Economic evaluation of reproductive performance

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Abstract

Reproductive improvement results in higher milk productivity and, therefore, higher milk income over feed cost, more calf sales and lower culling and breeding expenses. Therefore, as the reproductive efficiency improves, the herd net return increases. These increments follow the law of diminishing returns, increases at a decreasing pace, but are still positive even at high reproductive performance (e.g., 40% 21 day pregnancy rate). Most herds in the United States use a combination of timed artificial insemination (TAI) and estrous detection (ED) reproductive programs. The ratio of achievable pregnancies between ED and TAI determines the economic value difference between both and their combinations. Nonetheless, complex interactions between reproductive programs, herd relative milk yield, and type of reproductive programs exist. Improved reproductive efficiency produces extra replacements. The availability of additional replacements allow more aggressive culling policies (e.g., less services for non-pregnant cows) to balance on-farm supply and demand of replacements. More heifer replacements available result in additional economic benefits. The University of Wisconsin-Madison Dairy Management has developed a series of customizable decision support tools for optimal decision-making.The tool *"economic value of a dairy cow"* allow decision makers calculate the value of a pregnancy, the cost of a pregnancy loss, the economic value of improving the 21-day pregnancy rate, the cost of a day open and their interactions with milk production and other productive, economic, and management traits. The tool *"heifer pregnancy rate"* allow decision makers calculate the efficiency reproductive of heifers and their associated costs. The tool *"Wisconsin-Cornell dairy repro"* allow decision makers to define and evaluate in depth dairy reproductive programs including those that rely only on TAI, only on ED, or those that combine TAI and ED. Decision support tools are openly available at the University of Wisconsin Dairy Management Website: DairyMGT.info.

Introduction

Herd net return is strongly associated with reproductive performance (Giordano et al., 2012; Galvao et al., 2013). Efficient reproductive programs control herd population dynamics and herd structure allowing cows to take advantage of the most efficient part of the lactation curve (Ferguson and Galligan, 1999), while maximizing production of on-farm replacements (Giordano et al., 2012), minimizing costs associated with replacements and mortality (Giordano et al., 2011 and 2012; Galvao et al., 2013), and minimizing the relative costs associated with reproduction (Giordano et al., 2012). Most US dairy farms use a combination of synchronization to ovulation control protocols and estrous detection (ED) for their reproductive management (Caraviello et

al., 2006; Giordano et al., 2012; Galvao et al., 2013). Important traits of reproductive performance are the value of a pregnancy, the cost of a pregnancy loss, the cost of a day open and their associations with milk productivity an other productive, reproductive, and economic parameters (De Vries, 2006; Cabrera, 2012). Reproductive performance can be metered using the 21-day pregnancy rate (21-d PR; Ferguson and Galligan, 1999), which measures the rate at which eligible cows became pregnant in successive 21-day periods. A series of simulation studies in recent years (Cabrera, 2012; Giordano et al., 2011, 2012 and 2013; Galvao et al., 2013) attempt to quantify the economic value of these traits. Some of these studies also provide decision support tools that could be customised for herd-specific economic assessments related to reproduction.

The economic value of reproduction

The economic impact of reproduction in dairy cattle herds can be from these 6 most important traits: (1) increased milk productivity (and milk income over feed cost), (2) increased production of calves, (3) improved selective culling, (4) decreased reproductive culling, (5) decreased involuntary culling, and (6) decreased reproductive cost per pregnancy. The following evaluations include all these factors except (3) improved selective culling. Evidences exist that farmers are able to better select the best herd of animals if they have plenty of well nourished pregnant cows (Souza et al., 2013), however, no quantifications are reported yet. Therefore, economic values reported here might be undervalued.

The value of a pregnancy

The value of a pregnancy (at diagnosis time) is always positive and varies between $128 and $232 for a cow of average productivity. The value of a pregnancy increases and then decreased with months after calving (Figure 1). These values for first lactation ranged between $128 for a cow conceiving in MIM = 3 and $232 for a cow conceiving in MIM = 8. These values are between $185 and $230 for second lactation, between $184 and $202 for third lactation, and between $184 and $192 for fourth lactation cow. The peak values are reached in a pregnancy occurring in MIM = 7 for second lactation and in a pregnancy occurring in MIM = 6 for third and fourth lactations. The increase in the value of a new pregnancy continues for longer MIM for PAR = 1 because of its more persistent lactation curves and future lactations. All the economic factors, except feed costs, contribute positively to the value of a new pregnancy.

The value of a pregnancy is positively related to milk productivity of a cow. The more productive the cow the more its pregnancy value. More valuable cows are better positioned to realize their full potential when becoming pregnant The opposite is also true: less valuable cows have a lower value of pregnancy.

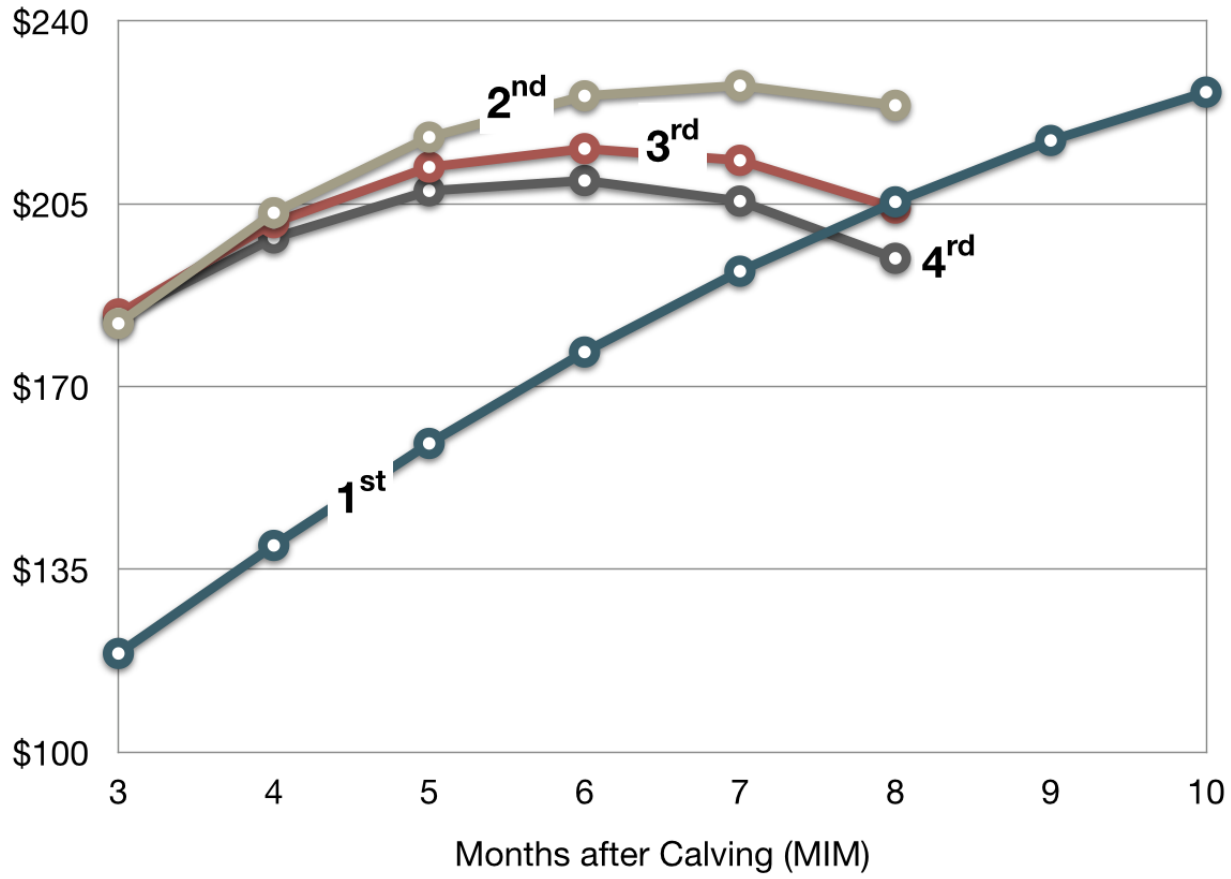

Figure 1. The value of a pregnancy at first diagnosed for by lactations and months after calving for an average production cow (modified from Cabrera, 2012)

The cost of a pregnancy loss

The cost of a pregnancy loss increases consistently with months in pregnancy (MIP). The lowest value is when the MIP = 1, and the largest value is when the MIP = 9 (Figure 2). It varies between $128 for a pregnancy loss in first lactation, MIM = 3, and MIP = 1 to $897 for a pregnancy loss in second lactation, MIM = 13, and MIP = 9. Lower milk sales, higher culling costs, lower calf revenues explain the cost of a pregnancy loss, and higher reproduction costs. In agreement with the pregnancy value, more productive (more valuable) cows incur in a higher cost when lose a pregnancy. A 10% more productive than the average cow has between 90% and 144% greater cost when a pregnancy is lost. A 10% less productive than the average cow has between -91% and -100% lower cost when a pregnancy is lost.

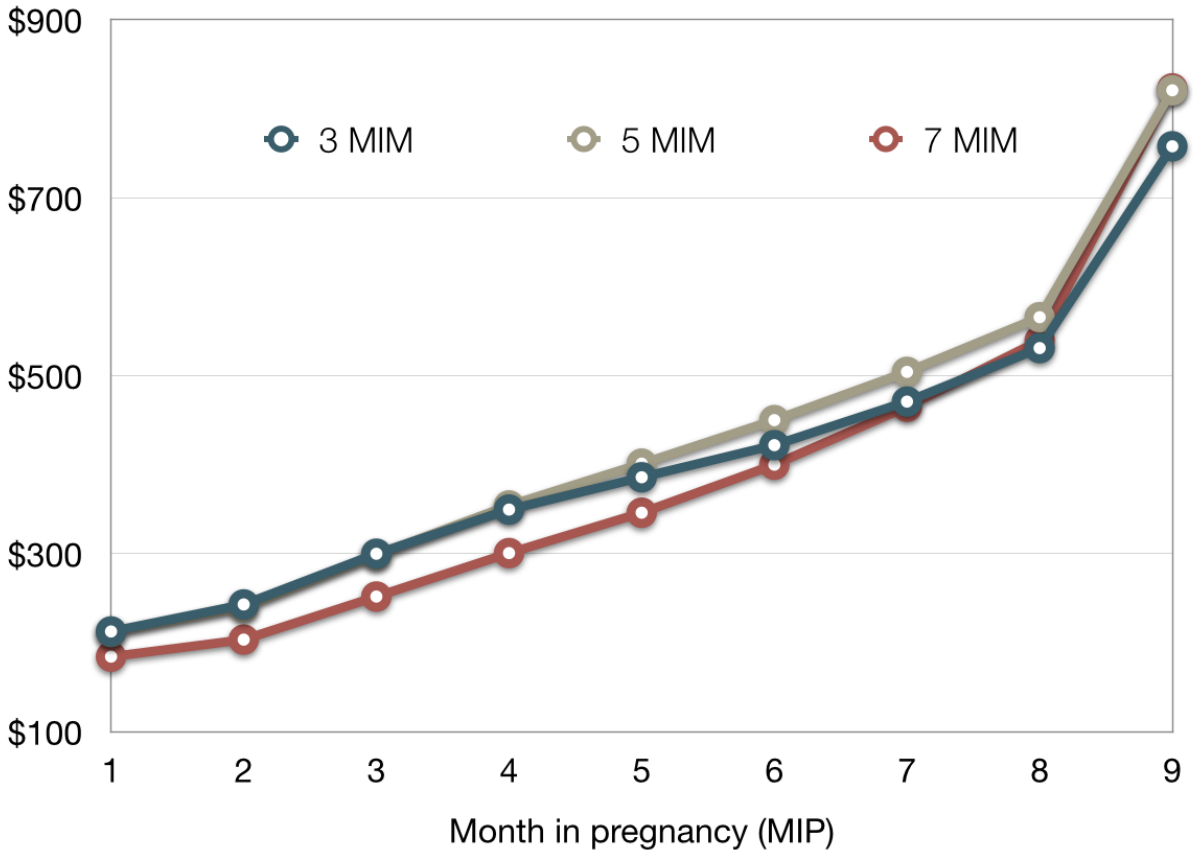

Figure 2. The cost of a pregnancy loss according to months after calving (MIM) when becoming pregnant and month in pregnancy (MIP) at the pregnancy loss occurs for a third lactation average production cow (extracted from Cabrera, 2012).

The value of improving 21-d PR

The economic value (net return) of the herd increases as the reproductive performance (21-d PR) increases (Figure 3). With reference to the lowest 21-d PR of 10%, it increases between $16/cow.year for 10 to 11% 21-d PR and $3/cow.year for 39 to 40% 21-d PR. The economic gain of increasing the 21-d PR from 15 to 20% is $50/cow.year and from 30 to 35% is $21/cow.year. The value of improving the 21-d PR follows a curve of diminishing returns: the greater the current 21-d PR the less the gain when improving it. However, even at very high 21-d PR (e.g., 40%, Cabrera 2014) there is still an economic value of improving reproductive efficiency.

Interestingly, the value of improving 21-d PR increases when either the milk production of the herd is lower or when the milk production of the herd is higher. Compared with a production of 10,900 kg/cow.year, the increase is between 2.2 and 2.1 times greater when milk production is 5,000 kg/cow per year and it is between 1.9 and 1.8 times greater when milk production is 13,600 kg/cow per year.

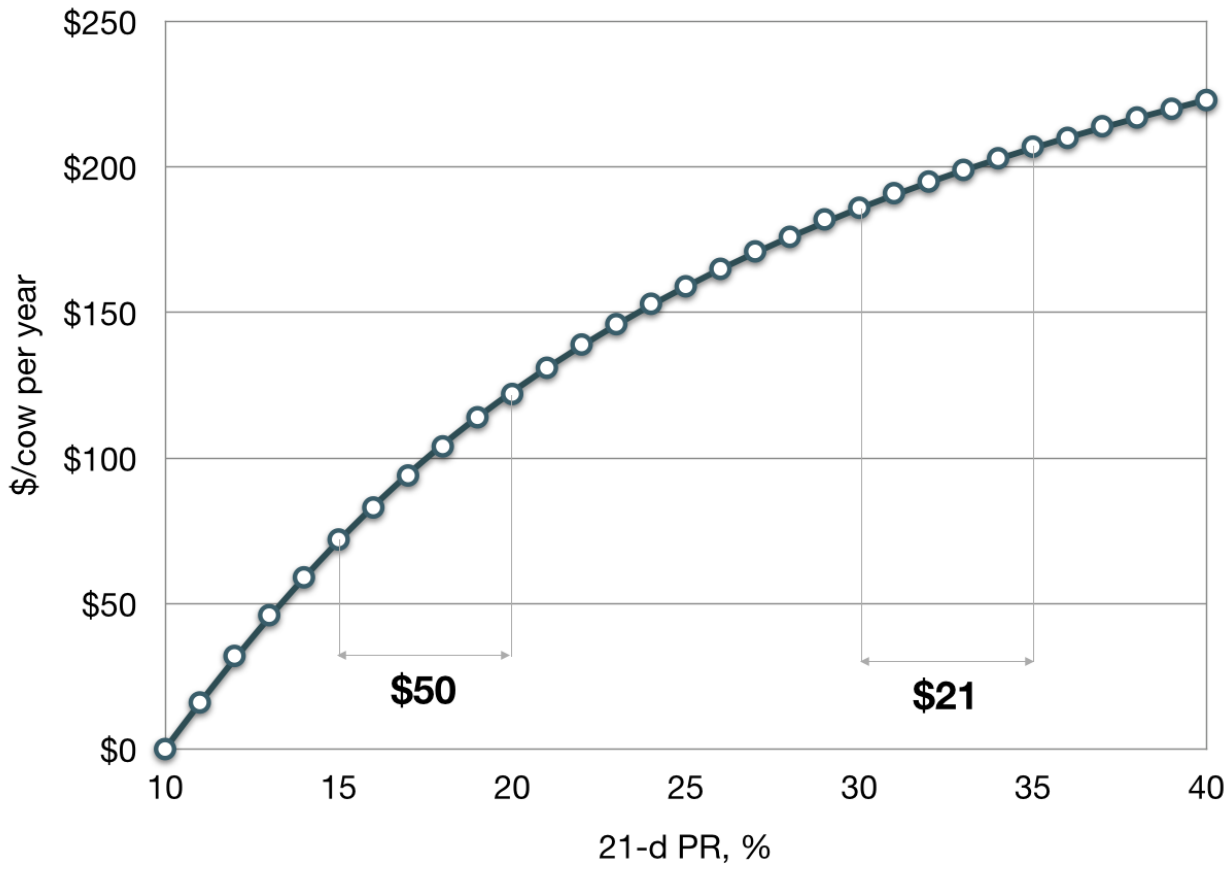

Figure 3. The economic value of improving reproductive efficiency (21 day pregnancy rate; 21-d PR) for an average production herd of about 10,900 kg/cow.year (values calculated using decision support tool *"economic value of a dairy cow"* from DairyMGT.info).

The cost of a day open

The economic cost of keeping a cow one extra day can be calculated based on the difference between the projected value of a cow in 2 consecutive months not becoming pregnant. This value in a third lactation varies between $5.5/day to $2.6/day for MIM=3 to MIM=8, respectively (Table 1). It decreases with time (MIM) consistent with the value of the cow that also decrease as time goes by. Therefore, the accumulated cost of a day open throughout an entire lactation approaches the value of the cow when first eligible (Table 1, last column). This cost of a day open is lower for first lactation cows and higher for later lactation cows.

The cost of a day open could increase or could decrease at different herd levels of productivity. In general it will increase as the herd milk production deviates from a production level of 10,900 kg/cow.year. For a level of production of 7,700 kg/cow.year, it increases between 1.27 and 1.04 times for MIM = 4 to 5 and then it decreases between 1.95 and 13 times for MIM = 6 to 8. For a level of production of 13,600 kg/cow.year, it always increases between 1.13 and 1.23 for MIM = 3 to 8.

Table 1. The economic cost of an extra day open for an average third lactation cow (values calculated using decision support tool *"economic value of a dairy cow"* from DairyMGT.info).

	Cost of day open		Total accumulated
Month after calving (MIM)	$.day	$/month	$/total
3	5.5	165	165
4	5.1	153	318
5	4.5	135	453
6	3.9	117	570
7	3.3	99	669
8	2.6	78	747

The additional cost of rearing heifers

Data from 30 rearing facilities in Wisconsin were used to study heifers average age at first calving (AFC), true pregnancy rate, their start breeding age, and the extra cost of rearing according to the fertility traits (Figure 4) by using the tool "*heifer pregnancy rate ©"* tool from DairyMGT.info). Only 8 or 27% of the herds had AFC at recommended age of between 23 and 24 months (Figure 4, left top panel). Two out of the 30 (7%) herds had AFC at less than 23 months and the rest 20 out of 30 (67%) of the herds had AFC at more than 24 months, which implies extra costs of rearing. Heifers need to become pregnant between 14 and 15 months of age in order to have an optimal AFC (Figure 4, left bottom panel). After the heifer breeding program starts, the true pregnancy rate is the reflect of the speed at which heifers become pregnant = reproductive efficiency. As important as start early breeding is the efficiency of pregnancy (service rate and conception rate, Figure 4 right top panel). All these factors determine the cost of rearing heifers. Under the assumption that heifers will perform similarly as adults regardless of the AFC, the major difference in reproductive efficiency is the extra time (deviation from an optimum) cows need to be reared because they did not became pregnant on time. This extra cost or excess rearing cost, in the 30 evaluated herds varied between $0 (optimal, 2 herds) to <$50 (4 herds), $50<$100 (11 herds), $100<$150 (4 herds), $150<$200 (5 herds), $200<$250 (3 herds), and $350 (1 herd) with an overall average of $111/heifer.

Economic effects of TAI with ED

A common reproductive management practice is to follow a synchronization protocol and perform inseminations at detected estrus in between-timed services. Giordano et al. (2011) included ED or TAI only programs as the main core of their analyses, but offered sensitivity analyses of the impacts of their combinations. Another study by Giordano et al. (2012) examined commonly used reproductive protocols that included Presynch-Ovsynch for first AI (Moreira et al., 2001) followed by Ovsynch protocol for re-synchronization (Pursley et al., 1995).

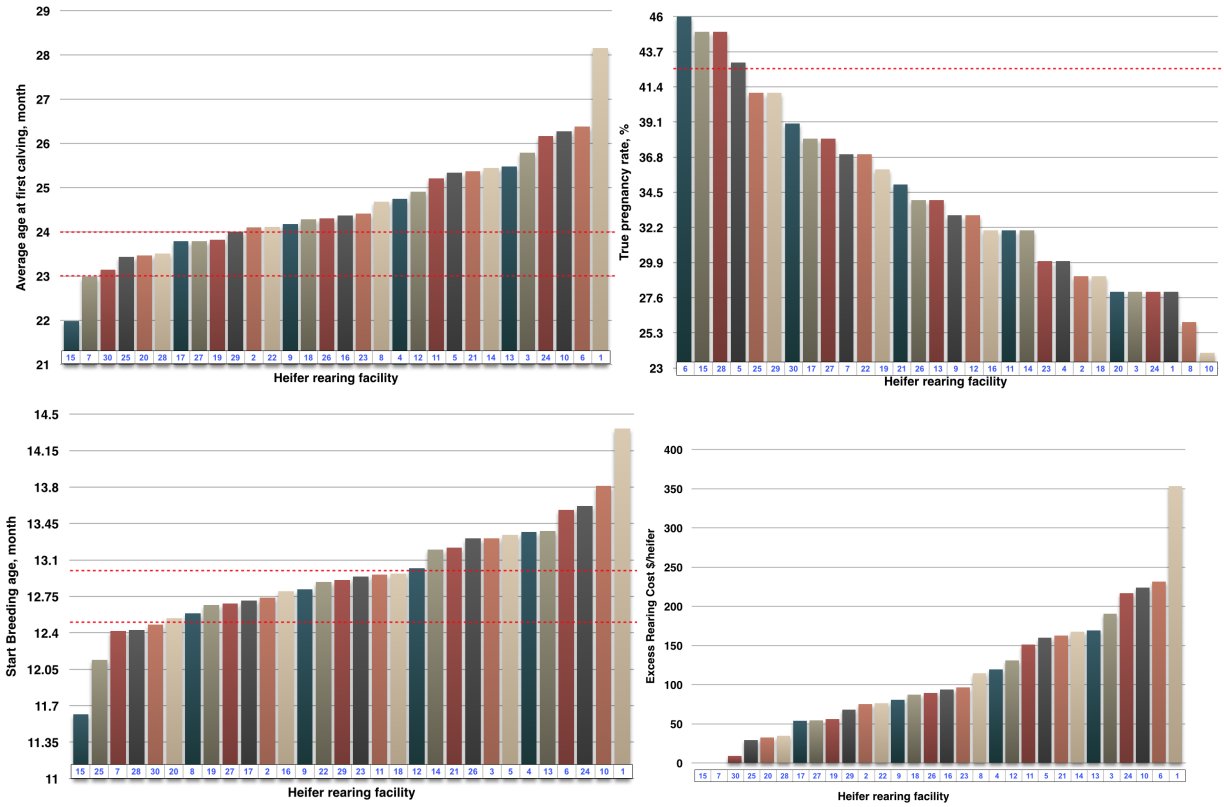

Figure 4. Average age at first calving (left top panel), true pregnancy rate (right top panel), start breeding age (left bottom panel), and excess rearing costs (right bottom panel) of 30 Wisconsin rearing facilities (values calculated using decision support tool *"heifer pregnancy rate"* from DairyMGT.info).

In Giordano et al. (2011) 3 reproductive programs were analyzed. Two were TAI only and the other was ED only. One of the TAI programmes was Double-Ovsynch followed on day 32 (D32) by Ovsynch re-synchronization and the other TAI was a Double-Ovsynch followed by Double-Ovsynch re-synchronization. Conception rate (CR) for the Double-Ovsynch programme was set at 45% for the first service and 39% for subsequent services, whereas Ovsynch was set at 30% CR for subsequent services (Table 2). The CR for the only ED programme was set at 33% for the first service and 30% for later services. Results showed that the TAI only programs had higher net return (US$/cow per year) than the ED program: $45/cow per year greater for the program using Ovsynch for the second and later services and $69/cow per year greater for the program only using Double-Ovsynch (best economic program in the study). Such study provided a sensitivity analysis of between 10% and 80% ED at 30% CR in between TAI for second and subsequent services. The net return of the reproductive program was negatively affected when combining TAI with OD when the CR of second and subsequent TAI was higher to the CR following ED. The opposite was also true. At a reasonable ED rate of 60%, a loss of about $12/cow per year in the Double-Ovsynch re-synchronization program is expected when including OD (30% CR) in the TAI program (Table 2).
Giordano et al. (2012) set a baseline of 100% TAI reproductive program with 42% CR for first TAI and 30% for subsequent TAI. Then they studied the implementation of ED before and after

the first TAI at 3 levels of performance, 25%, 30%, 35% CR under variable levels of ED rate (30% to 80% at 10% intervals). Also, CR was assumed to decrease 2 percentage points for every 10 percentage increase in OD after 30% before first TAI and to have 2 percentage points less after 50% OD after first TAI. Compared with the pure TAI program, combined programs having 25% CR for OD had lower economic values in all cases.This lower economic value was -$17 for the presynch-ovsynch + ovsynch with 42 and 30% CR, respectively (Table 2). Combined programs having 30% CR for OD had comparable or slightly better economic values, and combined programs having 35% CR for OD had better economic values. The study concluded that with a reasonable ED rates of 50% to 60% (Lima et al., 2009; Chebel and Santos, 2010), it would be recommendable to use ED only if the expected CR was greater than 30% or 35% (greater than the expected TAI CR). In agreement with previous findings (Giordano et al., 2011), this study also found that inseminating cows detected in estrus before completion of a synchronization protocol and expecting a low CR had a negative effect on the overall reproductive and economic performance. This occurred because cows completing synchronization have a better chance of becoming pregnant than those inseminated at estrus and not becoming pregnant are subject to a longer interbreeding interval until they are re-enrolled in a subsequent synchronization program.

Table 2. Economic impact when combining TAI with ED

	Net return gain TAI vs. TAI + ED, $/cow.yr				
	TAI CR, %		***60% OD CR, %***		
Study *Repro Program*	***First Serv.***	***Later Serv.***	***25***	***30***	***35***
Giordano et al., 2011					
Double Ovsynch + D32 Ovsynch	*45*	*30*		***14***	
Double Ovsynch + Double Ovsynch	*45*	*39*		***-12***	
Giordano et al., 2012					
Presynch-Ovsynch + Ovsynch	*42*	*30*	***-17***	***2***	***19***

Adapted from Cabrera (2014)

Giordano et al. (2011; 2012) introduced different levels of ED in defined TAI programs. They did not analyzed the introduction of TAI protocols in ED only programs. However, this can be easily achieved by using the *"Wisconsin-Cornell dairy repro"* decision support tool from DairyMGT.info. A baseline ED program was defined having 60% service rate with 30% CR. Then,different TAI programs were combined with it (Table 3). Defined TAI programs included PreSynch OvSynch followed by OvSynch and Double OvSynch followed by either OvSynch or Double OvSynch (Giordano et al., 2011; 2012). Reasonable and plausible CR were set. For first service the CR was 42% and 55% for PreSynch OvSynch and Double Ovsynch, respectively. For second and

later services the CR varied from 33, 35, and 38% for OvSynch and 42% for Double OvSynch. When Double Ovsynch was used for first service, no ED was allowed on first service.

Table 3. Economic impact of introducing TAI programs in a ED only program

	1st Service		2nd+ Service		Gain or loss
Program	ED	CR	ED	CR	$/cow.year
100% ED (base)	60	30	60	30	-
PreSynch OvSynch + OvSynch	Y	42	Y	33	$7.7
PreSynch OvSynch + OvSynch	Y	42	Y	35	$10.3
PreSynch OvSynch + OvSynch	Y	42	Y	38	$12.3
PreSynch OvSynch + OvSynch	N	42	Y	35	$17.0
Double OvSynch + OvSynch	N	55	Y	35	61.1
Double OvSynch + Double OvSynch	N	55	Y	42	$71.1

Results obtained using the "*Wisconsin-Cornell dairy repro"* decision support tool from DairyMGT.info.

The economic value of the 100% ED program improved in all scenarios explored in Table 3. It improved between $7.7 and $71.1/cow per year. As expected, greater improvement occurred when greater the CR of the TAI program, specially the CR of the first service. The economic value of reproductive programs is greatly influenced not only by the overall proportion of cows becoming pregnant, but also by the timing on when these cows become pregnant.

Conclusions

The economic reproductive gain increases between $16 and $3/cow.year for each 1% 21 d PR increase and this value will increase even more with either greater or lower herd production level. The value of a pregnancy varies between $128 and $232 and the cost of pregnancy loss between $128 and $897 for a cow of average productivity. The cost of a day open is calculated between $5.5/day to $2.6/day for MIM=3 to MIM=8, respectively, for an average production third lactation cow. The extra cost of rearing heifers due to reproductive inefficiencies is calculated at $111/heifer. Combined TAI and ED programs can be reproductively and economically efficient depending on their CR performance. Low ED CR in combined programs can have a double negative effect because cows completing synchronization have a better chance of becoming pregnant than those inseminated at estrus and not becoming pregnant, which are subject to a longer interbreeding interval. Introduction of PreSynch OvSynch + Ovsynch, Double OvSynch + OvSynch, or Double OvSynch + Double Ovsynch without ED before first TAI increased the most the most the value of the ED only program by $17, $61, and $71/cow per year, respectively.

Decision support tools to calculate farm and cow specific reproductive economic values are available at the University of Wisconsin Dairy Management, DairyMGT.info.

References

Cabrera VE 2012. A simple formulation and solution to the replacement problem: a practical tool to assess the economic cow value, the value of a new pregnancy, and the cost of a pregnancy loss. Journal of Dairy Science 95, 4683–4698.

Cabrera VE 2014. Economics of fertility in high-yielding dairy cows on confined TMR systems. Animal 8, 211-221.

Caraviello DZ, Weigel KA, Fricke PM, Wiltbank MC, Florent MC, Cook NB, Nordlund KV, Zwald NR and Rawson CL 2006. Survey of management practices on reproductive performance of dairy cattle on large US commercial farms. Journal of Dairy Science 89, 4723–4735.

Chebel RC and Santos JE 2010. Effect of inseminating cows in estrus following presynchronization protocol on reproductive and lactation performances. Journal of Dairy Science 93, 4632–4643.

De Vries A 2006. Economic value of pregnancy in dairy cattle. Journal of Dairy Science 89, 3876–3885.

Ferguson JD and Galligan DT 1999. Veterinary reproductive programs. In Proceedings of 32nd Annual Convention of the American Association of Bovine Practitioners (AABP), Nashville, TN. pp. 133–137. American Association of Bovine Practitioners, Opelika, AL, US.

Galvao KN, Federico P, De Vries A and Schuenemann G 2013. Economic comparison of reproductive programs for dairy herds using estrus detection, timed artificial insemination, or a combination. Journal of Dairy Science 96, 2681–2693.

Giordano JO, Fricke PM, Wiltbank MC and Cabrera VE 2011. An economic decision-making decision support system for selection of reproductive man- agement programs on dairy farms. Journal of Dairy Science 94, 6216–6232.

Giordano JO, Kalantari A, Fricke PM, Wiltbank MC and Cabrera VE 2012. A daily herd Markov-chain model to study the reproductive and economic impact of reproductive programs combining timed artificial insemination and estrous detection. Journal of Dairy Science 95, 5442–5460.

Lima JR, Rivera FA, Narciso CD, Oliveira R, Chebel RC and Santos JE 2009. Effect of increasing amounts of supplemental progesterone in a timed artificial insemination protocol on fertility of lactating dairy cows. Journal of Dairy Science 92, 5436–5446.

Moreira FC, Orlandi C, Risco A, Mattos R, Lopes F and Thatcher WW 2001. Effects of presynchronization and bovine somatotropin on pregnancy rates to a timed artificial insemination protocol in lactating dairy cows. Journal of Dairy Science 84, 1646–1659.

Pursley JR, Mee MO and Wiltbank MC 1995. Synchronization of ovulation in dairy cows using PGF2α and GnRH. Theriogenology 44, 915–923.

Souza AH, Carvalho PA, Shaver RD, Wiltbank MC and Cabrera VE 2013. Impact of timed AI use on reproductive performance and culling rate in Wisconsin dairy herds. Journal of Animal Science 91 (E-suppl. 2), W303.