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Assessment of the economic impacts of porcine epidemic diarrhea virus in the United States

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ABSTRACT: Porcine epidemic diarrhea virus (PEDV), which first emerged in the United States in 2013, spread throughout the U.S. hog population. Limited preemptive knowledge impeded the understanding of PEDV introduction, spread, and prospective economic impacts in the United States. To assess these impacts, this article reviews the timeline of PEDV in the United States and the corresponding impacts. PEDV is a supply-impacting disease and is not demand inhibiting, as pork demand remained strong since PEDV first appeared. Pig losses reached significant levels during September 2013 through August 2014, with the majority of pork production impacts occurring in 2014. PEDV had differing impacts for subsectors of the pork industry. A budget model demonstrates that producers could have had pig losses and decreases in productivity proportionally smaller than price increases, resulting in net returns above what was expected before the major outbreak of PEDV. Previous literature is reviewed to identify the potential main industry beneficiaries of the PEDV outbreaks in the United States. As a result of reduced volumes of available pig and hog supplies, reductions in annual returns likely occurred for packers, processors, distributors, and retailers. In addition, pork consumers who experienced reduced-supply-induced pork-price increases were likely harmed directly by higher prices paid for pork and indirectly as prices of competing meats were also likely strengthened by PEDV. This article also identifies future considerations motivated by the appearance of PEDV in the United States, such as discussions of industry-wide efficiency and competitive advantage, the future role of PEDV vaccines, enhancement in biosecurity measures, and consumer perceptions of food safety and insecurity.

Key words: animal health, economic impacts, PEDV, porcine epidemic diarrhea virus, pork, swine

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INTRODUCTION

The first U.S. cases of porcine epidemic diarrhea virus (**PEDV**) appeared in April 2013 (USDA APHIS, 2014). By May 2014, it had been identified in 29 of the contiguous states (Hennessy, 2014). PEDV is an enveloped, RNA coronavirus (Pan et al., 2012; Song and Park, 2012; Huang et al., 2013) that causes morbidity in pigs of all ages but is most fatal to preweaned pigs. Transmission of PEDV is mainly through the fecal–oral route, but many different modes of transmission are possible through either direct or indirect contact (Sun et al., 2012; Geiger and Connor, 2013). While PEDV is not a new swine disease globally, the April 2013 occurrence represented the first time the disease was identified within the United States, and prospective impacts of the disease were unclear.

The goal of this article is to consider, within the limitations of current knowledge, the economic impacts of PEDV in the United States. There is still much that is not known about PEDV. This holds at least as much for economic impacts as for other aspects of PEDV. Hence, the assessment to be presented here is more demonstrative than definitive. The U.S. hog market was certainly impacted by changes in input prices reflecting weather shocks, trade policy, meat demand, and macroeconomic factors that are not attributable to PEDV. Still, using economic theory and intuition and available data, the article assesses the economic impacts in broad terms,

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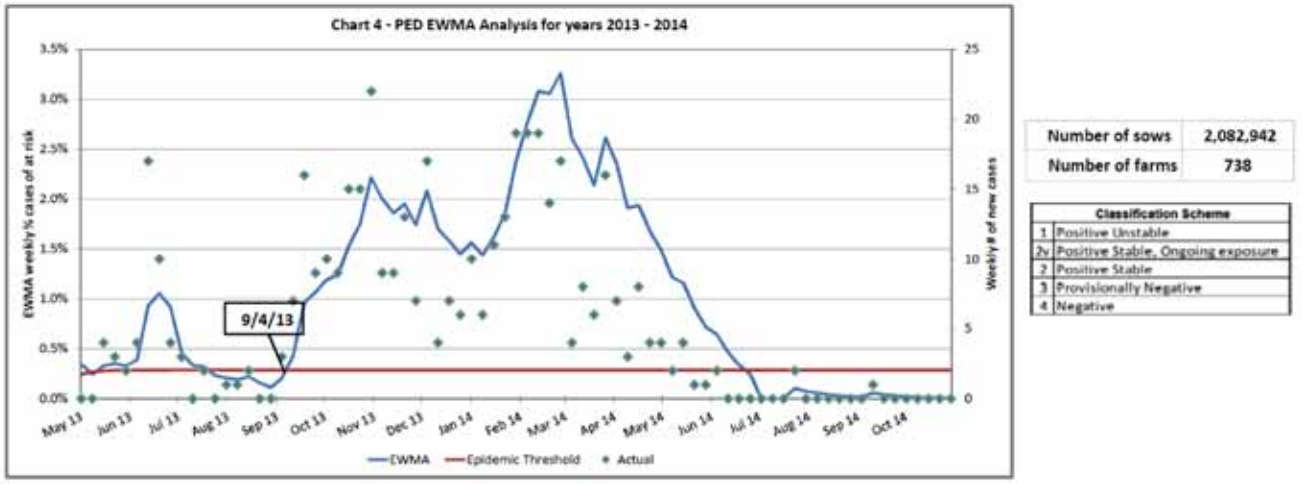

Figure 1. Swine health monitoring project: PEDV incidence analysis. This figure presents the PEDV exponentially-weighted moving average (EWMA) epidemic monitor (left vertical axis) with preliminary epidemic threshold based on 2013/2014 seasonal incidence. This figure also monitors the actual weekly number of incident cases of PED (right vertical axis). Updated through October 31, 2014. Source: UM SDEC, 2014.

providing a conceptual framework of the economic influence of PEDV.

TIMELINE OF PEDV AND CORRESPONDING SUPPLY AND DEMAND IMPACTS

Livestock diseases can have differing impacts depending on typology and severity. Diseases impacting the food supply can have extremely large impacts on the entire livestock industry as outbreaks of some diseases can lead to dramatic supply reductions, partial or full stoppages of varying duration with trading partners, as well as a hesitation to consume meat products from regions that are found to have livestock disease outbreaks. A less severe scenario includes a spread of disease throughout the herd, causing diminished productivity or an increase in mortality and morbidity rates or both.

PEDV Is a Supply Impacting Disease

The primary, and often only, clinical signs of PEDV are acute watery diarrhea and vomiting (Geiger and Connor, 2013). PEDV is most serious in neonatal piglets where morbidity and mortality can be 80% to 100%, with mortality increasing as age increases (USDA, 2013). The severity of PEDV can vary widely and is dependent on previous exposure and the immunological and epidemiologic status of the farm, region, or area affected (Geiger and Connor, 2013).

Any estimate of the supply impact of PEDV is inherently uncertain given the wide range in severity and length of the disease after an outbreak, any potential confounding effects (e.g., hog weights, inventory expansion or contraction, Porcine Reproductive and Respiratory Syndrome, etc.), and the imprecise reporting of PEDV cases. That said, available data can be used to formulate an estimate of the impact of PEDV on pork supply.

The Swine Health Monitoring Project provides a standardized way of tracking PEDV (UM SDEC, 2015). The project tracks about 2.1 million sows (out of a national total of approximately 5.8 million). The benefit of this project is that only new outbreaks of PEDV are reported. Furthermore, the project provides a PEDV epidemic threshold given the seasonality in the outbreak of coronaviruses. This project showed an increase in the number of PEDV cases in June 2013 and an even more dramatic increase that started in September 2013 (Fig. 1). The number of new cases of PEDV as tracked in the Swine Monitoring Project was then above epidemic threshold levels through June 2014. For illustrative purposes, the "year of PEDV" for inventory impacts was deemed September 2013 through August 2014, which allows comparisons across USDA Hogs and Pigs reports. Over 50% of sow farms tracked in the Swine Health Monitoring Project had new outbreaks during the "year of PEDV" (UM SDEC, 2014).

Year-over-year comparisons are a popular way to evaluate changes in swine inventories and pork production (Table 1). Annual inventory changes in the "year of PEDV" were estimated from USDA Hogs and Pigs reports. This report, issued four times yearly, presents data on the U.S. pig crop for 16 major states and the United States, including inventory number by class, weight group, farrowings, and farrowing intentions (USDA NASS, 2015a). The number of sows farrowing in the United States was slightly smaller (28,000 sows) in September 2013 through August 2014 compared to September 2012 through August 2013. However, the combined year-over-year reduction in the number of sows farrowing (−0.25%) pales in comparison to the

Table 1. U.S. swine inventory disposition[1]

	September 2012 to August 2013	September 2013 to August 2014	Change	% Change
U.S. sows farrowing, head[a]	11,372,000	11,344,000	−28,000	−0.25%
U.S. pigs saved per litter[a]	10.22	9.91	−0.31	−3.03%
U.S. pig crop, head[a]	116,201,000	112,476,000	−3,725,000	−3.21%
	January 2013 to December 2013	January 2014 to December 2014	Change	% Change
U.S. Commercial hog slaughter, head[b]	112,076,700	106,875,700	−5,201,000	−4.64%
U.S. average carcass weight, pounds[c]	206.89	213.74	6.85	3.31%
U.S. Commercial pork production, pounds[b]	23,187,100,000	22,843,300,000	−343,800,000	−1.48%

[1]This table presents U.S. swine inventories, commercial hog slaughter, carcass weights, and commercial pork production. Source: [a] USDA NASS, 2015a; [b] USDA NASS, 2015b; [c] Calculated based on U.S. commercial hog slaughter and U.S. commercial pork production.

reduction (−3.03%) in pigs saved per litter. Given that PEDV is a disease marked by death loss among young pigs through weaning age, the 0.31 decrease in the number of pigs saved per litter was the primary contributor to the reduced pig crop. The U.S. pig crop was estimated to be 112,476,000 based on a summation of the quarterly pig crop estimates from September 2013 through August 2014. This estimate of the U.S. pig crop was 3,725,000 head or 3.21% smaller than compared to the September 2012 through August 2013 period.

U.S. exports and imports of live hogs are relatively small compared to U.S. production and slaughter, such that no inventory disposition for live hog trade is included in the analysis. To put these numbers in perspective, the annual U.S. pig crop in September 2012 through August 2013 was 116,201,000 hogs. U.S. exports of live hogs to all destinations totaled 42,049 hogs, and live hog imports from all destinations totaled 5,296,826 hogs (USDA ERS, 2015a).

Annual inventory changes in the "year of PEDV" roughly corresponded to pork production impacts in the 2014 calendar year. In 2014, total commercial hog slaughter in the U.S. was estimated at 106,875,700 hogs, a decrease of 5,201,000 hogs or 4.64% below 2013 levels.

In 2014, producers likely found it profitable to feed hogs to heavier weights resulting in a short-term dramatic increase in carcass weights of 3.31%. There are a number of factors that could have influenced this including utilizing excess physical capacity caused by pig losses, capitalizing on an extremely favorable hog price to feed price ratio, and packers accepting (without discount) heavier hogs.

Marsh (1999) suggests short-run changes in market prices impact carcass weights, and hence commercial production. This is precisely the case in regard to U.S. pork production in 2014. The 3.31% increase in carcass weight offset some of the 4.64% reduction in commercial slaughter. In total, 2014 pork production decreased 1.48% below 2013 levels.

The market shock induced by the PEDV outbreak also caused changes in livestock breeding decisions. As part of the USDA Hogs and Pigs report, producers are asked their farrowing levels for the previous quarter and farrowing intentions over the next 2 quarters. Farrowing intentions are a primary indicator of U.S. hog supplies (Diersen, 2004). These intentions can be compared to actual farrowing levels from the previous quarter or year to identify general trends in supply. Sows farrowing during the "year of PEDV" (September 2013 through August 2014) were below the first and second intentions, except for the June–August 2014 quarter (Fig. 2). The decline in sows farrowing despite strong incentives to expand may have been a result of PEDV's effect on gilt retention and an overall tight supply of market hogs. Generally, pigs are slaughtered about 6 mo or 2 quarters after being farrowed. Thus, fewer hogs were expected to be marketed in March–May 2014 and the following 2 quarters than had earlier been anticipated. The level of intentions and actual sows farrowing for the June–August quarter indicated producers were likely adjusting to price signals and production capabilities as PEDV was beginning to be mitigated in the national herd.

Most economists consider the swine industry to operate like a textbook example of a commodity industry where long-run economic (not accounting) profits are zero. That is, in the long run, economists expect the swine industry to just cover its costs, making it neither advantageous for producers to expand production or exit the industry. The main implication of this is that 2014 profit levels were expected to lead swine producers to "bid away" margins in the form of buying or retaining replacement females or both to expand their herd, or making capital investments to increase herd capacity, etc. These adjustments, in time, are expected to return the breeding herd sector to more typical levels of profitability, increasing breeding inventories in the process.

Domestic Pork Demand

Pork produced from hogs that have had PEDV is safe for human consumption (UM CAHFS, 2013). News of PEDV has appeared extensively in the agriculture press

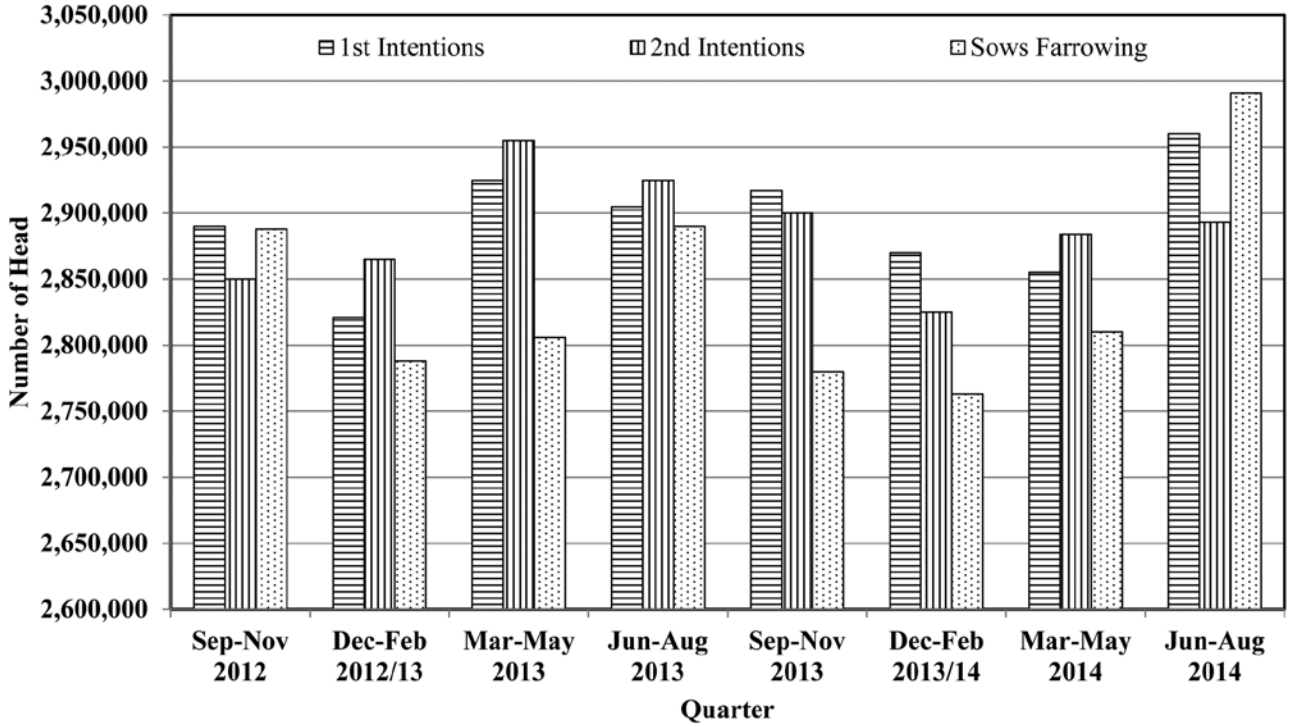

Figure 2. Quarterly U.S. sows farrowing and farrowing intentions. This figure presents USDA Hogs and Pigs report data regarding producers farrowing levels for the previous quarter and farrowing intentions over the next two quarters. Source: USDA NASS, 2015a.

but has received less attention by major national media, and there has been no noticeable effect on consumer demand for pork. It is critical to appreciate that PEDV having no impact on human health fails to guarantee no adverse pork demand impacts. That is, there are several other examples in the industry, such as the unfortunately labeled "swine flu" (2009 H1N1 situation), that have resulted in substantial, adverse economic impacts despite posing no "real" human health risk from pork consumption (Attavanich et al. 2011).

Demand is the relationship between the market price of a product and the quantity consumers are willing and able to buy. A measure of the responsiveness of the quantity demanded to changes in market price of a product is referred to as price elasticity of demand. In the short term, pork demand tends to be inelastic. For instance, Tonsor et al. (2010) estimate own-price pork elasticity to be −0.74 in the United States. This suggests short-term demand for pork is impacted, but not on a one-for-one basis when the price of pork changes. This is important to note as the pork industry has benefited from recent pork demand strength that warrants appreciation in assessing PEDV impacts.

A quarterly and annual pork demand index maintained at Kansas State University indicates year-over-year gains in pork demand for every quarter during the Q4.2012 to Q4.2014 period. In 2014, pork demand increased 7.4%, which was the second-largest annual gain since 1990. Pork demand is measured in terms of inflation-adjusted value of per capita pork consumption. While per capita consumption fell by 0.83% in 2014, pork prices increased 10.29% over that time (Tonsor, 2015). The price increase had been enough to more than offset the quantity reduction and allowed overall pork inflation-adjusted values to climb, which in turn increased hog prices and improved the overall economic situation of hog producers.

International Pork Trade

The current state of knowledge suggests that PEDV is not transmitted in pork (UM CAHFS, 2013). PEDV is not a disease that is listed as notifiable by the World Organization of Animal Health (OIE). Exports of U.S. pork and pork products were not expected to be subject to trade restrictions due to the outbreak of PEDV in the United States (Paarlberg, 2014). International pork markets did however react to higher U.S. pork prices. The U.S. pork price is not the only factor that affects international trade; however, the price influence was strong and likely was a major determinant of trade flows. The discussion below focuses on quantity adjustments in trade flows. Trade values would reflect the high prices that resulted in trade flow adjustments.

Pork exports from the United States decreased 133,855,000 pounds (2.68%) in 2014 compared to 2013 levels, but were 149,459,000 pounds (3.17%) higher than the 2008–2012 average (USDA ERS, 2015a). As

with domestic demand, wholesale pork export demand is inelastic at −0.89 (Paarlberg et al., 2008), such that trade volumes are impacted less than some may expect when domestic prices increase. Patterns of U.S. pork exports were likely further impacted by the situation of trading partners. In cases where other countries also experienced PEDV, some increased their import volumes such as Mexico (10.99% increase in 2014 compared to 2013; USDA ERS, 2015a).

Pork imports into the United States increased 127,895,000 pounds or 14.54% in 2014 compared to 2013 levels and 181,443,000 pounds (21.97%) compared to the 2008–2012 average (USDA ERS, 2015a). Pork imports into the United States, which supply pork cuts to deficit U.S. markets, reacted strongly to the sharp decrease in U.S. hog slaughter. Imports from Canada, the largest source of U.S. pork imports, increased 9.48% in 2014 compared to 1 yr earlier (USDA ERS, 2015a).

Despite these adjustments in trade flows, trade remains an important, growing, and supportive component of the U.S. hog and pork industry and adjustments are expected to moderate as supply and demand conditions equalize and pork prices rebalance. Moreover, the longer-term bullish forecasts for ongoing increases in U.S. pork exports reflect a fundamental desire of foreign consumers to purchase U.S. pork, which continues to support prices realized by U.S. swine producers (USDA ERS, 2015b).

WINNERS AND LOSERS OF PEDV

A critical step in assessing the economic impacts of PEDV is to identify the risks. To put these risks into context it is important to identify efficiency of the swine industry related to short- and long-term production. Three main aspects of efficiency in production are: (i) efficiency of the swine industry relative to food industries outside the livestock sector, (ii) efficiency of the swine industry relative to other livestock industries, and (iii) efficiency of one swine producer relative to others in the swine industry (Harris, 1970). The primary manifestation of the first of these will be in the magnitude of money spent by the consuming public for pork relative to other food products. The second aspect of efficiency leads to the relative levels of consumption of beef, pork, poultry, etc.

The efficiency of the swine industry may have short-term influences on the economic returns for the participants in that industry. For example, a single producer might be better off simply "riding out" an outbreak of PEDV, while others might insist rapid elimination measures are in the best interest of the industry as a whole. However, greater return on investment for all the participants in an industry will usually lead to either expansion within that industry or to new participants in the industry. So the long-term effects of industry-wide trends toward greater efficiency will not be greater profit for the participants in that industry but will be increased production, lower costs to the consumer, and greater consumption of the products. Hence, the main source of long-term profitability for a swine producer lies in their efficiency relative to other producers.

Producer Impacts

A budgeting approach was utilized to highlight the total cost of productivity (efficiency) losses for a representative farm. These returns were the market returns forecasted and ultimately realized in 2014 regardless of how the considered production levels were realized. That is, productivity levels can vary widely due to predetermined (e.g., facilities, genetics, geographic location of the operation, and some environmental factors), controllable (e.g., feed rations and biosecurity), and uncontrollable (e.g., weather and prevalence of specific diseases and pathogens) factors. A farrow-to-finish enterprise budget model that specified the mathematical relationships between production inputs and outputs, as well as the costs and revenues associated with production, was developed. The model captures the major relationships between productivity metrics, market pig prices, and input prices, making it possible to vary different market pig or feed prices, for example, to determine how they change the impact of PEDV on the profitability of the enterprise. To avoid the effect of operation-to-operation variation, constant standard reference values for capital expenditures and variable input prices not directly affected by PEDV were used in the budgeting model.

Costs per unit and net returns in livestock production are highly dependent on production levels. Production level, in terms of pigs sold per mated female per year, for farrow-to-finish operations is assumed to vary due to differences in the number of pigs sold per litter and the number of litters per sow per year. Varying these two factors results in different numbers of pigs sold per sow per year. Given that PEDV is a disease marked by death loss among young pigs through weaning age, the primary productivity impact of PEDV is reflected in the number of pigs sold per litter.

Table 2 includes forecasted net returns depicting the situation in September 2013 of a producer planning to sell market hogs in 2014 based on forecasts of both pigs sold per sow per year and forecasted market prices. Projected lean hog sales prices and feed prices result from Chicago Mercantile Exchange futures market prices for upcoming contracts, historical basis levels, and historical price/cost relationships. In this analysis, the 2014 average number of pigs sold per female per year was forecasted to be

Table 2. Forecasted and estimated costs and returns in a representative farrow-to-finish operation across varying levels of finished pigs sold per female in 2014[1]

		Scenario						
				2014 Estimate Finished pigs sold per mated female per year				
	2014 Forecast made September 2013	2014 Estimate with forecasted finished pigs sold/female/year	Difference	−43%	−33%	−23%	−13%	−3%
Productivity impact								
Finished pigs sold/female/year	20.48	20.48	0.00	11.67	13.72	15.77	17.82	19.87
Economic impact								
Average total revenue, $/head	$160.95	$204.52	$43.56	$204.52	$204.52	$204.52	$204.52	$204.52
Average total costs, $/head	$146.73	$150.16	$3.43	$186.61	$173.96	$164.59	$157.38	$151.65
Net return, $/head	$14.22	$54.36	$40.14	$17.91	$30.56	$39.93	$47.14	$52.87
Return on investment, %/head	9.66%	35.90%	26.24%	9.40%	17.34%	24.00%	29.68%	34.57%

[1]This table demonstrates that costs per unit and net returns in farrow-to-finish production are highly dependent on production levels. More information about the procedures for estimating returns can be found at http://www2.econ.iastate.edu/estimated-returns/.

20.48. Forecasting 2014 costs and returns in September 2013 suggested an average total revenue of $160.95 per finished hog, average total costs of $146.73 per finished hog, and returns over total costs of $14.22 per finished hog. The return on investment to farrow-to-finish production in 2014 was forecasted to be 9.66%.

The first scenario to consider is what would have happened if the forecasted pigs sold per female per year (20.48) were realized in 2014. Using realized 2014 lean hog sales prices and feed prices our estimate of 2014 costs and returns were: average total revenue of $204.52 per finished hog, average total costs of $150.16 per finished hog, and returns over total costs of $54.36 per finished hog. The return on investment to farrow-to-finish production in 2014 was estimated to be 35.90%. While the September 2013 forecast of average total costs was $3.43 per finished hog lower than what was estimated to have occurred in 2014, average total revenue was $43.56 per finished hog higher.

While this exercise demonstrates how returns on average exceeded expectations, it clearly masks over variation in economic impacts experienced by producers. Producers who realized no reduction in production clearly benefited by selling expected volumes at notably elevated price levels. Conversely, producers who were less fortunate and experienced reductions in throughput from PEDV would have realized lower net revenues and clearly been worse off.

Our farrow-to-finish model suggests that with a 3% decrease in finished pigs sold per female in 2014, consistent with the reduction in pigs saved per litter during the "year of PEDV," returns over total costs would have been $1.49 lower per finished hog, but still $38.64 per finished hog higher than the September 2013 forecast. In fact, 2014 returns over total costs and return on investment would be roughly consistent with the September 2013 forecast with a 43% decrease in finished pigs sold per female in 2014.

It is important to note that this demonstration assumes no differences across producers in costs such as investments in PEDV mitigation efforts. Inclusion of these cost differences would further expand the shown variation in impacts on individual producers.

Aggregate Impacts

While a complete economic assessment is beyond the scope of this paper, it is useful to summarize the main beneficiaries of the PEDV outbreaks in the United States. Given the reduced volumes of available pig and hog supplies, industry participants that rely on high-volume throughput (e.g., packers, processors, distributors, and retailers) are harmed. Paarlberg (2014) estimates pork packers experience reductions in annual returns of $481 million following a 3% reduction in pigs from PEDV and $929 million if supplies fall by 6%. Pork consumers who experience reduced-supply-induced pork-price increases are harmed directly (e.g., their pork costs more) but also indirectly as prices of competing meats (e.g., beef and poultry) are also strengthened by PEDV. Paarlberg (2014) suggests annual consumer surplus declines by $300 million to $600 million depending on the volume of supply reductions. The impact on producers is diverse and complicated as demonstrated throughout this article. This point is reinforced by Paarlberg (2014), who notes losses to infected producers are smaller than gains to uninfected producers leading to the "surprising outcome" of a net gain for producers in aggregate.

Ultimately, these gains for producers in aggregate are expected to incentivize expansion of the industry. In the absence of offsetting gains in externally driven pork demand, this expansion will proceed to erode producer profitability. This is just one of multiple longer-term impacts of PEDV that is still developing.

Other Considerations

Stakeholders throughout the pork industry have several goals that may have been impacted by PEDV. The industry collectively has a goal to produce a desired set of pork offerings at the least feasible cost to maintain industry-wide efficiency and sustain pork's competitive advantages compared to other meats. It could easily be argued that the uncertainty on production volume that followed PEDV outbreaks limited the industry's ability to meet this goal. Specifically, by introducing additional uncertainty on the volume of pigs, and hence pork, in the broader supply chain, segments of the industry operating in a risk-averse manner were less likely to make investments they otherwise would have made. Given this, it is possible the elevated hog prices observed reflect the market's recognition of a price premium being needed to offset uncertainty and encourage the process of expanding production.

A second consideration worth monitoring in the future is the role of PEDV vaccines. Narrowly, the animal health and economic impacts triggered by recent PEDV experiences are bound to notably expand efforts to derive and improve vaccines and related "tools for the industry's toolbox" to use in future efforts to mitigate PEDV risks. Exactly how these new measures perform and fit into industry protocol is yet to be established but important to monitor.

Perhaps a positive unintended consequence will be realized following observation of producers regarding the economic damage that operations with PEDV losses experienced. Narrowly, it is possible that the industry collectively will not only develop additional protocols and best practices for improving management of PEDV risks, but more broadly the entire industry may collectively implement more completely and stringently suggested biosecurity plans. If this is realized, it would certainly be an unexpected but valuable contribution.

Finally, one issue that has not materialized in the case of PEDV but may in future animal health challenges is adverse response from pork consumers. Narrowly, the U.S. PEDV experience occurred without a drop in either domestic or export pork demand following concerns over perceptions (regardless of how inaccurate or misplaced) about reduced safety of corresponding pork products. This fortunate outcome should not be missed by industry stakeholders and may well be different in the future or in alternative animal disease cases.

Conclusion

Being prepared for diseases that are rare, exist only in other countries, or have yet to be identified is a challenging proposition. With major outbreaks of Foot-and-Mouth disease over the past couple of years around the world, Classical Swine Fever having occurred in nearly 20 countries, and ongoing concerns about African Swine Fever, PEDV was not the foreign animal disease at the height of U.S. fears, considerations, or planning. Nevertheless, the PEDV outbreak in the United States crystallized concerns that producers, allied industries, and consumers share about the economic impacts of animal disease and the complexity of predicting the size of such impacts.

The pork industry did immediately respond to the PEDV outbreak in the United States through increased cooperation among pork producers, state and federal agencies, professional organizations, and other industry stakeholders. Each day more is learned about PEDV and its impact. With the benefit of more knowledge, the pork industry will be better equipped to address the virus, while preparing for other potential emerging disease scenarios.

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