Estimation of the Economic Impact of a Unit Change in Predicted Transmitting Ability for Daughter Pregnancy Rate and Other Predicted Transmitting Ability in the Merit Indexes

by

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Key words: Daughter pregnancy rate, relative net income, economic weight, herdlife opportunity, lifetime net income

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Abstract

These studies deal with lifetime profit analyses for individual cows, and using these estimates to determine the economic value of genetic changes in traits for which genetic evaluations (predicted transmitting ability, PTA) are currently available. Data were collected from six states processed by Dairy Records Management Systems (DRMS) from herds on continuous test for at least 10 yr.

The purpose of the first study was to determine how well estimators of lifetime net income based on 305-d lactation yields and a 10-yr opportunity (RNI305.10) and based on complete lactation data but a 5-yr opportunity (RNIc.5) predict the estimate based on complete lactations and a 10-yr opportunity (RNIc.10). Records for 22,854 cows in Virginia herds born in 1988, 1990, and 1992 from the DRMS in Raleigh, NC were used. Each RNI was calculated using fluid (skim/fat) pricing and milk-fat-protein pricing. Regression analyses including herd and birth year were used in the model to estimate the regression of RNIc.10 on RNIc.5, and RNIc.10 on RNI305.10. The resulting regression coefficients for fluid (skim/fat) pricing were \$1.53 and \$1.12 explaining 67 and 97% of the variation of RNIc.10, respectively. The corresponding results for milk-fat-protein pricing were \$1.52 and \$1.14 explaining 68 and 96% of the variation of RNIc.10, respectively. Using RNIc.10 as the measure to estimate lifetime profit is strongly recommended over the two alternatives tested.

In the second study, the economic impacts of a unit change in PTA of daughter pregnancy rate (DPR) and other PTA in the merit indexes on lifetime profit estimates of a bull's daughters were estimated to determine an economic weight for the $\mathrm{PTA}_{\mathrm{DPR}}$ and other PTA in economic indexes. Records for 71,094 cows born in 1988, 1990, and 1992 from six states processed at DRMS were used: Florida [10,940 cows], Indiana [8,231 cows], North Carolina [12,280 cows], Texas [4,786 cows], Virginia [20,341 cows], and Vermont [14,516 cows]. The basic RNI function consisted of [total milk, fat, and protein income – feed cost for production] (yield income, YI) + [net value of calves + net salvage value] (non yield income, NYI) – rearing cost (RC) – [(daily cost for labor, maintenance feed, supplies, and fixed expenses) x days in herd] (daily cost, DC). Some of the economic impacts of PTA described for the merit indexes were not included in the basic RNI. These were added to RNI by multiplying the respective sire PTA by the economic impact. These included -165*PTA_{SCS} (M); 33*udder composite + 15*feet and legs composite -14.86*body size composite (T); and 8.064*PTA for daughter pregnancy rate - 4.80*PTA for daughter calving ease (PRCE). Each ARNI was calculated using all production records initiated prior to the cow's tenth birthday with three milk pricing systems comparable to the prices in USDA three merit indexes: fluid (skim/fat) pricing (FARNI), milk-fat-protein pricing (NMARNI), and cheese pricing (CARNI). Two levels of prices for rearing cost per day and daily cost were used for calculating FARNI, NMARNI, and CARNI. Regression analyses including herd and birth year in the model were used to estimate the simple and partial regressions of ARNI or partitioned ARNI on sire PTA. Partial regression included all PTA in Net Merit, except service sire calving ease. Ignoring other PTA, one unit increase in PTA_{DPR} increased 476.25kg of lifetime total milk or 18 days of total DIM. One unit decrease in PTA_{SCS} increased 4372.50kg of lifetime total milk. With low daily and rearing costs, each 1% change in PTA_{DPR} increased ARNI by $59.31 to $55.82 depending on the milk pricing systems. The corresponding results with high daily and rearing costs were $27.50 to $24.01. Standardized multiple regression enabled the comparison of the economic weights of this study with those of USDA. The PTA for productive life (PL) in all three USDA merit index was emphasized less than the results from this study; however, PTA_{DPR} in USDA indexes was emphasized more than this study. In this study, the economic weight of PTA_{DPR} was negative within the low daily and rearing costs, but it was positive in the high daily and rearing costs.

Key words: Daughter pregnancy rate, relative net income, economic weight, herdlife opportunity, lifetime net income

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Chapter 1 Introduction

1.1 Motivation

An important goal of most dairy cattle producers is to increase profit. Because the major source of income is the sale of milk, milk yield has been treated as the most important trait in the dairy industry. Therefore, intense selection for high yielding cows has been employed for many years.

However, many studies have shown that selection for milk production increased health disorders such as mastitis and reduced reproductive efficiency. Shanks et al. (1978) suggested that reproductive problems occur because of stress imposed by high milk yield. Butler (1998) showed that the increased genetic merit for milk production has been associated with a decline in fertility of lactating cows. Nutritional requirements increase rapidly with milk production after calving and result in negative energy balance (NEB). The NEB delays the time of first ovulation through inhibition of LH pulse frequency and low levels of blood glucose, insulin, and insulin-like growth factor-I (IGF-I) that collectively reduce estrogen production by dominant follicles; consequently, NEB reduces fertility. As shown in Figure 1-1, his study established that the decline in conception rate was around 0.45% per year between 1975 and 1997.

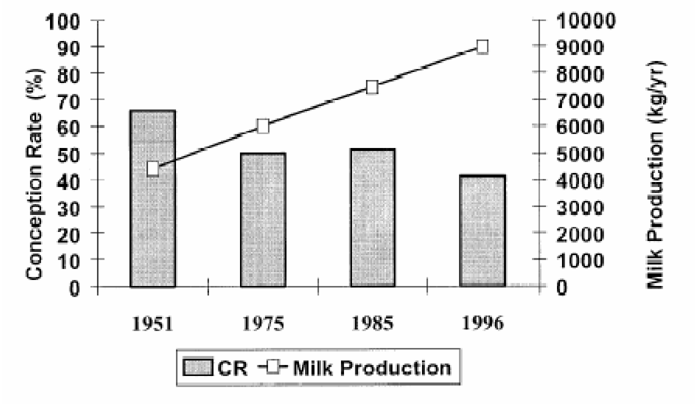

Figure 1-1. The inverse relationship between conception rate (CR) and annual milk production of Holstein dairy cows in New York [Butler, 1998]

Young (1970), Shanks et al. (1978), and Bertrand et al. (1985) showed that selection for increased milk yield over several generations has been associated with longer days open. Silvia (1998) showed changes in days open of Holstein herds in Kentucky from 1972 to 1996. During the period of study, average annual milk production per cow increased from 5853 to 7641 kg (74kg/year); during this same time period, days open increased from 132 to 159.

In these studies, it was shown that these reproductive problems could offset some of the added profit from the increased milk yield. Young (1970) showed that selection for production was related to increased costs for veterinary service and labor due to the high incidence of reproduction problems. In the study of Bertrand et al. (1985), daughters of high predicted difference milk (PDM) sires had to be bred more frequently and experienced reproductive problems.

Therefore, a primary goal of breeders should be to improve milk production with a minimum loss in reproductive efficiency. Selection for improved reproductive efficiency will be difficult because the heritability of reproductive traits are generally very low (<0.05). Unlike mastitis, fertility has not drawn much genetic attention because of its low heritability. Initially genetic evaluation focused on conception rate. However, genetic evaluations for conception rate were not routinely calculated because fertility data were not required in DHI and, consequently, the completeness of the data could not be validated. Calving interval and days open data have been available from Dairy Herd Improvement Association (DHIA) for many years. The current genetic evaluation is based on days open that are verifiable.

Even though reproductive performance has low heritability, it has a large phenotypic standard deviation and a high economic value. Cow fertility has been shown to be a major component of productive life (PL) because the genetic correlation of these two traits was very strong (0.59) compared to other traits (VanRaden and Seykora, 2003).

Figure 1-2 shows evidence of a reduction in the rate of decline in pregnancy rate beginning about 1994 when selection for PL was introduced. Selection for PL appears to have reduced the decline in fertility; however, direct selection for fertility traits is regarded to have additional benefit. Also, an additional factor favoring fertility is that it can be accurately measured earlier in the animals' lives.

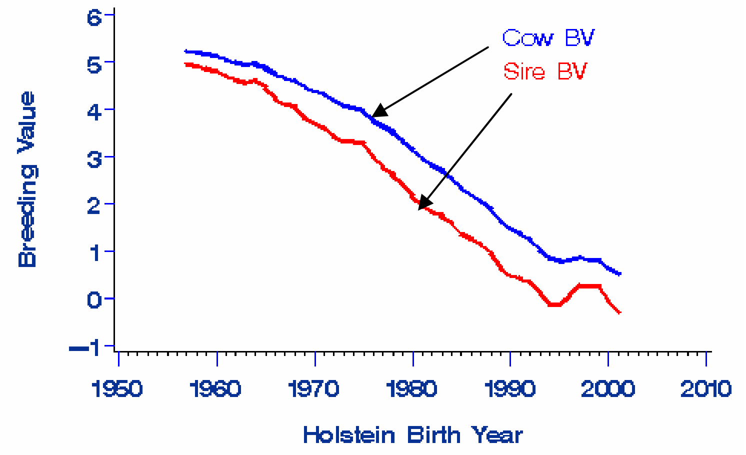

Figure 1-2. Trend in breeding values (BV) of pregnancy rate for Holsteins

[national genetic evaluation by USDA-AIPL]

http://www.aipl.arsusda.gov/dynamic/trend/current/trndx.html

Reproductive efficiency has tended to decrease as genetic capability for production increased. Consequently, Royal et al. (2002) and Pryce et al. (2000) suggested that breeding goals need to be broadened to include fertility. They advocated that fertility should be included as part of the breeding goal to slow down or reverse the rate of decline.

The necessity of including fertility traits in an aggregate genotype requires reliable estimates of genetic (co)variances for fertility and other traits of economic importance. Recent research by the AIPL-USDA has led to the development of a genetic evaluation for daughter pregnancy rate (DPR). Pregnancy rate and days open are almost the same trait genetically; a 1% higher pregnancy rate equals 4 fewer days open. Sire predicted transmitting ability (PTA) for DPR has a high reliability only after the data from hundreds of daughters are recorded. After the genetic evaluation for DPR was computed, the trait was included in selection indexes, known as the merit indexes.

1.2 Research Scope and Objectives

The objectives of this study were

1. To determine the relationship between lifetime RNI (10-yr opportunity) estimated from 305-d lactation data and RNI estimated from complete lactation data

2. To determine relationship between RNI with 5-yr opportunity and RNI with 10-yr opportunity

3. To investigate the relationship between sire PTA_{DPR} and other PTA in the merit indexes with daughter measures of phenotypic performance

4. To estimate the economic impact of a unit change in the PTA_{DPR} and other PTA in the merit indexes on estimates of lifetime profit.

Chapter 2 Review of Literature

This chapter reviews earlier studies about lifetime net income functions that combine phenotypic measure and Net Merit indexes that combine a number of PTA, including DPR. This chapter starts with an overview of relative net income (RNI).

2.1 Overview of Relative Net Income

This section will provide an overview of the RNI, a measure of cow profitability. The profit function includes income and expense variables collected over the lifetime of the cow. The RNI has been used as a profit function to determine the relative importance of different variables.

Selection for more profitable cows is a goal for all dairy producers, and the breeding goal for dairy cattle is to increase the economic merit of cows. The profitability of a dairy cow can be estimated through profit functions, which include sources of income and costs for production over the lifetime of the cow. Norman et al. (1981) suggested a profit function called RNI to estimate profit. The main four elements of RNI are the net value of the milk produced, the net value of calves produced each lactation, the net cow depreciation (springer cost – salvage value), and the fixed and operating costs during the cow's productive herd life. The authors used DHI data with a 72-mo opportunity length. They approximated the life time net value of milk and fat as 80% of the income from product. In this study, 18.2% of milk income was for feed cost for production and 1.8% of the milk income was assumed to cover discarded milk. Protein data was not available to them. The formula they used is:

Relative net income = (lifetime value of product x net percentage)

+ (number of lactations x net value of a calf)

+ salvage value – value at first calving

– feed cost for growth after first calving

+ [(days of productive life) x (feed cost for maintenance + fixed and operating cost/DPL)].

Over 20 yr, the RNI function has changed as more information has become available. However, the central concept of the original RNI has largely remained the same. To illustrate, all of the RNI functions consist of income sources (milk production and selling calves and beef) and expenses (rearing, maintenance, and daily operational costs).

Initially, Tigges et al. (1984) compared the profit estimated by a RNI function to that calculated from detailed cost and income from a research herd. They calculated the life time net value of milk and fat as 83% of the income from product, but they did not consider the variation of protein. The researchers concluded that the RNI function was successful for estimating lifetime profitability because it explained 95% of the variation in net income estimated from more detailed data. They concluded that RNI was a reasonable predictor of cow profitability.

Later, Van Arendonk (1991) adjusted a lifetime profit function for opportunity cost, which is the profit sacrificed by keeping an animal too long or by an animal culled prematurely and is estimated by the income produced by an average replacement. The author compared three profit equations: total lifetime profit; total lifetime profit, accounting for opportunity costs; and profit per day of herd life. This study calculated the opportunity cost as the average total profit divided by the average herdlife measured in days. This research showed that the relative value of herd life was overestimated by 260% when opportunity costs were not considered. Cassell et al. (1993) incorporated this concept of opportunity cost into the RNI function. The researchers examined RNI, discounted RNI (DRNI), and RNI adjusted for opportunity cost of a postponed replacement (RNIOC). This study used cows with opportunity for calving through 48, 60, and 72 mo of age. They found that RNIOC was less correlated with days of productive life (DPL) than the other two income functions. The researchers concluded that RNIOC is more useful than RNI or DRNI to evaluate the importance of characteristics of a cow or the mating that produced her with a herd, because RNIOC is largely independent of herd management practices that could affect overall net income.

Weigel et al. (1995) investigated the effect of applying an opportunity cost that was specific to each cow's lactation with 84 mo of herd-life opportunity. It was concluded that opportunity costs estimated on lactation basis were $35 higher than those from first freshening to all lactation for 84 month of opportunity. The researcher also utilized RNIOC for estimating economic weights for type traits.

Subsequently, Smith (1997) also modified the RNI by including somatic cell information. The profit function was:

$$\mathrm{RNI}_k = \sum_{i=1}^{n} \left[\sum_{j=1}^{3} \mathrm{Component}_{ij} \left(\mathrm{Value}_j - \mathrm{Cost}_j \right) \right] + \sum_{i=1}^{n} \left(\mathrm{kg\,milk}_i * \mathrm{SCA}_{ik} \right)$$

+ (number of lactations) (net value of a calf)

+ net salvage value

- rearing cost

- (total days in milk) (maintenance, fixed, and labor cost for 2x or 3x per day in milk)

- (total days dry) (maintenance, fixed, and labor cost per day dry)

where j is kilograms of the component (milk, fat, and protein) in the i^{th} lactation, initiated before the end of the 60-mo opportunity length with a somatic cell adjustment (SCA) for the k^{th} market. Furthermore, the author investigated the impact of inbreeding on RNIOC with 60 mo and 84 mo opportunities.

2.2 Genetic Measures of Lifetime Profit – Changes on the Net Merit Formula

These selection indexes are genetic estimates of the net profit of an individual. Development of and changes in USDA economic indexes started in 1971; the USDA has published economic indexes for sires. These indexes included transmitting abilities for multiple traits weighted by their price or more recently their economic values. This section uses Table 2-1 to overview the changes in the economic index over 35 yr.

Table 2-1. Relative emphasis on traits in USDA economic indices [VanRaden, P. M., 2002].

		Year introduced and index name					
	Year	1971	1977	1984	1994	2000	2003
PTA	Index [a]	PD$	MFP$	CY$	NM$	LNM$	LNM$
Protein			27	53	43	36	33
Fat		48	46	45	25	21	22
Milk		52	27	-2	6	5	0
Longevity (PL)					20	14	11
SCS[b]					-6	-9	-9
Udder						7	7
Feet & Legs						4	4
Body Size						-4	-3
DPR[c]							7
Service sire calving ease							-2
Daughter calving ease							-2

[a] PD$ = predicted difference dollars; MFP$ = milk-fat-protein dollars; CY$ = cheese yield dollars; NM$ = net merit dollars; LNM$ = lifetime net merit dollars.

[b] SCS = somatic cell score.

[c] DPR = daughter pregnancy rate.

In contrast to PD$, MFP$, and CY$ that were calculated by gross incomes of the yield traits, the net merit indices accounted for the net profit addressing both incomes and costs. In August 2000, the net merit was modified from a mixed lactation/lifetime basis to lifetime profitability, which enabled researchers to estimate legitimate net merit.

In 1971, the USDA used Predicted Difference Dollars (PD$) that combined milk (PDM) and fat (PDF) to rank sires. Beginning in 1977, the USDA also developed an index that included protein under multiple component pricing. In 1984, an index based on cheese production was introduced. Until 1993, the USDA indices included only milk, fat, and protein. The value of milk, fat, and protein under the three milk pricing systems is quite different. In skim/fat pricing milk yield received 52% of the weight in 1971. In the index aimed at cheese production, milk would get -2% of the weight. These selection indices reflect the economic values for each trait through relative emphasis on traits.

Over time, genetic evaluations on new traits of importance have become available; these have been addressed in succeeding indexes. In 1994, net merit dollars (NM$) began including PL and somatic cell score (SCS). This index included a mix of traits on a lactation and lifetime basis. In 2000, the lifetime net merit dollars (LNM$) included udder composite (UC), feet/legs composite (FLC), and body size composite (BSC), and the total focus changed to lifetime profit. Finally, in 2003, LNM$ also included DPR, service sire calving difficulty, and daughter calving difficulty.

The 1994 index could reflect type traits only though relationships with PL (VanRaden, 2000). However, lifetime net merit included several conformation traits, such as UC, FLC, and BSC. Each of the lifetime merit indexes consisted of three sub-indexes: yield dollar (Yield $ including milk, fat, and protein), udder dollar (Udder $ including UC and SCS), and other dollar (Other $ including PL, FLC, and BSC). Yield$ were differentiated for three different markets.

Fat and protein are highly correlated with milk yield, 0.45 and 0.81, respectively. Even though milk has a zero weight in the latest index, high economic values on protein and fat indirectly place continuous emphasis on milk.

2.3 The Calculation of Economic Weights in the Net Merit Index

The merit indexes calculated by the USDA weight the PTA for each of the included traits by its lifetime economic value. The three merit indexes – the NM\$, fluid merit (FM\$), and cheese merit (CM\$) – differ only in how PTA for milk, fat, and protein are weighted.

The 2000 and 2003 versions of the merit indexes were based on a several step process. First, partial budgeting was used to develop economic values for each trait in the non-linear profit equation. Second, the weights to be used in the merit indexes were calculated by taking the differential of the profit equation with respect to each of the PTA in the index at the mean value of any other PTA in the resulting differentials. As additional traits were added in 2003, several weights were adjusted to account for the impact of one of the new traits.

Because PTA of milk, fat, protein, UC, FLC, BSC, SCS, service sire calving ease (SSCE), daughter calving ease (DCE), and DPR are all calculated on a lactation basis, the lifetime weight must reflect the lifetime occurrences of the traits. The number of occurrences was included in the profit function and reflected in the resulting weights.

When the index is formed, each PTA (kg) is multiplied by its economic weight (\$/kg). Milk values of the three indexes in VanRaden and Seykora, 2003 are:

$$\text{Milk value of NM\$} = 0*\text{PTA}_{\text{Milk}} + 5.60*\text{PTA}_{\text{Fat}} + 10.61*\text{PTA}_{\text{Protein}}$$

$$\text{FM\$} = 0.229*\text{PTA}_{\text{Milk}} + 5.60*\text{PTA}_{\text{Fat}} + 2.93*\text{PTA}_{\text{Protein}}$$

$$\text{CM\$} = -0.123*\text{PTA}_{\text{Milk}} + 5.60*\text{PTA}_{\text{Fat}} + 14.73*\text{PTA}_{\text{Protein}}.$$

The full equation of 2003, which combines PTA for all traits included, is:

$$\begin{aligned}\text{Merit index} &= \text{Milk value}^{c} + 26^{b}*\text{PTA}_{\text{PL}} + (-166)^{c}*\text{PTA}_{\text{SCS}} + 33^{c}*\text{UC} + 15^{a}*\text{FLC} \\ &+ (-12)^{b}*\text{BSC} + 17^{c}*\text{PTA}_{\text{DPR}} + (-5)^{c}*\text{PTA}_{\text{SSCE}} + (-5)^{c}*\text{PTA}_{\text{DCE}}\end{aligned}$$

where [a] from merit 2000,

[b] from adjusted merit 2000, and

[c] from merit 2003.

There are two general assumptions for setting the 2003 merit equation.

1. Zero value for PTA_{PL} is assumed to be three lactations.

2. The 2003 economic weights for BSC and PL were arbitrarily adjusted downward from 2000 to avoid perceived double counting.

To understand how the AIPL-USDA determined the economic weight in the net merit index, it is necessary to observe the equation above. The explanation will begin with yield traits.

Yield

Sale value – additional feed cost (net value) of each yield trait is multiplied by three (the average number of lactations) for the lifetime base and by 0.89 ($Yield/Yield_{ME}$) to convert ME milk to actual milk. The net value for each component is in Table 3-4 (p 30).

PL

The lifetime net cost from PL is called as the "culling loss (VanRaden, 2000)" and represents cow depreciation. The cow depreciation is computed as \$715 [replacement cost (\$1240) – {mature cow average weight (680.4264 kg) x salvage value (\$0.7716/kg)}]. Replacement cost is computed as \$1,240 including a fixed charge of \$400 plus a variable cost (\$1.2345/kg) of a mature cow's average weight (680.4264 kg). The variable cost (\$1.2345/kg) is based on the weighted average of \$1.323/kg of average body weight at first calving (578.3624 kg) and \$0.6615/kg of 102.064 kg (weight difference from first calving to mature cow weight (680.4264 kg)). However, VanRaden used $708 as the cow depreciation or an average of $236/lactation. Because one lactation equals 10 mo of PL, 1 mo of PTA_{PL} equals 0.12 lactations. Thus, for a unit increase in PTA_{PL}, the cow depreciation decreases about $28.32 ($236/lactation x 0.12 lactations = $28.31). However, the value was reduced to $26 in 2003 to avoid double counting the part also attributed to DPR.

SCS

The SCS value ($55) is multiplied by three (the average number of lactations). The lactation value of SCS is the sum of a premium of $41 for low SCS and $14 for reduction in the cost of labor, drugs, discarded milk, and milk shipments lost due to antibiotic residues.

UC and FLC

Using research by Rogers and Hargrove (1993), the USDA set the udder value at $11 per lactation and the feet/legs at $5 per lactation. Those values are multiplied by three. In both cases, these are reductions in costs and, thus, are positive.

BSC

The lifetime net income or loss from a unit increase in BSC is set as [increased lifetime maintenance cost – increased variable cost of replacement + increased salvage value]. Maintenance cost per lactation (-$0.33/kg) is computed as -$0.39/kg of extra feed cost per lactation for heavier cows plus -$0.07/kg of additional housing cost, plus +$0.13/kg income from heavier calf weight. The maintenance cost per lactation (-$0.33/kg) multiplied by three to yield lifetime cost and by 0.91 to adjust weight for the culling age. In summary, the life time cost is -$1.36/kg: (-$0.33/kg x 3 x 0.91) – $1.2345/kg (variable cost) + $0.7716/kg (beef income). Each one point change in BSC was estimated to represent a 10.8868 kg change in mature body weight. This is based on Holstein data from the University of Minnesota size selection herd. Therefore, if one unit increases in PTA_{BSC}, the net merit decreases \$14.88 (10.8868 kg x -\$1.3668/kg = -\$14.88). However, the economic value was reduced to -\$12 to offset the effect of the added PTA_{CE} on body size.

DPR

Additional costs associated with DPR that are not included in PL are semen cost and insemination labor cost (\$0.5/day open), heat detection labor and supplies (\$0.1/day open), and labor cost for pregnancy check (\$0.12/day open). The loss in production due to low fertility was added to these additional costs. The initial estimate was set \$1.50/day open per lactation, and the estimate was multiplied by 2.8 to be converted to a lifetime value. This economic loss per days open is converted to economic loss per DPR by multiplying by -4. Therefore, the value of DPR is calculated as;

DPR/PTA unit = \$1.50 x 2.8 x -4 = -\$16.8. The value was rounded to -\$17.

DCE

The value of DCE was computed as \$5.76. The expense for a difficult calving cost is estimated as \$90 by Dematawewa and Berger (1997) and Dekkers (1994). This includes \$50 for veterinary and labor costs, \$25 for calf death, and \$15 for cow deaths before first test day. The expense is multiplied by two to include both clinical and sub-clinical difficulty; it is also multiplied by 1.6 to account for births from two later lactations. Additionally, it was doubled to account for the contribution of maternal grand sire effect. In short, the economic weight for a unit of DCE is calculated as:

Daughter calving ease value/PTA unit = \$90(2)(1.6)(2)/100 = \$5.76.

SSCE

The value of service sire calving ease is computed as \$5.12. The expense for service sire calving difficulty is computed by adding \$70 to the expense for a difficult calving cost. This includes \$40 for yield losses during the next lactation and \$30 for fertility and longevity losses. Therefore, service sire calving ease is calculated as:

Service sire calving ease value/PTA unit = \$160(2)(1.6)/100=\$5.12.

Both values of DCE and SSCE were rounded to \$5.

2.4 Methods of Estimating Economic Weight

Hazel (1943) developed an index selection theory for situations in which the objective of selection was a linear function of the genotypic or additive genetic values for each trait. In Hazel's method, the net genetic improvement is the sum of the genetic gains for the several traits of economic importance. The aggregate value of an animal is the sum of its several genotypic values; each genotypic value is weighted according to its relative economic value. The relative economic value for each trait depends upon the amount that profit may be expected to increase for each unit of improvement in that trait. Environmental factors, dominance, and epistasis may cause the phenotypic performance to differ from the genotypic value for that trait. The opportunity for increasing progress lies in increasing the correlation between aggregate genotype and the selection index (R_{IH}) as much as possible. Thus, the weight of the traits in a selection index can be obtained by setting the partial derivatives of the linear equation(s) to zero and solving.

Harris (1970) developed nonlinear functions for the goal of genetic improvement in a swine population. The researcher used ratios of income and expenses as the selection goal, thus: $\frac{\text{income}}{\text{expenses}}$ or $\frac{\text{expenses}}{\text{income}}$. The researcher pointed out that profit (income-expenses) of the individual animals did not accurately reflect their individual contributions to overall profit in the meat animal industries. He noted that the relative emphasis placed on traits in selection formulae depended on the combination of three factors: the economic importance of each of the traits, potential for genetic improvement for each of the traits, and the genetic interrelationship between traits.

Moav (1973) showed that the economic weights derived from profit equations depended on the evaluation base; thus, different relative economic weights might be obtained from different bases. This would lead to uncertainty and confusion about appropriate economic weights. Brascamp et al. (1985) argued that, if the profit is zero or transformed to zero, the relative economic weights would become the same for all bases of evaluation.

2.5 Reproductive Traits

This section will give a brief overview of the importance and measures of fertility traits. The estimated relative conception rate (ERCR) is an estimate of the ability of semen from a bull to produce progeny. Days open or calving interval is one of the traditional measures of female fertility. The end of this section will summarize the development of the DPR.

2.5.1 Measure of Male and Female Fertility

Measures of fertility include conception rate, days open, calving interval, and age at first calving. The ERCR is a measure of a bull's ability to produce fertile semen that will result in progeny; thus, it predicts a bull's direct effect on fertility at the time of insemination. Dairy Records Management System (DRMS) at Raleigh, NC calculates and publishes the ERCR for individual sires based upon Dairy Herd Improvement (DHI) data. The ERCR is expressed as a deviation from the average AI sire conception rate and indicates the value of semen. Traditionally, the conception rate has been used to estimate the pregnancy rate of a herd. This can be expressed as:

the pregnancy rate for herd = (heat detection rate) x (conception rate).

Days open or calving interval data has been available from the DHI milk recording system for many years, but researchers did not evaluate it from a genetic point of view because the reproductive performance has very low heritability (0.04).

2.5.2 Changes of Cow Fertility (or Importance of Cow Fertility)

Top herds currently produce more than 13,600 kg of milk per cow per year. According to the national evaluation, milk production per cow has nearly doubled over the past 40 yr (see Figure 2-1).

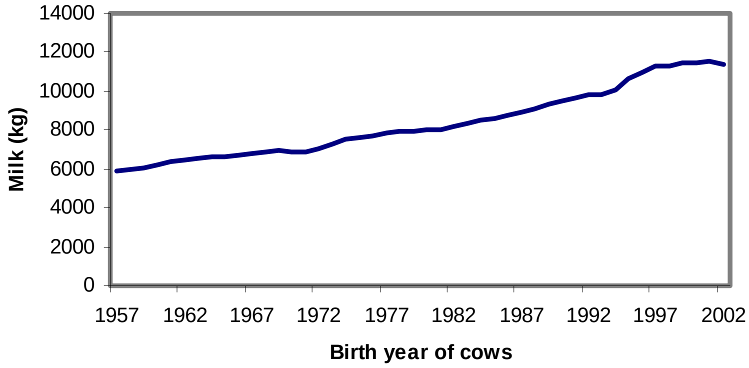

Figure 2-1. Phenotypic trend of mature equivalent milk yield for Holsteins [http://www.aipl.arsusda.gov/dynamic/trend/current/trndx.html]

Figure 2-2 shows the genetic trend of milk. During the first 10 yr, the trend line increased very slowly, but accelerated after 1970. This implies that genetic evaluation has improved. The genetic trend for birth years 1957 to 2002 has a linear scope of 83kg /yr. In recent years, the slope has approximated 100 kg per year.

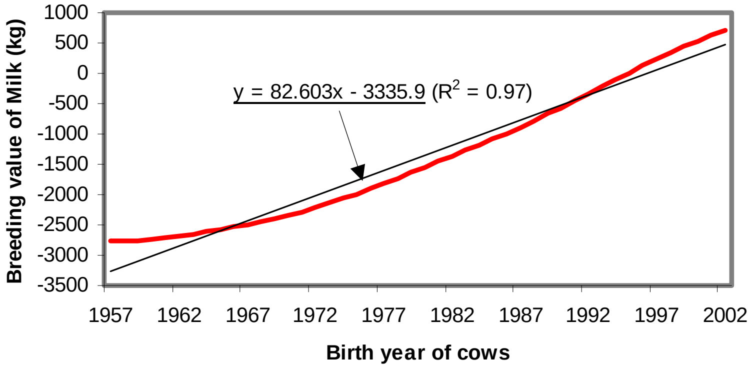

Figure 2-2. Trend in milk breeding values for Holsteins [http://www.aipl.arsusda.gov/dynamic/trend/current/trndx.html]

Over the same period, days open has also increased by about 40 d (see Figure 2-3). Consequently, selection for high-yielding cows has resulted in longer days open, as there is an unfavorable genetic correlation of about 0.3 between yield and days open (VanRaden, 2000).

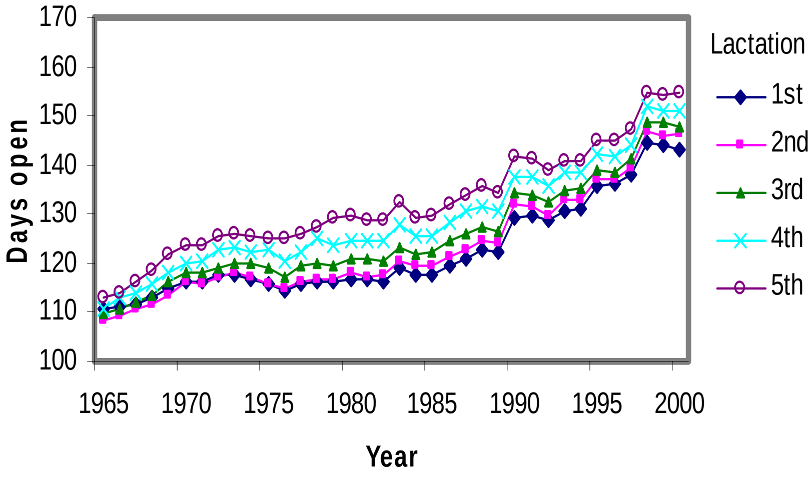

Figure 2-3. Phenotypic trend for days open by lactation for Holsteins 1965 to 2000 [VanRaden et al., http://www.aipl.arsusda.gov/reference/fertility/DPR_rpt.htm]

Until 20 yr ago, the commonly recommended calving interval for a Holstein was 12 mo with 280 gestation days and 85 days open. Many previous studies (Speicher and Meadows, 1967; James and Esselmont, 1979; Olds et al., 1979) presented the additional costs per day open by extending CI beyond 12 mo. These ranged from $0.50 to $2.00 per cow per day open. However, Britt (1981) found that the average CI of dairy cattle in the United States in 1981 was 13.5 mo. Other studies also noted this trend toward long CI (Spalding et al., 1975; Hansen et al., 1983). In 1984, Holmann et al. proposed an optimal calving interval and computed economic value of DO with phenotypic information, specifically milk yield through using budgeting simulations. The researchers used four variables in their analysis: calving intervals (12, 13, and 15 mo), milk producing ability (5900, 6800, 7700, 8600 kg / 300-d lactation), age groups of mature cows (≥36 mo and < 36 mo), and months of lactation.

In 2003, the average days open of cows in Virginia was about 166 d (DRMS-dairy metrics from PCDART); this reality is very far from Holmann's suggested days open of 115 d. This discrepancy occurs because of the constant selection for high-yielding cows. In other words, the unfavorable genetic and environmental correlation between milk yield and reproductive efficiency indicates a correlated increase of CI by selection for milk.

After milk production, fertility is the most important trait in dairy cattle (Boichard, 1990; Maijala, 1964; Philipsson, 1981; Jansen, 1985). Increasing DO extended periods of low daily milk yield and days dry, and it resulted in more milk yield per lactation. However, milk yield per day over a cow's entire lifetime decreases with increased DO (Louca and Legates, 1968). To increase annual profit, cows should have higher daily milk production, shorter calving interval, fewer reproductive culls, and less semen doses needed for conception. Consequently, improving reproductive efficiency is one way to increase profit. Poor reproductive performance reduces income and increases costs in several ways. First, long calving intervals result in less lifetime milk yield. Second, calving intervals have a significant effect on the number of replacement heifers available. If the calving interval is long, fewer calves are born per year; fewer calves result in fewer animals for sale and fewer heifers for replacement. Third, the culling due to reproductive failure increases replacement cost. Additionally, if reproductive culling is increased, culling for production must be limited to maintain a herd size. Forth, low conception rates result in higher semen costs because more units of semen must be used for pregnancy. Finally, low reproductive efficiency is associated with higher veterinary bills.

Since 1994, the Net Merit index has included PTA of PL. This has enabled indirect selection for fertility. The genetic correlation between PL and days open is 0.59 (VanRaden and Seykora, 2003). Thus, the reproductive trait plays a major role in both milk production and productive life. A heifer will not produce milk until she gives birth, and a cow will not add to her milk production until she calves again. Cows are culled if they do not get pregnant.

Boichard (1990) concluded that conception rate has great economic importance, so it should be included in an aggregate genotype, weighted by its economic value. The economic effects of better fertility result in a lower percentage of culling for infertility. Lower costs for insemination, shorter calving intervals, and less need for replacement heifers increase lifetime profitability. Royal et al. (2002) suggest that it is necessary to include fertility traits in breeding goals. This issue was taken seriously, and, in August 2003, the Animal Improvement Programs Laboratory (AIPL) provided genetic evaluation of a sire's effect on his daughters' fertility (PTA_{DPR}) when his daughters are bred.

2.5.3 Daughter Pregnancy Rate (DPR)

The DPR measures how quickly daughters of a sire become pregnant again after an assumed 60-d voluntary waiting period. The PTA for DPR is a measure of a sire's genetic effect on his daughters' ability to be pregnant. The original fertility data are recorded as days open, and then the days open data are converted as pregnancy rate for this genetic evaluation. Pregnancy rate can be expressed as the percentage of nonpregnant cows that become pregnant during each 21-d period. For example, if a cow is pregnant in the first 21-d period, her pregnancy rate is 100%; if a cow is pregnant in second 21-d period, her pregnancy rate is 50%.

One of the biggest advantages of using DPR over days open is that larger values of DPR are desirable, unlike those of DO because smaller values of DO indicate improvement. Acknowledging the realities of human nature, a parameter seems more logical if larger values of the parameter mean improvement. The nonlinear formula to convert from days open to pregnancy rate is:

Pregnancy rate = 21/ (days open – voluntary waiting period + 11).

The voluntary waiting periods is the initial phase of each lactation during which no inseminations occur; it is assumed to be 60 d. Figure 2-4 shows the relationships between pregnancy rate and days open.

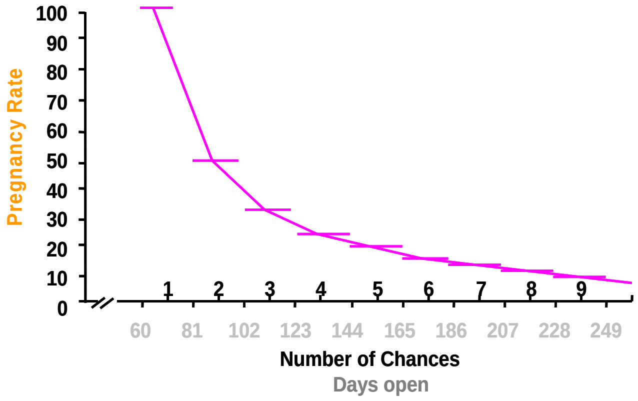

Figure 2-4. Pregnancy rate vs. days open [VanRaden et al., http://www.aipl.arsusda.gov/reference/fertility/DPR_rpt.htm]

Because the relationship between days open and pregnancy rate during most of the period when most cows are bred is nearly linear, a linear approximation gives very good results.

Figure 2-5 shows the linearized relationship between days open and pregnancy rate. Each increase of 1% in PTA DPR equals a decrease of 4 d in PTA days open; thus, PTA days open can be approximated as PTA DPR multiplied by -4. The linear formula to convert from days open to pregnancy rate is:

Pregnancy rate = 0.25(233 – days open).

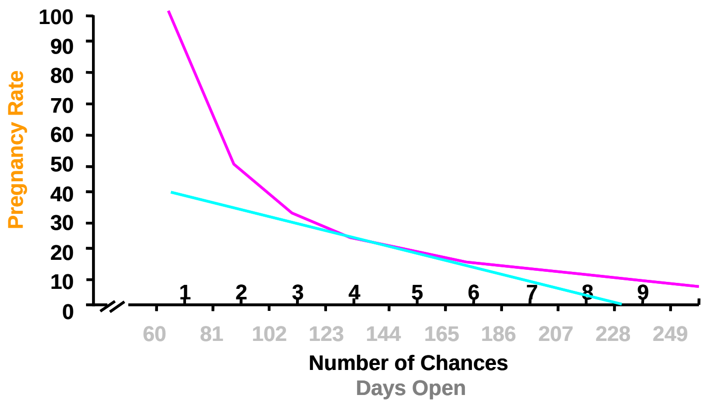

Figure 2-5. Linearization of the conversion formula [VanRaden et al., http://www.aipl.arsusda.gov/reference/fertility/DPR_rpt.htm]

Chapter 3 Materials and Methods

Dairy Herd Improvement (DHI) records for all cows born after 1988 for six states were provided by the Dairy Records Management Systems (DRMS) in Raleigh, NC. The DRMS has continuously processed and summarized production records for these states since 1988 or before. These data allowed us to compare the adequacy of the 305-d production information to that of the complete lactation period. These lactation data were used to estimate net income for cows born in 1988, 1990, and 1992. Genetic evaluations were obtained from the Animal Improvement Programs Laboratory (AIPL) of the United States Department of Agriculture (USDA), while the calving ease traits came from National Association of Animal Breeders (NAAB) and the type composites came from the Holstein Association (HA).

The Virginia data were used in the initial study to investigate the impact of 305-d versus complete lactation data and to compare 5-yr and 10-yr periods of opportunity. The DHI records of all six states were used to calculate the effect of a unit change in sire PTA of DPR and other PTA in the merit indexes on lifetime profit estimates. The states included (FL, IN, NC, TX, VA, and VT) were chosen because they were continuously processed at DRMS and because of their geographic diversity. For these studies, production records on a complete lactation basis were accumulated to calculate lifetime totals. These totals included total milk, total fat, total protein, total days in milk (DIM), days of productive life (DPL), and terminal lactation number. These accumulated variables were used to estimate lifetime net income. Total DIM was the sum of days in milk reported for all lactations of a cow. Calving interval was the difference between consecutive calving days. Finally, days open was calculated by subtracting 280 d (a typical gestation length) from each calving interval. The DPL was the interval between the first calving date and the last test date of the last lactation, which was calculated by adding DIM for the last lactation to the date of last freshening (the last calving date). The number of lactations was the count of calving dates in file for each cow. Thus, DPL= last test date – first calving date, while last test date = last calving date + DIM. The cows that did not have all of the critical information had to be eliminated. To do this, the original DRMS data were edited according to the following procedure. The edited data were then combined with sire evaluation data, type, and calving ease data.

3.1 Data Edits

Cow production data were restricted to Holstein cows that had cow identification and were born in 1988, 1990, or 1992. After duplicated records were removed, there were 70,548 Florida cows, 96,606 Indiana cows, 60,596 North Carolina cows, 89,582 Texas cows, 65,453 Virginia cows, and 49,143 Vermont cows. We kept only the cows whose herds had been on DHI for at least 10 yr. This restriction removed about 50 to 60% of the cows from each state. Removing those cows without sire identification removed 20 to 30% of the remaining cows for most of states. However, Texas and Indiana lost more than 60% of their remaining cows. This difference was attributed to cows on milk only testing programs.

Cow that changed herds, missed calving dates, did not have consecutive lactation records, or were sold for dairy, were deleted. We also removed cows with zero total milk, total fat, total protein, or cows with zero total days open if they had had more than two lactations. In this editing process, most of the states lost 11 to 32% of their remaining cows. However, Texas lost 61% of its remaining cows in this edit.

Cow production data were merged with sire genetic evaluation data (Sire summary in Nov., 2003). From the merged data, cows whose sires had not been evaluated by the USDA were eliminated. Additionally, cows whose sires did not have genetic evaluation for type or calving ease were eliminated. Finally, the herds that had less than five remaining cows were removed. Table 3-1 shows numbers and percentages of cows removed and those remaining after edits.

Table 3-1. Numbers and percentages of cows removed and those remaining after edits.

		Florida (State 55)			Indiana (State 74)			North Carolina (State 32)		
Edit	Explanation	Cows remaining after edits	No. of cows removed	% of cows removed	Cows remaining after edits	No. of cows removed	% of cows removed	Cows remaining after edits	No. of cows remove	% of cows removed
1	Restrict to Holsteins with identification born in given years and eliminate duplicated records	70,548			96,606			60,596		
2	Removed cows in herds with less than 10 yr herd opportunity	32,643	37,905	0.54	36,983	59,623	0.62	28,922	31,674	0.52
3	Removed those cows without sire registration	20,357	12,286	0.38	14,234	22,749	0.62	21,155	7,767	0.27
4	Removed those cows with missing first lactation in their present herd or calving date information	20,031	326	0.02	13,961	273	0.02	20,566	589	0.03
5	Removed cows with non-consecutive lactation records or sold for dairy Removed lactation initiated after 10-yr old	18,849	1,182	0.06	12,161	1,800	0.13	18,880	1,686	0.08
6	Removed cows with total milk=0, total fat=0, or total protein=0 Removed cows with more than 1 lactation with total DO=0	12,757	6,092	0.32	9,733	2,428	0.20	16,791	2,089	0.11
7	Removed daughters of any sires without USDA PTA Removed herds with less than five remaining cows	11,007	1,750	0.14	8,330	1,403	0.14	12,425	4,366	0.26
8	Removed daughters of sires with missing PTA types or calving ease data	10,940	67	0.01	8,231	99	0.01	12,280	145	0.01

Table 3-1. Numbers and percentages of cows removed and those remaining after edits (continued).

		Texas (State 58)			Virginia (State 52)			Vermont (State13)		
Edit	Explanation	Cows remaining after edits	No. of cows removed	% of cows removed	Cows remaining after edits	No. of cows removed	% of cows removed	Cows remaining after edits	No. of cows remove	% of cows removed
1	Restrict to Holsteins with identification born in given years and eliminate duplicated records	89,582			65,453			49,143		
2	Removed cows in herds with less than 10 yr herd opportunity	42,273	47,309	0.53	36,201	29,252	0.45	28,240	20,903	0.43
3	Removed those cows without sire registration	14,697	27,576	0.65	28,385	7,816	0.22	21,877	6,363	0.23
4	Removed those cows with missing first lactation in their present herd or calving date information	14,579	118	0.01	27,820	565	0.02	21,491	386	0.02
5	Removed cows with non-consecutive lactation records or sold for dairy Removed lactation initiated after 10-yr old	14,098	481	0.03	27,095	725	0.03	20,373	1,118	0.05
6	Removed cows with total milk=0, total fat=0, or total protein=0 Removed cows with more than 1 lactation with total DO=0	5,483	8,615	0.61	23,858	3,237	0.12	16,964	3,409	0.17
7	Removed daughters of any sires without USDA PTA Removed herds with less than five remaining cows	4,836	647	0.12	20,460	3,398	0.14	14,841	2,123	0.13
8	Removed daughters of sires with missing PTA types or calving ease data	4,786	50	0.01	20,341	119	0.01	14,516	325	0.02

3.2 Study 1 with Virginia Data: the Impact of Herd Opportunity and 305-d or Complete Lactation Recording Periods in Estimating Lifetime Net Income

This study evaluated two separate indicators of completeness. First, it considered the impact of herd life opportunity of 5- and 10-yr periods on the estimated lifetime net income. Second, it used 305-d vs. complete lactation data for calculating lifetime net income. This study used records for 22,854 cows in Virginia herds born in 1988, 1990, and 1992.

In each birth year, three different sets of data were accumulated from cow production records based on the herd opportunity and lactation recording periods. The first data set (c.10) had a 10-yr herd opportunity based on complete lactations; the second data set (305.10) had a 10-yr herd opportunity based on 305-d lactations; the last data set (c.5) had a 5-yr herd opportunity based on complete lactations. Within each data set, production records were accumulated to calculate lifetime net income. Table 3-2 shows the accumulated results. Lifetime and income variables were calculated on each of the 22,854 cows. The average number of lactations ranged from 2.23 to 3.09; the lifetime milk yield ranged from 20,840 kg to 28,534 kg; the lifetime fat yield extended from 737 kg to 1,009 kg; the lifetime protein yield ran from 665 kg to 904 kg; the total DIM ranged from 756 d to 1,009 d; and total days open increased from 204 d to 377 d.

Table 3-2. Means for daughter variables.

Traits[a]	RNI fluid ($)	RNI netmerit ($)	DPL (d)	lactations	Total milk (kg)	Total fat (kg)	Total protein (kg)	Total DIM (d)	Total days open (d)
c.10[b]	2038	2278	1146	3.09	28534	1009	904	1009	377
c.5[c]	1241	1445	833	2.23	20840	737	665	756	204
305.10[d]	1702	1856	1101	3.09	25310	823	792	850	377

[a] DPL = days of productive life; DIM = days in milk.

[b] c.10 = data set with 10-yr herd opportunity based on complete lactations.

[c] c.5 = data set with 5-yr herd opportunity based on complete lactations.

[d] 305.10 = data set with 10-yr herd opportunity based on 305-d lactations.

After several variables for lifetime performance were calculated, the RNI on each cow was calculated using two milk pricing systems: fluid (skim/fat) pricing (FRNI) and milk-fat-protein pricing (NMRNI). The milk prices and feed previously used by USDA in fluid merit and net merit cost (see Table 3-3) were used in the two RNI calculations.

3.2.1 RNI Calculation

This study used Virginia cow information to calculate the relative net income (RNI) for two milk markets with fluid pricing and standard milk-fat-protein pricing. The RNI function was similar to Weigel's (1993). RNI was calculated as:

$$\text{RNI} = \sum_{i=1}^{n} \left[\sum_{j=1}^{3} Component_{ij} \left(Value_j - Cost_j \right) \right]$$

+ (number of lactations)(net value of a calf)

+ net salvage value

- rearing cost

- (total days in milk) (maintenance, fixed, and labor cost for 2x or 3X per day in milk)

- (total days in dry) (maintenance, fixed, and labor cost per day dry)

where j is the kilograms of component (fluid, fat, and protein) in the i^{th} lactation. No adjustment was made for somatic cell information in this profit function. It used VanRaden (2000) values and costs for milk, fat, and protein [See Table 3-3], and Smith (1997) values and costs for other components. Smith used $100 for net value of a calf and $300 for net salvage value. The rearing cost per day, daily cost in milking, and daily cost in dry were $1.25, $2.80, and $1.34, respectively.

Table 3-3. Costs and values for yield used in calculation of relative net income in fluid (skim/fat) and milk-fat-protein pricing [VanRaden, 2000].

		Value	
Trait	Feed cost ($/kg)	Fluid ($/kg)	Net merit ($/kg)
Milk (kg)	0.007	0.192	0.022
Fat (kg)	0.772	2.536	2.536
Protein (kg)	1.698	-	5.623

A cow's RNI in c.10 data was calculated using all production initiated prior to her tenth birthday. All production initiated prior to her fifth birthday were used to calculated a cow's RNI in c.5 data. The RNI calculation in 305.10 data used only milk produced during the first 305 d of every lactation initiated prior to the cow's tenth birthday. Thus, three measures of RNI were calculated for each cow.

3.2.2 Model for Regression Analysis

Data were analyzed using the general linear models (GLM) in Statistical Analysis System (SAS). A PROC GLM was run in SAS to determine the relationship between the RNI from the first data set and the RNI from the second and third data sets. The following model was used:

$$Y_{ijk} = \alpha + h_i + y_j + \beta X_{ijk} + \varepsilon_{ijk}$$

where

Y_{ijk} = RNI of kth cow in ith herd in jth year of birth based on complete lactation within the 10-yr herd opportunity,

α = the intercept,

h_i = the fixed effect of the ith herd,

y_j = the fixed effect of the jth year of birth,

β = the regression coefficient,

X_{ijk} = RNI of kth cow in ith herd in jth year of birth based on 305-d lactation within the ten year herd opportunity, and

ε_{ijk} = the error associated with kth cow on ith herd in jth year of birth.

3.3 Study 2: Estimation of the Economic Impact of a Unit Change in PTA$_{DPR}$ and Other PTA in the Merit Indexes

The objective of this study was to evaluate the economic effect of a unit change in sire PTA$_{DPR}$ and other PTA in the merit indexes on lifetime profit estimates of a bull's daughter. This study used a 10-yr herd opportunity based on complete lactations. The final edited data had 10,940 Florida cows, 8231 Indiana cows, 12,280 North Carolina cows, 4786 Texas cows, 20,341 Virginia cows, and 14,516 Vermont cows. The records of these 71,094 cows were accumulated to calculate lifetime net income. The average number of lactations was 2.96, the lifetime milk yield averaged 27,506 kg, the lifetime fat yield averaged 992 kg, and the lifetime protein averaged 824 kg. The DPL averaged 1090 d. Through regressing lifetime profit of daughter on PTA of sire DPR, one should be able to estimate the economic impact of a unit change in PTA of sire DPR on the total lifetime performance of a cow. The basic RNI, which was used in Study 1, was augmented (ARNI) by adding the products of sire PTA for various traits and the net income for the trait proposed in the net merit calculation (VanRaden and Seykora, 2003) not included in the basic RNI function. The traits added in ARNI were somatic cell score (SCS), udder composite (UC), feet and legs composite (FLC), body size composite (BSC), DPR, and daughter calving ease (DCE). Therefore, the ARNI function consisted of [total milk, fat, and protein income – feed cost for production] (yield income, YI) + [net value of calves + net salvage value] (non yield income, NYI) – rearing cost (RC) – [(daily cost for labor, maintenance feed, supplies, and fixed expenses) x days in herd] (daily cost, DC) + SCS(mastitis net income, M) + type composites (net income from UC, FLC, and BSC, T) + DPR and DCE (net income from DPR and DCE, PRCE). Each ARNI was calculated using all production initiated prior to the cow's tenth birthday with three milk pricing systems: fluid (skim/fat) pricing (FARNI), milk-fat-protein pricing (NMARNI), and cheese pricing (CARNI). Two levels of prices for rearing cost per day and daily cost were used for calculating FARNI, NMARNI, and CARNI.

3.3.1 Calculation of ARNI

The ARNI function added several traits into the RNI function used in study I. The ARNI calculation was:

$$\text{ARNI} = \sum_{i=1}^{n} \left\lfloor \sum_{j=1}^{3} \text{Component}_{ij} \left(\text{Value}_j - \text{Cost}_j \right) \right\rfloor$$

+ (number of lactations) x (net value of a calf)

+ net salvage value (= initial salvage value – death loss – original cost of a heifer)

- rearing cost {= (first calving date – birth date) x rearing cost per day}

- (total days in milk) x (feed for maintenance, fixed, labor, and variable costs per day in milk)

- (total days in dry) x (feed for maintenance, fixed, and labor cost per day dry)

+ augmentation (M+T+PRCE)

where j is the kilograms of component (milk, fat, and protein) in the i^{th} lactation.

Augmentation

$M = -(165 \times (\text{PTAscs} - 3.10))$

$T = +(33 \times (\text{UC} - \overline{\text{UC}})) + (15 \times (\text{FLC} - \overline{\text{FLC}})) - (14.86 \times (\text{BSC} - \overline{\text{BSC}}))$

$\text{PRCE} = +(8.064 \times (\text{PTA}_{\text{DPR}} - \overline{\text{PTA}}_{\text{DPR}}) - (4.80 \times (\text{PTA}_{\text{DCE}} - \overline{\text{PTA}}_{\text{DCE}}))$

Adjustments for SCS, UC, FLC, BSC, DPR, and DCE were made in this profit function. Current VanRaden and Seykora's (2003) values and costs for milk, fat, and protein (see Table 3-4) were used, and the values and costs of the other components at the low level of daily and rearing costs were the same as those used by Smith (1997). Smith used $100 for net value of a calf and $300 for net salvage value. Table 3-5 shows the low and high levels of rearing and daily costs.

Table 3-4. Costs and values for yield used in calculation relative net income in fluid, cheese, and milk-fat-protein[VanRaden and Seykora, 2003].

		Value		
Trait	Feed cost ($/kg)	Fluid ($/kg)	Net merit ($/kg)	Cheese ($/kg)
Milk (kg)	0.026	0.112	0.026	-.020
Fat (kg)	0.772	2.867	2.867	2.867
Protein (kg)	1.103	2.205	5.072	6.615

Table 3-5. Two levels of rearing and daily costs.

	Low level	High level
Rearing cost per day ($)	1.25	1.50
Daily cost in milking ($)	2.80	4.25
Daily cost in dry ($)	1.34	2.50

3.3.2 Model for Regression Analysis

This study evaluated the economic effect of a unit change in sire PTA_{DPR}. The following model was run using PROC GLM in SAS to determine the relationship between the RNI and sire PTA:

$$Y_{ijk} = \alpha + h_i + y_j + \sum_{l=1}^{n} \beta_l (X_{ijkl} - \overline{X}_{...l}) + \varepsilon_{ijk}$$

where

Y_{ijk} = ARNI and components of ARNI (for high and low daily and rearing costs for three milk pricing systems) of kth cow on ith herd in jth year based on complete lactation within the ten year herd opportunity,

α = the intercept,

h_i = the fixed effect of the ith herd,

y_j = the fixed effect of the j^{th} year,

β_l = the regression coefficient on PTA for l^{th} trait of sire PTA,

X_{ijkl} = PTA for l^{th} trait in the merit indexes for the sire of the k^{th} cow in i^{th} herd in j^{th} year of birth,

$X_{...l}$ = population mean of PTA for l^{th} trait, and

ε_{ijk} = the residual associated with k^{th} cow in i^{th} herd in j^{th} year.

A similar model with only the regression of one PTA at a time (simple regression) was also run for each of the y variables.

Chapter 4 Results and Discussion

This chapter presents the experimental results and findings. It begins with determining the effectiveness of RNIc.5 and RNI305.10 to predict RNIc.10. These results form the basis for estimating the economic weights for the traits in the merit indexes.

4.1 Study 1

This study attempted to determine how effectively estimates of lifetime net income based on 305-d lactation yields with a 10-yr opportunity (RNI305.10) and based on complete lactation data but a 5-yr opportunity (RNIc.5) predict the estimate based on complete lactations with a 10-yr opportunity (RNIc.10). The means of FRNIc.10, FRNIc.5, and FRNI305.10 were $2038, $1242, and $1702, respectively; similarly, the means of NMRNIc.10, NMRNIc.5, and NMRNI305.10 were $2278, $1445, and $1856, respectively.

The regression coefficients of FRNIc.10 on FRNI305.10 in 1988, 1990, and 1992 were 1.12, 1.12, and 1.13, explaining 97%, 96%, and 97% of variation, respectively. The regression coefficients of NMRNIc.10 on NMRNI305.10 in those 3 yr were 1.14, 1.13, and 1.15, explaining 97%, 95%, and 95% of variation, respectively. The regression coefficients of FRNIc.10 on FRNIc.5 in those years were 1.65, 1.51, and 1.48, explaining 68%, 68%, and 69% of variation, respectively. Finally, the coefficients of NMRNIc.10 on NMRNIc.5 were 1.64, 1.50, 1.46, explaining 68%, 68%, and 70% of variation.

Table 4-1. Regression on RNIc.10[a] on RNI305.10[b] in 3 yr.

	FRNIc.10[c] on FRNI305.10[d]			NMRNIc.10[e] on NMRNI305.10[f]		
Birth year	1988	1990	1992	1988	1990	1992
β	1.12	1.12	1.13	1.14	1.13	1.15
R^2	0.97	0.96	0.97	0.97	0.95	0.95

[a] RNIc.10 = relative net income based on complete lactation yields with a 10-yr opportunity.

[b] RNI305.10 = relative net income based on 305-d lactation yields with a 10-yr opportunity.

[c] FRNIc.10 = RNIc.10 using fluid pricing.

[d] FRNI305.10 = RNI305.10 using fluid pricing.

[e] NMRNIc.10 = RNIc.10 using milk-fat-protein pricing.

[f] NMRNI305.10 = RNI305.10 using milk-fat-protein pricing.

Table 4-2. Regression on RNIc.10[a] on RNIc.5[b] in three years

	FRNIc.10[c] on FRNIc.5[d]			NMRNIc.10[e] on NMRNIc.5[f]		
Birth year	1988	1990	1992	1988	1990	1992
β	1.65	1.51	1.48	1.64	1.50	1.46
R^2	0.68	0.68	0.69	0.68	0.68	0.70

[a] RNIc.10 = relative net income based on complete lactation yields with a 10-yr opportunity.

[b] RNIc.5 = relative net income based on complete lactation yields with a 5-yr opportunity.

[c] FRNIc.10 = RNIc.10 using fluid pricing.

[d] FRNIc.5 = RNIc.5 using fluid pricing.

[e] NMRNIc.10 = RNIc.10 using milk-fat-protein pricing.

[f] NMRNIc.5 = RNIc.5 using milk-fat-protein pricing.

The regression results showed small differences among 3 yr; for this reason, regression analyses including herd and birth year in the model were made to estimate the regression of RNIc.10 on RNIc.5, and RNIc.10 on RNI305.10. The resulting regression coefficient of FRNIc.10 on FRNI305.10 was $1.12 with 97% of the variation explained; on the other hand, the coefficient of FRNIc.10 on FRNIc.5 was about $1.53 with 68% of the variation explained. In the same manner, the regression coefficient of NMRNIc.10 on NMRNI305.10 was about $1.14 with 96% of the variation explained; moreover, that of NMRNIc.10 on NMRNIc.5 was about $1.52 with 68% of the variation explained.

To summarize, RNI305.10 underestimates RNIc.10 by 12 to 14% and explained 96 to 97% of the variation of RNIc.10. Furthermore, RNIc.5 underestimated RNIc.10 by 52 to 53% and explained only 67 to 68% of the variation of RNIc.10. Using RNIc.10 is strongly recommended over the two alternatives tested.

Table 4-3. Regression coefficient with FRNI[a] and NMRNI[b].

Simple regression	FRNI[a]	NMRNI[b]
	10-yr opportunity	
βc.305[c]	1.12	1.14
(R^2)	(0.97)	(0.96)
	Complete lactation	
β10.5[d]	1.53	1.52
(R^2)	(0.67)	(0.68)

[a] FRNI = relative net income using fluid pricing.

[b] NMRNI = relative net income using milk-fat-protein pricing.

[c] βc.305 = regression coefficient of relative net income based on complete lactation yields on relative net income based on 305-d lactation yields.

[d] β10.5 = regression coefficient of relative net income based on a 10-yr opportunity on relative net income based on a 5-yr opportunity.

4.2 Study 2

The objective of this study was to estimate the economic impact of a unit change in PTA_{DPR} and secondarily to estimate the economic impact of all traits in merit indexes, except service sire calving ease, on the economic value of lifetime performance of a bull's daughters. This study estimates the economic weight for the PTA_{DPR} and several traits in economic indexes. The mean of FARNI, NMARNI, and CARNI with low daily and rearing costs were \$2032.32, \$2030.19, and \$2029.04, respectively. The corresponding value at high daily and rearing costs were \$280.23, \$278.10, and \$276.95, respectively.

4.2.1 Means of Daughter Variables

Table 4-4 and Table 4-5 show means of the physical and time traits used in ARNI for the three birth years and the six states included in study 2. Total milk and fat increased as year increases. Age of first calving tended to decrease with birth years. Vermont (VT) has highest means of total milk, total fat, total protein, total days in milk (DIM), days of productive life (DPL), and average terminal lactation followed by Indiana, Virginia, Florida, Texas, and North Carolina. However differences between the states were not large.

Table 4-4. Means of total milk, total fat, total protein, total days in milk (DIM), days of productive life (DPL), lactations, and age at first calving (AFC) by years and overall.

Year of birth	No. of animals	Total milk (kg)	Total fat (kg)	Total protein (kg)	Total DIM (d)	DPL (d)	Lactations	AFC (d)
1988	25707	26424	950	792	949	1075	2.94	849
1990	24014	28068	1013	843	978	1109	3.00	834
1992	21373	28175	1018	842	959	1086	2.94	826
Overall	71094	27506	992	824	962	1090	2.96	837

Table 4-5. Means of total milk, total fat, total protein, total days in milk (DIM), days of productive life (DPL), lactations, and age at first calving (AFC) by states and overall.

State	Num. of animals	Total milk (kg)	Total fat (kg)	Total protein (kg)	Total DIM (d)	DPL (d)	Lactations	AFC (d)
FL	10940	26700	954	794	960	1082	2.91	855
IN	8231	28763	1036	871	985	1119	2.99	824
NC	12280	25142	928	759	891	1002	2.81	813
TX	4786	26346	904	784	907	1028	2.74	779
VA	20341	27818	986	831	985	1113	2.95	872
VT	14516	29344	1085	880	996	1141	3.20	821
Overall	71094	27506	992	824	962	1090	2.96	837

4.2.2 Means of Sire Variables

Table 4-6 shows mean, minimum, and maximum for several sire variables. Especially, it enables us to observe the characteristics about PTA_{DPR}. Means of PTA_{DPR} is 0.27; the ranges for PTA_{DPR} is between -4.1 to 4.1 with σ^2=1.72.

Table 4-6. Means of sires' PTA and three merit indexes (71,094 cows by 3808 sires)

Variable[a]	Mean	Std Dev.	Minimum	Maximum
PTA_{Milk} (kg)	-34.26	259.77	-1493.88	845.80
PTA_{Fat} (kg)	-0.10	10.23	-55.33	33.11
$PTA_{Protein}$ (kg)	-1.49	7.60	-39.46	22.68
PTA_{PL} (month)	-0.07	1.37	-4.60	4.40
PTA_{SCS} ($\log_2$)	3.13	0.20	2.56	3.85
UC (SD units)	-0.47	0.92	-4.37	2.82
FLC (SD units)	-0.34	1.15	-4.64	3.16
BSC (SD units)	-0.35	1.11	-3.88	3.47
PTA_{DPR} (%)	0.27	1.31	-4.10	4.10
PTA_{SSCE} (%)	7.68	1.79	3.00	19.00
PTA_{DCE} (%)	7.88	1.50	4.00	14.00
Fluid merit ($)	-28.91	149.97	-840.00	493.00
Net merit ($)	-32.53	156.72	-800.00	569.00
Cheese merit ($)	-34.37	165.18	-799.00	610.00

PL = productive life; SCS = somatic cell score; UC = udder composite; FLC = feet and legs composite; BSC = body size composite; DPR = daughter pregnancy rate; SSCE = service sire calving ease; DCE = daughter calving ease.

4.2.3 Lactation Distribution

Table 4-7 shows the distributions of terminal lactations and the total number of lactations of each state. Virginia has the most cows (20,341) and Texas has the least (4,786) in the edited data. Overall, 16,882 cows have only one lactation out of 71,094 and only 15 cows have nine lactations.

Table 4-7. Distributions of terminal lactations by state.

Lact. no.	State						Total
	FL	IN	NC	TX	VA	VT	
1st	2709	1830	3085	1261	5249	2748	16882
2nd	2505	1991	3021	1235	4488	3169	16409
3rd	2173	1624	2529	961	3759	2934	13980
4th	1648	1203	1750	603	2764	2434	10402
5th	949	762	1009	405	2094	1572	6791
6th	543	493	573	192	1173	890	3864
7th	307	253	252	106	647	564	2129
8th	102	72	58	23	165	202	622
9th	4	3	3	0	2	3	15
Total	10,940	8,231	12,280	4,786	20,341	14,516	**71,094**

Table 4-8 includes the distributions of terminal lactations as a percentage of the total cows by state and percentage of culled cows. In most of states, 22 to 25% of cows have only one lactation, but in Vermont, only 19% of cows have one lactation. Overall, the percentage of culled cows after first lactation is 24%. The percentage of remaining cows culled increases as the lactation increases. Some lactations are not included because they occurred after the tenth birthday of these cows. However, the number is not great.

Table 4-8. Percentage distributions of terminal lactations by state.

Lact. no.	State						Total	% of culled cows
	FL	IN	NC	TX	VA	VT		
1st	25%	22%	25%	26%	26%	19%	24%	24%
2nd	23%	24%	25%	26%	22%	22%	23%	30%
3rd	20%	20%	21%	20%	18%	20%	20%	37%
4th	15%	15%	14%	13%	14%	17%	15%	44%
5th	9%	9%	8%	8%	10%	11%	10%	51%
6th	5%	6%	5%	4%	6%	6%	5%	58%
7th	3%	3%	2%	2%	3%	4%	3%	77%
8th	1%	1%	0%	0%	1%	1%	1%	98%
9th	0%	0%	0%	0%	0%	0%	0%	100%
Total	10940	8231	12280	4786	20341	14516	**71094**	

4.2.4 Simple Regression of Daughter Variables on Sire's PTA in the Merit Indexes

Table 4-9 shows the simple regression of daughter variables on sire PTA. When other variables are ignored, 1 kg increase in $\mathrm{PTA}_{\mathrm{Milk}}$ increases total milk 5.97 kg ; 1 kg increase in $\mathrm{PTA}_{\mathrm{Fat}}$ increases total fat 5.23kg; 1 kg increase in $\mathrm{PTA}_{\mathrm{Protein}}$ increases total protein 6.45kg. If selection is to increase only for PL, each 1-mo change of $\mathrm{PTA}_{\mathrm{PL}}$ increases total DIM by 51 d, about 2 mo DPL, and 1.5 mo of a lactation. If selection is to increase only for DPR, each one unit change in $\mathrm{PTA}_{\mathrm{DPR}}$ increases total milk by 476.25 kg and total DIM by 18 d.

Table 4-9. Simple regression of daughter variables on PTA in merit indexes (coefficients for all variables P <0.01, except AFC).

	y (Daughter variables) [a]						
x Variables[b] (sire PTA)	Total milk (kg)	Total fat (kg)	Total protein (kg)	Total DIM (d)	DPL (d)	Lactations	AFC (d)
PTA_{Milk} (kg)	5.97	0.15	0.15	0.12	0.12	0.00	0.00
PTA_{Fat} (kg)	81.02	5.23	3.07	2.09	2.15	0.00	-0.11**
$\text{PTA}_{\text{Protein}}$ (kg)	178.73	6.37	6.45	4.04	4.34	0.01	-0.14**
PTA_{PL} (month)	1647.72	57.29	48.11	50.87	59.39	0.15	-0.16
PTA_{SCS} ($\log_2$)	-4372.50	-179.59	-120.07	-150.95	-178.77	-0.43	-3.54*
UC (SD units)	802.25	30.22	24.24	27.78	33.65	0.07	0.42
FLC (SD units)	611.25	20.41	17.36	17.04	20.38	0.05	-0.67*
BSC (SD units)	-521.01	-17.47	-16.50	-14.72	-16.14	-0.04	-1.19**
PTA_{DPR} (%)	476.25	15.89	13.50	17.89	23.09	0.09	-0.65*
PTA_{DCE} (%)	-376.80	-12.58	-11.42	-12.23	-14.44	-0.04	0.85**

[a] DIM = days in milk; DPL = days of productive life; AFC = age at first calving.

[b] PL = productive life; SCS = somatic cell score; UC = udder composite; FLC = feet and legs composite; BSC = body size composite; DPR = daughter pregnancy rate; DCE = daughter calving ease.

* $P < 0.05$; ** $P < 0.01$

4.2.5 Means of Lifetime Profit Estimators and Their Components

Table 4-10 includes the means for RNI, ARNI, and the components of ARNI (YI, NYI, RC, DC, M, T, and PRCE) for the three milk pricing systems for low and high rearing and daily costs. There are slight differences in the yield income and, consequently, in RNI and ARNI for the three milk pricing system; however, all other components are identical (shaded area). Therefore, within a daily and rearing cost category, there is virtually no difference in ARNI between milk pricing systems. This is due to the three pricing systems yielding the same price per hundred weight for milk of breed average fat and protein percentage. However, there were about $1,752 differences in ARNI between low and high daily and rearing costs for each milk pricing system; the difference of about $209 came from that of RC and about $1,543 from that of DC. Referring to the two levels of daily and rearing costs, rearing cost per day for low and high levels were $1.25 and $1.50, respectively; daily cost in milking for two levels were $2.80 and $4.25, respectively; and daily cost in dry for low and high levels were $1.34 and $2.50, respectively (see Table 3-5).

Table 4-10. Means of relative net income (RNI) and augmented RNI (ARNI) and their components for three different milk prices.

			Components of ARNI[a]						
Milk pricing	RNI ($)	ARNI ($)	YI ($)	NYI ($)	RC ($)	DC ($)	M ($)	T ($)	PRCE ($)
			With low daily and rearing costs						
Fluid	2037	2032.32	5351.47	595.95	-1046.03	-2864.33	-4.86	0.10	0.02
NM[b]	2035	2030.19	5349.33	595.95	-1046.03	-2864.33	-4.86	0.10	0.02
Cheese	2034	2029.04	5348.19	595.95	-1046.03	-2864.33	-4.86	0.10	0.02
			With high daily and rearing costs						
Fluid	285	280.23	5351.47	595.95	-1255.23	-4407.21	-4.86	0.10	0.02
NM	283	278.10	5349.33	595.95	-1255.23	-4407.21	-4.86	0.10	0.02
Cheese	282	276.95	5348.19	595.95	-1255.23	-4407.21	-4.86	0.10	0.02

[a] YI = yield income (total milk, fat, and protein income – feed cost for production); NYI = non-yield income (net value of calves + net salvage value); RC = rearing cost; DC = daily cost {(daily cost for labor, maintenance feed, supplies, and fixed expenses) x days in herd}; M = predicted mastitis net cost ; T = predicted net income from improving type composites; PRCE = predicted net income form improving DPR and daughter calving ease.

[b] NM = milk pricing for net merit.

Table 4-11. Means of the augmented RNI (ARNI) and its components for three different milk prices by years.

			Components of ARNI[a]						
Birth year	Milk pricing	ARNI ($)	YI ($)	NYI ($)	RC ($)	DC ($)	M ($)	T ($)	PRCE ($)
			With low daily and rearing costs						
1988	Fluid	1834.29	5135.33	594.09	-1060.80	-2826.19	-0.26	-10.58	2.71
	NM[b]	1832.66	5133.70	594.09	-1060.80	-2826.19	-0.26	-10.58	2.71
	Cheese	1831.78	5132.83	594.09	-1060.80	-2826.19	-0.26	-10.58	2.71
1990	Fluid	2101.47	5464.68	600.07	-1042.02	-2913.44	-8.74	2.33	-1.42
	NM	2104.94	5468.15	600.07	-1042.02	-2913.44	-8.74	2.33	-1.42
	Cheese	2106.81	5470.02	600.07	-1042.02	-2913.44	-8.74	2.33	-1.42
1992	Fluid	2192.81	5484.23	593.54	-1032.76	-2855.01	-6.03	10.44	-1.60
	NM	2183.78	5475.19	593.54	-1032.76	-2855.01	-6.03	10.44	-1.60
	Cheese	2178.91	5470.33	593.54	-1032.76	-2855.01	-6.03	10.44	-1.60
			With high daily and rearing costs						
1988	Fluid	99.89	5135.33	594.09	-1272.96	-4348.44	-0.26	-10.58	2.71
	NM	98.26	5133.70	594.09	-1272.96	-4348.44	-0.26	-10.58	2.71
	Cheese	97.38	5132.83	594.09	-1272.96	-4348.44	-0.26	-10.58	2.71
1990	Fluid	323.48	5464.68	600.07	-1250.42	-4483.03	-8.74	2.33	-1.42
	NM	326.95	5468.15	600.07	-1250.42	-4483.03	-8.74	2.33	-1.42
	Cheese	328.82	5470.02	600.07	-1250.42	-4483.03	-8.74	2.33	-1.42
1992	Fluid	448.56	5484.23	593.54	-1239.32	-4392.71	-6.03	10.44	-1.60
	NM	439.52	5475.19	593.54	-1239.32	-4392.71	-6.03	10.44	-1.60
	Cheese	434.66	5470.33	593.54	-1239.32	-4392.71	-6.03	10.44	-1.60

[a] YI = yield income (total milk, fat, and protein income – feed cost for production); NYI = non-yield income (net value of calves + net salvage value); RC = rearing cost; DC = daily cost {(daily cost for labor, maintenance feed, supplies, and fixed expenses) x days

in herd}; M = predicted mastitis net cost ; T = predicted net income from improving type composites; PRCE = predicted net income form improving DPR and daughter calving ease.

[b] NM = milk pricing for net merit.

Table 4-11 includes the means for ARNI and its components for the three milk pricing systems with low and high daily and rearing costs by birth year. Means of ARNI and YI increase as birth year increases within each milk pricing. With low costs, the differences in FARNI, NMARNI, and CARNI are $358.52, $351.12, and $347.13, respectively, between cows born in 1988 and 1992. With high costs, the differences in FARNI, NMARNI, and CARNI are $348.67, $341.26, and $337.28, respectively, between cows born in 1988 and in 1992. Means of NYI, RC, DC, M, T, and PRCE (shaded area) are equal for all milk pricing within the same birth year for each costs. Between cows born in 1988 and in 1992, PRCE decreases by $4.31, RC decreases by $28.04, DC increases by 28.82, and T increases by $21.02.

4.2.6 Variation in Daughter Profit

Table 4-12 includes the percentage of variation explained by the base model of herd and birth year. Birth year and herd explain 23% of variation in ARNI with high daily and rearing costs; however, they explain only 13% of variation in ARNI with low daily and rearing costs. They also explain 9% of variation in YI, and 38% of variation in RC. When the regression of M on PTA_{SCS} was added to the base model, it explained 100% of the variation. When the simple regression of T on the UC was added to the base model, it explained 66% of the variation and when all PTA were added, R^2 increased to 100%. Similarly, adding PTA_{DPR} to the model for PRCE increases the R^2 to 79% and adding all PTA to the model explained 100% of the variation. The large increases in R^2 for M, T, and PRCE are the result of these y variables only including sire variation and thus result in PTA explaining 100% of the variation. Referring to the augmentation,

$M= - (165 \times (PTAscs -3.10))$

$$T = (33 \times (UC - \overline{UC})) + (15 \times (FLC - \overline{FLC})) - (14.86 \times (BSC - \overline{BSC}))$$

$$PRCE = (8.064 \times (PTA_{DPR} - \overline{PTA}_{DPR}) - (4.80 \times (PTA_{DCE} - \overline{PTA}_{DCE})).$$

These economic weights represent the economic impact not accounted for by the original RNI formula.

Table 4-12. Percentage of variation (R^2) explained by the base model of herd and birth year and for simple and multiple regression models with all PTA in the merit indexes except service sire calving ease.

Traits[a]	R^2 by base model	R^2 by simple regression (maximum)	R^2 by multiple regression
		Low daily and rearing costs	
FARNI	0.13	0.15	0.15
NMARNI	0.13	0.15	0.15
CARNI	0.13	0.15	0.15
		High daily and rearing costs	
FARNI	0.23	0.25	0.26
NMARNI	0.23	0.26	0.26
CARNI	0.23	0.26	0.26
		Unaffected by level of daily and rearing costs	
FYI	0.09	0.10	0.11
NMYI	0.09	0.10	0.11
CYI	0.09	0.10	0.11
NYI	0.08	0.09	0.09
RC	0.38	0.38	0.38
DC	0.09	0.10	0.10
M	0.07	1.00	1.00
T	0.14	0.66	1.00
PRCE	0.08	0.79	1.00

[a] FARNI = relative net income using fluid pricing; NMARNI = relative net income using milk-fat-protein pricing; CARNI = relative net income using cheese pricing; FYI = yield income with fluid pricing; NMYI = yield income with milk-fat-protein pricing; CYI = yield income with cheese pricing; NYI = non-yield income; RC = rearing cost; DC = daily cost; M = predicted mastitis net cost; T = predicted net income from improving type composites; PRCE = predicted net income form improving DPR and daughter calving ease.

Table 4-13, Table 4-14, and Table 4-15 shows the regression coefficient of ARNI and its components on a merit index with the same milk pricing systems. Referring to Table 4-12, fluid merit, net merit, and cheese merit explain additionally 2 to 3% more about ARNI. These small increases in R^2 indicated, as expected, that environment and management explain a majority of the variation of a cow's ARNI. The expectation is that the regression of ARNI on the corresponding merit index should be approximately 1. These results of Table 4-13, Table 4-14, and Table 4-15 indicate that the response is more than expected. However, no account has been taken of the timing of incomes and expenses in the ARNI calculation. This would tend to reduce the regression but not enough to lower the regression coefficients to near 1.

For each of the milk pricing systems, the regression coefficients of the components of ARNI on sire's merit index add up to the coefficient of ARNI on the corresponding merit index. Using high daily and rearing costs (Table 4-13), for a dollar increase in fluid merit, the fluid augmented ARNI (FARNI) increases $1.465 by increasing $3.111 of yield income (YIF), $0.107 of non-yield income (NYI), +$0.008 of decreasing rearing cost (RC), -$1.992 of daily cost (DC: increasing daily costs of $1.992), $0.089 of mastitis benefit (M: decreasing cost of +$0.089), $0.116 of type benefit (T), $0.026 of pregnancy and calving ease benefit (PRCE). Consequently, $3.111+$0.107+$0.008+(-$1.992)+ $0.089+$0.116+$0.026= $1.465.

The increase in each of the ARNI mostly results from increased lifetime milk. However, the DC is also increased because cows tend to stay in the herd longer. All other components result in small increase in income or decrease of costs. With low daily and rearing costs, the regressions for ARNI ranged from $2.16 and $2.01. The corresponding values at the high daily and rearing costs were between $1.47 and $1.44, respectively.

Table 4-13. Regression of daughter profit and components of profit on sires' fluid merit.

	y Variables[a]							
	FARNI ($)	FYI ($)	NYI ($)	RC ($)	DC ($)	M ($)	T ($)	PRCE ($)
	With low daily and rearing costs							
B	2.16**	3.11**	0.11**	0.01*	-1.29**	0.09**	0.12**	0.03**
R^2	0.15	0.10	0.09	0.38	0.09	0.20	0.33	0.14
	With high daily and rearing costs							
B	1.47**	3.11**	0.11**	0.01*	-1.99**	0.09**	0.12**	0.03**
R^2	0.25	0.10	0.09	0.38	0.09	0.20	0.33	0.14

[a] FARNI = relative net income using fluid pricing; FYI = yield income with fluid pricing; NYI = non-yield income; RC = rearing cost; DC = daily cost; M = predicted mastitis net cost; T = predicted net income from improving type composites; PRCE = predicted net income form improving DPR and daughter calving ease.

* *P*< 0.05; ** *P* < 0.01.

Table 4-14. Regression of daughter profit and components of profit on sires' net merit.

	y Variables[a]							
	NMARNI ($)	NMYI ($)	NYI ($)	RC ($)	DC ($)	M ($)	T ($)	PRCE ($)
	With low daily and rearing costs							
B	2.10**	2.97**	0.10**	0.01*	-1.18**	0.07**	0.11**	0.03**
R^2	0.15	0.10	0.09	0.38	0.09	0.17	0.32	0.14
	With high daily and rearing costs							
B	1.46**	2.97**	0.10**	0.01*	-1.82**	0.07**	0.11**	0.03**
R^2	0.26	0.10	0.09	0.38	0.09	0.17	0.32	0.14

[a] NMARNI = relative net income using milk-fat-protein pricing; NM = yield income with milk-fat-protein pricing; NYI = non-yield income; RC = rearing cost; DC = daily cost; M = predicted mastitis net cost; T = predicted net income from improving type

composites; PRCE = predicted net income form improving DPR and daughter calving ease.

* $P < 0.05$; ** $P < 0.01$.

Table 4-15. Regression of daughter profit and components of profit on sires' cheese merit (all *P*<0.01).

	y Variables[a]							
	CARNI ($)	CYI ($)	NYI ($)	RC ($)	DC ($)	M ($)	T ($)	PRCE ($)
	With low daily and rearing costs							
B	2.01	2.78	0.09	0.01	-1.06	0.06	0.10	0.02
R^2	0.15	0.10	0.09	0.38	0.09	0.15	0.30	0.14
	With high daily and rearing costs							
B	1.44	2.78	0.09	0.01	-1.63	0.06	0.10	0.02
R^2	0.26	0.10	0.09	0.38	0.09	0.15	0.30	0.14

[a] CARNI = relative net income using cheese pricing; CYI = yield income with cheese pricing; NYI = non-yield income; RC = rearing cost; DC = daily cost; M = predicted mastitis net cost; T = predicted net income from improving type composites; PRCE = predicted net income form improving DPR and daughter calving ease.

4.2.7 Genetic Net Milk Value

Table 4-16 shows net value of yield for the three milk pricing systems. It is used to calculate genetic net milk value (GNMV). This represents the economic value of the milk, fat, and protein PTA under the three milk pricing systems. Note that the values in the table are calculated from Table 3-4, which shows current three milk pricing systems (VanRaden and Seykora, 2003). This GNMV function was composed to correspond with the yield income component of the ARNI.

Table 4-16. Net value (value-cost) of yield for the three milk pricing systems [41].

	Net value		
Milk Pricing	Milk (kg)	Fat (kg)	Protein (kg)
Fluid (_F) ($/kg)	0.086	2.095	1.102
Milk-Fat-Protein (_NM) ($/kg)	0	2.095	3.969
Cheese (_C) ($/kg)	-0.046	2.095	5.512

The GNMV weights the PTA for milk, fat, and protein by their net value (from Table 4-16) and can be expressed as:

GNMV = (net milk value*PTA_{Milk}) + (net fat value*PTA_{Fat}) + (net protein value *$PTA_{Protein}$).

There are three types of GNMV: GNMV in fluid pricing (GNMV_F), GNMV in milk-fat-protein pricing (GNMV_NM), and GNMV in cheese pricing (GNMV_C). The three GNMV can be expressed as:

GNMV_F = (0.086* PTA_{Milk})+(2.095* PTA_{Fat})+(1.102* $PTA_{Protein}$)

GNMV_NM = (0* PTA_{Milk})+(2.095* PTA_{Fat})+(3.969* $PTA_{Protein}$)

GNMV_C = (-0.046* PTA_{Milk})+(2.095* PTA_{Fat})+(5.512* $PTA_{Protein}$).

4.2.8 Simple Regression of ARNI and Partitioned ARNI on Sire PTA

The main purpose of simple regression analysis was to calculate the change in ARNI and its component parts on a PTA in the merit functions. Table 4-17 and Table 4-18 contain the simple regressions of FARNI, NMARNI, and CARNI on PTA in merit indexes for low and high daily and rearing costs. The simple regressions of each components of ARNI (YI, NYI, RC, DC, M, T, and PRCE) on PTA in merit indexes were computed to help understand the regression coefficients of ARNI on PTA. The regression coefficients of ARNI component on each PTA add up to the coefficient of ARNI on PTA.

Table 4-17 shows regression coefficients across the three milk pricing systems with low daily and rearing costs, and Table 4-18 shows the comparison of regression coefficients with high daily and rearing costs. The regression coefficient of ARNI on each of the PTA is the sum of ARNI component regressions on that PTA.

Table 4-17. Comparison of the regression of ARNI and its components on PTA with the three milk pricing systems within low daily and rearing costs (coefficients for all variables except RC P <0.01).

	y (Daughter variables)[a]							
x Variables[b] (sire PTA)	FARNI ($)	FYI ($)	NYI ($)	RC ($)	DC ($)	M ($)	T ($)	PRCE ($)
GNMV_F ($)	5.04	7.21	0.12	0.03**	-2.26	-0.05	0.06	-0.07
PTA_{PL} (mo)	202.76	314.75	14.58	0.20	-153.86	10.57	10.67	5.84
PTA_{SCS} (log_2)	-667.46	-884.58	-42.85	4.42*	459.93	-165.00	-26.60	-12.78
UC (SD units)	124.28	159.01	7.39	-0.53	-85.65	10.46	32.65	0.95
FLC (SD units)	88.80	114.45	4.74	0.84*	-52.19	1.58	18.32	1.06
BSC (SD units)	-60.91	-99.60	-3.86	1.49**	43.12	5.70	-7.32	-0.44
PTA_{DPR} (%)	59.31	89.11	9.15	0.82 *	-57.06	5.26	2.34	9.69
PTA_{DCE} (%)	-49.35	-71.35	-4.20	-1.06**	37.20	-1.35	-1.74	-6.84
	NMARNI ($)	NMYI ($)	NYI ($)	RC ($)	DC ($)	M ($)	T ($)	PRCE ($)
GNMV_NM ($)	4.88	6.72	0.10	0.03**	-1.91	-0.07	0.06	-0.05
PTA_{PL}	198.97	310.96	14.58	0.20	-153.86	10.57	10.67	5.84
PTA_{SCS}	-635.63	-852.75	-42.85	4.42*	459.93	-165.00	-26.60	-12.78
UC	124.78	159.51	7.39	-0.53	-85.65	10.46	32.65	0.95
FLC	86.00	111.66	4.74	0.84*	-52.19	1.58	18.32	1.06
BSC	-63.42	-102.10	-3.86	1.49**	43.12	5.70	-7.32	-0.44
PTA_{DPR}	57.04	86.85	9.15	0.82*	-57.06	5.26	2.34	9.69
PTA_{DCE}	-49.67	-71.68	-4.20	-1.06**	37.20	-1.35	-1.74	-6.84
	CARNI ($)	CYI ($)	NYI ($)	RC ($)	DC ($)	M ($)	T ($)	PRCE ($)
GNMV_C ($)	4.63	6.16	0.09	0.03**	-1.58	-0.07	0.05	-0.04
PTA_{PL}	196.94	308.93	14.58	0.20	-153.86	10.57	10.67	5.84
PTA_{SCS}	-618.49	-835.61	-42.85	4.42*	459.93	-165.00	-26.60	-12.78
UC	125.05	159.78	7.39	-0.53	-85.65	10.46	32.65	0.95
FLC	84.50	110.16	4.74	0.84*	-52.19	1.58	18.32	1.06
BSC	-64.77	-103.45	-3.86	1.49**	43.12	5.70	-7.32	-0.44
PTA_{DPR}	55.82	85.63	9.15	0.82*	-57.06	5.26	2.34	9.69
PTA_{DCE}	-49.85	-71.85	-4.20	-1.06**	37.20	-1.35	-1.74	-6.84

[a] FARNI = relative net income using fluid pricing; FYI = yield income with fluid pricing; NYI = non-yield income; RC = rearing cost; DC = daily cost; M = predicted mastitis net cost; T = predicted net income from improving type composites; PRCE = predicted net

income form improving DPR and daughter calving ease; NMARNI = relative net income using milk-fat-protein pricing; NMYI = yield income with milk-fat-protein pricing; CARNI = relative net income using cheese pricing; CYI = yield income with cheese pricing.

[b] GNMV_F = genetic net milk value with fluid pricing; PL = productive life; SCS = somatic cell score; UC = udder composite; FLC = feet and legs composite; BSC = body size composite; DPR = daughter pregnancy rate; DCE = daughter calving ease; GNMV_NM = genetic net milk value with milk-fat-protein pricing; GNMV_C = genetic net milk value with cheese pricing.

* $P < 0.05$; ** $P < 0.01$ (only shaded areas change from one milk pricing system to another).

The shaded areas are the only simple regressions that vary with milk pricing system and most of these vary only slightly. These include the regression coefficients of (F, NM, C)ARNI and YI on PTA and all daughter variables on GNMV_(F, NM, C). This is in large part due to the fact that all three milk pricing systems yield the same milk value for milk of breed average milk composition.

Within the same milk pricing, the regression coefficients of FYI, NYI, M, T, and PRCE on PTA are the same for both levels of daily and rearing costs. However, the regression coefficients of RC, DC, and consequently ARNI on PTA are different between low and high costs.

With low daily and rearing costs (Table 4-17), if we select only for GNMV, each one unit change ($1) in GNMV increased daughter ARNI by $4.63 to $5.04 depending upon the milk pricing system employed. This results from increasing lifetime milk income (FYI) by $6.16 to $7.21, calf sale income (NYI) by $0.09 to $0.12, RC by $0.03 (decreasing cost of $0.03), income by improving type (T) by $0.05 to $0.06, DC by -$2.26 to -$1.58 (increasing cost of $2.26 to $1.58), mastitis cost (M) by -$0.05 to -$0.07 (increasing cost and decreasing income of $0.05 to $0.07), and decreasing net income from DPR and DCE by -$0.07 to -$0.04.

Table 4-18. Comparison of the regression of ARNI and its components on PTA with the three milk pricing systems within high daily and rearing costs (coefficients for all variables except RC *P* <0.01).

	y (Daughter variables) ^{a}							
x Variables (sire PTA)	FARNI ($)	FYI ($)	NYI ($)	RC ($)	DC ($)	M ($)	T ($)	PRCE ($)
GNMV_F ($)	3.85	7.21	0.12	0.04**	-3.45	-0.05	0.06	-0.07
PTA_{PL} (mo)	119.15	314.75	14.58	0.24	-237.50	10.57	10.67	5.84
PTA_{SCS} (log$_2$)	-415.43	-884.58	-42.85	5.31*	711.08	-165.00	-26.60	-12.78
UC (SD units)	77.08	159.01	7.39	-0.63	-132.74	10.46	32.65	0.95
FLC (SD units)	60.38	114.45	4.74	1.00*	-80.78	1.58	18.32	1.06
BSC (SD units)	-37.62	-99.60	-3.86	1.79**	66.11	5.70	-7.32	-0.44
PTA_{DPR} (%)	27.50	89.11	9.15	0.98*	-89.04	5.26	2.34	9.69
PTA_{DCE} (%)	-29.26	-71.35	-4.20	-1.27**	57.49	-1.35	-1.74	-6.84
	NMARNI ($)	NMYI ($)	NYI ($)	RC ($)	DC ($)	M ($)	T ($)	PRCE ($)
GNMV_NM ($)	3.88	6.72	0.10	0.04**	-2.91	-0.07	0.06	-0.05
PTA_{PL}	115.37	310.96	14.58	0.24	-237.50	10.57	10.67	5.84
PTA_{SCS}	-383.60	-852.75	-42.85	5.31*	711.08	-165.00	-26.60	-12.78
UC	77.58	159.51	7.39	-0.63	-132.74	10.46	32.65	0.95
FLC	57.58	111.66	4.74	1.00*	-80.78	1.58	18.32	1.06
BSC	-40.13	-102.10	-3.86	1.79**	66.11	5.70	-7.32	-0.44
PTA_{DPR}	25.23	86.85	9.15	0.98*	-89.04	5.26	2.34	9.69
PTA_{DCE}	-29.59	-71.68	-4.20	-1.27**	57.49	-1.35	-1.74	-6.84
	CARNI ($)	CYI ($)	NYI ($)	RC ($)	DC ($)	M ($)	T ($)	PRCE ($)
GNMV_C ($)	3.81	6.16	0.09	0.04**	-2.41	-0.07	0.05	-0.04
PTA_{PL}	113.33	308.93	14.58	0.24	-237.50	10.57	10.67	5.84
PTA_{SCS}	-366.46	-835.61	-42.85	5.31*	711.08	-165.00	-26.60	-12.78
UC	77.85	159.78	7.39	-0.63	-132.74	10.46	32.65	0.95
FLC	56.08	110.16	4.74	1.00*	-80.78	1.58	18.32	1.06
BSC	-41.48	-103.45	-3.86	1.79**	66.11	5.70	-7.32	-0.44
PTA_{DPR}	24.01	85.63	9.15	0.98*	-89.04	5.26	2.34	9.69
PTA_{DCE}	-29.77	-71.85	-4.20	-1.27**	57.49	-1.35	-1.74	-6.84

[a] FARNI = relative net income using fluid pricing; FYI = yield income with fluid pricing; NYI = non-yield income; RC = rearing cost; DC = daily cost; M = predicted mastitis net cost; T = predicted net income from improving type composites; PRCE = predicted net income form improving DPR and daughter calving ease; NMARNI = relative net income using milk-fat-protein pricing; NMYI = yield income with milk-fat-protein pricing; CARNI = relative net income using cheese pricing; CYI = yield income with cheese pricing.

[b] GNMV_F = genetic net milk value with fluid pricing; PL = productive life; SCS = somatic cell score; UC = udder composite; FLC = feet and legs composite; BSC = body size composite; DPR = daughter pregnancy rate; DCE = daughter calving ease; GNMV_NM = genetic net milk value with milk-fat-protein pricing; GNMV_C = genetic net milk value with cheese pricing.

* $P < 0.05$; ** $P < 0.01$ (only shaded areas change from one milk pricing system to another).

Previously it is mentioned that the regression coefficients of ARNI component on PTA add up to the coefficient of ARNI on PTA. As an example with the coefficient of NMARNI on GNMV_NM with low costs (Table 4-17), \$6.72 (FYI) + \$0.10 (NYI) + \$0.03 (RC) + (-\$1.91) (DC) + (-\$0.07) (M) + \$0.06 (T) + (-\$0.05) (PRCE) = \$4.88 (NMARNI). With high costs (Table 4-18), each one unit change in GNMV_NM increases NMARNI by \$3.88 because of increasing RC by 0.01 (decreasing cost of \$0.01) and DC by -\$1.00 (increasing cost by \$1.00) as compared with the low costs.

The regression coefficient of NMARNI on PTA_{PL} with low daily and rearing costs (Table 4-17) was \$198.97. If selection is to increase only for PL, huge amount of income comes from yield (\$310.96), but more DC (-\$153.86) must be paid because cows stay longer in their herds. The corresponding value at the high daily and rearing costs (Table 4-18) is \$115.37 because yield income stays constant (\$310.96) as that with the low costs, but DC differs about -\$84 (more cost of \$84).

If selection is to decrease SCS, each one unit change in PTA_{SCS} increases NMARNI by \$635.63 with low daily and rearing costs (Table 4-17) and \$383.60 with high daily and rearing costs (Table 4-18). Most gains come from increasing lifetime yield income (\$852.75) and decreasing mastitis cost (\$165). With high daily and rearing costs, DC increases \$251 more than that with low daily and rearing costs. However, in both daily and rearing costs, RC and DC are increased because cows without mastitis stay in the herd longer.

The regression coefficient of NMARNI on UC is \$124.78 with low costs and \$77.58 with high costs. If selection is to increase only for UC, most profit comes from yield income (\$159.51). Mastitis cost decreases \$10.46 and income from improving type increased \$32.65. The regression coefficient of NMARNI on FLC is \$86.00 with low costs and \$57.58 with high daily and rearing costs. Most income results from producing more milk (\$111.66), and consequently daily cost increases to yield more milk. If selection is to decrease BCS, each one unit change in BSC increases NMARNI mostly through increasing yield income. The DC increases because smaller cows tend to stay in the herd longer, and most other costs increased; however, the net value of decreased size is clearly positive.

The regression coefficient of NMARNI on PTA_{DPR} is \$57.04 with low costs and \$25.23 with high costs. Yield income increases by \$86.85; DC increases by \$57.06 with low costs, but by \$89.04 with high costs. Within the high costs, the extra costs of DC more than offset extra yield income. If selection is to decrease in DCE, each one unit change in PTA_{DCE} increases NMARNI by \$49.67 with low costs and by \$29.59 with high costs. Most income comes from increasing yield income. DC is increased by \$37.20 with low costs and by \$57.49 with high costs.

To aid in comparing the regressions on the individual PTA, the coefficients have been standardized by multiplying by the standard deviation of the PTA in Table 4-19.

Table 4-19. Standard deviations of PTA or functions of PTA developed from VanRaden and Seykora (2003)

	Standard deviation
GNMV_F[a] (\$)	64.30
GNMV_NM[b] (\$)	67.76
GNMV_C[c] (\$)	71.97
PTA_{Milk} (kg)	377.32
PTA_{Fat} (kg)	14.51
$PTA_{Protein}$ (kg)	11.34
PTA_{PL}[d] (month)	1.50
PTA_{SCS}[e] (log_2)	0.20
UC[f] (SD units)	0.78
FLC[g] (SD units)	0.88
BSC[h] (SD units)	0.94
PTA_{DPR}[i] (%)	1.40
PTA_{DCE}[j] (%)	1.40

[a] GNMV_F = genetic net milk value with fluid pricing.

[b] GNMV_NM = genetic net milk value with milk-fat-protein pricing.

[c] GNMV_C = genetic net milk value with cheese pricing.

[d] PL = productive life.

[e] SCS = somatic cell score.

[f] UC = udder composite.

[g] FLC = feet and legs composite.

[h] BSC = body size composite.

[i] DPR = daughter pregnancy rate.

[j] DCE = daughter calving ease.

Table 4-20 and Table 4-21 include the standardized simple regression coefficients representing the change associated with one standard deviation change in the PTA. Like the previous two tables in this section, the only coefficients in shaded area change from one milk pricing system to another. However, the differences are not large because all three milk pricing systems yield the same milk value for milk of breed average milk composition. By multiplying each regression by the appropriate standard deviation of PTA, comparisons of coefficients can be used to more directly compare the impact of the PTA. Those tables show that GNMV (milk, fat, and protein) is the most important trait for improving profit, followed by PL, SCS, UC, and DPR. The $\mathrm{PTA}_{\mathrm{PL}}$ is the most important trait to improve DPL because $\mathrm{PTA}_{\mathrm{PL}}$ increases DC the most, followed by GNMV (milk, fat, and protein), UC, and DPR.

Within the same milk pricing system, YI, NYI, M, T, and PRCE are same, but RC, DC, and, consequently, ARNI are changed. The RC and DC with high daily and rearing costs (Table 4-21) have bigger absolute values than those with low daily and rearing costs (Table 4-20). If other PTA stay constant, one unit increase in $\mathrm{PTA}_{\mathrm{DPR}}$ increases \$78.15 to \$83.03 with low daily and rearing costs, but \$33.61 to \$38.50 with high daily and rearing costs.

Table 4-20. Standardized (multiplied by standard deviation) simple regression of ARNI and its components on PTA with low daily and rearing costs.

	y (Daughter variables)[a]							
x Variables[b] (sire PTA)	FARNI ($)	FYI ($)	NYI ($)	RC ($)	DC ($)	M ($)	T ($)	PRCE ($)
GNMV_F	324.07	463.60	7.72	1.93	-145.32	-3.22	3.86	-4.50
PTA$_{PL}$	304.14	472.13	21.87	0.30	-230.79	15.86	16.01	8.76
PTA$_{SCS}$	-133.49	-176.92	-8.57	0.88	91.99	-33.00	-5.32	-2.56
UC	96.94	124.03	5.76	-0.41	-66.81	8.16	25.47	0.74
FLC	78.14	100.72	4.17	0.74	-45.93	1.39	16.12	0.93
BSC	-57.26	-93.62	-3.63	1.40	40.53	5.36	-6.88	-0.41
PTA$_{DPR}$	83.03	124.75	12.81	1.15	-79.88	7.36	3.28	13.57
PTA$_{DCE}$	-69.09	-99.89	-5.88	-1.48	52.08	-1.89	-2.44	-9.58
	NMARNI ($)	NMYI ($)	NYI ($)	RC ($)	DC ($)	M ($)	T ($)	PRCE ($)
GNMV_NM	330.67	455.35	6.78	2.03	-129.42	-4.74	4.07	-3.39
PTA$_{PL}$	298.46	466.44	21.87	0.30	-230.79	15.86	16.01	8.76
PTA$_{SCS}$	-127.13	-170.55	-8.57	0.88	91.99	-33.00	-5.32	-2.56
UC	97.33	124.42	5.76	-0.41	-66.81	8.16	25.47	0.74
FLC	75.68	98.26	4.17	0.74	-45.93	1.39	16.12	0.93
BSC	-59.61	-95.97	-3.63	1.40	40.53	5.36	-6.88	-0.41
PTA$_{DPR}$	79.86	121.59	12.81	1.15	-79.88	7.36	3.28	13.57
PTA$_{DCE}$	-69.54	-100.35	-5.88	-1.48	52.08	-1.89	-2.44	-9.58
	CARNI ($)	CYI ($)	NYI ($)	RC ($)	DC ($)	M ($)	T ($)	PRCE ($)
GNMV_C	333.22	443.34	6.48	2.16	-113.71	-5.04	3.60	-2.88
PTA$_{PL}$	295.41	463.40	21.87	0.30	-230.79	15.86	16.01	8.76
PTA$_{SCS}$	-123.70	-167.12	-8.57	0.88	91.99	-33.00	-5.32	-2.56
UC	97.54	124.63	5.76	-0.41	-66.81	8.16	25.47	0.74
FLC	74.36	96.94	4.17	0.74	-45.93	1.39	16.12	0.93
BSC	-60.88	-97.24	-3.63	1.40	40.53	5.36	-6.88	-0.41
PTA$_{DPR}$	78.15	119.88	12.81	1.15	-79.88	7.36	3.28	13.57
PTA$_{DCE}$	-69.79	-100.59	-5.88	-1.48	52.08	-1.89	-2.44	-9.58

[a] FARNI = relative net income using fluid pricing; FYI = yield income with fluid pricing; NYI = non-yield income; RC = rearing cost; DC = daily cost; M = predicted mastitis net cost; T = predicted net income from improving type composites; PRCE = predicted net income form improving DPR and daughter calving ease; NMARNI = relative net income using milk-fat-protein pricing; NMYI = yield income with milk-fat-protein pricing; CARNI = relative net income using cheese pricing; CYI = yield income with cheese pricing.

[b] GNMV_F = genetic net milk value with fluid pricing; PL = productive life; SCS = somatic cell score; UC = udder composite; FLC = feet and legs composite; BSC = body

size composite; DPR = daughter pregnancy rate; DCE = daughter calving ease; GNMV_NM = genetic net milk value with milk-fat-protein pricing; GNMV_C = genetic net milk value with cheese pricing.

Table 4-21. Standardized (multiplied by standard deviation) simple regression of ARNI and its components on PTA with high daily and rearing costs.

	y (daughter variables)[a]							
x variables[b] (sire PTA)	FARNI ($)	FYI ($)	NYI ($)	RC ($)	DC ($)	M ($)	T ($)	PRCE ($)
GNMV_F	247.56	463.60	7.72	2.57	-221.84	-3.22	3.86	-4.50
PTA_{PL}	178.73	472.13	21.87	0.36	-356.25	15.86	16.01	8.76
PTA_{SCS}	-83.09	-176.92	-8.57	1.06	142.22	-33.00	-5.32	-2.56
UC	60.12	124.03	5.76	-0.49	-103.54	8.16	25.47	0.74
FLC	53.13	100.72	4.17	0.88	-71.09	1.39	16.12	0.93
BSC	-35.36	-93.62	-3.63	1.68	62.14	5.36	-6.88	-0.41
PTA_{DPR}	38.50	124.75	12.81	1.37	-124.66	7.36	3.28	13.57
PTA_{DCE}	-40.96	-99.89	-5.88	-1.78	80.49	-1.89	-2.44	-9.58
	NMARNI ($)	NMYI ($)	NYI ($)	RC ($)	DC ($)	M ($)	T ($)	PRCE ($)
GNMV_NM	262.91	455.35	6.78	2.71	-197.18	-4.74	4.07	-3.39
PTA_{PL}	173.06	466.44	21.87	0.36	-356.25	15.86	16.01	8.76
PTA_{SCS}	-76.72	-170.55	-8.57	1.06	142.22	-33.00	-5.32	-2.56
UC	60.51	124.42	5.76	-0.49	-103.54	8.16	25.47	0.74
FLC	50.67	98.26	4.17	0.88	-71.09	1.39	16.12	0.93
BSC	-37.72	-95.97	-3.63	1.68	62.14	5.36	-6.88	-0.41
PTA_{DPR}	35.32	121.59	12.81	1.37	-124.66	7.36	3.28	13.57
PTA_{DCE}	-41.43	-100.35	-5.88	-1.78	80.49	-1.89	-2.44	-9.58
	CARNI ($)	CYI ($)	NYI ($)	RC ($)	DC ($)	M ($)	T ($)	PRCE ($)
GNMV_C	274.21	443.34	6.48	2.88	-173.45	-5.04	3.60	-2.88
PTA_{PL}	170.00	463.40	21.87	0.36	-356.25	15.86	16.01	8.76
PTA_{SCS}	-73.29	-167.12	-8.57	1.06	142.22	-33.00	-5.32	-2.56
UC	60.72	124.63	5.76	-0.49	-103.54	8.16	25.47	0.74
FLC	49.35	96.94	4.17	0.88	-71.09	1.39	16.12	0.93
BSC	-38.99	-97.24	-3.63	1.68	62.14	5.36	-6.88	-0.41
PTA_{DPR}	33.61	119.88	12.81	1.37	-124.66	7.36	3.28	13.57
PTA_{DCE}	-41.68	-100.59	-5.88	-1.78	80.49	-1.89	-2.44	-9.58

[a] FARNI = relative net income using fluid pricing; FYI = yield income with fluid pricing; NYI = non-yield income; RC = rearing cost; DC = daily cost; M = predicted mastitis net cost; T = predicted net income from improving type composites; PRCE = predicted net income form improving DPR and daughter calving ease; NMARNI = relative net income using milk-fat-protein pricing; NMYI = yield income with milk-fat-protein pricing;

CARNI = relative net income using cheese pricing; CYI = yield income with cheese pricing.

[b] GNMV_F = genetic net milk value with fluid pricing; PL = productive life; SCS = somatic cell score; UC = udder composite; FLC = feet and legs composite; BSC = body size composite; DPR = daughter pregnancy rate; DCE = daughter calving ease; GNMV_NM = genetic net milk value with milk-fat-protein pricing; GNMV_C = genetic net milk value with cheese pricing.

4.2.9 Multiple Regression of ARNI on Sire PTA

To aid in comparing the regression on the individual PTA, the coefficients have been multiplied by the standard deviation of the PTA in the Table 4-22. The regression coefficients represent the change associated with one standard deviation change in the PTA. Table 4-22 presents the partial regression coefficients of ARNI on PTA for three milk pricing systems with low and high daily and rearing costs. There are small differences in the regression coefficients of PTA_{Fat}, PTA_{PL}, PTA_{SCS}, UC, FLC, and PTA_{DCE} among the three milk pricing systems within low or high daily and rearing costs; however, coefficients of PTA_{Milk} and $PTA_{Protein}$ vary significantly between the three milk pricing systems. The coefficients of PTA_{PL}, PTA_{DPR}, and PTA_{DCE} differ greatly between the low and high daily and rearing costs. For example, with low costs, the partial regression coefficients of FARNI, NMARNI, and CARNI on PTA_{PL} are \$235.58, \$233.19, and \$231.90, respectively; the corresponding values at the high costs are \$103.67, \$101.30, and \$100.01, respectively. As it is mentioned, the coefficients for PTA_{PL} are similar (less than \$4 differences) across the three pricing systems, but there are \$132 differences between low and high costs. The partial regression coefficients for PTA_{DCE} are not significant at any case. Within low costs, the partial regression coefficients for BSC, PTA_{DPR}, and PTA_{DCE} are not significant; within high costs the partial regression coefficients for PTA_{DPR} and PTA_{DCE} are not significant.

Table 4-22. Standardized (multiplied by standard deviation) multiple regression of ARNI on PTA.

x Variables[b]	y (Daughter variables)[a]		
(sire PTA)	FARNI ($)	NMARNI ($)	CARNI ($)
	With low daily and rearing costs		
PTA_{Milk}	79.24**	-15.09	-64.15**
PTA_{Fat}	133.22**	135.11**	136.13**
$\text{PTA}_{\text{Protein}}$	70.63**	170.75**	224.60**
PTA_{PL}	235.58**	233.19**	231.90**
PTA_{SCS}	-39.43**	-40.06**	-40.40**
UC	42.92**	42.32**	41.99**
FLC	21.33**	21.82**	22.07**
BSC	-14.11	-13.58	-13.30
PTA_{DPR}	-9.30	-12.60	-14.39
PTA_{DCE}	6.37	7.14	7.56
	With high daily and rearing costs		
PTA_{Milk}	79.24**	-15.09	-64.15**
PTA_{Fat}	121.61**	123.50**	124.52**
$\text{PTA}_{\text{Protein}}$	55.22**	155.33**	209.18**
PTA_{PL}	103.67**	101.30**	100.01**
PTA_{SCS}	-37.90**	-38.53**	-38.88**
UC	35.06**	34.44**	34.12**
FLC	19.01**	19.48**	19.75**
BSC	-13.11**	-12.60**	-12.30**
PTA_{DPR}	12.88	9.58	7.80
PTA_{DCE}	2.06	2.83	3.25

[a] FARNI = relative net income using fluid pricing; NMARNI = relative net income using milk-fat-protein pricing; CARNI = relative net income using cheese pricing.

[b] PL = productive life; SCS = somatic cell score; UC = udder composite; FLC = feet and legs composite; BSC = body size composite; DPR = daughter pregnancy rate; DCE = daughter calving ease.

$*P < 0.05$; $**P < 0.01$.

The main purpose of running this multiple regression was to compare the economic weights of this study with those of USDA. Table 4-23 compares relative emphasis in merit indexes with the results from this study. First of all, within the low daily and rearing costs, the economic weights of PTA_{Fat}, UC, FLC, BSC were similar among three milk pricing systems. For PTA_{Milk}, PTA_{SCS}, and PTA_{DPR} in fluid merit, $\text{PTA}_{\text{Protein}}$, PTA$_{SCS}$, and PTA$_{DPR}$ in net merit, and PTA$_{Protein}$ in cheese merit, the weights of USDA are higher than the results from this study. However, PTA$_{PL}$ in all three merit index of USDA is emphasized less than the results from this study. Finally, explaining within high daily and rearing costs, PTA$_{Milk}$ in fluid merit, and PTA$_{DPR}$ in all three merit indexes of USDA received more weight than in these results. Again, PTA$_{PL}$ is less emphasized in the USDA indexes than in this study. Using income and expense prices that yield near zero profit (high costs) reduces the weight on PL but still does not bring it in line with the USDA value. Further study is suggested to investigate the differences. In this study, the economic weight of PTA$_{DPR}$ was negative within the low daily and rearing costs, but it was positive in the high daily and rearing costs.

Table 4-23. Comparison of relative values (%) between USDA and Virginia Tech (VT).

		PTA in the indexes[a]									
		PTA$_{Milk}$	PTA$_{Fat}$	PTA$_{Protein}$	PTA$_{PL}$	PTA$_{SCS}$	UC	FLC	BSC	PTA$_{DPR}$	PTA$_{DCE}$
Fluid Merit	VT low	12	20	11	36	-6	7	3	-2	-1	1
	USDA	24	22	9	11	-9	7	4	-3	7	-2
	VT high	17	25	12	22	-8	7	4	-3	3	0
Net Merit	VT low	-2	20	25	34	-6	6	3	-2	-2	1
	USDA	0	22	33	11	-9	7	4	-3	7	-2
	VT high	-3	24	30	20	-8	7	4	-2	2	1
Cheese Merit	VT low	-8	17	28	29	-5	5	3	-2	-2	1
	USDA	-10	18	36	9	-7	6	3	-2	5	-2
	VT high	-10	20	34	16	-6	6	3	-2	1	1

[a] PL = productive life; SCS = somatic cell score; UC = udder composite; FLC = feet and legs composite; BSC = body size composite; DPR = daughter pregnancy rate; DCE = daughter calving ease.

Chapter 5 Summary

Intense selection for high yielding cows has been employed for many years. As a result, milk production per cow has nearly doubled over the past 40 yr. However, over the same period, days open has increased by about 40 d. This demonstrates the antagonistic relationship between milk yields and fertility in milking cows. Fertility is a most important trait in dairy cattle, and even though reproductive performance has a low heritability, it has a high economic value. To increase annual profit, cows should have higher daily milk production, shorter calving interval, fewer reproductive culls, and less inseminations needed for conception. Consequently, improving reproductive efficiency is one way to increase profit. Therefore, a primary goal of breeders and geneticists is to improve milk production with a minimum loss in reproductive efficiency.

The primary objective of this study was to estimate the economic impact of a unit change in PTA_{DPR} and secondarily to estimate the economic impact of all traits in merit indexes, except service sire calving ease, on the economic value of lifetime performance of a bull's daughters. Service sire calving ease is not included in this study because of its moderately small expected effect and because it would require two generations of performance data to estimate. This study is anticipated to help in determining the economic weight for the PTA_{DPR} in economic indexes.

Study 1

Initially, this study evaluated two separate indicators of completeness. First, it considered the impact of herd life opportunity of 5- and 10-yr periods on the estimated lifetime net income. Second, it used 305-d vs. complete lactation data for calculating lifetime net income. This study used records for 22,854 cows in Virginia herds born in 1988, 1990, and 1992.

In each birth year, three different sets of data were accumulated from cow production records based on the herd opportunity and lactation recording periods. The first data set (c.10) had a 10-yr herd opportunity based on complete lactations; the second data set (305.10) had a 10-yr herd opportunity based on 305-d lactations; the last data set (c.5) had a 5-yr herd opportunity based on complete lactations. Within each data set, production records were accumulated to calculate lifetime net income. Relative net income (RNI) has been used as a profit function, and RNI on each cow was calculated using two milk pricing systems: fluid (skim/fat) pricing (FRNI) and milk-fat-protein pricing (NMRNI).

The regression results showed small differences among the three birth years; for this reason, regression analyses including herd and birth year in the model were made to estimate the regression of RNIc.10 on RNIc.5, and RNIc.10 on RNI305.10. Our research showed that RNI305.10 underestimates RNIc.10 by 12 to14% and explained 96 to 97% of the variation of RNIc.10. Furthermore, it showed that RNIc.5 underestimated RNIc.10 by 52 to 53% and explained only 67 to 68% of the variation of RNIc.10. Using RNIc.10 is strongly recommended over the two alternatives tested.

Study 2

The DHI records of six states (FL, IN, NC, TX, VA, and VT) were used to calculate the effect of a unit change in sire PTA of DPR on lifetime profit estimates. Cow production data was merged with sire genetic evaluation data (Sire summary in Nov., 2003). The final edited data had 10,940 Florida cows, 8231 Indiana cows, 12,280 North Carolina cows, 4786 Texas cows, 20,341 Virginia cows, and 14,516 Vermont cows.

The basic RNIc.10, which was used in Study 1, was augmented (ARNI) by adding the products of sire PTA for various traits and the economic weight for the trait proposed in the net merit calculation (VanRaden and Seykora, 2003). This procedure accounts for income and expenses not included in the basic RNIc.10 function.

Each ARNI was calculated using all production initiated prior to the cow's tenth birthday and was evaluated for three milk pricing systems: fluid (skim/fat) pricing (FARNI), milk-fat-protein pricing (NMARNI), and cheese pricing (CARNI). Two levels of prices for rearing cost per day and daily cost were used for calculating FARNI, NMARNI, and CARNI.

The mean of FARNI, NMARNI, and CARNI with low rearing and daily costs were \$2032.32, 2030.19, and 2029.04, respectively. The corresponding value with high rearing and daily costs was \$280.23, 278.10, and 276.95, respectively. The reason for the close correspondences for the three milk pricing systems is that they yield nearly identical milk price for average fat (3.5%) and protein (3.0%) composition milk.

Regression analyses including herd and birth year in the model were used to estimate the simple and partial regressions of ARNI or partitioned ARNI on PTA. Partial regression included all PTA in the net merit, except service sire calving ease. Birth year and herd explained 23% of variation in ARNI with high daily and rearing costs; however, they explained only 13% of variation in ARNI with low daily and rearing costs. When the regression of net mastitis cost (M) on PTA_{SCS} was added to the base model, PTA_{SCS} explained 100% of the variation of M. When the simple regression of T on UC was added to the base model, it explained 66% of the variation and when all PTA were added, R^2 increased to 100%. Similarly, adding PTA_{DPR} to the model for PRCE increases the R^2 to 79% and adding all PTA to the model explained all the variation. The large increases in R^2 for M, T, and PRCE are because these y variables only include sire variation and thus result in PTA explaining 100% of the variation.

The simple regression coefficients of component of ARNI on each PTA add up to the coefficient of ARNI on PTA. As an example with the coefficient of NMARNI on PTA_{DPR} with low costs, \$86.85 + \$9.15 + \$0.82 + (-\$57.06) + \$5.26 + \$2.34 + \$9.69 = \$57.04. With high costs, each one unit change in PTA_{DPR} increased NMARNI by \$25.23 because of increasing RC by \$0.98 (decreasing cost of \$0.98) and DC by -\$89.04 (increasing cost of \$89.04) compared with the low costs.

Within the same daily and rearing costs, the regression coefficients of (F, NM, C)ARNI and YI on PTA and all daughter variables on GNMV_(F, NM, C) are the only simple regressions that vary with milk pricing system and most of these vary only slightly. Within the same milk pricing, the regression coefficients of YI, NYI, M, T, and PRCE on PTA are same for both levels of daily and rearing costs. However, the regression coefficients of RC, DC, and consequently ARNI on PTA are different between low and high costs. After standardizing by multiplying each regression coefficient by the respective standard deviation of PTA, coefficients among PTA represented that milk value (GNMV: milk, fat, and protein) is the most important trait for improving profit, followed by PL, SCS, and UC.

The simple regression of direct physical trait on PTA in the merit indexes shows that a 1-kg increase in $\mathrm{PTA}_{\mathrm{Milk}}$ increased total milk 5.97 kg; a 1-kg increase in $\mathrm{PTA}_{\mathrm{Fat}}$ increased total fat 5.23 kg; and a 1-kg increase in $\mathrm{PTA}_{\mathrm{Protein}}$ increased total protein 6.45 kg. If selection is to increase only for PL, each one-mo change of $\mathrm{PTA}_{\mathrm{PL}}$ increased total DIM by 51 d, about DPL by 59 d, and 0.15 lactations. If we select only for DPR, each one unit change in $\mathrm{PTA}_{\mathrm{DPR}}$ increased total milk by 476.25 kg.

Comparing relative emphasis in merit indexes with the field results from this study, the economic weights of fat, UC, FLC, and BSC were similar among three milk pricing systems within the low daily and rearing costs. Milk, SCS, DPR in fluid merit, protein and DPR in net merit, and protein in cheese merit of USDA have higher weights than the results from this study. However, PL in all three merit indexes of USDA is less emphasized than the results from this study. Within high daily and rearing costs, milk in fluid merit index and DPR in all three merit of USDA are emphasized more than this study. Again, PL is emphasized less than ours. In our study, the economic weight of DPR was negative within the low daily and rearing costs, but it was positive in the high daily and rearing costs.

Chapter 6 Conclusions

The initial study showed RNI from 305-d underestimated RNI from complete lactation data by 12 to 14% and explained 96 to 97% of the variation. Moreover, RNI with 5-yr opportunity underestimated RNI with 10-yr opportunity by 52 to 53% and explained 67 to 68% of the variation. Therefore, as the measure of estimating lifetime profit, RNI with complete lactation data and 10-yr opportunity is recommended.

In the second study, when we ignored the PTA in merit indexes, a 1-kg increase in PTA_{Milk} increased total milk 5.97 kg; a 1-kg increase in PTA_{Fat} increased total fat 5.23 kg; and 1kg increased in $PTA_{Protein}$ increase total protein 6.45 kg. One unit decrease in PTA_{SCS} increased total milk by 4372.50 kg and total DIM by 151 d, so one unit changes in PTA_{SCS} increased 28.96 kg per day. If selection is to increase only for PL, each 1- mo change of PTA_{PL} increased total milk by 1647.72 kg, total DIM by 51 d, DPL by 59 d, and lactations by 0.15.

If selection is to increase only for DPR, each one unit change in PTA_{DPR} increased total milk by 476.25 kg and total DIM by 18 d; therefore, one unit increase in PTA_{DPR} increases milk yield by 26.46 kg per day at the margin. This suggests an increase in herd life but a decrease in production per day because mean production per day is 28.59 kg/day: mean of total milk (27,506 kg) / mean of total DIM (962 d). This study showed that the economic weight of PTA_{DPR} was negative within the low daily and rearing costs, but it was at least positive in the high daily and rearing costs. More investigations with ARNIOC are recommended to determine the economic weight of PTA_{DPR}.

The estimate of the economic weight of PTA_{PL} in this study was much larger than in USDA indexes. However, in this study, opportunity cost (OC) was not accounted for, and using ARNI adjusted for opportunity cost (ARNIOC) will possibly reduce the economic weight for PL even more than in the high daily and rearing costs scenario. This will require additional research to clarify.

Appendix

Table 1. Simple Regression of PTA on PTA, R^2 in parenthesis.

	y Variables[a]									
x Variables[a]	PTA$_{Milk}$ (kg)	PTA$_{Fat}$ (kg)	PTA$_{Protein}$ (kg)	PTA$_{PL}$ (mo)	PTA$_{SCS}$ (log$_2$)	UC (SD units)	FLC (SD units)	BSC (SD units)	PTA$_{DPR}$ (%)	PTA$_{DCE}$ (%)
PTA$_{Milk}$		0.012	0.020	0.001	0.000	0.000	0.000	0.000	-0.001	0.000
		(0.22)	(0.57)	(0.11)	(0.07)	(0.22)	(0.09)	(0.15)	(0.14)	(0.06)
PTA$_{Fat}$	7.182		0.391	0.007	0.000	-0.002	0.002	-0.006	-0.014	-0.001
	(0.28)		(0.45)	(0.06)	(0.07)	(0.22)	(0.07)	(0.14)	(0.14)	(0.06)
PTA$_{Protein}$	23.161	0.770		0.019	0.002	-0.003	0.006	-0.015	-0.019	-0.008
	(0.57)	(0.40)		(0.10)	(0.10)	(0.21)	(0.08)	(0.17)	(0.13)	(0.07)
PTA$_{PL}$	90.074	1.599	2.320		-0.064	0.165	0.199	-0.151	0.514	-0.353
	(0.25)	(0.15)	(0.25)		(0.25)	(0.27)	(0.12)	(0.16)	(0.36)	(0.16)
PTA$_{SCS}$	238.588	-4.829	13.540	-2.985		-1.101	-0.310	-0.968	-1.317	0.451
	(0.22)	(0.15)	(0.24)	(0.24)		(0.27)	(0.07)	(0.16)	(0.12)	(0.07)
UC	-49.156	-1.556	-0.951	0.442	-0.063		0.265	0.291	0.081	-0.061
	(0.21)	(0.15)	(0.21)	(0.12)	(0.13)		(0.10)	(0.18)	(0.09)	(0.06)
FLC	62.331	0.724	1.118	0.286	-0.010	0.142		0.092	0.103	-0.047
	(0.22)	(0.15)	(0.22)	(0.11)	(0.07)	(0.24)		(0.14)	(0.09)	(0.06)
BSC	-76.438	-2.462	-3.024	-0.251	-0.035	0.180	0.106		0.000	0.092
	(0.23)	(0.16)	(0.25)	(0.09)	(0.10)	(0.25)	(0.08)		(0.09)	(0.07)
PTA$_{DPR}$	-103.446	-3.914	-2.616	0.580	-0.032	0.034	0.081	0.000		-0.339
	(0.26)	(0.19)	(0.25)	(0.34)	(0.11)	(0.21)	(0.08)	(0.13)		(0.14)
PTA$_{DCE}$	-14.199	-0.223	-0.888	-0.298	0.008	-0.019	-0.028	0.047	-0.253	
	(0.21)	(0.14)	(0.22)	(0.15)	(0.07)	(0.21)	(0.07)	(0.13)	(0.16)	

[a] PL = productive life; SCS = somatic cell score; UC = udder composite; FLC = feet and legs composite; BSC = body size composite

DPR = daughter pregnancy rate; DCE = daughter calving ease.

Table 2. Correlation of Sires' PTA and Three Merit Indexes.

	PTA_{Milk}	PTA_{Fat}	$\text{PTA}_{\text{Protein}}$	PTA_{PL}[a]	PTA_{SCS}[b]	UC[c]	FLC[d]	BSC[e]	PTA_{PDR}[f]	PTA_{SSCE}[g]	PTA_{DCE}[h]	Fluid	NM[i]	Cheese
PTA_{Milk}	1.00	0.36	0.72	0.22	0.13	-0.01	0.15	-0.16	-0.30	-0.03	-0.04	0.65	0.51	0.43
PTA_{Fat}		1.00	0.60	0.10	-0.01	-0.01	0.05	-0.14	-0.27	-0.13	-0.00	0.62	0.68	0.69
$\text{PTA}_{\text{Protein}}$			1.00	0.20	0.20	0.04	0.11	-0.20	-0.26	-0.13	-0.07	0.68	0.75	0.76
PTA_{PL}				1.00	-0.43	0.28	0.25	-0.16	0.54	-0.22	-0.32	0.70	0.66	0.62
PTA_{SCS}					1.00	-0.26	-0.06	-0.21	-0.22	-0.02	0.06	-0.32	-0.28	-0.25
UC						1.00	0.24	0.30	0.04	0.03	-0.01	0.33	0.33	0.33
FLC							1.00	0.13	0.08	0.01	-0.03	0.33	0.30	0.28
BSC								1.00	0.02	0.39	0.07	-0.17	-0.18	-0.17
PTA_{PDR}									1.00	-0.15	-0.29	0.10	0.11	0.12
PTA_{SSCE}										1.00	0.46	-0.27	-0.29	-0.29
PTA_{DCE}											1.00	-0.25	-0.25	-0.25
Fluid												1.00	0.96	0.91
NM													1.00	0.99
Cheese														1.00

[a] PL = productive life.

[b] SCS = somatic cell score.

[c] UC = udder composite.

[d] FLC = feet and legs composite.

[e] BSC = body size composite.

[f] DPR = daughter pregnancy rate.

[g] SSCE = service sire calving ease.

[h] DCE = daughter calving ease.

[i] NM = net merit.

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