RESEARCH REPORT

SWINE HEALTH

Title: Monitoring and updating the value of productivity losses due to porcine reproductive and respiratory syndrome virus – **NPB #15-212**

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II. Industry Summary

The value of lost productivity due to porcine reproductive and respiratory syndrome virus (PRRSV) in the US was last updated for 2005 to 2010 (2010 Study). The value was estimated to be US$664 million annually. In 2014, the National Pork Board (NPB) developed a strategic plan that identified the following goal to drive sustainable production: "By 2020, the NPB will deploy tools and programs to decrease the annual economic impact of PRRS by 20 percent, as adjusted for inflation and measured against the 2012 ["2010 study"] PRRS economic impact baseline study." The objective of this study was to provide semi-annual updates of the estimated value of lost productivity in the US swine herd attributable to PRRS virus. This semi-annual report (October 2018) to the National Pork Board contains an assessment the value of lost productivity due to PRRSV for the five-year time period extending from October of 2013 to September of 2018.

The same economic classification of breeding herds and growing pigs, sources of data, and methods used to estimate the value of productivity losses due to PRRSV used for the 2010 study were used for this update. Changes in the value of lost productivity due to PRRSV at the national level is a function of four factors; 1) the distribution of breeding females and growing pigs in PRRSV affected and PRRSV unaffected herds, 2) productivity of breeding herds and growing pigs in PRRSV affected herds relative to PRRSV unaffected herds, 3) pig prices, input prices and costs and 4) the size of the national herd. The contribution of each factor to changes in the value of lost productivity due to PRRSV was assessed independently, by fixing values for all other factors at the levels estimated for the 2010 study. The combined effect of changes in all factors was also estimated to determine the overall impact on the value of lost productivity due to PRRSV. For the purpose of monitoring progress toward the NPB's goal of reducing the impact of PRRSV, changes in the prices and costs as well as the size of the national herd, factors that were not directly influenced by producer and veterinary efforts to manage PRRSV, were fixed at the values used for the 2010 study.

Key findings for this semi-annual update (October 2018):

1. The incidence of PRRS outbreaks has decreased since the 2010 study which contributed to a significant increase in breeding herds that are PRRS virus positive but have not had an outbreak for at least 12 months. However, the apparent shift favoring control of PRRSV over elimination in breeding herds also occurred since 2010. The net effect of these shifts in the distribution of herds was to increase the value of lost productivity due to PRRSV.

2. Since 2010, progress in managing PRRSV has led to an improvement in the productivity of PRRSV affected breeding herds relative to PRRSV unaffected herds, contributing to a significant reduction in the value of lost productivity.

3. Based on changes in all factors the annual value of productivity losses due to PRRSV was $560 million, down $103 million or 15.61%, compared to the $664 million per year estimated in the 2010 study.

4. For the purpose of monitoring progress toward the NPB's goal, the combined effect of changes in factors directly influenced by producer and veterinary efforts to manage PRRSV resulted in a net reduction in the value of productivity losses attributed to PRRSV to $525 million dollars. **This is down $138 million or 20.8%, compared to the $664 million per year estimated in the 2010 study.**
    a. Factors directly influenced by producer and veterinary efforts to manage PRRSV include a) the distribution of PRRSV affected and unaffected herds and b) productivity in PRRSV affected herds relative to PRRSV unaffected herds.
    b. While the goal of a 20% reduction by 2020 was apparently achieved, the analysis was based on a limited set of breeding herd production data. Therefore, caution should be exercised when interpreting the results.

III. Keywords

PRRSV, economics, swine

IV. Scientific Abstract

Same as industry summary.

V. Introduction

In a study using data from 2005 to 2010, Holtkamp et al. estimated that the value of lost productivity due to porcine reproductive and respiratory syndrome virus (PRRSV) in the US breeding and growing-pig herd was $664 million per year[1] (2010 study), an increase from the $560 million annual cost estimated in 2005[2]. Since the 2010 study, different approaches have been applied to prevent, control and eliminate PRRSV from swine herds. Given these changes, it was reasonable to postulate that the incidence, severity, and impact of PRRS outbreaks on pig health and productivity in the U.S. herd, and therefore the value of lost productivity due to PRRSV, may have changed since the 2010 study was conducted.

In 2014, the National Pork Board (NPB) developed a strategic plan that included the following goal to drive sustainable pork production in the US: "By 2020, the NPB will deploy tools and programs to decrease the annual economic impact of PRRS by 20 percent, as adjusted for inflation and measured against the 2012 ["2010"] PRRS economic impact baseline study." Semi-annual updates of the estimated value of lost productivity in the US swine herd attributable to PRRSV will permit the NPB to monitor progress toward the goal of reducing the impact of PRRSV.

VI. Objectives

The objective of this ongoing study is to provide semi-annual updates of the estimated value of lost productivity in the US swine herd attributable to PRRSV to monitor progress toward the goal of reducing the impact of PRRSV. The value of lost productivity due to PRRSV was reported as a five-year moving average to avoid misinterpretation of short-term variation in the estimates as progress or lack of progress. In addition to allowing the NPB to monitor progress toward its goal, the information generated from this ongoing study will demonstrate to veterinarians and producers where efforts to prevent, control and eliminate PRRSV at the herd, local, regional, and national level are succeeding or failing. The results will also provide information to help the NPB and other funding sources allocate research resources to address the areas where progress is lacking.

This semi-annual report (October 2018) to the National Pork Board contains an assessment the value of lost productivity due to PRRSV for the five-year time period extending from October of 2013 to September of 2018. Updated factors included 1) the distribution of breeding females and growing pigs in PRRSV affected and PRRSV unaffected herds, 2) productivity of breeding herds and growing pigs (not updated for this report) in PRRSV affected herds relative to PRRSV unaffected herds, 3) pig prices, input prices and costs and 4) the size of the national herd.

VII. Methods

Factors affecting the value of lost productivity due to PRRSV

The economic value of lost productivity due to PRRSV at the national level is a function of four factors (Table 1). The contribution of each factor was assessed independently to elucidate why the impact of PRRSV was changing. The combined effect of changes in all factors was also estimated to determine the overall impact on the value of lost productivity due to PRRSV. While

it is important to understand how changes in all of the factors over time affect the value of lost productivity due to PRRSV, some of the factors were directly influenced by producer and veterinary efforts to manage PRRSV and others were not. For the purpose of monitoring progress towards NPB's goal, the combined effect of changes only in factors directly influenced by producer and veterinary efforts to manage PRRSV, were estimated to determine whether progress is being made. Factors that were not directly influenced by producer and veterinary efforts to manage PRRSV were fixed at the values used for the 2010 study.

Table 1. Four factors affecting the value of lost productivity due to PRRSV.

Factor	Description of factor	Affected by management of PRRSV	Assessed in the April 2018 Update
1. Herd distribution	Percentage of breeding females and growing pigs in each economic classification	Yes	Yes
2. Productivity	Production outcomes in PRRSV affected breeding herds (BH-A) relative to PRRSV unaffected herds (BH-B, BH-C and BH-D)	Yes	No
	Production outcomes in PRRSV-affected groups of pigs (GP-A) relative to unaffected groups (GP-B and GP-C)	Yes	No
3. Prices and costs	Market hog and weaned pig prices, feed ingredient prices, other input costs	No	Yes
4. National herd inventory	Breeding female inventory, annual pig crop, annual imports of growing pigs and pigs marketed annually	No	Yes

To estimate the value of productivity losses due to PRRSV, breeding herds were classified according to their PRRSV status and outbreak history, just as they were in the 2010 study[1]. The resulting economic categories were based on the system for classifying the PRRSV status of herds defined by the American Association of Swine Veterinarians (AASV)[3]. The economic categories for breeding herds were BH-A, BH-B, BH-C and BH-D as described in Figure 1. Herds where productivity was deemed to be unaffected by PRRSV were classified as BH-A. Productivity in breeding herds deemed to be affected by PRRSV, BH-B, BH-C or BH-D, was compared to productivity in BH-A herds to assess the impact of PRRSV on key production outcomes. Groups of growing pigs were classified according to their PRRSV status at placement and marketing (GP-A, GP-B and GP-C) as shown in Figure 2. Groups of pigs where productivity

was deemed to be unaffected by PRRSV were classified as GP-A. Productivity in groups of pigs affected by PRRSV, GP-B and GP-C, was compared to productivity in GP-A groups of pigs to assess the impact of PRRSV on key production outcomes in growing pigs.

Figure 1. Economic categories for swine breeding herds used to assess the economic impact of PRRSV on US producers. PRRSV affected herds were defined as AASV categories I (PRRSV-positive, unstable) and II (PRRSV-positive, stable). PRRSV unaffected herds were defined as AASV categories III (provisionally PRRSV-negative) and IV (PRRSV-negative). Breeding herds designated as BH-A consisted of PRRSV unaffected herds. Herds designated as BH-B were PRRSV affected herds that had experienced a PRRS outbreak within the previous 12 months, but were PRRSV unaffected prior to the outbreak. Herds designated as BH-C herds were PRRSV affected herds that had not experienced a PRRS outbreak for at least 12 months, and BH-D herds were PRRSV affected herds that had experienced a PRRS outbreak in the previous 12 months and were PRRSV affected before the most recent outbreak.

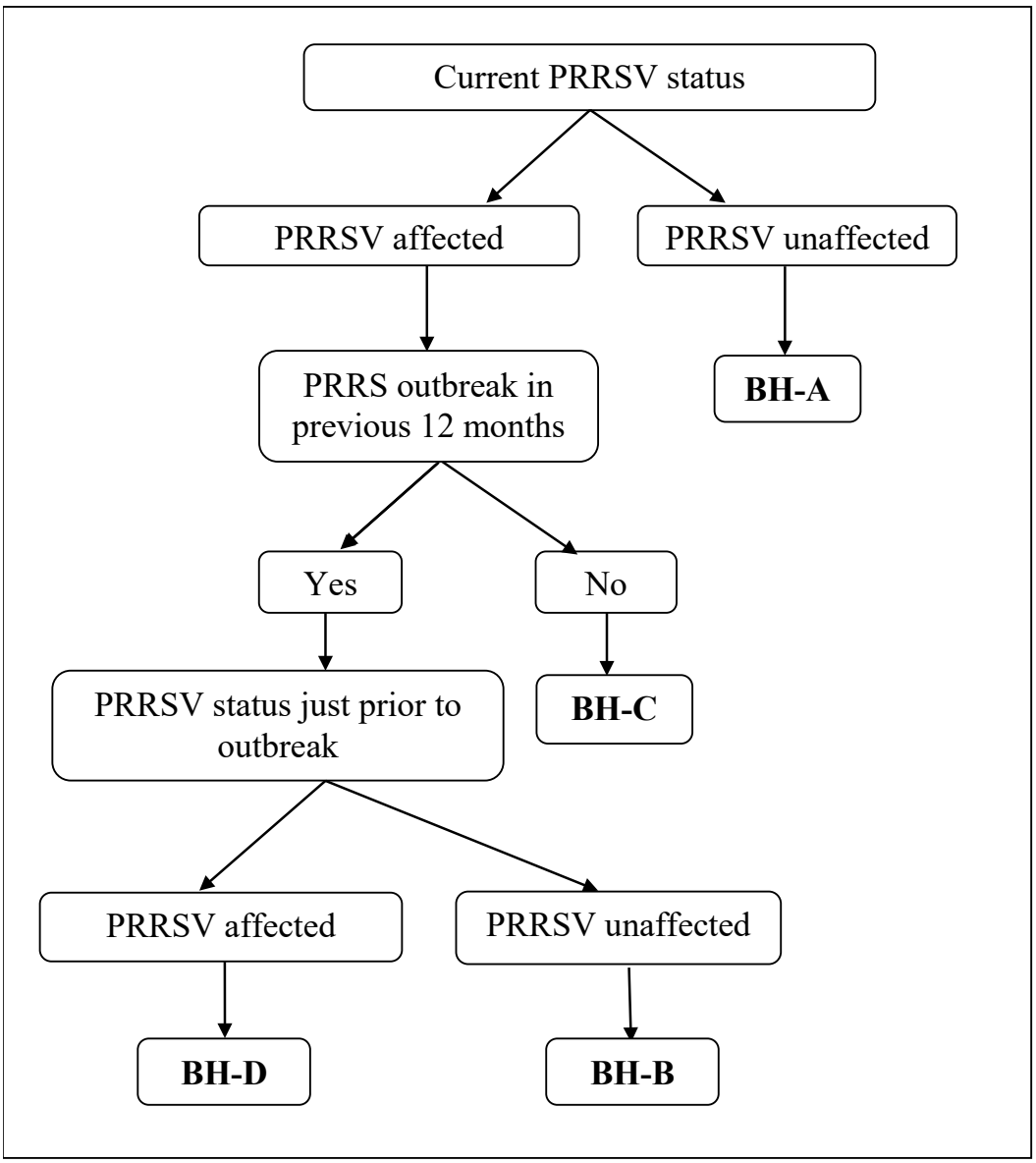
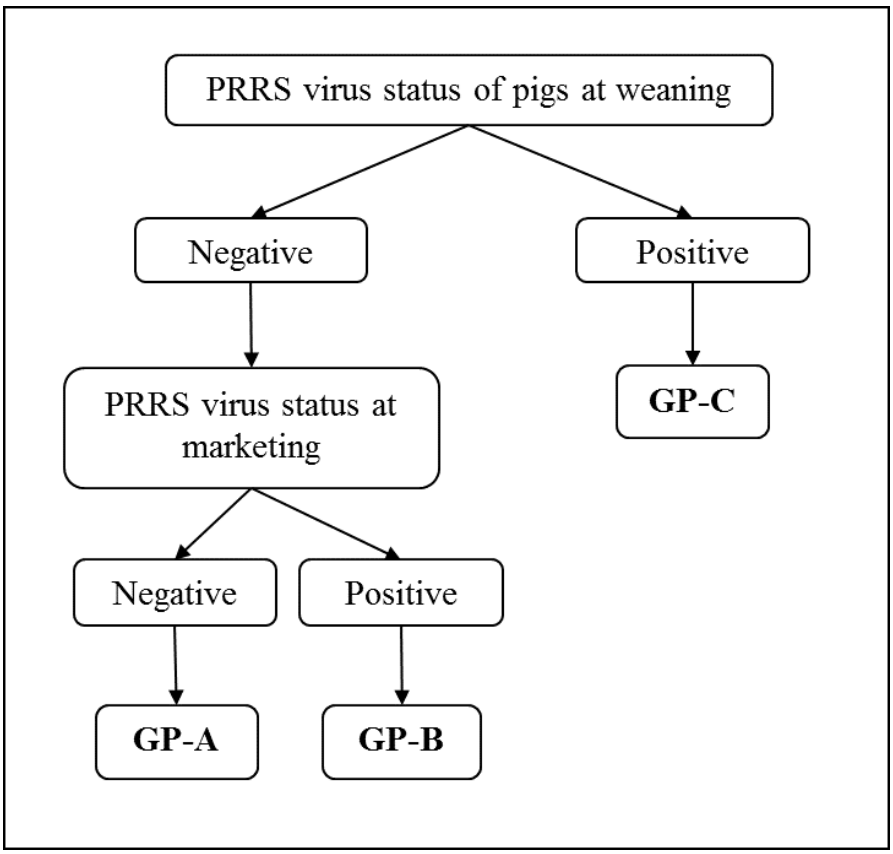


Figure 2. Economic categories for groups of growing pigs used to assess the economic impact of PRRSV on US producers. Groups of growing pigs designated as GP-A were negative at weaning and through marketing, GP-B groups were negative at weaning but became positive sometime prior to marketing to wild-type virus, vaccine virus or both, and GP-C groups were known to be positive at weaning. Positive groups were seropositive or affected due to exposure to vaccine or wild-type virus.



Herd distribution. The herd distribution was the proportion of breeding females and growing pigs in each economic classification (Figures 1 and 2) measured as a percentage of all breeding females and growing pigs in the US. The distribution of breeding females and growing pigs in each economic classification was influenced by the incidence of PRRS outbreaks in breeding herds, effectiveness of management efforts (bio-management and bio-exclusion) to control or eliminate the virus from breeding herds and effectiveness of biosecurity practices (bio-exclusion) to prevent the introduction of new isolates of the virus into breeding herds and groups of growing pigs. The distribution of breeding herds and groups of pigs in each economic classification was directly influenced by producer and veterinary efforts to manage PRRSV and therefore important for monitoring progress toward the NPB's goal of reducing the impact of PRRSV.

Productivity. Lost productivity attributed to PRRSV in breeding herds was measured by estimating production outcomes when herds were affected by PRRSV (BH-B, BH-C and BH-D) relative to when herds were unaffected by PRRSV (BH-A). Production measures evaluated included: 1) number of piglets born alive per litter (BA), 2) pre-weaning mortality rate (PWM),

3) litters farrowed per female per year (LFY), 4) breeding female cull rate (BCR) and 5) breeding female death rate (BDR). Lost productivity attributed to PRRSV in groups of growing pigs was measured by estimating production outcomes in PRRSV affected groups of pigs (GP-B and GP-C) relative to unaffected groups (GP-A). Production measures evaluated included: 1) wean-to-finish average daily gain (ADG), 2) wean-to-finish feed conversion rate (FCR), 3) percentage of pigs sold in the primary market (PMP) and 4) wean-to-finish mortality rate (MOR). The productivity of breeding herds and groups of growing pigs in each economic classification was influenced by the relative impact on productivity of management efforts (bio-management) to control or eliminate the virus from breeding herds and management efforts (bio-management) to reduce productivity losses in groups of growing pigs. Productivity of breeding herds and groups of pigs in each economic classification was directly influenced by producer and veterinary efforts to manage PRRSV and therefore important for monitoring progress toward the NPB's goal of reducing the impact of PRRSV.

Prices and costs. The value of lost productivity due to PRRSV, measured as the value of differences in estimated production outcomes between PRRSV affected breeding herds and PRRSV unaffected herds, depends on the market pig prices, feed prices and other input costs. The same is true for the value of lost productivity due to PRRSV in growing pigs affected by PRRSV compared to unaffected groups. In general, the value of lost productivity is highest when market pig prices are high, input prices and costs are low and raising pigs is highly profitable. Intuitively, as the profitability of raising pigs increases, the value of every pig or pound of pork lost due to PRRSV also increases. Consequently, the value of lost productivity due to PRRSV will increase when raising pigs is highly profitable independent of how effectively producers and veterinarians are managing PRRSV. While it is important to understand how changes in market pig prices, feed prices and other input costs over time affect the value of lost productivity due to PRRSV, for the purpose of monitoring progress toward NPB's goal of reducing the impact of PRRSV, the impact of changing prices and costs was excluded by using the same market hog and weaned pig prices, feed ingredient prices and other input costs used for the 2010 study[1].

National herd inventory. The value of lost productivity for the entire US is estimated by extrapolating breeding female and pig level estimates for the value of lost productivity due to PRRSV to all breeding females and pigs raised annually in the US. Independent of how effectively producers and veterinarians are managing PRRSV, the value of lost productivity due to PRRSV may increase solely because the size of the national breeding herd and the number of pigs raised increased. As with changes in prices and costs, it is important to understand how changes in the size of the national breeding herd and the number of pigs raised each year affects the value of lost productivity due to PRRSV. However, for the purpose of monitoring progress toward NPB's goal of reducing the impact of PRRSV, the impact of changes in the size of the national herd and the number of pigs raised annually was excluded by using the same breeding herd inventory, annual pig crop, annual imports of growing pigs and pigs marketed annually that were used for the 2010 study[1].

Procedures for estimating the value of lost productivity due to PRRSV

A flow diagram of the steps involved in estimating the five-year moving average of the value of lost productivity due to PRRSV in the breeding herd for the entire US is presented in Figure 3A (Appendix). The first step was to estimate the number of breeding females in each of the economic classifications (BH-A, BH-B, BH-C and BH-D). The number of breeding females in each economic classification was calculated as the product of the percentage of breeding females in each economic classification and the inventory of breeding females in the US. It was therefore influenced by two factors, the herd distribution and the size of the national herd. Five-year averages (October, 2013 to September, 2018) of the percentage of breeding females in each economic classification and the inventory of breeding females in the US were used in the calculation of the number of breeding females in each economic classification.

The second step involved estimating the value of the lost productivity for breeding females, on a US$ per breeding female per year basis, in each economic classification. By definition, the value of lost productivity in PRRSV unaffected herds, classified as BH-A, was 0 and the value of lost productivity in PRRSV affected breeding herds (BH-B, BH-C and BH-D) was calculated relative to PRRSV unaffected herds (BH-A). The value of the lost productivity was estimated with a budgeting model by inputting the estimated productivity losses and appropriate weaned pig prices, feed ingredient prices, other input costs. The value of lost productivity was calculated as the difference in net profit (revenue minus all costs) between females in PRRSV affected herds and those in PRRSV unaffected herds. The value of lost productivity for breeding females in each economic classification, therefore, was influenced by two factors, productivity and prices and costs. The same swine enterprise budgeting model for the breeding herd that was used to conduct the 2010 study was used to estimate the value of the estimated productivity losses for the semi-annual updates. Five-year averages (October, 2013 to September, 2018) of the estimated productivity losses and appropriate weaned pig prices, feed ingredient prices, other input costs were used in the budgeting model to estimate the value of the lost productivity for breeding females, on a US$ per breeding female per year basis, in each economic classification.

The third step was to calculate the value of lost productivity due to PRRSV for the entire US breeding herd as the product of the number of breeding females in each economic classification and the value of lost productivity per breeding female. Finally, the value of productivity losses for all breeding females in each economic classification was summed to arrive at the five-year moving average annual value of productivity losses due to PRRSV in the US breeding herd.

The flow diagram of the steps involved in estimating the value of lost productivity due to PRRSV in the growing pig herd for the entire US is presented in Figure 3B (Appendix). The first step was to estimate the number of growing pigs in each of the economic classifications (GP-A, GP-B and GP-C). The number of growing pigs in each economic classification was calculated as the product of the percentage of growing pigs in each economic classification and the annual weaned pig crop in the US. Growing pigs weighing less than fifteen pounds that were imported into the US were added to the weaned pig crop. The number of pigs in each economic classification was therefore influenced by two factors, the herd distribution and the size of the national herd. Five-year averages (October, 2013 to September, 2018) of the percentage of

growing pigs in each economic classification and the annual weaned pig crop in the US were used in the calculation of the number of growing pigs in each of the economic classifications.

The second step involved estimating the value of the lost productivity for growing pigs, on a US$ per pig placed basis, in each economic classification. By definition, the value of lost productivity in PRRSV unaffected groups, classified as GP-A, was 0 and the value of lost productivity in PRRSV affected groups (GP-B and GP-C) was calculated relative to PRRSV unaffected groups of pigs. The value of the lost productivity was estimated with a budgeting model by inputting the estimated productivity losses and appropriate market hog and weaned pig prices, feed ingredient prices, other input costs. The value of lost productivity for growing pigs in each economic classification, therefore, was influenced by two factors, productivity and prices and costs. The same swine enterprise budgeting model for the growing pig herd that was used to conduct the 2010 study was used to estimate the value of the estimated productivity losses for the semi-annual updates. Five-year averages (October, 2013 to September, 2018) of the estimated productivity losses and appropriate market hog and weaned pig prices, feed ingredient prices, other input costs were used in the budgeting model to estimate the value of the lost productivity for growing pigs, on a US$ per pig weaned/placed basis, in each economic classification.

The third step was to calculate the value of lost productivity due to PRRSV for the US growing pig herd as the product of the number of pigs weaned/placed in each economic classification and the value of lost productivity per pig weaned. Finally, the value of productivity losses for all growing pigs in each economic classification was summed to arrive at the five-year moving average annual value of productivity losses due to PRRSV in the US growing pig herd. The net profit in the growing pig phase of production for additions to the pig crop without PRRSV was added to the value of lost production due to PRRSV in the growing pig phase.

Figure 3A. Flow diagram of the steps involved in estimating the value of lost productivity due to PRRSV in the breeding herd for the entire US. Values are those estimated in the 2010 study. The factors that can affect the total costs are described in *italic* below each parameter.

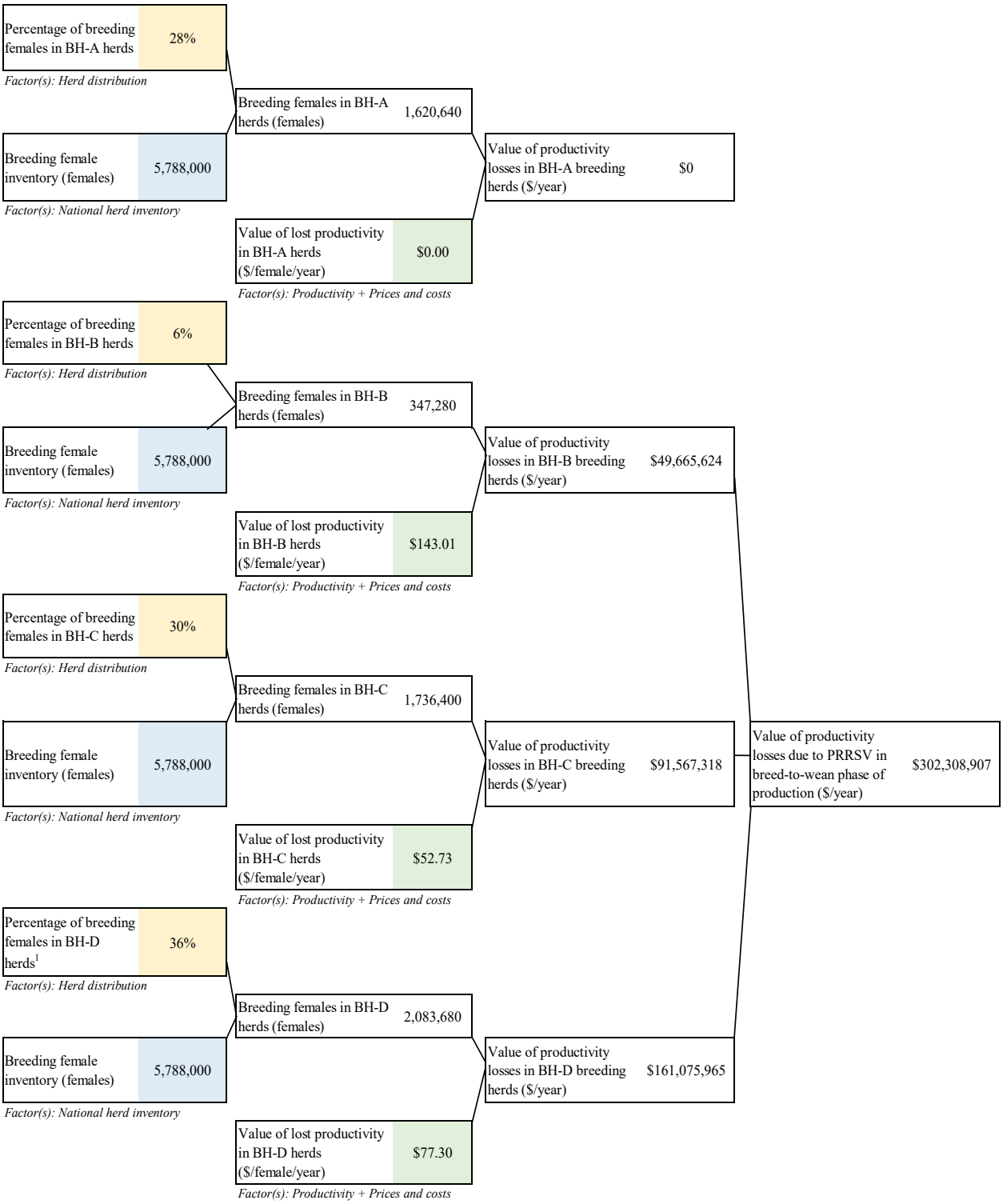
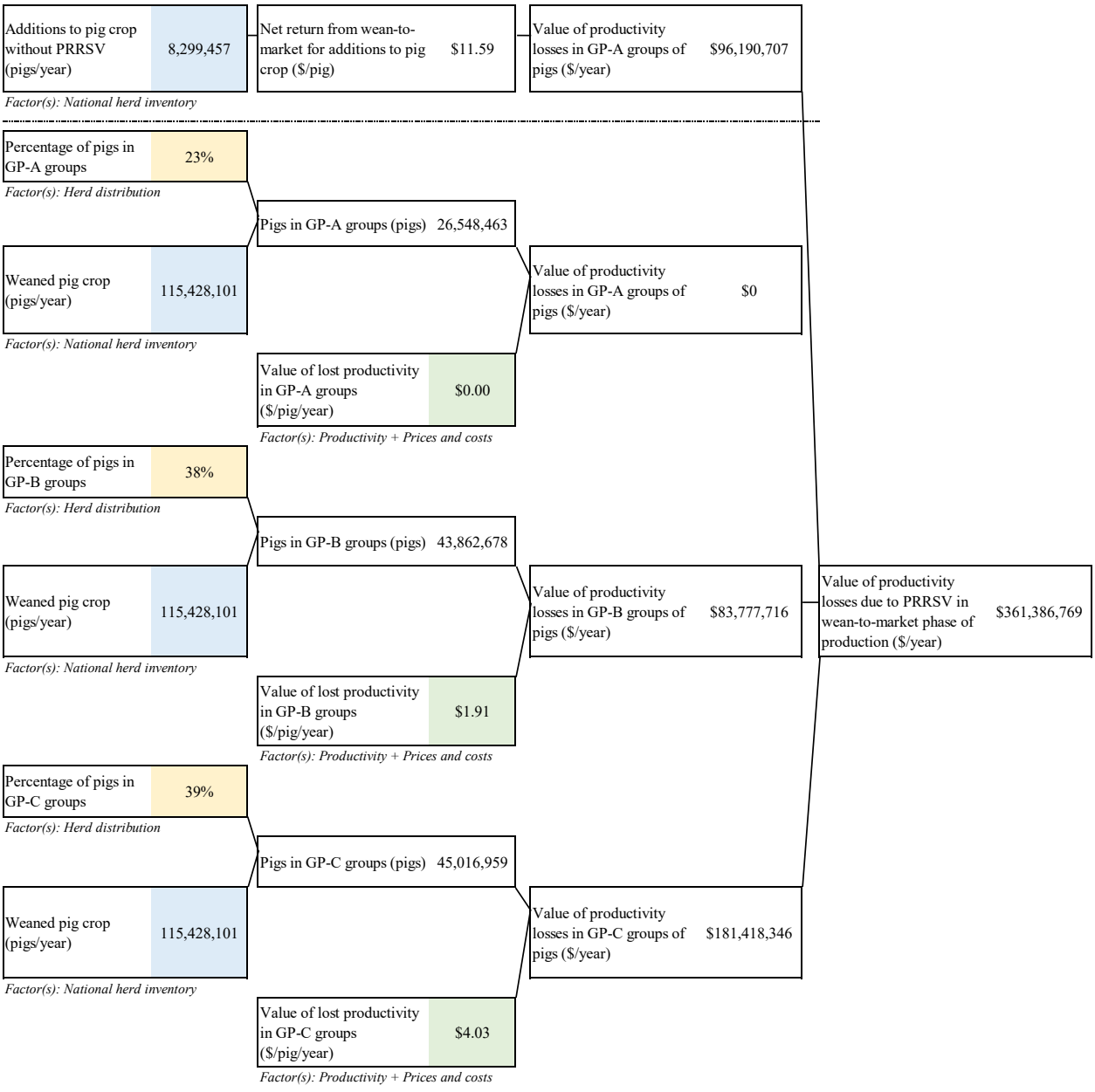


Figure 3B. Flow diagram of the steps involved in estimating the value of lost productivity due to PRRSV in the growing pig herd for the entire US. Values are those estimated in the 2010 study. The factors that can affect the total costs are described in *italic* below each parameter.



Sources of data

Herd distribution. Changes in the percentage of breeding herds and growing pigs in each PRRS economic classification (BH-A, B, C and D) were updated using information from the Morrison Swine Health Monitoring Project (MSHMP). The MSHMP is a national surveillance system reporting weekly changes in PRRSV status and the incidence of PRRS outbreaks (Appendix, Figure A.1 and Figure A.2). The MSHMP started in 2011 tracking the PRRSV status and outbreaks for 371 breeding herds in 14 production companies. Participants initially provided

retrospective data on the PRRSV status and outbreaks from July 2009 to the date of enrollment followed by prospective data on a weekly basis thereafter. Currently, 969 herds (2,819,283 sows) contribute data to the MSHMP.

Breeding herds in the MSHMP were assigned a MSHMP classification that was based on the system for classifying the PRRSV status of herds defined by the American Association of Swine Veterinarians (AASV).[3] The MSHMP classifications were the same as the AASV classifications except positive stable (AASV category II) herds were subdivided according to whether vaccine, wild-type virus or nothing was used to establish and maintain immunity in the herd. A description of how the MSHMP classification and outbreak history were mapped to the economic classification of breeding herds is in the Appendix of Tables (Table B.1).

For this analysis, the percentage of breeding herds in each economic classification estimated for the 2010 study was considered the baseline and the MSHMP data was used to estimate the changes in the percentage of herds in each PRRS economic classification since 2010. To estimate the changes in the percentage of breeding herds in each economic classification, the MSHMP database was used to calculate an index where the baseline value (index=100) was October 1, 2010, the date on which the estimates were made for the 2010 study. The weekly values of the index, calculated for October, 2013 to September, 2018, were multiplied by the baseline percentage of herds in each of the breeding herd economic classifications from the 2010 study to estimate the percentage of breeding herds in each economic classification by week.

Similarly, an index was calculated to measure the change in the percentage of pigs in each GP-classification (GP-A, B and C) in the MSHMP database, relative to the percentages estimated in the 2010 study. The baseline (index=100) was the year ending on October 1, 2010, the year for which the estimates were made for the 2010 study. The AASV PRRS category reported weekly for breeding herds enrolled in the MSHMP project was used to determine if groups of pigs from the breeding herd were positive or negative at placement (Appendix, Table B.2). Pigs sourced from herds that were in AASV category I (Positive unstable) were considered positive at placement and therefore in GP-C for the purposes of this study. Pigs from breeding herds in all other AASV categories were considered negative at placement and therefore in GP-A (also negative at marketing) or GP-B (positive at marketing). The allocation of pigs between GP-A and GP-B was based on the same relative percentage of pigs in these two groups estimated for the 2010 study, 42% for GP-A and 58% for GP-B. The 261-week, from October, 2013 to September, 2018, average of the index was multiplied by the baseline percentage of groups of growing pigs in each of the growing pig classifications from the 2010 study to estimate the percentages in each classification on those dates.

Productivity. The same estimates of productivity losses used in the October 2017 update were used for this October 2018 update. Estimates of productivity losses due to PRRSV were derived from an analysis of farm production records from 71 US breeding herds with known PRRSV infection status and outbreak histories. The selection of breeding herds in the study was not random and depended on the willingness of producers to share production records and to meet the eligibility criteria. Herds were eligible if weekly production data for the period of August 1, 2012 to July 30, 2017 was available and PRRSV status and outbreak histories were known since

2011. Weekly production data collected for the period August 1, 2012 to July 30, 2017 included pigs born alive per litter farrowed (BA), litters farrowed per mated female per year (LFY), pre-weaning mortality (PWM), breeding female death rate (BDR), and breeding female cull rate (BCR). To determine the economic classification each week, the AASV PRRSV classification status and dates of key events that changed the PRRSV classification of a herd were also collected. Key events included PRRS outbreaks, successful stabilization and completion of a PRRS virus elimination project. Herd veterinarians identified the onset of PRRS outbreaks, and dates of other key events.

The same statistical analysis of the production data done for the 2010 study was done for the production data of the October 2018 update, except weekly instead of monthly data was used. Using the weekly breeding herd production data, each breeding herd performance indicator (BA, LFY, PWM, BCR and BDR) was analyzed as response variables in separate linear mixed models. The predictor variables of economic classification, month, and year were modeled as fixed effects; farm and production system were included as random effects to account for the correlation between these two nested variables. Since the 2010 study, porcine epidemic diarrhea virus (PEDV) was first recognized in the US and has caused large neonatal losses in infected herds. To access the potentially large confounding effect of herds infected with PEDV, a dummy variable for PEDV status was created (Positive = 1; Negative = 0). For the breeding herd data models, an interaction term between the PRRSV economic classification and PEDV status was included to account for the variation due to PEDV. Least squares means estimates for PEDV negative herds were used to access the economic impact related only to PRRSV. The differences in mean response values for each PRRS economic classification were compared using a t-test with Tukey–Kramer's adjustment for multiple testing. P-values ≤ 0.05 were considered significant. The models were built using R program and the packages *car, nlme, lsmeans* and *multcomp*.

For this analysis, production records for groups of growing pigs were not collected. Therefore, the values for the production parameters for groups of growing pigs in each economic classification were the same as those used in the 2010 study.

Prices and costs. The weekly average weaned pig prices[4], market hog prices[5] and cull sow prices[6] used in the budgeting models were obtained from the same source used in the 2010 study for the period from October, 2013 to September, 2018. The market hog prices were based on the average of the weekly negotiated Iowa/Minnesota daily direct prior-day hog report (plant-delivered). The cull females price was based on the price of negotiated purchases sows (300-499 lbs.).

Breeding herd feed costs in the budgeting model were based on a single breeding herd diet calculated as the weighted average cost of lactation and gestation diets[7] where the weights were the typical proportion of each diet fed. Similarly, feed costs for growing pigs were based on a single wean-to-finish diet calculated as the weighted average cost of a sequence of diets fed from weaning to market[8] where the weights were the typical proportion of each diet fed. Diet composition was typical for the Midwestern U.S. and was broken into corn[9], soybean meal[10], distillers dried grains (DDG) [11] and "other ingredients". [7, 8]

National herd inventory. The U.S. breeding female inventory was calculated as the average of the quarterly breeding herd inventories reported by the United States Department of Agriculture (USDA) for each year from October, 2013 to September, 2018. [12] For the same time period the average number of pigs marketed annually in the U.S. was estimated based on the average total annual slaughter across all plants (which included domestic production and pigs imported for feeding/slaughter). [13] Pigs imported into the U.S weighing less than 15 pounds for feeding/slaughter were estimated for the period from October, 2013 to September, 2018. [14]

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. In the 2010 study, an adjustment was made to the breeding herd productivity measures so that the calculated number of pigs weaned in the budgeting model, for the reported US breeding herd inventory, plus the number imported from other countries was consistent with the number of pigs marketed as reported by USDA. For the October 2018 update the adjustment to BA, LFY and PWM was estimated to be 0.9306. The adjustment was determined by using the optimization function Goal Seek in Microsoft Excel (Microsoft Corporation, Redmond, Washington). The updated adjustment factor was used to estimate the productivity impacts due to PRRSV in the breeding herd. For the evaluation of all other factors, the same adjustment used in 2010 study was used (0.9649).

Estimates reported

The contribution to the economic value of lost productivity due to PRRSV of each factor was assessed independently by updating one of the four factors at a time and holding the other three factors constant at the same values from the 2010 study.

The combined effect of changes in the factors was also estimated. Given the objective of this study was to monitor progress toward NPB's goal of reducing the impact of PRRSV, the primary outcome (headline number) was the combined effect of changes only in factors directly impacted by producer and veterinary efforts to manage PRRSV. The factors directly impacted were the herd distribution and productivity. Therefore, the current value of lost productivity due to PRRSV used to benchmark the economic impact and monitor progress over time was the combined impact of changes on herd distribution and productivity holding constant the values for prices and costs and the national herd inventory at the baseline levels estimated in the 2010 study. However, the combined effect of all factors (herd distribution and productivity, prices and costs, and national herd inventory) was also estimated as this represents the entire impact of PRRSV, including factors directly impacted and those not directly impacted by producer and veterinary efforts to manage PRRSV.

VIII. Results and discussion

Assessment of factors independently

Herds Distribution

The five-year average, October 2013 to September 2018, percentage of females in breeding herds in each economic classification was reported in Table 2. Only 20.8 percent of all breeding

females were in herds unaffected by PRRSV (BH-A) for the October 2018 update, down from 28 percent in the 2010 study. Breeding herds that were affected by PRRSV but had not had an outbreak in the last 12 months (BH-C) accounted for 30.0% of all breeding herds in the 2010 study, now account for 44.2%. Breeding herds affected by PRRSV that had an outbreak in the last 12 months, BH-B and BH-D combined, were estimated to make up 35.0% of herds for the April 2018 update, down from the 42% estimated in the 2010 study.

Table 2. Percentage of females in each breeding herds classification, U.S.

Breeding herds classification	**2010 study*** *(Baseline)*	**October 2018 Update†‡**	**Change from 2010 study**	**% change from 2010 study**
BH-A	28.0%	20.8%	-7.2%	*-25.9%*
BH-B	6.0%	4.8%	-1.2%	*-20.0%*
BH-C	30.0%	44.2%	14.2%	*47.5%*
BH-D	36.0%	30.2%	-5.8%	*-16.1%*

*Estimates made for 2010 study were for October 1, 2010.
†Estimates made for the October 2018 update were weekly averages for October 2013 to September 2018.
‡To estimate the changes in the percentage of breeding herds in each economic classification, the MSHMP database was used to calculate an index where the baseline value (index=100) was October 1, 2010, the date on which the estimates were made for the 2010 study. The weekly values of the index, calculated October 2013 to September 2018, were multiplied by the percentage of herds in each of the breeding herd economic classifications from the 2010 study to estimate the percentage of breeding herds in each economic classification by week.

Breeding herds in economic classification BH-A included provisional negative (AASV category III) and negative (AASV category IV) herds. Since 2010, the percentage of herds in these two AASV categories has steadily declined (Appendix, Figures A.2, A.3 and A.4). This trend suggests that since the 2010 study, producers have favored control of PRRSV, where the goal is to maintain a positive stable (modified AASV category II, IIfvi or IIvx) herd, over elimination, where the goal is to achieve a provisional negative (AASV category III) or negative (AASV category IV) status. Data from the MSHMP also indicates a significant trend in the annual incidence of PRRS outbreaks (Appendix, Figure A.1). Prior to the 2013/14 season, July 2013 to June 2014, the annual cumulative incidence of PRRS outbreaks was between 30 and 42 percent of breeding herds in the MSHMP database. Since 2013/14, when the introduction of PEDV into the US led to a greater emphasis on bio-exclusion practices, the annual cumulative incidence of PRRS outbreaks has ranged from 23 to 26 percent. The lower incidence of PRRS outbreaks in breeding herds combined with the shift from elimination to control, resulted in an increase in herds that were positive unstable (AASV category I) or positive stable (AASV category II) but have not had a PRRS outbreak in the last 12 months and therefore in the BH-C economic classification. The trend toward fewer outbreaks also led to a reduction in breeding herds that were positive unstable (AASV category I) or positive stable (AASV category II) and have had a PRRS outbreak in the last 12 months, BH-B and BH-D combined.

The changes in groups of growing pigs in the economic classification of GP-A and GP-B declined while those classified as GP-C increased relative to the 2010 study (Table 3).

Table 3. Percentage of pigs in each growing pig economic classification, April 2018 update compared to 2010 study.

Growing-Pigs classification	2010 study* *(Baseline)*	October 2018 Update†‡	Change from 2010 study	% change from 2010 study
GP-A	25.5%	23.0%	-2.6%	*-10.0%*
GP-B	34.6%	31.1%	-3.5%	*-10.0%*
GP-C	39.8%	45.9%	6.0%	*15.1%*

*Estimates made for 2010 study were for the year ending in October 2010.
†Estimates made for the October 2018 update were weekly averages for October 2013 to September 2018.
‡To estimate the changes in the percentage of growing pigs in each economic classification, the SHMP database was used to calculate an index where the baseline value (index=100) was for the year ending on October 1, 2010, the dates on which the estimates were made for the 2010 study. The weekly values of the index, calculated for October 2013 to September 2018, were multiplied by the percentage of herds in each of the breeding herd economic classifications from the 2010 study to estimate the percentage of breeding herds in each economic classification by week.

An increase in the percentage of positive unstable (AASV category I) breeding herds (Appendix, Figure A.2) since the 2010 study led to an increase in pigs in the GP-C economic classification since pigs sourced from positive unstable breeding herds were considered positive at placement; and therefore, in the GP-C economic classification (Appendix, Figures A.5 and A.6). Pigs from breeding herds in all other AASV categories were considered negative at placement and classified as GP-A (also negative at marketing) or GP-B (positive at marketing). The allocation of pigs between GP-A and GP-B was based on the same relative percentage of pigs in these two groups estimated for the 2010 study. The increase in the percentage of positive unstable breeding herds was due to the apparent shift from elimination to control of PRRSV as well as an increase in the percentage of herds that were positive unstable (AASV category I) versus stable (AASV category II).

The net economic impact of the shifts in the distribution of breeding females and growing pigs in each economic classification, holding all other factors constant, was an increase in the value of productivity losses due to PRRSV relative to the 2010 study (Table 4). With the distribution of breeding herds and growing pigs in each economic classification estimated for October 2013 to September 2018, the annual value of productivity losses due to PRRSV in the US was $691 million, an increase of $27 million compared to the $664 million per year estimated in the 2010 study. The value of lost productivity due only to changes in the herd distribution increased in both the breeding herd and growing pig herd.

Table 4. Total value of productivity losses attributed to PRRSV ($/year) due only to changes in the herd distribution. All other factors; productivity, prices and costs and national herd inventory, fixed at levels estimated for the 2010 study.

Relative Costs	2010 study* *(Baseline)*	October 2018 Update†	Change from 2010 study	% change from 2010 study
Breeding herd	$302,060,642	$308,341,567	$6,280,924	2.08%
Growing-pig herds	$361,855,958	$382,790,081	$20,934,123	5.79%
Total	**$663,916,600**	**$691,131,648**	**$27,215,047**	**4.10%**

*Estimates made for 2010 study were for January 2005 to December 2010.
†Estimates made for the October 2018 update were weekly averages for October 2013 to September 2018.

Productivity

Weekly production data from 71 enrolled breeding herds, that were part of 3 production systems, were included in the analysis. Twenty-two of the 71 breeding herds were in the BH-A category for at least one week. Ten, 54 and 51 herds were in BH-B, BH-C and BH-D category respectively for at least one week.

The least squares means of the breeding herd productivity measures for each PRRS economic classification, estimated for this October 2017 update were reported in Table 5. Productivity losses in PRRSV affected breeding herds (BH-B, BH-C and BH-D) were estimated as the differences in the least squares means between them and PRRSV unaffected breeding herds (BH-A). A summary of productivity losses estimated for the October 2017 update compared to the 2010 study, by economic classification, is shown in Table 6. Relative to 2010, estimated losses in PRRSV affected breeding herds decreased for pigs born alive per litter farrowed and litters farrowed per mated female but increased for pre wean mortality. The least squares means of the breeding herd productivity estimated for the 2010 study are reported in Table B.3 (Appendix).

Table 5. Least squares means and standard error* by PRRS economic classification of breeding herd production parameters for October 2017 update. Based on analysis of weekly production values for August 2012 to July 2017.

Production Parameters	BH-A	BH-B	BH-C	BH-D
No. of pigs born alive/litter farrowed	12.47 ±0.17^{a}	12.17 ±0.18^{b}	12.34 ±0.17^{c}	12.11 ±0.17^{b}
Pre-weaning mortality (%)	11.56 ±0.01^{a}	15.52 ±0.01^{b}	13.54 ±0.01^{c}	15.00 ±0.01^{b}
No. of litters farrowed per mated female per year	2.42 ±0.03^{a}	2.35 ±0.03^{b}	2.44 ±0.03^{ac}	2.40 ±0.03^{ad}
Breeding female cull rate (%)	48.37 ±0.03^{a}	41.96 ±0.04^{ab}	45.37 ±0.03^{ab}	43.32 ±0.03^{b}
Breeding female death Rate (%)	9.11 ±0.01^{a}	10.44 ±0.01^{b}	9.20 ±0.01^{ac}	9.84 ±0.01^{ab}

*Least means squares and standard error from the linear mixed models.
^{abcd}For each production parameter, values with different superscripts are significantly different ($P<0.05$) between economic classifications (BH-A, BH-B, BH-C and BH-D).

Table 5. Least squares means and standard error* by PRRS economic classification of breeding herd production parameters for October 2017 update. Based on analysis of weekly production values for August 2012 to July 2017.

Table 6. Differences in least squares means; PRRSV affected (BH-B, BH-C and BH-D) compared to PRRSV unaffected breeding herds (BH-A). Differences estimated for the 2010 study and October 2017 update are in adjacent columns to illustrate how productivity impacts in PRRSV affected breeding herds have changed over time.

			Difference from BH-A					
	BH-A (PRRSV unaffected)		BH-B		BH-C		BH-D	
Production Parameter	**2010 study***	**Oct. 2017 Update†**	**2010 study***	**Oct. 2017 Update†**	**2010 study***	**Oct. 2017 Update†**	**2010 study***	**Oct. 2017 Update†**
No. of pigs born alive/litter farrowed	11.59	12.47	-0.95	-0.30	-0.44	-0.13	-0.62	-0.37
Pre-weaning mortality (%)	12.16%	11.56%	5.84%	3.96%	0.40%	1.98%	1.55%	3.44%
No. of litters farrowed per mated female per year	2.45	2.42	-0.12	-0.07	-0.06	0.02	-0.07	-0.02
Breeding female cull rate (%)	50.73%	48.37%	-3.33%	-6.40%	-0.28%	-2.99%	-0.90%	-5.05%
Breeding female death rate (%)	8.42%	9.11%	1.11%	1.32%	0.70%	0.08%	1.17%	0.72%

*Estimates made for 2010 study were for January 2005 to December 2010.
†Estimates made for the October 2017 update were weekly averages for August 2012 to July 2017.

Total production losses for the US estimated for the October 2017 update compared to the 2010 study, with the herd distribution and size of the national herd fixed at levels used in the 2010 study, are reported in Table 7. The improvement in the productivity of PRRSV affected herds, relative to PRRSV unaffected herds, has decreased losses due to PRRSV by 3.1 million pigs weaned annually.

Table 7. Estimated productivity impact of PRRSV on the US breeding herd due only to changes in productivity. Production losses in PRRSV affected herds (BH-B, BH-C and BH-D) compared to PRRSV unaffected breeding herds (BH-A) in October 2017 study compared to 2010 study. All other factors; herd distribution, prices and costs and national herd inventory, fixed at levels estimated for the 2010 study

Productivity impact	*Losses in PRRSV affected breeding herds*		**Change from 2010 study**	**% of change from 2010**
	2010 study* *(Baseline)*	**October 2017 Update†**		
Pigs weaned (pigs/year)	8,299,457	5,149,456	3,150,001	*-38.0%*
Pigs weaned / female / year	1.43	0.89	0.54	*-38.0%*

*Estimates made for 2010 study were for January 2005 to December 2010.
†Estimates made for the October 2017 update were weekly averages for August 2012 to July 2017.

The net economic impact on a per breeding female basis of changes in productivity of breeding herds in each economic classification, holding all other factors constant, was reported in Table 8. The value of productivity losses in PRRSV affected herds that had outbreaks in the last 11 months, BH-B and BH-D herds, decreased by 48.4 and 22.8 percent respectively. The value of productivity losses in PRRSV affected herds that had not had an outbreak in the last 12 months, BH-C herds, decreased by 61.3 percent. The results suggest that while the economic impact of PRRS outbreaks has increased since 2010, producers and veterinarians have adopted practices that have reduced the long-term, greater than 12 months, impact of PRRSV on breeding herd productivity.

Table 8. Value of productivity losses attributed to PRRSV ($/breeding female/year) due only to changes in productivity. All other factors; herd distribution, prices and costs and national herd inventory, fixed at levels estimated for the 2010 study.

Breeding herds classification	**2010 study*** *(Baseline)*	**October 2017 Update†**	**Change from 2010 study**	**% of change from 2010**
BH-A	---	---	---	---
BH-B	$143.00	$73.80	-$69.20	*-48.4%*
BH-C	$51.70	$20.02	-$31.68	*-61.3%*
BH-D	$76.30	$58.87	-$17.43	*-22.8%*

*Estimates made for 2010 study were for January 2005 to December 2010.
†Estimates made for the October 2017 update were weekly averages for August 2012 to July 2017.

The net economic impact of changes in productivity of breeding herds in each economic classification, holding all other factors constant, was a decrease in the value of productivity losses due to PRRSV relative to the 2010 study. For August 2012 to July 2017, the annual value of productivity losses due to PRRSV in the US was $517 million, a decrease of $147 million compared to the $664 million per year estimated in the 2010 study (Table 9). The value of lost

productivity due to changes in productivity since 2010 decreased in the breeding herd and in the growing pig herd. While estimates of the productivity of growing pigs in each economic classification were not updated, the value of lost productivity in growing pigs decreased. This reduction was the result of the improvement in the productivity of PRRSV affected breeding herds, relative to PRRSV unaffected herds, which decreased losses due to PRRSV by 3.1 million pigs weaned annually (Table 7) and reduced the additions to the pig crop placed in the growing pig phase without PRRSV. The net profit in the growing pig phase of production for additions to the pig crop without PRRSV that was added to the value of lost production due to PRRSV in the growing pig herd, was therefore lower for the October 2017 update.

Table 9. Total value of productivity losses attributed to PRRSV ($/year) due only to changes in productivity. All other factors; herd distribution, prices and costs and national herd inventory, fixed at levels estimated for the 2010 study.

Relative Costs	2010 study* *(Baseline)*	October 2017 Update†	Change from 2010 study	% change from 2010 study
Breeding herd	$302,060,642	$184,633,642	-$117,427,000	*-38.9%*
Growing-pig herds	$361,855,958	$331,925,226	-$29,930,732	*-8.3%*
Total	**$663,916,600**	**$516,558,868**	**-$147,357,732**	***-22.2%***

*Estimates made for 2010 study were for January 2005 to December 2010.
†Estimates made for the October 2017 update were weekly averages for August 2012 to July 2017.

Prices and costs

Weekly average weaned pig prices, market hog prices and cull sow prices used in the budgeting models were estimated for the period from October 2013 to September 2018 (Table 10). Prices for all three have increased since the 2010 study. However, compared to the last report (April 2018) the price of standard weaned pig produced, the market hog prices and the average cull price of females went down slightly.

Corn, soybean meal and distillers dried grains (DDG) prices used to estimate the cost of breeding herd and growing pig diets were estimated for the period from October 2013 to September 2018 (Table 11). Diet ingredient prices increased substantially since the 2010 study. Ingredient prices, increased the weighted average cost of a typical lactation and gestation diets and weighted average cost of a typical wean-to-finish diet by 17 percent relative to the 2010 study period. However, compared to the last reports (October 2017 and April 2018) the weighted average cost of feed for breeding herds and growing pigs declined.

Table 10. Weekly average weaned pig prices, market hog prices and cull sow prices, April 2018 update compared to 2010 study.

Market Price	2010 study*	October 2018 Update†	Change from 2010 study	% of change from 2010
Price of standard weaned pig produced ($/pig weaned)[1]	$36.19	$42.99	$6.80	18.8%
Market hog price ($/lb carcass wt)[2]	$67.26	$72.68	$5.41	8.0%
Average cull price of females ($/lb live wt.)[3]	$37.00	$47.51	$10.51	28.4%

*Estimates made for 2010 study were for January 2005 to December 2010.
†Estimates made for the October 2018 update were weekly averages for October 2013 to September 2018.
[1]Early weaned pig prices, 10-12 lb. basis, estimated 50-54 percent lean value ($/head).
[2]Hog prices, monthly average – Iowa/Southern Minnesota plant delivered ($/carcass cwt.).
[3]Sow prices, monthly average – National Negotiated Purchases, 300-499 lbs. ($/live cwt.).

Table 11. Corn, soybean meal, distillers dried grains (DDG) prices and cost of breeding herd and growing pig diets, October 2018 update compared to 2010 study.

Ingredient prices and diet costs	2010 study*	October 2018 Update†	Change from 2010 study	% of change from 2010 study
Price of breeding/gestation diet and lactation diet ($/ton)[1]	$173.23	$202.25	$29.02	16.8%
Price of wean-to-finish feed (US$/ton of feed)[2]	$168.76	$198.08	$29.31	17.4%
Corn[3]	$3.32	$3.64	$0.32	9.5%
Soybean meal[4]	$293.04	$363.08	$70.04	23.9%
DDG's[5]	$125.73	$149.10	$23.37	18.6%

*Estimates made for 2010 study were for January 2005 to December 2010.
†Estimates made for the Ocotber 2018 update were weekly averages for October 2013 to September 2018.
[1]Farrow-to-Weaned Pig Cost-Return Budget – K-State – MF2153.
[2]Swine Wean-to-Finish Cost-Return Budget – K-State – MF2757.
[3]IOWA - corn, grain - price received, measures in $/BU
[4]Decatur-Central Illinois, IL - high protein (46.5% to 48.0%)
[5]Central Illinois, IL - variety 10% - average value of low and high bid - price received per metric ton.

The net economic impact of changes in prices and costs, holding all other factors constant, was an increase in the value of productivity losses due to PRRSV relative to the 2010 study. With the prices and costs estimated for October 2013 to September 2018, the annual value of productivity losses due to PRRSV in the US was $670 million, an increase of $6 million compared to the $664 million per year estimated in the 2010 study (Table 12). The value of lost productivity due exclusively to changes in prices and costs since 2010 increased in the breeding herd by $57 million and decreased in the growing pig herd by $51 million. In general, the value of lost productivity increases as pig prices increase and input costs decrease and production becomes more profitable. The exception is the value of differences in feed conversion in growing pigs,

which is sensitive only to the price of feed. Since 2010, prices of weaned pigs, market hog prices and feed costs have all increased. The relative changes in weaned pig prices, cull sow prices and feed ingredient prices increased the profitability of breeding herds since the 2010 study (Table 13). This resulted in an increase in the value of lost productivity in the breeding herd, on a per female basis relative to the 2010 study (Table 14). The relative changes in market hog prices and feed costs since 2010 have decreased the profitability in the growing pig herd (Table 15) resulting in an decrease in the value of lost productivity attributed to PRRSV due to changes in prices and costs in the growing pig herd (Tables 16).

Table 12. Total value of productivity losses attributed to PRRSV ($/year) due only to changes in prices and costs. All other factors; herd distribution, productivity and national herd inventory, fixed at levels estimated for the 2010 study.

Relative Costs	**2010 study*** *(Baseline)*	**October 2018 Update†**	**Change from 2010 study**	**% of change from 2010**
Breeding herd	$302,060,642	$359,675,862	$57,615,220	19.1%
Growing-pig herds	$361,855,957	$310,399,445	-$51,456,513	-14.2%
Total costs	**$663,916,600**	**$670,075,308**	**$6,158,707**	**0.9%**

*Estimates made for 2010 study were for January 2005 to December 2010.
†Estimates made for the October 2018 update were weekly averages for October 2013 to September 2018.

Table 13. Impact of productivity losses attributed to PRRSV on revenue, cost and profit in the US breeding herd due only to changes in prices and costs. All other factors; herd distribution, productivity and national herd inventory, fixed at levels estimated for the 2010 study. Values are reported as losses in PRRSV affected herds. A negative value indicates it was lower in PRRSV affected herds.

	Losses in PRRSV affected breeding herds			
Economic impact	**2010 study*** *(Baseline)*	**October 2018 Update†**	**Change from 2010 study**	**% of change from 2010**
Revenue (million $/year)	$300.4	$356.8	$56.4	18.8%
Total cost (million $/year)	-$1.7	-$2.9	-$1.2	70.3%
Feed cost ($/pig weaned/year)	-$0.7	-$0.8	-$0.1	16.8%
Net profit (million $/year)	$302.1	$359.7	$57.6	19.1%
Net profit ($/breeding female/year)	$2.4	$2.4	$0.0	1.7%
Net profit ($/pig weaned/year)	$52.2	$62.1	$10.0	19.1%

*Estimates made for 2010 study were for January 2005 to December 2010.
†Estimates made for the October 2018 update were weekly averages for October 2013 to September 2018.

Table 14. Value of productivity losses ($/breeding female/year) attributed to PRRSV in the breeding herd due only to changes in prices and costs. All other factors; herd distribution, productivity and national herd inventory, fixed at levels estimated for the 2010 study.

Breeding herds classification	**2010 study*** *(Baseline)*	**October 2018 Update†**	**Change from 2010 study**	**% of change from 2010**
BH-A	---	---	---	---
BH-B	$143.00	$171.49	$28.49	19.9%
BH-C	$51.70	$61.43	$9.73	18.8%
BH-D	$76.30	$90.81	$14.51	19.0%

*Estimates made for 2010 study were for January 2005 to December 2010.
†Estimates made for the October 2018 update were weekly averages for October 2013 to September 2018.

Table 15. Impact of productivity losses attributed to PRRSV on revenue, cost and profit ($/head placed) in the growing pig herd due only to changes in prices and costs. All other factors; herd distribution, productivity and national herd inventory, fixed at levels estimated for the 2010 study. Values are reported as losses in PRRSV affected herds.

Economic impact	*Losses in PRRSV affected growing pig herds*		Change from 2010 study	% of change from 2010
	2010 study* *(Baseline)*	October 2018 Update†		
Revenue (million US$/year)	$1,615.3	$1,745.2	$130.0	8.0%
Total cost (million US$/year)	$1,253.4	$1,434.8	$181.4	14.5%
Feed cost ($/pig marketed/year)	$1.3	$1.5	$0.2	17.4%
Net profit (million $/year)	$361.9	$310.4	-$51.5	-14.2%
Net profit ($/pig marketed/year)	$2.24	$2.37	$0.13	5.6%

*Estimates made for 2010 study were for January 2005 to December 2010.
†Estimates made for the October 2018 update were weekly averages for October 2013 to September 2018.

Table 16. Value of productivity losses ($/head placed) attributed to PRRSV in the growing pig herd due only to changes in prices and costs. All other factors; herd distribution, productivity and national herd inventory, fixed at levels estimated for the 2010 study.

Growing pig herds classification	2010 study* *(Baseline)*	October 2018 Update†	Change from 2010 study	% of change from 2010
GP-A	---	---	---	---
GP-B	$2.06	$2.02	-$0.04	-1.8%
GP-C	$3.90	$3.93	$0.03	0.71%

*Estimates made for 2010 study were for January 2005 to December 2010.
†Estimates made for the October 2018 update were weekly averages for October 2013 to September 2018.

National herd inventory

Relative to the 2010 study, the U.S. breeding female inventory, calculated as the average of the quarterly breeding herd inventories reported by the USDA from October 2013 to September 2018, increased to 6,033,300 sows and the average of total annual pigs slaughtered, in the U.S. increased to 116,581,220. (Table 17). Pigs weighing less than 15 pounds that were imported into the U.S. declined to an annual average of 3,257,949.

The net economic impact of changes in the national herd inventory, holding all other factors constant, was an increase in the value of productivity losses due to PRRSV relative to the 2010 study. With the US breeding female inventory, pig crop and pigs slaughtered all increasing higher, the annual value of productivity losses due to PRRSV in the US was $691 million, an

increase of $27 million over the $664 million estimated in the 2010 study (Table 18). The size of the US breeding herd and pig crop serve as a multiplier for the value of lost productivity. Losses attributed to PRRSV estimated on a per breeding female or per pig placed basis were simply multiplied by more animals as the size of the breeding herd and the US weaned pig crop increased.

Table 17. Size of the US breeding herd and number of pigs produced and imported, April 2018 update compared to 2010 study.

Number of animals	**2010 study*** *(Baseline)*	**October 2018 Update†**	**Change from 2010 study**	**% of change from 2010**
U.S. Breeding female inventory[1]	5,788,000	6,033,300	245,300	4.2%
Growing pigs imported into the U.S.[2]	3,345,902	3,257,949	-87,952	-2.6%
Average of total annual pigs slaughtered[3]	109,636,000	116,581,220	6,945,220	6.3%

*Estimates made for 2010 study were for January 2005 to December 2010.
†Estimates made for the October 2018 update were weekly averages for October 2013 to September 2018.
[1]USDA, National Agricultural Statistics Service.
[2]USDA, National Agricultural Statistics Service. Growing pigs less than 15 pounds (pigs/year).
[3]USDA, National Agricultural Statistics Service. Average of year period.

Table 18. Total value of productivity losses attributed to PRRSV ($/year) due only to changes in the national herd inventory size. All other factors; herd distribution, productivity and prices and costs, fixed at levels estimated for the 2010 study.

Relative Costs	**2010 study*** *(Baseline)*	**October 2018 Update†**	**Change from 2010 study**	**% of change from 2010**
Breeding herd	$302,060,642	314,861,480.20	$12,800,838	4.2%
Growing-pig herds	$361,855,957	376,668,521.83	$14,812,564	4.1%
Total costs	**$663,916,600**	691,530,002.03	$27,613,402	4.2%

*Estimates made for 2010 study were for January 2005 to December 2010.
†Estimates made for the October 2018 update were weekly averages for October 2013 to September 2018.

Combined assessment of factors

Herd distribution and productivity

For the combined assessment of changes in the herd distribution and productivity since 2010, the others factors (prices and costs and national herd inventory) were held constant at the values used for the 2010 study. The independent assessment of changes in the herd distribution and productivity resulted in divergent impacts on the value of productivity losses due to PRRSV. Changes in the herd distribution since 2010 increased the losses due to PRRSV while changes in productivity have decreased the losses. The net effect of changes in both factors was to decrease the total annual losses due to PRRSV by $138 million to $525 million dollars compared to the $664 million per year estimated in the 2010 study (Table 19). The losses since 2010 due to changes in the herd distribution and productivity declined in the breeding herd as well as in the growing pig herd but the decrease in the combined losses in the latest was considerably smaller than for the breeding herd. Recall, however, that the productivity of growing pigs in each economic classification was not updated.

Table 19. Value of productivity losses attributed to PRRSV ($/breeding female/year) due to changes in the herd distribution and productivity. All other factors; prices and costs and national herd inventory, fixed at levels estimated for the 2010 study.

Relative Costs	2010 study* *(Baseline)*	October 2018 Update†	Change from 2010 study	% of change from 2010
Breeding herd	$302,060,642	$175,986,651	-$126,073,992	-41.7%
Growing-pig herds	$361,855,957	$349,730,088	-$12,125,870	-3.4%
Total costs	**$663,916,600**	**$525,716,739**	**-$138,199,861**	**-20.8%**

*Estimates made for 2010 study were for January 2005 to December 2010.
†Estimates made for the October 2018 update were weekly averages for October 2013 to September 2018.

The decrease in the value of lost production in the US breeding herd was due largely to an increase in the percentage of PRRSV affected herds that have not had an outbreak in the last 12 months (BH-C) and the nearly 50 percent decline in the value of lost productivity per breeding female in those herds. The data from the MSHMP strongly suggests that the reduction in the annual incidence of PRRS outbreaks in breeding herds contributed to the increase in the percentage of breeding females in herds classified as BH-C but the underlying cause of the lower impact of PRRSV on the productivity of PRRSV is less clear. One possible explanation may be the apparent shift away from using live virus to modified live vaccine to inoculate breeding females and incoming gilts in breeding herds that are positive stable. The data from the MSHMP supports the occurrence of this shift as the relative percentage of herds classified as 2fvi (positive stable, ongoing field virus exposure) has declined and the percentage of 2vx (positive stable, ongoing modified live vaccine exposure) has increased (Figure A.2).

All factors

Results from the independent assessment of each of the four factors indicated that changes in the herd distribution prices and costs, and the size of the national herd contributed to an increase in the value of lost productivity attributed to PRRSV while changes in productivity contributed to a decrease in losses. The net effect of changes in all factors was to decrease the total annual losses due to PRRSV to $560.3 million dollars, a decrease of almost $104 million compared to the $664 million per year estimated in the 2010 study (Table 20). The combined losses due to changes in all factors since 2010 decreased in the breeding herd but increased in the growing pig herd.

Table 20. Total value of productivity losses attributed to PRRSV ($/year) due to changes in all factors.

Relative Costs	2010 study* *(Baseline)*	October 2018 Update†	Change from 2010 study	% of change from 2010
Breeding herd	$302,060,642	$227,802,659	-$74,257,984	-24.6%
Growing-pig herds	$361,855,958	$332,473,172	-$29,382,786	-8.1%
Total costs	**$663,916,600**	**$560,275,831**	**-$103,640,770**	**-15.6%**

*Estimates made for 2010 study were for January 2005 to December 2010.
†Estimates made for the October 2018 update were weekly averages for October 2013 to September 2018.

The combined impact of all factors since 2010 resulted in a lower estimated value of losses per breeding female due to PRRSV for females in breeding herds in economic categories BH-B, BH-C and BH-D (Table 21). Changes in prices and costs which increased the value of productivity losses were offset by reductions in productivity losses in these herds.

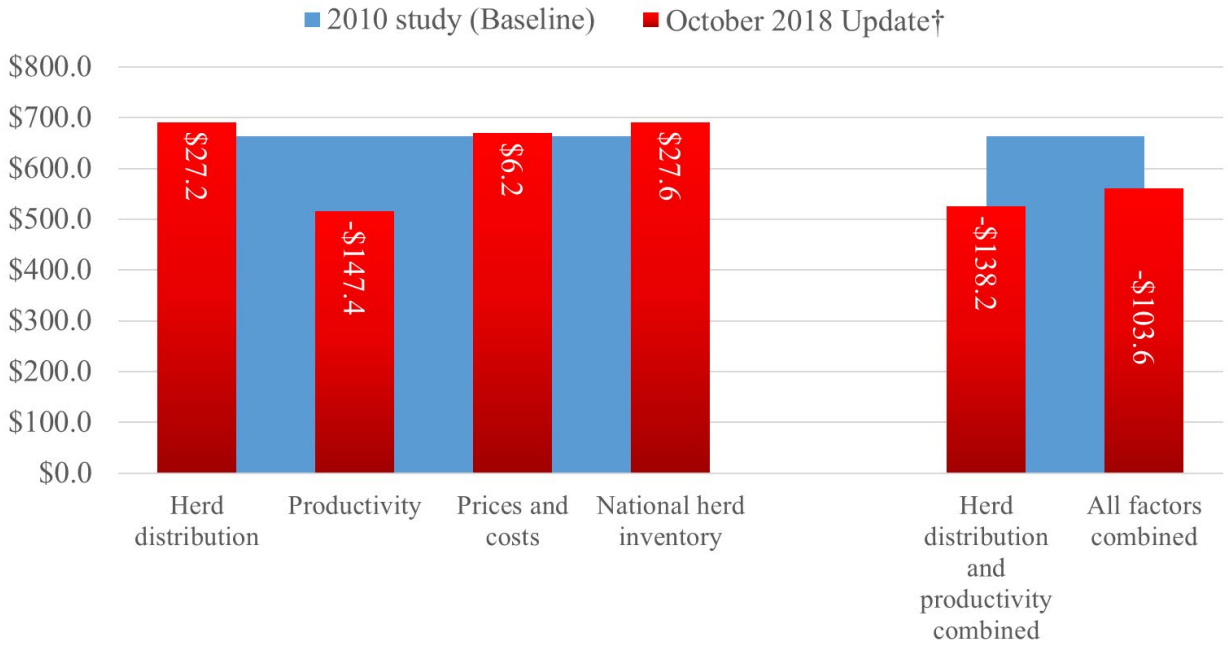
Table 21. Value of productivity losses attributed to PRRSV ($/breeding female/year) due to changes in all factors.

Breeding herds classification	2010 study* *(Baseline)*	October 2018 Update†	Change from 2010 study	% of change from 2010 study
BH-A	---	---	---	---
BH-B	$143.00	$90.76	-$52.2	-36.5%
BH-C	$51.70	$25.41	-$26.3	-50.9%
BH-D	$76.30	$72.50	-$3.8	-5.0%

*Estimates made for 2010 study were for January 2005 to December 2010.
†Estimates made for the October 2018 update were weekly averages for October 2013 to September 2018.

A summary of changes in the value of productivity losses since the 2010 study due to each factor independently and the combined effect of the herd distribution and productivity as well as the combined effect of all factors combined is shown in Figure 4.

Figure 4. Summary of changes in the annual value of productivity losses due to PRRSV since the 2010 study. Bar labels are changes ($ million) from $664 million annual losses estimated in 2010 study.



*Estimates made for 2010 study were for January 2005 to December 2010
†Estimates made for the October 2018 update were weekly averages for October 2013 to September 2018.

IX. Conclusions and Implications

- The incidence of PRRS outbreaks has decreased since the 2010 study which contributed to a significant increase in breeding herds that are PRRS virus positive but have not had an outbreak for at least 12 months. However, the apparent shift favoring control of PRRSV over elimination in breeding herds also occurred since 2010. The net effect of these shifts in the distribution of herds was to increase the value of lost productivity due to PRRSV.
- Since 2010, progress in managing PRRSV has led to an improvement in the productivity of PRRSV affected breeding herds relative to PRRSV unaffected herds, contributing to a significant reduction in the value of lost productivity.
- The combined effect of changes in factors directly influenced by producer and veterinary efforts to manage PRRSV, the distribution of PRRSV affected and unaffected herds and productivity in PRRSV affected herds relative to PRRSV unaffected herds, resulted in a net reduction in the value of productivity losses attributed to PRRSV to $525.7 million dollars for the October 2018 update.
- Since 2010, the producers and veterinarians have reduced the impact of PRRSV by 20.8%, $138 million annually, compared to the 2010 study.

X. References

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Appendix A - Appendix of Figures

Figure A.1. MSHMP cumulative incidence of PRRS outbreaks from 2009 to 2018.

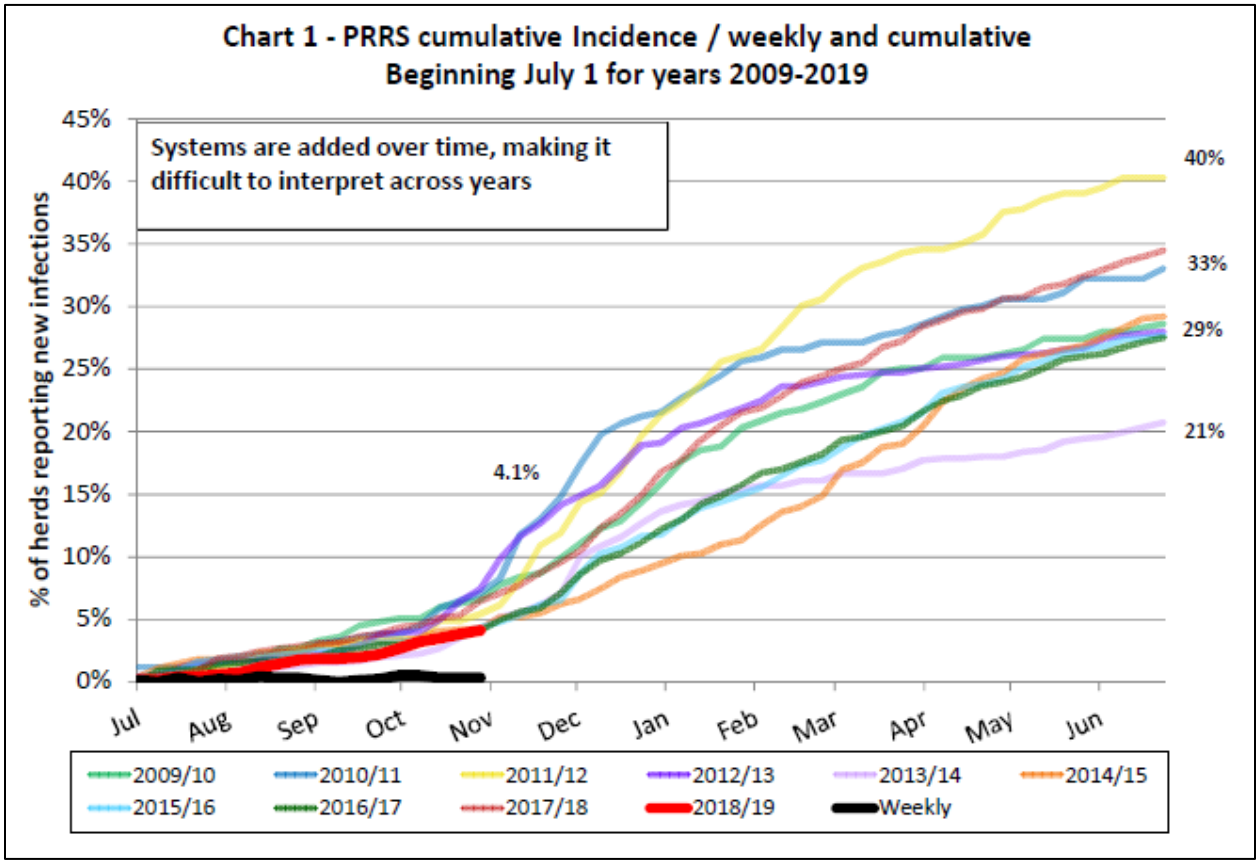
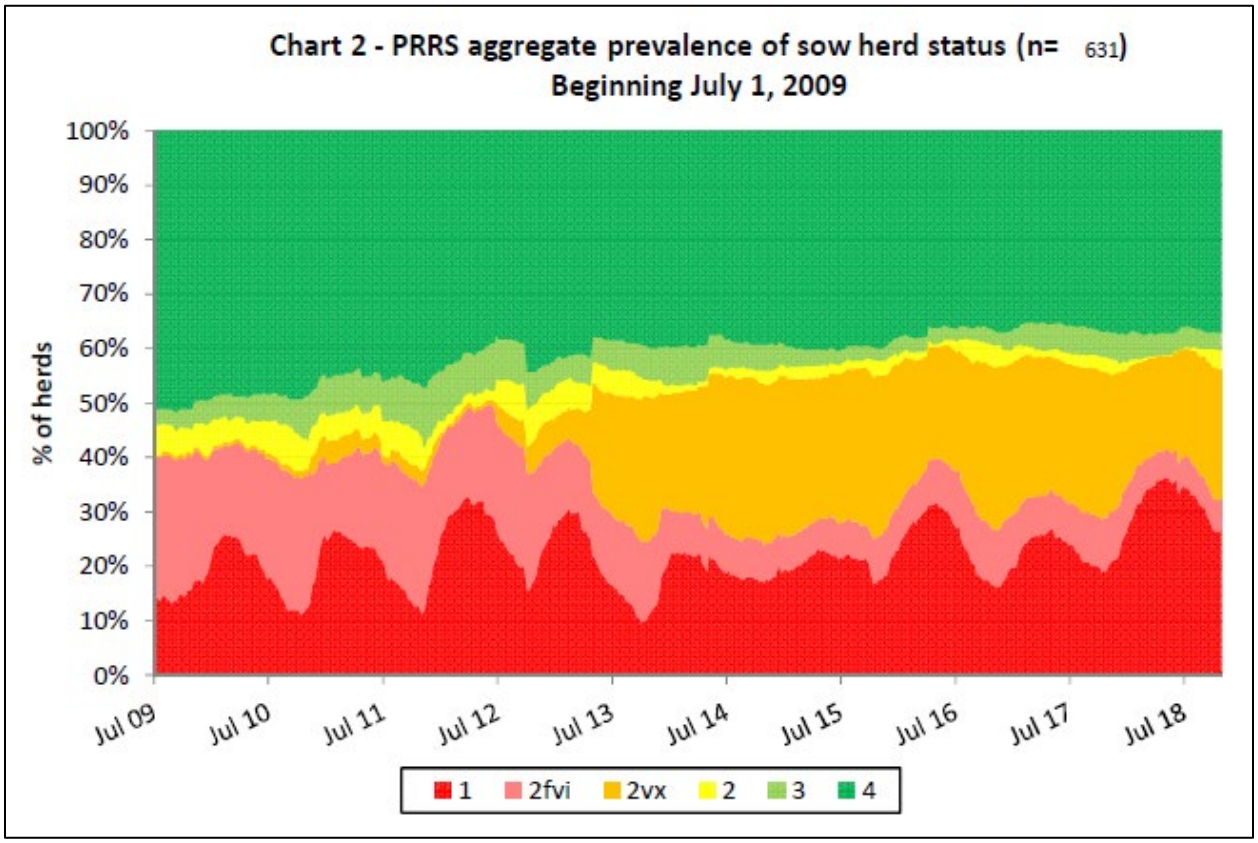


Figure A.2. Aggregate prevalence of breeding herds by modified AASV PRRS categories used in the MSHMP.



Legend for modified AASV PRRS categories

AASV category I (positive unstable
1 = Positive unstable
AASV category II (positive stable)
2fvi = Positive stable, ongoing field virus exposure
2vx = Positive stable, ongoing modified live vaccine virus exposure
2 = Positive stable
AASV category III (provisional negative)
3 = Provisional negative
AASV category IV (negative)
4 = Negative

Figure A.3. Percentage of breeding herds classified as BH-A, B, C or D by week (n = 421 herds).

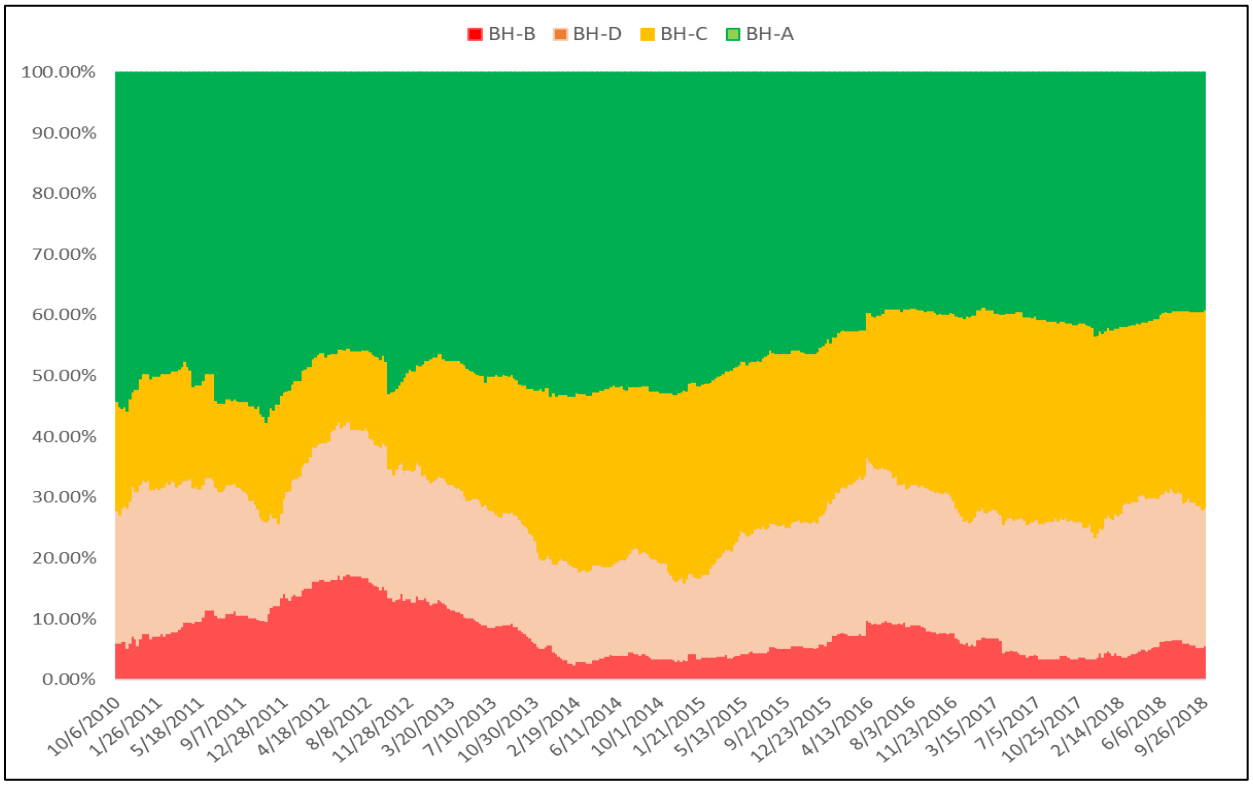


Figure A.4. Proportion of BH herds by week since October 2010 (n = 421 herds).

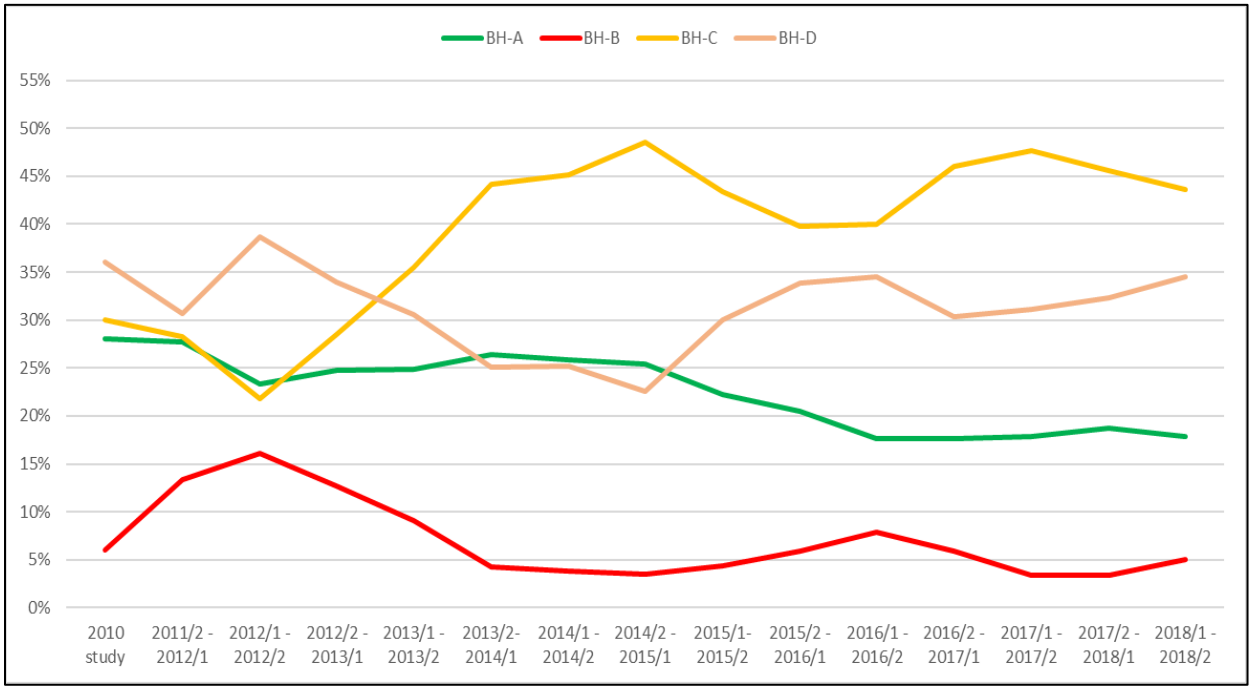


Figure A.5. Percentage of groups of growing pigs classified as GP-A, B or C by week (n = 421 herds).

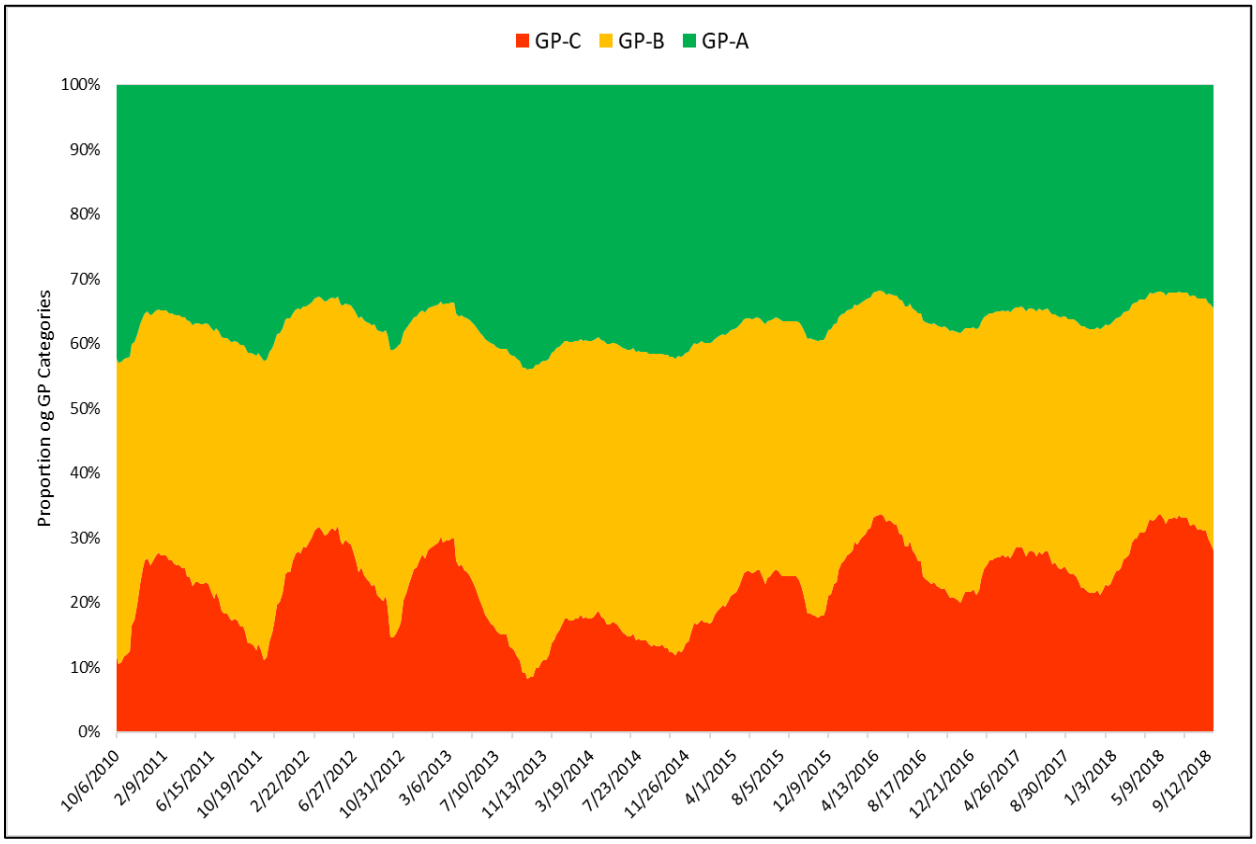
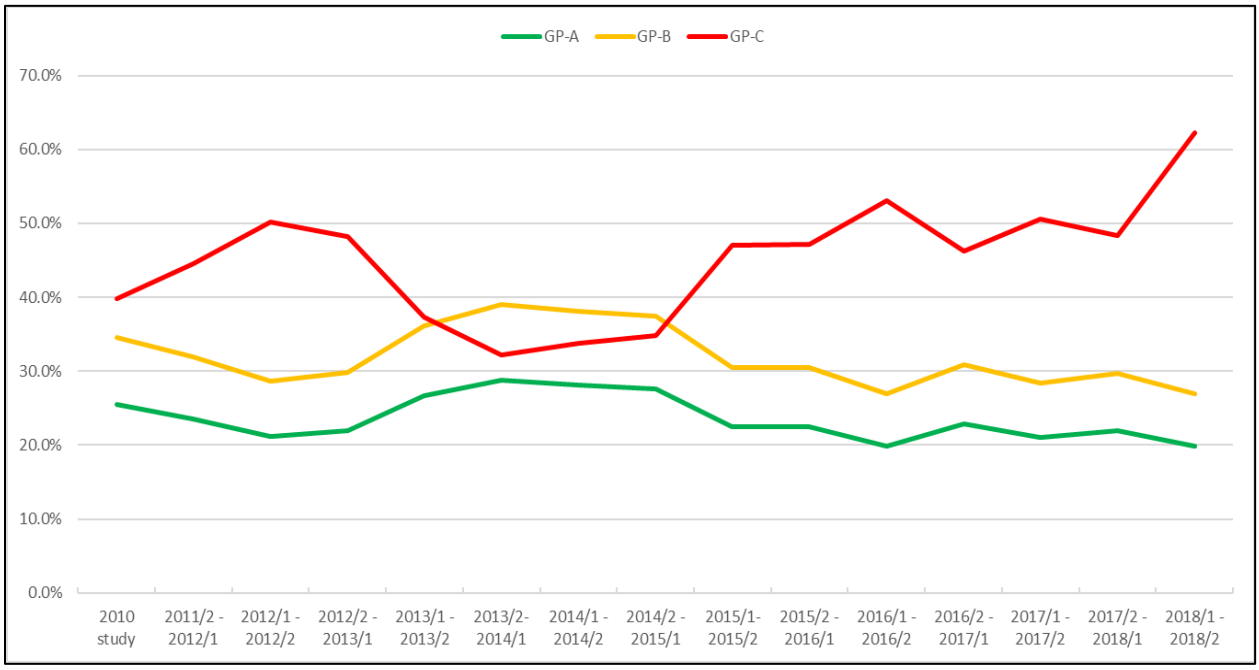


Figure A.6. Proportion of GP herds by week since October 2010 (n = 432 herds).



Appendix B – Appendix of Tables

Table B.1. Description of how MSHMP classification and outbreak history were used to determine the economic classification of breeding herds.

SHMP classification	***AASV classification***	***Outbreak history***	**Economic classification**
3 or 4	III (negative) or IV (provisional negative)		BH-A (unaffected by PRRSV)
1, 2fvi, 2vx or 2	I (positive unstable) or II (positive stable)	**One or more** outbreaks in previous 52 weeks ***AND*** was in MSHMP classification 3 or 4 when the most recent outbreak occurred	BH-B (affected by PRRSV)
1, 2fvi, 2vx or 2	I (positive unstable) or II (positive stable)	**No outbreaks** in the previous 52 weeks	BH-C (affected by PRRSV)
1, 2fvi, 2vx or 2	I (positive unstable) or II (positive stable)	**One or more** outbreaks in previous 52 weeks ***AND*** was in MSHMP classification 1, 2fvi, 2vx or 2 when the most recent outbreak occurred	BH-D (affected by PRRSV)

Table B.2. Table to classify MSHMP status to GP categories according to the status of the breeding herd source.

MSHMP classification of breeding herd source	AASV classification of breeding herd source	GP classification
2vx, 2fvi, 2, 3 or 4	II (positive stable), III (negative) or IV (provisional negative)	*42%* of the herds remained *negative* at closeout GP-A *58%* of herds became *positive* at closeout GP-B
1	I (positive unstable)	GP-C

Table B.3. Least squares means of the breeding herd productivity estimated in the 2010 study.

Production Parameters	**BH-A**	**BH-B**	**BH-C**	**BH-D**
No. of piglets born alive/litter farrowed	11.6 ±0.1[a]	10.6 ±0.2[b]	11.2 ±0.1[c]	11.00 ±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 farrowed 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 Cull 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]

*Least means squares and standard error from the linear mixed models.