UPDATED ESTIMATED ECONOMIC WELFARE IMPACTS OF PORCINE EPIDEMIC DIARRHEA VIRUS (PEDV)

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Abstract

Estimates of pig loss from Porcine Epidemic Diarrhea Virus (PEDv) determine changes in economic welfare. Hog and pork prices rise, so aggregate returns to hog growers increase. For a 3% annual pig loss, growers gain $1.2 billion annually, while for a 6% annual pig loss, the gain is $2.3 billion. Losses to infected growers are smaller than gains to uninfected growers. Annual returns to hog slaughter fall by $481 to $929 million. Retail value-added falls by $1.1 to $2.2 billion. Annual consumer surplus also declines from $300 to $600 million. The estimated net annual decrease for U.S. economic welfare from PEDv summed across all effects ranges from $900 million to $1.8 billion.

Keywords: Porcine Epidemic Diarrhea, PEDv, Economic Impacts

JEL Classification: Q1, Q13, Q11, Q18

Introduction

Porcine Epidemic Diarrhea Virus (PEDv) appeared in the United States during May 2013 with the number of operations on which the virus was detected reaching 199 sites in 13 states by the end of June (Huffstutter). During that period the weekly spread was 44-55 new cases per week (Meyer and Steiner). The virus continued to spread during the winter of 2013 and the spring of 2014. In May 2014 the number of cases was reported to have reached 6,421 (Grebner).

This analysis uses a simultaneous system of dynamic differential equations to estimate the national economic impacts of PEDv becoming endemic on commodity markets and economic welfare under alternative assumptions about disease behavior. The analysis considers how different assumptions of mortality and morbidity affect estimates of the national economic impacts on prices and measures of economic welfare along the supply chain.

The analysis begins with identifying critical potential drivers of economic impacts from PEDv. It discusses the assumptions used about the magnitudes and duration of the drivers. The magnitudes of the drivers for each quarter over the 5-year period from the first quarter of 2013 through the fourth quarter of 2018 are introduced into an economic sector model of U.S. agriculture. That model reports changes from a quarterly version of the USDA baseline for prices and market quantities. The changes in prices and quantities allow calculation of changes in measures of economic welfare. Changes relative to the baseline under alternative assumptions of mortality and spread are compared.

Critical Drivers of National Economic Impacts

This analysis considers the economic impacts at a national level rather than the impacts on individual hog growers. That is, it focuses on the impacts on prices, quantities produced and consumed, and on economic welfare along the supply chain. Critical potential drivers at a national level include the consumer response to PEDv, the response by trading partners, animal mortality, animal morbidity, and the cost of any disease prevention measures adopted by hog growers.

Consumer Response

One potential driver of the economic impacts is the response by U.S. consumers to a PEDv event. Pork produced from hogs that have had PEDv is safe for human consumption (University of Minnesota). At present, news of the PEDv spread has appeared extensively in the agriculture press but has received less attention by major national media, and there has been no noticeable effect on consumer demand for pork. The assumption in this analysis is that there is no demand reduction and the only demand effects are consumer responses to price changes due to PEDv.

Trading Partner Response

Examining live animal trade first, four nations report trade restrictions on U.S. hog exports because of PEDv. Mexico restricted imports of U.S. hogs on a case by case basis because of PEDv starting in June 2013 (Reuters, June 26, 2013). Japan banned swine imports from the United States in April 2014, while France did the same in May 2014. And in April 2014, China banned imports pending a testing protocol (Swineweb).

This analysis separates swine into market animals and breeding animals. The economic model considers live swine Not Elsewhere Specified or Included (NESOI) weighing less than 50kg as feeder pigs and live swine NESOI weighing over 50kg as market ready hogs. The impact on swine for breeding is done outside of the market model.

For the live swine NESOI weighing less than 50kg category U.S. export data for 2012 report total U.S. exports to all destinations of 2,664 head (U.S. International Trade Commission (USITC) trade dataweb). U.S. exports of swine weighing more than 50kg in 2012 were 3,176 head. France has not imported live swine NESOI weighing 50kg or more from the United States since before January 2000. Since January 2000 France imported live swine (NESOI) less than 50kg in weight in only two months, February 2008 and November 2009. China has been a sporadic importer of live swine from the United States in these categories. Export data show U.S. sales of live swine NESOI weighing less than 50kg in four months since January 2000: September 2008; January and April of 2009; and September 2010. China imported live swine NESOI weighing 50kg or more in seven months since January 2000: January and February 2007; March 2010; June, July, August, and November of 2011. Japan imported live swine NESOI weighing less than 50kg in two months since January 2000: November 2000 and March 2010. In most years since 2000 Japan imported live swine NESOI weighing 50kg or more twice per year. The usual pattern consists of imports sometime between January and May and again during the October to December period. The most recent imports occurred in October and November 2013. Since January 2000 Mexico imported live swine NESOI weighing less than 50kg in a few months each year. U.S. export data for 2012 show Mexico imported 139 head spread over 4 months (U.S. International Trade Commission (USITC) trade dataweb). In 2013, prior to the trade ban in June, Mexico imported no live swine weighing less than 50kg from the United

States. From January 2000 through May 2008 Mexico imported swine NESOI weighing more than 50kg in most months. After that date trade became less frequent. In 2012, 52 head were shipped

To put these numbers in perspective, the annual U.S. pig crop in 2012 was 116.7 million. U.S. exports of live swine NESOI to all destinations of 5,840 animals are so tiny compared to U.S. production and slaughter that no trade shocks for market swine are included in the analysis.

Exports of breeding swine by United States are larger and more consistent. During 2012 the United States exported 49,219 head of breeding swine. Mexico imported 26,602 head and China imported 12,535 head. Japan obtained 418 head. France did not import breeding swine from the United States in 2012 and has done so in only two months since January 2000 with the most recent being November 2009.

In contrast to live animals, the current state of knowledge suggests that PEDv is not transmitted in pork, so exports of U.S. pork and pork products should not be affected by the outbreak. Mexico did not restrict imports of U.S. pork. Other large importers of U.S. pork also continued to import from the United States. Thus, the assumption in this analysis is that pork exports from the United States will not be restricted because of PEDv.

Mortality

One critical driver of the economic impacts is mortality. PEDv primarily affects small pigs with mortality estimates ranging from 50% to 100% on infected operations (University of Minnesota). Older hogs experience morbidity but recover. Thus, the analysis requires assumptions about the loss of pigs.

The process begins with alternative assumptions about PEDv spread. The initial assumption is that PEDv becomes endemic for 23 quarters equivalent to the time period from the second quarter of 2013 through the fourth quarter of 2018. Because the disease kills newly born pigs, monthly pigs per litter data reported by Livestock Marketing Information Center (LMIC) are considered as a measure of the PEDv-induced loss. That data suggests a 2013 fourth quarter pig loss of 1.7% and a 2014 first quarter pig loss of 6%. A limitation with this method is that all of the decrease in pigs per litter is attributed to PEDv. However, the weather for the first quarter of 2014 in the Midwest was unusually cold and snowy with short liquid propane supplies and high liquid propane prices. Data from other years with severe winter weather in the late 1970s and early 1980s show decreases in pigs per litter during the December to May months of 1 to 3% (NASS, *Agricultural Statistics*). Another problem with using the change in pigs per litter is that the data indicate increases in the second and third quarters of 2013 compared to earlier years. The values for May and August 2013, 10.38 pigs per litter, are the highest values recorded. The values for June and July are just slightly lower but still above those for earlier years. Thus, calculating pig losses from the pig per litter data does not work for those two initial quarters so the losses are calculated based on the number of cases reported in the press.

The endemic steady state pig loss is based on the pig per litter data and ranges from 3% to 6%. The 6% pig loss treats the loss observed during January and February 2014 as the steady state loss for the remainder of the period. The lower 3% steady state pig loss represents a situation where the harsh weather in the Midwest compounded the decline in pigs per litter.

Because the economic model solves for quarterly logarithmic derivatives, dlnX or dX/X, and applies those results to a baseline, the absolute numbers of pigs lost must be converted to changes. That is accomplished by dividing the quarterly pig losses by the baseline national pig crop in each quarter. Those changes are reported in Table 1.

Morbidity

Older hogs are affected by PEDv but usually survive after going off feed which means delayed marketing. Industry analysts expect any delay in marketing to be slight (Meyer and Steiner). This analysis assumes that two weeks are lost, so that additional feed is required and additional feed costs are incurred.

Determination of the additional feed required by a morbid market hog means combining the number of cases of PEDv with estimated feed use of coarse grains, wheat, and protein meal per animal per farm. The economic model assumes uninfected market hogs are on feed for 155 days and use 671 pounds of feed per market animal or 4.33 pounds per hog per day over the time on feed. Because the economic model is quarterly, market hogs are separated into lighter grower hogs and heavier finisher hogs. Finisher hogs use more feed per day than do the grower hogs. It is assumed that each type of hog is equally likely to become sick so the average feed use per day per hog over the full production cycle is used to calculate the added feed needed for two weeks – 60.61 pounds of feed per infected market hog.

The number of market hogs that are morbid and require more feed is linked to the assumed steady state pig loss described above. Each morbid hog uses an additional 60.61 pounds of feed. The added feed used by all morbid hogs is converted to a logarithmic change in total U.S. feed use by dividing by total feed use for market hogs (Table 2). That shock to total feed use is introduced into the quarterly economic model's differential equations for the demands for soybean meal, wheat, and coarse grains. This methodology assumes that the mixture of feedstuffs in feed rations is not directly changed by PEDv, but use of individual feedstuffs in the model does respond to changes in relative feed ingredient prices.

Economic Model Structure

The Paarlberg et al. (2008) economic model of the U.S. livestock and feed sectors is used in this study to estimate the economic consequences associated with outbreak of PEDv. The model is designed to capture the effects of PEDv horizontally across commodities at the same point in the supply chain and vertically along the supply chain. The model includes the major livestock products, livestock, and feed crops for the United States. It is solved quarterly relative to observed data through 2013, to LMIC projections for meat through 2015, and to a quarterly version the USDA baseline released in the spring of 2014 created using seasonal adjustment factors for 2014 through 2018. Thus, the effects of PEDv may be partially included in the baseline values so results are reported as differences from baseline values.

The economic model is a system of several sets of dynamic differential equations describing logarithmic changes in endogenous variables such as the price of pork or the number of hogs slaughtered from benchmarked levels given shocks in exogenous variables. One set of differential equations relate a 11 x 1 column vector of changes in consumption, dln$\mathbf{C}$, for final goods to a 11 x 1 column vector of logarithmic changes in final goods prices, dln$\mathbf{P}$, via a 11 x 11 matrix of demand elasticities, $\boldsymbol{\varepsilon}$: dln$\mathbf{C} = \boldsymbol{\varepsilon}dln\mathbf{P}$. For the 11 final goods and soybeans there are zero profit conditions where perfectly competitive industries allocate changes in unit revenue (price) to determine changes in input costs, dln$\mathbf{W}$, according to a 39 x 11 matrix of unit revenue shares, $\boldsymbol{\theta}$: dln$\mathbf{P}$ = $\boldsymbol{\theta}$dln$\mathbf{W}$.

There are five types of inputs for which changes in derived demands must be specified.

The general form for the change in derived demand, dln**D**, links that change to the change in output, dln**Q**, via a matrix of changes in per unit input use, dln**A**: dln**D** = dln**A+** dln**Q**. One input type is obtained from the rest of the economy at exogenous prices, for example hired labor and fuel. The second type is sector specific capital stocks such as buildings, equipment, and human capital. The third type is species specific livestock which become meats. The fourth type describes species specific uses of feedstuffs like soybean meal and feed grains. Finally, because PEDv can affect feed use, the model includes crop land which is allocated among crops to equalize its expected return prior to the cropping season. Using the definition of the Morishima elasticities of substitution and envelop properties, the changes in per unit input demands, dln**A**, are the product of a matrix of unit revenue shares, $\boldsymbol{\beta}$, a matrix of substitution elasticities, $\boldsymbol{\sigma}$, and input prices, **W**: dln**A**= $\boldsymbol{\beta\sigma}$dln**W**.

Imports of commodities from the United States are determined by differentials of excess demand expressions of the form: dln**M** = $\boldsymbol{\eta}$[dln**P**, dln**W**] where $\boldsymbol{\eta}$ is a 17 x 17 matrix of excess demand elasticities. Because some commodities are only traded as intermediates the price vector is shown as partitioned between final price, **P**, and intermediate input prices, **W**. Because PEDv can affect other livestock sectors the model includes those products. Outputs of cattle, hogs, and lambs result from the decisions to hold breeding animals and the decision to breed. Breeding inventory for cattle, hogs, and sheep at a point in time depends on the difference between the expected future return to a bred animal and its salvage value relative to the current cull price. Quarterly production of chicken, eggs, and milk are determined as a continuous flow of output based on the output value relative to feed and other costs. Output of turkey is determined in the same manner but has a 1 quarter lag to reflect the time required to produce a turkey. The remaining equations are market clearing identities. Exports are the difference between supply (beginning stocks and production) and demand determined from the demands for final goods, for intermediate input use, and ending stocks. Markets clear where exports equal imports. The model provides percent changes in prices, quantities, and economic welfare.

Numerical Results for Market Hogs and Pork

Initial scenarios consider alternative pig mortality rates ranging from an annual pig mortality of 3% to annual mortality of 6%. Market hog morbidity consistent with those rates is also included. Calculated pig mortality for 2013 quarters 2-4 are common across both scenarios. The pig loss of 6% in 2014 quarter 1 matches the observed change in pigs per litter. The lower 2014 quarter 1 pig loss of 3% allows for effects of the unusually severe January to April weather.

Market Hog Impacts

Figures 1, 2, and 3 capture the effects on market prices, breeding inventory, and slaughter. The changes in prices and slaughter are mirror images of each other. In Figure 1 carcass hog prices increase relative to the baseline while Figure 3 shows hog slaughter falling relative to the baseline. The initial effects are small because few farms are infected. The model determines prices in a quarter based upon hogs coming to market in that quarter and packer demand. It does not allow market participants to include expectations of future anticipated supply disruptions in market price determination. Since market ready hogs are not affected and few pigs are lost in the second and third quarter of 2013, there is little initial price impact. As PEDv spreads hog slaughter contracts more and prices rise sharply. In each scenario prices peak and then trend downward while slaughter falls sharply and then begins to rise. These patterns arise from changes in breeding inventory (Figure 2). The model relies on naïve price expectation where producers expect last quarter's price to prevail in the future. Increased hog prices increase the incentive to boost breeding inventory and that effect begins to appear in quarter 5 or spring 2014 and becomes larger as hog prices increase. The steady state change is reached in the third quarter of 2016. Increased breeding inventory partially offsets the loss in pigs, so slaughter partially recovers during 2014 before reaching its steady state reduction.

Another clear pattern in Figures 1, 2, and 3 is the difference between the endemic situations. The 3% annual pig loss event shows steady state price increases compared to the baseline of around \$5 per cwt with the largest price increase being \$8 per cwt in the third quarter of 2014 – quarter 7. For the 6% pig loss outbreak, the steady state price increase is around \$10 per cwt with the largest increase in the U.S. carcass price being \$17 per cwt above the baseline in quarter 7 – July-September 2014.

Changes in economic welfare for hog producers are measured as the change in quarterly returns to capital and management for market hogs compared to the baseline or changes in sales value less changes in variable costs. These changes are shown in Figure 4. The virus is effectively a supply reduction program and with inelastic demand for hog slaughter means the percent increase in hog prices dominates the percent decrease in slaughter. Thus, total returns to capital and management for hog growers rise. The pattern mimics the price change with the greatest increases occurring in 2014 before the breeding inventory changes much. For the 3% annual pig loss scenario, the increases in quarterly steady state returns fluctuate around \$300 million with the largest quarterly increase above the baseline being nearly \$400 million in the third quarter of 2014. For the 6% pig loss scenario, the quarterly increases in returns to capital and management for hog growers range around \$600 million with the largest quarterly increase at nearly \$800 million in the third quarter of 2014.

The overall increase in returns to capital and management for hog growers disguises the distribution of gains and losses among growers. Figures 5 and 6 split the changes in hog grower returns between the return on a hog that survives and is sold at market and the forgone return from a pig lost to PEDv. These figures show a clear separation between the returns to hog growers with PEDv and those who do not get PEDv. In the 3% pig loss scenario, the increase in per hog return for market hogs sold ranges from $5-$6 per cwt with the largest increase being $8.20 per cwt (Figure 5). The per hog return forgone for animals lost to PEDv varies around $40 per cwt with the largest quarterly loss being over $46 per cwt. Larger pig losses (6% pig loss) increase the disparity because those with PEDv experience a greater loss in pigs and market forces increase the per cwt return to growers who have market hogs. Uninfected growers experience gains of $10 to $13 per cwt in returns per hog sold in most quarters with the greatest increase being $16 per cwt (Figure 6). Under the 6% pig loss scenario, the forgone returns from lost pigs range from $41 to $47 per cwt with the largest forgone returns at $55 per cwt.

Breeding Swine Exports

As discussed above four nations changed import rules for swine imported from the United States. The extent to which these changes adversely affected U.S. swine breeding exports is hard to determine. Breeding swine export values are highly volatile with even consistent buyers like Mexico and China showing no purchases in many months (USITC). Monthly U.S. breeding swine export values are summed to annual values to remove monthly volatility yet still exhibit much volatility (Table 3).

One conclusion from Table 3 is that the restrictions imposed by France do not represent a loss in U.S. export value. Since 2000 France imported breeding swine from the United States only in 2008 and 2009. Those shipments were small with the 2008 value being $18,000 and the 2009 trade at $28,000.

Japan has been a consistent importer of breeding swine since 2000. The largest imports of breeding swine from the United States valued at $500,000 occurred in 2004. The years 2007 and 2011 show no Japanese imports of U.S. breeding swine (Table 3). The import values in most other years are $200,000 - $300,000 with the recent years averaging $200,000. But in some months of each year Japan imports swine NESOI weighing 50 kg or greater that are not classified as breeding swine. These export values range between a low of $4,000 in 2009 and a high of $431,000 in 2001 (USITC) with the most recent years reporting export values of $43,000 to $179,000. The infrequency of this trade suggests these could be breeding animals. However, the export unit values for the live swine weighing 50kg or more are $136 per head whereas the export unit values for swine listed as for breeding are $500 per head. It is not possible to say for sure if the live swine NESOI weighing 50kg or more are breeding swine. Thus, the estimated lost U.S. swine export value because of the restriction imposed by Japan is set at $200,000.

In contrast, China has been a consistent buyer of U.S. breeding swine. The data in Table 3 combine China and Hong Kong. Since 2000 the smallest value of import of U.S. breeding swine is $7,000 in 2011. The greatest value occurs in 2013 at $19.8 million. Chinese purchases of breeding swine in excess of $5 million only occurred twice since 2000 with imports most years valued in the $1 million to $4 million range (Table 3). Thus, the value of $5 million is used as an estimated annual loss in sales of breeding swine to China.

Mexico is also a consistent buyer of U.S. breeding swine. The Mexican situation is different because that nation did not ban imports but only allowed imports of breeding swine on a case by case basis starting in June 2013. Monthly data for June shows a decline from May but the value of $44,000 is not inconsistent with the values in some months in earlier years. Indeed, no U.S. breeding swine went to Mexico in July 2012. July through November 2013 data report no U.S. breeding swine exports but the December 2013 value is $820,000 (USITC). Exports in January and February of 2014 are $87,000 and $89,000, respectively, with exports in March 2014 falling to $24,000. The annual data in Table 3 give a U.S. breeding swine export value for trade with Mexico in 2013 as $2.8 million. While that value is lower than the $6.4 million reported for 2012, it is greater than any other export value since 2002. With only July through November 2013 showing no trade and the annual value for 2013 being the third highest since 2000, there is little evidence in the data to support a conclusion of lost U.S. exports of breeding swine to Mexico.

To summarize, there is little evidence of lost U.S. breeding swine exports in 2013 when only Mexico reacted to the U.S. PEDv. For 2014 and beyond the lost value of U.S. breeding swine exports to Japan is estimated at $200,000. The 2014 lost export value on sales of breeding swine to China depends on whether or not an acceptable testing protocol is introduced. If a protocol is not implemented, the estimated annual loss is $5 million.

Pork Market Impacts

The above changes in the hog market impact the pork market. Figure 7 depicts the changes in retail pork prices. The patterns match those in Figure 1 but the magnitudes of retail price changes are smaller. Thus, margins are squeezed as the price shock moves upward through the supply chain.

Increasing prices for hogs and lower slaughter reduce returns to capital and management on hog slaughter (Figure 8). For the scenario where PEDv pig loss is 3%, quarterly returns to hog slaughter are about $120 million lower in most quarters with the largest quarterly loss at $155 million. For the scenarios where the annualized pig loss is 6%, the quarterly decline in returns to capital and management to U.S. hog slaughter ranges from $230 million to over $300 million.

The loss to hog slaughter is measured using the cutout value. In addition there is the return to capital and management to processors and retailers for supplying pork to consumers. This is measured as the change in the difference between the retail value of pork production and the cutout value – retail value-added. Changes in those returns relative to the baseline values are reported in Figure 9. The patterns mirror those in Figure 8 but the magnitude of changes are larger. For the 3% annual pig loss, an additional $260 to over $300 million decline in returns is incurred each quarter when the pork is moved to retail sale. The quarterly declines in returns to pork processing and retailing in the 6% annual pig loss scenario ranges in most quarters between $510 million and $600 million with a maximum quarterly loss of almost $800 million.

Consumer Welfare

The economic welfare of consumers is measured as consumer surplus which is the difference between the price the consumer is willing to pay and the price the consumer must pay for each unit consumed. The willingness to pay for a unit of consumption is determined by the demand schedule since each point on the demand represents the relative marginal utility of that quantity of consumption. Annual changes in consumer surplus for all livestock products and crops included in the model are analyzed because the quarterly cycle reflects seasonal crop price movements. In the 3% pig loss scenario the average annual loss in consumer surplus for all commodities once the steady state loss is reached is $309 million. Since some commodities like grains experience price declines via reduced feeding, the loss in consumer surplus for pork alone is greater with an annual average of $557 million. The larger price increases for pork when the annualized loss of pigs is 6% translate into larger losses in consumer surplus. In that scenario, annual average consumer surplus for all commodities falls by $598 million. Again the annual average decline in consumer surplus for pork alone is greater at -$1.1 billion.

The average annual changes in economic welfare along the pork supply chain from hog growers to pork consumers for the steady state pig losses are given in Figures 10 and 11. Both figures indicate increased economic welfare for hog growers in aggregate and losses in economic welfare for hog slaughter, processing and retail, and consumers. For the 3% annual pig loss, average annual returns to hog growers are $1.2 billion greater. The average annual return to hog slaughter is $481 million lower. Retail value-added falls by an average of $1.1 billion, and consumer surplus averages $556 million lower. For the scenario with an average annual pig loss of 6% the changes in economic welfare are greater. The annual average return to hog growers rises by $2.3 billion. The annual average return to hog slaughter is $929 million lower. Retail value-added falls $2.2 billion and consumer surplus for consumers of pork is $1.1 billion lower.

Effects on Other Agricultural Sectors

The model calculates the spillover effects to other sectors. One source of spillover effects occurs through demand substitution. Higher pork prices cause consumers to shift purchases to other commodities which increase prices for those goods. The estimated cross elasticities used in the model are small so these effects are small. Another source of spillover effects occurs through feed markets. Producers of livestock products other than pork are affected by changes in feed prices. Producers of crops experience conflicting effects. They gain from the increase in feed use because morbid hogs are on feed longer, but lose from lower feed use as pigs die before going on feed. Changes in the 2014 U.S. farm bill affect the changes in crop producer welfare. That legislation allows producers of program crops to sign up for either the Price Loss Coverage (PLC) program or the Agricultural Risk Coverage (ARC) program. At the time of this analysis no sign up data is available so the ARC sign up is assumed to match the ACRE participation under the 2008 legislation. Since baseline prices for program crops are close to the PLC reference prices, the 2014 program instruments dampen the producer welfare loss at taxpayer expense.

Tables 4 and 5 give the annual changes from baseline in returns to capital and management for all production sectors included in the model. Most of the spillover effects beyond the hog and pork sectors are estimated to be small. Coarse grain and forage show the largest declines. Thus, the effect on feed demands from the loss of pigs dominates the morbidity effects of hogs being on feed two weeks longer. Prices for soybean meal, soybeans, coarse grains, and wheat fall. Lower prices for coarse grains, wheat, and soybeans trigger sympathetic declines in forage and rice prices. Returns to soybean growers are supported by area shifts and the influence the soybean oil price plays via the crushing margin. In the scenario with the 3% annual pig loss, annual declines in returns for crop producers compared to the baseline exceed \$100 million (Table 4). Lower crop prices mean reduced demand for land so annual land rent losses are \$70 million. That loss is felt by cropland owners. In the high pig loss scenario, declines in annual crop returns relative to baseline returns are over \$200 million (Table 5). Payments to land owners are slightly less than \$150 million lower than in the baseline.

Animal and animal product sectors show mixed changes in economic welfare. One source of gains is spillover effects from lower feed costs. The impact on changes in returns differs according to the ability of producers to react to feed cost changes. Beef and beef cattle show the largest positive spillover effects but even in the high pig loss scenario the gains are small compared to baseline values. Lamb growers also experience small gains. Other producers are able to react to lower feed costs and boost production quicker so quarterly returns fluctuate between increases and decreases. The milk and dairy sectors show the greatest decline in returns compared to the baseline. Lower feed costs, especially for forage, induce increased milk production. With inelastic milk demand the resulting price decline exceeds the production increase. Again relative to the baseline value, the changes are small with the largest quarterly change being 0.17% in the 6% pig loss scenario.

Tables 4 and 5 give the annual total producer economic welfare change compared to the baseline for all of the production sectors. Those changes can be combined with the change in economic welfare for consumers to give the net impact on the United States. In total U.S. producers, including packing, processing, and retailing, lose economic welfare. For the 3% annual pig loss scenario, once the steady state is reached, the declines in annual producer returns are just over $600 million, while for the 6% annual pig loss the declines in annual returns are around $1.2 billion. Adding in the lost consumer surplus increases the national losses. For the 3% annual pig loss scenario, the annual average steady state decline in U.S. economic welfare compared to the baseline is just over $900 million. For the 6%scenario, the annual average steady state decline rises to $1.8 billion.

Conclusions

During May and June 2013 Porcine Epidemic Diarrhea Virus (PEDv) appeared in the United States. It has continued to spread through the U.S. hog population. This analysis assumes two alternative magnitudes of pig mortality based on reported cases in order to estimate a range of changes in economic welfare along the hog and pork supply chain. The economic model used is a system of dynamic, differential equations for the U.S. agricultural sector that determine changes from a baseline solution of no PEDv.

If U.S. pork exports are not disrupted, the mortality loss of pigs and the morbidity effects for market hogs raise the prices for hogs and pork. Higher prices for hogs mean increased returns to capital and management for hog growers in aggregate. With a 3% steady state pig loss, hog growers gain $1.2 billion annually and with a 6% steady state annual pig loss the gain is $2.3 billion. Within that aggregate group of hog growers, those growers with hogs to sell benefit from the higher prices while growers infected by PEDv experience losses. Hog slaughter firms, pork processors, and retailers experience lower returns to capital and management. Annual steady state returns to hog slaughter fall by $481 million in the 3% annual pig loss scenario and by $929 million in the 6% annual pig loss scenario. The value-added for bringing pork to retail also falls by $1.1 billion with the 3% pig loss and $2.2 billion with the 6% pig loss.

Consumers experience a loss in economic welfare from higher prices. For pork the annual steady state declines in consumer surplus average $557 million for the 3% annual pig loss scenario and $1.1 billion for the 6% annual pig loss scenario. Since prices for other commodities like coarse grains fall total losses in consumer surplus are smaller than those incurred for pork.

The average annual steady state consumer surplus decline for the 3% pig loss scenario is just over $300 million and is just under $600 million for the 6% annual pig loss scenario.

For the United States as a whole the PEDv outbreak causes a decline in national economic welfare. For the 3% annual pig loss scenario, the annual average steady state decline in U.S. economic welfare compared to the baseline is just over $900 million. For the 6% scenario, the annual average steady state decline rises to $1.8 billion.

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Table 1: Calculated Quarterly Loss in Pig Crop resulting from PEDv

		Decrease in Pig Crop	
Year	Quarter	3%	6%
		dlnX	dlnX
2013	I	0	0
	II	-0.001	-0.001
	III	-0.009	-0.009
	IV	-0.017	-0.017
2014-2018	I	-0.03	-0.06
	II	-0.03	-0.06
	III	-0.03	-0.06
	IV	-0.03	-0.06

Table 2: Calculated Increased Feed Use because of Morbidity induced by PEDv

		Decrease in Pig Crop	
Year	Quarter	3%	6%
		dlnX	dlnX
2013	I	0	0
	II	0.00017	0.00017
	III	0.0016	0.0016
	IV	0.00306	0.00306
2014-2018	I	0.0054	0.0108
	II	0.0054	0.0108
	III	0.0054	0.0108
	IV	0.0054	0.0108

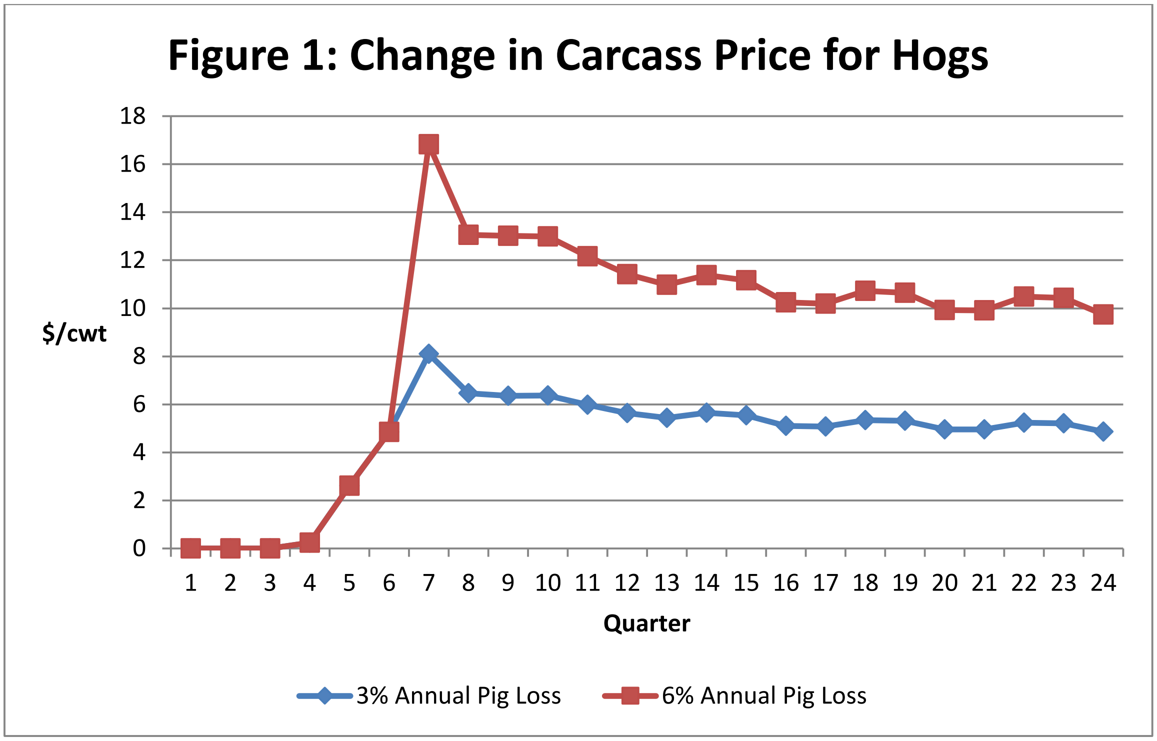

Figure 1: Change in Carcass Price for Hogs
$/cwt
18
16
14
12
10
8
6
4
2
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Quarter
3% Annual Pig Loss
6% Annual Pig Loss

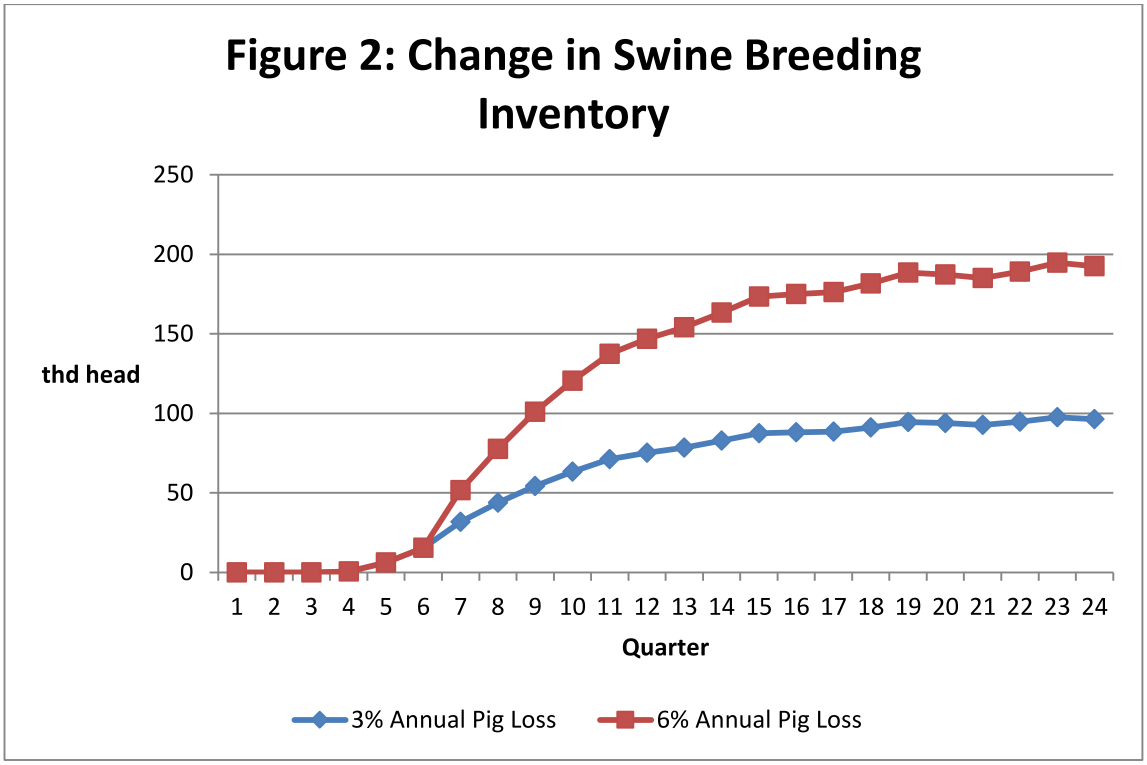
Figure 2: Change in Swine Breeding Inventory
250
200
150
100
50
0
thd head
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Quarter
3% Annual Pig Loss
6% Annual Pig Loss

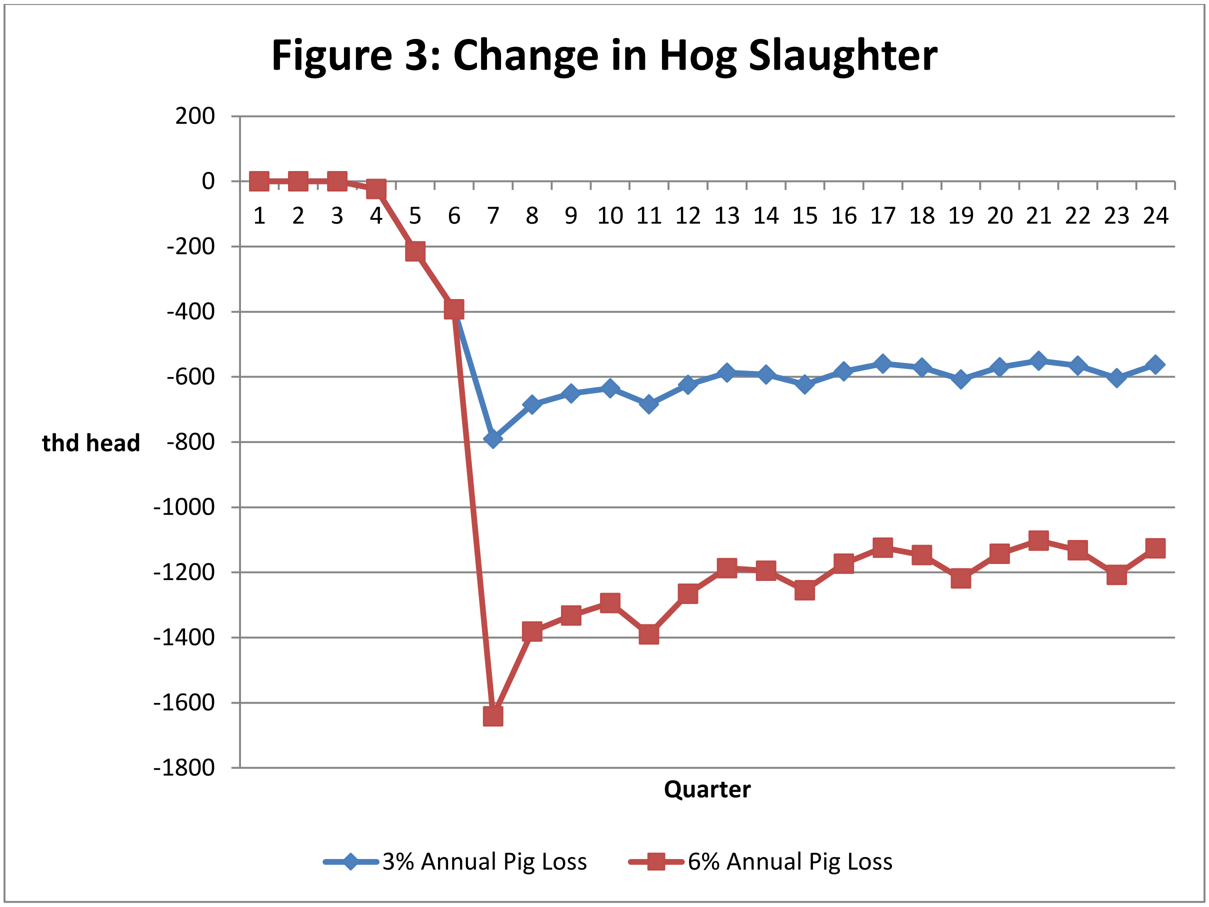
Figure 3: Change in Hog Slaughter
200
0
-200
-400
-600
-800
-1000
-1200
-1400
-1600
-1800
thd head
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Quarter
3% Annual Pig Loss
6% Annual Pig Loss

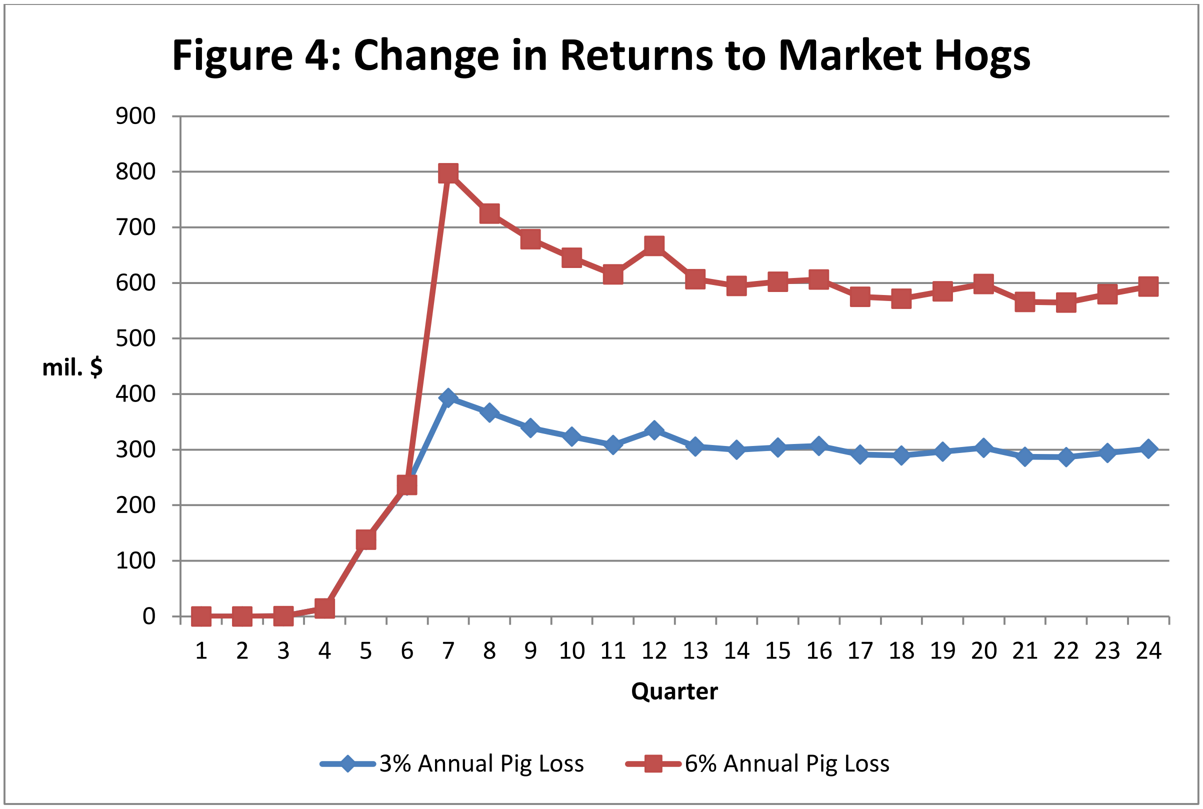
Figure 4: Change in Returns to Market Hogs
mil. $
900
800
700
600
500
400
300
200
100
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Quarter
3% Annual Pig Loss
6% Annual Pig Loss

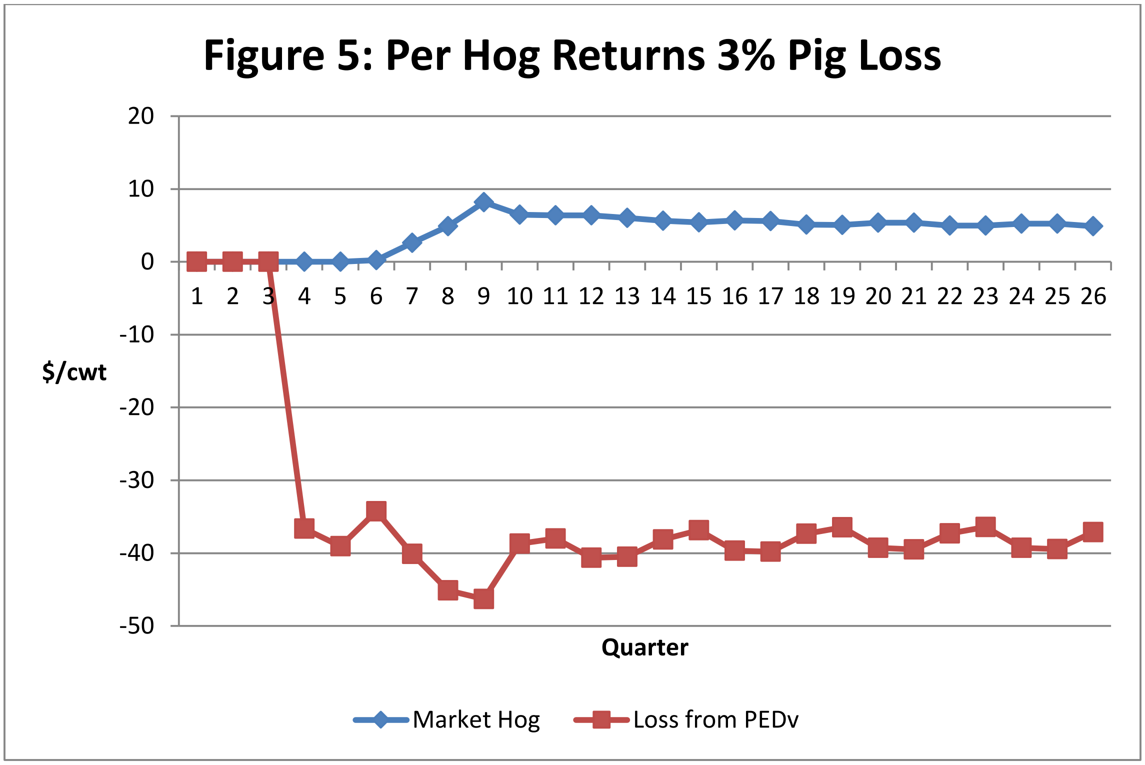
Figure 5: Per Hog Returns 3% Pig Loss
20
10
0
-10
-20
-30
-40
-50
$/cwt
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
Quarter
Market Hog
Loss from PEDv

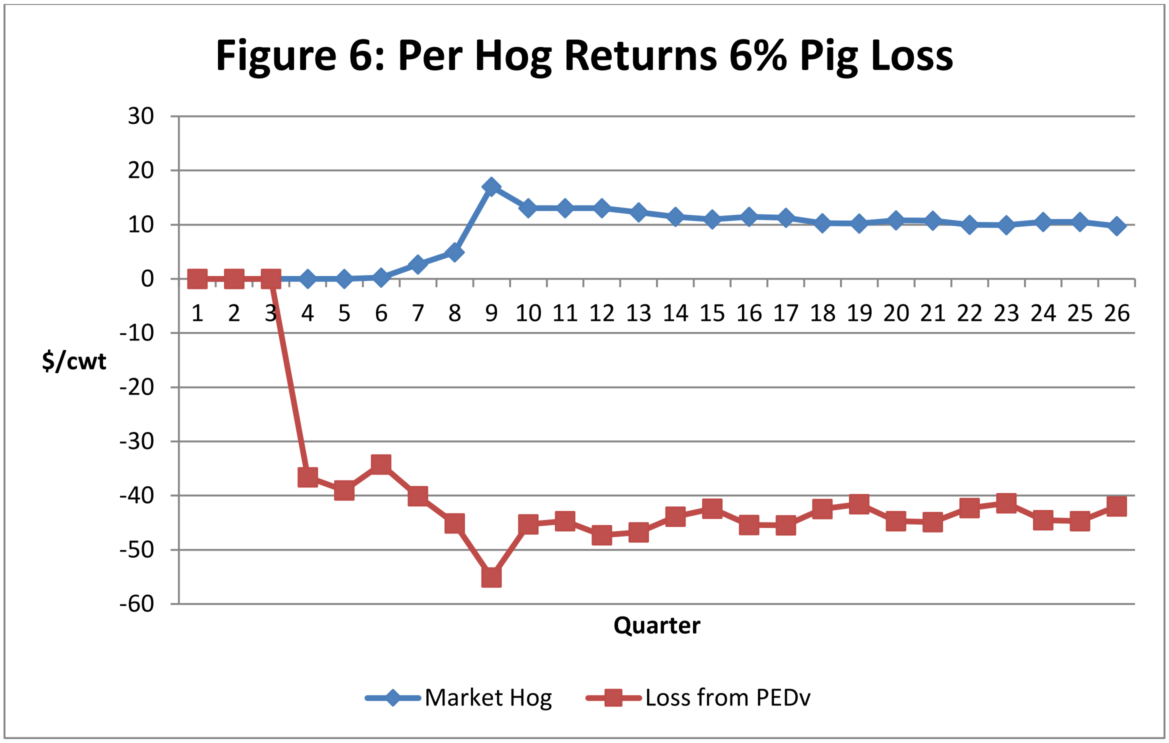

Figure 6: Per Hog Returns 6% Pig Loss
30
20
10
0
-10
-20
-30
-40
-50
-60
$/cwt
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
Quarter
Market Hog
Loss from PEDv

Table 3: Annual Value of Breeding Swine Exports to Mexico, China, Japan, and France

Year	Mexico	China	Japan	France
		-- thd dollars --		
2000	1847	1534	259	0
2001	2782	608	172	0
2002	19440	2630	440	0
2003	525	3626	174	0
2004	2230	3694	504	0
2005	548	4654	330	0
2006	915	3247	399	0
2007	948	2913	0	0
2008	415	13084	262	18
2009	948	4375	384	29
2010	1950	1216	203	0
2011	2488	7	0	0
2012	6366	1712	209	0
2013	2826	19794	179	0

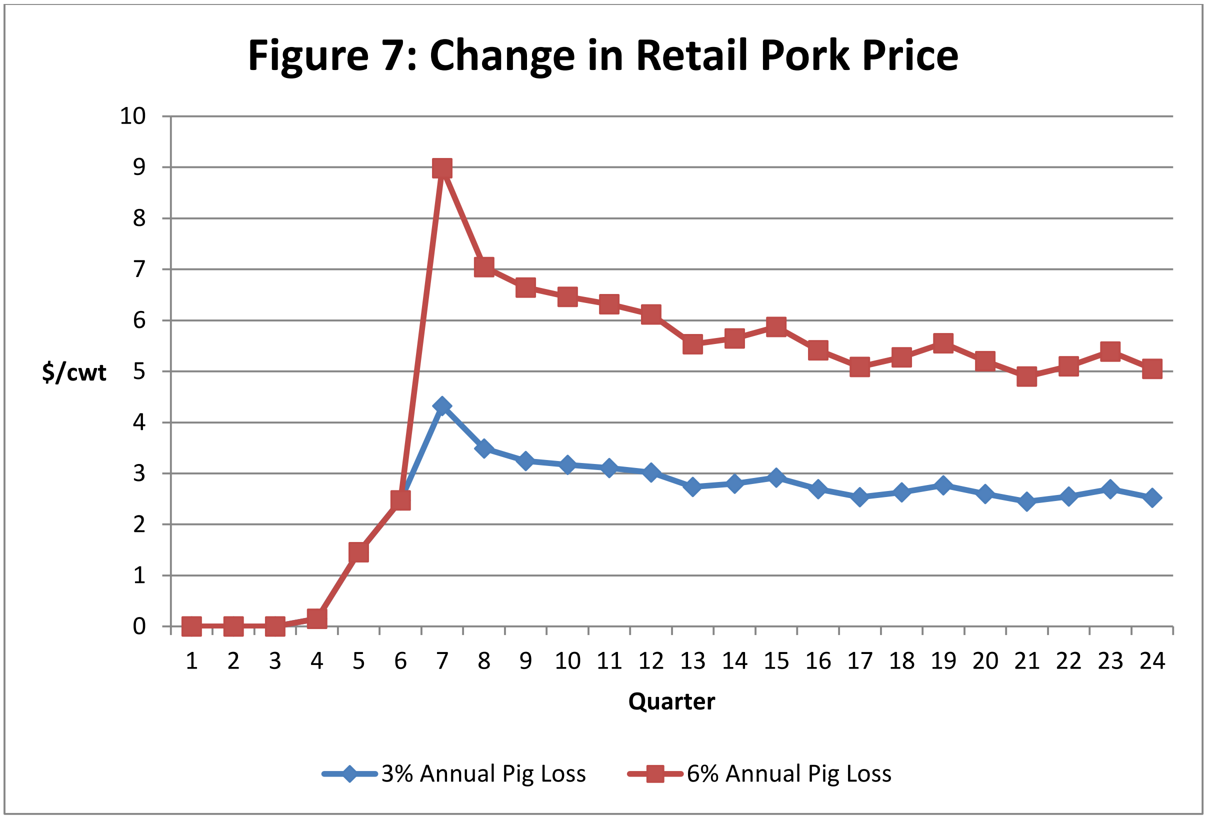
Figure 7: Change in Retail Pork Price
$/cwt
10
9
8
7
6
5
4
3
2
1
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Quarter
3% Annual Pig Loss
6% Annual Pig Loss

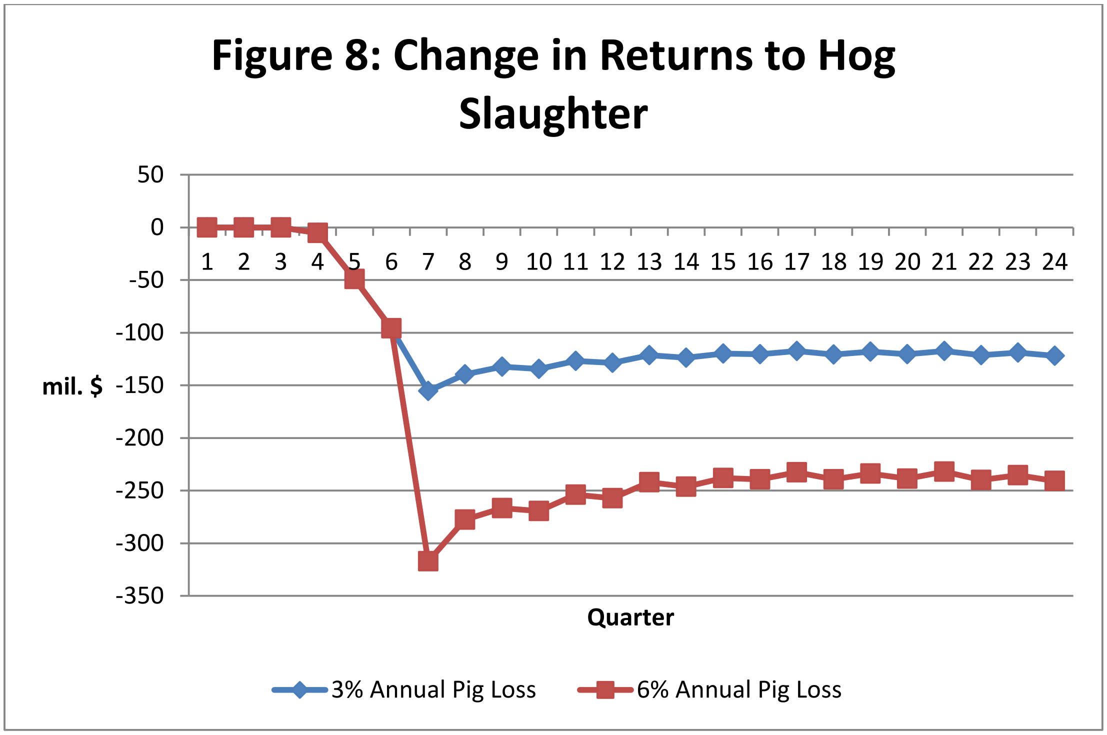
Figure 8: Change in Returns to Hog Slaughter
50
0
-50
-100
-150
-200
-250
-300
-350
mil. $
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Quarter
3% Annual Pig Loss
6% Annual Pig Loss

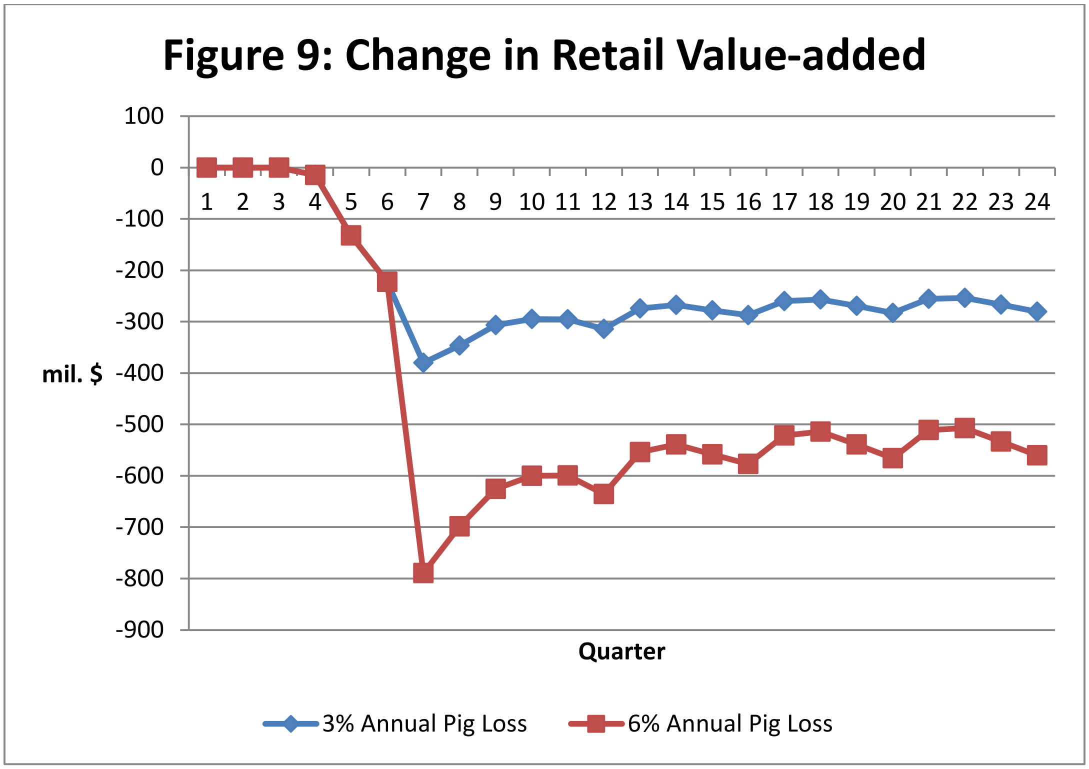
Figure 9: Change in Retail Value-added
mil. $
100
0
-100
-200
-300
-400
-500
-600
-700
-800
-900
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Quarter
3% Annual Pig Loss
6% Annual Pig Loss

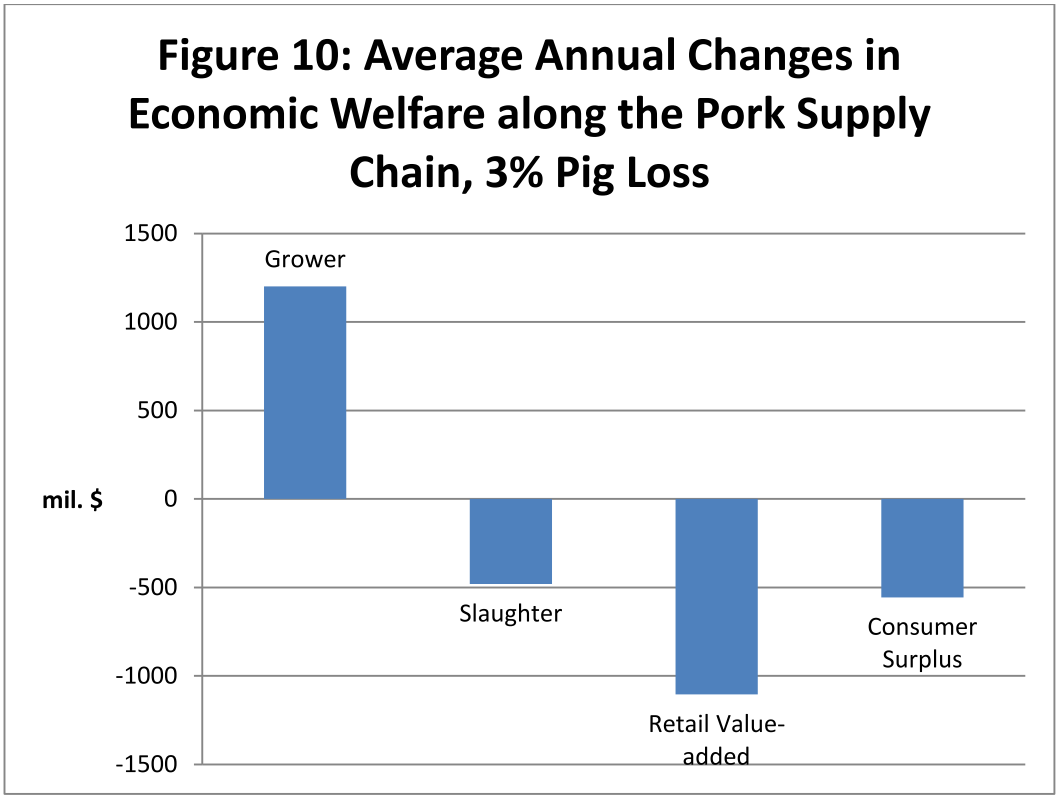
Figure 10: Average Annual Changes in Economic Welfare along the Pork Supply Chain, 3% Pig Loss
mil. $
1500
1000
500
0
-500
-1000
-1500
Grower
Slaughter
Retail Value-added
Consumer Surplus

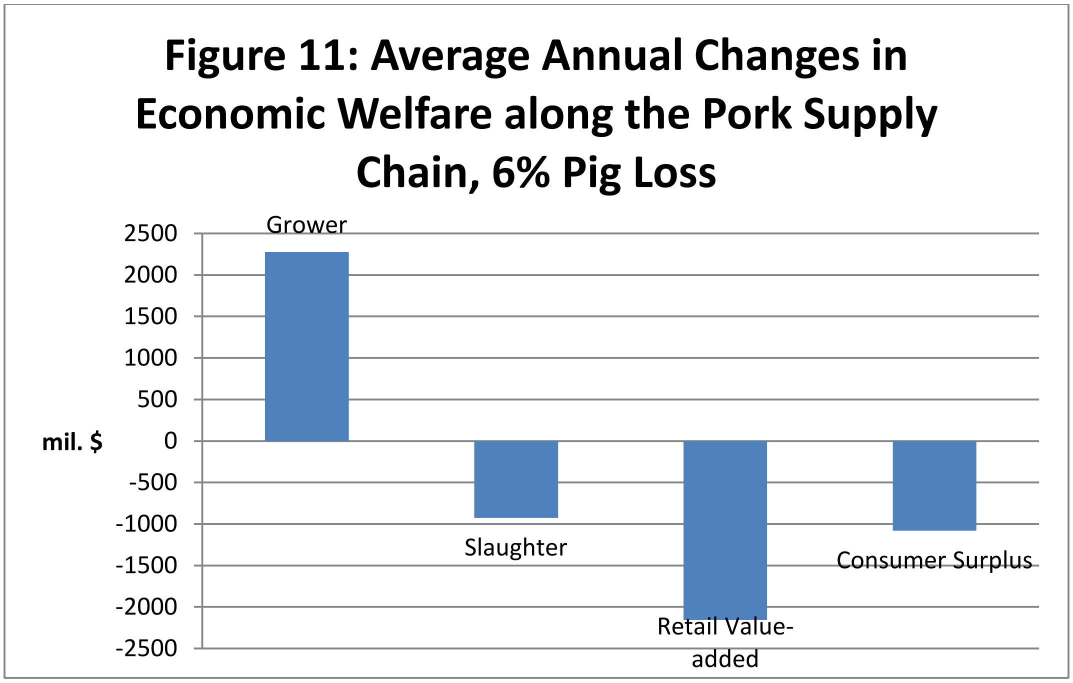
Figure 11: Average Annual Changes in Economic Welfare along the Pork Supply Chain, 6% Pig Loss
mil. $
2500
2000
1500
1000
500
0
-500
-1000
-1500
-2000
-2500
Grower
Slaughter
Retail Value-added
Consumer Surplus

Table 4: Change in Returns to Capital and Management for Producers by Sector and Year in the 3% Annual Pig Loss Scenario

	2013	2014	2015	2016	2017	2018
			-- million dollars --			
Beef	0.0	0.3	8.3	12.9	12.3	12.4
Cattle Slaughter	0.0	0.2	6.8	10.4	10.0	10.2
Beef Cattle	2.1	20.8	13.5	5.7	7.3	7.0
Pork	-14.2	-1082.1	-1210.4	-1107.1	-1068.3	-1056.0
Hog Slaughter	-5.1	-439.7	-522.1	-485.7	-476.7	-479.4
Swine	14.6	1133.4	1305.7	1216.5	1180.7	1169.3
Lamb Meat	0.0	0.0	0.0	0.0	0.0	0.0
Lamb Slaughter	0.0	0.0	0.0	0.0	0.0	0.0
Lambs	0.0	0.1	0.2	0.2	0.2	0.2
Dairy	-2.3	-32.0	-38.6	-40.4	-41.3	-41.8
Milk	0.5	0.8	1.5	-0.1	-1.1	-2.1
Eggs Retail	0.0	-0.4	-0.6	-0.6	0.6	-0.6
Eggs	0.2	1.7	1.6	1.3	1.3	1.3
Chicken Retail	0.5	3.7	5.1	5.7	5.6	5.4
Chicken Slaughter	0.5	1.4	-1.3	-3.0	-2.5	-2.2
Turkey Retail	-0.1	-1.5	-1.9	-1.9	-1.8	-1.8
Turkey Slaughter	0.0	-1.9	-2.4	-2.3	-2.2	-2.1
Coarse Grains	-9.6	-82.0	-71.6	-19.3	-20.3	-45.8
Soybeans	-0.3	-0.5	1.4	3.3	3.6	3.6
Wheat	-0.2	-2.1	-0.8	-0.6	-0.8	-0.8
Rice	0.0	0.0	-0.1	-0.2	-0.2	-0.2
Forage	-6.7	-75.8	-93.3	-94.8	-95.2	-94.4
Soybean Crushing	-1.5	-2.2	-0.3	0.2	0.3	-0.3
Land	0.0	-9.9	-69.3	-73.2	-72.8	-75.5
Total	-21.6	-567.7	-668.6	-573.0	-561.3	-593.6

Table 5: Change in Returns to Capital and Management for Producers by Sector and Year in the 6% Annualized Pig Loss Scenario

	2013	2014	2015	2016	2017	2018
			-- million dollars --			
Beef	0.0	0.1	14.2	25.5	25.1	24.8
Cattle Slaughter	0.0	0.0	11.6	20.6	20.5	20.3
Beef Cattle	2.1	37.8	31.1	12.1	13.8	14.4
Pork	-14.2	-1842.7	-2460.8	-2227.9	-2139.8	-2111.5
Hog Slaughter	-5.1	-739.1	-1047.1	-965.8	-944.0	-947.7
Swine	14.6	1897.0	2438.0	2409.6	2329.7	2303.8
Lamb Meat	0.0	0.0	0.0	0.0	0.0	0.0
Lamb Slaughter	0.0	0.0	0.0	0.0	0.0	0.0
Lambs	0.0	0.2	0.4	0.4	0.4	0.4
Dairy	-2.3	-56.2	-76.7	-81.2	-82.9	-84.0
Milk	0.5	1.1	2.5	-0.3	-2.3	-4.3
Eggs Retail	0.0	-0.9	-1.2	-1.2	-1.1	-1.1
Eggs	0.2	3.0	3.1	2.5	2.5	2.6
Chicken Retail	0.5	6.7	10.1	11.4	11.2	10.8
Chicken Slaughter	0.5	2.3	-2.8	-6.1	-5.1	-4.5
Turkey Retail	-0.1	-2.5	-3.9	-3.8	-3.7	-3.6
Turkey Slaughter	0.0	-3.3	-4.8	-4.7	-4.5	-4.2
Coarse Grains	-9.6	-144.9	-143.3	-38.9	-40.9	-78.9
Soybeans	-0.3	-1.4	2.4	6.2	7.2	7.1
Wheat	-0.2	-3.4	-1.6	-1.1	-1.5	-1.5
Rice	0.0	0.0	-0.2	-0.3	-0.3	-0.3
Forage	-6.7	-132.2	-185.6	-190.4	-191.1	-189.1
Soybean Crushing	-1.5	-5.2	-0.8	0.3	0.6	-0.5
Land	0.0	-9.9	-126.6	-146.5	-146.2	-151.6
Total	-21.6	-993.5	-1542.0	-1179.6	-1152.4	-1198.6