748,409)	$ (4,306,196,093)

All Commodities 28/29

Impact Type	Jobs	Labor Income	Value Added	Output
Direct	(13,428)	$ (429,223,560)	$ (987,209,761)	$ (2,735,375,532)
Indirect	(4,907)	$ (295,270,825)	$ (497,314,903)	$ (1,206,961,671)
Induced	(3,741)	$ (161,112,303)	$ (294,916,026)	$ (530,927,622)
Total	(22,076)	$ (885,606,711)	$ (1,779,440,690)	$ (4,473,264,825)

Total Annual Iowa Economic Impacts in the Two Year Only Scenario

All Commodities 20/21

Impact Type	Jobs	Labor Income	Value Added	Output
Direct	(606)	$ (21,051,161)	$ (48,501,390)	$ (144,502,029)
Indirect	(289)	$ (16,390,709)	$ (27,910,341)	$ (65,166,362)
Induced	(193)	$ (8,324,408)	$ (15,239,026)	$ (27,433,490)
Total	(1,089)	$ (45,766,279)	$ (91,650,756)	$ (237,101,882)

All Commodities 21/22

Impact Type	Jobs	Labor Income	Value Added	Output
Direct	(2,349)	$ (74,576,831)	$ (172,686,841)	$ (492,019,471)
Indirect	(884)	$ (52,904,659)	$ (89,177,326)	$ (215,593,227)
Induced	(658)	$ (28,349,310)	$ (51,893,336)	$ (93,421,911)
Total	(3,891)	$ (155,830,800)	$ (313,757,499)	$ (801,034,605)

All Commodities 22/23

Impact Type	Jobs	Labor Income	Value Added	Output
Direct	(3,581)	$ (113,158,296)	$ (261,224,743)	$ (730,500,908)
Indirect	(1,293)	$ (78,132,770)	$ (131,475,950)	$ (319,789,864)
Induced	(988)	$ (42,539,963)	$ (77,868,844)	$ (140,185,090)
Total	(5,862)	$ (233,831,028)	$ (470,569,531)	$ (1,190,475,856)

All Commodities 23/24

Impact Type	Jobs	Labor Income	Value Added	Output
Direct	(2,705)	$ (86,420,969)	$ (198,440,940)	$ (539,813,359)
Indirect	(947)	$ (57,588,136)	$ (96,788,425)	$ (236,469,170)
Induced	(744)	$ (32,025,817)	$ (58,622,467)	$ (105,536,635)
Total	(4,395)	$ (176,034,922)	$ (353,851,828)	$ (881,819,160)

All Commodities 24/25

Impact Type	Jobs	Labor Income	Value Added	Output
Direct	(1,075)	$ (33,692,591)	$ (77,227,361)	$ (203,605,680)
Indirect	(340)	$ (21,245,864)	$ (35,534,102)	$ (88,214,777)
Induced	(284)	$ (12,218,569)	$ (22,365,184)	$ (40,263,926)
Total	(1,699)	$ (67,157,023)	$ (135,126,645)	$ (332,084,382)

All Commodities 25/26

Impact Type	Jobs	Labor Income	Value Added	Output
Direct	(281)	$ (8,014,246)	$ (18,174,700)	$ (43,038,396)
Indirect	(61)	$ (4,250,218)	$ (6,974,368)	$ (18,457,382)
Induced	(63)	$ (2,728,086)	$ (4,993,295)	$ (8,989,584)
Total	(405)	$ (14,992,549)	$ (30,142,363)	$ (70,485,362)

All Commodities 26/27

Impact Type	Jobs	Labor Income	Value Added	Output
Direct	(128)	$ (3,129,014)	$ (7,064,759)	$ (13,766,175)
Indirect	(9)	$ (1,096,504)	$ (1,678,976)	$ (5,466,881)
Induced	(22)	$ (940,435)	$ (1,720,974)	$ (3,098,551)
Total	(159)	$ (5,165,953)	$ (10,464,708)	$ (22,331,607)

All Commodities 27/28

Impact Type	Jobs	Labor Income	Value Added	Output
Direct	(98)	$ (2,191,839)	$ (4,921,805)	$ (9,079,083)
Indirect	(4)	$ (703,134)	$ (1,046,982)	$ (3,698,805)
Induced	(15)	$ (644,310)	$ (1,179,071)	$ (2,122,876)
Total	(117)	$ (3,539,283)	$ (7,147,858)	$ (14,900,764)

All Commodities 28/29

Impact Type	Jobs	Labor Income	Value Added	Output
Direct	(64)	$ (1,175,713)	$ (2,595,590)	$ (2,635,432)
Indirect	7	$ (1,999)	$ 129,844	$ (806,121)
Induced	(6)	$ (262,482)	$ (480,100)	$ (864,564)
Total	(63)	$ (1,440,193)	$ (2,945,845)	$ (4,306,118)