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Economic impact of reduced milk production associated with Johne's disease on dairy operations in the USA

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Accurately assessing the economic impacts of diseases and other factors that affect milk production requires that the demand for milk be taken into account. Because demand for milk in the USA is relatively inelastic (i.e., consumers generally purchase a somewhat fixed amount over a given time frame, regardless of fluctuations in price), consumers tend to reap much of the benefit of enhanced production. An examination of the economic impacts of Johne's disease indicated that reduced milk production, associated with the determination of dairy operations as Johne's-positive, reduced consumer surplus by $770 million ± $690 million, and resulted in a total loss of $200 million ± $160 million to the US economy in 1996. Most of the economic surplus lost by consumers was transferred to producers, whose economic surplus increased by $570 million ± $550 million as a result of the reduced milk production associated with Johne's disease. Uncertainty analysis showed that the estimated reduction in milk production on Johne's-positive dairy operations accounted for most of the uncertainty in the economic-impact estimates. If Johne's disease had not been present on US dairy operations, then an additional 580 million ±460 million kg of milk would have been produced, but the price would have fallen by 1·1±1·0 cents/kg, and the total value of the milk would have decreased by $580 million ± $560 million.

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

Johne's disease (also called paratuberculosis) is a chronic inflammatory bowel disorder that affects ruminants and some non-ruminant animals (Gould, 2004). The aetiologic agent of Johne's disease is *Mycobacterium avium* subsp. *paratuberculosis*, which is shed from infected animals, and may contaminate meat and milk, as well as water run-off and the ground (including pasture) (Gould, 2004). *M. paratuberculosis* can persist in the environment (soil, pens, stream water, manure-slurry storage, etc.) for as long as 1 year (Sweeney, 1996).

In cattle and other ruminants, Johne's disease causes persistent scours, progressive weight loss and gradual death (Stehman, 1990). Johne's disease has been spreading through domestic livestock populations for many years, and is common in dairy herds throughout the world (Gould, 2004). Boelaert et al. (2000) reported that Johne's disease infected about 10% of dairy herds in Belgium. The National Animal Health Monitoring System (**NAHMS**), of the US Department of Agriculture (**USDA**), Animal and Plant Health Inspection Service (**APHIS**), found that 21·6% (SE = 1·7) of US dairy operations were Johne's-positive (USDA: APHIS, 1997). A ''Johne's-positive'' dairy operation was defined as a dairy operation where at least two dairy cows tested positive for *M. paratuberculosis* antibodies, or where one cow tested positive for *M. paratuberculosis* antibodies and at least 5% of culled cows exhibited symptoms consistent with Johne's disease during the previous 12 months (USDA:APHIS, 1997).

The principal means by which Johne's disease enters a herd is through acquisition of infected cattle (Gould, 2004). The UK Department for Environment, Food and Rural Affairs (2004) provided some practical guidance for dairy producers to control Johne's disease. Rossiter & Burhans (1996) emphasized two primary objectives for controlling Johne's disease in a herd: (1) prevent animals from ingesting *M. paratuberculosis* (in manure, milk, colostrum, etc.), and (2) decrease contamination of the environment and the prevalence of infection in the herd (to decrease exposure of uninfected animals).

Johne's disease may cause dairy producers to experience economic losses resulting from decreased milk

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production, increased veterinary and treatment costs, unrealized future income (based on age of culling), and reduced slaughter value (Hutchinson, 1996). Nordlund et al. (1996) found that subclinical paratuberculosis was associated with a 4% reduction in milk production. Infected dairy cows may produce 10% less milk than their potential yield during the lactation prior to the onset of signs of Johne's disease, and 25% less milk when clinical signs are apparent (Department for Environment, Food and Rural Affairs, 2004). In addition, cattle affected by Johne's disease may be more susceptible to other diseases, such as mastitis (Nordlund et al. 1996; Department for Environment, Food and Rural Affairs, 2004).

Relatively little academic work has been done on the economic importance of Johne's disease. Chiodini et al. (1984) estimated that Johne's disease cost the Wisconsin dairy industry at least $54 million annually. Braun et al. (1990) calculated that economic losses due to Johne's disease amounted to $9 million annually in Florida. Chiodini & Van Kruiningen (1986) computed an economic loss of $15 million due to Johne's disease in the New England states. Nationally, Stabel (1998) estimated that Johne's disease cost US agriculture approximately $1·5 billion per year. Using the USDA:APHIS (1997) results, Ott et al. (1999) determined that Johne's disease cost the US dairy industry between $200 million and $250 million annually. One problem with the previous analyses is that they did not consider the impact of Johne's disease on consumers and the consequent price effects. Previous researchers ignored the elasticities of supply and demand for milk, thus suggesting that producers would be the only beneficiary of controlling Johne's disease. As Fig. 1 suggests, an increased milk supply (which would result from eliminating Johne's disease in dairy cattle) would cause the market price of milk to fall, which would tend to benefit consumers. In addition, previous researchers provided no quantitative statement of the uncertainty in their estimates, thus making it impossible to compare or to assess the validity of their results.

The purpose of this analysis was to estimate changes in consumer and producer surplus, and the total loss to the US economy, caused by reduced milk production associated with Johne's-positivity on US dairy operations. Uncertainties in these estimates were evaluated in accordance with the *Guide to the Expression of Uncertainty in Measurement* (**GUM**) (International Organization for Standardization, 1995).

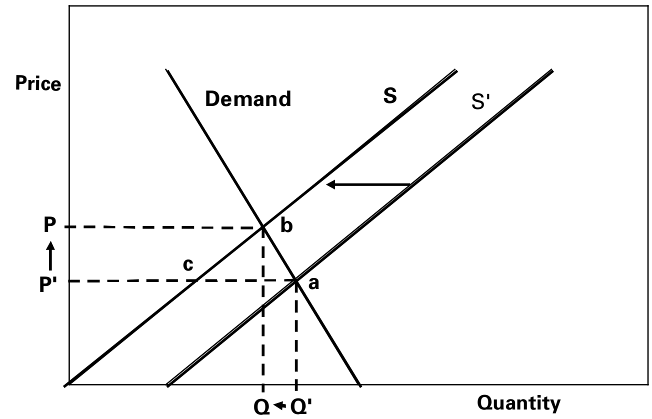

Fig. 1. Demand and supply for milk. When supply is determined by S′, the equilibrium market price is P′ and the equilibrium market supply is Q′. Consumer Surplus is the area below the demand curve and above the line-segment P′-a. Producer Surplus is the area above the supply curve (S′) and below the line-segment P′-a. When supply falls from S′ to S (due to Johne's-positivity on dairy operations), the equilibrium price rises from P′ to P, while quantity falls from Q′ to Q. Consumer Surplus decreases by the amount represented by the quadrilateral whose corners are P′, P, b and a. A portion of the lost Consumer Surplus (P′, P, b, c) is transferred to producers as a gain. Producer Surplus increases by this gain, but decreases by the area between the two supply curves and below the line segment c-a. The total loss to the economy is the area below the demand curve and between the two supply curves.

Materials and Methods

A welfare analysis was conducted to measure changes in producer and consumer surplus based on the assumption of linear demand and supply curves and a parallel supply shift (Fig. 1). The procedures followed were similar to those developed by Losinger (2005) to evaluate the economic impacts of *Actinobacillus pleuropneumonia* in pigs. Consumer surplus is the difference between what consumers are willing to pay for a product, and the amount that consumers actually pay. Producer surplus is the difference between the amount of money that producers receive for a commodity, and the amount that they would be willing to accept to supply a given quantity. Table 1 summarizes the inputs used in this analysis, and Table 2 provides the model equations. The reduction in milk production (associated with operations being Johne's-positive) was estimated by multiplying the estimated milk-production decline by the number of dairy cows and the percent of Johne's-positive dairy operations (divided by 100). The National Agricultural Statistics Service (**NASS**) of the USDA indicated that the population of dairy cows in the US was 9 372 000, and that these dairy cows produced 70 003 million kg of milk at a mean price of $0·328 per kg (USDA: NASS, 1999). The NASS provided relative uncertainties of 0·9% for milk production, and 1·3% for the population of dairy cows during 1996 (USDA: NASS, 1996). Since the NASS did not provide information on the uncertainty of the estimate of the price of milk during 1996, a relative uncertainty of 1·3% was used as a conservative estimate. When an uncertainty for an input is unknown, the GUM (International Organization for Standardization, 1995) permits analysts to use an educated guess, and this was the larger of the uncertainties

Table 1. Input quantities used in the computation of economic impacts of Johne's-positivity on US dairy operations, their sources and uncertainties

Input quantity	Distribution	Value	Standard Uncertainty	Degrees of Freedom	Source
Kg/cow milk-production decline on Johne's-positive dairy operations	Normal	288	111	50†	Ott et al. 1999
Percent of dairy operations that were Johne's-positive in 1996	Normal	21·6	1·7	50	USDA, APHIS, 1997
Number of dairy cows	Normal	9 327 000	122 000‡	50	USDA, NASS, 1999
Kg milk produced in 1996	Normal	70·003 billion	630 million‡	50	USDA, NASS, 1999
Mean price of milk in 1996 ($/kg)	Normal	0·328	0·004‡	50	USDA, NASS, 1999
Price elasticity of demand for milk	t	−0·25	−0·05	14	Meilke et al. 1996
Price elasticity of supply for milk	Rectangular§	0·56995	0·18855	∞	Adelaja, 1991

† For normally distributed Type B data, the GUM Workbench assigns a default value of 50 to the degrees of freedom (Metrodata GmBH, 1999)
‡ Uncertainties are based on USDA, NASS, 1996
§ For the rectangular distribution, the value is the midpoint between the upper and lower limits, and the half-width of this limit is listed in the uncertainty column. Degrees of freedom are infinite by definition (Metrodata GmBH, 1999)

Table 2. Model equations used in the analysis

Model Equations:

$\Delta Q = \text{Johneseffect} * (\text{pcposherds}/100) * \text{cows}$
$Q' = Q + \Delta Q$
$\Delta P = (\Delta Q * P)/(e_D * Q)$
$P' = P + \Delta P$
$Q_c = Q' - e_s * \Delta P * Q/P$
$CS_{trans} = |\Delta P * Q_c| + |0{\cdot}5 * \Delta P * (Q - Q_c)|$
$CS_{lost} = 0{\cdot}5 * (Q' - Q_c) * AP$
$\Delta CS = CS_{trans} + CS_{lost}$
$PS_{lost} = \Delta Q * P'$
$\Delta PS = CS_{trans} - PS_{lost}$
TOTAL ECONOMIC LOSS $= CS_{lost} + PS_{lost}$

ΔQ = Change in total milk production due to Johne's disease (kg)
Johneseffect = Reduced milk production on Johne's-positive dairy operations (kg/cow)
pcposherds = Percent of dairy operations that were Johne's-positive
ΔQ = Change in total milk production due to Johne's disease (kg)
cows = Number of dairy cows (*n*)
Q = Quantity of milk produced with Johne's disease (kg)
Q' = Quantity of milk produced without Johne's disease (kg)
ΔP = Change in price of milk ($/kg)
P = Price of milk with Johne's disease ($/kg)
P' = Price of milk without Johne's disease ($/kg)
e_D = Price elasticity of demand for milk
e_S = Price elasticity of supply for milk
Q_c = Quantity of milk produced at Point C (kg)
CS_{trans} = Consumer surplus transferred to producers ($)
CS_{lost} = Consumer surplus lost ($)
ΔCS = Change in consumer surplus ($)
PS_{lost} = Lost producer surplus ($)
ΔPS = Change in producer surplus ($)

given for milk production and for the number of dairy cows.

The price elasticity of demand (Nicholson, 1995) measures the extent to which changes in the price of a good relate to changes in the quantity purchased, and is defined as the relative change in the quantity purchased divided by the relative change in the price. Meilke et al. (1996) provided a list of 15 different researchers' estimates of the price elasticity of demand for fluid milk in North America. The estimates ranged from −0·04 to −0·73, with a mean of −0·25 (SD = 0·20, SE = 0·05) (Meilke et al. 1996).

The price elasticity of supply measures the extent to which relative changes in the price of a good are associated with relative changes in the quantity supplied (Nicholson, 1995). Adelaja (1991) provided price elasticities of milk supply of 0·6785, 0·3815, and 0·7585 for small, medium and large farm size categories, respectively. For the price elasticity of supply, this analysis assumed a rectangular distribution, with 0·3815 and 0·7585 set as the lower and upper limits. Kessel (2003) recommends using the rectangular distribution when a researcher considers that all values between two limits have the same likelihood, and where preferring specific values without having more knowledge is impossible (Kessel, 2003).

The GUM Workbench (Metrodata GmbH, 1999) was used to generate the estimates and uncertainties for the changes in consumer and producer surplus, and total economic loss caused by reduced milk production attributed to Johne's disease in dairy cows. Losinger (2004) furnished a review of the GUM Workbench. The GUM Workbench is specialized software that computes estimates, combined standard uncertainties, and coverage factors following the recommendations of the International Organization for Standardization (1995). The GUM Workbench calculates sensitivity coefficients by applying numerical partial differentiation, uses Taylor-series approximation to compute combined standard uncertainties, and Satterthwaite's approximation to compute combined degrees of freedom (Metrodata GmbH, 1999).

Table 3. Uncertainty budget for the change in consumer surplus as a result of reduced milk production attributed to Johne's-positive US dairy operations

Input quantity	Sensitivity coefficient†	Uncertainty contribution‡	Index§
Reduced milk production on Johne's-positive dairy operations (kg/cow)	$-2{\cdot}7\times10^{6}$	$-3{\cdot}0\times10^{8}$	75·1%
Percent of dairy operations that were Johne's-positive	$-3{\cdot}6\times10^{7}$	$-6{\cdot}1\times10^{7}$	3·1%
Number of dairy cows	$-8{\cdot}2\times10^{1}$	$-1{\cdot}0\times10^{7}$	0·0%
Kg milk produced in 1996	$-4{\cdot}6\times10^{-5}$	$-2{\cdot}9\times10^{4}$	0·0%
Mean price of milk in 1996 ($/kg)	$-2{\cdot}3\times10^{9}$	$-5{\cdot}0\times10^{6}$	0·0%
Price elasticity of demand for milk	$-3{\cdot}2\times10^{9}$	$-1{\cdot}6\times10^{8}$	21·7%

The final estimate for the change in consumer surplus is $-\$7{\cdot}68\times10^{8}$, with a standard uncertainty of $\$3{\cdot}44\times10^{8}$ and 68 degrees of freedom. The resulting value and expanded uncertainty, with a coverage factor of two, is then:

−$770 000 000 ± $690 000 000

† $\partial y/\partial x_i$: 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 4. Uncertainty budget for the change in producer surplus as a result of reduced milk production attributed Johne's-positive US dairy operations

Input quantity	Sensitivity coefficient	Uncertainty contribution	Index
Reduced milk production on Johne's-positive dairy operations (kg/cow)	$2{\cdot}0\times10^{6}$	$2{\cdot}2\times10^{8}$	64·4%
Percent of dairy operations that were Johne's-positive	$2{\cdot}6\times10^{7}$	$4{\cdot}5\times10^{7}$	2·7%
Number of dairy cows	$6{\cdot}1\times10^{1}$	$7{\cdot}4\times10^{6}$	0·0%
Kg milk produced in 1996	$1{\cdot}3\times10^{-5}$	$8{\cdot}0\times10^{3}$	0·0%
Mean price of milk in 1996 ($/kg)	$1{\cdot}7\times10^{9}$	$3{\cdot}8\times10^{6}$	0·0%
Price elasticity of demand for milk	$3{\cdot}2\times10^{9}$	$1{\cdot}6\times10^{8}$	32·8%
Price elasticity of supply for milk	$-1{\cdot}3\times10^{7}$	$-1{\cdot}4\times10^{6}$	0·0%

The final estimate for the change in producer surplus is an increase of $\$5{\cdot}73\times10^{8}$, with a standard uncertainty of $\$2{\cdot}75\times10^{8}$ and 62 degrees of freedom. The resulting value and expanded uncertainty, with a coverage factor of two, is then an increase of:

$570 000 000 ± $275 000 000

Results

The total value of the milk produced in the USA in 1996 was the quantity of milk produced times the price, or $23·0 billion (standard uncertainty = $0·3 billion). Results from the model equations and data entered into the GUM Workbench indicated that Johne's disease caused milk production to fall by 583 million kg (standard uncertainty = 230 million kg). If Johne's disease had not been present on US dairy operations, then milk production would have risen to 70·6 billion kg (standard uncertainty = 0·7 billion kg), and the market price would have declined to 31·7 cents/kg (standard uncertainty = 0·5 cents/kg). The value of milk production would have fallen to $22·4 billion (standard uncertainty = $0·4 billion). The decline in the value of milk production of $580 million (standard uncertainty = $280 million, df = 62) is significantly greater than zero ($P < 0{\cdot}05$).

The uncertainty budgets, estimates, and expanded uncertainties for the change in consumer surplus, change in producer surplus, and total economic loss due to reduced milk production attributed to Johne's-positivity on US dairy operations appear in Tables 3–5. The estimate of reduced milk production on Johne's-positive dairy operations contributed towards most of the uncertainty in the estimates. The price elasticity of demand for milk accounted for 21·7% (Table 3) and 32·8% (Table 4) of the uncertainty in the change in producer and consumer surplus respectively.

Most ($758 million, standard uncertainty = $335 million, df = 68) of the reduction in consumer surplus (due to reduced milk production associated with Johne's-positivity on dairy operations) was transferred to producers as a gain. For producers, this transfer offset the $185 million (standard uncertainty = $70 million, df = 54) of lost producer surplus (that accounted for most of the $200 million loss to

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Table 5. Uncertainty budget for the total economic loss resulting from reduced milk production attributed to Johne's-positive US dairy operations

Input quantity	Sensitivity coefficient	Uncertainty contribution	Index
Reduced milk production on Johne's-positive dairy operations (kg/cow)	$6{\cdot}9\times10^{5}$	$7{\cdot}7\times10^{6}$	95·8%
Percent of dairy operations that were Johne's-positive	$9{\cdot}2\times10^{6}$	$1{\cdot}6\times10^{7}$	4·0%
Number of dairy cows	$2{\cdot}1\times10^{1}$	$2{\cdot}6\times10^{6}$	0·1%
Kg milk produced in 1996	$-5{\cdot}8\times10^{-5}$	$-3{\cdot}7\times10^{4}$	0·0%
Mean price of milk in 1996 ($/kg)	$6{\cdot}0\times10^{8}$	$1{\cdot}3\times10^{6}$	0·0%
Price elasticity of demand for milk	$5{\cdot}0\times10^{7}$	$2{\cdot}5\times10^{6}$	0·1%
Price elasticity of supply for milk	$1{\cdot}3\times10^{7}$	$1{\cdot}4\times10^{6}$	0·0%

The final estimate for the total economic loss resulting from reduced milk production attributed to Johne's-positivity on US dairy operations is $\$1{\cdot}95\times10^{8}$, with a standard uncertainty of $\$7{\cdot}87\times10^{7}$ and 54 degrees of freedom. The resulting value and expanded uncertainty, with a coverage factor of two, is then:

$200 000 000 ± $160 000 000

the total US economy), so that the total impact on producers was an increased surplus of $573 million (Table 4). Lost consumer surplus that was not transferred to producers amounted to $10 million (standard uncertainty=$9 million, df=71). The total loss to the US economy was the sum of the lost producer surplus and the lost consumer surplus that was not transferred to producers (Table 5).

Discussion

Information on animal health, productivity and economics is crucial to livestock producers and to those who are employed in serving their needs. Surveys of producers are an important source of data that form the basis of epidemiological studies that evaluate associations between an observed condition and various aspects of the animals' management and environment (Martin et al. 1987). Economic information that producers provide in surveys can be used to determine optimal rates of input application, and to study changes in and relationships between various components of an agricultural sector (Debertin, 1986). NAHMS pilot studies demonstrated that, by means of surveys of livestock producers, animal health officials could collect useful information on animal diseases (King, 1990).

The National Dairy Heifer Evaluation Project (**NDHEP**), which was the first US national study of the health of dairy cattle, provided much knowledge and information never previously available at the national level (USDA:APHIS, 1993). Data from the NDHEP formed the basis of numerous studies that examined relationships between diseases or productivity and various management and environmental factors. For example, Losinger and Heinrichs (1997a) used NDHEP data to study factors associated with achieving a target age ($\leqslant$25 months) and body weight (>544 kg) at first calving for Holsteins. NDHEP data served as a foundation for identifying potential risk factors for *Cryptosporidium* infection in dairy calves (Garber et al. 1994), and for a risk-factor analysis of mortality among pre-weaned dairy heifers (Losinger & Heinrichs, 1997b). In addition, NDHEP data were used to pinpoint factors associated with *Salmonella* shedding by dairy heifers (Losinger et al. 1995).

In subsequent NAHMS national surveys, streamlining of methods resulted in the dissemination of more valuable and timely information (Losinger et al. 1997). Surveys were better targeted to specific objectives, and questionnaires were more concise and less burdensome to respondents (Losinger et al. 1997). Using well-defined study objectives to create descriptive-report table shells, and using the table shells, in turn, as the basis for developing survey questions, represented a notable innovation that enhanced the value and effectiveness of the national surveys (Losinger et al. 1997). In addition, pretests in each state permitted the survey coordinators to become more familiar with the survey instruments (so that the coordinators could more effectively train field staff), and afforded improvements to the questionnaires (Losinger et al. 1997).

The Dairy '96 Study was the second NAHMS national study of the US dairy industry (USDA:APHIS, 1996a). The first Dairy '96 descriptive report, which summarized data collected by NASS enumerators during January 1996, was published before the veterinary medical officers and animal health technicians had finished the second phase of on-farm data collection (USDA:APHIS, 1996a). A second report documented industry changes between the NDHEP and the Dairy '96 Study (USDA:APHIS, 1996b). A third descriptive report provided more detailed information on the health and health management of dairy cattle (USDA:APHIS, 1996c).

One of the main objectives of the NAHMS Dairy '96 Study was to estimate the operation-level prevalence of Johne's disease on US dairy operations, and to estimate economic losses caused by Johne's disease on dairy operations. A rather extensive interpretive report conveyed a lot of information (from the NAHMS Dairy '96 Study) about the prevalence of Johne's disease, risk factors for Johne's disease, and a statistical model which demonstrated that Johne's-positivity on an operation was associated with reduced milk production (USDA:APHIS, 1997). The statistical model was presented again by Ott et al. (1999). Other economic-indicator variables (calves born, net cow replacement cost, value of cows sold to other producers, cull cow revenue, and replacement cows) did not differ significantly between Johne's-positive and Johne's-negative operations (USDA:APHIS, 1997). Therefore, further analyses of these variables from the NAHMS Dairy '96 Study are unwarranted. In terms of producer knowledge of Johne's disease, 37·1% of respondents said that they knew some basics, and 17·7% considered themselves to be fairly knowledgeable (USDA:APHIS, 1997).

The USDA:APHIS (1997), and Ott et al. (1999), described some of the limitations in the determination of whether a dairy operation was Johne's-positive. No information was available on the total number of dairy cows that were on Johne's-positive operations. Multiplying the reduction in milk production (associated with operations being Johne's-positive) by the proportion of Johne's-positive dairy operations and the number of dairy cows, carries the implicit assumption that the proportion of Johne's-positive operations was independent of operation size. Larger operations were more likely to be Johne's-positive than smaller operations (USDA:APHIS, 1997). However, the percent of cows sero-positive for *M. paratuberculosis* did not vary significantly by operation size (USDA:APHIS, 1997). The USDA:APHIS (1997) gave one value that expressed the reduced milk production (kg/cow) associated with a dairy operation being Johne's-positive. The value derived from a statistical model which included operation size as an explanatory variable USDA:APHIS (1997), and would thus be applicable to all herd sizes. Uncertainty in the reduced milk production associated with Johne's-positivity accounted for most of the uncertainty in the estimates of the economic impacts of Johne's disease (Tables 3–5). One of the beneficial features of following the GUM (International Organization for Standardization, 1995) is the transparency and openness-to-scrutiny of the methods. Anyone who has a different value for an input quantity, or who wishes to modify the model equations, may easily take what I have done and improve upon my estimates. The NAHMS Dairy '96 Study provided the only estimate of milk-production effects due to Johne's disease at the national level in the USA. At present, no better estimate seems to exist.

Data that derive from sample surveys are almost invariably affected by non-sampling error (Sukhatme & Sukhatme, 1970). In a test-retest of a selection of questions from the NDHEP, Erb et al. (1996) found an 8·5% discrepancy rate. Ott et al. (1999) reported that, owing to poor questionnaire design, a lot of the economics data that were collected during the NAHMS Dairy '96 Study—for the purpose of studying the economics of Johne's disease—turned out not to be useful for analysis. However, milk production is regarded as a very important measure of the performance of a dairy herd. A total of 2 542 US dairy operations participated in the NAHMS Dairy '96 Study, and 46·8% of respondents provided a milk-production figure that was based on computerized records (USDA:APHIS, 1996a). Thus the milk production data were probably among the most reliable data collected during the NAHMS Dairy '96 Study. Losinger and Heinrichs (1996) used data from the NDHEP to study the relationships between dairy operation management practices and herd milk production.

Consumers stand to benefit more than producers from the increased milk production that would result from eliminating Johne's disease in dairy cows, given the transfer in economic surplus from producers to consumers. Besides primary producers and consumers, other stakeholders (e.g., feed suppliers, processors, wholesalers, retailers) are involved in production and distribution. For a fuller perspective on US society, the impacts of Johne's disease on these stakeholders should be addressed as well. The present analysis was limited to impacts on primary producers and consumers. Demand for milk tends to be fairly inelastic, meaning that consumers generally purchase a relatively fixed amount of milk over a given period of time, regardless of ordinary price fluctuations. For many US retailers, milk serves as a "loss leader," meaning that milk is sold at or below cost for the purpose of attracting customers (Maynard, 2000). Therefore, a lot of the savings of associated with an increased milk supply would probably be passed directly to consumers. However, producers of specialty ice creams, cheeses, etc. might receive higher profits if the supply of milk increased. Gould (2004) discussed various studies which suggested a possible link between *M. paratuberculosis* and Crohn's disease in humans. Millar et al. (1996), Gao et al. (2002), and Grant et al. (2000) found *M. paratuberculosis* in pasteurized milk. Donaghy et al. (2003) discovered that *M. paratuberculosis* survived a Cheddar cheesemaking process. If *M. paratuberculosis* were proven to cause Crohn's disease, then the benefits to consumers of eliminating Johne's disease from dairy cattle would be much higher.

In analysing the economics of bovine diseases (and other factors that affect milk production), the present study demonstrates that an understanding of the demand for milk is important. Determining a cost per cow, and then, for example, multiplying the result by the number of dairy cows in the country (as Ott et al. 1999, did), can lead to the erroneous conclusion that only dairy producers would benefit from the increased milk production associated with eliminating Johne's disease. Over time, increasing milk production per cow has been accompanied by a decline in the number of dairy operations and an augmentation in the number of dairy cows per operation (USDA:APHIS, 1996b).

The present analysis considers only two static situations: with and without Johne's disease. Johne's disease probably cannot be eradicated completely—hence, the degree of losses which could be avoided realistically is probably lower than the comparison of these two static situations would suggest. Economists frequently use the assumption that a relatively small change in the unit cost of production can be modelled as a parallel shift of the supply curve, and then measure economic impacts based on differences between the two static situations. For example, Losinger (2005) used procedures similar to those described here to measure the economic impacts of reduced pork production associated with the diagnosis of *Actinobacillus pleuropneumoniae* on US grower/finisher swine operations. Forsythe & Corso (1994) assumed a parallel shift in the supply curve when they measured the change in producer surplus resulting from the National Pseudorabies Eradication Programme. Kennedy et al. (2000) presumed a parallel shift in the supply curve, and two static situations, when they computed changes in producer and consumer surplus that resulted from Hazard Analysis and Critical Control Points.

The drop in producer surplus attributed to Johne's-positivity does not imply that dairy producers should be indifferent towards Johne's disease on their operations. Johne's-positive operations did have lower milk production per cow than Johne's-negative operations, and may be less profitable (USDA:APHIS, 1997). More studies are necessary to understand the economic consequences of the impacts of Johne's disease beyond reduced milk production (such as increased veterinary expenses, premature culling, diminished slaughter value, and reduced value of calves, dairy-bull semen and breeding stock). Given the substantial costs associated with national studies of US dairy producers, if the USDA intends to launch another survey to study the economics of Johne's disease, then the USDA ought to consider investing some effort in designing improved questions targeted to the specific economic implications (beyond reduced milk production) of Johne's disease in dairy cattle. Individual dairy producers need to weigh the costs of strategies recommended to reduce Johne's disease in their cattle *v.* the anticipated benefits. Many of the procedures commonly proposed for controlling Johne's disease on dairy operations concentrate on improved cleanliness and biosecurity (Department for Environment, Food and Rural Affairs, 2004). These same procedures would tend to contribute to the overall health of the herd, and, as a bonus, protect animals from other pathogens, such as *Salmonella* (Losinger et al. 1995) and *Cryptosporidium* (Garber et al. 1994), that may be spread in unsanitary environments.

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