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ABSTRACT

Data on 324 Holstein bulls from the July 1983 USDA Sire Summary and Holstein Association type evaluations were analyzed using multiple regression to determine which traits or combination of traits in a sire evaluation are most important in determining the price of a straw of semen. Over all bull studs, type was a major economic influence in determining price of semen. When bulls with outlier prices ($100 or more) were excluded, relative economic values over all bull studs were 4.31:2.63:1 for milk, type, and fat test. For three bull studs with more than 35 bulls with evaluations for milk, type, and fat test, relative economic values (values per phenotypic standard deviation) were 3.16:1.35:1, 4.81:1.93:1, and 4.06:2.15:1. With so much economic emphasis on type and fat test, genetic gain in milk production from the sire of cow path would be substantially less than if selection were for milk production alone. Unusual bulls (outlier prices) were associated with nonlinear economic values. When outliers were excluded, models including functions of sire evaluations accounted for 50 to 75% of the variation in semen prices.

INTRODUCTION

Genetic gain for production has been less than expected for established AI programs (1). An obvious reason is that emphasis on other traits dilutes the effect of selection for production. If economic values are assigned to production and other traits, those economic values will reflect the relative selection emphasis as well as the potential reduction in genetic improvement for production. Economic indexes are published for components of production and for combinations of production and type. Less obvious and unintended indexes as well as other factors are probably involved in pricing of semen by bull studs.

Bull studs probably price semen primarily on demand and also, in some cases, on supply as well as less tangible factors. Some genetic evaluations that might influence price of semen are Predicted Difference dollars (PD$), milk (PDM), milk fat (PDF), fat test (PD%), and type (PDT) as well as number of daughters (#DAU), and repeatability for milk (RPT), which is a nonlinear function of #DAU, and total performance index (TPI), which in turn is a linear function of PDM, PD%, and PDT.

Tomaszewski et al. (2) used information from DHIA members and found that criteria used by dairy managers for semen purchases were ranked in order as PDM, PD%, PD$, PDT, RPT, and price. Van Raden and Freeman (3) used multiple regression analyses to determine the relationship between price and sire evaluations for several traits of bulls available at the Select Sires bull stud. The variables included were PDM, PDF, PD$, PDT, TPI, RPT, and amount of semen production (PROD). Semen production was measured in 1000's of straws per year. They reported that linear, quadratic, cubic, and quartic terms in TPI were significant in determining price. Interactions of various powers of TPI with RPT and PROD were also significant in determining semen price. An exponential relationship between price and TPI was also indicated. For regressions using the natural log of semen price as the dependent variable, Van Raden and Freeman (3) found that PDF and PDT had more weight than was assigned to them in PD$ and TPI. Voelker (4) used semen prices of bulls available from AI

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studs in the United States from 1975 to 1983 and contemporary sire evaluations and found TPI to have the largest correlation with price, .57, followed by PD$, .53, PDM, .52, and PDT, .31.

The purpose of this project was to determine which traits or combinations of traits are most important in pricing semen.

MATERIALS AND METHODS

Data came from the July 1983 USDA Sire Summary. The PDT and repeatability for type (RPT-type) were from the Holstein Association of America. Price of semen was obtained from Elmer Clapp (1984, personal communication). After editing, there were 324 observations for nine variables (price, PD$, PDM, PD%, PDF, RPT, #DAU, PDT, and RPT-type). All 11 major bull studs at that time were represented. If any of the nine variables for a bull were missing, data for that bull were not included in the analysis. Except for preliminary analyses, RPT and RPT-type were not included in the multiple regression equations. Number of daughters provided a higher coefficient of determination than did RPT.

Multiple regression analysis was used to determine which traits are most important in pricing of bull semen. The regression variables were linear terms such as PDM, quadratic terms such as $(PDT)^2$, and product terms such as PDM × PDT. Total performance index was included in some analyses and was calculated (Holstein Association of America) as:

$$TPI = 50(3\ PDM\ (lb)/560 + PD\%/.09 + PDT/.70)$$

After editing, analyses were done for the data set that included all bulls in all studs. A second set of analyses was done separately for each stud. A third set of analyses was done after outliers were excluded. Outliers were defined as bulls with semen prices of $100 or more. Outliers are few and probably are not indicative of economic values assigned to traits of most bulls when pricing semen.

Because only bulls with type plus production evaluations were included in the analyses, the results probably do not indicate pricing policy or farmer demand for bulls without type proofs.

RESULTS AND DISCUSSION

Six different regression equations were computed. The simplest equation included PDM, PD%, #DAU, and PDT. Number of daughters was limited to 1000. The second equation included PD$. The next three equations added the polynomial terms $(PD\$)^2$, $(PDT)^2$, and PD$ × PDT sequentially. The sixth equation included only TPI and #DAU. An effect was included in the model for each bull stud; thus, the regression coefficients are pooled within

TABLE 1. Coefficients of determination (R^2) for regression of semen price on functions of sire evaluations. Number of observations are in parentheses.

Models[1]	Bull stud All	A	B	C	Bull stud (excluding outliers) All	A	B	C
	(324)	(35)	(72)	(61)	(320)	(35)	(69)	(60)
A	.258	.439	.370	.568	.483	.439	.704	.612
B: A and (PD$)	.275	.439	.382	.585	.574	.439	.710	.618
C: B and $(PD\$)^2$	.275	.520	.392	.621	.584	.520	.711	.619
D: C and $(PDT)^2$	.300	.523	.464	.656	.610	.523	.725	.664
F: D and (PD$) × (PDT)	.313	.524	.464	.780	.632	.524	.753	.695
G[2]	.242	.424	.342	.561	.467	.424	.698	.598

[1] A includes number of daughters (#DAU), PD milk, PD percent, PDT = PD type, PD$ = PD dollars.

[2] G includes #DAU and total performance index. Models for regression analyses for A through G for all bull studs include effects for the 11 bull studs.

stud. Coefficients of determination (R^2) as measures of fit for the models ranged from .24 to .31 (Table 1). There was no significant change in fit when $(PD\$)^2$ was added to the equation, but there were significant changes ($P<.05$) when $(PDT)^2$ and PD$ x PDT were added to the equation. From these trends one can infer that for studs, in general, emphasis on type is nonlinear when semen is priced.

Regression equations were computed for each of the 11 studs, but only results from 3, identified as A, B, and C, are reported due to the small number of observations (less than 30) in the other 8 studs (Table 1).

For bull stud A, the R^2 ranged from .424 to .524. Addition of $(PD\$)^2$ to the equation accounted for a significant amount of additional variation in price with the R^2 value ($P<.05$) increased from .439 to .520. The subsequent addition of $(PDT)^2$ and PD$ x PDT to the equation did not significantly account for additional variation in price.

The regression equations for bull stud B had R^2 values that ranged from .342 to .464 (Table 1). For this stud, the R^2 value (.392 to .464) increased ($P<.05$) when (PDT) was added to the equation, whereas no significant change was noted when the other two quadratic terms were included in the equation. Farmers buying semen from this bull stud probably put nonlinear emphasis on PDT rather than on other traits.

For bull stud C the best fitting equation came with the addition of the quadratic product term, PD$ x PDT ($R^2 = .780$) and provided an exceptionally good fit when compared with the fit for the other studs. Addition of each nonlinear term caused a significant increase in R^2 over the linear equation, but the greatest increase occurred when PD$ x PDT was added (.656 to .780). These results indicate that farmers buying semen from bull stud C may tend to emphasize bulls ranked high for both type and milk production.

Within some studs there were outliers that may have affected each equation significantly. For example, one bull had a price of $325, and high PDT and repeatability, but relatively low PDM and PD$. It seemed possible that removal of these outliers might yield better fitting equations.

In this data set four bulls were considered outliers on the basis of price, three from bull stud B and one from bull stud C. Most studs had bulls that were priced under $50, but the four outliers were priced at $100 or more and two of them at $300 or greater. These outliers had the usual effect of moving the regression equation away from the rest of the data points, resulting in poor fitting equations. To confirm this observation, the four outliers were removed from the data set and the analyses were repeated. Large increases in the coefficients of determination were obtained for the entire data set (Table 1). The range of R^2 values before removal of the outliers was .242 to .313, but after their removal the range was .467 to .632.

For bull stud B the range of R^2 with three outliers was .342 to .464. When outliers were removed from the data set, the range for R^2 was .698 to .753.

For bull stud C a rather unexpected change occurred when the single outlier was removed. With the outlier R^2 ranged from .561 to .780, but when the outlier was removed the range of R^2 was reduced to .598 to .695. On examining individual equations, four equations had better fits when the outlier was removed. Only the equation including the product of PD$ and PDT, however, had a significantly better fit when the outlier was present. This particular bull appears to have fit the equation well only when PD$ x PDT was a variable, which in turn indicates a high demand for this bull with high PD$ and PDT.

For all studs, when each quadratic term was added to the base equation (PD$, PDM, PD%, #DAU, and PDT), change in fit was significant ($P<.05$), although there was little numerical change in R^2. This result probably indicates an averaging of different pricing policies among the studs. For the regression equations for bull stud B, there were no changes in R^2 ($P<.05$) until PD$ x PDT was included. Comparison with the equation that included the three outliers indicates a definite change in pricing for the three outliers. In the equations that included outliers, the significant change occurred when $(PDT)^2$ was added to the equation. This indicates that for most bulls, farmers choosing bull stud B put emphasis on both PD% and PDT but put even more emphasis on type for highest priced bulls. For bull stud C, changes in R^2 ($P<.05$) occurred when $(PDT)^2$ and when PD$ x PDT were added to the equation. As noted before, addition of PD$

TABLE 2. Regression coefficients used to compute relative economic values and ratios of relative economic values.[1]

Bull stud	No. of observations	Partial regression coefficients					Ratios of relative economic values[2]				
		#DAU	PDM (kg)	PD%	PDT	R^2	Milk	Type	Test	Milk	Type
All[3]	324	.0286	.0489	44.8	11.70	.238	4.13	3.22	1	1.28	1
A	35	.0063	.0141	16.9	1.85	.439	3.16	1.35	1	2.34	1
B	72	.0641	.0968	117.0	29.50	.370	3.13	3.11	1	1.01	1
C	61	.0321	.0472	78.2	8.83	.568	2.28	1.39	1	1.64	1
					(Excluding outliers)						
All[3]	320	.0094	.0302	26.5	5.65	.453	4.31	2.63	1	1.64	1
A	35	.0063	.0141	16.9	1.85	.439	3.16	1.35	1	2.34	1
B	69	.0117	.0529	41.6	6.50	.704	4.81	1.93	1	2.49	1
C	60	.0053	.0403	37.6	6.56	.612	4.06	2.15	1	1.89	1

[1] #DAU = Number of daughters, PDM = PD milk, PD% = PD percent, PDT = PD type.

[2] Partial regression coefficient times phenotypic standard deviation divided by corresponding product for fat test, or by the product for type for the milk with type comparison.

[3] Effects for bull studs were not included.

× PDT to the equation did not give as great a change in R^2 as when the outlier was in the data set.

Relative Economic Values

The regression equation used for calculation of relative economic values was composed of PDM, PDT, PD%, and #DAU. Partial regression coefficients are listed (Table 2) for both the analysis including all bulls and the analysis excluding the four outliers. The economic values in an aggregate index are the coefficients of the PD. The partial regression coefficients can be considered as empirical economic values. Relative economic values traditionally have been expressed as the value for a standard deviation of one trait as compared to values per standard deviation of other traits. Thus, the appropriate phenotypic standard deviation (1136 kg milk, .3% test, 3.7 units of type) was multiplied by the corresponding partial regression coefficient. The ratios of these relative economic values were then determined by dividing by a constant (the constant was chosen to be the value of a phenotypic standard deviation of the trait with the smallest relative economic value, test or type). The ratios of relative economic values for milk production, type, and fat percent for all studs and the three major bull studs also are shown in Table 2. Type has considerably more economic emphasis in pricing semen than may have been expected.

Relative economic values also were recalculated after outliers were excluded. Over all studs, there was a slight increase in relative economic emphasis for milk production when outliers were excluded. There was a decrease in emphasis on milk production for bull stud C when the outlier was excluded. The most dramatic change was for bull stud B. The relative economic weights on milk, type, and fat test in the original data set were about 3:3:1, but when the three outliers were removed the relative economic weights became about 5:2:1, indicating milk production was emphasized for most bulls from bull stud B, but that type was a major factor in determining semen price for the three outliers.

Comparison of Total Performance Index with Linear Index for Milk, Test, and Type

The R^2 values obtained from the regression analysis for TPI were essentially the same as the R^2 values from the equations used to determine relative economic value (Table 1). This result might be expected, because the relative economic values for PDM, PD%, and PDT (Table 2) are not greatly different from the economic weights used in constructing TPI. Coefficients in the formula for TPI can be considered to be implied partial regression coefficients when multiplied by the coefficient for regression of price on TPI, e.g., for all bull studs, .0594(50) (3/560) = .0159, the regression coefficient for PDM implied by the formula for TPI and the regression of price on TPI. The implied regression coefficients are similar to those for multiple regression of price on PDM, PD%, and PDT (Table 3).

TABLE 3. Comparison of coefficients for regression of semen price on PD milk (PDM), PD percent (PD%), PD type (PDT) with regression coefficients implied from regression of semen price on total performance index (TPI) (outliers excluded).

Bull stud	Partial regression coefficients: PDM (lb)	PD%	PDT	Implied regression coefficients[1]: PDM (lb)	PD%	PDT	Regression coefficient for TPI
All	.0137	26.5	5.65	.0159	33.0	4.24	.0594
A	.0064	16.9	1.85	.0066	13.6	1.75	.0245
B	.0240	41.6	6.50	.0240	49.7	6.39	.0895
C	.0183	37.6	6.56	.0206	42.9	5.51	.0772

[1] Determined from $50b_{TPI}$ [(3/560)PDM + PD%/.09 + PDT/.70].

CONCLUSIONS

If prices assigned by bull studs to semen reflect consumer demand, then farmers appear to put more emphasis on type than may have been previously thought when purchasing semen for bulls with type proofs. There seem to be differences in emphasis by farmers in pricing semen among the studs. The linear economic weights assigned to milk, test, and type are remarkably similar to those assigned through the 1983 total performance index. Quadratic terms involving PDT and PD$ seem to be associated with pricing semen of a few bulls with high semen prices. The economic emphasis assigned on average to milk, test, and type could account for substantial reduction in genetic gain in milk production from that expected from selection for production alone.

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