This is to certify that the
thesis entitled

ECONOMIC ANALYSES OF REPRODUCTION
MANAGEMENT STRATEGIES AND TECHNOLOGIES ON
U.S. DAIRY FARMS

presented by

NICOLE J. OLYNK

has been accepted towards fulfillment
of the requirements for the

M.S. degree in Agricultural, Food, and Resource Economics

Major Professor's Signature

August 6, 2008

Date

ECONOMIC ANALYSES OF REPRODUCTION MANAGEMENT STRATEGIES AND TECHNOLOGIES ON U.S. DAIRY FARMS

By

Nicole J. Olynk

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Agricultural, Food, and Resource Economics

2008

ABSTRACT

ECONOMIC ANALYSES OF REPRODUCTION MANAGEMENT STRATEGIES AND TECHNOLOGIES ON U.S. DAIRY FARMS

By

Nicole J. Olynk

Reproductive management of dairy cattle is crucial to whole-farm profitability as it enables milk sales, provides replacement animals, and is a factor in culling decisions. The dairy industry has responded to challenges in managing dairy cattle reproduction with innovative technologies and reproductive management programs that enable producers to synchronize ovulation, thereby lessening or eliminating the need for visual heat detection, or to make heat detection more efficient through the use of aids or automated computer-based record keeping systems. Dairy producers today face decisions regarding which reproductive management program is optimal for their farm operation. The analyses presented built upon prior reproductive management studies and sought to inform economically sound decision making regarding reproductive program and technology adoption. The varying costs and revenues associated with reproductive performance across farms illustrated the need for farm-specific analysis regarding selection of economically optimal reproductive management programs. Through the use of surveys, sensitivity analyses to reproductive program costs, and assessment of farm manager decision making under risk, the reproductive program decisions made on farms are better understood.

ACKNOWLEDGEMENTS

I would like to thank my committee, namely Dr. Christopher Wolf, Dr. Stephen Harsh, and Dr. Richard Pursley for their guidance in this research. Special thanks go to Dr. Wolf, my research advisor and major professor. His encouragement, advice, and friendship have been invaluable in my graduate career thus far.

I would like to thank all of the graduate students and faculty with whom I have worked with at Michigan State, and who have been so helpful and supportive. Specifically, I thank Nicky Mason on whom I can always rely, regardless of the task or time of day. Lee Schulz deserves special thanks for his help and continuous support with this work, specifically with Chapter 4. Lee's patience and time in helping with Chapter 4, specifically, are greatly appreciated. I thank Joleen Hadrich for her willingness to help and availability to bounce ideas off of. More generally, I would like to thank all of my friends for all of their support and encouragement.

Finally, I would like to thank my family for their unending support. A special thanks goes to my fiancé, Dave, for his constant companionship, support, and ability to put things into perspective. I am forever grateful for his support and willingness to help in any way he can; his support has been invaluable.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: GENERAL INTRODUCTION

Dairy cattle reproductive efficiency is closely tied to the profitability of commercial dairy operations in the United States. Dairy farm profitability is affected through various factors which are dependent on reproductive performance, including milk production, number of replacements, voluntary and involuntary culling, breeding costs, and costs associated with veterinary care (Britt, 1985). Given the integral link between dairy cattle reproductive efficiency and total farm profitability, dairy producers have sought technologies and programs which facilitate efficiently managing cattle reproductive performance.

Recent trends towards decreased reproductive performance industry-wide have led to increased focus on development of reproductive management programs and technologies. Specifically, increased herd sizes and milk production levels have affected how dairy farms are managing dairy cattle reproduction (Pursley et al., 1997). Today, several reproductive technologies are available for use on commercial dairy farms, including artificial insemination (AI), estrus and ovulation synchronization programs, sex-sorted semen, pedometers, computer-based record systems, and multiple visual and electronic estrus detection aides. Farm-specific factors, including varying on-farm input costs, facilities used to handle and house cattle, previous levels of reproductive performance achieved, management ability, and knowledge cause costs and reproductive performance outcomes to vary on a given reproductive management program.

The operator's degree of risk aversion, financial positioning of the farm, availability of or access to information on available technologies, and the risk levels associated with the outcomes of the technology are a few of the factors that affect adoption of technologies on dairy farms. Additionally, labor availability, labor costs, ease of cattle handling, and previous or baseline measures of reproductive performance, may be influential in determining the profit maximizing reproductive management program for a farm operation. Certainly the program that is found to be optimal for a farm with one set of characteristics may not be optimal for a farm with a different set of characteristics.

Complicating the technology and program adoption decisions of dairy farmers is the fact that costs associated with and results expected from reproductive management technologies and programs are uncertain in many cases, and are variable across individual farms. Uncertainty about the performance of new technologies arises not only from a lack of performance history, but also from a lack of knowledge, which may be caused by asymmetric information. Dairy producers facing uncertainty in reproductive program outcomes could certainly benefit from decision-support tools which allow sensitivity analysis to key outcome parameters. With a user-friendly tool available to perform sensitivity analysis for programs or technologies for which the dairy might consider adoption, the dairy farm managers would be able to determine the range of outcomes that may be expected. The ease of performing such sensitivity analysis allows producers to make more informed adoption decisions when considering reproductive management programs.

This series of analyses begins by seeking to aid in understanding dairy farm decision support needs regarding decision making on reproductive technology and program adoption through surveying of dairy farmers across multiple states. Then, armed with the information recovered through survey analysis, a user-friendly decision support tool, designed for on-farm use, was developed to address the needs of dairy farmers as they make decisions regarding reproductive management. Finally, to address the heterogeneous risk preferences among dairy farmers, efficient sets of reproductive management programs were identified for producers within broad general categories of risk preference. Given the analysis presented consists of multiple-steps, a series of objectives are highlighted for each portion of the analysis.

Overall, the objectives of this series of analyses include identification of key issues for dairy farmers through surveying dairy managers, the development of a user-friendly decision-support tool, and finally the assessment of efficient sets of reproductive management programs for farms with various characteristics. This analysis uses survey data from US commercial dairy operations to provide economic insight into reproductive management program and technology adoption decisions. Specifically, survey data was collected and used to inform the economic analysis of various reproductive management program decisions, to aid in identifying factors affecting whether farms used reproductive management programs, and if so, to determine which programs a farm with given characteristics was likely to choose. After highlighting key farm characteristics that affect reproductive technology and management program decisions, a tool was developed that allows farm-specific parameters to be entered and used in evaluating reproductive management decisions. Additionally, since the decision tool allows farm managers to enter cow numbers per group rather than assessing all cows on the farm at once, farm managers can determine the optimal program for different groups of cows on their operation. To determine the economically optimal programs for dairy farms with various characteristics (i.e., farm size, risk preferences of farm managers, on-farm reproductive program costs) stochastic dominance was employed. Due to the heterogeneity of risk preferences among dairy farmers, stochastic dominance was utilized in order to separate the sets of risky options to identify the efficient sets of reproductive management programs for decisions makers with specific risk preferences.

As dairy farm profitability continues to rely on reproductive performance and efficiency, and increased production levels coupled with increasing farm sizes lead to challenges in managing reproductive performance, dairy managers can benefit from decision-support in identifying the economically optimal reproductive programs and technologies available.

This thesis proceeds as follows: an economic analysis, parameterized using survey data, highlights the reasons why farms with different characteristics select various reproductive management programs and technologies in chapter II. Survey analysis and assessments of the sensitivities of different types of reproductive management programs to varying on-farm costs and labor efficiencies are used to highlight why farms select the reproductive management programs that they do. Chapter III depicts a user-friendly spreadsheet tool which was developed for on-farm decision support regarding selection of reproductive management programs. Chapter IV describes the efficient sets of reproductive programs for dairy farms with varying characteristics under first and second degree stochastic dominance.

CHAPTER 2: ECONOMIC ANALYSIS OF REPRODUCTIVE MANAGEMENT STRATEGIES ON U.S. COMMERICAL DAIRY FARMS

2.1 Introduction

Reproductive performance on the dairy farm affects the farm profitability through milk production, number of replacements, voluntary and involuntary culling, breeding costs, and costs associated with veterinary care (Britt, 1985). The economic implications of reproductive management decisions are critical given the link between dairy herd management and reproductive performance. Today, many reproductive technologies are available for use on commercial dairy farms with the costs and reproductive performance associated with these technologies varying considerably across farms. Farm reproductive management programs differ due to varying on-farm costs, facilities, farm goals and values, and management styles. These factors, in addition to labor availability, cost of labor, ease of cattle handling, and previous levels of reproductive performance, determine profit maximizing reproductive management techniques and technologies for dairy herds.

Several survey-based studies in recent years focused on dairy herd reproductive performance and management practices. providing a great deal of information about the current practices, performance, and management techniques of dairy farms. These overviews are useful for dairy producers, extension educators, researchers, and related farm service industries as they provide current information regarding what practices are actually being adopted and used on commercial dairy operations. However, additional analysis is necessary to understand farm decisions relative to reproductive management programs and the resulting economics.

A recent survey across multiple states by Caraviello et al. (2006) analyzed 153 large US dairy herds in the Alta Genetics Advantage Progeny Testing Program in 2004. Caraviello et al. (2006) asked questions regarding general management, sire selection, reproductive management, inseminator training and technique, heat abatement, body condition scoring, facility design and grouping, nutrition, employee training and management, and animal health and biosecurity. Of the 103 herds which completed the survey, the average herd size was 613 cows, and 87% of those herds utilized hormonal synchronization or timed artificial insemination (**TAI**) in their reproductive management programs. Caraviello et al. (2006) provided an in-depth reference of management practices being used on large commercial US dairy herds in 2004 and a valuable resource for benchmarking or comparison purposes.

Meadows et al. (2005) found through the use of a spreadsheet-based model that "…inefficient reproduction becomes marginally more costly to producers as performance declines and warrants increased attention." Meadows et al. (2005) also found that there existed decreasing marginal benefits to improved reproduction as reproductive performance improves. These decreasing marginal benefits to reproductive performance improvements may explain why different farms use different reproductive management strategies. Those farms currently achieving high levels of reproductive performance may have less incentive to initiate a potentially performance enhancing change than a farm with sub-par current performance.

A survey of bovine practitioners was conducted to evaluate the cost effectiveness of systematic breeding programs (Nebel and Jobst, 1998). Using the values found through their survey Nebel and Jobst (1998) calculated estimated costs per pregnancy for

Ovsynch and Targeted Breeding™ (Pharmacia-Upjohn, Kalamazoo, MI). Further, Nebel and Jobst (1998) conclude that systematic breeding program decisions must be evaluated for cost effectiveness in order to determine the optimal program.

The objectives of this study were to utilize survey data to provide economic insight into why varying types of farms used different reproductive management programs, and to identify those factors affecting whether farms use various reproductive technologies. This analysis sought to build upon prior reproductive management studies and dairy industry surveys by using survey data to inform the economic analysis of various reproductive management programs. Survey data was used to parameterize the economic analysis and inform the discussion regarding economic and management implications of reproductive management decisions.

2.2 Materials and methods

A survey was mailed to 1,000 dairy farms in Michigan, New York, Texas, Wisconsin, and Florida between August and December of 2006. The survey was developed to obtain data regarding reproductive management and performance in 2005 and is displayed in Appendix 1. This analysis ultimately sought to identify the factors affecting farm reproductive management program adoption decisions and to explore the management and economic implications behind various reproductive management programs.

Dairy farms receiving surveys were selected randomly from those permitted to sell milk in the aforementioned states, thereby allowing a broad range of farms to participate in the survey. Out of the 1,000 surveys mailed, the number of farms receiving surveys in each state was selected proportionately to the total number of dairy farms in that state. A total of 102 surveys were returned, resulting in a 10.2% response rate. Only those respondents who were actively operating dairy farms in 2005 and chose to participate in the survey were included in this analysis, resulting in a total of 60 potential respondents for each question. Consistent with Michigan State University research requirements when administering a survey, respondents were presented the option to decline to answer individual questions or sections of the survey at their discretion, if they chose to participate at all.

The random selection of farms that received the survey allowed equal opportunity for selection regardless of participation in various farm programs or membership in a particular cooperative. The negative outcome of using such a selection process, where farms are drawn randomly from a diverse population, and likely with a perceived low incentive to participate, was a lower response rate. Although farms were randomly selected to receive surveys, given the relatively small sample size and response bias inevitably introduced with mailed surveys, the sample was not expected to be representative of the diverse population of US dairy farms. However, the survey data itself was not the primary focus of this analysis. The survey data collected was used to parameterize the analysis of factors affecting the decisions of farms to use various reproductive management programs. In addition, management and economic implications of various reproductive management programs were explored.

The survey included questions about dairy reproductive management and performance of both heifers and cows on the operation in 2005. Questions relating to general farm and operator characteristics, including cow numbers, record keeping methods, labor costs, and culling were asked in order to better understand the characteristics of the farms which used various reproductive management techniques. More in-depth questions were then asked in sections surrounding reproductive management and performance, heat detection methods, synchronization programs, and recent reproductive management changes implemented on the farm. A description of Ovsynch, Presynch with Ovsynch, Heatsynch, Cosynch, controlled internal drug-releasing intravaginal insert (**CIDR**) containing progesterone with PGF2α, and the Targeted Breeding Protocol were provided as an appendix to the reproductive management survey for reference and is included in Appendix 2.

Summary statistics were computed for continuous variables. Throughout the results, the "number of total responses" accompanies summary statistics, which indicates the total number of usable responses to a given question. Many questions allowed a respondent to check all answers which were applicable to the operation from a multiple choice list, and such questions were analyzed by tabulating the total number of responses and computing frequencies.

The survey described above was used in order to inform the economic based assessment of the use of various reproductive management techniques and technologies. Economic assessments were based upon the underlying assumption that respondents were seeking to maximize their individual profitability through their management decisions.

Budgets were developed in Excel (Microsoft, Seattle, WA) with the understanding that the costs associated with achieving various levels of reproductive performance and with the administration of reproductive management programs will vary across farms. For example, synchronization program costs include the cost of hormones, supplies, and the labor needed to administer the injections. Time required to administer injections is a function of facilities employed and the skill level of the person administering the treatments. Additionally, visual heat detection program costs vary depending on the hourly labor costs for those people performing the visual heat detection and the efficiency with which they detect heats.

Reproductive program costs were calculated on a per cow basis to facilitate comparison across different program types. Synchronization program costs were calculated on a per cow basis, although visual heat detection costs had to be adjusted to obtain a per cow program cost. Heat detection program costs were adjusted by dividing the cost of heat detection for a group of cows over the number of cows in the group. The time value of money was ignored due to the relatively small time frame analyzed and because programs were compared beginning at the same point in time. Therefore, a program's cost would only differ in timing due to increased number of services to achieve a 90% cumulative probability of pregnancy. The resulting differences due to time value of money were negligible for the analysis completed, which sought to highlight relative sensitivity to specific on-farm costs among programs.

In calculating program costs, the total cost of each program was calculated by first determining the number of months required to achieve a 90% cumulative probability of pregnancy under that program's resulting conception rate **(CR)** and heat detection rate **(HDR)**. The number of months necessary to achieve the 90% cumulative probability of pregnancy will clearly depend on the pregnancy rate **(PR)** achieved monthly, which will in turn be dependent on the CR and HDR achieved on-farm. By calculating the number of months over which the program would necessarily be administered to achieve the target cumulative PR, the total program cost can be calculated by multiplying the number of months the program will be administered by the monthly cost of the program. The services per conception were calculated for each program to achieve the cumulative probability of pregnancy of 90%. This means that a cow was assumed to be bred multiple times until an expected cumulative 90% chance of pregnancy occurred. Total costs across programs were compared by calculating all program costs subject to achieving the 90% cumulative probability of pregnancy.

The budgets allowed for entry of CR, HDR, labor efficiency in detecting heats or giving injections, artificial insemination (**AI**) costs, synchronization program costs, and the cost of labor. Additionally, the budgets allowed calculation of breakeven costs, indicating at what labor cost farms with a given set of characteristics should switch from one program to another. Using the cost of labor as an example, holding other on-farm costs constant, the authors calculated the labor cost below which the farm should utilize visual heat detection and above which the farm should switch to a synchronization program rather than use labor for heat detection tasks.

Heat detection program costs, assessed on a monthly per cow basis were calculated as follows:

$$\text{Heat Detection Program Cost/Cow/Month} = [((\text{TIME} * \text{OBS} * 30.4) * \text{LABOR}_{(HD)})/\text{COWS}] + \text{AID} + (\text{CI} * \text{HDR}),$$

where:

TIME = Minutes per day invested in heat detection for a single group of cows,

OBS = Number of times the group is observed per day,

$\text{LABOR}_{(HD)}$ = Cost of labor (in dollars per minute) to performs heat detection, COWS = Number of cows in the group,

AID = Cost per cow per period of heat detection aid utilized,

CI = Cost of an artificial insemination, and

HDR = Heat detection rate.

Synchronization program costs, assessed on a monthly per cow basis were calculated as follows:

Synchronization Program Cost/Cow/Month = $(P_{GnRH} * X_{GnRH}) + (P_{PGF2\alpha} * X_{PGF2\alpha}) + (MIN * INJ * Labor_{(Inject)}) + (CI * HDR)$,

where:

P_{GnRH} = Cost of GnRH per injection,

X_{GnRH} = Number of GnRH injections administered,

$P_{PGF2\alpha}$ = Cost of PGF2α per injection,

$X_{PGF2\alpha}$ = Number of PGF2α injections administered,

MIN = Minutes to give a single injection,

INJ = Total Number of injections in the series,

$LABOR_{(Inject)}$ = Cost of labor (in dollars per minute) to gives injections,

CI = Cost of an artificial insemination, and

HDR = Heat detection rate.

It should be noted that in the calculation of the program costs for both synchronization and visual heat detection programs, the cost of labor to perform the program was assessed according to the wage paid if the task was performed by paid labor or through the opportunity cost of the labor if unpaid labor was used. The cost of paid labor is easily accounted for via wage rates paid, although in order to assess the true costs associated with various reproductive management programs a charge for the opportunity cost of unpaid labor must also be included.

Using the heat detection and synchronization costs per cow per month, the total breeding program costs were calculated by summing the program costs per month over the number of months necessary to obtain a 90% cumulative probability of pregnancy. For example, if based on the inputted CR and HDR it is calculated to take four months in order to achieve a 90% cumulative probability of pregnancy, the total program cost was the monthly program cost multiplied by four.

Sensitivity analyses were performed, holding all other variables constant, for differing costs of labor, minutes required per injection, and efficiency of heat detection. Heat detection labor efficiency was altered by holding the minutes of heat detection per day constant while changing the resulting HDR. Efficiency in giving injections was altered by adjusting the labor minutes required per single injection. Additionally, breakeven labor costs were calculated to determine at which labor cost a synchronization program becomes less costly than a visual heat detection program, holding all other variables constant.

Baseline assumptions for CR, HDR, costs per AI, time spent on heat detection per day, time required to give a single injection, and costs per injection for GnRH and $PGF_{2\alpha}$ were obtained from the survey averages. The baseline values used were a CR of 38% (calculated using average services per conception (**SPC**) reported in survey of 2.66, as 1/SPC), HDR of 52% for visual heat detection, HDR of 100% under synchronization protocols (because cows are assumed bred by TAI), cost per AI of $17.30, time spent on heat detection of 2.15 labor hours per day (calculated from 3 observations, on average, of 43 minutes per observation, on average), 2.1 minutes required to give a single injection, and costs per injection of GnRH and PGF2α of $3.59 and $2.52 respectively. Program cost comparisons and sensitivity analysis focus on AI strategies. The synchronization protocol chosen for use in this example was Ovsynch, as it was the most common program used among those using synchronization in the survey, with 38% of those respondents using synchronization having employed Ovsynch for their cows. Ovsynch consists of an injection of GnRH, followed 7 days later by PGF2α, followed 48 hours later by a second GnRH injection, and followed by breeding 24 hours after the second GnRH injection (Pursley et al., 1995). These baseline assumptions were used to create a scenario in which sensitivity analysis could be performed to examine differences in costs due to changes in the parameters used.

2.3 Results and discussion

Survey results were organized into sections regarding farm and operator characteristics, reproductive management and performance, heat detection methods, synchronization programs, and recent reproductive management changes. These survey findings are discussed with regards to how they inform the underlying economic analysis of factors affecting which farms use various reproductive management programs. Economic and management implications were then parameterized using the survey results. Economic analyses, including sensitivity analyses of program costs to labor costs, visual heat detection efficiency, and time required to give injections, are presented to highlight those factors affecting on-farm decisions regarding reproductive program use.

The mean total herd size (including milking and dry cows) of survey respondents was 238 cows with a range of 20 to 1588 cows (57 respondents). Herds of less than 200 cows accounted for 69% of the respondents. In 2005, 40.1% of operations in the US dairy industry had less than 200 milk cows (NASS, 2007). Individual states varied considerably in farm size distributions, with New York, Michigan, and Wisconsin having had 53.5%, 45.5%, and 68.5% of their farms under 200 cows, respectively (NASS, 2007).

Number of heifers ranged from 0 to 1401 (56 respondents), with 7 farms reporting the use of a custom heifer raiser. The average number of bulls on the farms was 2, with a range of 0 to 13, and a mode of zero (53 respondents). The number of females per bull varied greatly across farms, from 13.2 to 250 females per bull, which illustrated the different ways bulls were used on these operations, ranging from solely natural breeding to a clean-up bull for only limited numbers of animals or problem breeders. A commonly used ratio is one bull for every 25 females (Fricke and Niles, 2003) and the range of survey responses for the number of females per bull indicated a wide range of reproductive management practices using natural service.

While a question specifically regarding whether the farm was an organic dairy was not included in this survey, reasons provided in response to various management related questions indicated whether the farm was managed organically. Of the 60 responses used in this analysis, 10% of respondents noted explicitly in survey responses that they operated organic dairies.

Facilities affect reproductive management decisions regarding ease and efficiency of heat detection and sorting cattle for administering shots or performing AI. Facilities used for housing heifers and cows were reported separately by respondents through an inclusive list which allowed respondents to select more than one housing option if different housing types were used throughout the year. For example, those farms which utilize stanchion barns for a portion of the year but also utilize pasture for a portion of the year for their heifers would have two responses to this question for their heifers. Survey results regarding housing facilities are provided in Table 2a.

Table 2 a. Summary of survey responses regarding facilities used to house cows and heifers

Housing Type	**Cows**	**Heifers**
	Percent of responses	
Stanchion Barn	27	5
Freestall Barn	29	23
Bedded Pack Barn	7	24
Drylot	13	13
Pasture	24	34
Other	0	1
Total Number of Responses	**105**	**107**

In order to complete an economic assessment of the costs associated with various reproductive management strategies, an estimate of the associated labor costs must be calculated. Respondents were asked questions regarding numbers of paid and unpaid employees and the salaries received by workers of the following levels: hired managers, full-time workers, part-time workers employed throughout the year, seasonal workers, and others not fitting any of these categories. Results regarding paid and unpaid labor usage in 2005 are provided in Table 2b. Note that the data collected regarding family and hired labor usage in this survey differs in structure from other surveys seeking data on number of employees. For example, Caraviello et al. (2006) reported the number of people involved in the management and operation of the farm, thereby providing valuable insight into the cows per worker and other efficiency measures. For economic based decision making, however, it is the total cost of all labor used that is important. The cost of paid labor is easily assessed via survey responses for wage rates paid, although in order to assess the true costs associated with various reproductive management programs a charge for the opportunity cost of unpaid labor must also be included.

Table 2 b. Summary of survey responses to questions regarding paid and unpaid labor usage in 2005 with corresponding means (number of responses = 35)

Worker Type	Number of workers	Months worked per year	Hours worked per month	Wage rates reported for paid labor	
				Hourly Pay	Annual Salary
Unpaid Labor					
Spouse(s) of Operator(s)	1.3	11.6	235		
Children over 12	1.6	9.9	106		
Other unpaid labor	1.8	7.4	104		
Paid Labor					
Hired managers/operators	1.6	12	273	$12.78	$30,742
Full-time	4.75	11.9	220	$8.83	$23,360
Part-time	1.5	10.9	154	$8.16	$6,667
Seasonal	3.4	4.9	150	$8.71	

Record keeping is integrally important to the success of a reproductive program. Records regarding observed heats, treatments administered, behavior observed, or past challenges aid in efficient decision making on the dairy operation. Respondents were asked about all of the herd management record keeping systems used on the farm. Sixty-nine responses from 60 farms were received regarding record keeping, indicating that some farms utilized more than a single method. Overall 41% of responses were for paper records, 28% used their Dairy Herd Improvement Association, 14% used PC Dart (Dairy Records Management Systems, www.drms.org/pcdart.htm), 12% used Dairy Comp 305 (Valley Agriculture Software, Inc., Tulare, CA) or Scout (Valley Agriculture Software, Inc., Tulare, CA), and 6% used another method. The most common entry for a method other than those options given was an in-house developed Excel (Microsoft, Seattle, WA) spreadsheet designed for individual herd record keeping.

Survey questions regarding cull rates and reasons for culling were asked, primarily to assess how much culling was due to reproductive failure. The average cull rate reported was 20.5% across the 55 herds which responded to this question, with reported figures ranging from 0 to 41%. The average cull rate of 20.5% was lower than expected, although previous studies have found that average cull rates increase with herd size (Hadley et al., 2006), and 69% of the sample is comprised of herds with less than 200 cows. On average, of the 31 respondents answering this question, 19% of total culls were due to poor reproductive performance. This finding is similar to the previous findings of Hadley et al. (2006) who indicated that 18.9% of total culls were attributed to reproductive performance across all of the states included in their study. Clearly, with nearly a fifth of culls being attributed to reproduction, the reproductive performance of the dairy farm has far-reaching implications for not only reproductive efficiency, but culling patterns as well.

Survey data collected on overall reproductive management and performance included average age of heifers at first service and first calving, days open, calving interval, voluntary waiting period, SPC for heifers and cows, and length of dry period. The average calving interval found in this survey was 13.1 months, which is similar to the previously published survey data of Caraviello et al. (2006), who reported 13.8 months as the average calving interval. The average SPC reported in this survey were 2.66 for cows and 1.8 for heifers. A summary of the responses to the questions regarding general reproductive management, including the number of respondents answering each individual question, is provided in Table 2c.

Table 2 c. Summary of survey responses to questions regarding general reproductive management parameters with corresponding means

Question	Response	Number of respondents
Age of heifers at first service (months)	15.5	53
Age of heifers at first calving (months)	24.5	52
Percent of lactating cows open greater than 150 days in milk	19.6	48
Average number of days open	106.8	46
Voluntary waiting period (days)	63	51
Average number of days to first service	70.7	51
Average calving interval (months)	13.1	50
Average length of dry period (days)	54.3	58
Percent of farms using AI to breed cows	78	58
Percent of farms using AI to breed heifers	64	57
Average percent of cows being bred AI of farms using AI	87	45
Average percent of heifers being bred AI of farms using AI	89	37
Average cost per straw of semen used on cows ($)	17.30	43
Average cost per straw of semen used on heifers ($)	18.83	35

A series of in-depth questions regarding AI usage were asked in the survey, including whether AI is used on cows and/or heifers, and the average cost of semen used. Overall, 78% and 64% of farms surveyed indicated that AI was used to breed cows and heifers, respectively, for at least some services. Caraviello et al. (2006), in their survey of dairy farms, also sought to determine the extent of AI use and found that 58 of the 103 herds surveyed, or 56%, used solely AI. Zwald (2003), in comparing 14,500 herds, found that approximately half of the herds used a bull for at least some services.

In order to assess the reasons for not exclusively using AI to service cows and heifers, respondents were asked to select reasons for not using only AI. For cows, the most frequently cited reason was a lack of labor for heat detection and to perform AI, with 35% of total responses (34 total responses for cows). Additionally, semen costs were cited in 24% of responses, other reasons not listed were cited in 20% of responses, using a clean-up bull was cited in 12% of responses, and lacking handling facilities was cited in 9% of responses as to why AI alone was not used to breed cows. Similar to cows, the most prominent reason reported for not using solely AI on heifers was a lack of labor for heat detection and to perform AI, with 29% of total responses (34 total responses for heifers). Heifer responses differed from cows in that 26% of responses cited a lack of handling facilities, 21% cited other reasons not listed, 12% cited semen costs, and 12% cited the use of a clean-up bull as the reasons that solely AI was not used to breed heifers.

Several respondents for both cows and heifers indicated that there were reasons for not using solely AI beyond those listed in the survey. Some of those other reasons given in survey responses were increased convenience with natural service, poor HDR, seasonal calving schedules that required a tight breeding window which is better accomplished through natural service, poor CR with AI, that natural service allows longer seasons for pasture use, and that natural service yielded better results during summer heat stress.

Accurate and efficient heat detection is crucial in the management of an AI-based reproductive program and is necessary for managing a profitable dairy farm (Nebel and Jobst, 1998). Nebel and Jobst (1998) found that accurately and efficiently performing heat detection was the major limiting factor for reproductive performance on many dairy farms. Survey respondents were asked to select from a multiple choice list all heat detection methods used in 2005 in cows or heifers. Heat detection methods provided in the survey included visual heat detection without aides, passive mount detectors, and electronic heat detection aides. Respondents were also invited to add any additional methods that they employed that were not listed as options in the survey. Passive mount detectors listed for selection in the survey included Kamar Heatmount Detectors (Steamboat Springs, CO), chin ball markers, tail chalking or crayon, and a section for other passive mount detectors. Electronic aides listed in the survey included HeatWatch Estrus Detection System (CowChips, LLC, Denver, CO), pedometers, AfiAct System and associated herd management software (SAE Afikim, Kibbutz Afikim, Israel), or other electronic aided heat detection methods. Multiple responses were allowed for both cows and heifers, and the total number of responses was 82 for cows and 53 for heifers. A summary of the heat detection methods used by respondents is presented in Table 2d.

Table 2 d. Summary of survey results to questions regarding heat detection methods used for cows and heifers (number of responses = 82 and 52 for cows and heifers, respectively)

Type of heat detection method		Cows	Heifers
		Percent of responses	
Visual heat detection	Visual heat detection without aides	62	74
Passive mount detectors	Kamar HeatMount Detectors	5	2
	Chin ball markers	0	0
	Tail chalking, crayon, or paint	20	11
	Other passive mount detectors	2	6
Electronic aided heat detection	HeatWatch	1	2
	Pedometers	0	0
	AfiAct and associated herd management program	1	0
	Other electronic aided heat detection program	0	0
Other	Other method not categorized above	9	5

Visual heat detection without the use of aids was the most prominent heat detection method used for both cows and heifers. Also for both cows and heifers, tail chalking, crayons, or paint was the second most common method of heat detection employed. Caraviello et al. (2006) also found that tail chalk was the most common heat detection aid out of their list of tail chalk, pedometers, pressure patches, and other, with tail chalk receiving 60 of the 80 responses regarding heat detection aides used.

If visual heat detection was being used in either cows or heifers, respondents were asked to provide additional information on the times per day animals were observed, for how long animals were observed each time, and who was responsible for heat detection. Of those farms reporting the use of visual heat detection in cows, on average 78% of the cows on those operations were bred solely by visual heat detection. Of those farms reporting the use of visual heat detection in heifers, on average 90% of the heifers on those operations were bred solely by visual heat detection. The average overall HDR reported for cows was 52%.

On average, cows and heifers were observed for estrus 3 and 2.2 times per day, respectively. These observation frequencies for heat detection were similar to those found by Caraviello et al. (2006) where cows were reportedly checked for estrus 2.8 times per day on weekdays and 2.5 times per day on weekends. In addition, Stevenson (2003) indicated that in a survey of top dairy herds as measured by yearly rolling herd averages, cows were observed for estrus 3.1 times per day, on average, and that this was likely responsible for successful AI breeding. The most commonly reported times for heat detection were moving cows, pre-milking and post-milking, and while feeding. Of the 31 farms reporting heat detection times the average times spent observing cows and heifers were 43 and 19.5 minutes per observation, respectively. Compared to previous survey results by Caraviello et al. (2006) which indicated cows were observed for 27 minutes on weekdays and 25 minutes on weekends per observation, cows were reportedly observed for longer and heifers were observed for a shorter time period.

Questions regarding who was responsible for heat detection did not provide multiple choices for respondents, but allowed respondents to indicate people as they wished. Job levels were then grouped and frequencies were calculated. Of the 42 total responses, the person most commonly responsible for heat detection was the owner with 55% of responses, followed by a shared responsibility by all employees which received 26% of responses, herdsman with 17% of responses, and milkers with 2% of responses. The person responsible for heat detection will likely affect the true cost of a heat detection program as the owner or herdsman will likely have a higher labor cost than other farm employees.

Separate responses regarding synchronization programs were invited for cows and heifers to allow for different management programs. In total, 56 and 45 responses were received for whether any synchronization program was used for cows and heifers in 2005, respectively. Synchronization programs were used proportionately more in cows than heifers, with 45% of responses indicating the use of some synchronization program in cows versus only 27% in heifers. In comparison to previous survey analysis by Caraviello et al. (2006) which found that the majority of herds in their survey used hormonal synchronization or TAI programs, a significantly smaller proportion of survey respondents used synchronization programs. Possible explanations for the smaller proportion of herds having used synchronization programs are the differences in average herd size between the two surveys or even the differing sampling methods. Given that prior studies have surveyed farms associated with a given organization, the type of organization that a survey is associated with may affect the willingness of survey participants to use certain technologies.

Respondents who indicated no synchronization programs were used were asked to select reasons why they did not use a synchronization program from a multiple choice list. Possible reasons provided for cows or heifers included the expense of synchronization programs, manager or breeder preference to breed cows off of visual heat detection, inadequate facilities to restrain cows for injections, lack of management time to manage a synchronization program, not being convinced of the benefits of synchronization, poor previous CR to TAI, and other. A summary of the responses to why synchronization programs were not used is provided in Table 2e.

Table 2 e. Summary of survey results regarding reasons why synchronization programs were not used for cows or heifers (number of responses = 25 and 43 for cows and heifers, respectively)

Reason	Cows	Heifers
	Percent of responses	
Synchronization protocols too expensive	16	12
Prefer to breed to visually detected estrus	28	24
Inadequate handling facilities	4	21
Lack of management time	8	9
Not convinced of benefits of synchronization	16	12
Poor previous conception rate to timed AI on farm	8	3
Other	20	21

In order to determine which synchronization programs were used, a list of common programs was provided and respondents were asked to select any programs they used on cows or heifers or to provide information on any other protocols they have used, and explain what proportion of the herd each program was used on. Separate answers were encouraged for heifers and cows to allow for differing management programs. More responses for programs used were received than the number of farms reporting having used a synchronization program as several farms used multiple synchronization programs. Given the small sample of farms which used synchronization programs for heifers in 2005, the proportion of the herd having used each program was not calculated due to insufficient number of farms using each program to make the proportion of the herd valuable. Table 2f provides a summary of the responses for cows and heifers related to synchronization programs.

Table 2 f. Summary of survey responses regarding synchronization programs used (number of responses = 53 and 15 for cows and heifers, respectively)

Question	Cows	Heifers	Percent of cows on which the program was used
	Percent of responses		
Ovsynch	38	33	42
Presynch	13	7	72
Cosynch	6	0	57
Heatsynch	2	0	10
Controlled internal drug-releasing intravaginal insert (**CIDR**) with PGF2α	19	20	7
Targeted breeding protocol	6	20	63
Single PGF2α injection (with AI upon detected estrus)	13	20	
Single PGF2α injection with timed AI	2	0	
Other	2	0	14

Farms were also asked to provide cost information for any treatments used in cows or heifers. Costs per dose were collected and ranged significantly across farms in the survey. For example, PGF2α costs per dose ranged from $1.25 to $6.00 per dose. Given the large variation in costs per dose reported, the costs of hormones available to a specific farm may indeed be different than those available to another, and such differences may alter decisions made regarding reproductive management programs. Overall, the average costs per dose reported for 2005 for all respondents were $3.59 per dose for GnRH, $2.52 per dose for PGF2α, and $9.22 per CIDR. When farms were sorted into groups of 100 cows or less, 101 to 200 cows, and more than 200 cows, the costs per injection varied significantly across farm sizes. Costs for GnRH per dose were $4.49, $3.13, and $2.70 per dose for those size categories described above. PGF2α costs by those same size categories were $3.10, $2.13, and $2.10 per dose.

In order to more completely assess a farm's reproductive management program and decisions, respondents were also asked the amount of time needed per cow to give a single injection and the person responsible for giving synchronization program related injections. Time required for injections and the facilities used for injections varied considerably across farms, ranging from 17 seconds where shots are given to cows already in the milking parlor to 10 minutes where heifers must be caught in a freestall and put into a headlocks one at a time. Given the wide variation in facilities used and the time it takes to give an injection, ideal reproductive management programs will be different for farms with varying circumstances. Across the wide variety of facilities used for cows and heifers on the 26 farms responding to this question the average time taken to give an injection was 2.1 minutes. Twenty-seven responses were received regarding the person responsible for injections related to synchronization programs and were categorized. The person on the dairy responsible for synchronization-related injections the majority of the time was the owner with 59% of responses. Following the owner, in order of frequency were the herdsman or herd manager, milker labor, AI technicians and farm family members. The person responsible for giving injections affects the cost of a synchronization program due to differences in costs of labor across farm workers.

Respondents were asked to comment on their most recent major reproductive management change and report in what year it took place. Several farms indicated the initiation of a synchronization program or moving to AI from natural service as their latest reproductive management change. In light of recent developments in reproductive technologies for on-farm use, such as ultrasound for pregnancy detection and sex-sorted semen allowing altered sex ratios, perhaps the most surprising changes reported were the several farms that reported a departure from the use of reproductive technologies. Examples included giving up a synchronization program in favor of unaided visual heat detection or moving from an AI based breeding system in favor of natural breeding. AI has been said to have been the most readily accepted technology on the dairy farm, with the exception of the milking machine (Stevenson, 2003). Even so several reasons were given for using bulls over using AI, ranging from costs associated with AI to the belief that the bull was better at heat detection and yields a higher CR. Other changes reported included increased time devoted to visual heat detection rather than relying upon heat detection aides, switching AI technicians, or ceasing use of hormones for synchronization.

With several farms reporting their most recent change being reverting to natural service it should be highlighted that there are several concerns associated with keeping dairy bulls on the farm. Costs associated with the bull can range from daily maintenance costs to costs for diseases spread by bulls throughout the herd. In addition, the bull-to-female ratio on the particular farm and the number of pregnancies produced by the bull each year will affect the cost per pregnancy associated with using natural service (Fricke and Niles, 2003). Increased HDR and CR are common reasons for maintaining a bull within the dairy herd, but without testing, the fertility of the on-farm bull is unknown. In addition, Schutz (Purdue University, September 2007, personal communication, e-mail) highlights that while using a bull for natural service may seem like a good way to increase CR, in reality additional factors may be introduced that are difficult to monitor, such as infertility, reduced breeding success due to sperm abnormalities, or decreased libido (particularly during hot weather).

Fricke and Niles (2003) warn that in many cases, costs of maintaining bulls can approach or exceed AI related costs without consideration of the long-term genetic advantages of using AI. Overton (2005) states that the additional lost opportunity cost of the room which could be used to house more lactating cows if the bulls were removed should also be recognized. Perhaps the largest factor to consider when assessing the decision to use bulls for natural service is the safety of those employees, family members, or others who may visit the farm. Schutz (Purdue University, September 2007, personal communication, e-mail) pointed out the often overlooked danger for farm employees unfamiliar with working with dairy bulls, particularly on expanding dairy farms where bulls may be combined with employees with limited experience in working with cattle.

Of those 26 farms detailing their most recent change in response to the survey, 77% of farms latest reproductive management change took place between 2000 and 2005. With such a high percentage of farms making recent reproductive management changes, increased volumes of research revolving around reproductive management programs are warranted by industry action.

Johnson (2005) applied the principle of diminishing marginal returns to dairy farm inputs to highlight that given decreasing marginal benefits of a costly input, the best economic returns are nearly always found at some level of that input which is lower than the level that gives the highest output. Further, Johnson (2005) explains that the higher the cost of the input relative to the value of the output, the less of that input you will invest in order to be profitable. These economic principles, when applied to dairy farm inputs which produce decreasing marginal effects, imply that farmers must select levels of inputs which maximize their profitability. Further, the levels of inputs chosen to maximize profitability will almost certainly not be those levels which maximize production. For example, seeking an 80% HDR through visual heat detection may be attainable, but the time and money invested in doing so may be difficult to justify economically.

Prior reproductive performance was important in assessing which reproductive management program was the optimal program for a given farm. Farms which have already experienced success in their reproductive management programs will have less economic incentive to pursue reproductive management changes due to decreased marginal returns from increased reproductive performance. Overall, farms which have experienced success with their current programs stand to gain less from reproductive improvements than farms which have faced reproductive performance challenges.

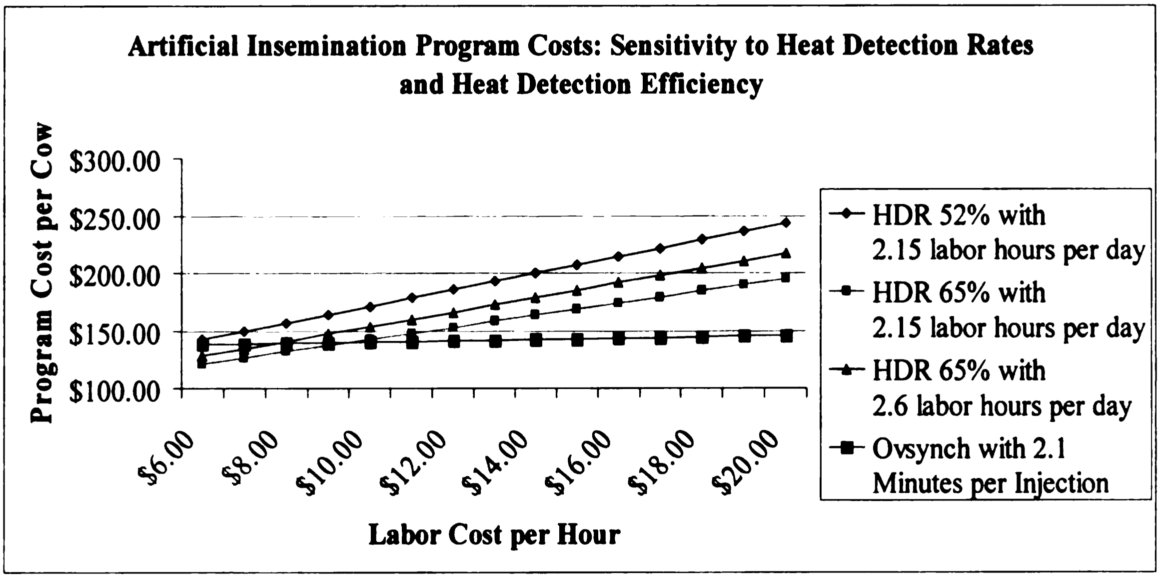
Other farm management factors, perhaps not as easily quantified as labor or treatment costs, exist when decisions regarding reproductive management are made. For example, farm managers may prefer to work in a particular environment, or to work with only family labor versus expanding the dairy and managing several employees. Human resource management challenges were identified by Caraviello et al. (2006) in their survey of dairy herd managers, where managers identified finding good employees as the greatest labor challenge, followed by training and supervising employees. Managers of smaller dairies often supply much of the day-to-day labor and focus on herd or crop management activities. Increased dairy farm size leads to focus being placed on new areas, such as financial requirements and implications of expansion; hiring, training, evaluating and retaining employees; sourcing adequate inputs (e.g., land, feed, replacements); meeting environmental and zoning regulations; and managing public relations (Hadley et al., 2002). Managers who enjoy day-to-day hands-on management of the dairy herd or cropping operation may seek ways other than expansion to increase profitability. These management preferences and farm management goals must be taken into account when determining farm-specific optimal reproductive management programs.

Use of synchronization programs aimed at decreasing the time, and therefore expense, devoted to heat detection aim to either shorten the time during which cows or heifers must be observed, or eliminate the need for heat detection completely with TAI. Timed ovulation allows for breeding cows by appointment, thereby eliminating the need for heat detection, and has similar pregnancy outcomes to those obtained through AI performed after heat detection (Pursely et al., 1997). The benefits of adopting a program designed to decrease heat detection duties will be dependent on the HDR and efficiency achieved on the dairy previously. Given the farm-specific aspects of reproductive management decisions the cost effectiveness of using a systematic breeding program must be assessed for each herd to decide if such a management program is the optimal choice (Nebel and Jobst, 1998).

Focusing on reproductive programs using AI, program costs for visual heat detection and synchronization protocols were calculated and sensitivity analyses performed. Using the base scenario described in Materials and Methods with a group size of 100 cows, costs for visual heat detection without aides and synchronization via Ovsynch were focused upon. Costs of AI programs are presented in Figure 1. Program costs for four reproductive management programs are displayed together to allow comparison across increasing labor costs. As labor costs increased, holding all other parameters constant, different reproductive management programs became the optimal program to achieve the 90% cumulative probability of pregnancy. The differences in the slopes of the lines for the HDR achieved through visual heat detection versus the line for Ovsynch indicate the differing relative labor intensities of the programs. Visual heat detection requires more labor hours per cow and was more sensitive to increased labor costs than the administration of a synchronization program.

The effect of labor efficiency in heat detection is highlighted in Figure 2a by comparing the costs associated with achieving a 65% HDR with 2.15 labor hours per day invested versus the 65% HDR with 2.6 labor hours per day invested. Farms with higher levels of labor efficiency in heat detection have lower per cow costs than those with less efficient heat detection. The more efficiently the farm was able to detect heats visually, the higher the cost of labor before the Ovsynch program becomes the least cost program. Simply stated, the better the current performance in visual heat detection, the higher the labor cost must be before synchronization with Ovsynch becomes a lower cost program than visual heat detection. This supports the contention that current farm-level reproductive performance is important in assessing the lowest cost program for a particular farm.

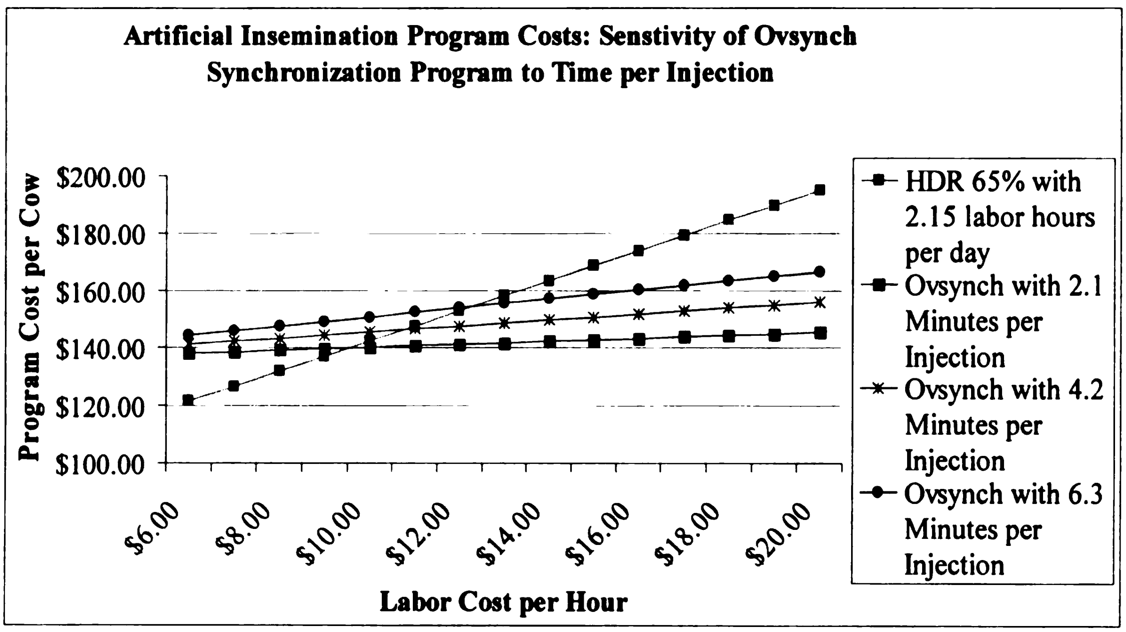
Figure 2 a. Artificial insemination program costs: sensitivity to heat detection rates and heat detection efficiency



Given the base scenario depicted above, with a HDR of 52% achieved through 2.15 labor hours per day of heat detection being compared to the Ovsynch program, the two programs have the same cost at a labor cost of $5.39 per hour. Therefore, at any labor cost greater than $5.39 per hour, the Ovsynch program is less costly than visual heat detection. If a 65% HDR requires 2.6 labor hours per day of heat detection to achieve, the labor cost below which visual heat detection was less costly is $7.74 per hour. With greater efficiency in detecting heats, where a 65% HDR was achieved through 2.15 hours of labor per day, the labor cost below which visual heat detection was less costly than Ovsynch is $9.55 per hour.

Another key parameter in determining and comparing program costs is the time required to give an injection in the synchronization protocol. Program costs were calculated for the Ovsynch program with 2.1, 4.2, and 6.3 minutes per shot. Program costs, compared with a visual heat detection program in which a HDR of 65% was achieved with 2.15 labor hours per day are presented in Figure 2b. Figure 2b clearly displays that the visual heat detection program was the least costly at relatively low labor cost, and the cost of labor at which the synchronization program becomes the lower cost program depends on the time required per injection. Using a visual heat detection program where a 65% HDR was achieved through 2.15 labor hours per day, the Ovsynch protocol becomes the lower cost program at a labor cost of $9.55, $10.73, and $12.26 for 2.1, 4.2, and 6.3 minutes required per injection, respectively. The longer it took for a single injection to be administered, the more sensitive the program was to the cost of labor, and the higher the labor cost must be before the synchronization program is the lower cost program in comparison to visual heat detection.

Figure 2 b. Artificial insemination program costs: sensitivity of Ovsynch synchronization program to time per injection



2.4 Conclusion

This analysis built upon prior reproductive management studies and dairy industry surveys to inform the economic analyses of various reproductive management programs.

Costs associated with reproductive technologies, and with a given level of reproductive performance, vary considerably across farms, illustrating the need for farm-specific costs in the analysis regarding which reproductive management program is best for a given farm operation.

Reproductive program costs were found to be highly sensitive to on-farm labor costs. As labor costs increased, holding all other parameters constant, differing reproductive management programs became the lowest cost program of achieving the performance parameter of a 90% cumulative probability of pregnancy. In addition, different types of reproductive management programs had different relative sensitivities to costs, such as on-farm labor costs. For example, visual heat detection requires more labor hours per cow and therefore is more sensitive to increasing labor costs than a synchronization program. Current farm-level reproductive performance was also found to be important in assessing the lowest cost program. Farms which have obtained high levels of visual heat detection efficiency, for example, have less incentive to adopt a synchronization program than those farms with less efficient visual heat detection.

Overall, reproductive management programs differ across farms due to varying on-farm costs, facilities, farm goals and values, and management styles. These factors, in addition to labor availability, labor costs, ease of cattle handling, and previous levels of reproductive performance helped to determine why different farms select different reproductive management techniques and technologies when seeking to maximize their profitability through reproductive performance.

CHAPTER 3: DECISION SUPPORT FOR REPRODUCTIVE MANAGEMENT TECHNOLOGY AND PROGRAM ADOPTION ON U.S. COMMERICAL DAIRY FARMS

3.1 Introduction

Economic analysis of reproductive management programs and technologies is motivated by the fact that reproductive performance and efficiency of dairy cattle affects dairy herd profitability through milk yields and revenues, numbers of days open, and potentially expensive culling repercussions of poor reproductive performance. In short, reproductive performance and efficiency are critical drivers in determining the profitability of the dairy herd.

Efficient and accurate heat detection is crucial to achieve optimal management of individual cows and the major limiting factor to reproductive performance is estrus detection (Nebel and Jobst, 1998). In addition to challenges with detecting cattle in estrus, first artificial insemination **(AI)** service conception rates **(CR)** for cows have fallen substantially from 60% to 40% since AI has been practiced in the Unites States (Nebel, 2002). Movement towards increased herd sizes and higher producing cows has been associated with decreases in reproductive efficiency (Lucy, 2001). Combining the challenges of identifying cattle in heat, decreasing CR, and the need for management to adjust techniques and methods as herd sizes increase has led to industry-wide challenges with achieving optimal reproductive performance. The decline in reproductive performance is likely partially explained by physiological adaptations to high milk production (Lucy, 2001), although other factors are likely responsible as well. In response to challenges associated with achieving reproductive efficiency, several reproductive management programs have been developed to synchronize estrus or ovulation, thereby greatly reducing or entirely eliminating the need for visual estrus detection on dairy farms. The costs associated with visual heat detection are heavily dependent on the efficiency with which on-farm labor was able to detect heats, although labor costs and other farm factors will influence the program costs associated with visual heat detection as well.

Dairy farmers can benefit from decision-support which aids them in selecting the optimal available reproductive management program or technology for their operation. "Rules of thumb" can aid producers in deciding which programs may potentially work on their operation, although on-farm support can aid farmers in selecting the optimal program for their situation specifically. Producers must remember that program or technology adoption decisions must be made subject to the available technology set, skill sets of managers and other farm labor, previous levels of reproductive performance, and farm goals and values. A decision support-tool was developed for on-farm use to aid dairy farmers in decision making surrounding economically optimal choices for reproductive management technologies and programs. Dairy farmers, veterinarians, extension agents, and consultants in the dairy industry could all benefit from a user-friendly decision support tool capable of providing economic analyses of reproductive management programs and technologies.

The decision-tool developed in this analysis is based upon a model which was developed to calculate the expected value associated with a given reproductive program, subject to user-inputted farm-specific values. Program values are calculated by determining the expected revenues and expected costs. Program costs are calculated subject to user-defined cutoff points after which the cow is no longer bred, but is assessed at the retention pay-off (**RPO**) of an open cow at that point in time. Technologies and programs which can be analyzed using the on-farm decision tool include synchronization programs (e.g., Ovsynch, Cosynch, Targeted Breeding Protocol^{TM} (Pharmacia-Upjohn, Kalamazoo, MI), Presynch), CIDRs, passive visual heat detection aides, and electronic heat detection aides. Common passive estrus detection aides include Kamar Heatmount Detectors (Steamboat Springs, CO), chin ball markers, and tail chalk or crayon. Common electronic aides include HeatWatch Estrus Detection System (CowChips, LLC, Denver, CO), pedometers, AfiAct System and associated herd management software (SAE Afikim, Kibbutz Afikim, Israel). The extent to which heat detection aides improve reproductive performance will depend on farm-specific characteristics and farm management abilities and knowledge. The tool was designed to be flexible in allowing user-specified programs to be entered as sequences of shots or combinations of heat detection aids, thereby allowing producers to alter programs or to assess new programs as they become available.

Several spreadsheet-based models exist to aid producers in decision making regarding reproductive programs. Groenendaal et al. (2004) constructed a spreadsheet based model to aid in optimal breeding and replacement decisions on the dairy farm. The results of Groenendaal et al. (2004) indicated that the costs per additional day open ranged from $0 to $3.00 in which heifers were available as replacements (using the typical input parameters for Pennsylvania); the results were dependent on many factors, four of which were availability of replacement heifers, lactation number, milk production levels (of individual cow and herdmates) and the calving interval. Meadows et al. (2004) developed a spreadsheet based model to allow comparisons of scenarios and to determine the economic effect of varying reproductive performance in dairy herds. Meadows et al. (2004) highlight that "… inefficient production becomes marginally more costly to producers as performance declines and warrants increased attention." In short, the better the present reproductive performance of a herd, the less economic incentive there is to improve that performance (Meadows et al., 2004).

Flexibility to incorporate varying farm systems, on-farm costs, and labor scenarios is important in creating a tool that can be used for decision making across various farm operations. A difficult balance must be struck in spreadsheet-based models intended to be used on-farm as decision support between incorporating the complexity needed to adequately model the problem while retaining simplicity to make the model user-friendly and easily understood. Tools which allow reproductive program protocols to be parameterized by the user, in terms of what injections are given within a program, will be better suited to adapt to new programs as they are developed.

The objective of this paper is to describe a user-friendly spreadsheet tool capable of farm-specific analysis of values of reproductive management programs which use AI. The decision support tool described in this paper is capable of assessing any user-specified synchronization program through entering program protocols and the farm-specific costs for each portion of that protocol. Reproductive performance, or expected reproductive performance, for a given farm operation under each program can be entered, and sensitivity analysis to key parameters is easily completed. Further, the tool was designed to allow flexibility by allowing the farm to specify CR, AI submission rate, labor costs, and other reproductive parameters and associated costs. The goal of the tool itself was to provide decision support to dairy farmers as they make reproductive technology and program adoption decisions for various groups of cattle on their dairy farm. Decisions made for individual groups are possible within the tool as costs per cow are adjusted according to the number of cattle in the group.

3.2 Materials and methods

Tool description and development

The decision-tool was developed in Excel (Microsoft, Seattle, WA) to determine farm-specific or individual group-specific costs and values associated with achieving various levels of reproductive performance through the use of various reproductive management programs. All reproductive management decisions made within the tool are assumed to use AI as the sole breeding method.

The decision-tool allows user-specified inputs for key farm values and costs associated with reproductive management programs and technologies. The inputs allowed into the decision-tool are explained in the sections that follow. AI service cutoff criteria are necessary in order to compare values across reproductive management programs. Values of reproductive programs are assessed subject to two possible cutoff criteria for breeding, namely a herd-manager specified number of AI before a cow will no longer be bred or a herd-manager specified cumulative probability of pregnancy. In order to calculate the cumulative probability of pregnancy, the pregnancy rate **(PR)** is estimated by:

PR = CR * SUBRATE,

where

PR = pregnancy rate,

CR = conception rate, and

SUBRATE = AI submission rate.

Using the estimation above, the cumulative probability of pregnancy can be calculated after each AI. Clearly the PR is dependent on the CR and AI submission rate, and therefore changes in the CR or AI submission rate will affect how many services are necessary to achieve a specified cumulative probability of pregnancy. In order to compare values across synchronization programs the values must be assessed subject to achieving a specified level of reproductive success and discounted to a specific point in time. If the decision is being assessed by using a cutoff number of AI after which the cow will no longer be bred, then the CR and AI submission rate will affect the remaining probability that the cow is not pregnant (or remains open) after that predetermined cut-off number of services. For instance, scenarios can be assessed in which cows are bred for a predetermined number of AI. Costs can be extremely sensitive to the cutoff criteria employed, and such sensitivities are assessed.

Using a scenario in which the CR was 35% and the AI submission rate was 50%, the cumulative pregnancy rate is calculated in Table 3a for illustration. For comparison, the cumulative pregnancy rate for a synchronization program scenario in which the AI submission rate is 100% and the CR is 35% is shown in Table 3b. The breeding in which 90% cumulative probability of pregnancy is achieved is highlighted in both Tables 3a and 3b.

Table 3 a. Calculating cumulative probability of pregnancy (AI submission rate = 50%, CR= 38%)

Breeding	Probability of pregnancy	Remaining probability of being open	Cumulative probability of pregnancy
1	0.18	0.83	0.18
2	0.14	0.68	0.32
3	0.12	0.56	0.44
4	0.10	0.46	0.54
5	0.08	0.38	0.62
6	0.07	0.32	0.68
7	0.06	0.26	0.74
8	0.05	0.21	0.79
9	0.04	0.18	0.82
10	0.03	0.15	0.85
11	0.03	0.12	0.88
12	0.02	0.10	0.90

Table 3 b. Calculating cumulative probability of pregnancy (AI submission rate = 100%, CR= 35%)

Breeding	Probability of pregnancy	Remaining probability of being open	Cumulative probability of pregnancy
1	0.35	0.65	0.35
2	0.23	0.42	0.58
3	0.15	0.27	0.73
4	0.10	0.18	0.82
5	0.06	0.12	0.88
6	0.04	0.08	0.92
7	0.03	0.05	0.95
8	0.02	0.03	0.97
9	0.01	0.02	0.98
10	0.01	0.01	0.99
11	0.00	0.01	0.99
12	0.00	0.01	0.99

In order to allow the most accurate decisions possible for individual cattle groups, herd managers are able to enter values for cow or heifer groups, thereby creating specific analysis for cattle groups on the farm, rather than imposing the same values (or program) on the entire herd. For example, given that group-specific input values were available, the cost calculations are sensitive to the number of cows on a given program, and the tool is able to determine the economically optimal program for given groups of cows while taking into account any economies or diseconomies of scale associated with the number of cows managed under a specific reproductive management program. The group size is most important when assessing programs using visual heat detection because the hours of labor spent detecting heats for a group is spread over the number of cattle which are watched at a single time. For example, if an hour a day is spent detecting heats on a group of 50 cows, the per-cow costs associated with labor for heat detection would be higher than if that same time was spent watching a 100 cow group.

Time required to administer injections is an important component of cost and is a function of facilities employed and skill level. Similarly, visual heat detection program costs vary depending on hourly labor costs and efficiency with which heats are detected. Reproductive program costs were calculated on a per cow basis to facilitate comparison across programs and herd sizes. Heat detection program costs were adjusted to obtain a per cow basis by dividing the cost of heat detection for a group of cows over the number of cows in the group. In calculating the program costs for both synchronization and visual heat detection programs, the cost of labor to perform the program was assessed as wage paid if the task was performed by paid labor or as opportunity cost of the labor if unpaid labor was used. Opportunity cost is cost of having that labor participate in the reproductive management tasks rather than in the next best alternative activity. Due to the fact that many herds, especially smaller herds, utilize unpaid family or managerial labor for their reproduction program, in order to assess the true costs associated with various reproductive management programs a charge for the opportunity cost of unpaid labor must be included.

While heat detection rate is the percentage of cows correctly detected in estrus in a 21 days period, AI submission rate is the percent detected in heat and bred in that same period. The cumulative probability of pregnancy was defined as the sum of PR from the first AI through the most recent AI. In calculating number of services necessary to reach a cumulative probability of pregnancy, the CR was assumed to decrease as AI number increased. The second and third or later AI were assumed to be 90.7% and 81.4% of the first AI CR, based on Cassell et al. (2001). The AI submission rate was held constant for each program.

Once the predetermined cutoff was achieved, the cow's value was included by incorporating her retention pay-off **(RPO)**. The RPO is the difference in total net returns from keeping the cow in the herd versus culling and replacing her immediately. The RPO is defined as the total additional profit expected from attempting to keep the cow until her optimal age compared to immediately removing her from the herd and replacing her (taking into account changes in involuntary culling); the higher the RPO, the more valuable the animal and, thus, the larger the loss if the cow is culled at that time (Groenendaal et al., 2004). The RPO values used were obtained using DairyVIP© version 1.1 (De Vries, 2006). Input values used to obtain the RPO for pregnant and open cows were from De Vries (2006) unless otherwise specified.

For each period, the RPO of a cow which conceived in that period was multiplied by the CR for that period and discounted. The probability that the cow remained open after the last breeding period was multiplied by the RPO of an open cow in the period in which the cutoff criteria was reached. The cost per breeding for calculating the RPO was set at zero because breeding costs were accounted for in calculating the net present value (NPV) of the breeding programs. The RPO values included in the model were greater than zero and values that were negative were evaluated at zero. Feed and yardage of $2.00 per day was charged in the calculating of the breeding program cost for each period that the cow remained open after her first AI. An annual discount rate of 9% was used for all calculations, as an entry for the RPO calculation as well as for calculating the NPV of the breeding programs (Wolf et al. 2002). Cows were assumed to be bred beginning at their third month in lactation and were bred once during every eligible period until the cutoff criteria was reached, which in the example cases used here was a cut-off criteria of 6 AI. Eligible periods for breeding differed based upon the program in which cows were being bred. Cows bred with visual heat detection were assumed to have breeding periods of 21 days. Cows on a synchronization program were assumed to begin resynchronization upon a nonpregnant diagnosis at either 26 or 33 days after TAI.

Heat detection program costs, assessed on a per period per cow basis were calculated as follows:

$$PROG_{HD} = [(((TIME * OBS) * PER) * LABOR_{HD})/COWS] + AID + (CI * SUBRATE),$$

Where,

$PROG_{HD}$ = Heat detection program costs per cow per period,

TIME = Heat detection minutes per observation for a group of cows,

OBS = Number of times the group is observed per day,

PER = Number of days in a single breeding period,

$LABOR_{HD}$ = Cost of labor (in dollars per minute) to perform heat detection,

COWS = Number of cows in the group,

AID = Per period cost per cow of heat detection aid utilized,

CI = Cost of an artificial insemination, and

SUBRATE = AI submission rate.

Synchronization program costs, assessed on a per period per cow basis were calculated as follows:

$$PROG_{Synch} = (P_{GnRH} * X_{GnRH}) + (P_{PGF2\alpha} * X_{PGF2\alpha}) + (MIN * INJ * Labor_{Inj}) + (CI * SUBRATE),$$

where,

$PROG_{Synch}$ = Synchronization program costs per cow per breeding period,

P_{GnRH} = Cost of GnRH per injection,

X_{GnRH} = Number of GnRH injections administered,

$P_{PGF2\alpha}$ = Cost of PGF2α per injection,

$X_{PGF2\alpha}$ = Number of PGF2α injections administered,

MIN = Number of minutes to give a single injection,

INJ = Total number of injections in the series,

$LABOR_{Inj}$ = Cost of labor (in dollars per minute) to give injections,

CI = Cost of an artificial insemination, and

SUBRATE = AI submission rate.

The formula used to calculate the expected NPV of each program, with NCF_T for the last time period including the RPO values:

$NCF_t = (CR_t * RPOPREG_t - (1 - PR_{cum}) * Feed - PROG_j)$ for $t = 0,\ldots,T-1$, and

$NCF_T = (CR_T * RPOPREG_T - (1 - PR_{cum}) * Feed - PROG_j + (1 - PR_{cum}) * RPOOPEN_T)$ for $t=T$, where,

NCF_t = Net cash flow in period t,

PROG = Program costs for either synchronization or heat detection program per cow per period,

CR_t = Current AI CR,

$RPOPREG_t$ = Retention payoff in time t for a pregnant cow,

PR_{cum} = Cumulative probability of pregnancy, defined as sum of PR from 0 through the current AI, in time t, (e.g., $PR_{cum,\,3} = CR_0 + (1 - CR_0) * CR_1 + (1 - CR_0) * (1 - CR_1) * CR_2$),

Feed = Per period feed and yardage cost of nonpregnant cow = (\$2.00 per day * days per period),

$PROG_j$ = Cost of program j, where j is the reproductive program used on the cow,

$RPOOPEN_T$ = Retention payoff in time T for an open cow, and

$RPOPREG_T$ = Retention payoff in time T for a pregnant cow.

The NPV of the strategy was the sum from time period 0 through T, in which the final time period, T, was determined by a predetermined cutoff criteria, such as the maximum number of AI:

$$NPV = \sum_{t=0}^{T} \left[\frac{1}{(1+r)^t} * NCF_t \right],$$

where r is the discount rate and NCF_t is the net cash flow in period t.

Sensitivity analyses were performed for differing costs of labor, minutes required per injection, and labor efficiency of heat detection, holding all other variables constant. Further, sensitivity analysis was conducted for cows of different lactations. Heat detection labor efficiency was altered by holding the AI submission rate constant while changing the labor hours required to achieve that performance. Efficiency in giving injections was altered by adjusting labor minutes required per single injection.

The synchronization protocol chosen for use in the example was Ovsynch. Ovsynch consists of (1) an injection of GnRH, (2) an injection of $PGF2\alpha$ 7 days later, (3) a second GnRH injection 48 hours later, and (4) timed breeding 24 hours after the second GnRH injection (Pursley et al., 1995). In order to resynchronize cows not conceiving to the first AI, all cows were assumed to receive a GnRH injection at a nonpregnant diagnosis (assumed to be 33 days post Ovsynch TAI), a $PGF2\alpha$ injection 40 days after the initial Ovsynch TAI, and a second GnRH injection and TAI approximately 42 days after the initial Ovsynch TAI. For comparison, resynchronization beginning 26 days after Ovsynch TAI was assessed. Fricke et al. (2003) compared these resynchronization programs to other programs with altered timing to beginning of resynchronization. The assumptions described here were used to create baseline farm scenarios. In this analysis scenarios were assessed in which cows were bred for 6 AI.

Input parameters for tool

General farm information that is required for input into the tool include the number of cows in the group, the labor costs for visual heat detection, the labor costs for administering shots, the feed and yardage costs to maintain an open breeding-age heifer, and the annual discount rate used to compute the expected net present value of breeding strategies. The farm-specific costs and revenues assessed in this analysis can be expanded to include altering the user-specified inputs in DairyVIP© version 1.1 (De Vries, 2006) where values such as average heifer calf values, replacement heifer costs, and milk prices can be changed. AI costs which are not program specific can be entered into the tool directly, by specifying breeding costs of zero dollars in the RPO calculation and deducting AI breeding costs directly in the Excel spreadsheets constructed. Costs associated with AI which are not program specific would include the semen costs per straw and the costs associated with the insemination itself. If AI is performed by an outside inseminator, a per-AI fee is entered. If AI is performed by farm labor the labor costs per hour and the minutes of labor required per AI are entered. The general formula used to calculate the cost of an AI is as follows:

$$\text{Cost per AI} = \text{Straw} + \text{Fee} + \left(\frac{\text{Mins}_{\text{Breed}}}{60}\right) * \text{Labor}_{\text{Breed}},$$

where

Straw = Cost of semen per straw,

Fee = AI fee for outside inseminator for single breeding,

$Mins_{Breed}$ = Minutes of on-farm labor required for a single breeding, and

$Labor_{Breed}$ = Cost per hour of labor that performs AI on the farm.

Different costs for labor associated with insemination (if done by farm labor), heat detection, and administering shots are able to be entered. The difference in labor costs for each of these tasks allows farms to accurately account for different skill levels, and therefore pay levels, of labor associated with each of these tasks. For example, feeders or milkers on the farm may be responsible for heat detection duties, while administering shots for a synchronization program is done by the herdsman or manager. Additionally, heat detection performed by the manager of the herd will be more costly than if other employees completed the heat detection. In short, given the sensitivity of program costs to labor costs, the person on the farm who is performing a given task may affect which program is economically optimal for a given farm operation.

To evaluate synchronization programs, users must specify their expected CR and AI submission rate. Note that if ovulation synchronization is used, the AI submission rate will likely be approaching 100%, because nearly all cows which are on the program will be submitted for AI, barring any unusual circumstances. A key value that must be entered when considering synchronization programs is the number of minutes it takes to administer a shot to a cow in the group to be evaluated. Several factors affect the minutes required per shot, and the total time is likely a function of the ease of handling cattle within the facilities. Again, individual group evaluations are helpful in determining optimal programs for a given group of cattle on the farm when facilities, or ease of handling, in one group is different from another group. For example, when selecting a program for heifers which are housed away from the home farm on a bedded pack without adequate headlocks, the time required to administer a shot will be far greater than for cows housed in a stanchion barn.

Program costs are heavily dependent on the cutoff criteria specified by the manager, as is highlighted through sensitivity analysis. Once the reproductive program cutoff criteria has been established, the tool uses the cumulative probability of pregnancy at the cutoff point as the probability that the cow is pregnant at cutoff to calculate the value of the program. The remaining probability, or (1 - $PROB_{Preg}$), is the probability that the cow is not pregnant at the cutoff of her breeding program and is also the probability that the open RPO value is received.

3.3 Results and discussion

To demonstrate the decision making support provided by the spreadsheet-based tool an example scenario was analyzed using the on-farm tool. On-farm costs and values and the farm managers' cutoff rule for stopping breeding cows will affect the value of the reproductive programs as calculated through the use of the decision tool. It is crucial that managers use their own farm-specific values in order to find the optimal program for their operation at the given time. Optimal programs will change across farms as well as for a given farm over time. If labor costs, reproductive program supplies costs, or reproductive efficiency to a given program were to change for a farm operation, the optimal program for that farm may change as well. Sensitivity analysis must also be performed to determine the sensitivity of the program costs and program value to key parameters.

Costs and sensitivity to cutoff criteria

As stated previously, the cutoff that the manager selects to determine when to stop breeding the cow will affect the program cost. Program costs subject to various cutoff criteria are presented in Table 3c for both the visual heat detection and Ovsynch programs. For simplicity, the breeding period for both programs in Table 3c is held constant at 30 days. For illustration, program costs only, without inclusion of RPO values or other revenues, are assessed subject to different cutoff criteria for these reproductive management programs. The scenario being analyzed included a 100 cow dairy herd comparing visual heat detection to the Ovsynch ovulation synchronization program. The farm used semen that costs $15.00 per straw and the labor used for AI is on-farm labor that costs $11.00 per hour. Fifteen minutes of on-farm labor were required per AI, meaning that on-farm labor costs per AI were $2.75. Including semen costs, the total farm costs for a single AI were $17.75. The labor costs per hour for visual heat detection and administering synchronization shots were $9.00 and $14.00 per hour, respectively. The farm expected to be able to purchase PGF2α for $3.50 per shot and GnRH for $4.50 per shot. The on-farm costs of maintaining an open cow an additional day was $2.25 per day. The discount rate used to discount revenues and costs was an annual rate of 9% (Wolf et al., 2002). Reproductive program parameters included that the farm currently uses visual heat detection and achieves a 55% AI submission rate when all 100 cows are observed 2 hours per day. The CR that the farm has achieved in the past to visually detected estrus is 42%. When evaluating Ovsynch, the farm estimates a CR of 36%, but enters that the AI submission rate will be 100% because all cows are expected to be submitted for AI after they are synchronized.

Table 3c, in addition to presenting the program costs as calculated in the decision tool, also presents the probability that a cow is pregnant after the cutoff. The probability of pregnancy is crucial in determining the value of the program, as it weighs the RPO values for pregnant and open cows by the likelihood they are realized. Note that the program costs associated with visual heat detection, in this example, are generally higher than those with Ovsynch. These higher program costs with visual heat detection may be surprising, given the cost to administer the program per cycle was lower for visual heat detection. Note that although the cost to administer a visual heat detection program is lower per month than Ovsynch, the probability that the cow is pregnant after each breeding is lower as well. Due to the smaller pregnancy rate achieved with the visual heat detection program in this example the farm must pay for additional months of maintenance on an open cow, thereby increasing the costs associated with the visual heat detection program. There is clearly an inherent tradeoff between the program costs incurred monthly to administer the program and the probability that a cow is pregnant at the end of each month. Such tradeoffs must be assessed using farm specific costs to be sure that the farm is recognizing all additional costs associated with having a cow remain open on the farm for an additional month.

Table 3 c. Program cost sensitivity to cutoff rule in example scenario

	Cutoff rule	Cost of program	Probability of pregnancy	Probability open
Visual heat detection	85% Cumulative probability of pregnancy	$708.98	86%	14%
	90% Cumulative probability of pregnancy	$879.71	92%	8%
Ovsynch	85% Cumulative probability of pregnancy	$484.62	89%	11%
	90% Cumulative probability of pregnancy	$579.40	93%	7%
Visual heat detection	3 AI Services	$270.85	53%	47%
	4 AI Services	$359.79	65%	35%
	5 AI Services	$448.07	71%	29%
	6 AI Services	$535.69	77%	23%
Ovsynch	3 AI Services	$292.94	74%	26%
	4 AI Services	$389.14	83%	17%
	5 AI Services	$484.62	89%	11%
	6 AI Services	$579.40	93%	7%

Value of reproductive management programs

Focusing on using the cutoff criteria of 6 AI and the reproductive management programs of visual heat detection and Ovsynch, the values for the breeding programs were calculated. The inputs for the tool were as follows: CR of 30% to Ovsynch, CR of 38% to visual heat detection, AI submission rate of 100% to Ovsynch, AI submission rate of 65% to visual heat detection (with 100 cow group), and a cost per AI of $17.75. The farm expected to be able to purchase PGF2α for $2.52 per shot and GnRH for $3.59 per shot. The on-farm costs of maintaining an open cow an additional day was $2.00 per day. The discount rate used to discount revenues and costs was an annual rate of 9% (Wolf et al., 2002). Using these inputs, and the RPO values from DairyVIP© version 1.1 (De Vries, 2006), values of reproductive management programs for cattle of various lactation numbers can be determined. Reproductive program values for Ovsynch assuming that shots take 2.1 and 6.3 minutes are assessed. Further, efficiency of visual heat detection is assessed by altering the time required to obtain the visual heat detection rate from 2.15 to 2.6 hours per day. Table 3d shows the values of the reproductive management programs for various labor costs for cattle in their first lactation, assuming a 26 day period for Ovsynch and a 21 day period for visual heat detection. Table 3e, for comparison, shows the values of the reproductive management programs for various labor costs for cattle in their first lactation, assuming a 33 day period for Ovsynch and a 21 day period for visual heat detection.

Table 3 d. Reproductive management program values for first lactation cows (26 day period for Ovsynch)

Labor cost per hour	Ovsynch with 30% CR and 2.1 minutes per shot (26 day period)	Ovsynch with 30% CR and 6.3 minutes per shot (26 day period)	AI submission rate 65% with visual heat detection, 2.15 labor hours per day	AI submission rate 65% with visual heat detection, 2.6 labor hours per day
$6.00	$517.52	$510.08	$555.66	$550.79
$7.00	$516.90	$508.22	$551.79	$546.11
$8.00	$516.28	$506.36	$547.91	$541.43
$9.00	$515.66	$504.50	$544.04	$536.75
$10.00	$515.04	$502.64	$540.17	$532.07
$11.00	$514.42	$500.78	$536.30	$527.39
$12.00	$513.80	$498.92	$532.43	$522.70
$13.00	$513.18	$497.06	$528.56	$518.02
$14.00	$512.56	$495.20	$524.69	$513.34
$15.00	$511.94	$493.34	$520.81	$508.66
$16.00	$511.32	$491.48	$516.94	$503.98
$17.00	$510.70	$489.62	$513.07	$499.30
$18.00	$510.08	$487.76	$509.20	$494.61
$19.00	$509.46	$485.90	$505.33	$489.93
$20.00	$508.84	$484.04	$501.46	$485.25

Table 3 e. Reproductive management program values for first lactation cows (33 day period for Ovsynch)

Labor cost per hour	Ovsynch with 30% CR and 2.1 minutes per shot (33 day period)	Ovsynch with 30% CR and 6.3 minutes per shot (33 day period)	AI submission rate 65% with visual heat detection, 2.15 labor hours per day	AI submission rate 65% with visual heat detection, 2.6 labor hours per day
$6.00	$484.89	$477.48	$555.66	$550.79
$7.00	$484.27	$475.63	$551.79	$546.11
$8.00	$483.66	$473.78	$547.91	$541.43
$9.00	$483.04	$471.93	$544.04	$536.75
$10.00	$482.42	$470.07	$540.17	$532.07
$11.00	$481.80	$468.22	$536.30	$527.39
$12.00	$481.19	$466.37	$532.43	$522.70
$13.00	$480.57	$464.52	$528.56	$518.02
$14.00	$479.95	$462.66	$524.69	$513.34
$15.00	$479.33	$460.81	$520.81	$508.66
$16.00	$478.72	$458.96	$516.94	$503.98
$17.00	$478.10	$457.11	$513.07	$499.30
$18.00	$477.48	$455.26	$509.20	$494.61
$19.00	$476.86	$453.40	$505.33	$489.93
$20.00	$476.25	$451.55	$501.46	$485.25

Tables 3f and 3g, respectively, show the values of reproductive management programs for cattle in their third lactation with similar sensitivity analysis as presented above.

Table 3 f. Reproductive management program values for third lactation cows (26 day period for Ovsynch)

Labor cost per hour	Ovsynch with 30% CR and 2.1 minutes per shot (26 day period)	Ovsynch with 30% CR and 6.3 minutes per shot (26 day period)	AI submission rate 65% with visual heat detection, 2.15 labor hours per day	AI submission rate 65% with visual heat detection, 2.6 labor hours per day
$6.00	$351.74	$344.30	$361.66	$356.80
$7.00	$351.12	$342.43	$357.79	$352.12
$8.00	$350.50	$340.57	$353.92	$347.44
$9.00	$349.88	$338.71	$350.05	$342.76
$10.00	$349.26	$336.85	$346.18	$338.08
$11.00	$348.64	$334.99	$342.31	$333.39
$12.00	$348.02	$333.13	$338.44	$328.71
$13.00	$347.40	$331.27	$334.56	$324.03
$14.00	$346.78	$329.41	$330.69	$319.35
$15.00	$346.16	$327.55	$326.82	$314.67
$16.00	$345.54	$325.69	$322.95	$309.98
$17.00	$344.92	$323.83	$319.08	$305.30
$18.00	$344.30	$321.97	$315.21	$300.62
$19.00	$343.68	$320.11	$311.34	$295.94
$20.00	$343.05	$318.25	$307.46	$291.26

Table 3 g. Reproductive management program values for third lactation cows (33 day period for Ovsynch)

Labor cost per hour	Ovsynch with 30% CR and 2.1 minutes per shot (33 day period)	Ovsynch with 30% CR and 6.3 minutes per shot (33 day period)	AI submission rate 65% with visual heat detection, 2.15 labor hours per day	AI submission rate 65% with visual heat detection, 2.6 labor hours per day
$6.00	$320.25	$312.84	$361.66	$356.80
$7.00	$319.63	$310.99	$357.79	$352.12
$8.00	$319.01	$309.13	$353.92	$347.44
$9.00	$318.40	$307.28	$350.05	$342.76
$10.00	$317.78	$305.43	$346.18	$338.08
$11.00	$317.16	$303.58	$342.31	$333.39
$12.00	$316.54	$301.73	$338.44	$328.71
$13.00	$315.93	$299.87	$334.56	$324.03
$14.00	$315.31	$298.02	$330.69	$319.35
$15.00	$314.69	$296.17	$326.82	$314.67
$16.00	$314.07	$294.32	$322.95	$309.98
$17.00	$313.46	$292.46	$319.08	$305.30
$18.00	$312.84	$290.61	$315.21	$300.62
$19.00	$312.22	$288.76	$311.34	$295.94
$20.00	$311.60	$286.91	$307.46	$291.26

Clearly, the value of the reproductive management program is affected by the costs of administering the program, the lactation number (because it influences the value of the cow through the RPO), and the reproductive performance achieved with a given reproductive management program. By allowing farm-specific parameters to be entered into the decision tool individual dairy farms can determine the value of the reproductive management program to their operation, and thereby make more informed decisions when selecting reproductive management programs.

3.4 Conclusion

Challenges within the dairy industry with getting cattle pregnant efficiently exist due to decreasing CR, difficulty detecting cattle in heat, and adjustments to management as herd sizes grow larger over time. In response to the challenges regarding reproduction in the dairy industry, various programs and technologies have been developed to aid producers in effectively and efficiently getting cattle bred. The tool described here aids producers in deciding which of these programs is economically optimal, subject to farm-specific costs and values. In addition, reproductive management programs are valued according to manager specified cutoff criteria, and managers are able to compare program values across various programs. Farm managers are able to evaluate visual heat detection programs and synchronization programs, and can perform sensitivity analysis to key parameters such as CR, AI submission rates, and on-farm costs. Through the use of this decision tool managers are able to determine the economically efficient reproductive management tool for their specific farm operation.

CHAPTER 4: A STOCHASTIC ECONOMIC ANALYSIS OF DAIRY CATTLE ARTIFICAL INSEMINATION REPRODUCTIVE MANAGEMENT PROGRAMS

4.1 Introduction

Dairy herd reproductive performance is integrally linked to profitability of commercial U.S. dairy operations. Reproductive success is critical to the financial success of the farm because reproduction is necessary to generate the next lactation, and the largest source of revenue for a U.S. commercial dairy herd is milk sales (Wolf, 1999). Further, the direct link between reproductive performance and dairy herd management is widely accepted and has long been recognized in the dairy industry (Britt, 1985). In response to reproductive efficiency challenges felt industry-wide, reproductive management programs have been developed and are now available to aid producers in efficiently breeding their dairy cattle. Given the increasing number of reproductive management programs available, economic assessments are necessary to determine the economically efficient sets of programs for farm managers with given characteristics.

For many dairy farms it is the failure to detect estrus efficiently that limits reproductive performance (Nebel and Jobst, 1998). In recent years, increased levels of production coupled with increased herd sizes have influenced how dairy farms manage dairy cattle reproduction (Pursley et al., 1997), spurring increased attention to the development of reproductive programs to increase reproductive efficiency and performance. Today, various reproductive technologies are available for use on commercial dairy farms, including artificial insemination **(AI)**, estrus and ovulation synchronization programs, sex-sorted semen, pedometers, computer-based record systems, and multiple estrus detection aides. Costs associated with the use of reproductive management programs, and with achieving a given level of reproductive performance, are expected to vary significantly across farms due to varying on-farm costs, facilities employed, previous levels of reproductive performance, management ability, and other economic factors. Reproductive performance and success under various reproductive management programs will also vary across dairy farms due to herd-specific or farm-specific characteristics.

In recent years, reproductive management programs have focused on hormonal synchronization of dairy cattle. Synchronization programs aim to decrease the expenses associated with estrus detection by either shortening the time during which cattle must be observed through ovulation synchronization or to eliminate the need for estrus detection completely with timed artificial insemination **(TAI)**. Timed ovulation allows for breeding cows by appointment, thereby eliminating the need for heat detection completely, and has similar pregnancy outcomes to those obtained through AI performed after heat detection (Pursley et al., 1997). There are several systematic breeding programs available for use on commercial dairy farms today. Benefits for the dairy farm using systematic breeding programs include increased efficiency in the use of labor of heat detection and AI, and the convenience of managing the herd under synchronization (Nebel and Jobst, 1998). Farms may use more than one synchronization protocol and the program(s) best suited to a particular operation will depend on farm-specific costs and herd-characteristics. Farm managers are left to determine whether a hormonal synchronization protocol or visual heat detection is the optimal choice for their farm, and then to determine the specific program best suited to their operation.

In addition to varying outcomes achieved with reproductive programs and varying on-farm costs, farm goals and farm manager characteristics may affect the reproductive programs chosen. In particular, risks associated with the outcomes of reproductive programs and the risk preferences of the farm manager will likely aid in determining the optimal program for a given operation. Farm managers have heterogeneous risk preferences and may be classified as risk averse, risk neutral, or risk loving. The riskiness of a given program's outcome (i.e., the certainty with which a given program will yield a certain conception rate (**CR**) or heat detection rate (**HDR**)) will affect the decision of a particular farm to adopt a given program.

Reproductive management programs used on dairy farms will be affected by multiple farm-specific costs. With the abundance of reproductive management programs available, a dairy producer is left to ask: which reproductive management program is the economically optimal program for my dairy farm? Identification of suitable or optimal programs for farms with a given set of general characteristics (i.e., manager risk attitudes, farm size, on-farm costs, goals for reproductive performance) is necessary to improve recommendations to dairy farm managers and to further the understanding of why farms adopt the reproductive technologies that they do.

Several spreadsheet-based models (Groenendaal et al., 2004, Meadows et al., 2005, and Olynk and Wolf, 2007) have been developed to assess reproductive management decisions. Spreadsheet models range from general assessments of reproductive performance, often on a limited number of dairy operations or within a given geographical region, to in-depth investigations into specific reproductive technologies. Groenendaal et al. (2004) used a spreadsheet-based model called OptiCow to support economically optimal breeding and replacement decisions on dairy farms through the use of the marginal net revenue technique. Meadows et al. (2005) used a spreadsheet-based model to estimate the economic effect of changes in herd-level reproductive performance in Ohio dairy herds. Olynk and Wolf (2007) developed a spreadsheet-based model to compare the expected net present values of pure and mixed sexed semen AI strategies and identified breakeven values for which sexed semen strategies had higher expected net present values than conventional semen strategies. A commonly recognized theme in such models, which allow some flexibility in parameterization, are that costs associated with supplies for reproductive programs and the time required to administer the programs vary widely with manager skill and experience levels, as will reproductive efficiency gains associated with a particular program, underscoring the need for sensitivity analyses.

More generally, several models have been developed to determine the costs of reproductive inefficiency. Some examples of such models include Meadows et al. (2005) who focused on varying reproductive performance in Ohio dairy herds, Tenhagen et al. (2004) who used field trials to compare reproductive efficiency and economic implications, and the DairyVIP model by De Vries (2006) which was intended to estimate the value of a pregnancy. Such models allow calculations of the costs of reproductive inefficiency. The models currently available do not explicitly consider the risk associated with the outcomes of various programs or technologies, nor do they incorporate the risk attitudes of the decision maker. Further, it should be noted that the flexibility to simulate numerous reproductive programs is necessary to adequately address the question of which program is optimal for a given farm operation. A model which is capable of assessing reproductive program adoption questions while incorporating the riskiness of alternative programs and risk attitudes of the manager is necessary in order to recommend the efficient set of programs for farms with given sets of characteristics.

Stochastic dominance is a powerful tool for identifying preferred sets of risky options for a decision maker with a given set of characteristics. Stochastic dominance analysis has been used in several areas of agricultural decision making, including preferred milking parlor investment options (Thomas et al., 1997), pest management (Zacharias and Grube, 1984), water-conserving irrigation strategies (Harris and Mapp, 1986), alfalfa management strategies on dairy farms (McGuckin, 1983), and tillage practices (Klemme, 1985). Stochastic dominance is a risk efficiency criteria that has clearly been employed in various applications of decision making in agriculture.

The main objective of this study was to determine the economically optimal programs for dairy farmers with various characteristics (i.e., farm size, risk preferences of managers, on-farm reproductive program costs). Assessing reproductive technology decisions under risk (i.e., risks associated with the outcomes of a particular program, namely HDR and CR) was a primary focus of this analysis, and stochastic dominance was used to separate the sets of risky options and identify efficient sets for decision makers given risk preferences. Sensitivity analysis of the results to changes in key on-farm parameters was used to assess differences in efficient sets for farms with varying cost structures. Given that dairy farmers have heterogeneous risk preferences, efficient sets of programs were sought for broad risk preference groups of farm managers.

4.2 Materials and methods

The variability in response to a specific program and the attitude of the decision maker towards that variability were assessed through stochastic dominance analysis. By including the risk associated with the response to the program, as well as the willingness to accept risk by the decision maker, the problem for the farm manager becomes maximizing expected utility. It is hypothesized that the inclusion of the risk associated with the reproductive performance resulting for a specific program or technology, and the risk attitude of the decision maker adds an important component to existing models and decision support tools. It is also hypothesized that farm-specific costs for labor and program administration will aid in determining which programs or protocols are stochastically dominant for farms with a given set of characteristics. Risk attitudes (i.e., whether the manager is risk averse, risk neutral, or risk loving) are expected to be integrally important in determining which reproductive programs are adopted by particular farm managers.

Producer behavior

The assumption implicitly underlying this analysis was that individual dairy producers seek to maximize their utility. The assumption employed in the construction of the stochastic budgets was that dairy producers are seeking to select the minimum cost program available to them, subject to achieving a certain level of reproductive performance. It should be noted that utility maximization under risk neutrality is equivalent to profit maximization. Cost minimization is a necessary condition for profit maximization (Mas-Collel et al., 1995) because an important implication of a dairy farm selecting the profit-maximizing production plan is that there is no way to produce the same level of output at a lower total input cost. For example, if producers are able to achieve a 35% pregnancy rate (**PR**) through visual heat detection or through hormonal synchronization, it is assumed that producers will choose the method which minimizes the costs of attaining this level of performance. Underlying the choice of cost minimizing methods is the assumption that the revenue is constant regardless of the option chosen. For example, it is reasonable to assume that the milk revenue resulting from a pregnancy would be the same regardless of what methods were employed to achieve that pregnancy. Theoretically, a simplified version of this problem under the assumption of free disposal of output could be represented as:

$$\text{Min} \sum_{i=1}^{n} w_i x_i \text{ subject to } f(x) \geq q,$$

where:

$f(x)$ = Production function where $x=(x_1, x_2, \ldots x_n)$,

q = Specified level of output,

w_i = Input cost of input i (input costs are assumed to be strictly positive), and

x_i = Inputs.

The method which maximizes utility will depend on farm-specific values for labor costs, heat detection or injection administration efficiency (referring to labor time invested to achieve a certain outcome), and other farm-specific factors. In this way, the PR can be thought of as an output, because although it in itself cannot be marketed or sold, it does have a value to the farm operation. In addition, the PR, which depends directly on the HDR and CR, will vary according to the distribution of the CR and HDR in response to various reproductive management programs.

Stochastic budget development

A series of budgets were developed in Excel (Microsoft, Seattle, WA) that were capable of simulating reproductive performance under numerous reproductive management programs. An underlying assumption was that the total milk produced over a lactation initiated through any reproductive program which results in a pregnancy is independent of the reproductive program used to initiate that lactation. In other words, it is assumed that a cow bred via one program will yield the same amount of milk revenue as if that same cow were bred via a different program.

Costs for various reproductive management programs were calculated in the aforementioned budgets. The budgets were used to determine the costs associated with various reproductive management programs, subject to achieving a 90% cumulative probability of pregnancy. By summing the costs subject to achieving a fixed cumulative probability of pregnancy, it is possible to directly compare the costs across programs. Costs for heat detection programs and synchronization programs were generally calculated as follows:

Monthly Visual Heat Detection Program Cost per Cow =

$$\frac{\left[(TIME * OBS * 30.4) * LABOR_{HD}\right]}{COWS} + AID + (CI * HDR_{Visual}) ,$$

where,

TIME = Minutes per day invested in heat detection for a single group of cows,

OBS = Number of times the group is observed per day,

$LABOR_{HD}$ = Cost of labor (in dollars per minute) to perform heat detection,

COWS = Number of cows in the group,

AID = Cost per cow per period of heat detection aid utilized,

CI = Cost of an AI, and

HDR_{Visual} = Heat detection rate to visual heat detection.

Monthly Cost of Synchronization Program using GnRH and PGF2α per Cow =

$$(P_{GnRH} * X_{GnRH}) + (P_{PGF2\alpha} * X_{PGF2\alpha}) +$$

$$(MIN * SHOTS_{Total} * LABOR_{I}) + (CI * HDR_{Synch})$$

where,

P_{GnRH} = Price per injection of GnRH,

X_{GnRH} = Number of GnRH shots given in the synchronization protocol,

$P_{PGF2\alpha}$ = Price per injection of PGF2α,

$X_{PGF2\alpha}$ = Number of PGF2α shots given in the synchronization protocol,

MIN = Minutes to give a single injection,

$SHOTS_{Total}$ = Total number of injections in the series,

$LABOR_{I}$ = Cost of labor (in dollars per minute) to give injections,

CI = Cost of an AI, and

HDR_{Synch} = Heat detection rate under synchronization.

Using the heat detection and synchronization costs per cow per month, the total reproductive program costs were calculated by summing the program costs per month over the number of months necessary to obtain a 90% cumulative probability of pregnancy. For example, if, based on the inputted CR and HDR, it is calculated to take four months in order to achieve a 90% cumulative probability of pregnancy, the total program cost was the monthly program cost summed over four months.

Using the above described budgets it was possible to evaluate decisions regarding which reproductive management systems are best suited for various operations. Additionally, since the budgets allow entry of cow numbers per group rather than assessing all cows on the farm at once, farm managers can determine the optimal program for different groups of cows on their operation (i.e., select different programs for cows which have had better prior reproductive performance than others or select different programs for cows versus heifers).

Stochastic variables were incorporated into the budgets to account for the riskiness of the HDR and CR in response to various reproductive management programs. Simulation models that do not account for the riskiness of outcomes give a deterministic result in response to the input variables. Stochastic models are used to account for variables for which the values are not known with certainty, although for which a known probability distribution exists. Through the use of stochastic variables, the interactions of risky variables (in particular the interaction of the CR and HDR to achieve a given PR) allow the user of the tool to determine how a program may perform under alternative outcomes. Stochastic dominance is a popular method for ranking risky alternatives without in-depth knowledge about the preferences of the decision maker (McCarl, 1990).

Stochastic dominance analysis

Stochastic dominance is a powerful risk efficiency criteria. Such criteria separate a set of possible actions into an efficient set which is preferred by the decision maker and a risk-inefficient set which is undesirable to the decision maker (Thomas, et al., 1997). Efficient sets are defined to include the choice of every decision maker (farm manager) to whom the specified decision rules apply. Efficient sets are identified by comparing the cumulative distribution function **(CDF)** of possible options for the decision maker which have risky outcomes. First degree stochastic dominant **(FSD)** and second degree stochastic dominant **(SSD)** efficient sets were both evaluated in this analysis. An underlying assumption for both of FSD and SSD is that the alternatives compared, in this case the reproductive management programs compared, are mutually exclusive, meaning that one program or the other must be chosen and that a program which combines the two options is not feasible.

FSD has the intuitive meaning, according to Mas-Collel et al. (1995) that "the distribution F(.) yields unambiguously higher returns than the distribution G(.).". The distribution F(.) first-order stochastically dominates G(.) if, for every non-decreasing function u: $\int u(x)dF(x) \geq \int u(x)dG(x)$, where u indicates the utility function of the decision maker. Therefore, FSD can identify the efficient set for all those decision makers who prefer 'more to less' or, in this case, prefer the lower cost program. The SSD analysis then seeks to introduce a comparison based on relative riskiness or dispersion. SSD identifies the efficient set for decision makers who prefer 'more to less' at a diminishing rate, and are therefore risk averse. For any two distributions F(.) and G(.), F(.) second-order stochastically dominates G(.) if, for every non-decreasing concave function u: $\int u(x)dF(x) \geq \int u(x)dG(x)$, where u indicates the utility function of the decision maker. Second degree stochastic dominance analysis does not require identical means, although the assumption of identical means reduces the analysis to assessing one distribution as a mean preserving spread of the other. A risk averse individual is known to prefer a mean preserving contraction over a mean preserving spread. Through the use of these rules, efficient sets were identified for those decision makers fulfilling the aforementioned assumptions.

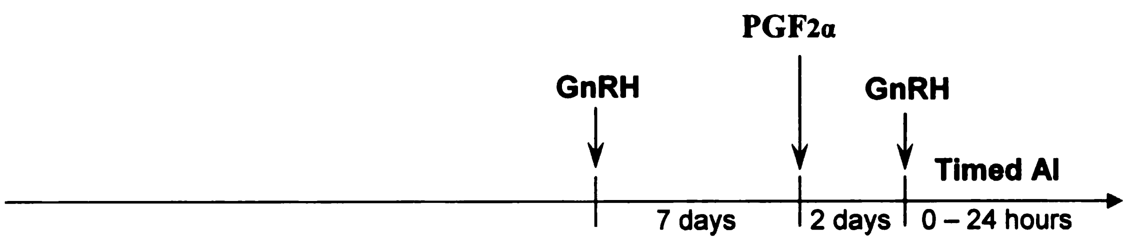
An economic analysis was conducted to determine the optimal reproductive program for farms with a given set of characteristics. Stochastic budgeting was used to account for the uncertainties in the decision, namely the HDR and CR resulting from a reproductive program, and to give an indication of the distribution of the outcomes expected. This analysis began by running the decision tool for multiple iterations with key parameters (i.e., CR, HDR, and the resulting PR) distributed across the range of values identified in previous studies. In this way, the data from previous reproductive performance studies was used in conjunction with survey data to parameterize the economic analysis. The stochastically efficient or efficient set was then identified by comparing the CDF of the risky alternatives, i.e., the various reproductive programs. Through the use of @RISK (Palisade Corp., Newfield, NY) the budgets were evaluated for 10,000 iterations. The resulting CDF of the risky alternatives were graphed for ease of visual observation in Stata software (Intercooled Stata for Windows, version 8.2, Stata Corporation, College Station, TX).

Key outcome parameters from the reproductive management programs were made stochastic by parameterization of triangular distributions for those variables. In particular, farm-size differences in program costs were assessed to highlight sensitivity to farm-specific costs. Triangular distributions were used due to the limited sample data available. Often triangular distributions are used in such cases as limited sample data because only a minimum, maximum, and most likely value are necessary to parameterize the model. Multiple scenarios are necessary in order to identify the efficient sets for decision makers with various baseline farm characteristics. A general base-case example scenario was constructed for illustration from previous survey data under the assumptions that on-farm labor costs $12.78 per hour for either heat detection or to give injections, costs per AI were $17.30, labor hours devoted to heat detection were 2.15 per day if visual heat detection was used, labor time to give a single injection was 2.10 minutes if synchronization was used, GnRH cost $3.59 per shot and PGF2α cost $2.52 per shot. The number of cows per group, or number able to be observed at a single time was assumed to be 100.

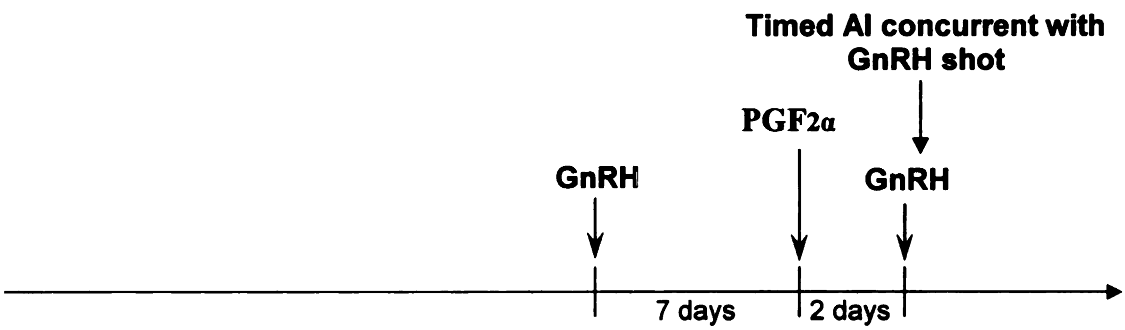
Visual heat detection without aides, Ovsynch, and Cosynch were investigated under this general scenario. The protocols for Ovsynch and Cosynch are nearly identical, varying only by timing of AI. The protocols for both Ovsynch and Cosynch are diagramed for reference in Figure 4a. Cosynch is essentially a specific modification of Ovsynch in which cows receive TAI concurrently with the second GnRH injection. Cosynch has the advantage of allowing dairy farms to restrain cows one less time than the Ovsynch program, and allows for all cow-handlings to occur at the same time daily (Fricke, 2003). Although there may be advantages for the Cosynch program from a cattle handling standpoint, optimal conception rates are not achieved using Cosynch (Pursley et al., 1998). Due to the similarities between the Cosynch and Ovsynch programs, they offer an interesting comparison, as dairy farms considering one of these programs would likely consider the other as well.

Figure 4 a. Ovulation synchronization programs used as examples

Ovsynch *(Does not include PGF2α injections before the first GnRH injection)*



Cosynch *(Specific form of Ovsynch in which breeding occurs concurrently with the second injection of GnRH.)*



The distribution used for the CR to visual heat detection was parameterized using survey data and a triangular distribution with a minimum of 26%, maximum of 60%, and most likely value of 41%. For Ovsynch, the CR was also distributed triangularly, although with a minimum of 23%, maximum of 57%, and a most likely value of 38%. The minimum and maximum values were adjusted slightly from the CR distribution used for visual heat detection, as mixed opinions exist regarding the differences in CR between AI to visually detected heat versus TAI. The most likely value for Ovsynch was taken from Pursley et al. (1997). The triangular distribution for CR under Cosynch reflected the lower CR expected with Cosynch versus Ovsynch, which is expected to be approximately 6 percentage points, on average (J. R. Pursley, personal communication, 2007). The triangular distribution included a minimum CR of 21%, a maximum of 55%, and a most likely value of 32%.

The triangular distribution used for visual heat detection without aides was parameterized using survey data and had a minimum of 20%, maximum of 75%, and a most likely of 52%. The HDR used for Ovsynch was a triangular distribution of 96%, 99%, and 100% for the minimum, most likely, and maximum values, because most cows are being bred to TAI; similarly values for Cosynch were 97%, 99%, and 100% because cows are almost certainly bred TAI, except under unexpected circumstances. The PR resulting from each of these programs was affected by the distributions of the HDR and CR under each program.

Numerous base scenarios are possible to allow stochastic dominance assessments for farms of various herd-sizes. Multiple iterations must be run for farms with a given herd-size and on-farm labor cost. By holding these factors describing the general characteristics of the farm fixed and running several iterations with the HDR and CR being treated as stochastic, CDFs can be generated and compared to determine efficient sets for decision makers with different risk preferences and given certain farm characteristics.

In order to assess the sensitivity of the analysis to farm-specific costs, sensitivity analysis was conducted using the same reproductive programs as above. In particular, sensitivity to on-farm costs and cow group sizes were assessed. Farms with less than 100 cows had higher costs for purchasing hormones and higher per AI costs according to survey data. For comparison, a scenario indicative of small-farm costs and values was constructed from survey data. The survey data used, broken down by farm size, is presented in Table 4a. Parameterization of the small farm comparison used the following parameters: labor costs were maintained at $12.78 per hour, per AI costs were $21.00 for visual heat detection and Cosynch, per AI costs were $24.20 for Ovsynch and were adjusted in the same way as prior, 2.67 labor hours were devoted to heat detection per day, labor time to give a single injection was 1.7 minutes, $4.49 per shot of GnRH and $3.10 per shot of PGF2α. The number of cows to be observed at a single time was assumed to be 35, in order to be in keeping with the smaller total farm size.

Table 4 a. On-Farm values affecting costs by farm size

Farm size (cows)	HD time (minutes per day for group)	Cost per AI	Minutes per shot	Cost of GnRH per shot	Cost of PGF_{2a} per shot
<100	160	21	1.7	4.49	3.1
100-200	122	17	6	3.13	2.13
>200	94	11	1.9	2.7	2.1

Source: Survey described in Chapter 2

Farms will vary on whether they incur additional costs associated for breeding cows on Ovsynch due to various factors. Farms may have facilities that enable automatic sorting, thereby making an additional cow-handling very efficient. Other farms, however, may incur significant costs associated with sorting and handling cattle an additional time for breeding with Ovsynch versus Cosynch. Such differences warrant sensitivity analysis to such factors. Further, a comparison case was constructed for sensitivity analysis where additional costs were incurred for breeding with Ovsynch versus the other programs. Such sensitivity analysis highlights the differences that the initial farm costs and group size assumptions can have on the analysis. There is an inherent tradeoff between these programs in that cattle must be handled an additional time with Ovsynch for breeding, but the expected CR is slightly higher than that with Cosynch. In order to account for the additional handling associated with breeding in the Ovsynch program, the cost per AI was adjusted from the $17.30 described above to include 15 additional minutes of labor cost, which was assessed at the $12.78 per hour as described above. Therefore, the cost per AI for the Ovsynch protocol was assessed at $20.50, to include the $17.30 per AI from the base scenario plus $3.20 in added labor costs for an additional cattle handling. All other costs were held constant with the base example scenario described above.

4.3 Results and discussion

Farm-specific technology adoption decisions were found to be highly sensitive to on-farm costs and individual farm characteristics. Further, risk attitudes of the farm decision maker affected the efficient set of reproductive programs for a given scenario. Examining the uncertainty of the response in reproductive performance to reproductive management programs, and therefore the changes in costs associated with reproductive management programs, will help determine why different farms select different reproductive management programs when seeking to maximize total farm profitability through reproductive management. In this way risk preferences are expected to affect what technologies or programs are in the efficient sets.

Table 4b illustrates the summary statistics for the costs of the programs resulting from the 10,000 iterations run on the afore-described base example analysis. Directly following the summary statistics is Figure 4b, which illustrates mean-variance analysis, where the program with the lowest average cost and the smallest variance (standard deviation is used here) is selected. In this analysis, Ovsynch was found to have the lowest average cost for a program, and also to have the lowest standard deviation of the programs considered.

Table 4 b. Summary statistics for program costs in example analysis

Visual heat detection without aides		Ovsynch		Cosynch	
Mean	-164.13	Mean	-123.97	Mean	-140.48
Median	-162.74	Median	-112.68	Median	-140.46
Mode	-205.40	Mode	-167.98	Mode	-224.49
Standard deviation	36.08	Standard deviation	33.37	Standard deviation	38.92
Most costly	-262.31	Most costly	-226.44	Most costly	-254.79
Least costly	-76.96	Least costly	-55.58	Least costly	-56.27

Figure 4 b. Mean-variance analysis for example

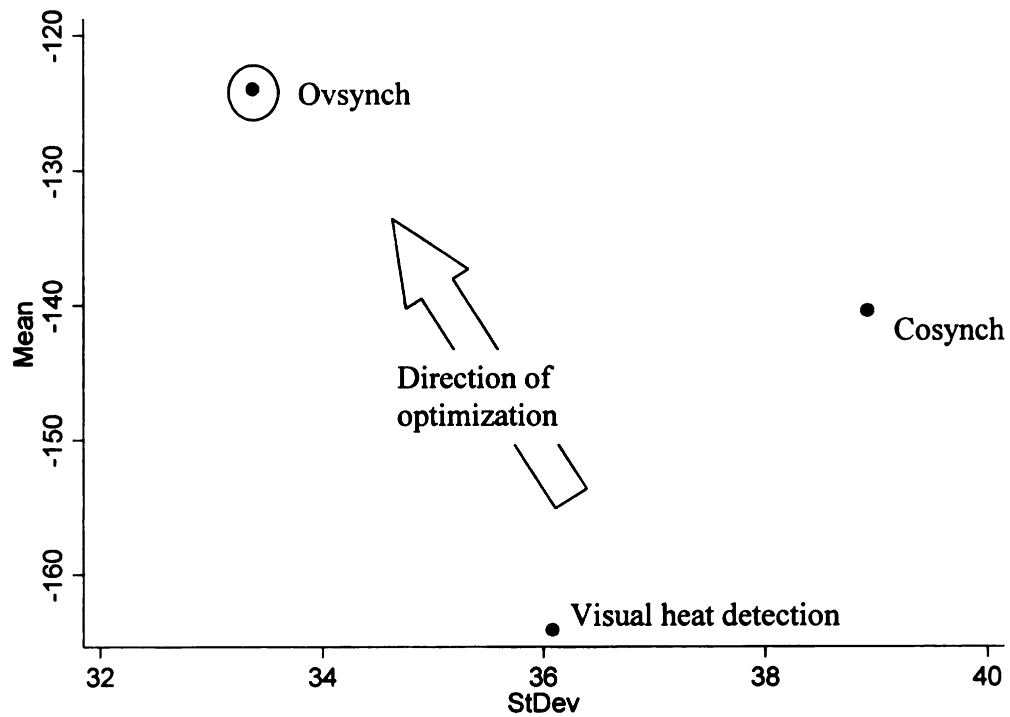
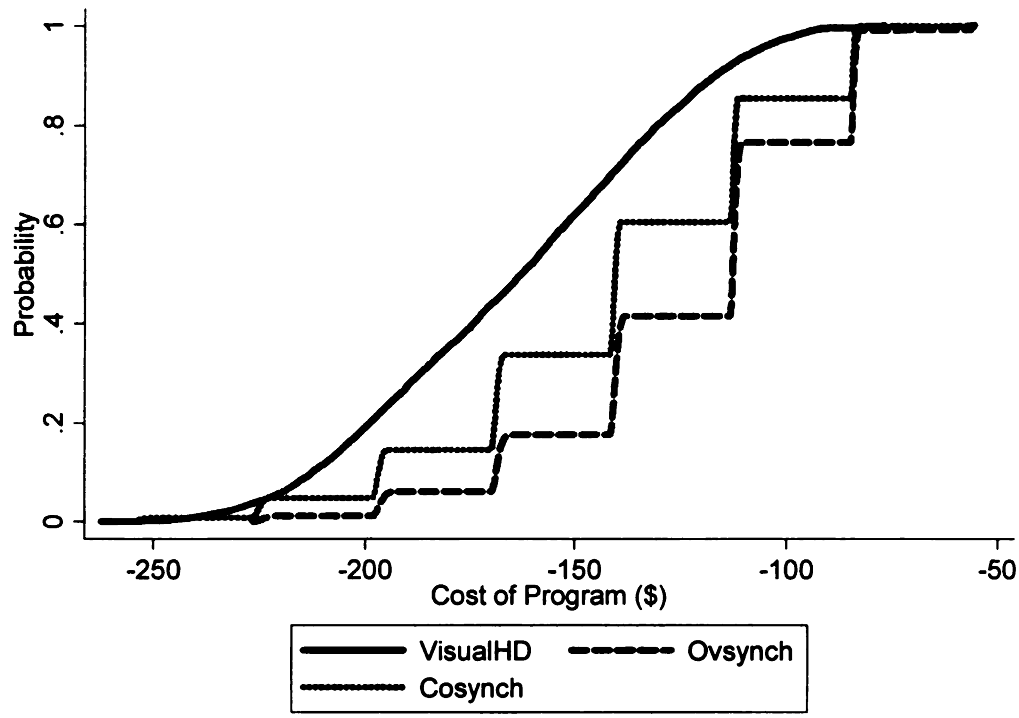


Figure 4c illustrates the CDFs of the various reproductive management programs available. In Figure 4c, comparing visual heat detection without aides to Ovsynch, Ovsynch has FSD and SSD over the visual heat detection program. When comparing visual heat detection with no aides to the Cosynch program, there is no FSD and no SSD. It is important to note that while no FSD or SSD dominance exists between visual heat detection without aides and Cosynch, this is due to the slightly higher chance of having a very high cost program, and that the vast majority of the time the synchronization programs are cheaper than visual heat detection with no aides. When comparing Ovsynch and Cosynch to one another, there is FSD of and SSD of Ovsynch over Cosynch, although the FSD looks deceiving graphically. Note that all FSD and SSD outcomes described above are subject to the parameters outlined in this example. For this example case, the efficient set for FSD includes Ovsynch because it FSD visual heat detection and Cosynch. Additionally, Ovsynch is in the efficient set for SSD because it SSD visual heat detection and Cosynch.

Figure 4 c. Cumulative density functions for example analysis



Farm location and farm size have effects on the on-farm costs associated with reproductive management programs. In order to assess sensitivity to on-farm costs, FSD and SSD was assessed for small farms, as indicated in the Methods sections, and results are shown in Figure 4d. Sensitivity to on-farm costs can be seen in the higher costs associated with reproductive programs on small farms. Perhaps most significant is the extreme difference in the visual heat detection without aides program. Costs are considerably higher for small farms due to watching fewer cattle at a time for visual heat detection and higher per injection hormone costs for synchronization. In addition, per AI costs were higher on small farms. For small farms (less than 100 cows) the efficient set for FSD is Ovsynch because Ovsynch FSD both visual heat detection and Cosynch. Since FSD is present, Ovsynch SSD Cosynch and visual heat detection, which was also true in the all-farm analysis presented prior.

Figure 4 d. Small farm sensitivity analysis

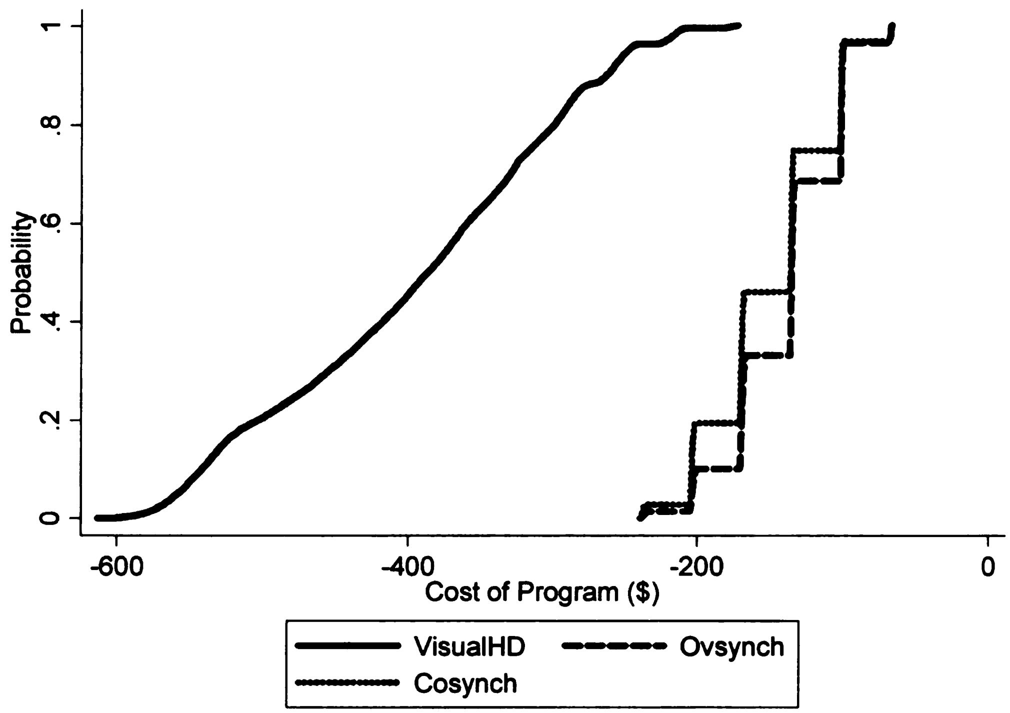
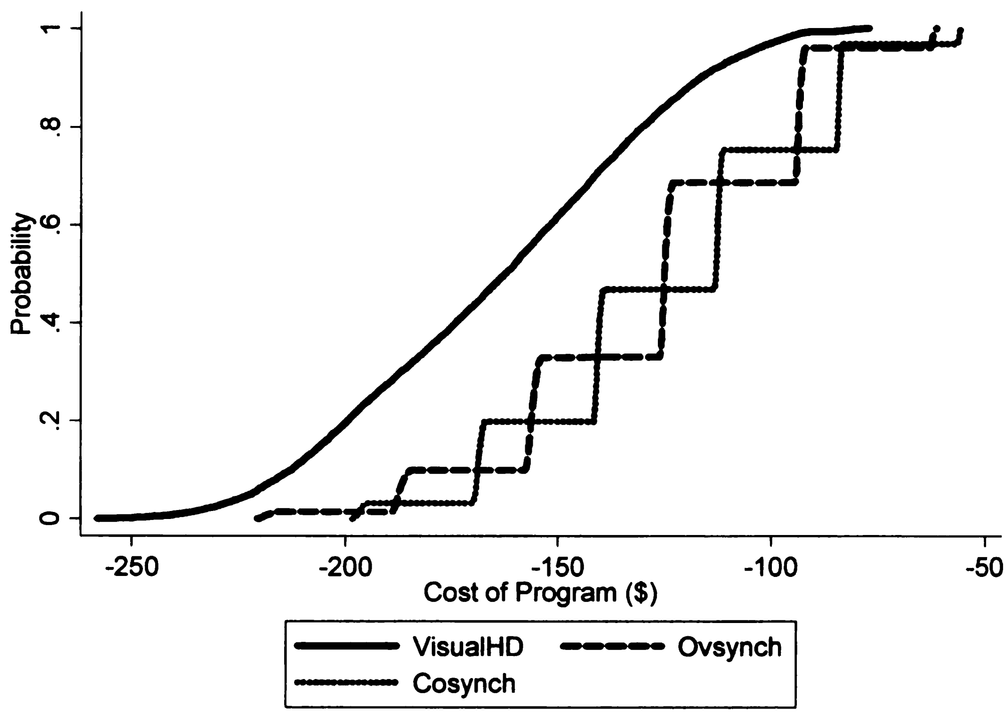


Figure 4e displays the CDF comparison when Ovsynch incurs additional breeding costs compared to the other two programs. Notice that both Ovsynch and Cosynch have FSD over visual heat detection in this case; given this FSD, Ovsynch and Cosynch are both SSD over visual heat detection. The interesting case in this example is the comparison between Ovsynch and Cosynch. Notice there is no FSD between Ovsynch and Cosynch in this case. When assessing SSD, Cosynch is SSD over Ovsynch. The additional 15 minutes of labor costs incurred per AI in the Ovsynch program in this case has led to Cosynch being SSD over Ovsynch. SSD of Cosynch over Ovsynch would indicate that risk averse managers prefer the Cosynch program to the Ovsynch program, in which they have to incur additional costs associated with handling cows an additional time, an assumed 15 minutes in this example, for breeding purposes. Given this analysis, in the case in which Ovsynch incurs 15 minutes of additional labor costs over the other two programs, the efficient set for FSD is Ovsynch and Cosynch because both dominate visual heat detection. The efficient set for SSD is Cosynch because it dominates visual heat detection and the Ovsynch program.

Figure 4 e. Sensitivity analysis: Ovsynch incurring additional breeding cost



Through FSD and SSD analysis, the efficient sets of reproductive programs have been identified for those producers who, 1) prefer a less costly program (FSD), and 2) prefer a less costly program and are risk averse. It is important to note that the programs which are present in the efficient set depend integrally on the parameters set up in the example problem. Those programs in the efficient set will be different for farms with varying on-farm labor costs, labor efficiencies, and decision maker preferences. This fact strengthens the notion that regional data or farm size specific data sets would be useful in parameterization of this analysis to allow costs which are more specific to a given locale.

4.4 Conclusion

Dairy herd reproductive performance is closely tied to whole-farm profitability for commercial U.S. dairy operations. Identification of optimal programs for farms with a given set of general characteristics (i.e., operator risk attitudes, farm size, and on-farm costs) is necessary in order to enable recommendations to dairy farm operators and to further the understanding of why farms adopt the reproductive technologies that they do. In this analysis, stochastic variables were incorporated into a series of budgets to account for the riskiness of the reproductive program outcomes, namely HDR and CR. FSD and SSD were used to determine the efficient sets of reproductive programs for decision makers with heterogeneous risk preferences.

Perhaps the most interesting and surprising finding, highlighted through the base example case, was the FSD and SSD of Ovsynch over Cosynch, which indicates that decision makers of all risk preferences prefer Ovsynch rather than Cosynch. This dominance of Ovsynch indicates that decision makers do not want to take the CR risks associated with Cosynch. Although the synchronization programs employ the same number and type of hormonal injections, the timing of these injections affects the CR. When Ovsynch cost 15 minutes more in labor time for each AI, however, Cosynch became SSD over Ovsynch indicating that risk averse managers would then prefer Cosynch. This analysis has highlighted that risk aversion is affecting which programs remain in the efficient set, and since dairy farmers are likely risk averse, the SSD analysis is particularly important for the dairy industry. These types of decisions among synchronization programs are one of the key contributions of this model.

Given the flexibility of the on-farm decision tool, parameterization of the model is possible for regional or even farm-specific data. When assessing only small farms, all program costs were found to be higher than the general assessment, indicating that regions with large proportions of small farms will find such analysis particularly important in assessing the optimal program for their operations. Further, farm costs, such as labor costs associated with breeding for a particular program are important in identifying efficient sets for farms with given characteristics.

Overall, the incorporation of the risk preferences of the decision maker is an important contribution to farm-level decision making. By identifying efficient sets of programs for decision makers with various risk preferences we are better able to make recommendations for managers with given farm characteristics.

CHAPTER 5: SUMMARY AND DISCUSSION

Reproductive management of dairy cattle is crucial to whole-farm profitability as it enables milk sales, provides replacement animals, and is an important factor in potentially costly culling decisions. Further, reproductive management has become a challenge industry-wide as dairy producers face: (i) conception rates in cows that have decreased from 60% to 40% over the years in which AI has been practiced in the United States (Nebel, 2002); and (ii) increasing challenges with detecting cattle in estrus as herds become larger. The dairy industry has responded with innovative technologies and reproductive management programs that enable producers to synchronize ovulation, thereby eliminating the need for heat detection. Beyond synchronization programs, heat detection aides enable more efficient and accurate visual heat detection; automated computer-based record keeping systems make in-depth record keeping on individual cows possible, and technologies such as ultrasound and embryo transfer are offering options to dairymen that never existed before.

With all of the recent innovation and the multitude of programs and technologies available, dairy producers must decide which programs are economically optimal for their farm operations. The economically optimal choice for a given farm operation will be dependent on several factors, including on-farm costs and values, farm manager ability and knowledge, facilities used to handle and manage cattle, and the goals of the farm operation. In addition, the risk preferences of the manager, meaning whether the manager is risk loving, risk neutral, or risk averse, will affect the amount of risk that a manager will accept in the outcome of a program. Stochastic dominance analyses of reproductive management programs highlighted that risk preferences of decision makers, in addition to the on-farm costs and values used to parameterize the problem, affected the reproductive management programs that were within the efficient set for a farm manager. In the base case example shown in this analysis, Ovsynch dominated Cosynch and visual heat detection in the first degree, making it the selected option for decision makers of all risk preferences who simply prefer 'more to less' of the outcome. In the case of reproductive programs, all decision makers who prefer a higher pregnancy rate to a lower pregnancy rate would choose Ovsynch, given the parameters used to characterize the farm situation in the model. When the base case example was altered to include a charge for the additional handling required for breeding cattle under the Ovsynch program, Cosynch dominated Ovsynch in the second degree, indicating that risk averse decision makers would prefer Cosynch over Ovsynch. These differences in which programs are dominant, based on the parameters used to describe the farm situation, highlight the need to perform farm-specific analysis. Further, risk preferences clearly aid in explaining farm managers' choice of reproductive management programs.

The analyses presented built upon prior reproductive management studies and sought to inform economically sound decision making regarding reproductive program and technology adoption. The varying costs and revenues associated with reproductive performance across farms illustrated the need for farm-specific analyses regarding selection of economically optimal reproductive management programs. In particular, sensitivity to on-farm labor costs highlights the necessity to evaluate adoption decisions for individual farms; the reproductive management program that is optimal for one farm is likely not also optimal for a farm with differing labor costs. Different reproductive management programs will vary in sensitivity to labor costs; synchronization programs which require labor for administering shots are generally less sensitive to on-farm labor costs than visual heat detection based AI programs. The differences in sensitivity to labor are dependent on the amount of time required to administer each program, namely the amount of time needed to administer a series of shots versus the amount of time necessary to perform heat detection for a group of cows each day.

Previous work by Meadows et al. (2004) highlighted that the marginal benefits of improved reproductive performance are decreasing as reproductive performance improves. Current farm-level reproductive performance was found to be important through these analyses in assessing reproductive management programs for a given farm operation. Farms that had obtained high levels of reproductive efficiency through visual heat detection, for example, had less incentive to adopt a synchronization program than those farms with less efficient visual heat detection. This highlighting of previous reproductive performance when selecting reproductive management programs is illustrative of the multitude of programs that are seen on farms today. Farms that have experienced success with visual heat detection, for example, will have less incentive to adopt a different reproductive management program. Combine the riskiness associated with the outcome of reproductive management programs with the low levels of incentives to adopt a new program, and it can be better understood why there is such a range of breeding technologies and programs used in the industry today.

With survey responses indicating that 77% of farms had made a change in their reproductive management system between 2000 and 2005, there is clearly an ongoing need for continued research in the area of reproductive management. Several farms reported changes involving the initiation of a synchronization program in place of visual heat detection or moving from breeding with natural service to using AI. While many producers indicated adoption of technology as their most recent reproductive management change, other producers indicated a departure from the use of technologies such as synchronization or AI. With the array of adoption and disadoption decisions being made, it is clear that the program that is optimal for one farm is not necessarily optimal for another. Even for an individual farm, the program that is optimal currently may not be optimal in the future if on-farm costs change. Further, producers will benefit from decision support tools which aid in reproductive management program and technology adoption decisions as they seek to identify the economically optimal programs for their operations.

Overall, the reproductive management programs employed differ across farms due to varying on-farm costs and values, farm goals, management preferences, facilities used, and previous reproductive performance and experience. Differing characteristics across farms aid in explaining why the reproductive program that is optimal for one farm may not be economically feasible for another. Through the use of surveys, sensitivity analyses to reproductive program costs, and assessment of farm manager decision making under risk, the reproductive program decisions made on farms are better understood. Many factors are taken into account when farm managers make decisions regarding which reproductive management programs and technologies to use on their operation. By better understanding the factors that farm managers consider important and incorporating them into decision support tools for use on individual farm operations, the industry is better able to serve producers.

APPENDICES

APPENDIX 1: DAIRY PRODUCER SURVEY

Survey – Reproduction and Heifer Rearing on Dairy Farms

General Farm Characteristics – Part A

A1. How many head of dairy stock were on hand January 1st, 2005?

Total Milk Cows (including first calf heifers and dry cows)	_____
Total heifer calves and replacement heifers	_____
Bulls	_____
Dairy steers and bull calves	_____

A2. Types of facilities for cows and heifers. (Please mark predominant type with "P" and all others that apply with an X)

	Cows	**Heifers**
Stanchion/tie stall barn	☐	☐
Free stall barn	☐	☐
Bedded pack barn	☐	☐
Dry lot	☐	☐
Pasture	☐	☐
Other (Please Specify) __________	☐	☐
Age of current housing facilities (years)	_____	_____

A3. Total pounds of milk sold by this farm in 2005 __________ pounds

A4. Family and hired labor usage in 2005

	Number of Workers	Avg. Months Worked/ Worker	Avg. Hours Worked/ Month
a. Unpaid labor			
Spouses	_______	_______	_______
Children over 12	_______	_______	_______
Other unpaid labor	_______	_______	_______
b. Paid labor			
Hired manager/operators	_______	_______	_______
Full-time	_______	_______	_______
Part-time (year around)	_______	_______	_______
Seasonal workers	_______	_______	_______

A5. What were the wage/salary levels for workers of all levels of your operation in 2005?

	Wage Rate/hr	**or**	**Salary level/year**
Hired Managers/operators	_____/hr	or	_____/year
Full-time workers	_____/hr	or	_____/year
Part-time workers (year around)	_____/hr	or	_____/year
Season workers	_____/hr	or	_____/year
Other (Please specify) __________	_____/hr	or	_____/year

A6. Who is responsible for record keeping in your operation?

Job Title ____________________

Other Responsibilities ____________________

A7. What is the primary herd management record keeping system utilized in your operation?

- ☐ Paper
- ☐ Dairy Comp 305 or SCOUT
- ☐ DHI
- ☐ PCDART
- ☐ Other (Please Specify) ____________________

A8. Who comprises the management team (decision making team) on your operation?

(Please check all that apply and give a brief description of their primary role/responsibility in affecting decision making.)

	Roles/Primary Responsibilities
☐ Owners/operators	______________
☐ Veterinarian	______________
☐ Nutrition Consultant	______________
☐ Banker	______________
☐ Accountant	______________
☐ AI Sales Representative	______________
☐ Herd Manager/Herdsman	______________
☐ Other Employees (Please Specify) ______________	______________

A9. What was your cull rate for 2005? __________

A10. Were the reasons for culling recorded in 2005?

- ☐ Yes *(If yes, please proceed to question A11)*
- ☐ No *(If no, please skip to question A12)*

A11. If reasons for culling were recorded, what percentage of culls were due to the following reasons in 2005?

Sold for dairy purposes	_____	Injury	_____
Low milk production	_____	Death	_____
Feet and legs	_____	Mastitis	_____
Reproductive performance	_____	Disease	_____
Udder problems	_____		

A12. What criteria are utilized for voluntary culling decisions? (Please check all that apply.)

- ☐ Current heifer and/or cow prices
- ☐ Number of springing heifers in cattle inventory
- ☐ Space available
- ☐ Other (Please Specify) _______________

Calves and Heifers – Part B

B1. Did this farm utilize a custom heifer raiser in 2005?

- ☐ No *(If no, please skip to question B5)*
- ☐ Yes *(If yes, please proceed to question B2)*

B2. Please indicate your reasons for utilizing a custom heifer raiser. (Please check all that apply.)

- ☐ Management time constraints
- ☐ Lack of adequate facilities on home farm
- ☐ Manure management concerns
- ☐ Better growth/performance from custom raiser
- ☐ Expansion of milking herd/cow numbers
- ☐ Other (Please Specify) ____________________

B3. If you have previously raised calves/heifers in your operation and have switched to utilizing a custom heifer grower → Have you noticed better performance and growth with the utilization of the custom raiser?

- ☐ No
- ☐ Yes → Please comment on any differences you have noticed.

____

B4. Please rate your <u>overall satisfaction</u> with the utilization of a custom heifer raiser on the following scale of 1 – 6, with one being extremely dissatisfied and six being extremely satisfied.

Extremely Dissatisfied ... Extremely Satisfied

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6

B5. Did you utilize an accelerated heifer growth program in 2005 at any stage of heifer growth?

☐ Yes *(If yes, please proceed to question B6 and skip question B7)*
☐ No *(If no, please skip to question B7)*

B6. If you are utilizing an accelerated growth heifer program please indicate the stages of growth being accelerated below.

____

B7. If you are not utilizing an accelerated heifer growth program please indicate your reasons why. (Please check all that apply.)

☐ Expense
☐ Lack of knowledge/information on management of a program
☐ Lack of management time to oversee the program
☐ Not convinced of the benefits
☐ Other (Please Specify) ____________________

B8. What are pre-weaned calves being fed?

☐ Milk replacer _____% fat _____% protein
☐ Non-pasteurized waste milk
☐ Pasteurized waste milk

B9. What criteria are utilized in weaning calves?

	Criteria Used
☐ Age	_____ weeks old
☐ Daily grain intakes	_____ lbs/day
☐ Other (Please Specify) ______________	_____

B10. What is the average age at weaning on your farm? __________

B11. What is the average weight at weaning on your farm? __________

B12. Are calves/heifers being weight taped regularly with height and weight recorded?

☐ Yes *(If yes, please proceed to question B13)*
☐ No *(If no, please skip to question B14)*

B13. If calves/heifers are being weight taped, how often is this recorded at each stage of life? (Please mark any stages at which weight taping occurs.)

Taped During Stage	**Frequency of Weight Taping**
☐ Pre-weaning	_____
☐ Post-weaning – breeding age	_____
☐ Bred – springing	_____

B14. What proportion of heifer calves born survived to first service in 2005?

_____

Reproduction – Part C

C1. What is your average age and weight of heifers at their first insemination/breeding?

Age __________ Weight __________

C2. What is your average age and weight at first calving?

Age __________ Weight __________

C3. What percentage of lactating cows were open at greater than 150 days in milk (OPEN>150) in 2005? __________

C4. What is your voluntary waiting period for lactating cows? __________

C5. What is the average number of days to first service for lactating cows?__________

C6. What is your calving interval?

____

C7. What is the average length of your dry period?

____

C8. What is your average number of days open?

____

C9. What are the heifer breeding criteria used on your farm? (Please check all that apply.)

	Criteria Used
☐ Age	_____ months
☐ Percentage of mature bodyweight	_____ % at breeding
	_____ % at calving
☐ Frame size	_____ inches at withers
☐ Other (Please Specify) __________	_____

C10. Do you utilize artificial insemination for breeding cows and/or heifers?

Cows	**Heifers**
☐ Yes	☐ Yes
☐ No	☐ No

Please Note: If you answered no to both heifers and cows in question C10, please skip ahead to question C17.

C11. Percentage of breeding using artificial insemination (AI):

	Percentage
Cows	_______
Heifers	_______

C12. Who is responsible for AI on your operation for cows and/or heifers? (Please check all that apply.)

	Number of Breeders
☐ Owner/operator	__________
☐ Herdsman	__________
☐ Heifer manager	__________
☐ Breeding manager	__________
☐ Outside AI technician (Genex, Alta, Select Sires, etc)	__________
☐ Other (Please Specify) __________	__________

C13. Was sexed semen being used in your operation in 2005?

☐ No
☐ Yes → Please specify which groups of animals it was used on.

____

C14. What is the average price per straw of semen used on your farm to breed cows and heifers?

Cows	$__________/straw
Heifers	$__________/straw

C15. Please state your top 3 criteria used in sire selection for **cows**.

1st ____
2nd ____
3rd ____

C16. Please state your top 3 criteria used in sire selection for *heifers*.

1st ____
2nd ____
3rd ____

C17. If you do not use 100% AI, for what reason(s) do you use natural service? (Please check all that apply.)

	Cows	**Heifers**
Cost of semen	☐	☐
Lack handling facilities	☐	☐
Lack labor for estrus detection and servicing	☐	☐
Bred 1st service AI, then introduce clean-up bulls	☐	☐
Other (specify) __________________________	☐	☐

Heat Detection Methods – Part D

D1. Which heat detection methods are currently being utilized on your farm. (Please check all that apply, and provide percentage of animals in each category.)

Cows

☐ Visual heat detection without aides
% cows _____

☐ Passive mount detectors
% cows _____
- ☐ Kamar
- ☐ Chin ball markers
- ☐ Tail chalking/crayon
- ☐ Other (Please Specify)

____

☐ Electronic aides
% cows _____
- ☐ Heat Watch
- ☐ Pedometers
- ☐ Afi System
- ☐ Other (Please Specify)

____

☐ Other (Please Specify)

____

Heifers

☐ Visual heat detection without aides
% heifers _____

☐ Passive mount detectors
% heifers _____
- ☐ Kamar
- ☐ Chin ball markers
- ☐ Tail chalking/crayon
- ☐ Other (Please Specify)

____

☐ Electronic aides
% heifers _____
- ☐ Heat Watch
- ☐ Pedometers
- ☐ Afi system
- ☐ Other (Please Specify)

____

☐ Other (Please Specify)

____

D2. If visual heat detection without aides is being utilized in **cows**:

How many times per day _____
At what times of the day _____ _____
For how long are cows observed at each time _____
Where are cows being observed _____
Who is responsible for the heat detection _____

If the person responsible for heat detection is unpaid, what are the other responsibilities of this person?

____

D3. If visual heat detection without aides is being utilized in *heifers*:

How many times per day _____

At what times of the day _____ _____

For how long are heifers observed at each time _____

Where are heifers being observed _____

Who is responsible for the heat detection _____

If the person responsible for heat detection is unpaid, what are the other responsibilities of this person?

____

Synchronization Programs – Part E

E1. Were any synchronization programs being used on your farm in 2005?

Cows
- ☐ Yes *(Skip to E4)*
- ☐ No *(Skip to and answer E2)*

Heifers
- ☐ Yes *(Skip to E4)*
- ☐ No *(Skip to and answer E3)*

Please note: If you answered 'No' to utilization of synchronization programs in both heifers and cows, please skip ahead to Part F.

E2. If synchronization programs were not utilized in 2005 for **cows**, please check all reasons that apply:

- ☐ Synchronization protocols too expensive to use
- ☐ Prefer to breed cows to a visually detected estrus
- ☐ Inadequate facilities to restrain cows for injections
- ☐ Lack management time required to manage a synchronization program
- ☐ Not convinced of benefits of synchronization programs
- ☐ Poor conception rate to timed artificial insemination
- ☐ Other (Please Specify) ____________________

E3. If synchronization programs were not utilized in 2005 for *heifers*, please check all reasons that apply:

- ☐ Synchronization protocols too expensive to use
- ☐ Poor response of heifers to synchronization protocols
- ☐ Prefer to breed heifers to a visually detected estrus
- ☐ Heifers are at an inconvenient location
- ☐ Lack of handling facilities for heifers
- ☐ Lack management time required to manage a synchronization program
- ☐ Not convinced of benefits of synchronization programs
- ☐ Poor conception rate to times artificial insemination
- ☐ Other (Please Specify) ____________________

E4. If synchronization programs were being used in <u>cows and/or heifers</u> in 2005, please select the reasons for use below. (Check all that apply,)

- ☐ Setting up cows/heifers for first postpartum AI service
- ☐ Resynchronization for 2nd or greater service
- ☐ Synchronizing and breeding problem breeders
- ☐ Breeding cows/heifers with ovarian cysts
- ☐ Breeding anestrus/anovular cows/heifers
- ☐ Other (Please Specify) ____________________

E5. If synchronization programs were used in cows and/or heifers in 2005, please select those that were used in your operation. **Please note any changes from the described protocols in the margins.**

Cows

☐ Ovsynch
% cows _____

☐ Presynch
% cows _____

☐ Cosynch
% cows _____

☐ Heatsynch
% cows _____

☐ CIDR with $PGF_{2\alpha}$
% cows _____

☐ Targeted Breeding Protocol
% cows _____

☐ Use of a single injection of $PGF_{2\alpha}$ to bring lactating cows into estrus for AI

☐ Use of a timed AI in lactating cows after a single injection of $PGF_{2\alpha}$

☐ Other (Please Specify)
____

Heifers

☐ Ovsynch
% heifers _____

☐ Presynch
% heifers _____

☐ Cosynch
% heifers _____

☐ Heatsynch
% heifers _____

☐ CIDR with $PGF_{2\alpha}$
% heifers _____

☐ Targeted Breeding Protocol
% heifers _____

☐ Single injection of $PGF_{2\alpha}$ for synchronizing estrus

☐ Two injections of $PGF_{2\alpha}$ administered at 11-14 day intervals

☐ Melengestrol acetate (MGA) combined with $PGF_{2\alpha}$

☐ Other (Please Specify)
____

E6. If synchronization programs were utilized on your dairy in 2005, were cows and/or heifers monitored for estrus and inseminated between synchronization intervals?

☐ Yes
☐ No

E7. What was the average cost per dose of the following items which you utilized in synchronization programs?

	Did Not Use	**Used**	**Cost/dose**
GnRH	☐	☐	________
$PGF_{2\alpha}$	☐	☐	________
ECP	☐	☐	________
MGA	☐	☐	________
CIDR	☐	☐	________
Other	☐	☐	________

(Please Specify) ______________

E8. If synchronization programs involving injections were utilized in 2005, what facilities were utilized for giving shots? (If more than one type of facility is utilized, please state all facilities used.)

____

E8a. Please specify the amount of time per cow needed to give a shot using the above facilities.

____

E8b. Who was responsible for administering the shots/program?

____

Reproduction Summary – Part F

F1. Please fill in the following table referring to conception rates, heat detection rates, and services per conception in heifers and cows. Please label each group column according to the program/method used. For example, there may be two groups of heifers – one group receiving visual heat detection and one group using CIDRs. Each of these groups would be labeled under heifers and their respective conception rates, heat detection rates, and services per conception reported.

	Example	**Heifers**			**Cows**		
	All Heifers	**All**	**Group 1**	**Group 2**	**All**	**Group 1**	**Group 2**
Program/ Method Used	*Visual Heat Detection*						
Heat detection rate	*65%*						
Conception rate (all services)	58%						
Services per conception	1.72						

F2. When was the last major change in your reproduction program?

____

F3. What was the last major change in your reproduction program?

____

____

____

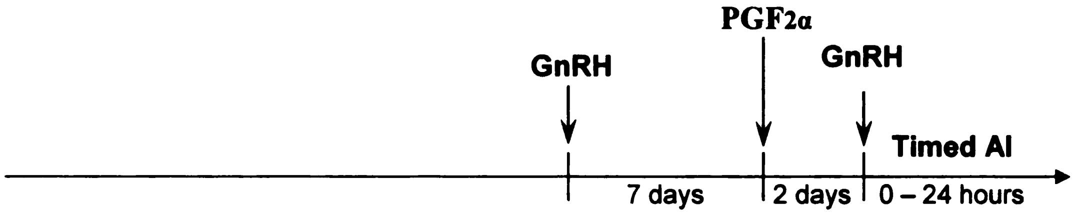
Why was the above change in your reproduction program made?

- ☐ Herd expansion
- ☐ To remedy reproductive performance
- ☐ Advice of management team
- ☐ New/different facilities
- ☐ Other (Please Specify) __________________

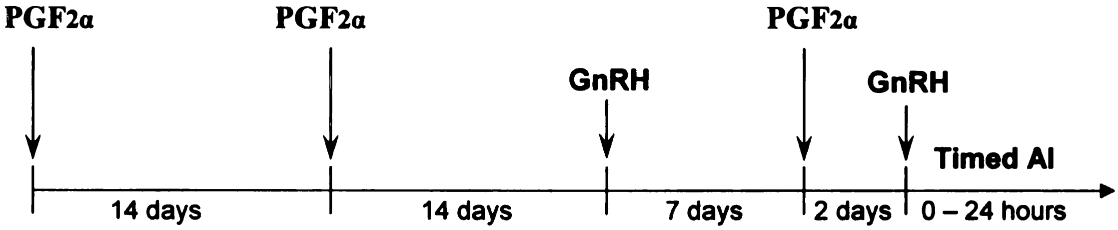
APPENDIX 2: SYNCHRONIZATION PROGRAM REFERENCE SHEET INCLUDED WITH SURVEY

Prostaglandin F2α (PGF2α)
→ Common commercial products include Lutalyse, Estrumate, Prostomate
Gonadotropin Releasing Hormone (GnRH)
→ Common commercial products include Cystorelin, Fertagyl, Factrel
Estradiol Cypionate (ECP) – Long acting estrogen
CIDR– intravaginal progesterone insert
Melengestrol acetate (MGA) – progestin that suppresses heat and prevents ovulation

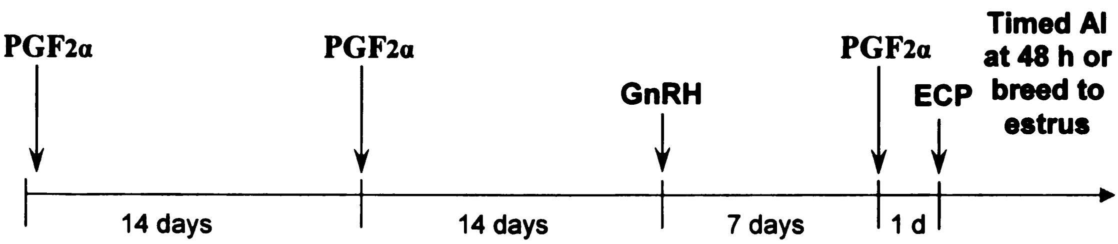
Ovsynch *(Does not include PGF2α injections before the first GnRH injection)*



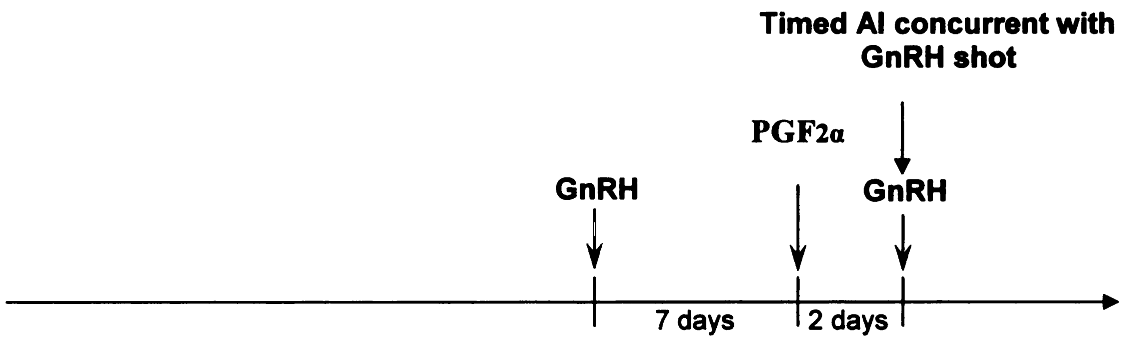
Presynch *(May include an additional PGF2α injection 14 days before the first PGF2α injection)*



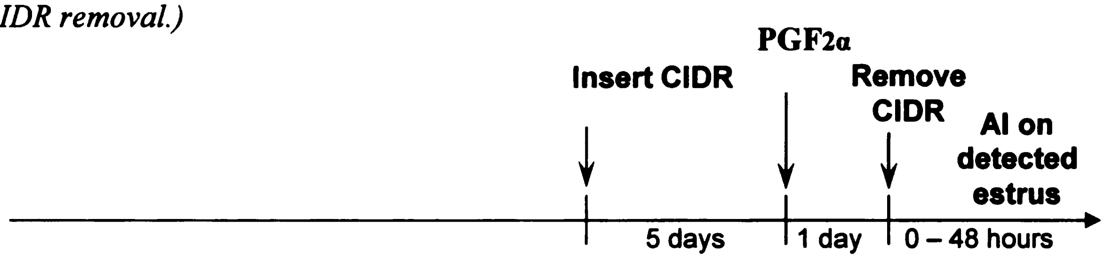
Heatsynch *(Modification of either the Ovsynch or Presynch protocols illustrated above in which ECP is used in place of the second GnRH injection as the ovulatory stimulus)*



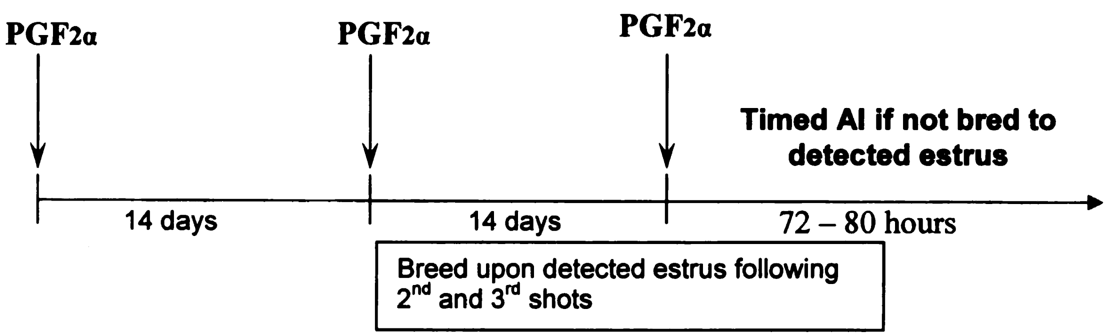
Cosynch *(Specific form of Ovsynch in which breeding occurs concurrently with the second injection of GnRH.)*



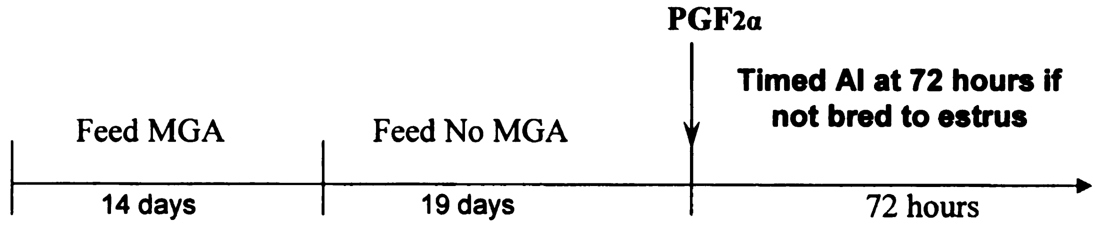
CIDR with PGF2α *(The CIDR is inserted on day 1, followed by a PGF2α shot on day 6, and removal of the CIDR on day 7. Insemination occurs on detected estrus following CIDR removal.)*



Targeted Breeding Protocol *(PGF2α injections are given 14 days apart and inseminations occur on detected estrus after the second and third injection. When estrus is not detected after the third injection, one timed AI can be given 72–80 hours after the third injection.)*



Melengestrol acetate (MGA) combined with PGF2α *(Oral feeding of MGA at .5mg/head/day for 14 days and then fed no MGA for the next 19 days. An injection of PGF2α on day 33 is administered. Breed heifers showing heats beginning 24 hours post PGF2α, and used timed AI at 72 hours post PGF2α shot for those not showing heats.)*



REFERENCES

REFERENCES

Britt, J. H. 1985. Enhanced reproduction and its economics implications. J. Dairy Sci. 68:1585-1592.

Caraviello, D. Z., Wiegel, K. A., Fricke, P. M., Wiltbank, M. C., Florent, M. J., Cook, N. B., Nordlund. K. V., Zwald, N. R., and C. L. Rawson. 2006. Survey of management practices on reproductive performance of dairy cattle on large US commercial farms. J. Dairy Sci. 89:4723-4735.

De Vries, A. 2006. Economic value of a pregnancy in dairy cattle. *J. Dairy Sci.* 89:3876-3885.

Fricke, P. M. 2003. Monitoring reproduction from the starting gate. Proceedings of the 6th Western Dairy Management Conference. pg 77-88.

Fricke, P. and D. Niles. 2003. Don't fall for the bulls-are-cheaper, more-fertile myth. Hoards Dairyman. Oct 25:8.

Groenendaal, H., D. T. Galligan, and H. A. Mulder. 2004. An economic spreadsheet model to determine optimal breeding and replacement decisions for dairy cattle. *J. Dairy Sci.* 87:2146-2157.

Hadley, G. L., S. B. Harsh, and C. A. Wolf. 2002. Managerial and financial implications of major dairy farm expansions in Michigan and Wisconsin. J. Dairy Sci. 85:2053-2064.

Hadley, G. L., C. A. Wolf, and S. B. Harsh. 2006. Dairy cattle culling patterns, explanations, and implications. J. Dairy Sci. 89:2286-2296.

Harris, T. R., and H. P. Mapp. 1986. A stochastic dominance comparison of water-conserving irrigation strategies. *Am. J. Agric. Econ* 68:2 298-305.

Johnson, D. 2005. Reduced input dairy farming may be an option. http://www.extension.umn.edu/dairy/dairystar/02-26-05-Johnson.htm Accessed June 7, 2007.

Klemme, R. M. 1985. A stochastic dominance comparison of reduced tillage systems in corn and soybean production under risk. *Am. J. Agric. Econ.* 67:550.

Lucy, M. C. 2001. Reproductive loss in high-producing dairy cattle: where will it end? *J. Dairy Sci.* 84:1277-1293.

Mas-Collel, A., M. D. Whinston, and J. R. Green. 1995. *Microeconomic Theory*. Oxford University Press, Inc.

McCarl, C. A. 1990. Generalized stochastic dominance: An empirical examination. *Southern Journal of Agricultural Economics.* 49-56.

McGuckin, T. 1983. Alfalfa management strategies for a Wisconsin dairy farm: an application of stochastic dominance. *North Central Journal of Agricultural Economics.* 5:1 43-49.

Meadows, C., Rajala-Schultz, P. J., and G. S. Frazer. 2005. A spreadsheet-based model demonstrating the nonuniform economic effects of varying reproductive performance in Ohio dairy herds. *J. Dairy Sci.* 88:1244-1254.

Meyer, J. 1977. Choice Among Distributions. *J. Econ. Theory.* 14:326-336.

NASS (National Agricultural Statistics Service. 2007. Quick Stats (Dairy) U.S. & All States Data – Dairy. Milk Cows by Size Groups: Operations. http://www.nass.usda.gov/QuickStats/ Accessed June 15, 2006

Nebel, R. L. and S. M. Jobst. 1998. Evaluation of systematic breeding programs for lactating dairy cows: a review. J. Dairy Sci. 81:1169-1174.

Nebel, R. L. and S. M. Jobst. 1998. Symposium: Gonadotropin-releasing hormone and prostaglandin for estrus detection. *J. Dairy Sci.* 81: 1169-1174.

Nebel, R. L. 2002. Subject: What should your AI conception rate be? http://www.ext.vt.edu/news/periodicals/dairy/2002-05/aiconception.html Accessed March 19, 2008.

Olynk, N. J. and C. A. Wolf. 2007. Expected net present value of pure and mixed sexed semen artificial insemination strategies in dairy heifers. *J. Dairy Sci.* 90:2569-2576.

Overton, M. Theriogenology. 2005. Cost comparison of natural service sires and artificial insemination for dairy cattle reproductive management. Theriogenology. 64:589-609.

Pursley, J. R., M. R. Kosorok, and M. C. Wiltbank. 1997. Reproductive management of lactating dairy cows using synchronization of ovulation. *J. Dairy Sci.* 80:301-306.

Pursley, J. R., M. O. Mee, and M. C. Wiltbank. 1995. Sychnronization of ovulation in dairy cows using $PGF_{2\alpha}$ and GnRH. Theriogenology 44:915.

Pursley, J. R., R. W. Silcox, and M. C. Wiltbank. 1998. Effect of time of artificial insemination on pregnancy rates, calving rates, pregnancy loss, and gender ratio after synchronization of ovulation in lactating dairy cows. *J. Dairy Sci.* 81:2139-2144.

Seidel, G. E., Jr., and J. L. Schenk. 2002. Field trials with sexed, frozen bovine semen. Pages 64-49 in Proc.19th Technol. Conf. Artif. Insemination Reprod. Natl. Assoc. Anim. Breeders, Columbia, MO.

Seidel, G. E., Jr., J. L. Schenk, L. A. Henrickhoff, S. P. Doyle, Z. Brink, R. D. Green, and D. G. Cran. 1999. Insemination of heifers with sexed sperm. *Theriogenology* 52:1407-1420.

Stevenson, J. 2003. Why natural service is not the solution. Hoards Dairyman. Supplement, Oct. 25:6

Tenhagen, B. –A., M. Drillich, R. Surholt, and W. Heuwieser. 2004. Comparison of timed AI after synchronized ovulation to AI at estrus: reproductive and economic considerations. *J. Dairy Sci.* 87:85-94.

Thomas, C. V., M. A. DeLorenzo, D. R. Bray, R. N. Weldon, R. A. Bucklin, and J. G. Martin, III. 1997. A stochastic economic analysis of large herringbone and parallel milking parlors. *J. Dairy Sci.* 80:2418-2428.

Wolf, C. A. 1999. Analyzing reproductive management strategies on dairy farms. Michigan State University Agricultural Economics Staff Paper 99.

Wolf, C., S. Hanson, E. Wittenberg, and S. Harsh. 2002. Discount rates for dairy farms. Michigan State University Agricultural Economics Staff Paper 02-08.

Zacharias, T. P., and A. H. Grube. 1984. An economic evaluation of weed control methods used in combination with crop rotation: a stochastic dominance approach. *North Central J. Agric. Econ. 6:113.*

Zwald, N. 2003. Does the extra effort of AI pay off? Supplement, Hoards Dairyman. Oct 25:11.