



Optimum Model for Analyzing Lifetime Profitability of Holstein Cows

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ABSTRACT : This study was on the relative net income (RNI) for 18,286 Iranian Holstein cows from 799 herds, with first freshening between 1991 and 2000. Two kinds of production system, which differed mainly in milk pricing system and feed cost, were considered. Four different models adopted from the literature were examined to find the optimum model. They differed by the cost of rearing and growth after first calving and they needed different amounts of economic data at the farm level. Results showed that four measures of RNI were highly correlated (>0.96) and could be used equally to measure lifetime profitability of cows. Therefore, in herds without a regular system for recording economic and management data, use of the simplest model is recommended. Multiple regression analysis revealed that RNI was affected by age at first freshening, milk yield and days of productive life (DPL), regardless of production system, and a similar breeding goal could be defined for the two systems. Multiple regression analysis of RNI showed that in order to obtain an unbiased estimate of economic value for DPL, the per day milk yield, not total lifetime milk yield, should be included in the regression model along with DPL. Regression analysis suggested that it is possible to predict RNI using information on age at first freshening along with the length of first lactation and per day milk yield with a coefficient of determination ranging from 0.44 to 0.47. (**Key Words :** Relative Net Income, Regression Analysis, Iranian Holstein)

INTRODUCTION

The economic merit of a dairy cow depends on profitable performance across a relatively long productive life. It can be measured by a profit function accounting for income and expense items over the cow's lifetime (Balaine et al., 1981). Detailed economic data on lifetime performances of cows are rarely available to researchers. Their effort is limited by the possibility of utilizing performance records kept for purposes other than detailed economic analysis (Cassell and Weigel, 1994). For the first time, Norman et al. (1981) introduced the concept of Relative Net Income (RNI) which could be computed using data available from an ordinary dairy farm.

Various profit equations have been used to compute RNI. In Norman et al. (1981), RNI included milk income adjusted for average feed costs for production, value of each freshening reflecting average price of a calf adjusted for breeding costs and a salvage value. Additional costs were considered for growth from first freshening up to 42 months or disposal (whichever was first), feed costs and fixed and operating costs during days of productive life (DPL), and

rearing cost. Rearing cost was computed as age at first freshening in days (AFF) multiplied by the ratio of average price of a cow calved for the first time to herd average AFF. The rearing cost depended mainly on price of a heifer in the market and did not necessarily reflect the costs of rearing period. This method of computing the rearing cost could be done easily and needs no detailed economic data. Tigges et al. (1984) used a modified version of RNI proposed by Norman et al. (1981). In their model, rearing costs were divided into feed and non-feed cost. A constant value was considered for feed cost from birth to first calving. Non-feed cost was defined as a function of AFF. Beaudry et al. (1988a) applied a similar model to calculate RNI, but in their model rearing cost was defined as a function of AFF reflecting both feed and non-feed cost.

When several traits contribute to economic merit of cows, their economic values should be estimated for selection purposes. Methods for calculating economic values can be grouped into two categories: a normative approach, also referred to as bio-economic modeling, and a positive approach, which involves analysis of field data. (Groen, 1989). Van Arendonk (1991) and Weigel et al. (1995) used a RNI function to determine economic value of DPL in a positive approach. Weigel et al. (1995) obtained negative values for within herd-year of first calving coefficients of DPL to predict 84-month RNI, while Van

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Table 1. Unit prices (in RIs, Iranian monetary unit) of variables by production system

Variable	System	
	A	B
Fluid market milk price	1,300	1,626
Manufacturing market price per kg milk with 3.2% fat	-	1,400
Price per 0.1% fat differential	-	20
Fraction of milk sold for governmental price	0	0.943
Net value of calf	643,059	1,020,072
Value at first freshening	5,800,000	6,000,000
Salvage value	3,990,000	2,768,139
Net percentage of milk value	0.75	0.67
Initial cost of a heifer calf	850,000	1,150,000
Daily rearing feed and non feed cost	6,797	7,668
Daily rearing fixed cost	2,087.3	2,225.75
Feed cost to first calving	3,367,713	4,691,263
Daily feed cost for growth during first lactation	854.9	1,074.8
Daily maintenance feed and non feed cost	6,448.5	8,390.3
Feed and non-feed cost per kg milk with 3.2% fat	325.8	464.2
Marginal feed cost per 0.1% fat differential	0.69	0.93

Arendonk (1991) found a positive regression coefficient of RNI on herd life. Such studies differed mainly in their model of RNI, method of analysis and statistical properties of the data sets. This indicates that more investigations are needed to find a proper regression model to calculate economic value for DPL.

The first study on RNI in Iran was carried out by Shadparvar (1999) to examine the relationship between first lactation performances and RNI of Iranian Holstein cows. In the model proposed by Shadparvar (1999), income and cost of milk production reflected milk fat percentage. From a technical point of view, that model needed more detailed data than other RNI models which are reported in the literature. However, the RNI model presented by Shadparvar (1999) was used by Mehdizadeh (2002) and Farahany Poor (2004). They used data collected from Holstein dairy farms in the North of Iran, which did not represent the whole population of Iranian Holstein cows. There are two major types of dairy cattle production system in Iran. They differ in payment system for milk yield and also in cost levels. The impact of different types of production systems in Iran has not been studied in the above-mentioned studies on RNI.

The first objective of the present study was to compare some different models for RNI that were provided in the literature in order to find the optimum model. The second objective was to find an appropriate regression model for estimation of economic value of DPL using RNI. The third objective was to investigate the possibility of the prediction of RNI from first lactation records. All of these calculations were done for each production system and their results were compared.

MATERIALS AND METHODS

The original data set for this study was obtained from

the Iranian Animal Breeding Center. The data included registration number, herd number, birth date, date of each calving, actual milk and milk fat record per lactation, and culling date for each cow. The following edits were applied: 1) First freshening between year 1991 and 2000 was used. 2) Only first calving between 20 and 42 months of age were accepted. 3) Calving intervals of less than 270 d or over 760 d eliminated the cow in question. The final data set included information for 18,286 cows from 779 herds.

Two kinds of production system were considered to derive economic parameters. In one system (system A) milk was sold on the basis of a fluid market price independent from its fat percentage. In the other system (system B) a portion of milk was sold for a manufacturing market price and the rest for a fluid market price. Manufacturing market price was determined by a base price per kg milk with 3.2% fat and an increment per 0.1% increase in fat percentage above 3.2. Therefore in system B income from milk sold reflected variation in milk fat percentage. Feed cost in system A was lower than in system B. Prices and other system parameters are shown in Table 1. They represent different aspects of two kinds of production system and economic condition of dairy farms at year 2000 in Iranian Rials (RIs).

Four different measures were used for RNI. The first one was as follows (Shadparvar, 1999):

$$\text{RNIS} = (\text{lifetime actual milk and fat production}) \times (\text{milk price} - \text{milk production cost}) + (\text{number of freshening}) \times (\text{net value of calf}) + \text{salvage value} - (\text{AFF} \times \text{daily rearing feed and non feed cost}) - \text{DPL} \times (\text{daily maintenance feed and non feed cost}) - \text{feed cost for growth after first and second calving} - \text{initial cost of a heifer calf}.$$

As shown in Table 1, milk price in system A was 1,300

Table 2. Means and standard deviations for performance records of 18,286 Iranian Holstein cows

Variable	Mean	Standard deviation
Age at first freshening (d)	822	103
Days of first lactation (d)	313	94
Milk yield in first lactation (kg)	7,236	2,827
Total lifetime milk yield (kg)	18,202	12,576
Milk production per day (kg/d)	24	3,245
Mean fat percentage (%)	3.2	0.41
Days of productive life (d)	1,015	635

Rls per kg regardless of fat content, and in system B manufacturing market milk price was 1,400 Rls per kg of milk with 3.2% fat and 20 Rls per 0.1% increase in fat percentage above base test. In the latter system, 94.3% of total milk was sold for manufacturing market price and the rest was sold for 1,626 Rls per kg. Milk production cost consisted of feed and non-feed cost of milk with 3.2% fat and a marginal feed cost per 0.1% fat differential. Net value of the calf was the calf value adjusted for insemination cost and the cost of feed to support gestation. For cows with a second lactation, daily feed cost for growth during second lactation was also considered and it was taken to be equal to half of the corresponding cost during first lactation.

The second measure for RNI was adopted from Norman et al. (1981) as follows:

$$\text{RNIN} = (\text{lifetime actual milk and fat production}) \times (\text{milk price} \times \text{net percentage}) + (\text{number of freshening}) \times (\text{net value of calf}) + \text{salvage value} - \text{value at first calving} - \text{DPL} \times (\text{daily maintenance feed and non feed cost}) - \text{feed cost for growth after calving}.$$

In this model net percentage adjusts the value of product for an average cost associated with production. Value at first calving was computed as AFF multiplied by value at first freshening divided by average AFF.

The third method of calculating RNI was taken from Tiggs et al. (1984) as follows:

$$\text{RNIT} = (\text{lifetime actual milk and fat production}) \times (\text{milk price} \times \text{net percentage}) + (\text{number of freshening}) \times (\text{net value of calf}) + \text{salvage value} - \text{AFF} \times \text{daily rearing fixed cost} - \text{DPL} \times$$

(daily maintenance feed and non feed cost) - feed cost for growth after calving - feed cost to first calving - initial cost of a heifer calf.

The fourth measure was as follows (Beaudry et al., 1988a):

$$\text{RNIB} = (\text{lifetime actual milk and fat production}) \times (\text{milk price} \times \text{net percentage}) + (\text{number of freshening}) \times (\text{net value of calf}) + \text{salvage value} - \text{AFF} \times \text{daily rearing feed and non feed cost} - \text{DPL} \times (\text{daily maintenance feed and non feed cost}) - \text{initial cost of a heifer calf}.$$

Using economic parameters of system A and system B and four RNI measures, eight different kinds of RNI were calculated for each of 18,286 cows in the final data set.

Two covariance models were applied to examine relationships of lifetime performance records with RNI. The first model included the effects of herd and year of first calving as classified variables with AFF, DPL, total lifetime milk yield (TM) and mean fat percentage (f%) as covariates. The same variables were included in the second model except that milk production per day (MD) was substituted for TM. To investigate the prediction of a cow's RNI from its first lactation performance records, a covariance model was used which included the effects of herd and year of first calving and three covariables, namely AFF, days of first lactation (D1) and milk yield in first lactation (M1). The PROC GLM of SAS (2002) was used for the analysis. Correlation coefficients between various RNI functions in each production system were estimated using PROC CORR of SAS (2002).

RESULTS

Means and standard deviations for performance records of the 18,286 cows are shown in Table 2. The average age at first calving was 822 d (27 months) of age. Average length of first lactation was 313 d and average milk yield during that period was 7,236 kg. In this study, the average productive life was 1,015 d and total lifetime milk yield was 18,202 kg with 3.2% fat content. The mean milk production per day was 24 kg.

Table 3. Means \pm standard deviation and coefficient of variation (%) (in brackets) for different measures of relative net income of 18,286 Iranian Holstein cows by production system

Production system ¹	Relative net income measure ²			
	RNIS	RNIN	RNIT	RNIB
A	9,980,284 \pm 10,136,589 (102)	10,151,710 \pm 101,86,548 (100)	10,573,168 \pm 10,086,695 (95)	10,338,222 \pm 10,189,794 (99)
B	5,798,726 \pm 9,166,651 (158)	7,298,969 \pm 9,124,244 (125)	5,348,151 \pm 9,043,011 (169)	5,903,560 \pm 9,164,634 (155)

¹ Definitions for production systems are given in the text.

² RNIS = Relative net income model proposed by Shadparvar (1999); RNIN = Relative net income model proposed by Norman et al. (1981); RNIT = Relative net income model proposed by Tiggs et al. (1984); RNIB = Relative net income model proposed by Beaudry et al. (1988a).

Table 4. Correlation coefficient¹ between various measures of relative net income in two production systems

Production system ²	Relative net income measure ³	Relative net income measure ³		
		RNIN	RNIT	RNIB
A	RNIS	0.9999	0.9988	0.9999
	RNIN		0.9984	0.9999
	RNIT			0.9986
B	RNIS	0.9982	0.9969	0.9984
	RNIN		0.9986	0.9999
	RNIT			0.9981

¹ All coefficients were different from zero ($p < 0.001$).

² Definitions for production systems are given in the text.

³ RNIS = Relative net income model proposed by Shadparvar (1999); RNIN = Relative net income model proposed by Norman et al. (1981); RNIT = Relative net income model proposed by Tigges et al. (1984); RNIB = Relative net income model proposed by Beaudry et al. (1988a).

Table 5. Within herd-year of first calving multiple regression coefficients¹ of RNIN² on age at first freshening (AFF), days of productive life (DPL), total lifetime milk yield (TM) and mean fat percentage (f%) and corresponding values of coefficient of determination (R²) in two production systems

Production system ³	Variables				R ²
	AFF	DPL	TM	f%	
A	-7,949	-6,142	1,024	240,214	0.999
B	-7,380	-8,059	1,001	2,201,217	0.990

¹ All coefficients were statistically different from zero ($p < 0.001$).

² RNIN = Relative net income model proposed by Norman et al. (1981).

³ Definitions for production systems are given in the text.

Table 6. Within herd-year of first calving multiple regression coefficients¹ of RNIN² on age at first freshening (AFF), days of productive life (DPL), milk production per day (MD) and mean fat percentage (f%) and corresponding values of coefficient of determination (R²) in two production systems

Production system ³	Variables				R ²
	AFF	DPL	MD	f%	
A	-8,945	7,728	806,591	753,814	0.68
B	-8,352	5,494	787,031	2,698,671	0.61

¹ All coefficients were statistically different from zero ($p < 0.001$).

² RNIN = Relative net income model proposed by Norman et al. (1981).

³ Definitions for production systems are given in the text.

Means, standard deviations and coefficients of variation (CV) (%) of four different RNI measures in two production systems are shown in Table 3. Means of RNI measures varied from 9,980,284 to 10,573,168 in system A, and from 5,348,151 to 7,298,969 in system B. The CV's in system A were smaller than those in system B.

The correlation coefficients between different RNI measures in two production systems are shown in Table 4. Within each production system correlation coefficients were higher than 0.99.

Within herd-year of first calving, multiple regression coefficients of RNI on various variables in the first covariance model were calculated using different measures of RNI, but only the results for RNIN are shown in Table 5. The values of R² were equal or greater than 0.99. The results for two production systems showed that R² value in system A was bigger than in system B.

The results of multiple regression analysis of RNIN using the second covariance model are shown in Table 6. In this model, MD was in place of TM while the remaining variables were the same as variables in the first model. Similar to results from the first model, the regression

coefficients of RNIN on AFF and f% were positive. Despite results from the first model, the coefficients of DPL were positive in the second model.

Within herd-year of first calving, multiple regression coefficients for prediction of RNIN from first lactation performance records and their corresponding standard values are shown in Table 7. Coefficients of determination varied from 0.44 to 0.47. The coefficients of AFF and D1 were negative and those of M1 were positive.

DISCUSSION

Within system A, minimum and maximum RNI were obtained for RNIS and RNIT, respectively. Relative to other measures, RNIS contained the highest cost for growth after calving and RNIT had the lowest rearing cost. In system B, the means of various measures of RNI were ranked differently to system A. Within system B, RNIT and RNIN had the lowest and the highest average, respectively. In that system, RNIT and RNIN had the highest and the lowest rearing cost, respectively. The RNI measures were similar in respect of income from milk, calf and culled cow as well

Table 7. Within herd-year of first calving multiple regression coefficients¹ of RNIN² on age at first freshening (AFF), days of first lactation (D1) and milk yield in first lactation (M1), their corresponding standardized values in parentheses (sb) and the coefficient of determination (R²) in two production systems

Production system ³	Intercept	Variables			R ²
		AFF(sb)	D1(sb)	M1(sb)	
A	8,722,816	-12,780 (-0.13)	-30,825 (-0.29)	2,176 (0.61)	0.47
B	6,583,931	-11,003 (-0.12)	-25,780 (-0.27)	1,776 (0.61)	0.44

¹ All intercepts were not different from zero ($p > 0.05$) and all coefficients were different from zero ($p < 0.001$).

² RNIN = Relative net income model proposed by Norman et al. (1981).

³ Definitions for production systems are given in the text.

as cost for maintenance during productive life. However, they partly differed in cost of heifer rearing and growth after first calving. These differences led to different ranking of RNI by the two production systems.

Within system A, CV for RNI measures were smaller than corresponding values within system B. This was a result of the milk pricing method in system B in that a portion of milk was sold for a manufacturing market price. In that pricing system, milk income was a function of milk fat percentage and therefore reflected variation in milk fat percentage of individual cows. This source of extra variation led to higher CV within system B compared to that within system A. Beaudry et al. (1988b) found that various economic situations had a dramatic impact on the variation of RNI. In their study, higher product value resulted in higher standard deviation of RNI. The CV for RNIN, RNIT and RNIB obtained within system B were close to those values observed by Norman et al. (1981), Tigges et al. (1986) and Beaudry et al. (1988a) (136, 164 and 132%, respectively).

Regardless of production system, the CV for RNIS was greater than for other measures of RNI. This was partly attributable to the way of incorporating milk production cost into RNIS, which reflects the variation in milk fat percentage of individual cows, whereas in other RNI measures an average cost was considered for milk production not reflecting that variation. In addition, the possible participation of second lactation in cost of growth after calving made RNIS more variable than other models of RNI. Therefore, relative to other models, RNIS was more capable of expressing differences between individual cows.

High estimated correlation coefficients between various measures of RNI indicated that regardless of production system, different measures of RNI are almost the same trait. Although there are some differences between the structures of various RNI functions, they could be equally used to measure lifetime profitability and to recognize the most profitable cows in a population. The various functions of RNI had some common components such as net value of calf, salvage value, daily maintenance and initial cost of a heifer calf. This was the reason for the high correlation observed between these functions. However, they differed in cost of rearing before first calving and growth thereafter. Among the four functions, RNIN was the simplest one

because it was free from daily rearing cost and could be calculated using records of cost and income that are readily available in many dairy herds.

The regression coefficients of RNIN on AFF were negative. AFF has been introduced in models of RNI as a cost variable. Therefore, its coefficient was negative. A similar result was reported by Cassell et al. (1993) and Weigel et al. (1995). Reducing AFF would result in more lifetime profit due to reduced rearing cost, although a negative effect of early calving on milk yield was reported in Nilforooshan and Edriss (2004). They suggested that reducing AFF to 23 or 24 months is more profitable than 21 or 22 months. The RNIN was positively affected by TM. Although milk production had the most effect on the lifetime profit of dairy cows, producers should not benchmark to the highest level of production (Stokes et al., 2007).

Results from the first covariable model showed that the sign of regression coefficients of DPL were generally negative. Weigel et al. (1995) obtained a negative coefficient of regression of RNI on DPL. They used a model including herd-year of first calving with AFF, TM and DPL as covariates. Negative values for DPL are not acceptable because it is a very important economic trait in dairy cattle and all studies using a normative approach to estimate economic weight for DPL of dairy cows (e. g. Groen, 1989) resulted in positive economic values.

Despite results from the first model, the coefficients of DPL were positive in the second model. The reason can be explained by considering the structure of RNI models. In all models of RNI, the DPL is included as a cost variable and lifetime income is incorporated through inclusion of TM. The TM is in turn a function of per day milk production (MD) and DPL. Therefore, inclusion of TM in the regression model along with DPL will result in an underestimate for economic value of DPL. Our results showed that, in order to obtain an unbiased estimate of economic value for DPL, MD should be included in the regression model.

The coefficients of determination of multiple regression models for prediction of RNIN from first lactation performance records were in the range of values reported in other studies. In Norman et al. (1981), R² values of regression models for prediction of RNI from first lactation

type and production information varied from 0.56 to 0.577. In Tigges et al. (1986), the R^2 value for prediction of deviated RNI from milk and fat production along with type traits was rather smaller (0.123). In Cassel et al. (1990), RNI of grade or registered cows was predicted from genetic evaluation of their sire for production and type traits by using some models in which their R^2 varied from 0.47 and 0.68. The R^2 values varied from 0.477 to 0.490 in de Hann et al. (1992) and from 0.16 to 0.178 in Cassel et al. (2002). Generally, in studies on prediction of RNI, fixed regression models were been applied. However, it was shown by Park and Lee (2006) that random regression models may result in higher R^2 values (>0.89) in prediction of future milk yield on the basis of test-day records. This suggests the necessity of further works on implementation of random regression models to predict RNI using first lactation test-day records.

The coefficients of AFF and D1 were negative and those of MI were positive. Standardized regression coefficients show the grater importance of production records for predicting RNI. This result was in agreement with that of other studies such as Norman et al. (1981), Tigges et al. (1986) and Cassell et al. (2002).

CONCLUSIONS

This study showed that when definition of a variable such as rearing cost differs in different models of RNI, the rank of RNIs in respect of their means will differ in various production systems and will depend on economic characteristics of the system. On the other hand, it was shown that the various models of RNI are highly correlated. Therefore, they could be used equally to estimate the lifetime profit of individual cows. Among the various RNI functions, the formula proposed by Norman et al. (1981) was technically the easiest one. This model was free from the daily rearing cost which is not readily available or is not possible to be estimated in many herds due to lack of a regular data recording system. Although the model proposed by Shadparvar (1999) was more capable of reflecting the individual variability of cows, it needs more detailed economic and management data. Therefore, the model of Norman et al. (1981) seems to be optimal and is recommended to measure relative lifetime profit in Iranian dairy herds.

Results of multiple regression analysis of profit functions revealed the similarity of two production systems in respect to influencing factors. Regardless of production system, cows with earlier first calving, longer productive life and more milk production were expected to be more profitable. This indicates that a relatively similar breeding goal can be applicable in two production systems. However there are several traits other than milk yield affecting longevity and lifetime profitability. Inclusion of such traits,

as well as some fertility traits, in models for prediction of lifetime profitability would result in higher R^2 values. Therefore, further research is needed to incorporate conformation and fertility traits into prediction models.

Comparison between two regression models revealed that in order to obtain an unbiased estimate of economic value for days of productive life, per day milk production should be included in the regression models of RNI.

Our results showed that, according to estimated coefficient of determination, it is possible to predict life time profitability of cows using information on their first lactation, namely, age at first freshening, days of and milk production in first lactation.

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