REDUCED REVENUES ASSOCIATED WITH JOHNE'S DISEASE IN U.S. DAIRY HERDS

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ABSTRACT

Johne's disease, or paratuberculosis, is a chronic, infectious, wasting disease that affects dairy cattle. Estimation of its economic impact on U.S. diary operations was part of the USDA National Animal Health Monitoring System's (NAHMS) 1996 national dairy study. Herds that tested positive for the disease and reported cull cows showing clinical signs experienced reduced milk production of over 450 kg per cow, culled more cows but had lower cull cow revenues, and had greater mortality than herds that tested negative and showed no clinical signs of Johne's disease. These production impacts resulted in test positive clinically positive herds experiencing an economic loss of $157-$166 per cow inventory. Nationally, these losses translate to a $36-$38 per cow cost which is at least a third more than previous estimates.

INTRODUCTION

Johne's disease, or paratuberculosis, is a chronic infectious disease of domestic and exotic ruminants, including dairy and beef cattle, sheep, goats, cervids, and camelids. The disease, caused by *Mycobacterium paratuberculosis*, occurs worldwide. *M. paratuberculosis* is a slow-growing bacteria that causes thickening of the intestinal wall of cattle with reduced absorptive capability. Johne's disease in cattle and other species is characterized by chronic, granulomatous degenerative enteritis that causes intermittent but persistent diarrhea, progressive weight loss, and eventually death. The disease is untreatable and slowly progressive.

United States Department of Agriculture's (USDA) National Animal Health Monitoring System (NAHMS) conducts national surveys of various livestock commodities. These surveys collect animal health information on a national basis, as well as the use of livestock management practices . One objective of the 1996 dairy study was to measure the economic impact of Johne's disease on U.S. dairy producers. This paper reports the findings of the economic analysis.

METHODOLOGY

Dairy Survey

In January 1996 a stratified random sample of dairy producers in 20 selected states that represented 83 percent of U.S. dairy cows was surveyed by USDA's National Agricultural Statistics Service (NASS, Figure 1). USDA-NASS enumerators collected dairy health and management information from 2,542 producers. Participating producers with at least 30 milk cows were asked to participate in a second phase of the study. During the second phase, USDA or state veterinary medical officers or animal health technicians administered another questionnaire and collected blood samples from a random sample of milk cows on participant operations. This second questionnaire assessed producer familiarity with and recognition of Johne's disease and use of management practices associated with the disease. A total of 1,219 dairy producers responded to the questionnaire with 1,008 agreeing to blood testing.

The blood samples collected were sent to USDA's National Veterinary Services Laboratories for *M. paratuberculosis* testing using a commercially available enzyme-linked immunosorbant assay (ELISA, IDEXX Laboratories, Westbrook, ME). The IDEXX ELISA test has a reported test sensitivity of 45-50 percent and test specificity of 99.0-99.7 percent (Collins and Sockett, 1993 and Sweeny et al., 1995). In this study, we assumed all herds identified as being positive were indeed positive with Johne's disease and likewise all herds identified as being negative were truly negative. Possible misclassification of Johne's disease herds is beyond the scope of this paper.

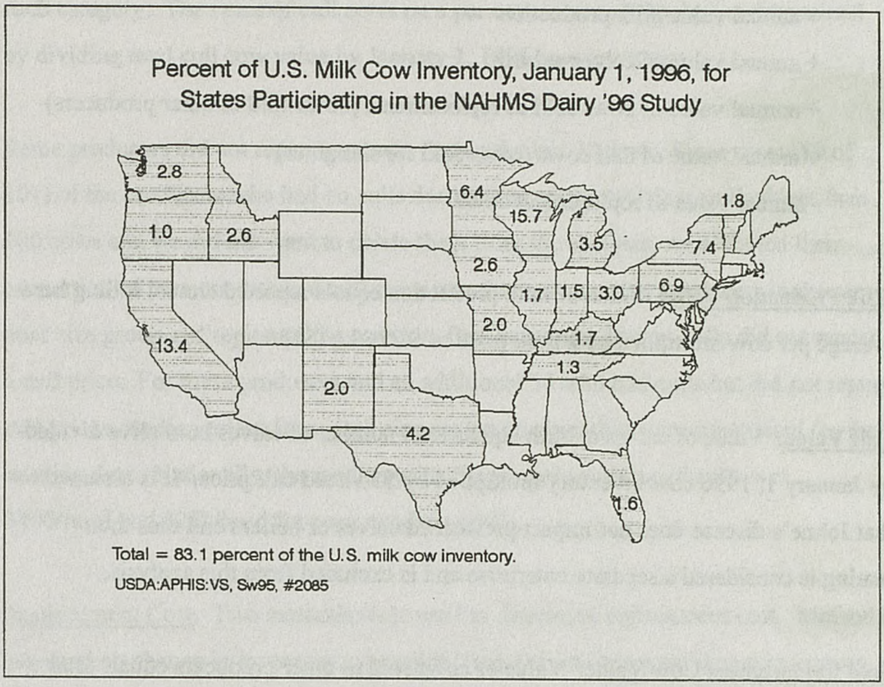

Figure 1.

Definitions:

Adjusted Value of Production (Revenue). Reduced value of production from Johne's disease included losses such as reduced milk production and decreased weight and salvage value for clinically affected cattle at cull market. Also included was value of calves born alive as herds with Johne's disease would be expected to market a higher proportion of pregnant cull cows than herds without the disease. On the cost side, expected higher culling and mortality rates and the resulting increase in number of cow replacements would increase costs. Data on other costs such as feed, labor, or veterinary expenses were not collected. Thus we could not measure a change in net farm income so the term adjusted value of production was used as it includes both revenue and some cost changes. Adjusted value of production is an annual value measured on a per cow basis and equals:

+ annual value milk production

+ annual value of calves at birth

+ annual value of cows sold as replacements (cows sold to other producers)

+ annual value of cull cows (cows sold for slaughter)

- annual value of replacement cows.

Milk Production Value. Value of milk production equals reported annual rolling herd average per cow multiplied by a milk price of $.286/kg ($13/cwt).

Calf Value. Value of calves at birth equals total number of calves born alive divided by January 1, 1996 cow inventory multiplied by $50/head calf price. It is assumed that Johne's disease does not impact preweaned calves or heifers and thus their rearing is considered a separate enterprise and is excluded from this analysis.

Sold Replacement Cow Value. Value of cows sold to other producers equals total number of cows sold to other producers divided by January 1, 1996 cow inventory multiplied by a cow price of $1100/head (based on prices received for replacement cows as reported by USDA- NASS).

Cull Cow Value. Value of cull cows has two components: culls in normal body condition and culls in poor body condition. Producers were asked how many cull cows in the previous 90 days were in normal body condition and in poor body condition (low cutter or canner grade) and the per head price received for each category. The proportion of cows in each category was then determined by dividing the number of head in each category by the total number of cows culled during the last 90 days. Proportions for normal and poor culls were then multiplied by the number of cows culled during the previous year to obtain an estimate of annual number of normal and poor cull cows. Total value then was determined by multiplying the number of cows in each category by the price received per head for each category. The value of cull cows on a per cow inventory basis was determined by dividing total cull cow value by January 1, 1996 cow inventory.

Some producers did not report any culls during the last 90 days. Since most (89 of 101) of the producers who had no culls during the previous 90 days milked less than 100 cows and we did not want to delete them from the analysis, we assumed their proportion of poor conditioned cull cows was the same as other producers in the same herd size group and region of the country. Producers who had no culls did not report a cull price. For these producers and an additional 55 who had culls but did not report cull prices, median prices from each size-region combination were substituted for the missing data. Nationally, the median price for normal conditioned culls was $400/head and $250/head for poor condition culls.

Replacement Cost. Two methods were used to determine replacement cost. Method I assumed no change in inventory as we didn't ask for previous year's cow inventory. With method I, total number of cows needed for replacement equaled the number that were sold plus those that died.

Method II allows for changes in cow inventory. It was assumed that the number of raised heifers that entered the milking string equaled the number of first calf heifers at time of inventory minus bred heifers that were brought onto the dairy operation the previous year. Cow replacement then equaled the number of farm raised heifers plus the number of bred heifers, milking cows, and dry cows that were brought onto the operation during the previous year. Change in inventory equals total replacements minus total removals.

The cost of a replacement cow was assumed to be $1100/cow (USDA-NASS) and when multiplied by the number of replacement cows gives total herd replacement cost. Total herd replacement cost divided by January 1, 1996 inventory gives replacement cost on a per cow inventory basis.

Modeling Economic Impact

Both *M. paratuberculosis* serum ELISA results and clinical signs were used to classify herds. Each dairy producer was asked how many culled cows exhibited the following clinical signs during the last 12 months: chronic diarrhea and weight loss that didn't respond to treatment despite a normal appetite. If the producer answered that one or more cull cows showed these clinical signs then the herd was classified as being positive for Johne's clinical signs. The four possible categories were test negative clinically negative, test positive clinically negative, test negative clinically positive, and test positive clinically positive. The test negative clinically negative herds were considered the reference group for analysis. Of the 1,008 herds with ELISA test results, 980 had complete data for analysis assuming constant cow inventory (model I) and 974 herds had complete data for model II (flexible cow inventory).

Herd size and region were included as covariates. Herd size was split into four categories: fewer than 100 cows, 100-199 cows, 200-499 cows, and 500 or more cows. The smallest herd size was the reference group. (For percentages of herds in each size group and percentages of other covariates see Table 1). Herds were grouped into four regions (midwest, west, southeast, and northeast) with the midwest being the reference level for analysis.

Other variables were added to the model because of their expected influence on one or more of the components of adjusted production value. Use of Dairy Herd Improvement Association (DHIA) records was included as a proxy variable to measure management ability of the producer. It was expected that operations using DHIA records would produce more milk per cow and have a higher adjusted value of production.

Table 1. Herd Characteristics of Variables Used in Johne's Disease Regression Models[a b]

	Model I[d]	Model II
Number of Herds		
actual	980	974
represented[c]	76,015	75,522
Number of cows represented	7,961,034	7,876,258
Herd Size		
less than 100 cows	77.3%	77.3%
100 - 199 cows	15.2%	15.2%
200 - 499 cows	4.9%	4.9%
500 or more cows	2.6%	2.6%
Herd Location		
midwest	60.9%	60.7%
west	8.3%	8.3%
southeast	4.5%	4.5%
northeast	26.3%	26.5%
Use DHIA Records (yes)	51.6%	51.9%
Graze Pastures (yes)	53.6%	53.6%
Of those that pasture, pastures supply 90% or more of roughages (yes)	36.1%	36.3%
BST (yes)	13.5%	13.6%
BST (% of cows on herds that use BST)	49.3%	49.3%
First Calf Heifers		
25% or less	36.5%	36.1%
26% - 33%	24.4%	24.5%
34% or more	39.1%	39.4%
Bulk Tank Somatic Cell Count		
199,999 or less	28.9%	28.9%
200,000 - 399,999	54.1%	54.0%
400,000 or more	17.0%	17.1%
Percent Holstein		
0 - 49	6.6%	6.6%
50 - 89	6.5%	6.5%
90 - 99	13.1%	13.2%
100	73.9%	73.7%
90% or more cows registered (yes)	12.5%	12.5%

a. Some categories may not total to 100% due to rounding.
b. Percentages based on represented herds.
c. Weighted number of herds based on sampling procedures.
d. Model I - herd size remains constant. Model II - herd size allowed to change.

Rotational pasture grazing has gained in popularity as a method for controlling per hundred weight production cost even though milk production per cow may drop. Producers were asked if they pastured their cows during the summer months and if so, whether or not the pasture during this time period provided 90 percent or more of the cow's roughage requirement. Milk production and adjusted production value were expected to be less for those herds that were pastured, especially if the pasture provided 90 percent or more of the cow's roughage requirement. No use of pasture was the reference category.

Bovine Somatotropin (bST) use can increase milk production per cow (Thomas, et al., 1991). The greater the percentage of cows receiving bST, the greater the expected increase in average milk production per cow. Initial analysis focusing on milk yield and bST use showed that the relationship between milk production per cow and percent bST use was nonlinear. This nonlinear relationship was modeled by transforming percent bST use into square root of percent bST use.

Cows in their first lactation generally produce less milk than in later lactations. Thus, as the percentage of first calf heifers increases, expected average herd milk production per cow would decline. On the other hand, if the producer is selecting top sires, first calf heifers should have greater milk production potential than the cows they replaced. Three levels of first calf heifers were used: 25 percent or less, 26 to 33 percent, and greater than 33 percent. The 25 percent or less level was the reference category.

High somatic cell count is associated with a decrease in milk production (Bartlett, et al., 1990 and Miller et al., 1993). Bulk tank somatic cell count was divided into three levels: less than 200,000 cells/ml, 200,000 to 399,999 cells/ml and 400,000 or more cells/ml. The less than 200,000 cells/ml was the reference level.

Holsteins generally produce more milk than other breeds of dairy cows. Four levels of percent Holsteins in the herd were included: 100 percent, 90 to 99 percent, 50 to 89 percent, and 0 to 49 percent. Hundred percent Holstein was the reference level.

Herds with 90 percent or more registered cows were expected to sell more cows to other producers than herds with less than 90 percent registered cows.

When cow inventory is flexible an additional covariate is added, percent change in cow inventory. By definition, cow replacement costs will vary with changes in cow inventory.

MODEL RESULTS

Johne's disease can greatly reduce value of production in dairy herds, especially when clinical signs are evident. For herds tested for antibodies to *M. paratuberculosis* as part of the NAHMS Dairy '96 study, test positive clinically negative herds had $28 or $29, for models I and II respectively, per cow less adjusted annual value than test negative clinically negative herds, although this difference was not statistically significant (Table 2). (Hereinafter results refer to the two models with model I presented first.) Tested negative clinically positive herds had a $91 or $94 per cow reduction in adjusted annual value. Tested positive clinically positive herds had adjusted annual values $166 or $157 per cow less than test negative clinically negative herds.

The greatest contributor to the decline in adjusted value was lost milk production. Almost 80 percent of the decline in adjusted value could be attributed to reduced milk production. Herds that tested positive and had clinical signs had 458 kg or 456 kg. ($131) less milk production per cow than herds that tested negative and showed no clinical signs (Tables 2 and 3).

Table 2. Impact of Johne's Disease on Adjusted Value of Dairy Production and Its Individual Components.

Parameter	----------------Johne's Disease Status--------------		
	test positive clinically neg.	test negative clinically pos.	test positive clinically pos.
	---------------------------$/cow---------------------------		
Total change in adjusted value			
model I[a]	-27.51	-90.98	-165.81
	(.4170)[c]	(.0414)	(.0000)
model II	-28.59	-93.88	-156.90
	(.4020)	(.0411)	(.0001)
Milk value			
model I	-24.50	-71.67	-131.22
	(.4590)	(.0996)	(.0006)
model II	-21.94	-68.81	-130.67
	(.5124)	(.1155)	(.0006)
Calf value			
model I	+0.10	-1.23	+2.13
	(.9146)	(.3057)	(.0763)
model II	+.22	-.85	+2.03
	(.8185)	(.4323)	(.0727)
Net replacement cost[b]			
model I	+3.11	+18.08	+36.71
	(.6854)	(.1854)	(.0030)
model II	+6.88	+24.21	+28.25
	(.3603)	(.0636)	(.0261)
Cull revenue			
model I	-0.51	-6.56	-1.80
	(.8904)	(.1850)	(.6759)
model II	+.74	-2.68	-2.10
	(.8098)	(.5366)	(.6096)

a. Model I - herd size remains constant. Model II - herd size allowed to change.
b. An increase in costs reduces total adjusted value.
c. Test statistic (p-value) that coefficient differs from 0.

Table 3. Impact of Johne's Disease on Dairy Production Parameters.

Parameter	Johne's Disease Status: test positive clinically neg.	test negative clinically pos.	test positive clinically pos.
Milk production (kg. per cow)			
model I[a]	-85.57	-250.07	-457.87
	(.4590)[b]	(.0996)	(.0006)
model II	-76.55	-240.10	-455.95
	(.5124)	(.1155)	(.0006)
Cull cows (number per 100 cows)			
model I	+0.18	-0.24	+2.00
	(.8422)	(.8441)	(.0912)
model II	+0.53	+0.85	+1.93
	(.4257)	(.4191)	(.0529)
Poor body condition culls (no. per 100 cull cows)			
model I	+2.05	+16.22	+9.85
	(.3260)	(.0011)	(.0085)
model II	+2.22	+16.59	+9.80
	(.2913)	(.0008)	(.0080)
Cow deaths (number per 100 cows)			
model I	+0.06	+1.29	+1.17
	(.8407)	(.0786)	(.0237)
model II	+0.13	+1.46	+1.18
	(.6623)	(.0320)	(.0160)
Pregnant culls (no. per 100 cull cows)			
model I	+4.13	+5.28	+11.40
	(.0995)	(.1285)	(.0074)
model II	+3.97	+5.21	+11.23
	(.1160)	(.1331)	(.0089)
Calves born (number per 100 cows)			
model I	+0.21	-2.46	+4.25
	(.9146)	(.3057)	(.0763)
model II	+0.44	-1.71	+4.05
	(.8185)	(.4323)	(.0727)
Cows sold as replacements (no. per 100 cows)			
model I	-0.01	+0.43	+0.72
	(.9765)	(.4510)	(.3218)
model II	-0.03	+0.35	+0.73
	(.9402)	(.5358)	(.3195)

a. Model I - herd size remains constant. Model II - herd size allowed to change.

b. Test statistic (p-value) that coefficient differs from 0.

The second most important component in reducing adjusted value was increased net cow replacement cost (Table 2). Increased culling and increased death loss were the two major contributors of net cow replacement cost. Test positive clinically positive herds had a net replacement cost of $37 or $28 per cow higher than test negative clinically positive herds.

Even though herds that tested positive for Johne's disease had an increased number of pregnant cows culled (Table 3), they also had an increased number of calves born and thus had increased calf revenue over herds that tested negative for Johne's disease (Table 2). However, herds that tested negative but had clinical signs had fewer calves born alive per cow.

DISCUSSION

Cost of Johne's disease reported in other studies varies widely. To reduce this variance, the costs were standardized to a common milk price and when possible to a common loss of reduced cull value for clinical cases (Table 4). Estimated economic impact of Johne's disease using a $.286/kg ($13/cwt) milk price ranged from $401 to $959 per cow with clinical signs of Johne's disease and $123 to $696 per cow for cows not showing any clinical signs. Two of the studies didn't separate costs between clinical and subclinical cows. Overall, cost per identified Johne's cow, combining both clinical and subclinical cows, ranged from $145 to $1,094 per cow with Johne's disease. Some of the variance between studies can be attributed to replacement cost as some studies included this cost while others did not.

Even though these studies showed a wide variance in cost per cow with Johne's disease, they have much narrower range of cost when based on all cows in the study-$20 to $26 per cow for all but one study. To convert our findings to all cows, we need to adjust for percent of cows in each Johne's disease category. Test positive clinically negative herds represented 26.1 percent of the cows in our economic analysis, while test positive clinically positive herds had 18.9 percent of the cows.

Table 4. Summary of Annual Economic Impact of Johne's Disease in Dairy Cows Standardized to a Common Milk Price [$.286/kg ($13/cwt)].

Study	Prevalence[g] (%)	-------Johne's Disease Cows------- w/ clinical signs	w/o clinical signs	both	All cow inventory
		----------------------$ per cow-------------------			
Bendictus, Dijkuizen, Stelwagen (1987)[a, c]	-	887	696	-	-
Meyer and Hall (1994)[b, c]	6.2[h]				
Method I [e]		-	-	365	23
Method II [f]		-	-	387	24
Whitlock et al. (1985)[b, c]	1.8[h]	-	-	1094	20
Buergelt and Duncan (1978)[a, d]	17.5[i] 27.5[j]	959	517	689	310
Abbas, Riemann, and Hird (1983)[b, d]	0.9[i] 7.2[j]	389	239	256	21
Chiodini and Van Kruiningen (1986)[b, c]	1.4[i] 16.6[j]	401	123	145	26

a. Economic impact includes lost milk production, reduced cull value, and extra replacement costs.
b. Economic impact includes lost milk production and reduced cull value.
c. Data collected from multiple herds.
d. Data collected from single herd.
e. Net present value method over cow's lifetime.
f. Reduced annual revenue flows.
g. Percent based on total cow inventory.
h. Both clinical and subclinical.
i. Clinical only.
j. Subclinical only.

Per cow cost of Johne's disease for all cows equals $39 ($27.51 x 26.1% + $165.81 x 18.9%) or $36 ($28.59 x 26.3% + $156.90 x 18.5%). On a national basis then, our study shows Johne's disease to cost at least a third more than previous estimates.

The $166 or $157 per cow per year for test positive clinically positive herds is significant compared to net earnings a cow generates. For example, USDA's Economic Research Service has estimated that the middle 50 percent of dairy producers based on cost of production earned $243 per cow over cash expenses in 1993. Thus to average cost producers, Johne's disease could reduce net cash earnings by one-half or more.

The economic impact presented in this analysis is an annual cost. Assuming a producer has an opportunity cost of capital at a 10 percent interest rate and a 10 year planning horizon, the maximum lump sum payment to eradicate Johne's disease from a herd would be $1,019 or $964 per cow. Given that average replacement cows cost approximately $1,100 per head and cull cows sell for approximately $400 per head, i.e. a $700 per head difference, there is strong economic incentive for producers with herds that tested positive for Johne's disease and have clinical signs to consider replacing their whole herd with Johne's free cows.

Of course, other agents can result in clinical signs similar to that of Johne's. Herds which tested negative but had clinical signs consistent with Johne's disease had a reduction in adjusted annual production value of $91 or $94 per cow. Assuming that herds that tested positive for Johne's were equally likely to have these other agents, then the lower bound of per cow annual impact of Johne's disease, if clinical signs are present, would be $75 or $63 per cow ($166 - $91) or ($157-$94). Even at this lower value, cost of Johne's disease is still significant. Once again assuming a 10 year planning horizon and an opportunity cost of capital at 10 percent interest, a producer could afford a lump sum payment of $460 or $387 per cow inventory to eradicate Johne's from his herd.

Another way to analyze the cost of Johne's disease is to compare it against other costly dairy health problems such as mastitis as measured by high bulk tank somatic cell counts (BTSCC). Herds with BTSCC of 300,000/ml to 399,999/ml had reduced milk production of 257 kg or 269 kg per cow and reduced adjusted value of production of $81 or $82 per cow when compared to herds with BTSCC below 300,000/ml (Tables 5 and 6). Herds with BTSCC of 400,000/ml or greater had 864 kg or 876 kg per cow less milk production and a $291 or $292 per cow decline in adjusted value of production when compared to herds with BTSCC below 300,000/ml. On an U.S. industry basis, high BTSCC costs $82 or $82 per cow which is more than twice the industry impact of Johne's disease.

One limitation to this study is that costs, except for cow replacements, were not included. Feed cost, the greatest expense on a dairy operation (USDA-ERS, 1996), is related to milk production. With Johne's disease positive herds producing less milk, one might expect their feed cost per cow to be lower. The definition of clinical signs of Johne's disease, however, was chronic diarrhea and weight loss that didn't respond to treatment despite a normal appetite and the mechanism for this includes intestinal malabsorption. Thus, the suggested reduction in feed intake may not be significant for herds with clinical signs of Johne's disease. Other costs such as labor and capital charges are largely a function of the number of cows within the herd. Therefore, while the inclusion of costs would have been preferred, they were not included since the quality of this data by producer reporting via questionnaires was expected to be low, and their impact on the study results would not be expected to be great.

One disturbing result of this study in terms of disease control was that herds that tested positive for Johne's disease and had clinical signs were more likely to sell replacements to other producers than herds that tested negative and had no signs. Though the statistical significance of this associations was not high, this result should serve as a warning to producers to be careful about purchasing cattle and to select cows only from herds free of Johne's disease.

Table 5. Impact of Johne's Disease on Adjusted Value per Cow ($ per cow inventory)

Variable	Model I[a] Parameter estimate	Model I[a] Prob > |t|	Model II Parameter estimate	Model II Prob > |t|
Johne's disease				
test neg. clinical neg.	base	n.a.	base	n.a.
test pos. clinical neg.	-27.51	.4170	-28.59	.4020
test neg. clinical pos.	-90.98	.0414	-93.88	.0411
test pos. clinical pos.	-165.81	.0000	-156.90	.0001
Herd Size				
1 - 99 cows	base	n.a.	base	n.a.
100 - 199 cows	98.06	.0008	76.85	.0083
200 - 499 cows	113.80	.0036	83.52	.0471
500 or more cows	207.19	.0006	203.48	.0012
Region				
midwest	base	n.a.	base	n.a.
west	21.45	.6376	29.84	.5287
southeast	-168.73	.0123	-163.58	.0155
northeast	-31.33	.3504	-27.38	.4226
use DHIA	195.05	.0000	214.63	.0000
pasture grazing (<90% roughage)	5.77	.8446	-13.13	.6622
pasture grazing (≥90% roughage)	-116.52	.0091	-128.02	.0055
square root - % cows BST	41.37	.0000	40.65	.0000
first calf heifers				
25% or less	base	n.a.	base	n.a.
26 % - 33%	101.60	.0050	82.49	.0243
34% or more	91.75	.0075	46.26	.2135
bulk tank somatic cell count				
299,000 or less	base	n.a.	base	n.a.
300,000 - 399,999	-81.12	.0072	-82.26	.0075
400,000 or more	-291.16	.0000	-292.07	.0000
percent Holstein				
100%	base	n.a.	base	n.a.
90% - 99%	-90.66	.0100	-107.83	.0022
50% - 89%	-253.74	.0001	-274.16	.0001
0% - 49%	-664.38	.0000	-679.53	.0000
90% or more registered	29.20	.5122	49.32	.2841
cow inventory change (percent)	n.a.	n.a.	-7.89	.0000
intercept	2120.54	.0000	2134.92	.0000
mean adjusted revenue	2112.24		2038.85	
R-square	.4638		.4763	
number of observations	980		974	

a. Model I: cow inventory fixed. Model II cow inventory allowed to change.

Table 6. Impact of Johne's Disease on Milk Production per Cow (kg per cow per year)

Variable	Model I[a] Parameter estimate	Model I[a] Prob > |t|	Model II Parameter estimate	Model II Prob > |t|
Johne's				
test neg. clinical neg.	base	n.a.	base	n.a.
test pos. clinical neg.	-85.48	.4590	-76.55	.5124
test neg. clinical pos.	-250.07	.0996	-240.10	.1155
test pos. clinical pos.	-457.87	.0006	-455.95	.0006
Herd Size				
1 - 99 cows	base	n.a.	base	n.a.
100 - 199 cows	291.87	.0045	311.89	.0024
200 - 499 cows	277.09	.0473	386.82	.0368
500 or more cows	768.22	.0003	758.62	.0004
Region				
midwest	base	n.a.	base	n.a.
west	80.75	.6215	70.35	.6653
southeast	-585.55	.0121	-587.07	.0113
northeast	-106.34	.3542	-100.11	.3866
use DHIA	752.85	.0000	752.53	.0000
pasture grazing (<90% roughage)	-55.19	.5830	-56.29	.5799
pasture grazing (≥90% roughage)	-501.77	.0012	-488.78	.0016
square root - % cows BST	151.70	.0000	152.36	.0000
first calf heifers				
25% or less	base	n.a.	base	n.a.
26 % - 33%	460.34	.0002	476.35	.0002
34% or more	503.13	.0000	546.19	.0000
bulk tank somatic cell count				
299,000 or less	base	n.a.	base	n.a.
300,000 - 399,999	-257.03	.0125	-269.03	.0091
400,000 or more	-864.47	.0000	-876.32	.0000
percent Holstein				
100%	base	n.a.	base	n.a.
90% - 99%	-360.77	.0028	-347.36	.0040
50% - 89%	-945.13	.0000	-925.24	.0001
0% - 49%	-2346.96	.0000	-2348.00	.0000
90% or more registered	34.48	.8211	38.86	.7984
cow inventory change (percent)	n.a.	n.a.	-2.58	.3864
intercept	7820.76	.0000	7814.31	.0000
mean milk production	7921.20		7921.82	
R-square	.5007		.5025	
number of observations	980		974	

a. Model I: cow inventory fixed. Model II cow inventory allowed to change.

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