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# Assessment of the economic impact of porcine reproductive and respiratory syndrome virus on United States pork producers

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**Keywords**
swine, porcine reproductive and respiratory syndrome virus, economics, PRRSV

**Disciplines**
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## Summary

**Objective:** To estimate the current annual economic impact of porcine reproductive and respiratory syndrome virus (PRRSV) on the US swine industry.

**Materials and methods:** Data for the analysis was compiled from the US Department of Agriculture, a survey of swine veterinarians on the incidence and impact of PRRSV, and production records (2005 to 2010) from commercial farms with known PRRSV status. Animal-level economic impact of productivity losses and other costs attributed to PRRSV were estimated using an enterprise budgeting approach and extrapolated to the national level on the basis of the US breeding-herd inventory, number of pigs marketed, and number of pigs imported for growing.

**Results:** The total cost of productivity losses due to PRRSV in the US national breeding and growing-pig herd was estimated at US $664 million annually, an increase from the US $560 million annual cost estimated in 2005. The 2011 study differed most significantly from the 2005 study in the allocation of losses between the breeding and the growing-pig herd. Losses in the breeding herd accounted for 12% of the total cost of PRRSV in the 2005 study, compared to 45% in the current analysis.

**Implications:** Despite over 25 years of experience and research, porcine reproductive and respiratory syndrome remains a costly disease of pigs in the United States. Since 2005, some progress has been made in dealing with the cost of productivity losses due to the disease in the growing pig, but these were offset by greater losses in the breeding herd.

**Keywords**: swine, porcine reproductive and respiratory syndrome virus, economics

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**Resumen - Evaluación del impacto económico del virus del síndrome reproductivo y respiratorio porcino en los productores porcinos de los Estados Unidos**

**Objetivo:** Evaluar el impacto económico anual actual del virus del síndrome reproductivo y respiratorio porcino (PRRSV por sus siglas en inglés) en la industria porcina de los Estados Unidos (US por sus siglas en inglés).

**Materiales y métodos:** La información para el análisis se recopiló del Departamento de Agricultura de los Estados Unidos, de una encuesta a veterinarios porcinos sobre la incidencia e impacto del PRRSV, y de los registros de producción (2005 a 2010) de granjas comerciales con un estatus conocido de PRRSV. Se evaluaron el impacto económico a nivel animal de las pérdidas de productividad y otros costos atribuidos al PRRSV utilizando un enfoque de presupuesto global y extrapolado a nivel nacional en base al inventario del hato de cría de US, número de cerdos enviados al mercado, y el número de cerdos importados para engorda.

**Resultados:** El costo total de las pérdidas de productividad debido al PRRSV en los hatos de cría y cerdos para engorda nacional de los US se calculó en $664 millones de dólares americanos anualmente, un incremento de los $560 millones de dólares americanos anuales calculado en 2005. El estudio de 2011 difirió significativamente del de 2005 en la distribución de las pérdidas entre los hatos de hembras y la engorda. Las pérdidas en los hatos de cría explicaron el 12% del costo total del PRRSV en el estudio de 2005, comparado con el 45% del análisis actual.

**Implicaciones:** A pesar de más de 25 años de experiencia e investigación, el síndrome reproductivo y respiratorio porcino sigue siendo una enfermedad costosa de cerdos en los Estados Unidos. Desde 2005, se han logrado progresos al tratar con el costo de la pérdida de productividad en el cerdo en engorda, pero estos fueron nivelados por mayores pérdidas en el hato de cría.

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**Résumé - Évaluation de l'impact économique du virus du syndrome reproducteur et respiratoire porcin sur les producteurs de porcs des États-Unis**

**Objectif:** Estimer l'impact économique annuel actuel du virus du syndrome reproducteur et respiratoire porcin (VSRRP) sur l'industrie porcine américaine.

**Matériels et méthodes:** Les données pour les analyses ont été compilées à partir du US Department of Agriculture, d'un sondage auprès des vétérinaires porcins sur l'incidence et l'impact du VSRRP, et des registres de production (2005 à 2010) de fermes commerciales dont le statut pour le VSRRP était connu. L'impact économique des pertes de productivité et des autres coûts attribués au VSRRP au niveau de l'animal ont été estimés en utilisant une approche de budgétisation au niveau de l'entreprise et en l'extrapolant au niveau national en se basant sur l'inventaire des troupeaux reproducteurs américains, le nombre de porcs mis en marché, et le nombre de porcs importés au fin d'engraissement.

**Résultats:** Aux États-Unis le coût total des pertes de production dues au VSRRP dans le cheptel de porcs reproducteurs et de porcs d'engraissement a été estimé à $664 millions par année, une augmentation par rapport au coût de $560 millions par année estimé en 2005. L'étude de 2011 différait significativement de celle de 2005 dans la distribution des pertes entre le cheptel des animaux reproducteurs et le cheptel des animaux en engraissement. Les pertes chez les reproducteurs représentaient 12% du coût total du VSRRP dans l'étude de 2005, comparativement à 45% dans la présente analyse.

**Implications:** Malgré 25 années d'expérience et de recherche, le syndrome reproducteur et respiratoire porcin demeure une maladie porcine coûteuse aux États-Unis. Depuis 2005, des progrès ont été réalisés en rapport à la gestion des coûts associés aux pertes de productivité dus à la maladie chez les porcs en engraissement, mais ceux-ci ont été contrebalancés par des pertes plus importantes chez les reproducteurs.

Outbreaks due to porcine reproductive and respiratory syndrome virus (PRRSV) were first recognized in the late 1980s in the United States.[1,2] Clinical signs included dramatic reproductive losses, increased pneumonia, and reduced pig growth.[3] Shortly thereafter, a disease with similar clinical signs began spreading across Europe.[4-8] By the early 1990s, outbreaks had also been documented in Asia, and later the disease was confirmed in Poland and the Czech Republic.[9-11] Retrospective studies using archived serum samples confirmed these observations. Serum samples collected in 1980 in Canada were positive for PRRSV antibodies.[12] Serum samples collected from Iowa pigs in 1980 were free of PRRSV antibodies, while samples collected in 1985 were antibody-positive.[13] Thus, the disease became pandemic in a relatively short time.

Clinical outbreaks and long-term effects of PRRSV are highly variable, but the clinical picture described in 1991 is still accurate. In the breeding herd, initial signs are variable, but may include anorexia, fever, and cyanosis.[14] This may be followed by increases in breeding-herd mortality (1 to 2 percentage points), late-term abortions (1 to 2 percentage points), premature farrowing events (1 to 20 percentage points), dead and mummified piglets in farrowed litters, and variation in breeding and farrowing intervals.[14] During an acute outbreak, more than half of the litters may be affected. Infected boars may be lethargic, but often show few overt clinical signs. Semen quality may decline temporarily. In piglets, pre-weaning mortality may increase by 10 to 40 percentage points and secondary infections become more prevalent.[14] Mortality often increases in the growing-pig population, nearly always in conjunction with increases in other respiratory infections. Slower growth rates, non-uniform performance, and persistent respiratory disease with secondary infections are common sequelae in affected growing pigs. Cumulatively, porcine reproductive and respiratory syndrome (PRRS) may reduce the annual production of the herd by 15%.[14]

Early on, the cost of clinical outbreaks of PRRS was recognized as significant. In perhaps the earliest economic analysis, a 1991 study reported that losses in herds infected with PRRSV for 3 months reduced gross returns (minus feed costs) by 6% to 8% in each month of the outbreak.[15] However, the authors also conceded that they were not able to document all losses, and thus not all costs were incorporated into their estimate. For the purposes of this paper, all costs are provided in US$. Hoefling[16] reported that acute PRRS outbreaks in four breeding herds in Illinois cost an estimated $100, $170, $428, and $510 per breeding female, respectively. These estimates were based on decreased production of weaned pigs and increased treatment costs. Polson et al,[17] describing a 4-month outbreak in a 250-sow herd in Minnesota, estimated the cost of the outbreak at $236 per breeding female for the year following the outbreak. The losses consisted primarily of lost opportunity for revenues on 966 pigs that would have been produced had the herd performed at the baseline productivity levels of the previous 3 years. This loss represented a reduction of 3.8 pigs weaned per female per year and translated into a decrease in profits of $59,781 for the year of the outbreak, otherwise stated as a decrease in profit of $9.42 per cwt produced (1 cwt = 45.36 kg). In another study, Dee et al[18] documented losses averaging $228 per sow over a 12-month period due to elevated mortality rates, reduced growth rates, and increased medication and vaccination costs.

Schaefer and Morrison[19] evaluated productivity in 15 genetic-supplier breeding herds (500 to 1200 sows per herd) undergoing "herd closure" for elimination of PRRSV. These herds reported an average of 686 more pigs weaned per herd for the 52 weeks post closure than for the 52 weeks prior to closure. However, the authors did not describe the PRRSV status or the number of PRRS outbreaks in these herds prior to closure. Thus, the study did not produce an estimate of the cost of PRRSV infections; rather, it suggested that productivity was better in the absence of PRRSV, and this improvement could be maintained during the course of PRRSV elimination efforts.

In growing pigs, PRRSV typically affects both growth performance and overall level of health. The clinical effect of PRRSV is exacerbated by interactions between PRRSV and other infectious agents present in the population. Kerkaert et al[20] reported a 70% loss in profits in a feeder-pig operation due to endemic PRRSV infection in the nursery. A reduction of over $5.00 per pig was attributed to the nursery stage alone due to decreased growth rates, increased feed conversion, and increased mortality. Using a financial model, Polson et al[21] estimated that the difference between PRRSV-affected and non-affected nursery pigs ranged from $0.73 to $18.21 per head. Dee and Joo[22] estimated the cost of endemic PRRS in a 600-sow herd at $225 per sow per year ($10.50 to $12.50 per pig marketed). This cost estimate was based on 10% nursery mortality, a 50% reduction in average daily gain, and a 33% rate of non-marketable pigs. On the basis of productivity levels in herds that had successfully eliminated PRRSV by nursery depopulation, Dee and Joo[23] estimated that PRRSV infection and its synergistic interaction with secondary bacterial infections resulted in an increase of 14 to 30 days to market in the finishing stage, adding $7.50 to $15.00 to the cost of each pig marketed due to reduction in growth rates, increased mortality, and increased numbers of non-marketable pigs.

In addition to direct production losses, PRRSV can significantly increase animal-health costs for pharmaceuticals, biologicals, and diagnostics. Animal-health costs associated with prevention and treatment of secondary infections increased 60% during the 12 months following an outbreak of PRRS in a 2700-sow operation in Poland.[24] During the peak of the outbreak, animal-health costs were four times higher than prior to the outbreak, and a year after the outbreak this parameter had not returned to pre-PRRS-outbreak levels.

An economic analysis of the impact of PRRSV on the US pork-production industry, published in 2005, estimated productivity losses attributed to the disease cost producers $561 million dollars annually.[25] Since that time, a number of changes have occurred in the industry that may have changed the effect of PRRSV, eg, both pork-production strategies and PRRSV control and elimination strategies have evolved and changed. In the 2006 National Animal Health Monitoring System (NAHMS) survey of pork production operations,[26] PRRS was the disease most frequently diagnosed in breeding herds (27.3%), nursery pigs (26.6%), and grow-finish production sites (30.2%). The study revealed striking increases in the occurrence of PRRS in all phases of production when compared to a similar NAHMS study conducted in 2000.[26,27] The primary objective of the present study was to estimate the current annual economic impact of PRRSV on the US swine industry and provide data useful to development of strategies for the control or elimination of PRRSV at the herd, local, regional, and national levels.

# Materials and methods

The economic impact of PRRSV was estimated separately for the US national breeding and growing-pig herds. Costs evaluated included those arising from productivity losses, increased expenditures on pharmaceuticals, biologicals, and diagnostics, implementation of enhanced biosecurity measures, and changes to pig management implemented to reduce the impact of PRRS outbreaks. Data for the analysis was obtained both from production records from 2005 to 2010 retrieved from a sample of commercial swine farms with known PRRSV status and from a survey of swine veterinarians completed in 2011. Regression analysis on the data from the production records was used to estimate the effect of PRRSV on important herd performance metrics. The key performance metrics were combined in an enterprise budgeting model to ascertain the cost of the disease at the animal level. The animal-level costs were then combined with information from the United States Department of Agriculture (USDA) on breeding-herd inventories, pig imports, and pigs marketed, and information on PRRSV infection rates and incidence of outbreaks at a national level from the survey of swine veterinarians to obtain the estimate of the annual cost of the disease to the US industry.

The macro-economic impact on the market price of pigs due to productivity losses resulting from the PRRSV was not evaluated. If PRRSV were eliminated from the United States, it would impact the supply of pork, pork demand including exports, and market-hog prices. An analysis of these impacts was not conducted for this study.

**Box 1:** Parameter abbreviations

**ADG:** average daily gain

**BA:** no. of piglets born alive per litter farrowed

**BCR:** breeding female cull rate

**BDR:** breeding female death rate

**FCR:** feed conversion rate

**LFY:** litters farrowed per female per year

**MOR:** mortality rate

**PMP:** percent of pigs sold in the primary market

**PWM:** preweaning mortality

## Breeding-herd performance

Estimates of productivity losses due to PRRSV were derived from an analysis of farm production records from 80 US commercial breeding herds with known PRRSV infection status. The selection of breeding herds in the study was not random and depended on the willingness of producers to share production records. Breeding herds were selected from various geographic regions and herd sizes. Monthly production data collected for the period January 1, 2005 to December 31, 2010 included BA, BCR BDR, LFY, and PWM, (parameter abbreviations defined in Box 1). Seventy-two months of data were requested from each farm, with at least 24 consecutive months of data required for inclusion in the study. When breeding-female mortality and culling information were provided as monthly counts, annualized cull and death rates were calculated by dividing the count data by the female inventory and then multiplying by 12 months. In months where cull rates exceeded 200% (a situation suggesting rapid, planned depopulation events), the data were excluded from the analyses. Information on animal-health costs, including pharmaceutical, immunization, and diagnostics costs, was collected from each breeding herd when available.

Data on BA, LFY, and PWM were extracted from the production records and then used to calculate the number of pigs weaned per female per year so that the relative effect of PRRSV on each of these parameters could be determined. Data on BCR and BDR were also collected to estimate the effect of PRRSV on a farm's culling practices, a management decision that has a direct effect on the cost of female replacements for breeding.

The PRRSV infection status and dates of key events that changed the PRRSV infection status of the herd were also collected. Key events included PRRS outbreaks and successful completion of a PRRSV elimination project. Herd veterinarians identified the onset of PRRS outbreaks, as well as other key events.

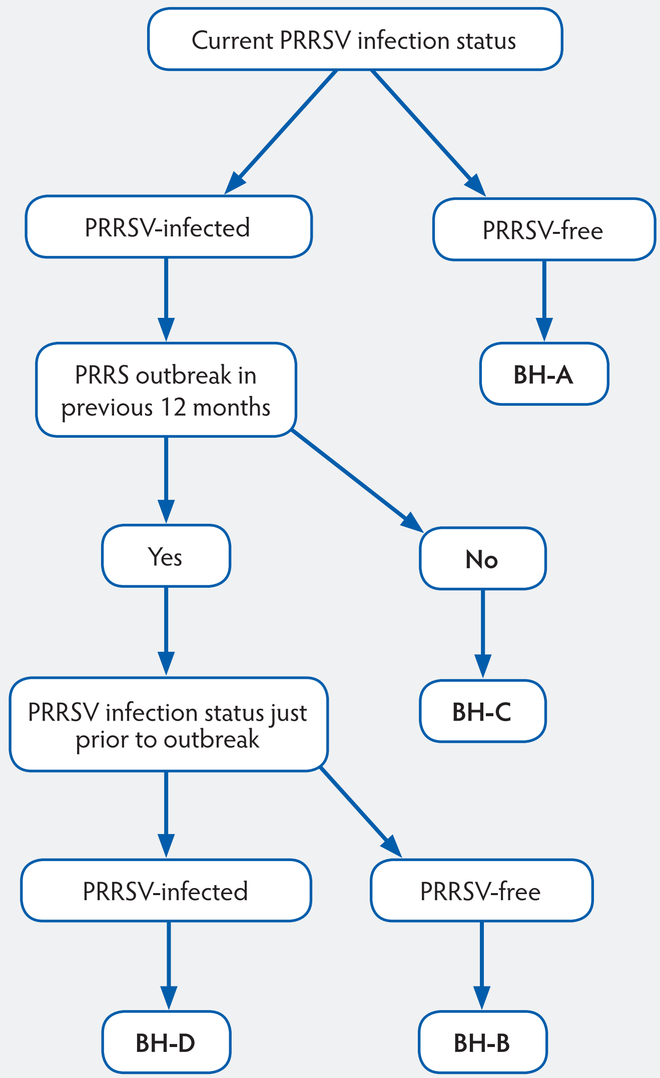
To capture the long-term effects of PRRSV infection status and outbreaks on productivity in the breeding herd, a PRRS classification was determined for each month of the recording period. The PRRS classification was based on three criteria. First was PRRSV infection status; second, whether the herd experienced one or more PRRS outbreaks in the previous 12 months; and third, for herds in which an outbreak had occurred in the previous 12 months, PRRSV infection status immediately prior to the outbreak. Including infection status immediately prior to the outbreak allowed for comparing losses in PRRSV-free herds to losses due to re-breaks in PRRSV-infected (ie, partially immune) herds.

The PRRSV infection status of breeding

herds was considered either PRRSV-free or PRRSV-infected, using the classification system developed by a committee supported by the American Association of Swine Veterinarians (AASV) and the USDA PRRS Coordinated Agricultural Program (PRRS-CAP): Category I (PRRSV-positive, unstable), Category II (PRRSV-positive, stable), Category III (provisionally PRRSV-negative), or Category IV (PRRSV-negative).[28] In accordance with the AASV-PRRS-CAP system, breeding herds classified as Category III included those that had apparently succeeded in eliminating the virus, but had not yet culled all breeding animals that had been previously exposed to the PRRSV. Breeding herds classified as Category IV consisted of herds of seronegative animals where no animals in the herd had ever been infected with PRRSV. For this analysis, breeding herds classified as Category I or II, including vaccinated breeding herds, were designated PRRSV-infected, and breeding herds classified as Category III or IV were designated PRRSV-free.

The PRRS classifications used in this study to achieve a more precise estimate of costs are shown in Figure 1. Breeding herds (BH) designated as BH-A consisted of PRRSV-free herds. Herds designated as BH-B were PRRSV-infected herds that had experienced a PRRS outbreak within the previous 12 months, but were PRRSV-free prior to the outbreak. Herds designated as BH-C were PRRSV-infected herds that had not experienced a PRRS outbreak for at least 12 months, and BH-D herds were PRRSV-infected herds that had experienced a PRRS outbreak in the previous 12 months and had been PRRSV-infected before the most recent outbreak. Herds designated as BH-B and BH-D were analyzed for the 12-month period following the outbreak to capture both the immediate and long-term effects of the outbreak on productivity.

**Figure 1**: Porcine reproductive and respiratory syndrome (PRRS) classification system for swine breeding herds used to assess the economic impact of PRRS virus (PRRSV) on US producers. Breeding-herd designations: BH-A herds were PRRSV-free herds; BH-B herds were PRRSV-infected herds that had experienced a PRRS outbreak within the previous 12 months, but had been PRRSV-free prior to the outbreak; BH-C herds were PRRSV-infected herds that had not experienced a PRRS outbreak for at least 12 months; BH-D herds were PRRSV-infected herds that had experienced a PRRS outbreak in the previous 12 months and had been PRRSV-infected before the most recent outbreak. PRRS virus-infected herds were defined according to American Association of Swine Veterinarians-PRRS-Coordinated Agricultural Program (-CAP) categories I (PRRSV-positive, unstable) and II (PRRSV-positive, stable). PRRS virus-free herds were defined as AASV-PRRS-CAP categories III (provisionally PRRSV-negative) and IV (PRRSV-negative).[28]

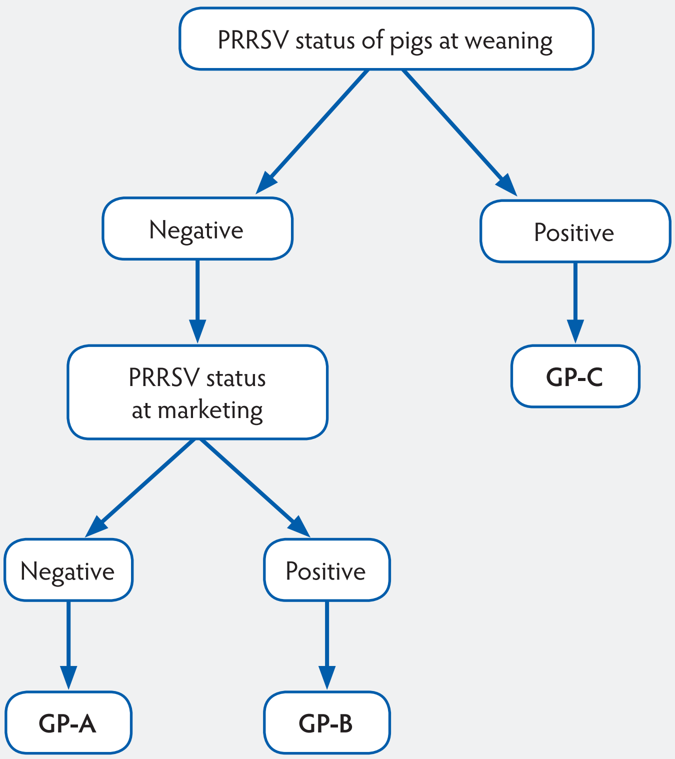



## Growing-pig herd performance

Data on groups of growing pigs with a marketing close-out date between January 1, 2005 and December 31, 2010 were obtained through a convenience sampling from both one-site wean-to-finish systems and systems having separate nursery and finisher sites. For the sake of data quality, only groups managed as all-in, all-out by site, and for which the PRRSV infection status was known at the time of placement on feed and at the time of marketing, were included in the study. In systems with separate nursery and finisher sites, only data from systems that maintained group integrity between sites, where data could be reliably combined into single postweaning cohorts, were accepted. The metrics required to include a group in the study were wean-to-finish ADG, FCR, MOR, and PMP. Data on animal-health costs (pharmaceutical, immunization, and diagnostic testing costs) were collected when available.

Each group of growing pigs was classified in one of three PRRS classifications according to PRRSV status at time of placement (weaning) and at time of marketing (Figure 2). A negative PRRSV status meant the pigs were seronegative and not infected. Pigs that were

**Figure 2:** Porcine reproductive and respiratory syndrome (PRRS) classification system for groups of growing pigs used to assess the economic impact of PRRS virus (PRRSV) on US producers. Groups of growing pigs designated as GP-A were negative at weaning and through marketing, GP-B groups were negative at weaning but became positive, at some time prior to marketing, to wild-type or vaccine virus or both, and GP-C groups were known to be positive at weaning. Positive groups were seropositive or infected due to exposure to vaccine or wild-type virus.




infected with the PRRSV or seropositive were considered positive. Groups of growing pigs (GP) designated as GP-A were negative at weaning and through marketing, GP-B groups were negative at weaning but became positive sometime prior to marketing to either or both wild-type or vaccine virus, and GP-C groups were known to be positive at weaning.

## Statistical analysis of herd performance

Using the monthly breeding-herd data obtained from the farm production records, each of the breeding-herd productivity measures (BA, BCR, BDR, LFY, and PWM) were analyzed as response variables in separate linear mixed regression models using standard statistical software (SAS version 9.2; SAS Institute Inc, Cary, North Carolina). The predictor variables of PRRS classification, month, and year were modeled as fixed effects; herd and production system were included as random effects to account for the correlation between these two nested variables. Production systems were one or more herds under common management. Similarly, each of the productivity measures in the growing pig data (ADG, FCR, MOR, and PMP) was analyzed as the response variable in separate linear mixed regression models. PRRS classification, month, and year were modeled as fixed effects, and herd and production system were again included as random effects in the models. For both the breeding-herd and growing-pig data, differences in mean response values for each PRRS classification were compared using a *t* test with Tukey-Kramer adjustment to *P* values for multiple testing. *P* values < .05 were considered significant.

## Economic analysis, animal level

A budgeting approach similar to that used in the PRRSV cost study published in 2005 was utilized to estimate the total cost of productivity losses attributed to the disease in the US industry.[25] A swine-enterprise budgeting model that specified the mathematical relationships between production inputs and outputs, as well as the costs and revenues associated with swine production, was developed. The model captures the major relationships between the productivity metrics, market-pig prices, and input prices, making it possible to plug in different market-pig or feed prices, for example, to see how they change the impact of PRRS on the profitability of the enterprise. The budgeting model was applied independently for breeding herds in each of the PRRS classifications (BH-A, BH-B, BH-C, and BH-D) using estimates for key performance metrics obtained from statistical analysis of the production records (BA, BCR, BDR, LFY, and PWM). A similar approach was used for each of the PRRS classifications of growing pig herds (GP-A, GP-B, and GP-C) and utilized estimates for ADG, FCR, MOR, and PMP obtained from statistical analysis of the production records. It was assumed that pigs had a fixed time to grow. Therefore, a decrease (increase) in ADG resulted in lighter (heavier) live-pig and carcass weights marketed. Because of variation in packer pricing grids and the relatively small differences in the average carcass weight for each of the PRRS classifications modeled, it was assumed that market-hog prices did not change as carcass weights changed. The more significant impact of PRRSV on market-hog prices received would likely result from a change in the variability of market weights; however, the impact of PRRSV on variation in market weights was not evaluated in this analysis. To avoid the effect of farm-to-farm variation, standard reference values for capital expenditures, variable input prices, weaned-pig prices, market-hog prices, and production metrics not directly affected by PRRSV were used in the budgeting model. The weaned-pig price used in the budgeting model ($36.19 per pig) was based on an average of weekly prices reported during the period from 2005 to 2010.[29] The market-hog price used in the model ($67.26 per cwt of carcass weight) was based on the average of the monthly negotiated Iowa-Minnesota daily direct prior-day hog reports (plant-delivered) for 2005 to 2010.[30] Breeding-herd feed costs in the budgeting model were based on a single breeding-herd diet calculated as the weighted-average cost of typical lactation and gestation diets, weighted by the relative percentage of each diet fed. Similarly, feed costs for growing pigs were based on the use of a single wean-to-finish diet calculated as the weighted-average cost of a typical sequence of diets fed from weaning to market.[31,32] Diet composition was typical for the US Midwest, and in each case included corn, soybean meal, distillers dried grains (DDGs), and other ingredients. The corn price used in the model diets ($3.32 per bushel) was based on the average of monthly prices in Iowa from 2005 to 2010.[33] The high protein (46.5% to 48.0%) soybean-meal price ($293.04 per metric tonne) was based on the average monthly price in central Illinois from 2005 to 2010.[34] The price for DDGs used in the budgeting model ($125.73 per metric tonne) was based on the average monthly price in central Illinois from 2005 to 2010.[34] The cost of other ingredients and diet processing were based on estimates published by Kansas State University.[31,32] The resulting diet cost in the breeding herd was $190.95 pet metric tonne, and the diet cost for the growing pigs was $186.03 per metric tonne.

The other costs included in the budgeting analysis were grouped into all other non-feed variable costs and fixed costs. In the breeding-herd model, non-feed variable costs included breeding (semen and other breeding-related expenses), animal health, labor and management, and other. "Other" included such things as marketing; fuel; oil; gas and utilities; supplies; general and administrative; and miscellaneous expenses. In the growing-pig model, non-feed variable costs included the weaned-pig cost, which was transferred from the breeding herd at the same market price used in the breeding model (ie, the average weaned-pig price from 2005 to 2010). The other subcategories of non-feed variable costs included in the model for the growing pigs were the same as for the breeding herd, with the exception of the breeding costs. Fixed costs in both the breeding-herd and growing-pig models included depreciation, interest, repairs, taxes, and insurance. Fixed costs were estimated for buildings and improvements, machinery and equipment, and vehicles in the breeding and growing-pig models. Fixed costs were also estimated for breeding animals in the breeding-herd model. The annual depreciation estimates were derived using straight-line depreciation. Interest, repairs, taxes, and insurance were estimated as a percentage of the capital investment in each. The parameter values used to estimate the non-feed variable and fixed costs, as well as production metrics that were assumed to not be directly affected by PRRSV, are reported for the breeding herd in Table 1 and for the growing-pig herd in Table 2. The cull price of females used in the model was based on the average of monthly prices in the United States from 2005 to 2010.[33] The basis for the other parameter values in Tables 1 and 2 was the experience and industry knowledge of the authors about the average values of each from 2005 to 2010.

### Economic analysis, national level

The estimated annual cost of PRRSV in the United States was defined as the difference between the estimated total revenue and total costs (net profit) for the US industry when operating as an entirely PRRSV-free population and the net profit for the US industry operating under the current situation as a partially PRRSV-infected population. Breeding herds and growing-pig herds were analyzed separately and then combined to estimate the total difference in national economic performance due to PRRSV. For the national breeding-herd estimate, a "No-PRRSV" scenario was created and defined as having 100% of US breeding herds operating free from the virus (category BH-A). Next, a "Current" scenario was created and defined as the average production of all four PRRS classifications (BH-A, BH-B, BH-C, and BH-D), weighted according to the estimated percentage of swine breeding herds in each classification. A similar approach was used for analysis of the national growing herd: a No-PRRSV scenario was created assuming 100% of groups in the United States were produced as GP-A, and a Current scenario was defined as the average production of all three classifications (GP-A, GP-B, and GP-C), weighted according to the estimated percentage of groups of pigs in each. The weighting factors for both the breeding-herd and growing-herd Current scenarios were derived from the survey of swine veterinarians.

The cost of PRRSV was extrapolated to the national level on the basis of the US breeding-herd inventory, number of pigs marketed annually, and number of pigs imported for growing. The US breeding-female inventory of 5,788,000 breeding females was based on an average of the quarterly breeding-herd inventories reported by the USDA for each year from 2005 through 2010.[35] For the same time period, the average total annual pigs marketed at all slaughter plants (which included domestic production and pigs imported for feeding and harvest)[36] in the United States was 109,636,000. An annual average of 3,346,000 pigs weighing < 6.8 kg were imported into the United States for feeding and harvest during the period 2005 through 2010.[37] So that the predicted number of pigs weaned in the budgeting model plus the number imported from other countries resulted in the correct number of pigs marketed as reported by USDA, BA, LFY, and PWM were adjusted downward by a factor of 0.9649. The adjustment was determined by using the optimization function Goal Seek in Microsoft Excel (Microsoft Corporation, Redmond, Washington).

### Survey of swine veterinarians

Swine veterinarians were purposively sampled from the list of members of the AASV and surveyed to obtain subjective data on the incidence, severity, and cost of PRRSV on US swine farms. All veterinarians were employed full-time in commercial swine-production systems or specialty swine veterinary practices and were selected to ensure that swine herds of all sizes in various geographic locations of the United States were represented in the survey responses. Veterinarians supplied information based on personal experience and data only from herds for which they provided veterinary services. Care was taken to avoid duplication of information in those instances where more than one veterinarian provided services to the same herd or production system. Information supplied by the veterinarians included data on herd sizes by region and the proportion of breeding and growing-pig herds in each of the PRRS classifications. Information was also provided on the impact of PRRSV on animal-health costs, biosecurity costs, and other costs that might be incurred due to changes in pig flow, stocking and movement changes, more intensive care of pigs, and production or contract penalties during and after an outbreak of PRRS. Survey responses that required quantitative answers were reported as numeric ranges rather than point estimates.

## Results

### Summary of production records and survey of swine veterinarians

Estimated productivity losses due to PRRSV were based on production records from 2005 to 2010 retrieved from commercial swine farms, including 3963 monthly observations from 80 breeding herds in which PRRS classification was established for each month. Breeding herds from 18 states and 14 production systems were enrolled

**Table 1:** Parameter values used to estimate the non-feed variable and fixed costs as well as production metrics assumed to not be directly affected by porcine reproductive and respiratory syndrome virus (PRRSV) in the breeding herd in a study estimating the annual economic impact of PRRSV on the US swine industry*

| Parameter | Value |
| --- | --- |
| **Performance** | |
| Average lactation length (days) | 20.0 |
| Average gestation length (days) | 115.0 |
| Average weaning weight (kg/pig) | 5.4 |
| **Non-feed variable costs** | |
| **Animal health** | |
| Cost/breeding female/year ($) | 20.00 |
| Cost/pig weaned ($) | 0.25 |
| **Breeding** | |
| Cost/breeding female/year ($) | 30.00 |
| **Labor and farm management** | |
| Labor and management/breeding female/year (hours) | 7.5 |
| Wages and benefits ($/hour) | 15.00 |
| **Other non-feed variable** | |
| Cost/breeding female/year ($) | 75.00 |
| **Fixed costs** | |
| **Depreciation on breeding animals** | |
| Average purchase price or cost/replacement female ($) | 200.00 |
| Average cull price of females ($/kg live weight) | 0.82 |
| Average weight of cull females (kg) | 215.5 |
| **Depreciation on buildings and improvements** | |
| Capital investment ($/breeding female) | 1200.00 |
| Expected useful life (years) | 20 |
| Salvage value after useful life (% of capital investment) | 10 |
| **Depreciation on machinery and equipment** | |
| Capital investment ($/breeding female) | 400.00 |
| Expected useful life (years) | 10 |
| Salvage value after useful life (% of capital investment) | 5 |
| **Depreciation on vehicles** | |
| Capital investment ($/breeding female) | 45.00 |
| Expected useful life (years) | 5 |
| Salvage value after useful life (% of capital investment) | 10 |
| **Insurance, repairs, taxes, and interest** | |
| For breeding animals (% of capital investment/year) | 6.0 |
| For buildings and improvements (% of capital investment/year) | 7.0 |
| For machinery and equipment (% of capital investment/year) | 7.5 |
| For vehicles (% of capital investment/year) | 10.0 |

* All currency in $US.

in the study. Herd inventories ranged from 400 to 15,800 breeding females, with eight of the breeding herds (10%) having ≤ 999 breeding females, 33 (41%) having 1000 to 3999 breeding females, and 39 (49%) having ≥ 4000 breeding females. Among the 80 breeding herds, 42 were classified as BH-A herds for some part of the time for which data was provided. Herds were classified as BH-B (n = 19), BH-C (n = 38), or BH-D (n = 30) for at least part of the time. Results presented in Table 3 showed that BH-A herds outperformed BH-B, BH-C, and BH-D herds in all key performance metrics. Herds classified as BH-C performed significantly better for BA and PWM than did herds classified as BH-B and BH-D, suggesting the occurrence of outbreaks in both PRRSV-free and PRRSV-infected farms was detrimental to production. Outbreaks in breeding herds that were PRRSV-free immediately prior to the outbreak (BH-B) were more severe, as measured by BA and PWM, than in herds that were PRRSV-infected at the time the outbreak occurred (BH-D), suggesting that the immune status of breeding females in herds that are PRRSV-infected immediately prior to an outbreak offers some protection against the detrimental productivity impact of outbreaks.

Of the 639 groups of growing pigs enrolled in the study, 149 (23%) were classified as GP-A, 243 (38%) as GP-B, and 247 (39%) as GP-C. Groups of pigs grown in Iowa, Minnesota, and Oklahoma from six business entities were enrolled in the study. Groups included in the study were marketed throughout the year, with the fewest groups (45 groups per month) being marketed in April and in May. November was the most frequent month for marketing (68 groups). The least squares means of the growing-pig performance metrics for each PRRS classification are reported in Table 4. Groups classified as GP-A had significantly better ADG and MOR than groups classified as GP-B or GP-C. Groups classified as GP-B had significantly better MOR than groups classified as GP-C. Feed conversion rate was numerically better for the groups classified as GP-B or GP-C than for those classified as GP-A, but the difference was not statistically significant. Values for PMP were numerically better for the groups classified as GP-A relative to GP-B or GP-C, but the difference was also not statistically significant.

Estimates of the proportion of breeding herds and growing pigs in each of the PRRS classifications were made from the survey of

**Table 2:** Parameter values used to estimate the non-feed variable and fixed costs as well as production metrics that were assumed to not be directly affected by porcine reproductive and respiratory syndrome virus (PRRSV) in the growing-pig herd in a study estimating the annual economic impact of PRRSV on the US swine industry*

| Parameters | Value |
|---|---|
| **Growth performance** | |
| Carcass yield (%) | 75.0 |
| Average live weight of light-weight pig at market (kg) | 82 |
| **Production times** | |
| Target days on feed, wean-to-market | 167 |
| Average days in nursery | 45 |
| Average downtime between turns (days) | 2 |
| **Revenue: market pigs** | |
| Market price of light-weight pigs (% of full value price) | 50 |
| **Variable costs: feed** | |
| Gain at time of death for mortality (% of total to market) | 25 |
| **Variable costs: non-feed** | |
| **Animal health** | |
| Animal health cost wean-to-finish ($/pig placed) | 2.50 |
| **Labor and farm management** | |
| Hours required per pig placed | 0.10 |
| Wages and benefits ($/hour) | 15.00 |
| **Other non-feed variable costs** | |
| Other wean-to-finish non-feed variable costs ($/kg of gain) | 0.077 |
| **Fixed costs** | |
| **Depreciation on buildings and improvements** | |
| Capital investment in nursery buildings and improvements ($/pig space) | 175.00 |
| Capital investment in finisher buildings and improvements ($/pig space) | 225.00 |
| Expected useful life of buildings and improvements (years) | 20 |
| Salvage value after useful life (% of capital investment) | 10 |
| **Depreciation on machinery and equipment** | |
| Capital investment in nursery machinery and equipment ($/pig space) | 10.00 |
| Capital investment in finisher machinery and equipment ($/pig space) | 15.00 |
| Expected useful life of machinery and equipment (years) | 10 |
| Salvage value after useful life (% of capital investment) | 10 |
| **Depreciation on vehicles** | |
| Capital investment in nursery vehicles ($/pig space) | 1.00 |
| Capital investment in finisher vehicles ($/pig space) | 2.50 |
| Expected useful life (years) | 5 |
| Salvage value after useful life (% of capital investment) | 20 |
| **Insurance, repairs, taxes, and interest** | |
| For buildings and improvements (% of capital investment/year) | 7.0 |
| For machinery and equipment (% of capital investment/year) | 10.0 |
| For vehicles (% of capital investment/year) | 10.0 |

* All currency in $US.

swine veterinarians. Of the 59 veterinarians contacted, 26 (44%) agreed to provide input on the effect of PRRSV in their clients' herds. These individuals provided veterinary services to 2.34 million breeding females or approximately 46% of the breeding females in the US herd. For the breeding herds to which they provided veterinary services, the respondents were asked to estimate the proportion of breeding females in each of the four PRRS classifications on October 1, 2010. A substantial number of breeding females, 28%, were in US breeding herds that were PRRSV-free (BH-A) on October 1, 2010. Forty-two percent of all breeding females were in PRRSV-infected herds that had a PRRS outbreak in the 12 months prior to October 1, 2010 (BH-B and BH-D): 6% were PRRSV-free before the outbreak (BH-B) and 36% were PRRSV-infected before the outbreak (BH-D). The remaining 30% were in PRRSV-infected herds that had not had a PRRS outbreak in the 12 months prior to October 1, 2010 (BH-C).

The swine veterinarians who responded to the survey were also responsible for 41.5 million growing pigs, representing approximately 40% of growing pigs marketed annually in the United States. On the basis of their experience with these animals for the year ending October 1, 2010, 25% of the growing pigs were PRRS-negative at placement (weaning) and throughout the postweaning phase (GP-A); 35% were negative at placement, but then became positive during the growing period (GP-B); and 40% were positive at weaning (GP-C).

## Economic cost of productivity losses

The least squares means estimates for BA, BCR, BDR, LFY, and PWM in the breeding herd (Table 3) and ADG, FCR, MOR, and PMP in the growing pigs (Table 4) from the statistical analysis of the production records survey were considered the best estimates available and therefore were used to populate the budgeting model. Estimates of the proportion of breeding herds and growing pigs in each of the PRRS classifications from the survey of swine veterinarians and data from the USDA on the number of pigs marketed annually and the national sow inventory were then used to expand the analysis from an individual-herd level to a national level.

In the breeding-herd analysis, it was estimated that PRRSV reduced reproductive

**Table 3:** Least squares means with standard errors of breeding-herd performance metrics for herds in each breeding-herd PRRS classification in a study estimating the annual economic impact of PRRSV on the US swine industry*

| | Breeding-herd PRRS classification† | | | |
|---|---|---|---|---|
| **Parameters** | **BH-A** | **BH-B** | **BH-C** | **BH-D** |
| No. of pigs born alive per litter farrowed | 11.6 ± 0.1[a] | 10.6 ± 0.2[b] | 11.2 ± 0.1[c] | 11.0 ± 0.1[d] |
| Pre-weaning mortality (%) | 12.2 ± 0.8[a] | 18.0 ± 1.2[b] | 12.6 ± 0.8[a] | 13.7 ± 0.8[c] |
| No. of litters per mated female per year | 2.45 ± 0.04[a] | 2.33 ± 0.04[b] | 2.39 ± 0.04[b] | 2.38 ± 0.04[b] |
| Breeding-female culling rate (%) | 50.7 ± 2.2 | 47.7 ± 2.6 | 50.5 ± 2.2 | 49.8 ± 2.3 |
| Breeding-female death rate (%) | 8.4 ± 0.6[a] | 9.5 ± 0.8[ab] | 9.1 ± 0.5[ab] | 9.6 ± 0.6[b] |

* Estimates based on production records from January of 2005 to December of 2010 retrieved from a sample of commercial breeding herds with known PRRSV status.

† Classifications defined in Figure 1.

abcd Values within a row with different superscripts are significantly different ($P < .05$). A linear mixed regression model, with breeding-herd PRRS classification, month, and year modeled as fixed effects and herd and production system as random effects, was used to analyze differences between breeding-herd PRRS classifications.

PRRS = porcine reproductive and respiratory syndrome; PRRSV = PRRS virus.

**Table 4:** Least squares means with standard errors of growing-pig performance metrics for groups of pigs in each growing-pig PRRS classification in a study estimating the annual economic impact of PRRSV on the US swine industry*

| | Growing-pig PRRS classification† | | |
|---|---|---|---|
| **Parameters** | **GP-A** | **GP-B** | **GP-C** |
| Mortality rate (% of pigs placed) | 6.0 ± 0.8[a] | 7.4 ± 0.8[b] | 9.3 ± 0.9[c] |
| Average daily gain (g/day) | 709.8 ± 18.0[a] | 695.9 ± 18.0[b] | 692.1 ±18.2[b] |
| Feed conversion rate (g feed/g gain) | 2.61 ± 0.04 | 2.57 ± 0.04 | 2.57 ± 0.04 |
| Pigs sold in the primary market (% marketed) | 96.4 ± 0.5 | 95.7 ± 0.6 | 95.8 ± 0.6 |

* Estimates based on production records for groups of pigs with a marketing close-out date between January 1, 2005 and December 31, 2010 retrieved from a sample of commercial growing-pig herds with known PRRSV status.

† Classifications defined in Figure 2.

abc Values within a row with different superscripts are significantly different at $P < .05$. A linear mixed regression model with growing-pig PRRS classification, month, and year of marketing modeled as fixed effects and herd and production system as random effects was used to analyze differences between growing-pig PRRS classifications.

PRRS = porcine reproductive and respiratory syndrome; PRRSV = PRRS virus.

efficiency by 1.44 pigs weaned per breeding female per year and the annual number of pigs weaned in the United States by 8.30 million pigs (Table 5). The total annual cost of productivity losses in US breeding herds was estimated to be $302.06 million, equivalent to an average of $52.19 per breeding female or $2.36 per pig weaned for the entire US breeding-female inventory. The majority of the loss in the breeding herd ($300.39 million) was due to a reduction in revenue caused by fewer pigs being weaned.

The estimated annual cost of productivity losses in the growing-pig herd was $361.85 million (Table 6). As in the breeding herd, lost revenue ($1.61 billion), rather than increased cost, was the primary source of losses attributed to PRRSV. With PRRS, fewer pigs and kilograms of pork were produced, and consequently costs of production were lower by $1.25 billion, thereby offsetting some of the lost revenue. Losses in the breeding and growing-pig herds resulted in 9.93 million fewer pigs per year, or approximately 1.09 billion fewer kilograms of pork (as measured by carcass weight), marketed per year in the United States. The total annual cost of PRRSV in the United States due to the combined productivity losses in the breeding and growing-pig herds was estimated to be $663.91 million or $1.8 million per day. The per-female cost was $114.71 per year for every sow in the US breeding-female inventory. On a per-pig basis, PRRSV costs the industry $4.67 for every pig marketed in the United States.

## Sensitivity analysis on economic cost of productivity losses

The sensitivity of these results to changes in the price of weaned pigs, market hogs, corn, soybean meal, and DDGs was also explored to provide some appreciation for the extent to which feed and hog prices impact the value of the productivity losses attributed to PRRSV. In addition to a baseline model, eight other scenarios were created by simultaneously increasing or decreasing the feed ingredient prices by 20% and simultaneously increasing or decreasing the weaned-pig and market-hog prices by 20% (Table 7). Over the range of prices evaluated, the total annual cost of productivity losses due to PRRSV, for breeding and growing-pig herds combined, ranged from $233.54 million dollars to $1.104 billion dollars. The annual cost increased as weaned-pig and market-hog prices increased and as feed-ingredient prices declined. The

**Table 5:** Productivity and economic impact of porcine reproductive and respiratory syndrome virus (PRRSV) in the US national breeding herd, 2005 to 2010, in a study estimating the annual economic impact of PRRSV on the US swine industry

| | Scenario | | |
|---|---|---|---|
| | Current* | No-PRRSV† | Difference‡ |
| **Productivity impact** | | | |
| Breeding-female inventory (millions) | 5.79 | 5.79 | 0.00 |
| Litters farrowed (million litters/year) | 12.39 | 12.66 | 0.27 |
| Pigs born alive (million pigs/year) | 133.68 | 141.54 | 7.86 |
| Pigs weaned (million pigs/year) | 115.43 | 123.73 | 8.30 |
| Pigs weaned/female/year | 19.94 | 21.38 | 1.44 |
| **Economic impact (annual) (all currency in $US)** | | | |
| Total revenue (million $/year) | 4177.72 | 4478.11 | 300.39 |
| Total costs (million $/year) | 4038.05 | 4036.38 | -1.67 |
| Net profit (million $/year) | 139.67 | 441.73 | 302.06 |
| Profit/breeding female/year ($/year) | 24.13 | 76.32 | 52.19 |
| Profit/pig weaned ($) | 1.21 | 3.57 | 2.36 |

* Current scenario: average production of all four PRRS classifications (BH-A, BH-B, BH-C, and BH-D, defined in Figure 1) weighted according to the percentage of swine breeding herds estimated to be in each classification.

† No-PRRSV scenario: 100% of US breeding herds operating free from the virus (Category BH-A, defined in Figure 1).

‡ Difference is the value for the No-PRRSV scenario less the value for the Current scenario.

**Table 6:** Productivity and economic impact of porcine reproductive and respiratory syndrome virus (PRRSV) in the US national growing-pig herd, 2005 to 2010 in a study estimating the annual economic impact of PRRSV on the US swine industry

| | Scenario | | |
|---|---|---|---|
| | Current* | No-PRRSV† | Difference ‡ |
| **Productivity impact** | | | |
| Pigs marketed (million pigs/year) | 109.47 | 119.40 | 9.93 |
| Live weight marketed (million kg/year) | 12,812.27 | 14,270.91 | 1458.64 |
| Carcass weight marketed (million kg/year) | 9609.20 | 10,703.18 | 1093.98 |
| **Economic impact (annual) (all currency in $US)** | | | |
| Total revenue (million $/year) | 14,451.78 | 16,067.03 | 1615.25 |
| Total costs (million $/year) | 13,414.19 | 14,667.58 | 1253.39 |
| Net profit (million $/year) | 1037.60 | 1399.45 | 361.85 |
| Profit/breeding female/year ($/year) | 179.27 | 241.79 | 62.52 |
| Profit/pig marketed/year ($) | 9.48 | 11.72 | 2.24 |

* Current scenario: average production of all three classifications (GP-A, GP-B, and GP-C, defined in Figure 2), weighted according to the percentage of groups of pigs in each classification.

† No-PRRSV scenario: 100% of groups of pigs in the United States produced as GP-A.

‡ Difference is the value for the No-PRRSV scenario less the value for the Current scenario.

financial impact of PRRSV was highest under the scenario where pork production was expected to be most profitable.

## Other costs attributed to PRRSV

Data on animal-health costs provided from the survey of production records was sparse. Information on animal-health costs provided through the survey of swine veterinarians, while more subjective, was more complete and was therefore used to estimate the annual increase in animal-health-related costs attributed to PRRSV.

The animal-health costs in the breeding herd were reported on a per-pig-weaned basis. In the growing-pig herd they were reported on a per-pig-marketed basis. To arrive at a national cost figure, the values provided by the survey respondents were multiplied by the total annual number of pigs weaned and the annual number of pigs marketed in the United States for both the Current and No-PRRSV scenarios. The difference in the total animal-health costs between the two scenarios represented additional animal-health costs attributed to PRRSV. The additional animal-health costs were estimated to be $62.62 million and $77.49 million annually in the breeding and growing-pig herds, respectively, for a total of $140.11 million per year or $1.71 per pig marketed (Table 8).

Data on biosecurity costs attributed to PRRSV and other outbreak-related costs during and after an outbreak (due to changes in pig flow, stocking rates and pig movements, more intensive care of pigs, and production and contract penalties) were also collected in the survey of swine veterinarians. They were reported on a per-pig-marketed basis for the entire production system (or herd if the production system was composed of a single herd) and were not split between the growing-pig and breeding herds. Like animal-health costs, the values provided by the survey respondents were multiplied by the total annual number of pigs marketed in the United States for both the Current and No-PRRSV scenarios to estimate a total cost per year. The annual biosecurity-related and other outbreak-related costs attributed to PRRSV were estimated at $337.68 million per year or $3.08 per pig marketed (Table 8). The total additional costs attributed to PRRSV for animal health, biosecurity, and other outbreak-related costs were $477.79 million annually.

**Table 7:** Sensitivity of the annual cost of productivity losses due to PRRSV in the United States to alternative commodity prices (sensitivity analysis) in a study estimating the annual economic impact of PRRSV on the US swine industry

| Weaned pig and market hog prices | Feed costs* | | |
|---|---|---|---|
| | 20% price increase ($) | Baseline ($)† | 20% price decline ($) |
| 20% price decline | 233.54 | 340.87 | 458.19 |
| Baseline‡ | 546.59 | 663.91 | 781.24 |
| 20% price increase | 869.64 | 986.97 | 1104.29 |

* All currency in $US.

† Baseline price assumptions for feed ingredients: corn $3.32 per bushel, soybean meal $293.04 per metric tonne, distillers dried grains $125.73 per metric tonne.

‡ Baseline price assumptions for pigs: weaned pigs $36.19 each and market hogs $67.26 per cwt (1 cwt = 45.45 kg).

PRRSV = porcine reproductive and respiratory syndrome virus.

**Table 8:** Annual animal health, biosecurity, and other outbreak-related costs attributed to PRRSV in the US national breeding and growing-pig herds, 2005 to 2010, in a study estimating the annual economic impact of PRRSV on the US swine industry*

| | Scenario† | | |
|---|---|---|---|
| | Current | No-PRRSV | Difference‡ |
| **Animal health costs (immunization, pharmaceutical, and diagnostics)** | | | |
| Breeding herd (million $/year) | 319.09 | 256.47 | -62.62 |
| Growing-pig herd (million $/year) | 396.23 | 318.74 | -77.49 |
| Total (million $/year) | 715.32 | 575.21 | -140.11 |
| ($/breeding female/year) | 123.59 | 99.38 | -24.21 |
| ($/per pig marketed) | 6.53 | 4.82 | -1.71 |
| **Annual biosecurity and other outbreak-related costs** | | | |
| Biosecurity costs attributed to PRRSV (million $/year) | 191.86 | 0.00 | -191.86 |
| Other outbreak-related costs (million $/year) | 145.82 | 0.00 | -145.82 |
| Total (million $/year) | 337.68 | 0.00 | -337.68 |
| ($/breeding female/year) | 58.34 | 0.00 | -58.34 |
| ($/per pig marketed) | 3.08 | 0.00 | -3.08 |

* All currency in $US.

† Values reported from 26 swine veterinarians surveyed for information on the basis of their personal experience, or data only from herds for which they provided veterinary services, or both. Responding veterinarians provided veterinary services to 2.34 million breeding females (approximately 46% of the breeding females in the United States) and 41.5 million growing pigs, (representing approximately 40% of growing pigs marketed annually in the United States).

‡ Difference is the value for the No-PRRSV scenario less the value for the Current scenario.

PRRSV = porcine reproductive and respiratory syndrome virus.

## Discussion

The total US annual cost of PRRSV due to productivity losses in the breeding and growing-pig herds during the period 2005 to 2010 was approximately $104 million higher than the $560 million annual cost estimated in 2005.[25] In addition, the relative proportions of losses in the breeding and growing-pig herds differed from those reported in 2005. In the 2005 study, the breeding herd accounted for 12% of the total cost of PRRSV, compared to 45% in the current analysis.

Inflation alone explains 40% of the increase in the cost of PRRSV during the 5 years between studies. Average annual rate of inflation between 2005 and 2010, as measured by the Consumer Price Index, was 2.4%.[38] The future value of the cost of PRRS estimate published in 2005 is equal to $602 million measured in 2010 dollars.

Since 2005, the incidence and severity of PRRS outbreaks may have changed, pork production strategies have evolved, and PRRSV control and elimination strategies have changed. Co-infection of pigs with PRRSV and porcine circovirus type 2 (PCV2) has been associated with expression of severe clinical disease. The effect of the emergence of PCV2-associated disease and widespread use of PCV2 vaccines since 2005 on the cost of PRRSV to the US industry is unknown.[39] Methods used to increase the likelihood of weaning PRRSV-free pigs from PRRSV-infected breeding herds have evolved significantly. Use of vaccination, live-virus inoculation, temporary closure of herds to new breeding replacements, and limiting use of cross-fostering to stop circulation of PRRSV in the breeding herd following a PRRS outbreak have likely increased the number of PRRSV-free groups of pigs being weaned in the United States. However, these strategies may also have impacted productivity in the breeding herd or changed the incidence of PRRS and severity of outbreaks in breeding and growing-pig herds nationwide. Reliable data to support or refute these speculations are not available, highlighting a significant gap in our knowledge and ability to monitor progress in fighting PRRSV.

In addition to the cost of productivity losses due to PRRSV, $140.11 million in animal-health costs, $191.86 million in biosecurity-related costs, and $145.82 million in other outbreak-related costs per year were estimated in this study. The total attributed to PRRSV for these additional costs, which were based on subjective estimates reported by the survey of swine veterinarians, was $477.79 million annually. These costs were not included in the 2005 study. The estimates for biosecurity-related costs and other outbreak-related costs should be interpreted with caution, since it is very difficult to attribute these costs to a specific pathogen or disease such as PRRS.

A potential source of bias in the analysis is reliance on convenience sampling for the survey of production records. Selection of breeding herds and groups of growing pigs in the study was not random and depended on the willingness of producers to share production records. In addition, the analysis may have been biased by the restrictive selection criteria used in order to reasonably establish the PRRSV status of the groups of growing pigs at weaning and marketing. Only groups managed as all-in, all-out by site, and for which PRRSV infection status was known at the time of placement on feed and at the time of marketing, were included in the study. In systems with separate nursery and finisher sites, only data from systems that maintained group integrity between sites, where data could be reliably combined into single post-weaning cohorts, were accepted.

Losses not considered part of this study included those uniquely associated with outbreaks in genetic supplier herds (suppliers of female breeding replacements or boar studs). Nearly all genetic herds and boar studs in the United States are maintained PRRSV-free, because genetic customers demand PRRSV-free replacement breeding females and semen. When PRRS outbreaks do occur in genetic supplier herds, costs often exceed those associated with an outbreak in a commercial herd due to the resultant effects of disrupted genetic supply, loss of customers, direct loss of genetic sales, additional diagnostic-testing costs, creation of secondary outbreaks, and high cost of elimination due to the need to return to PRRSV-free status as rapidly as possible.

The herd-level productivity losses related to the PRRSV, when expanded to the national level, were estimated to result in 9.93 million fewer pigs marketed per year, or approximately 1.09 billion fewer kilograms of pork (as measured by carcass weight) marketed per year in the United States. Therefore, if the PRRSV were eliminated from the United States, it would impact the supply of pork, pork demand (including exports), and market-hog prices. An analysis of these impacts was not conducted for this study. However, it is likely that the price of pigs at slaughter and retail prices for pork would be lower, which would also lead to more exports, as the United States would become more competitive in the global market for pork.

## Implications

- Despite a global investment in PRRS-related research for more than 25 years, PRRS remains an important disease of pigs in the United States as measured by its detrimental effect on productivity and substantial financial cost to producers.
- Since 2005, some progress has been made in dealing with the cost of productivity losses due to the disease in the growing pig, but these were offset by greater losses in the breeding herd.
- Investment in research and new approaches to control and eliminate the virus are needed.

### Conflict of interest

None reported.

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