Economic impacts of the mortality rate for suckling pigs in the United States

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Objective—To measure economic impacts attributable to the mortality rate for suckling pigs in the United States.

Design—Economic analysis that incorporated data from various sources.

Sample Population—Suckling pigs on US swine farms.

Procedure—Economic impacts associated with the mortality rate for suckling pigs during 1995 were estimated from supply-and-demand curves for pork and from an estimate of the elasticity of production for pigs entering the grower-finisher phase of production.

Results—A decrease in the mortality rate for suckling pigs would have caused an increase in pork production and a decrease in price and total value of production. Assuming no suckling pigs had died during 1995, consumer surplus would have increased by (mean ± SE) $430 ± $160 million, whereas producer surplus would have decreased by $180 ± $140 million. The total gain to the US economy would have been $250 ± $30 million.

Conclusions and Clinical Relevance—Researchers who attempt to estimate the economic impact of mortality and morbidity rates of livestock should not ignore the influence of demand and the possibility of price adjustments. Consumers would stand to benefit from an increase in pork production associated with a reduction in the mortality rate for suckling pigs, whereas the swine industry would experience an economic loss. Individual producers need to compare the costs of measures intended to reduce the mortality rate for suckling pigs with the anticipated benefits. (*J Am Vet Med Assoc* 2005;227:896–902)

The period from birth to weaning is the stage of life when pigs are most likely to die. In 1928, the mortality rate for suckling pigs in the United States was approximately 35%, and it is currently > 30% in some countries.[1]

The mortality rate for suckling pigs has been reported[2-5] in 3 national studies conducted by the USDA, **Animal and Plant Health Inspection Service (APHIS), National Animal Health Monitoring System (NAHMS)**. Mortality rate of suckling pigs decreased from 1990 to 1995 and then increased back to 1990 values by the year 2000. In 1990,[2] mean ± SE mortality rate was 11.62 ± 0.04%. Data gathered for the period from December 1, 1994, through May 30, 1995,[3] revealed that the mean mortality rate had decreased to 9.34 ± 0.27%, but data gathered for the period from December 1, 1999, through May 31, 2000,[4] revealed that the mean mortality rate had increased to 11.0 ± 0.3%. For data gathered for the period from June 1 through November 30, 2000,[5] the mean mortality rate was 12.2 ± 0.4%.

Outbreaks of infectious diseases can cause an increase in the mortality rate for neonatal pigs.[6,7] By use of data from the NAHMS 1990 National Swine Survey, investigators in 1 study[8] established that mortality rates for suckling pigs differed on the basis of flooring type, heat source, water-delivery system, cleaning frequency, cleaning method, and the length of time between subsequent farrowing groups. In a separate analysis of the same data, other investigators[9] found that all-in–all-out management and cleaning of the farrowing areas before introducing new sows were associated with a reduction in the mortality rate for suckling pigs. Analysis of data obtained for the 3 NAHMS surveys indicated that the leading cause of death for suckling pigs was crushing by sows.[2,4] Most crushing deaths happen within 2 days after birth.[10] In 1 report,[1] numerous studies were described that have examined the relationships between farrowing crates (designed to restrict the movement of sows) and mortality rates for suckling pigs. Cross-fostering during the early postnatal period to create uniformity in weights of the baby pigs suckling on each sow can also reduce mortality rates.[11]

Data on costs and economic returns from the NAHMS 1990 National Swine Survey were used by investigators in 1 study[12] to calculate the amount of income lost for each suckling pig that died and estimate the increase in income that would result from a decrease in the mortality rate for suckling pigs in various regions and operations of various sizes. The increased income calculated by those investigators ignored the impact of consumer demand on the market price of pork and on the financial returns to producers.

Investigators in 1 study[1] estimated that the cost to the US swine industry attributable to the mortality rate for suckling pigs was between $130 million (assuming a value of $13.50/weaned pig) and $330 million (assuming a value of $33.00/weaned pig) in 2000. That analysis assumed that the increase in the number of weaned pigs would not affect the value of a weaned pig and that the swine industry would have been the sole

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economic beneficiary of the increase in the number of pigs. This implies that the market price of pork would have remained unchanged and that consumers' appetite for pork was such that they would have purchased all of the increased supply at the same price.

The purpose of the study reported here was to provide a better understanding of the economic impacts attributable to changes in the mortality rate for suckling pigs by measuring changes in pork supply, market price, and producer and consumer surplus that would result if all pigs born alive in 1995 survived through weaning. An additional goal was to measure changes in these variables that would result from incremental decreases in the mortality rate for suckling pigs.

Materials and Methods

The procedures followed for the study were similar to those developed[13] to measure the economic impacts of *Actinobacillus pleuropneumonia* on grower-finisher swine operations in the United States. Input quantities used in the computation of economic impacts attributable to the mortality rates for suckling pigs, in addition to their sources and uncertainties, were summarized (**Appendix 1**).[14-18] The percentage of pigs that died before weaning for the period from December 1, 1994, through May 30, 1995, and the elasticity of pork production for pigs entering the grower-finisher phase were derived from data collected during the NAHMS 1995 National Swine Study. Details on the design and implementation of the NAHMS 1995 National Swine Study have been reported elsewhere.[19] Briefly, the **National Agricultural Statistics Service (NASS)** gathered information during June 1995 from 1,477 swine producers involved in all phases of swine production (farrowing, nursery, and grower-finisher) in 16 major swine-producing states.[2] In subsequent stages of data collection (between July 1995 and January 1996), state and federal veterinary medical officers visited swine operations that had participated in the first stage of data collection and that had ≥ 300 finisher pigs at the time of the first interview; their intent was to collect more detailed data that related specifically to the grower-finisher phase of production.[4]

Production data and other questionnaire variables were used to construct a Cobb-Douglas production function, which served to examine returns to scale for the production of pork in the United States.[14] For a Cobb-Douglas production function, an input's partial elasticity of production (ie, the percentage change in output divided by the percentage change in input) is equal to the input's coefficient variable.[20] The percentage change in pork output that would have resulted if all pigs born alive had survived through weaning was obtained by multiplying the elasticity of production for pigs entering the grower-finisher phase of production (data derived from 1 report[14]) by the percentage of suckling pigs that died between December 1, 1994, and May 30, 1995 (data derived from results of a USDA—APHIS report[2]). During 1995, US pork producers sold 8,096 million kg (17,811 million lb) of pork at a mean price of \$0.899/kg (\$0.409/lb).[16] The increase in the quantity of pork that would have been produced in 1995 if all pigs born alive had survived through weaning was calculated by multiplying the quantity of pork produced during 1995 by the percentage change in pork output that would have resulted if all pigs born alive had survived through weaning.

Changes in market price, producer surplus, and consumer surplus were estimated on the basis of the assumption of linear supply-and-demand curves and a parallel shift in supply (**Figure 1**). Price elasticities of the supply and demand for pork used in the study were the means and standard uncertainties of a list of estimates (with the high and low values removed) reported elsewhere.[17] The price elasticity of supply is defined as the relative change in the quantity supplied divided by the relative change in the price, and it measures the extent to which changes in the price of a good interrelate with changes in the quantity supplied.[21] The price elasticity of demand is a measure of the extent to which changes in the price of a good relate with changes in the quantity purchased, and it is defined as the relative change in the quantity purchased divided by the relative change in the price.[21]

Model equations were used to measure the economic impacts attributable to the mortality rate for suckling pigs in the United States during 1995 (**Appendix 2**). A specialized computer program for the measurement of uncertainty[18,a] was used to create estimates and propagate uncertainties for the changes in market prices, consumer surplus, producer surplus, and total economic gain that would result from eliminating deaths of suckling pigs in 1995. A review of the specialized computer program and details on how to use the software to generate estimates and associated uncertainties have been reported elsewhere.[22] The specialized computer program computes estimates, combined standard uncertainties, and coverage factors in accordance with recommendations established by the International Organization for Standardization.[23] The specialized computer program calculates sensitivity coefficients by use of a numeric partial differentiation and applies Taylor-series approximation to compute combined standard uncertainties.

In addition, the specialized computer program was used to estimate the quantity, price, and total value of pork that would have been produced and changes in consumer surplus, producer surplus, and total gains to the economy that would have

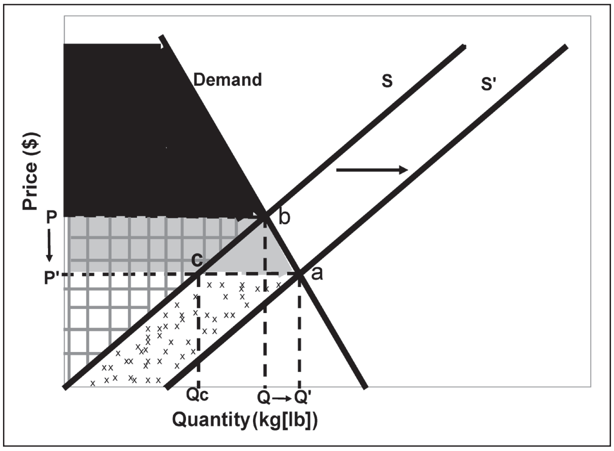

Figure 1—Supply-and-demand curves for pork. When supply (S) is at a given point, the equilibrium market price (P) and equilibrium market supply (Q) are at specified values. Consumer surplus is the area below the demand curve and above the line segment P-b (black area). Producer surplus is the area above the supply line and below the line segment P-b (cross-hatched area). When supply increases from S to S' (as a result of eliminating deaths of suckling pigs), the equilibrium price decreases from P to P', quantity increases from Q to Q', and consumer surplus increases by the amount represented by the quadrilateral bounded by points P', P, b, and a (gray-shaded area). A portion of the increased consumer surplus (quadrilateral bounded by points P', P, b, and c; cross-hatched gray-shaded area) is transferred from producers. Producer surplus decreases by the amount transferred to consumers but increases by the area between the 2 supply curves and below the line segment c-a (stippled area). The total gain to the economy is the area below the demand curve and between the 2 supply curves (gray-shaded and stippled areas). Qc = Quantity of pork that would have been produced at point C, which was measured for the sake of convenience to be able to compute the surplus transferred between consumer and producers.

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Table 1—Uncertainty budget for the change in consumer surplus that would have resulted from increased pork production associated with eliminating deaths of suckling pigs on US swine operations during 1995.

Input quantity	Sensitivity coefficient*	Uncertainty contribution†	Index (%)‡
Mortality rate for suckling pigs (%)	4.8×10^7	1.3×10^7	2.6
Elasticity of pork production for the No. of pigs entering the grower-finisher phase of production	1.2×10^9	4.8×10^7	36.4
Quantity of pork produced (kg [lb])	5.3×10^{-2}	2.1×10^7	7.2
Mean price of pork ($/kg [$/lb])	4.7×10^8	2.4×10^6	0.0
Price elasticity of the demand for pork	7.1×10^8	5.8×10^7	53.7
Price elasticity of the supply of pork	2.3×10^7	9.5×10^5	0.0

The final estimate for the change in consumer surplus is an increase of $426.4 million, with a standard uncertainty of $79.3 million (42 *df*). The resulting 95% confidence interval is $270 million to $590 million.

*The sensitivity coefficient (ie, $\vartheta Y/\vartheta x_i$) describes how the output estimate (ie, y) varies with changes in the value of the input estimate (ie, $x_1, x_2, \ldots x_n$). †Absolute value of the product of the standard uncertainty and the sensitivity coefficient; the sum of the squares of the values in this column equals the square of the measurand's uncertainty. ‡Percentage contribution to the square of the measurand's uncertainty; this value is 100 times the square of the uncertainty contribution, divided by the square of the measurand's uncertainty. The values in this column should sum to 100% but may not because of rounding errors. Values in this column provide information on the relative importance of the contribution of each input quantity to the uncertainty of the measurand.

Table 2—Uncertainty budget for the change in producer surplus that would have resulted from increased pork production associated with eliminating deaths of suckling pigs on US swine operations during 1995.

Input quantity	Sensitivity coefficient*	Uncertainty contribution†	Index (%)‡
Mortality rate for suckling pigs (%)	-2.2×10^7	5.9×10^6	0.9
Elasticity of pork production for the No. of pigs entering the grower-finisher phase of production	-5.5×10^8	2.2×10^7	11.9
Quantity of pork produced (kg [lb])	-2.2×10^{-2}	9.0×10^6	2.0
Mean price of pork ($/kg [$/lb])	-2.0×10^8	1.0×10^6	0.0
Price elasticity of the demand for pork	-7.2×10^8	5.9×10^7	85.2
Price elasticity of the supply of pork	-1.1×10^7	4.7×10^5	0.0

The final estimate for the change in producer surplus is a decrease (–$180.7 million with a standard uncertainty of $63.5 million [19 *df*]). The resulting 95% confidence interval is –$320 million to –$40 million.

See Table 1 for remainder of key.

Table 3—Uncertainty budget for the total economic gain that would have resulted from increased pork production associated with eliminating deaths of suckling pigs on US swine operations during 1995.

Input quantity	Sensitivity coefficient*	Uncertainty contribution†	Index (%)‡
Mortality rate for suckling pigs (%)	2.6×10^7	6.9×10^6	5.5
Elasticity of pork production for the No. of pigs entering the grower-finisher phase of production	6.5×10^8	2.6×10^7	76.9
Quantity of pork produced (kg [lb])	3.0×10^{-2}	1.2×10^7	17.3
Mean price of pork ($/kg [$/lb])	2.7×10^8	1.4×10^6	0.2
Price elasticity of the demand for pork	-6.0×10^6	-4.9×10^5	0.0
Price elasticity of the supply of pork	1.1×10^6	4.7×10^5	0.0

The final estimate for the total economic gain resulting from increased pork production associated with eliminating deaths of suckling pigs on US swine operations is $245.7 million, with a standard uncertainty of $29.5 million (80 *df*). The resulting 95% confidence interval is $187 million to $305 million.

See Table 1 for remainder of key.

resulted from incremental decreases (decrease of 1% to 7%) in the mortality rate for suckling pigs in 1995. The procedures were similar to those described for the total mortality rate but with differing mortality rates entered into the set of equations.

Results

The production function[14] indicated that if the number of pigs entering the grower-finisher unit in the United States had increased by 9.34% (ie, the mortality rate for suckling pigs) during 1995, then pork production would have increased by 3.5% (**standard uncertainty** [SU], 0.4%; *df*, 57), which is equivalent to 279 million kg (614 million lb; SU, 34 million kg [75 million lb]; *df*, 78). Total pork production would have increased to 8,375 million kg (18,425 million lb; SU, 420 million kg [924 million lb]; *df*, 50). The price of pork would have decreased by $0.051/kg ($0.023/lb; SU, $0.009/kg [$0.004/lb]; *df*, 35) to $0.849/kg ($0.386/lb; SU,

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Table 4—Quantity, price, and value of pork produced and changes in consumer, producer, and total economic surplus that would have resulted from incremental decreases (from 1% to 7%) in the mortality rate for suckling pigs on US swine operations during 1995.

Reduction in mortality rate for suckling pigs (%)	Quantity of pork produced (× 10^9 kg [× 10^9 lb])	Price of pork ($/kg [$/lb])	Value of pork produced ($ billions)	Change in consumer surplus ($ millions)	Change in producer surplus ($ millions)	Change in total economy ($ millions)
0	8.10 ± 0.81 (17.82 ± 1.78)	0.899 ± 0.010 (0.409 ± 0.004)	7.28 ± 0.73	NA	NA	NA
1*	8.13 ± 0.81 (17.89 ± 1.78)	0.894 ± 0.010 (0.406 ± 0.004)	7.26 ± 0.73	44 ± 16	–17 ± 13	27 ± 6
2*	8.16 ± 0.82 (17.95 ± 1.80)	0.888 ± 0.011 (0.404 ± 0.004)	7.24 ± 0.73	88 ± 32	–35 ± 25	54 ± 13
3*	8.19 ± 0.82 (18.80 ± 1.80)	0.883 ± 0.011 (0.401 ± 0.004)	7.23 ± 0.73	133 ± 48	–53 ± 39	80 ± 19
4*	8.22 ± 0.82 (18.08 ± 1.80)	0.877 ± 0.012 (0.399 ± 0.005)	7.21 ± 0.73	178 ± 65	–72 ± 52	107 ± 25
5*	8.25 ± 0.83 (18.15 ± 1.83)	0.872 ± 0.013 (0.396 ± 0.006)	7.19 ± 0.73	224 ± 82	–91 ± 65	133 ± 31
6*	8.28 ± 0.83 (18.22 ± 1.83)	0.867 ± 0.015 (0.394 ± 0.007)	7.17 ± 0.73	270 ± 98	–111 ± 79	159 ± 37
7*	8.31 ± 0.83 (18.29 ± 1.83)	0.861 ± 0.016 (0.391 ± 0.007)	7.15 ± 0.73	320 ± 120	–131 ± 93	185 ± 43

*Not defined.
NA = Not applicable.
Values reported are 95% confidence intervals calculated as the mean ± 2SD.

$0.010/kg [$0.004/lb]; *df*, 55). Although more pork would have been produced, the total value of the pork produced would have decreased from $7.28 billion (SU, $370 million; *df*, 51) to $7.11 billion (SU, $363 million; *df*, 54) because of the lower price. Thus, the decrease in the total value of production would have been $172 million (SU, $62 million; *df*, 18; $P < 0.05$) if no pigs had died before weaning.

Uncertainty budgets, estimates, and expanded uncertainties for the change in consumer surplus, change in producer surplus, and total economic gain that would have resulted from increased pork production resulting from eliminating the deaths of suckling pigs were summarized **(Tables 1–3)**. Analysis of the indices, which reveal the percentage contribution of each input to the square of the uncertainty for each measurand, indicated that the uncertainty in the elasticity of demand contributed to most of the uncertainty in the change in consumer surplus and the change in producer surplus. The uncertainty in the elasticity of production of pork for pigs entering the grower-finisher phase contributed to most of the uncertainty in the total loss to the economy.

Most ($418 million; SU, $77 million; *df*, 42) of the increase in consumer surplus associated with eliminating death of suckling pigs was a result of a direct transfer in economic surplus from producers. This transfer offset $237 million (SU, $28 million; *df*, 82) of economic gain that producers would otherwise have enjoyed and that accounted for most of the $246 million gain to the total US economy; thus, the total impact on producers was a decrease in economic surplus of $180 million (Table 2). The increase in consumer surplus that was not transferred from producers amounted to $8.7 million (SU, $2.5 million; *df*, 70). The total gain to the US economy was the sum of the gains in producer surplus and consumer surplus, not including the transfer in economic surplus between producers and consumers (Table 3).

As the mortality rate for suckling pigs decreased, the quantity of pork produced increased, whereas the price and total value of pork produced decreased **(Table 4)**. Consumer surplus and net economic gains increased, but producer surplus decreased.

Discussion

A publication[23] culminated from the recognized need for consensus on an internationally accepted procedure for expressing uncertainty in measurement and combining separate uncertainty components into a single total uncertainty. The accepted procedure involves 8 steps.

- Express mathematically the relationship between the measurand Y and the input quantities X_i on which Y depends.
- Determine x_i (ie, the estimated value of X_i) either by statistical analysis of a series of observations or by other means. (Capital letters indicate true values, and lowercase letters denote estimates of true values).
- Evaluate the standard uncertainty of each x_i (ie, $u[x_i]$) from the statistical analysis of a series of observations (type A evaluation of standard uncertainty) or by other means (type B evaluation of standard uncertainty).
- Evaluate the covariances associated with any input quantities that are correlated.
- Calculate the result of the measurement (ie, the estimate y of the measurand Y) from the mathematical expression of the relationship between Y and the input quantities X_i by use of the estimates x_i.
- Determine the combined standard uncertainty of the measurement result y (ie, $u_c[y]$) from the standard uncertainties and covariances associated with the input estimates.
- Determine an expanded uncertainty U, such that the interval for (y – U) to (y + U) encompasses a large fraction of the distribution of values that could reasonably be attributed to Y. The value for U is obtained by multiplying the standard uncertainty by a coverage factor reflective of the degree of confidence required for the interval.
- Report the result of the measurement y along with its combined standard uncertainty $u_c(y)$ or expanded uncertainty U and describe how y and $u_c(y)$ or U were obtained.

Standard error is the term that is most frequently used by statisticians to indicate the variability of estimates. Standard error typically is derived from the statistical evaluation of a series of measurements (which, in accordance with the language in the uncertainty publication,[23] would correspond to a type A evaluation of standard uncertainty). The term standard uncertainty encompasses both type A and type B evaluations. A type B evaluation of standard uncertainty[23] is based on available information for the possible variability of X_i, which may include measurement data, experience with

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or general knowledge of the behavior and properties of materials or measurement instruments, uncertainties obtained from handbooks or government publications, or data obtained from articles in scientific journals.

Researchers are increasingly encouraged to document the quality of their results by providing a measure of the confidence that can be placed on their results and the degree to which their results would be expected to agree with the results of others. A principal advantage of adhering to the recommendations in the uncertainty publication[23] is the transparency of the methods. Providing an uncertainty budget that lists the source, distribution, value, uncertainty, and degrees of freedom for each input quantity and that analyzes the contribution of each input quantity to the uncertainty of the measurand is an effective means of conveying the confidence that can be placed in a researcher's results.

Indices of the uncertainty contributions quickly reveal to readers the input quantities that had the greatest impact on the uncertainty of the measurand (Tables 1–3). The price elasticity of demand for pork accounted for most of the uncertainty in the estimates of the consumer and producer surplus. The elasticity of pork production for the number of pigs entering the grower-finisher phase accounted for most of the uncertainty in the total economic impact, which suggests that the greatest improvement in the estimate of the total economic impact of decreasing the mortality rate for suckling pigs could be derived by concentrating on finding a better estimate of this variable. For example, a more precise estimate of the mean price of pork in 1995 (whose contribution to the overall uncertainties of the economic impacts was < 1%) would have had a trivial impact on the uncertainties of the measurands. Readers who wish to propose another value for an input quantity or use another model equation may easily take the information reported here and make the appropriate modifications.

A limitation of the study reported here is that the mortality rate for suckling pigs, as reported[2] for the period of December 1, 1994, through May 30, 1995, was applied for the entire year of production for 1995. Therefore, the estimate of economic impacts may be incorrect if the assumption that the mortality rate for suckling pigs did not vary during the second half of 1995 is erroneous. However, for producers that participated in the entire year of data collection for the NAHMS 1995 National Swine Study, the mortality rate for suckling pigs did not differ significantly between the first half of the year and the second half of the year.[3] Participation in the second half of the NAHMS 1995 National Swine Study was limited to producers with ≥ 300 finisher pigs at the time of the initial interview.[13]

In the study reported here, economic impacts of the mortality rate for suckling pigs during 1995 were examined by use of the mortality rate reported[2] from the period of December 1, 1994, through May 30, 1995, which included data from producers involved in all phases of swine production. Results of this analysis could have been biased if mortality rates of suckling pigs changed during the second half of 1995 on operations eligible to participate in the first stage of data collection for the NAHMS 1995 National Swine Study but not eligible to participate in the second half of that survey. Furthermore, the data were dependent on the respondent's ability to recall mortality rates throughout a 6-month period. Some respondents may have kept better records than others, and the quality of the data may have been variable among respondents. In a test-retest study[24] that used a sample of questions from an early NAHMS survey of dairy producers, investigators reported an overall discrepancy rate of 8.5% in the answers that respondents provided during different interviews. Discrepancy rates for the NAHMS 1995 National Swine Study were not studied and are not known. However, every effort was made during the data-validation phase to ascertain that the final data set was as complete and accurate as possible.[19]

Price elasticities of supply and demand are usually calculated from observed market conditions. As extrapolations are made outside of real-market conditions, assumptions about the shape of the supply-and-demand curves can become less realistic. Calculation of the change in consumer surplus in the study reported here was based on a shift in supply along a small portion of a stationary demand curve. Measuring the change in producer surplus involved finding the area between 2 parallel supply curves projected to the horizontal axis. Therefore, the estimated change in consumer surplus is probably more accurate than the estimated change in producer surplus. The shapes of supply curves outside of observed market conditions cannot be known. Therefore, some sort of simplifying assumptions must be made to estimate changes in producer surplus that result from shifts in supply. Computing changes in consumer and producer surplus on the basis of assumptions of parallel shifts in linear supply-and-demand curves remains a fairly common practice, particularly for economists working in multidisciplinary settings. For example, investigators in 1 study[25] assumed a parallel shift in the supply curve when they measured the change in producer surplus resulting from the National Pseudorabies Eradication Program. In another study,[26] investigators assumed a parallel supply shift when they estimated changes in producer and consumer surplus that resulted from implementation of hazard analysis and critical control points. Finally, a parallel shift in the supply curve was assumed when estimates in the economic impacts of *Actinobacillus pleuropneumonia* were calculated in another study.[13]

The mortality rate for suckling pigs remained fairly stable (approx 10%) during the period from 1995 to 2000. Although a number of researchers have investigated preweaning mortality of pigs, policy decisions regarding the reduction of the mortality rate for preweaning pigs in the United States have not been proposed and are unlikely to be seen in the near future.

The price response to increased production is a generally recognized concern for the swine industry. However, it is usually addressed by 2 factors. The first factor is that there is really not a logical response for producers. Producers who want to stay in business have an incentive to remain competitive and thus need to improve productivity. The second factor is a long-range concern that the swine industry must also compete against other meat suppliers who are also becoming

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more efficient. Replacement of pork with other meat proteins as a response to increases in the price of pork will be modified over time through increased technical efficiency. When that technical efficiency is not met in swine production, there should be an expectation of a natural decrease in consumption over time. Thus, the pork industry should emphasize technical improvement with the assumption that technical improvement will, in the long run, address competitive requirements.

Consumers clearly stand to benefit more than producers from a reduction in the mortality rate for preweaned pigs, given the transfer in economic surplus from producers to consumers that would result from increased pork production. Impacts on other meat industries are beyond the scope of this analysis. Assuming pork prices are reduced as a result of increased production, it is likely that consumers will substitute pork in place of other meats that become relatively more expensive.[27] In 1 study,[28] investigators documented that an increase in the number of pigs saved per litter could cause a decrease in prices and returns to producers. However, investigators in that study believed that new technologies that tended to enhance output rather than reduce cost could cause producers to be in a worse economic condition. Although a reduction in the mortality rate for suckling pigs may prompt some producers to reduce the number of sows required to produce a specified amount of pork, pork production is an extremely competitive business. Particularly because of increasing returns to scale in the US swine industry,[14] it is more likely that a producer would respond to a diminished mortality rate for suckling pigs by increasing output.

The analysis reported here was conducted at the macroeconomic level (ie, on the assumption that all producers would reduce the mortality rate for suckling pigs). A producer who does not produce a sufficient amount of pork to affect the market price is regarded as a price taker who faces perfect competition. Each producer's situation is unique. Given the mean market price and price elasticity of supply for pork, a producer would earn more money by reducing the preweaning mortality rate by 1%, assuming the mean ± SD cost to do so is < \$0.13 ± 0.074/kg (\$0.06 ± 0.034/lb) of finished pork. However, if all producers reduced the mortality rate by 1%, the impact would be a reduction of \$17 ± \$13 million, which does not include the costs associated with reducing the mortality rate (Table 4).

a. GUM Workbench, Metrodata GmbH, Grenzach-Wyhlen, Germany.

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Appendix 1

Input quantities (including sources and uncertainties) used in the computation of the economic impacts of the mortality rate for suckling pigs in the United States in 1995.

Input quantity	Distribution	Value	Standard uncertainty	Degrees of freedom	Reference
Mortality rate of suckling pigs in 1995	Normal	9.34%	0.27%	50*	2
Elasticity of pork production for pigs entering the grower-finisher phase	Normal	0.3693	0.0398	50*	14
Pork produced in 1995 (kg [lb])	Normal	8,096 million	809.6 million† (17,811 million)	50* (1,781 million)	15
Mean price of pork in 1995 ($/kg [$/lb])	Normal	0.899 (0.409)	0.005 (0.002)	50*	16
Price elasticity of the demand for pork	t	–0.6139	0.0816	14	17
Price elasticity of the supply of pork	t	0.1451	0.0413	8	17

*The specialized computer program for the measurement of uncertainty[a] assigns a default value of 50 for the degrees of freedom for normally distributed type B data.[18] †Uncertainty is based on a 10% imputation rate.[15]

Appendix 2

Model equations used in the analysis of the economic impact attributable to mortality rate for suckling pigs in the United States in 1995.

$\Delta Q\% = E_P \times \text{Mortality rate}$

$\Delta Q = (Q \times \Delta Q\%)/100$

$Q\Delta = Q + \Delta Q$

$\Delta P = (\Delta Q \times P)/(e_D \times Q)$

$P\Delta = P + \Delta P$

$Q_c = ([Q\Delta - e_S] \times \Delta P \times Q)/P$

$CS_{trans} = (\Delta P \times Q_c) + (0.5 \times \Delta P \times [Q - Q_c])$

$CS_{lost} = ([0.5 \times \{\Delta Q\}^2 \times P \times \{e_D - e_S\}]/[e_D{}^2 \times Q])$

$\Delta CS = CS_{trans} + CS_{lost}$

$PS_{lost} = \Delta Q \times P\Delta$

$\Delta PS = CS_{trans} - PS_{lost}$

Total economic loss = $CS_{lost} + PS_{lost}$

$\Delta Q\%$ = Percentage change in pork production assuming no suckling pigs had died during 1995. E_P = Elasticity of pork production for the number of pigs entering the grower-finisher phase of production. Mortality rate = Mortality rate (percentage) for suckling pigs during 1995. ΔQ = Loss in pork production (kg [lb]) associated with mortality of suckling pigs. Q = Quantity of pork (in kg [lb]) produced during 1995. $Q\Delta$ = Quantity of pork (kg [lb]) that would have been produced had no suckling pigs died during 1995. ΔP = Change in price of pork ($/kg [$/lb]) associated with loss in pork production attributable to the deaths of suckling pigs. P = Mean price of pork ($/kg [$/lb]) during 1995. e_D = Price elasticity of demand for pork. $P\Delta$ = Price of pork ($/kg [$/lb]) had there been no production decrease associated with deaths of suckling pigs during 1995. Q_c = Quantity of pork (in kg [lb]) produced at the point where the horizontal line from $P\Delta$ intersects the supply line. e_S = Price elasticity of supply for pork. CS_{trans} = Consumer surplus ($) transferred to producers. CS_{lost} = Consumer surplus ($) lost. ΔCS = Change in consumer surplus ($). PS_{lost} = Producer surplus ($) lost. ΔPS = Change in producer surplus ($).

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