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Economics of estrus synchronization and AI

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Introduction

Commercial cow-calf producers have an increasing number of options available for the synchronization of estrus and ovulation to facilitate the incorporation of an artificial insemination (AI) program. At the same time, low-cost production and/or the ability to produce a higher valued product are essential for economic success in the cow-calf industry. Previous research has examined the costs of various artificial insemination (AI) breeding systems and/or compared those costs to natural service options (Loseke, 1989, Johnson and Jones, 2005, Miller et al., 2004). From a strict "cost per pregnancy" perspective, it has been difficult to identify AI systems that consistently compete well with natural service options. This may explain why AI technology has not been widely adopted by commercial cow-calf producers. However, when even modest genetic value premiums associated with higher quality calves or retained ownership marketing options are added to the equation, several AI systems have the potential to increase net returns to the cow-calf enterprise. With continued improvements in success of synchronization systems, and with the continually evolving beef cattle marketing system that may lead to greater genetic premiums (or discounts) being passed down to the cow-calf producer, there is a need for continued evaluation of the economic ramifications of the breeding system decision.

The AI cost model developed by Johnson and Jones, 2005 examines costs for a fixed set of inputs but fails to consider the real life variability of various inputs and associated economic risk. A stochastic model incorporates probability and recognizes the random nature of input components. The present stochastic model was developed to compare costs of several systems for synchronization of estrus and AI with natural service breeding systems and to identify the most important factors in determining the differences between costs of breeding systems. The affects of herd size and cow to bull ratio on the relationships are explored.

Materials and Methods

An abbreviated cow-calf enterprise budget focused on breeding costs was the basis of the model (Johnson and Jones, 2005). This partial budget approach includes only those cost and revenue items that would be expected to change based on the breeding system selected. For example, most of the annual costs of maintaining a cow (i.e., cow feed costs) are not dependent upon the breeding system chosen, and are not included in the model. Annual bull costs are estimated because the number of bulls is allowed to vary. Stochastic stimulations were performed using @Risk for Excel (Palisade Corporation, Newfield, NY, www.palisade.com) which is a risk analysis spreadsheet add-in tool that allows the user to model various outcomes based on predefined distributions of input variables.

Breeding herds of 35, 116, and 348 head were examined to allow for culling of nonpregnant and physically impaired cows to yield 30-, 100-, and 300-head calving herds. The sizes are used to represent the variance in beef cow herds typical operating within the beef industry.

One factor under management control that can significantly influence breeding cost is the cow to bull ratio. Three cow to bull ratios of 20, 30, and 40 were examined to determine the impact on breeding costs across various breeding systems.

The following systems for synchronization of estrus and ovulation were utilized in the model to represent relatively lower and higher cost protocols: heat detection only systems - Select Synch, Select Synch + CIDR, MGA-PG; combination heat detection and clean-up timed AI – Select Synch, Select Synch + CIDR; fixed-timed AI – CoSynch + CIDR, MGA-PG. The model assumes one synchronization and AI period followed by a natural service period. To determine number of clean-up bulls needed, the assumption was made that AI pregnancy rate would be roughly 50 percent and clean-up bulls would be needed to cover the remaining 50 percent of each herd. Each simulation model estimates costs associated with one of these synchronization and AI breeding systems and compares it to the natural service option.

In all models, we account for the fact that calves born as a result of a synchronized AI program should be on average older and thus heavier at weaning due to synchronization alone and for the possibility that AI sired calves may be worth more at weaning either based on genetic merit for carcass or maternal traits or for preweaning gain. The magnitude of these premiums is allowed to vary with each iteration of the simulation.

Table 1. Distributions of modeled input variables.

Modeled Input variables	Average Value	Standard Deviation	Minimum Value	Maximum Value
Bull purchase price	2422	1025	400	
Calf crop, %	82	9.8	65	100
Calf price, $/cwt	87	15.6		
Conception rate - estrus AI	63.2	9	46	80
Conception rate - timed AI	53	11	30	94
Cull bull value, $/cwt	54.37	6.12		
Cull bull weight, lbs	1780	400		
Genetic value weaned AI-sired calf, $/head			0	50
Heat detection rate	88	11	60	100
Season pregnancy rate	88.6	7.2	74	100
Semen - $/straw	19.1	6	4	150
Synchronized calving weight advantage (lbs)	16	12	2	40

Simulations were performed for each of the seven AI systems, three herd sizes, and three cow to bull ratios, for a total of 63 simulations. Each simulation consisted of 100 iterations. Each simulation summarizes the response (the average value and the dispersion around that average) when the input factors are allowed to vary. For example, in one iteration, the cull bull weight might be 1500 pounds and in the next iteration the weight is 2200 pounds. The input mean and standard deviation guide the program in dispersion of the individual iterations.

The simulations are driven by the assumed distributions of the random input variables shown in Table 1. With the exception of genetic value, all distributions were assumed to be normal. In some cases minimum and/or maximum values were dictated. While the minimum value for bull purchase price seems unrealistically low ($400), this decision was made based on the size of the standard deviation and expectation that a higher minimum would distort the distribution of bull purchase prices to an undesirable degree. Genetic value ($/animal) used a triangle distribution with three points, a minimum (0), most likely ($5) and maximum ($50).

Because in reality the stochastic input variables do not necessarily behave independently, the following correlations were imposed on the model; cull value and calf price, 0.70; semen cost and genetic value, 0.25; season pregnancy rate and percent calf crop, 0.90. Imposing these correlations (readily accomplished using the @Risk software) assures that it is very unlikely that the simulation will use a pregnancy rate from the upper end of the input distribution along with a calf crop percentage from the lower end of the input distribution in the same iteration. In addition, it is relatively unlikely that the model will use a very high cull price and a very low calf price in the same iteration (perhaps representing the same marketing year, for example). Finally, the semen cost – genetic value correlation assumes that there is at least some degree of association on average between what is paid for AI semen and the genetic value premiums associated with AI calves.

Table 2. Fixed input assumptions

Item	**Values/Costs used**
Bull Costs	
Interest rate	7%
Years of bull use	4
Total variable costs per bull	$483
Depreciation of equipment	$12.39
Depreciation on bull purchase price	(purchase price – salvage price)/4
Death loss	1% of purchase
Synchronization costs	
MGA, $/14-day treatment	$0.50
CIDR - $/CIDR	$9.47
GnRH - $/dose	$2.61
PGF - $/dose	$2.51
Disposables - per insemination charge	$0.50
Fixed costs for AI equipment	$175.00
Hours of labor for treatments, heat detection and AI	2.53(no. of cows x no. of days worked)$^{.5}$
Labor cost per hour	$10.77
Number of days worked	Number of treatment, heat detection and AI days dictated by protocol

Data for the input distributions as well as for the fixed input assumptions (Table 2) came from a variety of sources further detailed in the appendix. For each system, the model relies on the appropriate inputs (both fixed and stochastic) to calculate the desired output variables for each simulation iteration.

Three output variables were generated in each simulation. The output variable **breeding cost per pregnant female** includes the costs of synchronization of estrus and one artificial insemination and a natural service clean-up period. The **breeding cost per hundred of weaned calf** output variable reduces breeding system costs per exposed female for any increased revenue from AI-sired calves and is expressed as a 500-lb equivalent, weaned-calf, breeding cost per hundred (cwt). The breeding cost per hundred for each synchronization system is compared to a comparable standardized value for natural service alone using the output variable referred to as "**difference**". A positive difference value indicates the AI breeding system has lower costs than a natural service breeding system. Simulation model results provide the average expected value of the difference and the percentage of time the difference value is expected to be positive given the random events considered in the model.

Results and Discussion

Figure 1 provides an example of the graphical results generated by the simulation modeling effort. In this instance, the distribution of the cost per pregnant female output variable for the Select Synch + CIDR heat detection only system applied to a calving herd size of 100 and cow to bull ratio of 30 reveals an expected mean of $68.57, with a standard deviation of $9.90. Ninety percent of the draws resulted in cost per pregnant female values between $53.47 and $87.07. Approximately 68% of the values would be expected to fall within one standard deviation of the mean ($58.67 to $78.47).

Figure 1. Distribution of cost per pregnant female output for herd size 100, cow:bull 30, Select Synch +CIDR

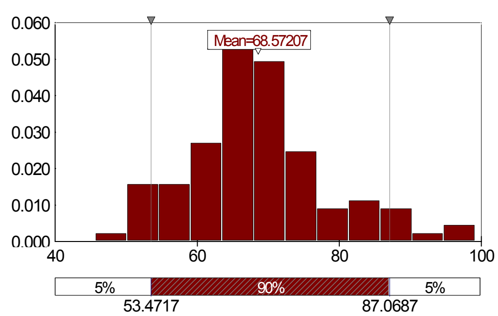


Table 3 summarizes the numerical results of the 63 simulation models. Cost per pregnancy for breeding systems that include both AI and natural service costs ranged from $46 to $95. Table 4 summarizes the impact of herd size and cow to bull ratio on cost per pregnancy. Average cost for the small herd size is the same across all cow to bull ratios because all require one bull for clean-up regardless of the cow to bull ratio and within a herd size and synchronization system, the same iteration values are used across bull to cow ratios. As herd size increases, the opportunity to more fully utilize a bull's expected serving capacity is reflected in reduced cost per pregnancy as herd size increases and at higher cow to bull ratios in the large herd size.

Table 3a. Simulation model output.

System	Herd Size	Cow to Bull Ratio	Cost per Pregnancy	Breeding Cost/cwt	Breeding Cost Difference (Natural Service - AI)	Proportion of Simulations AI is Lower Cost than Natural Service
Heat detection						
Select Synch	30	20	82.55	13.55	0.8	59
	30	30	82.55	13.55	0.8	59
	30	40	82.55	13.55	-6.37	2
	100	20	67.97	10.42	2.53	83
	100	30	57.97	8.26	0.37	55
	100	40	57.97	8.26	1.79	16
	300	20	63.19	9.41	3.59	90
	300	30	53.16	7.24	1.42	72
	300	40	49.81	6.52	-0.02	50
Select Synch + CIDR	30	20	92.3	15.67	-1.32	36
	30	30	92.3	15.67	-1.32	36
	30	40	92.3	15.67	-8.5	0
	100	20	78.62	12.73	0.28	53
	100	30	68.57	10.56	-1.68	18
	100	40	68.57	10.56	-4.05	5
	300	20	74.22	11.86	1.18	70
	300	30	64.17	9.68	-0.99	32
	300	40	60.82	8.96	-2.44	13
MGA/PGF	30	20	77.03	12.35	1.92	74
	30	30	77.03	12.35	1.92	74
	30	40	77.03	12.35	-5.22	1
	100	20	64.02	9.56	3.52	87
	100	30	53.95	7.38	1.34	70
	100	40	53.95	7.38	-0.84	28
	300	20	59.59	8.59	4.36	94
	300	30	49.59	6.43	2.2	80
	300	40	46.26	5.71	0.77	60

Table 3b. Simulation model output

System	Herd Size	Cow to Bull Ratio	Cost per Pregnancy	Breeding Cost/cwt	Breeding Cost Difference (Natural Service - AI)	Proportion of Simulations AI is Lower Cost than Natural Service
Combination heat detection and clean-up fixed timed AI						
Select Synch	30	20	85.43	14.24	0.07	51
	30	30	85.43	14.24	0.07	51
	30	40	85.43	14.24	-7.09	0
	100	20	71.8	11.26	1.73	74
	100	30	61.76	9.1	-0.44	43
	100	40	61.76	9.1	-2.6	14
	300	20	67.31	10.28	2.65	83
	300	30	57.29	8.12	0.5	56
	300	40	53.95	7.4	-0.94	33
Select Synch + CIDR	30	20	94.78	16.32	-2.04	23
	30	30	94.78	16.32	-2.04	23
	30	40	94.78	16.32	-9.18	0
	100	20	82.19	13.49	-0.54	44
	100	30	72.16	11.34	-2.7	15
	100	40	72.16	11.34	-4.86	4
	300	20	78.22	12.57	0.44	53
	300	30	68.17	10.4	-1.72	20
	300	40	64.82	9.68	-3.17	7
Fixed-time AI						
CoSynch+CIDR	30	20	93.37	15.86	-1.57	32
	30	30	93.37	15.86	-1.57	32
	30	40	93.37	15.86	-8.72	0
	100	20	81.84	13.4	-0.45	41
	100	30	71.83	11.24	-2.61	18
	100	40	71.83	11.24	-4.77	1
	300	20	78.42	12.7	0.18	49
	300	30	68.45	10.56	-1.97	21
	300	40	65.13	9.84	-3.4	7
MGA/PGF- TAI	30	20	77.4	12.51	1.71	68
	30	30	77.4	12.51	1.71	68
	30	40	77.4	12.51	-5.4	2
	100	20	66.77	10.21	2.69	80
	100	30	56.81	8.06	0.54	59
	100	40	56.81	8.06	-1.61	22
	300	20	63.9	9.58	3.34	88
	300	30	53.89	7.43	1.19	66
	300	40	50.56	6.71	-0.25	38

Table 4. Cost per pregnancy

Herd Size	Cow to bull ratio			Average
	20	30	40	
30	83.96	83.96	83.96	83.96
100	70.20	60.16	60.16	63.51
300	65.67	55.64	52.30	57.87
Average	73.28	66.59	65.47	68.45

Figure 2 provides an example to illustrate the difference in breeding cost output variable. The distribution of the expected difference in breeding cost variable for the MGA/PGF heat detection only system for a herd size of 100, and cow to bull ratio of 30 resulted in a mean of \$1.34, with a standard deviation of \$2.44. The difference in breeding cost for a typical production system with similar constraints would be expected to be positive about 70 percent of the time. In other terms, an AI program with an MGA/PGF heat detection system (herd size of 100, cow to bull ratio 30) would be lower cost than natural service on average and would be equal to lower cost about 70% of the time.

Figure 2. Distribution of difference in breeding cost output variable for MGA/PG estrus AI, herd size 100 and cow to bull ratio of 30

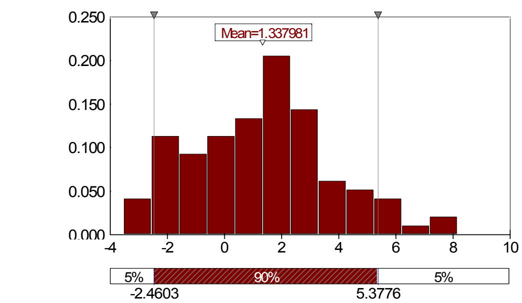
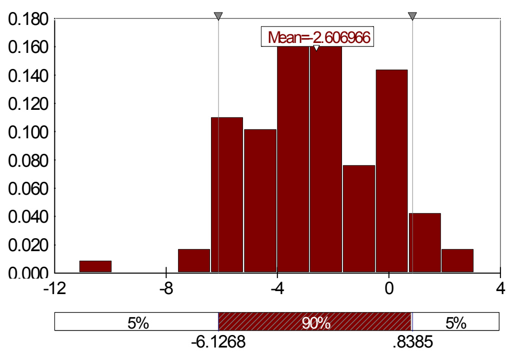


Figure 3. Distribution of difference in breeding cost output variable for CoSynch + CIDR, herd size 100 and cow to bull ratio of 30



The cost per pregnancy of a CoSynch + CIDR system for a herd size of 100 and cow to bull ratio of 30 is approximately \$18 greater than a MGA/PG heat detection system under similar conditions. The distribution of the difference output variable for CoSynch + CIDR in Figure 3 illustrates a negative mean difference in breeding cost of \$-2.61 and a reduction in iterations where AI is lower cost than natural service. Note that a majority of the observations are to the left of zero or negative values. For the current inputs, AI is not an economically attractive breeding program.

The difference in breeding system costs between natural service and AI systems are summarized in Table 5 averaged over all synchronization systems. At a cow to bull ratio of 40, the average difference is -\$3.66/cwt. across all systems and herd sizes, indicating natural service tends to be a lower cost breeding system at higher cow to bull ratios. When more bulls are used (lower cow to bull ratio) the difference value becomes more positive indicating AI systems are in general more economically attractive. Averaged across all synchronization systems, AI produces pregnancies for \$1.19/cwt less than natural service for a cow to bull ratio of 20. According to the 1997 NAHMS survey, the average cow to mature bull ratio for herds less than 49 head was 23, 27 for herd sizes 100 to 299 head and 26 for herds greater than 300 head. This implies that if producers are not comfortable identifying bulls to service higher cow to bull ratios they should evaluate synchronization and AI more seriously.

Synchronization systems were classified based on amount of heat detection required as heat detection alone, heat detection plus a clean-up fixed-time AI or strict fixed-time AI. The average proportion of the iterations where the difference in breeding cost output variable indicated the AI system was equal to or more economically attractive than natural service by amount of heat detection required is summarized in Table 6.

Table 5. Difference in breeding cost output variable summarized by herd size and cow to bull ratio.

	Cow to bull ratio			
Herd Size	20	30	40	Average
30	-0.06	-0.06	-7.21	-2.44
100	1.39	-0.77	-2.42	-0.60
300	2.25	0.09	-1.35	0.33
Average	1.19	-0.25	-3.66	-0.90

The trends discussed earlier for herd size and cow to bull ratio are also apparent in this table. For a herd size of 30 and a cow to bull ratio of 40, there was rarely if ever an advantage to any AI system. Synchronization systems using strict fixed-time AI were lower cost than natural service 38% of the time, whereas this value increased to 49% for heat detection only systems. Heat detection only systems in large herds using low cow to bull ratios were lower cost than natural service 85% of the time.

Table 6. Frequency of lower breeding system costs for AI compared to natural service breeding.

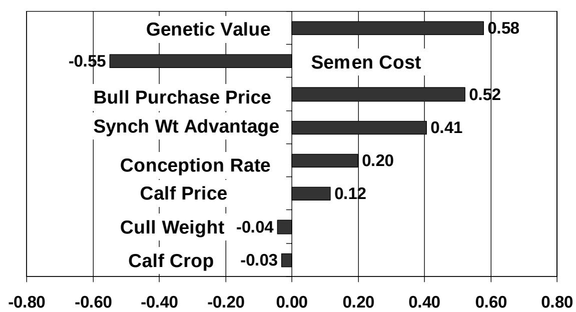
		Cow to bull ratio			
System Type	Herd Size	20	30	40	Average
Heat Detection	30	56	56	1	38
	100	74	48	16	46
	300	85	61	41	62
subtotal		72	55	19	49
Heat Detection plus clean-up fixed-time AI	30	37	37	0	25
	100	59	29	9	32
	300	68	38	20	42
subtotal		55	35	10	33
Fixed-time AI (TAI)	30	50	50	1	34
	100	61	39	12	37
	300	69	44	23	45
subtotal		60	44	12	38
Grand Total		63	46	14	41

Simulation model results for each run include standardized beta coefficients that quantify the expected relative impact of each randomly drawn input on each of the targeted outputs. These coefficients identify which factors truly drive the variability of the targeted output. The magnitude of the standardized beta's cannot be compared across models, however the ranking and relative magnitudes of various inputs can be compared across synchronization systems, herd sizes and cow to bull ratios.

The scope of our simulation modeling effort precludes us from providing a detailed discussion of all of the standardized beta coefficient results. Therefore, the focus of the discussion will be on the difference in breeding cost output variable.

The standardized beta coefficients for the difference in breeding cost output variable resulting from one simulation are presented in Figure 4. The variation in the genetic value input variable is the most important determinant of the magnitude of the difference in breeding costs output variable (it has the longest bar on the graph). Whether or not this particular AI system will provide an economic advantage in a particular management setting, and how much, is largely determined by the ability to garner a genetic value premium associated with the AI calves. The standardized beta coefficient for genetic value is positive (the bar on the graph goes to the right) indicating that higher genetic value premiums are associated with a positive move in the difference in breeding cost variable, as one would expect.

Figure 4. Standardized beta coefficients for MGA/PG estrus AI, herd size 100, cow to bull ratio 30



Semen cost variability is nearly as important as genetic value in influencing the difference in breeding cost output variable (bars are roughly equal length). Since the coefficient is negative, higher AI semen costs would be expected to result in a smaller (or negative) economic advantage for the AI system relative to natural service. Bull purchase price is third in terms of relative importance on this list for this particular system comparison. Higher bull purchase prices result in the AI system becoming more economically competitive. This is expected because higher bull purchase prices would increase the cost of the natural service alternative relative to the AI choice.

For this specific system comparison, the synchronized calving weight advantage variable, and the conception percentage variable are marginally important contributors to the economic advantage (disadvantage) of the AI system. Calf price variability, cull weight variability, and the percent calf crop variability are relatively unimportant. This observation is consistent across the systems and management regimes evaluated in this study.

What does this mean from a management perspective? First, the results are not consistent across all management scenarios so consider results from a model that most nearly matches your situation. For this example, consider a herd size of 100 cows with an average cow to bull ratio of around 30, using an MGA/PGF protocol. For a producer affiliated with a marketing system where genetic value premiums flow down to his production level, genetic value premium can have a large influence on the decision to use AI. Similarly, access to high quality semen at average or below average costs, makes the AI system a more attractive alternative (less risky). If the purchase price for natural service bulls is a relatively high cost, AI becomes a significantly more economically attractive alternative.

On the other hand, factors such as a slightly below average AI conception rate (within reason), below average cull weights, or below average overall calf crop percentage expectations should not drive decisions regarding the adoption of AI.

Standardized beta coefficient results are very much AI system and management system specific. However, some general observations can be made for the difference in breeding cost output variable across all 63 simulations. First, genetic value premiums and semen cost variability are always in the top three in terms of relative importance across all systems, herd sizes, and assumed cow to bull ratios. Therefore, one generalization across systems would be that the ability to garner a genetic value premium, and the ability to obtain average or above average quality AI semen for a reasonable cost are important determinants of the magnitude of the economic advantage of any of the AI systems studied here under any of the assumed herd management scenarios.

Second, variability in bull purchase price is always the most important factor when the assumed cow to bull ratio is low (20). If you are in a management system that dictates a low cow to bull ratio (small pastures, etc.) then bull purchase price becomes a driving factor in your decision regarding whether or not to AI from an economic perspective. Bull purchase price consistently drops down in the ranking of important factors that influence the difference in breeding cost output variable as the assumed cow to bull ratio is increased. When a constant cow to bull ratio of 30 was used, Miller et al., 2004 found bull purchase price, semen price and percent genetic change as the most prominent variables in determining net return when comparing synchronized AI and natural service breeding systems.

The model used a fairly conservative estimate of genetic value for AI-sired calves. Reducing the genetic value distribution to a minimum of zero, most likely of $2/hd and maximum value of $25/hd reduced the proportion of times a CO-Synch + CIDR fixed-time AI system was lower cost than natural service by zero to ten percent for a herd size of 100. Averaged across all fixed-time AI systems, the average proportion of times AI had lower breeding costs compared to natural service was 38%. If the genetic value distribution is changed to a minimum of zero, most likely value of 10 and a maximum of 100, the proportion of simulations where AI cost is lower than natural services increases to 64%. This further emphasizes the importance of capturing value from AI sired calves in making an AI program economical in a commercial herd.

An interesting question surrounds periods of abnormally high overall cattle (calf) prices, and the impact of that phenomenon on the AI advantage (difference) in general. For all of our 63 simulation runs across AI systems, herd sizes, and cow to bull ratio comparisons, the calf price variable is always only marginally important determining the AI advantage. Calf prices are a positive influencer on the difference variable, indicating that high calf prices (high overall cattle price periods) should marginally increase the economic advantage of AI. The proportion of simulations where AI was lower cost than natural service for Select Synch and Select Synch + CIDR heat detection only systems was 42% when calf price averaged $0.87/cwt. If calf price is increased to $1.20/cwt for those same systems, the proportion of times where AI was lower cost only increased to 49%.

The current model assesses the costs of breeding systems with the end point considered to be a weaned calf. Any post weaning increase in value from an AI-sired calf that might be attributed to the AI program and cow herd is lumped into one genetic value input. Conversely, Miller et al., 2004 considered various retained ownership opportunities when comparing AI and natural service breeding systems. Retaining ownership to harvest and marketing either on a cash or grid market was advantageous to AI in all of the synchronization protocols evaluated when compared to natural service.

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Appendix

Table 7. Source of distributions for modeled input variables.

Variables	Average Value	Standard Deviation	Source(s)
Bull Purchase price, $/head	2422		American Angus Association reported average 1999 - 2005
		1025	Adapted from Dhuyvetter et al., 2005
Calf Crop, %	82	9.8	TX, OK and NM SPA data, personnel communication Stan Beavers
Season pregnancy rate	88.6	7.2	
Calf price, $/cwt	87	15.6	Long term average USDA price reports
Conception Rate - estrus AI	63.2	9	Johnson 2005
Conception Rate - timed AI	53	11	Larson et al., 2006
Heat Detect Rate	88	11	Lamb et al., 2006
Cull bull value	54.37	6.12	Long term utility cow price average (USDA) plus $10/cwt
Cull bull weight	1780	400	Calculated from 2005 online sale reports from two different sale barns
Genetic value weaned AI-sired calf, $/hd			SWAG
Semen - $/straw	19.1	6	2006 Book prices from 4 major semen distributors
Synchronized calving weight advantage (lbs)	16	12	Estimated from unpublished data and Anderson and Deaton, 2003 Deutscher et al., 1991 Geary, 2003 Schafer et al., 1990

Table 8. Deterministic input values and sources.

Item	Values/Costs used	Source
Bull Costs		
Interest	7%	Updated from Johnson and Jones, 2005
Years of bull use	4	
Total variable costs per bull	$483	
Depreciation of equipment	$12.39	
Depreciation on bull purchase price	(purchase price – salvage price)/4	
Death loss	1% of purchase	
Synchronization Costs		
MGA	$0.50	
CIDR - $/CIDR	$9.47	Average of values available from online sources June, 2006
GnRH - $/dose	$2.61	
PGF - $/dose	$2.51	
Disposables - per insemination charge	$0.50	
Fixed costs for AI equipment	$175.00	
Hours of labor for treatment, heat detection and AI	2.53(no. of cows x no. of days worked)$^{.5}$	Loseke, 1989
Number of days worked	Number of treatment, heat detection and AI days dictated by protocol	
Labor cost per hour	$10.77	Fogleman et al., 2002