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# **Swine Producers' Willingness to Pay for Tier 1 Disease Risk Mitigation under Ambiguity**

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## Abstract

Risk mitigation of foreign animal diseases has characteristics of a public good, which results in government intervention to incentivize individual producers in their decision making. Understanding producers' risk perceptions of foreign animal diseases and their willingness to cooperate in prevention efforts is crucial for effective policymaking as well as a communication strategies, yet there has been limited empirical evidence on this subject. This article provides evidence on risk perceptions and willingness to pay for risk mitigation efforts by U.S. swine producers who face decisions characterized by risk uncertainty. The main findings include that producers have a mean willingness to pay of \$0.63 per pig per year for foreign animal disease risk mitigation. We also find evidence that producers are more responsive and show ambiguity aversion when losses are unknown compared to when they are known.

*Keywords:* ambiguity, contingent valuation, foreign animal disease, swine industry, uncertainty, willingness to pay

The U.S. Department of Agriculture Animal and Plant Health Inspection Service (USDA-APHIS) characterize foreign animal diseases based upon their risk level. Diseases characterized as Tier 1 are those of national concern and pose the most significant threat to animal agriculture as they have the highest risks and consequences. Currently known Tier 1 swine diseases include African swine fever (ASF), classical swine fever (CSF), and foot and mouth disease (FMD) (USDA-APHIS-VS, 2013). In the United States, ASF has never occurred, CSF was eradicated in 1978, and FMD was eradicated in 1929, according to the World Organization for Animal Health (OIE) Information database. However, Tier 1 diseases are prevalent in other countries in the world, and the extensive movement of people, animals, meat, and related products makes the environment more vulnerable to the accidental or intentional spread of epidemic diseases along with the rise of travel and trade around the world. The countries currently free of the diseases remain under constant threat of an outbreak because it can be transmitted through not only direct contact but also indirect contact.

In 2018, ASF spread, for the first time, into China and Southeast Asia (FAO, 2019). Such dramatic change in the global epidemiological conditions of ASF has resulted in concerns the disease may continue to spread into disease-free regions, such as the United States. Numerous swine industry partners have been working to aggregate resources for producers. Many of these resources can be found through the U.S. Department of Agriculture, the National Pork Board and Center for Food Security and Public Health. Among all these resources, a unified message continues to be put forth—prepare for foreign animal diseases through biosecurity.

Protecting against the introduction and spread of highly contagious transboundary animal diseases is generally considered to be a public good due to the nature of non-rivalrous demand for biosecurity and non-excludable benefits from a risk-free environment. Government funding

and public research aids development and production of vaccines and protocols for surveillance and rapid response. Furthermore prevention and control can be heightened with coordination and biosecurity from producers.

Knight (1921) used the term “risk” for events with known probabilities and “uncertainty” for events with unknown probabilities. Ellsberg (1961) confirmed ambiguity aversion and showed that people prefer known probability over unknown probability. When it comes to the probability of Tier 1 disease outbreaks, there is no known probability, so producers are making risk mitigation decisions under uncertainty. How a producer perceives this uncertainty could be reflected in their biosecurity decisions. For example, if a producer perceives the risk to contract disease on his/her farm to be negligible, he/she could be unlikely to invest in its prevention. Weak or absent biosecurity could lead to a negative externality and neutralize mitigation efforts from other producers. As such, there are biases and risk perception issues that must be overcome for producers to make appropriate disease prevention decisions.

One of the core objectives of this research is to determine the relative, and total, impacts of several ambiguous dimensions that potentially can characterize disease outbreaks including probability of occurrence (% risk), damages (losses in dollars), and damage duration (months of losses). For example, we determine if a producer’s perception of ambiguity is the same across risk likelihood, outcome, and damage duration dimensions and if ambiguity aversion has an impact on willingness to pay for risk mitigation. We also determine how willingness to pay interacts with other factors that research has identified as being important determinants of disease risk mitigation such as operation characteristics, producer demographics, and business arrangement.

Understanding risk attitudes of producers and determinants of willingness to pay for risk mitigation could support effective intervention by government in addressing the public goods problem regarding disease prevention. This information could be leveraged in designing gentle nudges in policies such as with indemnity provisions and cost sharing strategies between public and private sectors. Moreover, knowing producers' willingness to pay for Tier 1 diseases risk mitigation could help identify potential policy alternatives. For example, by comparing producers' willingness to pay to social costs associated with Tier 1 diseases risk mitigation effort, government could weigh the trade-off between designing cost share programs to reduce producers' expenses and incentivizing producers to participate more via communication or education. Likewise, government may find it more effective to invest in research and development that may lead to reduced costs of risk mitigation investments.

## **Literature Review**

### *Uncertainty of Tier 1 animal diseases*

Uncertainty can be categorized into “environmental uncertainty” and “strategic uncertainty”: Environmental uncertainty exists when the optimal size of a public good and effective mitigation strategies are uncertain, and strategic uncertainty exists when the behavior of other group members are uncertain, according to Messick, Allison, and Samuelson (1998). Risk mitigation of Tier 1 animal diseases can be characterized as a public good problem, and more precisely, a public bad prevention problem under environmental and strategic uncertainty. Producers are under environmental uncertainty since the optimal size of public bad is uncertain. There are a number of studies estimating the loss from Tier 1 diseases based on actual outbreak occurrence as well as possible hypothetical scenarios, including Meuwissen et al. (1999), Thompson et al. (2002), and Knight-Jones and Rushton (2013), but probabilities of an outbreak used in the

analyses and estimation of losses are highly dependent on the scenarios used in the studies. One commonality across the studies is that the social cost of a disease outbreak is significantly high and exceeds the individual cost. The fact that there is an uncertainty in effective mitigation strategies also induces further environmental uncertainty. This arises because even if existing biosecurity plans protect endemic diseases, they may not be sufficient for protecting against Tier 1 animal diseases. The Secure Pork Supply plan suggests voluntary preparation methods before an outbreak including requesting a premise identification number (PIN) and keeping movement records of animals, people, equipment and other items; designating a biosecurity manager and preparing a written site-specific enhanced biosecurity plan, and adopting the perimeter buffer area (PBA) and line of separation (LOS) practices.<sup>1</sup> It is worth noting that it is not practical for a producer to implement a disease-specific protocol for preventing Tier 1 diseases. A vaccine is unavailable for ASF. For FMD, the vaccine is not used as a prevention method because the vaccine is specific for a particular strain and it is impossible to vaccinate for all the strains. Moreover, vaccinating often has international trade repercussions.

In addition to environmental uncertainty, producers also face strategic uncertainty. Bio-containment is defined as preventing the spread of disease agents to neighbors or long distance transfer, and producers tend to focus more on bio-exclusion and bio-management while often neglecting bio-containment (Baker, 2011). Merrill et al. (2018) pointed out that information about disease and biosecurity is incomplete or kept confidential within small networks, which can intensify the strategic uncertainty.

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<sup>1</sup> For more information refer to the SPS plan website at <http://www.securepork.org/>.

### *Ex-ante prevention of Tier 1 animal diseases and producer decision-making*

The investment in ex-ante prevention has been emphasized more than the investment in ex-post control of Tier 1 diseases. Sumner (2005) states that the cost involved with ex-post control or eradication of a disease is higher than ex-ante prevention, where the difference in magnitude depends on the number of farms and production quantity. Jin et al. (2009) also recommend that ex-ante investment is more desirable when the probability of disease outbreak increases, the targeted disease is more contagious with substantial damages, ex-post response strategy is less effective or more costly, and the public is risk-averse.

When it comes to disease prevention, the role of a producer in implementing biosecurity is a crucial factor. Hennessy (2008) points out that biosecurity is provided at many levels and decisions are made with different objectives in mind so that completely centralized decision making on biosecurity in the decentralized sector of agriculture is impossible. The Organization for Economic Cooperation and Development highlight risk and uncertainty as well as farm size, industry structure, and spatial issues as major factors in producer decision-making surrounding animal disease management (OECD, 2017). The OECD study emphasizes the continued lack of evidence on producers' risk perception and preference. Our research begins to fill this gap by providing empirical evidence on risk perceptions and attitudes of producers making biosecurity investments focused on Tier 1 animal disease mitigation under ambiguity.

### *Producer decision-making under ambiguity*

The United States has maintained ASF-, CSF-, and FMD-free status. As such, there is a chance that producers perceive this as a low probability event. Camerer and Weber (1992) showed that most individuals are ambiguity averse in the loss domain for low probability events, and

Brunette et al. (2013) found ambiguity averse attitudes of individuals in the loss domain for low probability losses, and also higher willingness to pay for insurance.

In order to understand risk perceptions and attitudes of producers under ambiguity, our empirical analysis is motivated by Di Mauro and Maffioletti's (2004) laboratory experiment with student respondents. They showed that the fourfold pattern of risk aversion suggested by prospect theory (Tversky and Kahneman, 1992) could be extended to ambiguity attitudes so that there is risk aversion at low probability and risk-seeking at high probability in the loss domain, and there is risk aversion at high probability and risk-seeking at low probability in the gain domain. They examined two different representations of ambiguity by using a best estimate and an interval of probability. In the experiment, the best estimate was operated as a symmetric distribution centered on the best estimate, and the interval probability was operated as a uniform probability distribution bounded by the extremes of the interval. They conclude that the best estimate and the interval of the probability scenario are interpreted as equally ambiguous sources of uncertainty, and found no difference in subjects' responses.

The results from Di Mauro and Maffioletti (2004) suggest that producers could show an ambiguity aversion in the loss domain at low probability, and there may be no difference in response with the representation of the ambiguity. We test this hypothesis. Furthermore, we extend the analysis to examine whether different ambiguity representations in the dimensions of risk probability of occurrence, outcome, and damage duration affect producers willingness to pay for an intervention that reduces losses from a Tier 1 disease outbreak.

## **Data and Methods**

The U.S. swine industry is used as the context for this study because it has dealt with endemic diseases, such as porcine respiratory and reproductive syndrome (PRRS), influenza, Porcine

circovirus 2 (PCVAD), and mycoplasma pneumonia (USDA-APHIS-VS-CEAH-NAHMS, 2016). Since 2013, several diseases affecting swine have been introduced into the U.S. herd, including porcine epidemic diarrhea virus (PEDV), porcine delta corona virus (PDCoV) and orthoreovirus (Lambert and Leedom Larson, 2016; Niederwerder and Hesse, 2018). The swine industry has advanced in the development of biosecurity and biocontainment practices that decrease risks of these disease. However, while existing risk mitigation efforts offer protection against endemic diseases, heightened safeguards are needed for foreign animal diseases.

The swine industry is an important part of agricultural production in the United States, accounting for over \$21.1 billion in farm receipts in 2017 (USDA-ERS, 2019). When the swine industry earns revenue through sales, that revenue is spent throughout the economy on wages, agricultural inputs, and consumption of goods and services. As a result, the U.S. economy is highly dependent on the swine industry, which amplifies strengthening safeguards to protect the U.S. swine herd.

#### *Sampling strategy, survey instrument, and experimental design*

The target population for our survey is swine producers from major hog and pig producing states. For example, USDA's quarterly hogs and pig report regularly publishes inventories of the largest hog and pig producing states. Ideally we could draw a random sample from a list of addresses for all swine operations in these states, but no such list is readily available. In an effort to reach as many producers as possible, we partnered with state pork producer associations in Iowa, Illinois, Indiana, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Carolina, Ohio, Oklahoma, South Dakota, Wisconsin to serve as an intermediary to contact producer members. According to the 2017 USDA Census of Agriculture, these 13 states represent 52% of U.S. hog operations

with sales and 90% of the U.S. hog sales (USDA NASS, 2019a). Roe, Sporleder, and Belleville (2004) employed a similar sampling framework.

Survey methodology, data collection, and processing were provided by Iowa State University's Center for Survey Statistics and Methodology (CSSM). The survey was programmed for web application using Qualtrics survey software (Qualtrics, Provo, UT). An eligible sample of 2,155 Iowa Pork Producer Association member email addresses was used for a custom link survey. An open link survey was employed for swine producers outside of Iowa, where state pork producer associations distributed a uniform resource locator (URL), or web address, to access the survey through an email list serve of members and/or included a URL to access the survey in their online newsletters. The first email notifications for the custom link survey were sent on March 23, 2017, with reminders sent on March 29 and April 5. The open link survey was made live on March 30, 2017, and was distributed shortly thereafter, with reminders sent periodically, by partner state pork producer associations.

Fully completed surveys were received from 279 respondents, including 169 custom link surveys and 110 open link surveys. When combined with the partially complete surveys, the total number of surveys received was 371, with 224 custom link surveys and 147 open link surveys. The response rate for the custom link survey was 10.4%. No response rate could be calculated for the open link survey because there was no defined sample. We excluded respondents that did not answer the contingent valuation question, and limited the analysis to operations producing market hogs (farrow to finish, wean to finish, and finishing) to create a uniform output for effectively testing the proposed hypotheses, which reduced the sample to 230 completed or partially completed survey responses from producers.<sup>2</sup>

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<sup>2</sup> Respondents who answered "other" for business arrangement were also dropped. Other business arrangements included research, university, consulting/evaluation.

Detailed respondent demographic information reveals a good match with the U.S. swine producer population when comparing our sample to USDA Census of Agriculture statistics in terms of producer and operation characteristics (Table 1). The average respondent years of experience is 33.3. The 2017 Census of Agriculture for the hogs and pigs farming North American Industry Classification System (NAICS1122) reports average years of experience of 20.9 operating any farm and 18.9 on the present farm for the 13 surveyed states (USDA NASS, 2019b). Over half of the survey participants have at least a bachelor's degree.

PRRS and PEDV were two diseases appearing on the U.S. National List of Reportable Animal Diseases for 2017 (USDA-APHIS, 2017). In the three years prior to the spring 2017 survey, 74.1% of respondents reported outbreaks of these diseases on their operation.

In our sample, swine operation characteristics are similar to averages of the 13 states surveyed—57.0% independent hog operations (census=75.2%), 34.8% contract growers (census=23.4%) and 8.3% contractors or integrators (census=1.4%). The operation types in our sample are 37.0% farrow to finish, 44.8% wean to finish, and 18.3% finishing. Census figures for operations producing market hogs, include and 33.9% farrow to finish and 66.1% finishing only (USDA NASS, 2019a).<sup>3</sup> The average number of production sites (unique premise ID, unique address) per operation is 16.

In addition to demographic questions, respondents were asked a contingent valuation (CV) question to examine willingness to pay under ambiguity. The contingent valuation method is one common approach used to elicit stated preferences, which directly asks survey respondents' willingness to pay for hypothetical projects or programs (Portney, 1994). The

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<sup>3</sup> The U.S. Department of Agriculture defines a finishing hog operation as a swine facility that includes market hogs, but not breeding stock, that are fed until they are sold for slaughter (USDA-NASS, 2009). As such, this definition doesn't separate wean to finish and finisher production as is often done in industry designations and in our survey.

survey instrument was developed after consulting many prior surveys of swine industry characteristics, biosecurity adoption, and risk elicitation. The authors consulted with swine researchers, extension specialists, and producers in selecting the language used in the survey.

#### *Contingent valuation experiment*

To estimate swine producer willingness to pay for interventions (biosecurity) that eliminate the potential loss from a Tier 1 disease outbreak, we employed a CV approach in a multiple choice framework, which is also referred to as the “payment card” method. Providing the range of values for which respondents’ willingness to pay may lie reduces survey fatigue by making it easy to scan possible responses, thereby, helping avoid non-response. The multiple choice framework is widely applied in many CV studies including Cameron and Huppert (1989), Kirchhoff et al (1997), Carlsson et al. (2012) and Yang et al. (2012).

Five treatments were designed so that questions varied in whether fixed or ambiguous framing of probability of occurrence (% risk of disease outbreak), damages (losses in dollars per pig sold), and damage duration (months of losses). For example, in Treatment 1 where all three components were fixed, respondents were told:

*Assume there is a 3% chance a Tier 1 disease outbreak occurring in the U.S. swine industry including on your operation. That is, the outbreak is expected to occur 3 times every 100 years.*

*If this outbreak occurs, you will suffer a loss of \$30 per pig sold and losses would persist for 6 months.*

As a follow-up question, respondents were asked:

*What is the maximum amount you would be willing to pay (annually per pig) for an intervention that reduced this potential loss to zero?*

Available answers included \$0, \$0.01 to \$0.25, \$0.26 to \$0.50, \$0.51 to \$0.75, \$0.76 to \$1.00, \$1.01 to \$1.25, \$1.26 to \$1.50, \$1.51 to \$1.75, \$1.76 to \$2.00, or over \$2.00. All willingness to pay figures were presented as dollars per pig per year.

Table 2 shows the fixed or ambiguous framing of each of the five treatments. Respondents were provided with one information treatment text (see appendix) that defined the scenario.<sup>4</sup> Figure 1 shows the distribution of willingness to pay provided by respondents as pooled across treatments. Among the 230 respondents to this question, 9% answered a \$0 willingness to pay, while 73.5% are willing to pay between \$0.01 and \$1.00, 10.9% are willing to pay between \$1.01 and \$2.00, and the remaining 6.1% are willing to pay over \$2.00 per pig per year.

A likelihood ratio test based on the parameters from maximum likelihood estimation (MLE) with normality assumption was used to confirm if it is appropriate to pool CV responses from survey versions 1 and 7, which contained the same information treatment text (Treatment 1). We failed to reject the null hypothesis that the pooled responses are homogeneous with respect to estimated parameters. A likelihood ratio test also failed to reject the pooling of versions 2 and 6, which had the same information treatment text (Treatment 2) in common. However, a likelihood ratio test rejected, at 10% significance level, pooling survey responses with different information text treatments. The box plot in Figure 2 shows the difference in mean willingness to pay across the different treatments, using the midpoint for the willingness to pay interval.

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<sup>4</sup> Because the base survey consisted of seven versions, we double-sampled on Treatment 1 (fixed risk, fixed damages, fixed damage duration) and Treatment 2 (ambiguous risk, ambiguous damages, ambiguous damage duration).

### *Econometric methods and estimation*

Following Kirchhoff et al. (1997), under random utility framework, a producer will have lower expected utility when they are under an ambiguous environment regarding an outbreak of Tier 1 disease if they are ambiguity averse in the loss domain for low probability events (Camerer and Weber, 1992). This will lead to a producer having a willingness to pay for a less ambiguous environment, which can be summarized as:

$$(1) \quad E[u(e, \varphi = 1, \boldsymbol{\gamma}, \mathbf{X}, \varepsilon)] = E[u(e - y(e, \mathbf{X}, \varepsilon), \varphi = 0, \boldsymbol{\gamma}, \mathbf{X}, \varepsilon)]$$

where  $u$  is the producer's utility function,  $y$  is willingness to pay,  $e$  is a producer's current spending on risk mitigation,  $\varphi \in \{0,1\}$  is outbreak of a Tier 1 diseases, with  $\varphi = 1$  indicating an outbreak and  $\varphi = 0$  indicating a risk-free environment from Tier 1 diseases.  $\boldsymbol{\gamma}$  is a vector of different treatments regarding the representation (ambiguity versus certainty) of the environment,  $\mathbf{X}$  is a vector of producer and operation characteristics, and  $\varepsilon$  is a stochastic component.

True willingness to pay of producer  $y_i^*$  is unobservable or latent and is contained in the two thresholds of \$  $\theta_j$  and \$  $\theta_{j+1}$  in each category, and a producer will choose the  $j$  category as an answer if the true willingness to pay is within the two thresholds, that is \$  $\theta_j < y_i^* \leq \theta_{j+1}$ , where  $j = 1, 2, \dots, 9, 10$ , and  $\theta_0 = 0$  and  $\theta_{10} = 2$ . The last category is presented in the CV question as “\$2.00 or more”, which is  $(\theta_{10} = \$2.00) < y_i^* \leq (\theta_{11} = \infty)$ .  $\theta_{11} = \$4$  is used in the analysis for model tractability.<sup>5</sup> As Cameron and Huppert (1989) suggest, sensitivity analysis with respect to an arbitrary chosen upper bound should be conducted which we provide in the appendix in Table A.

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<sup>5</sup> Alberini and Cooper (2000) affirm an upper bound of willingness to pay may be infinity, or a respondent's income. Since it is impractical to assume that willingness to pay for an intervention to mitigate losses from a Tier 1 disease outbreak exceeds either a producer's income or current expenditure on biosecurity, a value of \$4 per pig per year is arbitrarily chosen. This value is double the highest upper bounded of the provided intervals in the CV question and aligns with roughly doubling the total financial expenditure annually spent on biosecurity by swine producers (Pudenz, Schulz, and Tonsor, 2017).

There are two hypotheses of interest. The first hypothesis is that the different representations of an uncertain event has no impact on a producer's decisions. It is possible to test this by comparing Treatments 2, 3, 4, and 5 with Treatment 1. If producers are sensitive to the difference in the representation of ambiguity, they will find Treatment 2 the most ambiguous as all dimensions are described with an interval and producers who are exposed to Treatment 2 may be willing to pay more if they are ambiguity averse. The second hypothesis is that the response to ambiguity is different across the dimensions of risk occurrence, damages, and damage duration. If producers are more sensitive to one of the three dimensions, then their willingness to pay could be significantly different when one of the dimensions are given with intervals. The two hypotheses can be tested in a regression as follows:

$$(2) \quad y_i^* = \gamma_i \alpha + X_i \beta + \varepsilon_i$$

where  $y_i^*$  is the true unobserved or latent willingness to pay;  $\gamma_i$  is a vector of dummy variables that contains information about the different treatments used in the analysis;  $X_i$  are a set of explanatory variables;  $\alpha$  and  $\beta$  are coefficients to be estimated; and  $\varepsilon_i$  is a residual term with independently and identically distributed random disturbances.

A baseline estimate can be calculated by applying ordinary least squares (OLS) on the midpoint of the willingness to pay interval as the dependent variable. However, as shown in Cameron and Huppert (1989), the OLS midpoint method may yield biased parameter estimates. To account for this potential of biased parameter estimates, an interval regression is applied using MLE under the assumption of normality. In the interval regression, the probability of choosing the interval of willingness to pay by a producer is summarized as follow:

$$(3) \quad \begin{aligned} \Pr[ \theta_j < y_i^* \leq \theta_{j+1} ] &= \Pr [ (y_i^* \leq \theta_{j+1}) - \Pr [y_i^* \leq \theta_j] \\ &= F^*(\theta_{j+1}; \alpha, \beta | \gamma_i, X_i) - F^*(\theta_j; \alpha, \beta | \gamma_i, X_i) \end{aligned}$$

where  $F^*$  is a cumulative distribution function of a normal distribution, and parameter values of  $\gamma, \beta$  are estimated by MLE with normality assumption.

## Results

The models with producer characteristics, operation characteristics, operation types, and business arrangement explanatory variables are examined before testing the effect of the representation of ambiguity via the alternative information treatments provided to respondents. These results for each model using OLS regression and interval regression are provided in Table 3. The results show that the coefficients from the OLS regression and the interval regression have close magnitudes at a similar statistical significance levels.<sup>6</sup> For brevity, we confine of discussion to interval regression results. In Table 3, model (1) only includes producer characteristics and operation characteristics. The variables related to business arrangement are added in model (2), and operation type variables are added in model (3). Multicollinearity in the models were tested using the Variance Inflation Factor (VIF) test.<sup>7</sup>

Previous research has found that higher education results in greater adoption of technologies, management practices, and production systems (Wozniak, 1984; Ward et al., 2008). We find similar results as producers who hold at least a four-year college degree, compared to those who do not, are willing to pay \$0.193 per pig per year more for Tier 1 disease risk mitigation as shown in model (1). It could be that the higher the level of education a producer has, the greater the probability that he/she understands risks and is willing to implement

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<sup>6</sup> According to Yang et al. (2012), comparing the coefficients from these two regressions can serve as an ad hoc check for the normality assumption used in MLE in the interval regression. Because the coefficient estimates from the two regressions are quantitatively similar, the assumption of normality in the MLE estimations is validated.

<sup>7</sup> A value of ten was used as a benchmark for whether or not multicollinearity existed in a variable (Kutner, Nachtsheim, and Neter, 2004). All variables showed a VIF value of less than two.

additional risk mitigation efforts. More production sites as part of an operation is found to have a small but positive impact on willingness to pay in model (1). This suggests the presence of potential economies of scale in implementing disease mitigation efforts. For instance, there is a \$0.04 per pig per year increase in mean willingness to pay with doubling of production sites. However, the production sites variable loses explanatory power when business arrangement variables are added in model (2), and operation type variables are also added in model (3). Business arrangement had an impact on willingness to pay in model (3). For example, compared to independent producers, contractor or integrators were willing to pay \$0.275 per pig per year more for Tier 1 disease risk mitigating interventions. Many hog production contracts that pay on a per animal basis also have incentives to encourage contract growers to achieve certain benchmarks. These incentives are often based on achieving minimum death losses, or levels of average daily gain or feed efficiency and would encourage biosecurity investment and compliance as a means to meet these benchmarks. Our results suggest contractors or integrators may be willingness to pay, thereby upping incentives, for interventions undertaken by producers that may aid in continuity of business during a Tier 1 disease outbreak.

The control variables included in model (3) are used in further analysis.<sup>8</sup> In Table 4, the treatment variables related to different representations of uncertainty were examined. In the regressions, the treatments are included as four binary variables. The producers who were exposed to Treatment 1 with fixed probability of occurrence, damages, and damage duration in the Tier 1 disease scenario are considered as a base. Model (4) in Table 4 only includes the binary variables for the different treatments. Model (5) includes the binary variables for the different treatments as well as all other explanatory variables to control for producer and

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<sup>8</sup> For all three models, F-tests show that the explanatory variables used in the OLS regressions are jointly statistically significant.

operation characteristics. It is shown that producers who were exposed to Treatments 2, 3, 4, or 5 did not have statistically different willingness to pay than those who were exposed to Treatment 1. That is, there is no statistically significant evidence from the sample that the change in representation from the best estimate or fixed number to the interval or range of numbers influence producers' perception about uncertainty and impacts their willingness to pay to mitigate potential disease losses. This result is consistent with Di Mauro and Maffioletti (2004) that found that respondents perceived the two uncertainty representations of the best estimate and the interval of probability as equivalently ambiguous.

The other control variables used in model (5) relay consistent results with model (3) that excludes the treatment variables. One more thing to note in Table 4 is regarding the sign on the coefficients for the treatment variables, although they are not statistically significant. The Treatment 4 coefficient, which has the scenario with interval for losses but fixed numbers for probability of occurrence and damage duration has a positive coefficient while all other treatment variables have negative coefficients. Models using alternative binary variables to explain the impact of ambiguity representation are also employed for further examination in the appendix (Tables B and C), but results are consistent with those presented in Table 4.

In Table 5, the subset of the survey responses from Treatments 3, 4, and 5 are utilized for further analysis. When the scenario regarding the uncertain event of Tier 1 diseases outbreak is provided in the survey using different representations of risk of occurrence, damages, and damage duration, respondents can likely easily notice the difference in representation if only one of the three dimensions is described with an interval while others are described with fixed numbers. If this is the case, it may induce respondents to keep the representational difference in mind while they are selecting a willingness to pay. Therefore, the comparison focusing on the

three treatments may better reveal how producers' perceptions of ambiguity vary when they are confronted with two different representations for each of the dimensions. In this context, comparing all 5 treatments together in a sample makes it difficult to distinguish the effect of two ambiguous representations for each dimension. For example, Treatment 1 has fixed values for all three dimensions and Treatment 2 has interval representations for all three dimensions.

Respondents who are exposed to Treatments 1 and 2 may not discern the representation of the dimensions as all the dimensions are explained with the same representation. Therefore, excluding Treatments 1 and 2 from the subset provides a direct comparison of each dimension.

Table 5 shows that producers who are exposed to Treatment 4, which uses an interval for losses only, have a statistically significant higher willingness to pay as shown in model (6) without other control variables and in model (7) with control variables, than respondents who are exposed to Treatment 3 ( $t$ -statistic=13.06) or Treatment 5 (the base case). According to the results from the model (7), producers have a \$0.210 higher willingness to pay when they are exposed to the interval representation in the damages (losses per pig) dimension. This suggests that producers may react more sensitively to a potential outcome or loss from an uncertain event of Tier 1 disease outbreak so that this makes them perceive the interval representation in the damages dimension more ambiguous than the best estimate representation, and this may activate the ambiguity averse attitude of producers and induce them to be willing to pay more when they are randomly assigned to Treatment 4. Meanwhile, operation type had an influence on willingness to pay in model (7). When compared to farrow to finish operations, finishing operations were willing to pay \$0.343 less to mitigate Tier 1 disease losses. These results are expected given the health pyramid concept (Ramirez and Zaabel, 2012), which seeks to minimize the downstream effects of disease by controlling for disease toward the top of the

pyramid and thus prioritizes the health of animals in the genetic nucleus and multiplication population, followed by farrowing and gestation, nursery, and lastly finishing animals which have the shortest production cycle.

## **Conclusions**

A Tier 1 disease outbreak is an uncertain event which could bring catastrophic loss to the swine and related industries, but risk mitigation has characteristics of a public good so that government intervention would likely be required for effective prevention. Furthermore, due to the highly contagious characteristics of the diseases, incentivizing individual producers to participate in the optimal level of the prevention effort becomes crucial. OECD (2017) emphasizes the behavioral drivers in disease management decisions which can be activated by information services, education, advice, and communication. In this circumstance, analyzing risk perceptions and willingness to pay of producers for Tier 1 disease risk mitigation provides essential information not only for effective communication but also for policy design.

This article utilizes the contingent valuation method to understand swine producers' willingness to pay, and producers' response toward the different representation of uncertain or ambiguous scenarios. The predicted values from the interval regressions provide statistically significant evidence that producers are willing to pay \$0.63 per pig per year on average for Tier 1 disease risk mitigation. We find that producers perceive the best estimate or fixed probability as ambiguous as an interval of probabilities for the uncertain scenario of a Tier 1 disease outbreak. Furthermore, we find that producers are more responsive and have higher willingness to pay for Tier 1 diseases risk mitigation when they are exposed to the treatment of the interval representation in the damages dimension, comparing to the case of using the interval representation in other dimensions of probability of occurrence and damage duration.

Understanding willingness to pay under ambiguity and predicting the share of producers likely to adopt interventions under different conditions provides prescriptions on how to better design appealing industry education and communication strategies. The result from this article shows that appealing to the potential damages from Tier 1 diseases could induce more response from producers, and research on potential losses from Tier 1 disease outbreaks could relieve this uncertainty or ambiguity. Furthermore, the results of the article support targeted policy and communication strategies to effectively incentivize producers with diverse producer and operation characteristics.

The implications for policymaking of this ambiguity aversion is not as straightforward. On one hand, from a purely accounting view, prioritizing concerns for ambiguity aversion at the government level might lead to too much protection and too much investment in avoiding unmeasurable risks. On the other hand, producers' preferences could favor governmental policies that pay attention to their aversion to ambiguous situations. Our results contribute to this debate by identifying that the representation of ambiguity does not affect the Tier 1 disease mitigation investment decisions of individual producers, but that they may become ambiguity averse when damages dimension is perceived to be ambiguous.

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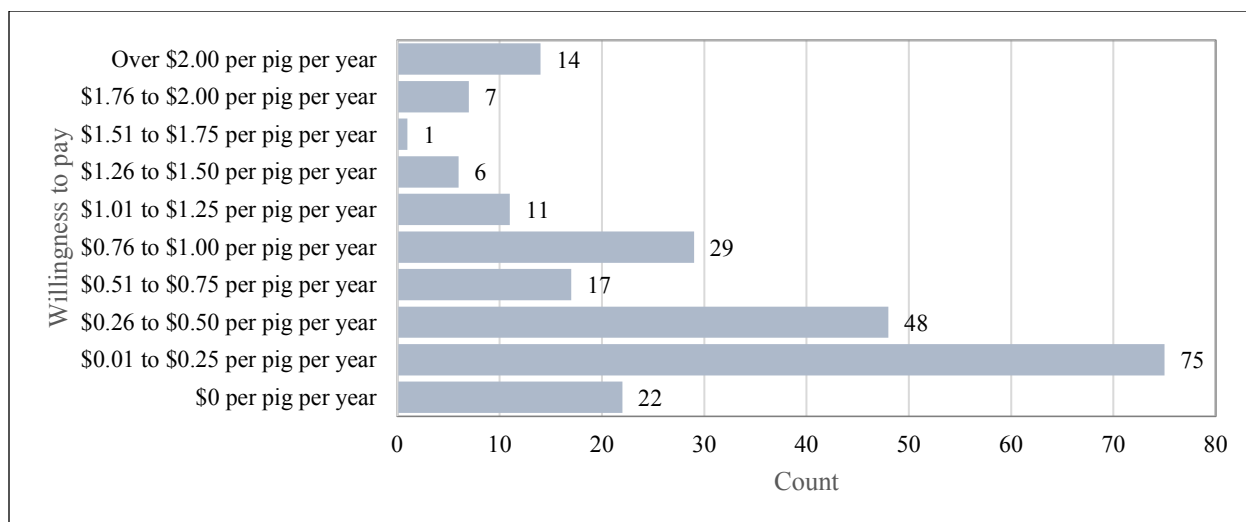
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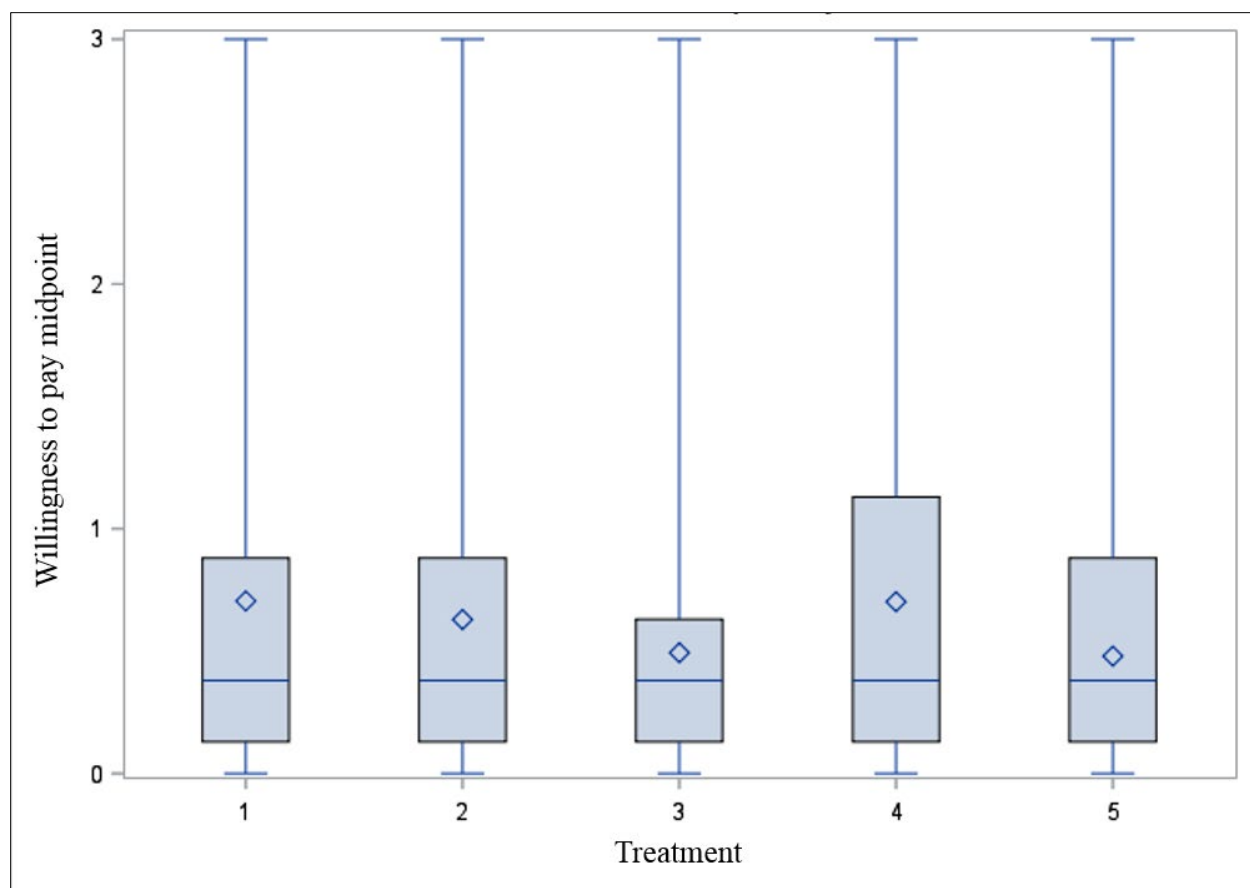
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**Figure 1. Distribution of WTP for Tier 1 diseases risk mitigation (N=230)**



**Figure 2. Box and whisker plot for WTP by information text treatment (N=230)**

**Table 1. Select summary statistics of survey respondents**

| Variable                     | Description of Variable  | N   | Mean   | Std Dev |
|------------------------------|--|-----|--------|---------|
| Experience                   | Experience of producers in the swine industry (in years)   | 216 | 33.329 | 13.383  |
| Education                    | = 1 if 4 year college or above; 0 otherwise  | 216 | 0.556  | 0.498   |
| Reportable                   | = 1 if a producer's operation has experienced PRRSV and/or PEDV in the past 3 years; 0 otherwise | 230 | 0.739  | 0.440   |
| Sites                        | Number of separate production sites (unique premise ID, unique address) in 2016                  | 230 | 16.683 | 60.915  |
| Independent                  | = 1 if independent producer; 0 otherwise   | 230 | 0.570  | 0.496   |
| Contractor or integrator     | = 1 if contractor or integrator; 0 otherwise   | 230 | 0.083  | 0.276   |
| Contract grower (contractee) | = 1 if contract grower (contractee); 0 otherwise   | 230 | 0.348  | 0.477   |
| Farrow to finish             | = 1 if farrow to finish; 0 otherwise   | 230 | 0.370  | 0.484   |
| Finishing                    | = 1 if finish; 0 otherwise   | 230 | 0.183  | 0.387   |
| Wean to finish               | = 1 if wean to finish; 0 otherwise   | 230 | 0.448  | 0.498   |

**Table 2. Description of the Tier 1 diseases scenarios by treatment**

| Treatment                                | Treatment 1 | Treatment 2 | Treatment 3 | Treatment 4 | Treatment 5 |
|--|-------------|-------------|-------------|-------------|-------------|
| Survey version                           | 1, 7        | 2, 6        | 3           | 4           | 5           |
| Probability of occurrence (% risk)       | 3%          | 1% - 5%     | 1% - 5%     | 3%          | 3%          |
| Damages (losses in dollars per pig sold) | \$30        | \$10 - \$50 | \$30        | \$10 - \$50 | \$30        |
| Damage duration (months of losses)       | 6           | 2-18        | 6           | 6           | 2-18        |

**Table 3. Determinants of the willingness to pay for Tier 1 diseases risk mitigation**

|  | (1)                    |                             | (2)                    |                             | (3)                    |                             |
|--|------------------------|-----------------------------|------------------------|-----------------------------|------------------------|-----------------------------|
| Dependent Variable                               | WTP<br>midpoint<br>OLS | WTP<br>interval<br>Interval | WTP<br>midpoint<br>OLS | WTP<br>interval<br>Interval | WTP<br>midpoint<br>OLS | WTP<br>interval<br>Interval |
| Intercept  | 0.236<br>(0.199)       | 0.281*<br>(0.161)           | 0.345*<br>(0.212)      | 0.360*<br>(0.170)           | 0.457*<br>(0.228)      | 0.421*<br>(0.183)           |
| Experience                                       | 0.003<br>(0.004)       | 0.001<br>(0.003)            | 0.002<br>(0.004)       | 0.0003<br>(0.003)           | 0.001<br>(0.004)       | 0.0002<br>(0.003)           |
| Education  | 0.244*<br>(0.106)      | 0.193*<br>(0.085)           | 0.244*<br>(0.106)      | 0.195*<br>(0.085)           | 0.244*<br>(0.106)      | 0.196*<br>(0.085)           |
| Reportable                                       | 0.101<br>(0.117)       | 0.104<br>(0.094)            | 0.101<br>(0.117)       | 0.103<br>(0.094)            | 0.099<br>(0.117)       | 0.100<br>(0.094)            |
| ln(Sites)  | 0.074*<br>(0.039)      | 0.061*<br>(0.032)           | 0.039<br>(0.044)       | 0.033<br>(0.035)            | 0.018<br>(0.046)       | 0.019<br>(0.037)            |
| <u>Business Arrangement (base = independent)</u> |                        |                             |                        |                             |                        |                             |
| Contractor or integrator                         |                        |                             | 0.238<br>(0.201)       | 0.215<br>(0.162)            | 0.326*<br>(0.214)      | 0.275*<br>(0.172)           |
| Contract grower (contractee)                     |                        |                             | -0.141<br>(0.114)      | -0.098<br>(0.091)           | -0.054<br>(0.130)      | -0.046<br>(0.104)           |
| <u>Operation Type (base = farrow to finish)</u>  |                        |                             |                        |                             |                        |                             |
| Finishing  |                        |                             |                        |                             | -0.226<br>(0.182)      | -0.150<br>(0.146)           |
| Wean to finish                                   |                        |                             |                        |                             | -0.151<br>(0.127)      | -0.078<br>(0.102)           |
| N  | 216                    | 216                         | 216                    | 216                         | 216                    | 216                         |
| F-value  | 2.68*                  |                             | 2.33*                  |                             | 1.99*                  |                             |
| R <sup>2</sup>                                   | 0.048                  |                             | 0.063                  |                             | 0.071                  |                             |
| Log likelihood                                   |                        | -463.047                    |                        | -461.499                    |                        | -460.899                    |
| Scale  |                        | 0.588                       |                        | 0.584                       |                        | 0.583                       |
| Average median WTP                               | 0.622                  | 0.634                       | 0.622                  | 0.624                       | 0.631                  | 0.627                       |
| Average mean WTP                                 | 0.625                  | 0.632                       | 0.625                  | 0.632                       | 0.625                  | 0.632                       |

Notes: Standard errors are in parentheses. \* indicates statistical significance at the 1%, 5%, 10%, or 15% level.

**Table 4. The impact of the uncertainty representation on willingness to pay**

|  | (4)                    |                             | (5)                    |                             |
|--|------------------------|-----------------------------|------------------------|-----------------------------|
| Dependent variable                               | WTP<br>midpoint<br>OLS | WTP<br>interval<br>Interval | WTP<br>midpoint<br>OLS | WTP<br>interval<br>Interval |
| Intercept  | 0.705*<br>(0.096)      | 0.628*<br>(0.078)           | 0.487*<br>(0.239)      | 0.443*<br>(0.189)           |
| <u>Information text (base = Treatment 1)</u>     |                        |                             |                        |                             |
| Treatment 2                                      | -0.076<br>(0.133)      | -0.047<br>(0.108)           | 0.017<br>(0.138)       | 0.029<br>(0.110)            |
| Treatment 3                                      | -0.211<br>(0.159)      | -0.179<br>(0.128)           | -0.117<br>(0.166)      | -0.102<br>(0.131)           |
| Treatment 4                                      | -0.003<br>(0.162)      | 0.050<br>(0.131)            | 0.001<br>(0.166)       | 0.047<br>(0.132)            |
| Treatment 5                                      | -0.225<br>(0.159)      | -0.171<br>(0.128)           | -0.159<br>(0.165)      | -0.116<br>(0.131)           |
| Experience                                       |                        |                             | 0.002<br>(0.004)       | 0.0004<br>(0.003)           |
| Education  |                        |                             | 0.252*<br>(0.107)      | 0.201*<br>(0.085)           |
| Reportable                                       |                        |                             | 0.083<br>(0.120)       | 0.085<br>(0.095)            |
| ln(Sites)  |                        |                             | 0.015<br>(0.047)       | 0.016<br>(0.037)            |
| <u>Business Arrangement (base = independent)</u> |                        |                             |                        |                             |
| Contractor or integrator                         |                        |                             | 0.345*<br>(0.220)      | 0.284*<br>(0.175)           |
| Contract grower (contractee)                     |                        |                             | -0.026<br>(0.134)      | -0.024<br>(0.106)           |
| <u>Operation Type (base = farrow to finish)</u>  |                        |                             |                        |                             |
| Finishing  |                        |                             | -0.250<br>(0.185)      | -0.169<br>(0.146)           |
| Wean to Finish                                   |                        |                             | -0.157<br>(0.129)      | -0.084<br>(0.102)           |
| N  | 230                    | 230                         | 216                    | 216                         |
| F-value  | 0.85                   |                             | 1.45*                  |                             |
| R <sup>2</sup>                                   | 0.015                  |                             | 0.079                  |                             |
| Log likelihood                                   |                        | -495.018                    |                        | -459.736                    |
| Scale  |                        | 0.600                       |                        | 0.579                       |
| Average median WTP                               | 0.629                  | 0.634                       | 0.645                  | 0.625                       |
| Average mean WTP                                 | 0.616                  | 0.625                       | 0.625                  | 0.632                       |

Notes: Standard errors are in parentheses. \* indicates statistical significance at the 1%, 5%, 10%, or 15% level.

**Table 5. The impact of the ambiguous representation in different dimensions on willingness to pay**

|  | (6)                    |                             | (7)                    |                             |
|--|------------------------|-----------------------------|------------------------|-----------------------------|
| Dependent variable                               | WTP<br>midpoint<br>OLS | WTP<br>interval<br>Interval | WTP<br>midpoint<br>OLS | WTP<br>interval<br>Interval |
| Intercept  | 0.479*<br>(0.108)      | 0.455*<br>(0.087)           | 0.517*<br>(0.330)      | 0.458*<br>(0.255)           |
| <u>Information text (base = Treatment 5)</u>     |                        |                             |                        |                             |
| Treatment 3                                      | 0.014<br>(0.153)       | -0.009<br>(0.123)           | 0.019<br>(0.170)       | -0.004<br>(0.131)           |
| Treatment 4                                      | 0.222<br>(0.155)       | 0.221*<br>(0.125)           | 0.218<br>(0.166)       | 0.210*<br>(0.128)           |
| Experience                                       |                        |                             | 0.004<br>(0.005)       | 0.002<br>(0.004)            |
| Education  |                        |                             | 0.190<br>(0.145)       | 0.178*<br>(0.112)           |
| Reportable                                       |                        |                             | 0.009<br>(0.154)       | 0.041<br>(0.119)            |
| ln(Sites)  |                        |                             | -0.037<br>(0.069)      | -0.024<br>(0.054)           |
| <u>Business Arrangement (base = independent)</u> |                        |                             |                        |                             |
| Contractor or integrator                         |                        |                             | -0.161<br>(0.281)      | -0.175<br>(0.216)           |
| Contract grower (contractee)                     |                        |                             | -0.062<br>(0.167)      | -0.096<br>(0.129)           |
| <u>Operation Type (base = farrow to finish)</u>  |                        |                             |                        |                             |
| Finishing  |                        |                             | -0.497*<br>(0.238)     | -0.343*<br>(0.184)          |
| Wean to finish                                   |                        |                             | -0.248<br>(0.183)      | -0.124<br>(0.141)           |
| N  | 103                    | 103                         | 98                     | 98                          |
| F-value  | 1.27                   |                             | 1.15                   |                             |
| R <sup>2</sup>                                   | 0.025                  |                             | 0.117                  |                             |
| Log likelihood                                   |                        | -212.342                    |                        | -197.784                    |
| Scale  |                        | 0.511                       |                        | 0.492                       |
| Average median WTP                               | 0.494                  | 0.507                       | 0.554                  | 0.567                       |
| Average mean WTP                                 | 0.555                  | 0.566                       | 0.564                  | 0.574                       |

Notes: Standard errors are in parentheses. \* indicates statistical significance at the 1%, 5%, 10%, or 15% level.

## **Appendix**

### **Information Treatment Text for Contingent Valuation Questions**

#### *Treatment 1 (Fixed Risk, Outcome, and Duration): Survey Version 1 and 7*

Assume there is a 3% chance a Tier 1 disease outbreak occurring in the U.S. swine industry including on your operation. That is, the outbreak is expected to occur 3 times every 100 years.

If this outbreak occurs, you will suffer a loss of \$30 per pig sold and losses would persist for 6 months.

#### *Treatment 2 (Ambiguous Risk, Outcome, and Duration): Survey Version 2 and 6*

Assume there is a chance of a Tier 1 disease outbreak occurring in the U.S. swine industry including on your operation. An expert, hired by a governmental agency, estimates the probability of the outbreak occurring is between 1% and 5%. That is, the outbreak is expected to occur between 1 and 5 times every 100 years.

If this outbreak occurs, the expert estimates the losses suffered would be between \$10 per pig sold and \$50 per pig sold and losses would persist for between 2 and 18 months.

#### *Treatment 3 (Ambiguous Risk, Fixed Outcome, and Fixed Duration): Survey Version 3*

Assume there is a chance of a Tier 1 disease outbreak occurring in the U.S. swine industry including on your operation. An expert, hired by a governmental agency, estimates the probability of the outbreak occurring is between 1% and 5%. That is, the outbreak is expected to occur between 1 and 5 times every 100 years.

If this event occurs, you will suffer a loss of \$30 per pig sold and losses would persist for 6 months.

*Treatment 4 (Fixed Risk, Ambiguous Outcome, and Fixed Duration): Survey Version 4*

Assume there is a 3% chance a Tier 1 disease outbreak occurring in the U.S. swine industry including on your operation. That is, the outbreak is expected to occur 3 times every 100 years.

If this outbreak occurs, an expert, hired by a governmental agency, estimates the losses suffered would be between \$10 per pig sold and \$50 per pig sold. These losses would persist for 6 months.

*Treatment 5 (Fixed Risk, Fixed Outcome, and Ambiguous Duration): Survey Version 5*

Assume there is a 3% chance a Tier 1 disease outbreak occurring in the U.S. swine industry including on your operation. That is, the outbreak is expected to occur 3 times every 100 years.

If this outbreak occurs, you will suffer a loss of \$30 per pig sold. An expert, hired by a governmental agency, estimates these losses would persist for between 2 and 18 months.

**Table A. Sensitivity analysis for the upper bound of open ended answer**

| Dependent Variable                              | Upper bound=\$4 |              | Upper bound=\$40 |              | Upper bound=infinity |              |
|---|-----------------|--------------|------------------|--------------|----------------------|--------------|
|   | WTP midpoint    | WTP interval | WTP midpoint     | WTP interval | WTP midpoint         | WTP interval |
|   | OLS             | Interval     | OLS              | Interval     | OLS                  | Interval     |
| Intercept                                       | 0.457*          | 0.421*       | 1.226            | 0.421*       | 0.338*               | 0.421*       |
|   | (0.228)         | (0.183)      | (1.505)          | (0.183)      | (0.143)              | (0.183)      |
| Experience                                      | 0.001           | 0.0002       | 0.023            | 0.0002       | -0.002               | 0.0002       |
|   | (0.004)         | (0.003)      | (0.027)          | (0.003)      | (0.003)              | (0.003)      |
| Education                                       | 0.244*          | 0.196*       | 1.402*           | 0.196*       | 0.092                | 0.196*       |
|   | (0.106)         | (0.085)      | (0.697)          | (0.085)      | (0.067)              | (0.085)      |
| Reportable                                      | 0.099           | 0.100        | 0.092            | 0.100        | 0.109*               | 0.100        |
|   | (0.117)         | (0.094)      | (0.772)          | (0.094)      | (0.073)              | (0.094)      |
| ln(sites)                                       | 0.018           | 0.019        | 0.006            | 0.019        | 0.025                | 0.019        |
|   | (0.046)         | (0.037)      | (0.306)          | (0.037)      | (0.029)              | (0.037)      |
| <u>Business Arrangement (base= independent)</u> |                 |              |                  |              |                      |              |
| Contractor/integrator                           | 0.326*          | 0.275*       | 1.619            | 0.275*       | 0.179                | 0.275*       |
|   | (0.214)         | (0.172)      | (1.413)          | (0.172)      | (0.138)              | (0.172)      |
| Contract grower (contractee)                    | -0.054          | -0.046       | -0.211           | -0.046       | -0.021               | -0.046       |
|   | (0.130)         | (0.104)      | (0.858)          | (0.104)      | (0.083)              | (0.104)      |
| <u>Operation Type (base= farrow to finish)</u>  |                 |              |                  |              |                      |              |
| Finishing                                       | -0.226          | -0.150       | -2.022*          | -0.150       | 0.021                | -0.150       |
|   | (0.182)         | (0.146)      | (1.200)          | (0.146)      | (0.116)              | (0.146)      |
| Wean to finish                                  | -0.151          | -0.078       | -1.875*          | -0.078       | 0.089                | -0.078       |
|   | (0.127)         | (0.102)      | (0.839)          | (0.102)      | (0.082)              | (0.102)      |
| N   | 216             | 216          | 216              |              | 203                  |              |
| F   | 1.99*           |              | 1.87*            |              | 1.72*                |              |
| R <sup>2</sup>                                  | 0.071           |              | 0.067            |              | 0.066                |              |
| Log likelihood                                  |                 | -460.9       |                  | -460.899     |                      | -460.899     |
| Scale   |                 | 0.583        |                  | 0.583        |                      | 0.583        |
| Average median WTP                              | 0.631           | 0.627        | 1.653            | 0.627        | 0.472                | 0.627        |
| Average mean WTP                                | 0.625           | 0.632        | 1.708            | 0.632        | 0.474                | 0.632        |

Notes: Standard errors are in parentheses. \* indicates statistical significance at the 1%, 5%, 10%, or 15% level.

**Table B. The impact of degree of ambiguity representation on the willingness to pay**

|  | (a)                 |                          |
|--|---------------------|--------------------------|
| Dependent variable   | WTP midpoint<br>OLS | WTP interval<br>Interval |
| Intercept  | 0.476*<br>(0.237)   | 0.428*<br>(0.189)        |
| <u>Information text (base = Treatment 1 with all fixed representation)</u>   |                     |                          |
| Partially ambiguous (=1 if range representation is used for one of the risk occurrence, damages, and damage dimensions; =0 otherwise)    | -0.093<br>(0.126)   | -0.058<br>(0.100)        |
| All ambiguous (=1 if range representation is used for all of the risk occurrence, damages, and damage duration dimensions; =0 otherwise) | 0.016<br>(0.138)    | 0.028<br>(0.110)         |
| Experience   | 0.002<br>(0.004)    | 0.001<br>(0.003)         |
| Education  | 0.249*<br>(0.106)   | 0.199*<br>(0.085)        |
| Reportable   | 0.096<br>(0.118)    | 0.097<br>(0.094)         |
| ln(sites)  | 0.015<br>(0.047)    | 0.017<br>(0.037)         |
| <u>Business Arrangement (base = independent)</u>   |                     |                          |
| Contractor or integrator   | 0.355*<br>(0.218)   | 0.299*<br>(0.174)        |
| Contract grower (contractee)   | -0.029<br>(0.133)   | -0.027<br>(0.106)        |
| <u>Operation Type (base = farrow to finish)</u>  |                     |                          |
| Finishing  | -0.245<br>(0.184)   | -0.165<br>(0.147)        |
| Wean to finish   | -0.157<br>(0.128)   | -0.082<br>(0.102)        |
| N  | 216                 |                          |
| F  | 1.68                |                          |
| R <sup>2</sup>   | 0.076               |                          |
| Log-likelihood   |                     | -460.487                 |
| Scale  |                     | 0.582                    |
| Average median WTP   | 0.626               | 0.628                    |
| Average mean WTP   | 0.625               | 0.632                    |

Notes: Standard errors are in parentheses. \* indicates statistical significance at the 1%, 5%, 10%, or 15% level.

**Table C. The impact of ambiguous dimension on the willingness to pay**

| Dependent Variable  | (b)                    |                             | (c)                    |                             | (d)                    |                             |
|---|------------------------|-----------------------------|------------------------|-----------------------------|------------------------|-----------------------------|
|   | WTP<br>midpoint<br>OLS | WTP<br>interval<br>Interval | WTP<br>midpoint<br>OLS | WTP<br>interval<br>Interval | WTP<br>midpoint<br>OLS | WTP<br>interval<br>Interval |
| Intercept   | 0.453*<br>(0.235)      | 0.422*<br>(0.188)           | 0.436*<br>(0.23)       | 0.398*<br>(0.183)           | 0.462*<br>(0.231)      | 0.424*<br>(0.185)           |
| <u>Information text (base = Treatment 1 with all fixed representation)</u>  |                        |                             |                        |                             |                        |                             |
| Ambiguous risk occurrence (=1 if a range representation is used for risk occurrence dimension; =0 if a fixed number is used for occurrence dimension) | 0.009<br>(0.105)       | -0.001<br>(0.084)           |                        |                             |                        |                             |
| Ambiguous damages (=1 if a range representation is used for damages; =0 if a fixed number representation is used for damages)                         |                        |                             | 0.084<br>(0.103)       | 0.093<br>(0.082)            |                        |                             |
| Ambiguous duration (=1 if a range representation is used for damage duration; =0 if a fixed number representation is used for damage duration)        |                        |                             |                        |                             | -0.014<br>(0.102)      | -0.007<br>(0.081)           |
| Experience  | 0.001<br>(0.004)       | 0.0002<br>(0.003)           | 0.001<br>(0.004)       | 0.0002<br>(0.003)           | 0.001<br>(0.004)       | 0.0002<br>(0.003)           |
| Education   | 0.245*<br>(0.106)      | 0.196*<br>(0.085)           | 0.246*<br>(0.106)      | 0.198*<br>(0.085)           | 0.245*<br>(0.106)      | 0.196*<br>(0.085)           |
| Reportable  | 0.098<br>(0.118)       | 0.101<br>(0.095)            | 0.087<br>(0.118)       | 0.086<br>(0.094)            | 0.099<br>(0.117)       | 0.100<br>(0.094)            |
| ln(sites)   | 0.018<br>(0.047)       | 0.019<br>(0.037)            | 0.017<br>(0.046)       | 0.018<br>(0.037)            | 0.018<br>(0.047)       | 0.020<br>(0.037)            |
| <u>Business Arrangement (base = independent)</u>  |                        |                             |                        |                             |                        |                             |
| Contractor/integrator   | 0.330*<br>(0.218)      | 0.275*<br>(0.175)           | 0.337*<br>(0.215)      | 0.286*<br>(0.172)           | 0.324*<br>(0.216)      | 0.274*<br>(0.173)           |
| Contract grower (contractee)  | -0.054<br>(0.131)      | -0.046<br>(0.104)           | -0.047<br>(0.131)      | -0.038<br>(0.104)           | -0.055<br>(0.131)      | -0.046<br>(0.104)           |
| <u>Operation Type (base = farrow to finish)</u>   |                        |                             |                        |                             |                        |                             |
| Finishing   | -0.227<br>(0.183)      | -0.150<br>(0.146)           | -0.238<br>(0.183)      | -0.163<br>(0.146)           | -0.225<br>(0.183)      | -0.149<br>(0.146)           |
| Wean to finish  | -0.150<br>(0.128)      | -0.078<br>(0.102)           | -0.153<br>(0.128)      | -0.079<br>(0.102)           | -0.150<br>(0.128)      | -0.078<br>(0.102)           |
| N   | 216                    | 216                         | 216                    | 216                         | 216                    | 216                         |
| F   | 1.76                   |                             | 1.84                   |                             | 1.76                   |                             |
| R <sup>2</sup>  | 0.071                  |                             | 0.074                  |                             | 0.071                  |                             |
| Log likelihood  |                        | -460.899                    |                        | -460.260                    |                        | -460.895                    |
| Scale   |                        | 0.583                       |                        | 0.581                       |                        | 0.583                       |
| Average median WTP  | 0.632                  | 0.627                       | 0.623                  | 0.626                       | 0.632                  | 0.628                       |
| Average mean WTP  | 0.625                  | 0.632                       | 0.625                  | 0.632                       | 0.625                  | 0.632                       |

Notes: Standard errors are in parentheses. \* indicates statistical significance at the 1%, 5%, 10%, or 15% level.