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Welfare effects of reduced milk production associated with Johne's disease on Johne's-positive *versus* Johne's-negative dairy operations

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An examination of the economic impacts of reduced milk production associated with Johne's disease on Johne's-positive and Johne's-negative dairy operations indicated that, if Johne's disease had not existed in US dairy cows in 1996, then the economic surplus of Johne's-negative operations would have been \$600 million ± \$530 million lower, while the economic surplus of Johne's-positive operations would have been higher by \$28 million ± \$79 million, which was not significantly different from zero. The data available for projecting changes in surplus were not sufficiently precise to allow an exact statement on whether Johne's-positive operations would have been better or worse off economically, in terms of the value received for producing more milk if they had not been affected by Johne's disease. The changes in producer surplus, based upon eliminating specific epidemiological risk factors for Johne's disease, were disaggregated between Johne's-positive dairy operations exposed to the risk factor and all other US dairy operations. Eliminating the risk factor of having any cows not born on the operation would have had a significant positive effect on the economic surplus of Johne's-positive operations that had any cows not born on the operation.

Keywords: Cost of disease, dairy cows, dairy production, economic surplus, welfare analysis, uncertainty propagation.

A previous report indicated that, with 95% confidence, 21·6% ± 3·4% US dairy operations were Johne's-positive in 1996 (US Department of Agriculture, 1997). A Johne's-positive operation was defined as a dairy operation where at least two dairy cows tested positive for *Mycobacterium paratuberculosis* antibodies, or where one cow tested positive for *Mycobacterium paratuberculosis* antibodies and at least 5% of culled cows exhibited symptoms consistent with Johne's disease, during the 12 months prior to being interviewed for a national survey of dairy producers (US Department of Agriculture, 1997). Recently, Losinger (2005) calculated that if Johne's disease had not been present in US dairy herds in 1996, then the total quantity of milk produced would have risen from 70·0 ± 1·2 billion kg to 70·6 ± 1·4 billion kg, the market price of milk would have fallen from 32·8 ± 0·8 cents/kg to 31·7 ± 1·0 cents/kg, and the total value of the milk produced would have fallen from \$23·0 ± 0·6 billion to \$22·4 ± 0·8 billion (95% confidence intervals are presented). The changes in price and quantity would have increased consumer surplus by \$770 million ± \$690 million, reduced producer surplus by \$570 million ± \$550 million, and resulted in a net benefit of \$200 million ± \$160 million to the US economy. The change in producer surplus was computed overall, and not for Johne's-positive and Johne's-negative dairy operations as individual groups.

For consumers, the gains that would have been realized from eliminating Johne's disease were clear. Much of the increase in consumer surplus would have resulted from a direct transfer of \$758 ± \$670 million in economic surplus from producers, as the quantity increased and the market price fell (Losinger, 2005). The transferred surplus is illustrated by the area with vertical stripes in Fig. 1. For producers as a whole, this loss in economic surplus would have been mitigated (to some extent) by a gain in economic surplus of \$185 ± \$140 million that would have been realized from selling the additional milk that would have been produced if Johne's disease had not been present in US dairy cows (Losinger, 2005). This gain is illustrated by the cross-hatched area in Fig. 1. It should be pointed out that only producers who had been affected by Johne's

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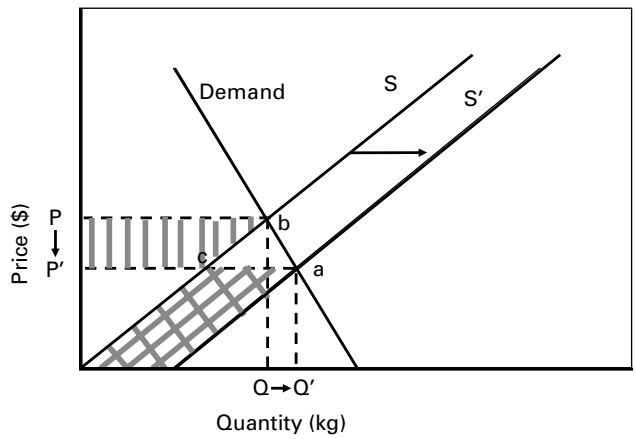

Fig. 1. Demand and supply for milk. S represents the supply curve for milk in the USA in 1996. S intersected with the Demand for milk, to determine the quantity of milk produced (Q) and the market price (P). Producer surplus was the area above S, and below the line segment P–b. If the supply of milk had expanded to S′ (owing to eliminating Johne's disease in dairy cows), and the demand for milk had not changed, then the quantity produced would have increased to Q′, and the market price would have fallen to P′. A portion of what had been a part of the producer surplus (the vertically striped area enclosed by the quadrilateral defined by the points P′, P, b and c) would have been lost to both Johne's-positive and Johne's-negative producers but gained by consumers. The surplus of Johne's-negative operations would have increased by the cross-hatched area between the two supply curves and below the line segment c–a, as their output expanded owing to eliminating Johne's disease in their dairy cows.

disease would potentially stand to gain economically from increased production associated with eliminating Johne's disease: all of the potential producer gain (the cross-hatched area of Fig. 1) would go to Johne's-positive dairy operations. Dairy operations that did not have Johne's disease would only stand to lose economic surplus if Johne's-positive operations could increase production (through eliminating Johne's disease). Johne's-positive and Johne's-negative operations would both share in losing economic surplus to consumers as the price fell (both would share in the area with vertical stripes in Fig. 1). Whether Johne's-positive operations, as a group, would stand to gain from eliminating Johne's disease would depend upon whether their potential gain (the cross-hatched area of Fig. 1) exceeded their potential loss (their share of the vertically striped area of Fig. 1).

The purpose of this analysis was to estimate the potential economic impact, separately for Johne's-positive and Johne's-negative US dairy operations, of increased milk production that could potentially have resulted from eliminating Johne's disease in US dairy cows in 1996. In addition, the potential producer impacts were assessed for individual epidemiological risk factors for Johne's disease. The insights gained from this analysis could potentially be useful in assessing the possible impacts of disease mitigation strategies.

Materials and Methods

The methods followed for computing the overall economic impacts of Johne's disease, including the impact on producer surplus as a whole, have been described in detail (Losinger, 2005). Losinger (2005) also listed the input quantities used, including their sources and uncertainties. The analytical method was a basic welfare analysis, based on the assumption of linear demand and supply curves and a parallel shift in the supply curve to represent increased milk production if Johne's disease had not been present in US dairy cows in 1996 (Losinger, 2005). Uncertainties in the estimates were evaluated in accordance with the *Guide to the Expression of Uncertainty in Measurement* (**GUM**) (International Organization for Standardization, 1995), using the GUM Workbench (Metrodata GmbH, 1999). For this particular analysis, all of the potential producer gains to be realized from eliminating Johne's disease were assigned to Johne's-positive operations. The $758 ± $670 million in economic surplus that producers would lose to consumers was divided proportionally based upon the amount of milk produced in 1996 by Johne's-positive and Johne's-negative operations. The economic surplus that Johne's-positive dairy producers would have lost to consumers was subtracted from the potential producer gains, to determine the net impact for Johne's-positive operations.

In addition, the changes in producer surplus, based upon eliminating specific epidemiologic risk factors for Johne's disease (Losinger, 2006), were disaggregated between Johne's-positive dairy operations exposed to the risk factor and all other US dairy operations. 'All other US dairy operations' included dairy operations not exposed to the risk factor (whether Johne's-positive or not), and Johne's-negative operations exposed to the risk factor. Only Johne's-positive dairy operations exposed to the risk factor would stand to benefit from increased milk production if exposure to the risk factor were eliminated. Equations associated with computing the changes in economic surplus based upon eliminating exposure to specific risk factors for Johne's disease were previously provided (Losinger, 2006). All of the potential producer gains to be realized from increased milk production associated with eliminating exposure to a risk factor were assigned to Johne's-positive operations exposed to the risk factor. The potential increase in milk production was based upon the population-attributable fraction (*i.e.* the fraction of disease that could be prevented by shifting everyone in a particular category to the base category of the risk factor) as previously computed (Losinger, 2006). The economic surplus that would have been transferred to producers to consumers (as the price of milk fell) was divided proportionally based upon the amount of milk

Table 1. Uncertainty budget for the change in surplus (for Johne's-negative dairy operations) that would result from increased milk production if milk production had increased owing to Johne's disease being eliminated from US dairy operations in 1996

Input quantity	Sensitivity coefficient†	Uncertainty contribution‡	Index§
Reduced milk production on Johne's-positive dairy operations, kg/cow	$-2{\cdot}1\times10^{6}$	$-2{\cdot}3\times10^{8}$	76·4%
Percent of dairy operations that were Johne's-positive	$-2{\cdot}0\times10^{7}$	$-3{\cdot}4\times10^{7}$	1·7%
Number of dairy cows	$-6{\cdot}4\times10^{1}$	$-7{\cdot}8\times10^{6}$	0·0%
kg milk produced in 1996	$7{\cdot}9\times10^{-6}$	$5{\cdot}0\times10^{3}$	0·0%
Mean price of milk in 1996, \$/kg	$-1{\cdot}8\times10^{9}$	$-3{\cdot}9\times10^{6}$	0·0%
Price elasticity of demand for milk	$-2{\cdot}4\times10^{8}$	$-1{\cdot}2\times10^{8}$	21·8%
Price elasticity of supply for milk	$1{\cdot}0\times10^{7}$	$1{\cdot}1\times10^{6}$	0·0%

The final estimate for the change in surplus for Johne's-negative dairy operations is $-\$6{\cdot}00\times10^{8}$, with a standard uncertainty of $\$2{\cdot}65\times10^{8}$ and 66 degrees of freedom. The resulting value and expanded uncertainty, with a coverage factor of two, is then: $-\$600\,000\,000\pm\$530\,000\,000$

† $\partial y/\partial x_i$: describes how the estimated value of the measurand, y, varies with changes in the estimated value of the input quantity x_1, x_2, … (International Organization for Standardization, 1995)

‡ Product of the standard uncertainty (Table 1) and the sensitivity coefficient. The sum of the squares of the values in this column equals the square of the uncertainty in the estimated value of the measurand y

§ Percent contribution to the square of the measurand's uncertainty. This is 100 times the ratio of square of the input quantity's uncertainty contribution to the square of the uncertainty in the estimated value of the measurand. This column sums to 100%

Table 2. Uncertainty budget for the change in producer surplus (for Johne's-positive dairy operations) that would result from increased milk production, if these particular dairy operations did not have Johne's disease in 1996

Input quantity	Sensitivity coefficient	Uncertainty contribution	Index
Reduced milk production on Johne's-positive dairy operations, kg/cow	$1{\cdot}0\times10^{5}$	$1{\cdot}1\times10^{7}$	9·1%
Percent of dairy operations that were Johne's-positive	$-6{\cdot}5\times10^{6}$	$-1{\cdot}1\times10^{7}$	8·2%
Number of dairy cows	$3{\cdot}1\times10^{0}$	$3{\cdot}8\times10^{5}$	0·0%
Kg milk produced in 1996	$-2{\cdot}1\times10^{-5}$	$-1{\cdot}3\times10^{4}$	0·0%
Mean price of milk in 1996, \$/kg	$8{\cdot}4\times10^{7}$	$1{\cdot}8\times10^{5}$	0·0%
Price elasticity of demand for milk	$-6{\cdot}8\times10^{8}$	$-3{\cdot}4\times10^{7}$	82·8%
Price elasticity of supply for milk	$2{\cdot}6\times10^{6}$	$2{\cdot}9\times10^{5}$	0·0%

The final estimate for the change in surplus for Johne's-positive operations is an increase of $\$2{\cdot}75\times10^{7}$, with a standard uncertainty of $\$3{\cdot}71\times10^{7}$ and 20 degrees of freedom. The resulting value and expanded uncertainty, with a coverage factor of 2·13, is then an increase of: $\$28\,000\,000+\$79\,000\,000$

produced in 1996 by Johne's-positive dairy operations with the risk factor, and 'all other' dairy operations. The economic surplus that Johne's-positive dairy producers with the risk factor would have lost to consumers was subtracted from the potential producer gains, to determine the net impact for Johne's-positive operations with the risk factor.

Results

Tables 1 and 2 present, respectively, the uncertainty budgets for the changes in producer surplus (for Johne's-positive and Johne's-negative dairy operations) that would have resulted from increased milk production if Johne's disease had not been present in US dairy cows in 1996. Johne's-negative operations would have lost \$600 million ± \$530 million in economic surplus, if Johne's disease had not reduced production on Johne's-positive farms. The principal source of uncertainty in this estimate was the reduced milk production on Johne's-positive dairy operations, followed by the elasticity of demand for milk (Table 1). Johne's-positive operations would have gained \$28 million ± \$79 million, which was not significantly different from zero (Table 2). Thus, from the data available, it is not clear whether Johne's-positive operations would have benefitted economically from the increased milk production that would have resulted from eliminating Johne's disease. The primary source of uncertainty in this estimate was the elasticity of demand (Table 2).

Table 3 presents the changes in producer surplus (in millions of US dollars) attributed to increased milk production that would be associated with eliminating Johne's disease from US dairy operations, disaggregated between Johne's-positive operations exposed to specific risk factors and all other operations. Across each row, the impact on Johne's-positive operations exposed to the risk factor, and the impact on all other operations, sums to the total impact on producers, but may not appear to do so owing to rounding at different orders of magnitude. The model suggests that increased milk production associated with removing the Johne's-disease fraction associated with

Table 3. Changes in producer surplus (in millions of US dollars) attributed to increased milk production associated with removing specific risk factors for Johne's disease from the US population of dairy cows in 1996. The coverage factor is two (*i.e.* plus or minus twice the standard uncertainty). The changes in producer surplus have been disaggregated between Johne's-positive US dairy operations exposed to the risk factor, and all other US dairy operations

	Johne's-positive dairy operations exposed to the risk factor	All other US dairy operations	All US dairy operations
Total impact of removing Johne's disease	28±79	−600±530	−570±550
Number of dairy cows			
100–299	13±14	−52±66	−40±53
⩾300	55±47	−360±330	−300±300
Total	56±50	−400±360	−340±340
Region			
Southeast	3±11	−13±44	−10±34
Northeast	10±18	−39±79	−30±62
Midwest	48±41	−260±260	−210±230
Total	52±44	−300±300	−250±270
Percent of dairy cows not born on the operation			
1–24%	27±29	−120±150	−90±120
25% or more	27±25	−120±130	−100±110
Total	45±39	−230±240	−190±210
Multiple-cow-maternity housing used in previous year			
Yes	30±32	−140±170	−110±140
Multiple-preweaned-calf housing used in previous year			
Yes	27±29	−120±150	−90±120

operations having ⩾100 cows would have significantly increased the economic surplus of Johne's-positive producers with ⩾100 cows and decreased the economic surplus of all other producers. The results also suggest that increased milk production associated with removing the Johne's-disease fraction associated with exposure to the Midwest region would have significantly increased the economic surplus of Johne's-positive dairy operations in the Midwest and decreased the economic surplus of all other producers. Eliminating the risk factor of having any cows not born on the operation would have had a significant positive effect on the economic surplus of Johne's-positive operations that had any cows not born on the operation; the effect on other operations was not statistically significant. The economic impacts of multiple-cow-maternity housing and of multiple-preweaned-calf housing were not statistically significant.

Discussion

Overall limitations in the present study are essentially identical to those previously discussed (Losinger, 2005; Losinger, 2006). It should be emphasized that the present analysis considered only two static situations: with and without Johne's disease. Johne's disease probably cannot be eradicated completely – hence, the gains that could be realized realistically are probably less than the comparison of these two static situations would suggest. Still, it is fairly common for economists to assume that a relatively small change in the unit cost of production can be modelled as a parallel shift of the supply curve, and that economic impacts can be measured based on differences between the two static situations.

The analysis of supply shifts, as a result of either animal disease or technological enhancements in production, has had a checkered history. The US Department of Agriculture (1997) and Ott et al. (1999) determined that Johne's disease cost the US dairy industry between $200 million and $250 million annually. That analysis did not consider the impact of Johne's disease on consumers and the consequent price effects, thus suggesting that producers would be the only beneficiaries of controlling Johne's disease (US Department of Agriculture, 1997; Ott et al. 1999). Such analyses do have utility in terms of galvanizing public sentiment in favour of launching research and control efforts. The present finding, that eliminating Johne's disease from dairy cows would have reduced producer surplus by $570 million±$550 million owing to the steep price decline, would hardly serve as a rallying cry for increased expenditure to combat this disease.

Citing US Department of Agriculture figures that Johne's disease and porcine reproductive and respiratory syndrome (PRRS) together caused more than $800 million per year in losses to US agriculture and the food-consuming public, the Secretary of the US Department of Agriculture announced on 14 April 2004, that the US Department of Agriculture would contribute $8·8 million to two

international research collaboratives working on Johne's disease and porcine reproductive and respiratory syn-
TQ1 drome (Kahler, 2004). Subsequently, Neumann et al. (2005) determined that PRRS cost $560·32 million in losses each year, which was considerably higher than previous estimates of the economic impacts of other swine diseases. The Neumann et al. (2005) calculations were based on the average differences in production data between 'case' and 'control' farms from ten different pork producers, and were projected to the national level based on US Department of Agriculture, National Animal Health Monitoring System estimates of PRRS in breeding herds, nursery-age pigs, and grower/finisher pigs during 2000. Neumann et al. (2005) performed no statistical comparisons in the production parameters between the case and control farms; apparently did not select their farms from throughout the country (which would mean that their computations of national-level impacts were invalid); did not take price effects into account; made no attempt to address uncertainty in their computations; and did not analyse the price effects. If Neumann et al. (2005) had performed *t* tests based upon paired differences (Snedecor & Cochran, 1967), they would have found that many of the observed differences between case and control farms were not significant. Other studies have shown that diagnosis of PRRS had no substantial impact on pork production (Losinger et al. 1999), nor on the feed-conversion ratio (Losinger, 1998) nor mortality (Losinger et al. 1998) in the grower/finisher phase of pork production, which suggests that the Neumann et al. (2005) estimate of the economic impact of PRRS was greatly inflated.

Crooks et al. (1994) pointed out the problem that health-cost estimation techniques often ignored the inelastic demand for agricultural products, and stated that economic theory would suggest that diseases and other problems that reduce production may serve to support livestock prices and producer revenues above what they otherwise might be. Crooks et al. (1994) developed a model to show how a 1% increase in the supply of live hogs (as a result of reduced mortality) would affect consumers and producers of pork, beef and poultry over time. A reduction in the price of pork would cause consumers to substitute it for beef and poultry (which become relatively more expensive) thus affecting beef and poultry producers. Milk does not have ready substitutes; hence there is a much more inelastic demand for milk than for different types of meat. It would be nice to imagine that great numbers of US consumers would substitute milk for beer and sugary carbonated soft drinks if milk were to become relatively cheaper, but this scenario seems unlikely. Crooks et al. (1994) concluded that a new technology would have to reduce costs, more than the resulting increase in production would reduce prices, in order to benefit producers. Reduced milk production has been identified as the chief economic concern related to Johne's disease (US Department of Agriculture, 1997; Ott et al. 1999); thus, eliminating Johne's disease would probably achieve greater results in terms of reducing the price of milk than in reducing the cost of producing the milk.

Ebel et al. (1992) found that some producers would experience a net gain, and others a net loss from the eradication of pseudorabies, depending on regional and herd-size differences. Ebel et al. (1992) used formulas initially developed by Lichtenberg et al. (1988) for measuring changes in consumer and producer surplus. However, Ebel et al. (1992) modified the formula for computing the change in producer surplus, because Ebel et al. (1992) noticed that Lichtenberg et al. (1988) had omitted part of the change in producer surplus in their calculations. Subsequently, Forsythe & Corso (1994) found that Ebel et al. (1992) were correct in noting that Lichtenberg et al. (1988) had omitted part of the change in producer surplus in their calculations, but also found that the formula of Lichtenberg et al. (1988) for measuring the change in producer surplus overstated the change in producer surplus, and that the correction by Ebel et al. (1992) of the omitted change in producer surplus compounded the overstatement. Another problem with the methods used by Ebel et al. (1992) for computing the change in producer surplus was that the same formula was applied whether the elasticity of supply was taken to be >1 (and had a positive *Y*-intercept) or <1 (and had a negative *Y*-intercept). Supply curves are usually depicted as having a positive *Y*-intercept, because the marginal cost of providing the first unit of output is positive; however, inelastic supply curves (with elasticities <1) do not have a positive *Y*-intercept, and economic surplus changes should not be computed from negative prices (Zhao et al. 1997). Forsythe & Corso (1994) focused on the case where the elasticity of supply was >1 and found that the majority of benefits of eliminating pseudorabies would accrue to producers with infected herds in high hog production states, and that producers with noninfected herds in high hog production states would suffer the largest losses due to the reduced price. A limitation of the present study was that the definition of a Johne's-positive operation (based on the number of dairy cows that tested positive for *Mycobacterium tuberculosis* and the percent of culled dairy cows that had symptoms of Johne's disease, US Department of Agriculture, 1997) may have made it more likely that a large operation would be classified as Johne's-positive. As previously mentioned (Losinger, 2006), animal disease risks may become augmented when large numbers of animals are raised together, and consequent losses associated with disease outbreaks may become increasingly substantial. The present study differed from that of Ebel et al. (1992) and Forsythe & Corso (1994) in examining the impact of eliminating the impact of epidemiological risk factors from the population, rather than eliminating Johne's disease from a particular region or herd size. Not all operations exposed to a risk factor have Johne's disease; nor would removing a risk factor have eliminated Johne's disease from all exposed dairy operations. It would not be meaningful to discuss removing exposure of dairy

operations from regions or herd size categories. Rather, these variables should be regarded as proxies for a diverse set of other risk factors, and whose inclusion in the risk-factors model helped to prevent other variables from entering the model merely because of regional or herd-size differences in management (Losinger, 2006).

Citing the equations provided by Lichtenberg et al. (1988); Ebel et al. (1992) and Forsythe & Corso (1994); Curlett (2005) determined that elevated bulk tank somatic cell counts reduced consumer surplus by $1·687 billion, reduced the surplus of dairy producers by $740 million, with a net economic loss of $2·427 billion in 1996. Curlett (2005) felt that it was important to demonstrate that producers were not positively affected by reduced milk productivity, and stated that the total economic impact of high bulk tank somatic cell counts in the national dairy herd was substantial because both producers and consumers were negatively affected. Curlett (2005) felt that his analysis demonstrated that producers had an incentive to control mastitis on the farm. Curlett (2005) did not provide his equations, but seemed to have committed the same errors made by Ott et al. (2003) when they determined that bovine leukosis virus caused a $285 million loss in economic surplus for producers, a $240 million loss in economic surplus for consumers, and a net economic loss of $525 million: the 'net economic loss' was the simple sum of the individual changes in consumer and producer surplus, and ignored the transfer in economic surplus between producers and consumers when the supply curve shifted; the fact that the supply curve had a negative *Y*-intercept was ignored, which meant that producer gains were attributed to negative prices; and the formula for the change in consumer surplus was incorrect.

Lindner & Jarret (1978) and Miller et al. (1988) examined variations in the changes in producer surplus when supply shifts were other than parallel. For dairy producers not affected by Johne's disease, the computation of change in economic surplus may be less disputable, as it involves a portion of the producer surplus that is transferred to consumers as milk production increases and the price falls. For dairy producers affected by the disease, the change in surplus also involves an increase that results from augmented production (Fig. 1) and estimating the area between two supply curves projected to the horizontal axis may be open to interpretation. The goal of the present analysis was not to find exact values for the changes in producer surplus that would result from eliminating Johne's disease (or from eliminating risk factors for Johne's disease) but to find confidence intervals that contained a large portion of the values that could reasonably be attributed to the changes in producer surplus. Piggot (2003) applied Monte Carlo integration to estimate a confidence interval for the change in producer surplus that resulted from generic advertising for meat. Losinger (2005) was the first to apply the GUM Workbench to analyse uncertainties in changes in producer and consumer surplus that were caused by decreased milk production associated with Johne's disease in dairy cows. The GUM Workbench allows one to derive a confidence interval for a derived quantity (such as a change in economic surplus) and simultaneously identifies major contributors to the uncertainty of the derived quantity. Thus considerable statistical rigor is added to the process. The primary contributor to the uncertainty of the change in surplus for Johne's-positive operations was the price elasticity of demand (Table 2). Finding a more precise estimate for the price elasticity of supply in milk would have had the greatest impact in improving the precision of the estimated economic impact of Johne's disease on Johne's-positive operations.

The present analysis expands previous work (Losinger, 2005, 2006) by showing how Johne's-positive and Johne's-negative operations are affected differently by the presence of Johne's disease in the US dairy population. Dairy producers who are able to maintain their status as Johne's-negative would stand to lose economic surplus, if Johne's disease were to be eliminated from other operations and if this were to result in an overall increase in the milk supply. Johne's-positive operations would, on the one hand, lose economic surplus if the price were to fall as they increased output, but would, on the other hand, tend to gain from having additional output to sell (if they did not have Johne's disease). Operators of Johne's-positive operations would have a clearer idea of what to do, if they knew that the potential gains were different from the potential losses. The data available for the present analysis did not yield a clear answer overall, as the potential impact did not differ significantly from zero for Johne's-positive operations. Operator's of Johne's-negative operations would clearly be hurt by the lower price, if Johne's disease had not reduced production on their competitors' farms. The epidemiological analysis demonstrated that eliminating the risk associated with having any cows that were not born on the operation would have had a substantial impact (Table 3). Gould (2004) reported that acquisition of infected cattle was the predominant manner in which Johne's disease entered a herd.

Beyond reduced milk production, other economic consequences of Johne's disease include increased veterinary expenses, premature culling, diminished slaughter value, and reduced value of calves, dairy-bull semen and breeding stock (Losinger, 2005). It should be mentioned as well that Johne's-negative operations may benefit from reduced fear of being infected with Johne's disease, if overall rates of Johne's-positivity were to decline. Each dairy producer's situation is unique and individual dairy producers need to weigh the costs of strategies recommended to reduce Johne's disease in their dairy cattle *v.* the anticipated benefits. In 1996, few US dairy farmers considered themselves to be 'fairly knowledgeable' about Johne's disease (US Department of Agriculture, 1997) and it is possible that shifts in the welfare effects via the milk market was not among their principal concerns. One possible lesson of this paper (for policy-makers) is that those farmers who may have done the most to keep

Johne's disease out of their farms have the least to gain from further progress, and that it may not be reasonable for the industry to strive towards eradication. Further investigations are warranted to determine whether policy intervention would be justified to benefit consumers, and to benefit the environment, animal welfare and human health, and to identify those who should take responsibility for the intervention.

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