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The Effect of Selected Farm Characteristics on Dairy Farm Profitability: A Logistical Regression Analysis

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THE EFFECT OF SELECTED FARM CHARACTERISTICS ON DAIRY FARM PROFITABILITY: A LOGISTICAL REGRESSION ANALYSIS

Kevin E. Jack*

ABSTRACT

The cost, efficiency, technical and locational factors influencing dairy farm financial success were analyzed using records from 384 specialized New York dairy farms. Logistic regression models were constructed for the following size-neutral financial performance variables: net farm income per cow; labor and management income per cow; percentage return on equity; and, percentage return on investment. Milk sold per cow, machinery expense per cow, feed expense as a percentage of net milk receipts, hired labor expense per cow, "mailbox" milk price, and percentage of total farm receipts from dairy were the most consistently important explanatory variables. Herd size was inconsistent, statistically significant in only two models.

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INTRODUCTION

Mirroring national trends, the number of dairy farms in New York declined by over 30 percent between 1980 and 1990, based on market order data (Jack and Novakovic). While not unprecedented, this significant reduction in producer numbers begs important questions, including, why were some dairy farm operations successful and why were others not in surviving?

An important consideration in farm survival is the probability of achieving and maintaining financial success. Such issues point up the need to focus on key factors which appear to significantly affect the likelihood of farm financial success, and hence, survival. However, the particular set of factors is often contingent upon the choice of financial performance indicator. For example, in a recent analysis of New York farms, debt per cow and debt-to-asset ratio were found to be important in distinguishing between farms with high and low net farm incomes, but were insignificant in differentiating between farms with high and low percent return on investment (Jack et al.).

OBJECTIVE AND ORGANIZATION

The primary objective of this paper is to examine four accrual measures of profitability on New York dairy farms, and to assess which structural, technical and locational factors are most important in accounting for variation in the probability of achieving financial success, based on the four measures used here. The remainder of this paper is organized as follows: first, a brief literature review is presented; second, the data set is described; next, the statistical methodology underlying the logistical regression model is briefly reviewed; and, finally, model specifications and results are presented with some concluding remarks regarding their implications.

LITERATURE REVIEW

A substantial volume of published literature has been devoted to the questions and related issues outlined above. For example, Kauffman and Tauer used stochastic dominance to separate farms into successful and less successful groups using four different performance measures and sixteen independent variables, while Haden and Johnson employed multiple linear regression to relate financial performance to ten farm-level characteristics. Jack et al. used analysis of variance techniques to determine what farm-level variables differed significantly between the upper- and lower quartiles for five financial performance measures. Jeffrey simulated dairy farm financial performance with Monte Carlo techniques by assuming alternative herd sizes, levels of milk production per cow and debt-to-asset ratios. Fowers made extensive use of correlation techniques to identify important dairy practices and management factors which were associated with successful financial performance.

DATA AND METHODS

Data were obtained from farms participating in Cornell University's Dairy Farm Business Summary (DFBS) in 1989. Farms participate in DFBS on a voluntary basis, and their average performance tends to be better than the average of all dairy farms in New York. The data set used in this analysis includes only "specialized" dairy farm operations, and purposely excludes dairy farm renters, dairy-cash crop farmers with crop sales exceeding 10% of milk sales, and part-time dairy operators.[2]

DFBS herds with more than 10% non-Holstein cows were deleted from this analysis to avoid confusing the results of poorly managed Holstein herds with those from typically lower-producing colored breed herds. In addition, farms not growing hay or haylage were omitted due to the overwhelming preponderance of hay production on New York dairy farms and the desire to include a hay-production variable in this analysis. In sum, twenty-nine such herds were identified, reducing the total number of useable observations to 384.

Four accrual financial performance measures form the basis of this analysis. Each measure is "scale-neutral" with income measures reported on a per-cow basis, and return measures reported on a percentage rather than absolute basis. All measures exclude appreciation of farm asset values and are defined as follows:

1) <u>Net Farm Income per Cow--(NFIC)</u>: Total returns less total expenses including changes in inventories and accrual adjustments. Represents total combined return to the farm operator(s) and other unpaid family members for their labor, management and equity capital, divided by average number of cows.

2) <u>Labor and Management Income per Cow--(LMIC)</u>: Net farm income less charges for unpaid family labor (@ $750/month) and less the opportunity cost of using equity capital (5% of assets), divided by the average number of cows.

3) <u>Rate of Return on Equity Capital--(ROE %)</u>: Net farm income less the value of unpaid family labor and less the value of operator's labor & management (operator determined), as a percentage of equity capital.

4) <u>Rate of Return on Investment--(ROI %)</u>: Net farm income plus interest payments on debt less the value of unpaid family labor less the value of operator's labor & management, as a percentage of average farm assets. Farm assets are the average of beginning and year-end values of land and buildings,

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[2] General information on the DFBS is found in Putnam et al. and additional statistical background on the 1989 summary may be found in Smith et al.

machinery and equipment, livestock, supplies in inventory, and farm coop stock and certificates.

Logistic regression models feature a binary-choice (0/1) dependent response variable; a farm is either in the top quartile for a financial measure (Y=1) or it is not (Y=0). These values taken by the dependent variable are merely a coding for some qualitative outcome and are not meaningful themselves.

The logit probability model, which is the link between the outcome of financial success and a set of factors hypothesized to influence this outcome, is associated with the logistic cumulative distribution function.[3] The underlying probability density function is similar to the normal distribution in that it is symmetric around 0, but with significantly heavier tails and with variance equal to $\pi^2/3$, not 1.[4]

If P_i is the probability of being among the top 25% farms for an individual financial performance measure and $(1-P_i)$ is the probability of not being among the top 25%, then the ratio $[\frac{P_i}{1-P_i}]$ represents the "odds ratio" of being among the top 25%. The value of the estimated logit equation equals the natural logarithm of $[\frac{P_i}{1-P_i}]$.

The logit model possesses several key features. Chief among them is that all estimated probabilities of success are bounded by 0 and 1. In addition, the value of the logit is linear in changes in explanatory variables, but the underlying probabilities change at a non-linear rate. Unit change in an explanatory variable at either extreme of the logistic probability distribution leads to smaller and smaller incremental changes in the value of the probability function, yielding the familiar "S" shaped curve.

Maximum likelihood techniques were used to estimate model parameters that maximize the probability of having obtained the original set of observations. The formulated likelihood function expresses the probability of having obtained the observed data set as a function of the unknown parameters. In turn, the natural logarithm of the estimated likelihood function provides parameter values which maximize the probability of the maximum likelihood estimators.

The probability of the *i*th farm achieving financial success for a given financial performance variable is given by

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[3] Aldrich and Nelson (1984) and Amemiya (1981) provide a detailed, theoretical background on the logistic model.

[4] William H. Greene, *Econometric Analysis*, (NY: Macmillan Publishing Co., 1990), p. 666.

$$P_i = F(z_i) = e^{z_i}/(1+e^{z_i}),$$
$$-\infty < z_i < \infty, \text{ where } z_i = x_i'\beta$$

where x_i' is the i th row of the n x p matrix of regressors, $i=1,.....,n$ (n refers to the sample size and p refers to the number of coefficients); and, β, the p x 1 vector of parameters.

The partial derivative of the probability, P_i, with respect to a particular independent variable, x_i, is given by

$$\partial P_i/\partial x_i = (\partial F/\partial z_i)(\partial z_i) = f(z_i)\beta$$

where $f(z_i)$ represents the value of the density function associated with each possible value of the underlying index z_i. For a continuous explanatory variable x, the value of e^{z_i} is interpreted as the ratio of the odds of a farm with value (X+1) relative to the odds of a farm with value X. Thus, e^{z_i} is the incremental odds ratio corresponding to a one unit increase in the variable x, everything else held constant. However, in the case of a dummy explanatory variable, the computation of a partial derivative is not meaningful.[5]

The general logit model used to analyze farm financial success is given by:

$$\begin{aligned} SUCCESS = {} & \beta_0+\beta_1 PPC100+\beta_2 COWS10+\beta_3 CAPCOW+\beta_4 DAR100+\beta_5 MEXPCOW \\ & +\beta_6 NETMILK+\beta_7 HIREDLAB+\beta_8 VETCOW+\beta_9 HAYLAGE+\beta_{10} DIVERSE \\ & +\beta_{11} FEEDNET+\beta_{12} PROPRI+\beta_{13} PARLOR+\beta_{14} FREESTALL+\beta_{15} AGE55 \\ & +\beta_{16} WPCR+\beta_{17} OMHR+\beta_{18} NNYR \end{aligned}$$

Eighteen cost, efficiency, locational and structural explanatory variables were selected from among those found useful in previous farm management studies utilizing DFBS records and other variables thought important for distinguishing between dairy farms. Listed in Table 1, they include eleven continuous, quantitative variables and seven dichotomous, qualitative variables. Qualitative variables took on a value of 1 if they exhibited that attribute or 0 otherwise.

Mean values are also listed in Table 1. Means of dummy variables simply represent the proportion of farms with that attribute. Most of the continuous variables were scaled, as indicated in Table 1. Variables with relatively large means (e.g. capital investment per cow) were divided by 10 or 100, and continuous variables normally expressed as a decimal (e.g. debt-to asset ratio) were multiplied by 100. This scaling increases the interpretability and meaningfulness of unit changes in explanatory variables. For example, a one unit change in the CAPCOW variable (representing a $100 change in capital investment per cow) is more meaningful and realistic than a $1 change. Similarly, a one unit increase in the DAR100

[5] Greene, p. 665.

Table 1. Variable Definitions and Means

Name	Description	Units	Mean
PPC100	Milk Sold per Cow	Pounds ÷ 100	169.04
COWS10	Milking Herd	Cows ÷ 10	10.69
CAPCOW	Capital Investment per Cow	$100	60.42
DAR100	Debt-to-Asset Ratio	Ratio X 100	32.44
MEXPCOW	Machinery Expense per Cow	$10	44.71
NETMILK	Milk Receipts Net of Marketing Expense per Cwt.	$1	13.89
HIREDLAB	Hired Labor Expense per Cow	$10	21.03
VETCOW	Veterinary Expense per Cow	$1	48.11
HAYLAGE	Haylage/Total Hay Production	Ratio X 100	54.17
DIVERSE	Gross Dairy Receipts/Total Farm Receipts	Ratio X 100	87.86
FEEDNET	Feed Expenses/Total Net Milk Receipts	Ratio X 100	37.90
PROPRI	1=Sole Proprietorship 0=Otherwise		.6641
PARLOR	1=Milking Parlor 0=Otherwise		.3906
FREESTALL	1=Freestall Barn 0=Otherwise		.4427
AGE55	1=Principal Operator age 55+ 0=Otherwise		.2109
WPCR	1=Western Plain & Central Region 0=Otherwise		.2266
OMHR	1=Oneida-Mohawk & Hudson Region 0=Otherwise		.2812
NNYR	1=Northern New York Region 0=Otherwise		.1849

variable from 33 to 34 (representing a change from .33 to .34 in debt-to asset ratio) is more interpretable than a one unit change, from .33 to 1.33, in the original debt-to-asset variable.

The Dairy Farm Business Summary segments New York State into four production regions, which are outlined in Figure 1. Areas excluded for lack of dairy farms include: New York City, Long Island, two counties in the Adirondack Mountains, and three suburban counties to the north of New York City. Regional differences in farm financial performance are expected because farms in the Western Plain and Central Region (WPCR) and the Oneida-Mohawk and Hudson Region (OMHR) have consistently reported the highest and lowest figures, respectively, for net farm income per cow and labor & management income per cow (data for percentage return on equity and return on investment were not published) since regional comparisons of DFBS data were first published in 1989. Dummy variables were included for the WPCR, OMHR and Northern New York (NNYR) regions to serve as intercept shifters in the model. The Plateau Region serves as the "base" region in this analysis, and was excluded to avoid the "dummy variable" trap.

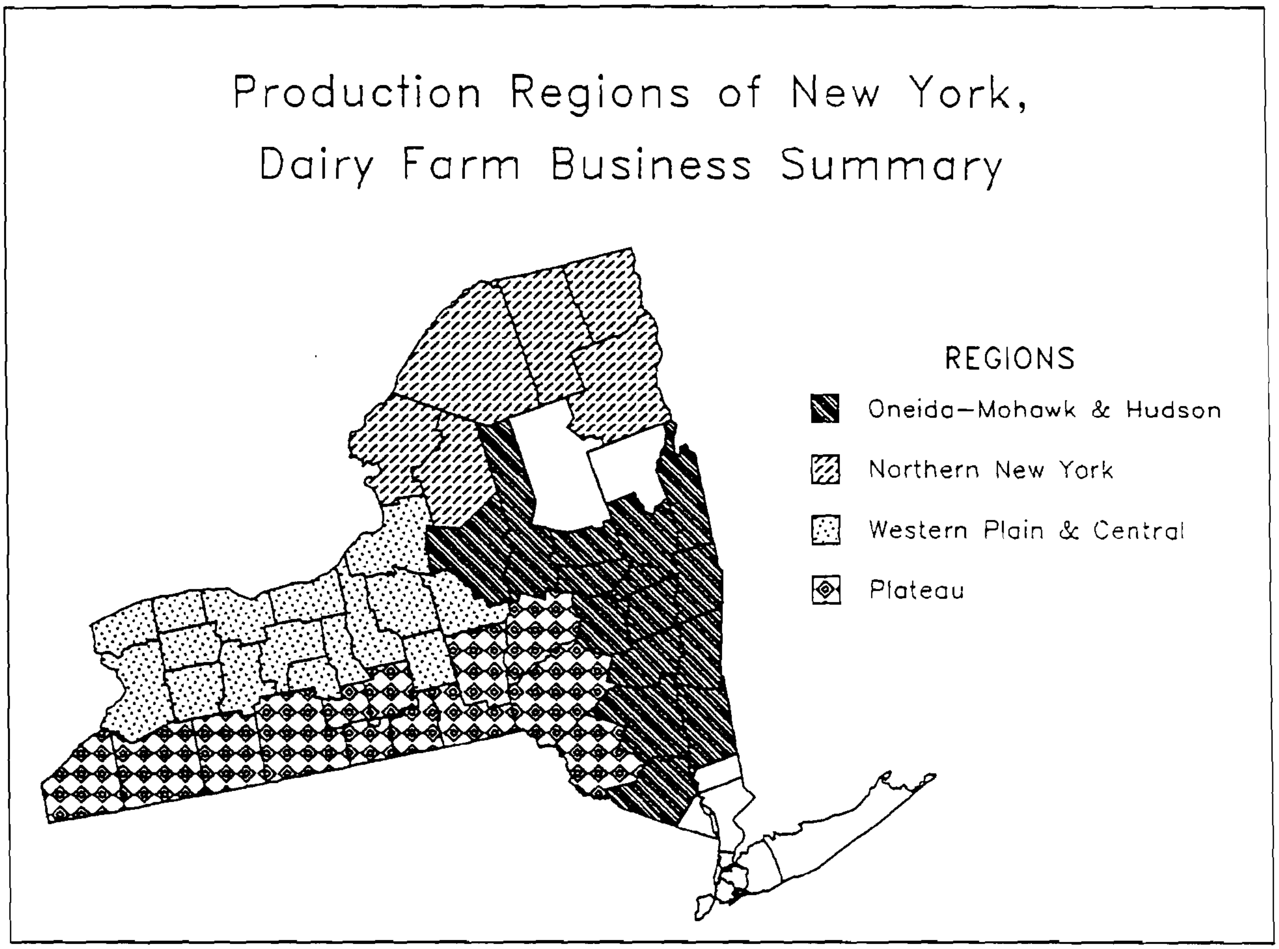

Figure 1.

RESULTS

Regressions were estimated using the LOGISTIC procedure of the Statistical Analysis System (SAS). Maximum likelihood parameter estimates are reported in Table 2. The Wald statistic, which is the maximum likelihood chi-square statistic, was used to test the null hypothesis that a coefficient was zero since parameter estimates are asymptotically normal. The Wald statistic is calculated by dividing the parameter estimate by its respective standard error, and then squaring the result.

Similarly, the -2 Log Likelihood statistic, which also has a chi-square distribution, is used to test the overall significance of the estimated model. A p-value is calculated for this test and is indicated at the bottom of Table 2. In all cases, the estimated logistic model is highly significant, and the null hypothesis of all explanatory variables being zero is rejected at the 1% level.

Table 2. Maximum Likelihood Estimates, 384 New York Dairy Farms, 1989

Explanatory Variable	Regression Coefficient For the Dependent Variable: NFIC	LMIC	ROE	ROI
INTERCEPT	15.4900**	12.3994**	9.9360*	12.2886**
	(6.6619)	(5.6899)	(5.4991)	(5.7994)
PPC100	.1219***	.1124***	.0741***	.0773***
	(.0161)	(.0147)	(.0120)	(.0124)
COWS10	.00936	.00332	.1366***	.1406***
	(.0175)	(.0211)	(.0392)	(.0401)
CAPCOW	-.00243	-.0628***	-.0862***	-.0936***
	(.0122)	(.0150)	(.0190)	(.0203)
DAR100	-.0676***	-.0167	-.00855	-.00273
	(.0136)	(.0104)	(.0097)	(.0099)
MEXPCOW	-.1168***	-.1110***	-.0979***	-.1035***
	(.0212)	(.0197)	(.0193)	(.0201)
NETMILK	.9373**	1.0188***	.9816***	.9575***
	(.4186)	(.3548)	(.3381)	(.3546)
HIREDLAB	-.1046***	-.0899***	-.0484***	-.0555***
	(.0179)	(.0164)	(.0153)	(.0160)
VETCOW	-.0306***	-.0316***	-.0124	-.00840
	(.0097)	(.00869)	(.00779)	(.00787)
HAYLAGE	-.00164	.00036	-.000528	.00719
	(.00783)	(.00718)	(.00752)	(.00789)
DIVERSE	-.3852***	-.3252***	-.2726***	-.3087***
	(.0553)	(.0458)	(.0418)	(.0460)
FEEDNET	-.1823***	-.1707***	-.1358***	-.1352***
	(.0341)	(.0327)	(.0304)	(.0313)
PROPRI	-.2832	-.2370	1.1670**	1.5447***
	(.4549)	(.4243)	(.4587)	(.4851)
PARLOR	.6652	.1496	.4028	.4243
	(.7038)	(.6093)	(.5673)	(.6047)
FREESTALL	-.8373	.0933	.1364	.2936
	(.7200)	(.6235)	(.5850)	(.6304)
AGE55	1.1146**	.8827*	.9109**	.6062
	(.4923)	(.4631)	(.4502)	(.4710)
WPCR	.1030	-.7394	-.7700	-.6387
	(.5713)	(.5311)	(.5053)	(.5186)
OMHR	.6674	.0185	-.3578	-.3957
	(.5194)	(.4578)	(.4595)	(.4843)
NNYR	.5311	-.8493	-.3551	.1177
	(.5673)	(.5196)	(.4757)	(.4768)
Likelihood Ratio				
Chi-Square	234.95***	203.16***	197.80***	210.40***
McFadden's R^2	.5440	.4704	.4580	.4872

Level of significance; '***': p≤.01, '**': p≤.05, '*': p≤.10.

Milk sold per cow (PPC100), machinery expense per cow (MEXPCOW), milk price received per hundredweight (net of marketing expenses) (NETMILK), hired labor expense per cow (HIREDLAB), dairy receipts as a percentage of total farm receipts (DIVERSE) and feed expense as a percentage of net milk receipts (FEEDNET) were the most consistently important explanatory variables across all four regression models. The PPC100 and NETMILK variables had positive coefficients, and the coefficients on the three cost variables (HIREDLAB, MEXPCOW and FEEDNET) were all negative, as expected.

The major surprise was the significant negative coefficient on the DIVERSE variable in all four equations. In this sample, farms receiving a higher proportion of their income from dairy operations had a lower probability of being among the top 25% farms. This result is unanticipated given the strong recent trend towards increasingly specialized dairy farms. However, a similar analysis of New England dairy farm records by Wadsworth and Bravo-Ureta reported a negative relationship between gross returns from milk as a percentage of total gross returns and farm financial performance.

COWS10, the herd size variable, was statistically significant in the ROE and ROI regressions, but in neither of the income per cow measures. This outcome reflects the fact that, among DFBS farms, larger herds have significantly less capital investment per cow (Jack et al.) Thus, if small and large herds have equal dollar returns per cow, then the larger herds will experience higher returns when measured on a percentage basis.

Among other variables, debt-to-asset ratio (DAR100) was only significant in the NFIC equation, but did possess the anticipated sign. Veterinary expense per cow was important in explaining variation in the two income per cow measures, NFIC and LMIC. Sole proprietorships (PROPRI) had a higher probability of achieving financial success as measured by ROE and ROI.

The dummy variable for operators age 55 and older was significant and positive in the NFIC, LMIC and ROE models, indicating that farms with older principal operators had an increased likelihood of obtaining financial success. This result is contrary to findings by Carley and Fletcher and by Haden and Johnson that older operators used older management practices and received lower dollar returns to operator labor and management. Six explanatory variables, HAYLAGE, PARLOR, FREESTALL, and the three regional dummies, were not statistically significant in any of the four logistic regression models.

An important issue with any regression model is, R^2, the proportion of the variance in the dependent variable explained by the independent variables. However, there is no analogous, universally accepted measure in logistic regression. Fienberg notes that "as long as some of the (regressors) ... are not categorical ... no ... omnibus goodness-of-fit test for a model ... such as R^2 is available ..."[6] Similarly, Aldrich and Nelson claim that since "no one (R^2 type)

[6] Stephen Fienberg, *The Analysis of Cross-Classified Categorical Data*, (Cambridge, MA: The MIT Press, 1980), p. 104.

measure is universally accepted or employed ... the usefulness of these or any other summary measure is diminished."[7]

Despite these misgivings, McFadden's pseudo R^2 is one measure often reported in logit analyses. It is calculated as $1-[\frac{L_0}{L_{MAX}}]$, where L_0 is the initial value of the likelihood function with all model coefficients restricted to zero, and L_{MAX} is the maximum value of the unrestricted likelihood function. Values for McFadden's pseudo R^2 in the current analysis are reported at the bottom of Table 2.

The parameters presented in Table 2 do not report changes in probability, but rather the change in the natural log of the odds ratio, given a one unit change in an explanatory variable. The actual change in probability of financial success not only depends on the slope coefficient, but also on the level of the probability from which the change is measured.

Figure 2 illustrates the change in the value of the estimated logit equation for Net Farm Income per Cow, given 10-unit changes (1000 pounds) in the milk sold per cow (PPC100) variable. As noted earlier, the logit is linear in changes in explanatory variables, but as Figure 3 shows, the associated probability function changes at a non-linear rate. All continuous explanatory variables are held at sample means, while all dummy variables, except the sole proprietorship variable, are set equal to 0.

In Figure 3, an increase in milk sold per cow from 15,000 to 16,000 pounds is associated with a rather small increase in the probability of being among the 25% farms for Net Farm Income per Cow, from .026 to .082. On the other hand, an increase from 17,000 to 18,000 pounds sold per cow brings about a much larger change in probability of success from .232 to .505. As indicated earlier, these changes reflect the fact that the slope of the cumulative logistic probability futest at the midpoint. Thus, changes in explanatory variables have their largest impact on the probability function at the midpoint. The relatively low slopes at the endpoints of the distribution mean that large changes in explanatory variables are required to bring about small changes in the probability function.

SUMMARY AND CONCLUSIONS

Structural, technical and locational farm-level factors which influence attainment to the probability of financial success on New York dairy farms, defined here as being among the top 25% for a particular financial performance variable, were analyzed using logit probability models. The financial performance measures were: net farm income per cow; labor and management income per cow; percentage return on equity; and, percentage return on investment. Milk sold per cow, hired labor expense per cow, machinery expense per cow, milk price net of marketing expenses per hundredweight, feed expense as a percentage of net dairy receipts, and

[7] Aldrich and Nelson, pp. 57-58.

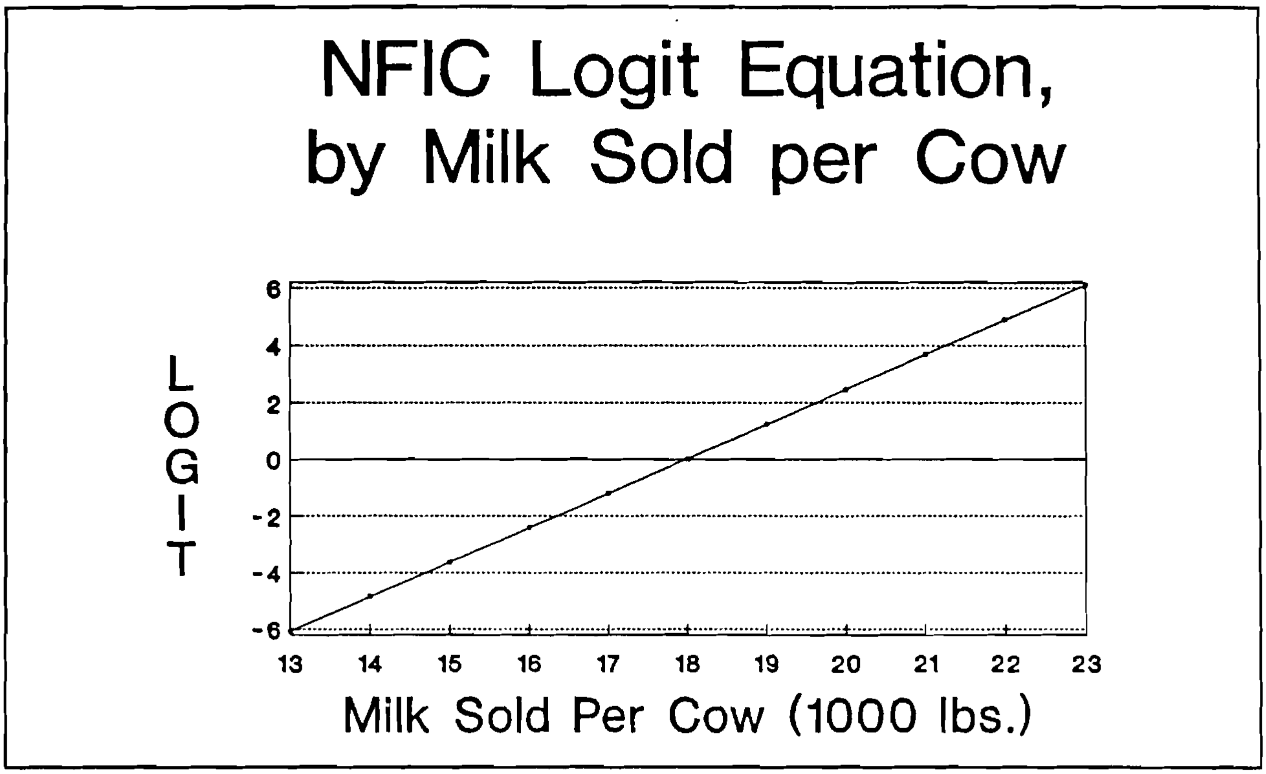

Figure 2.

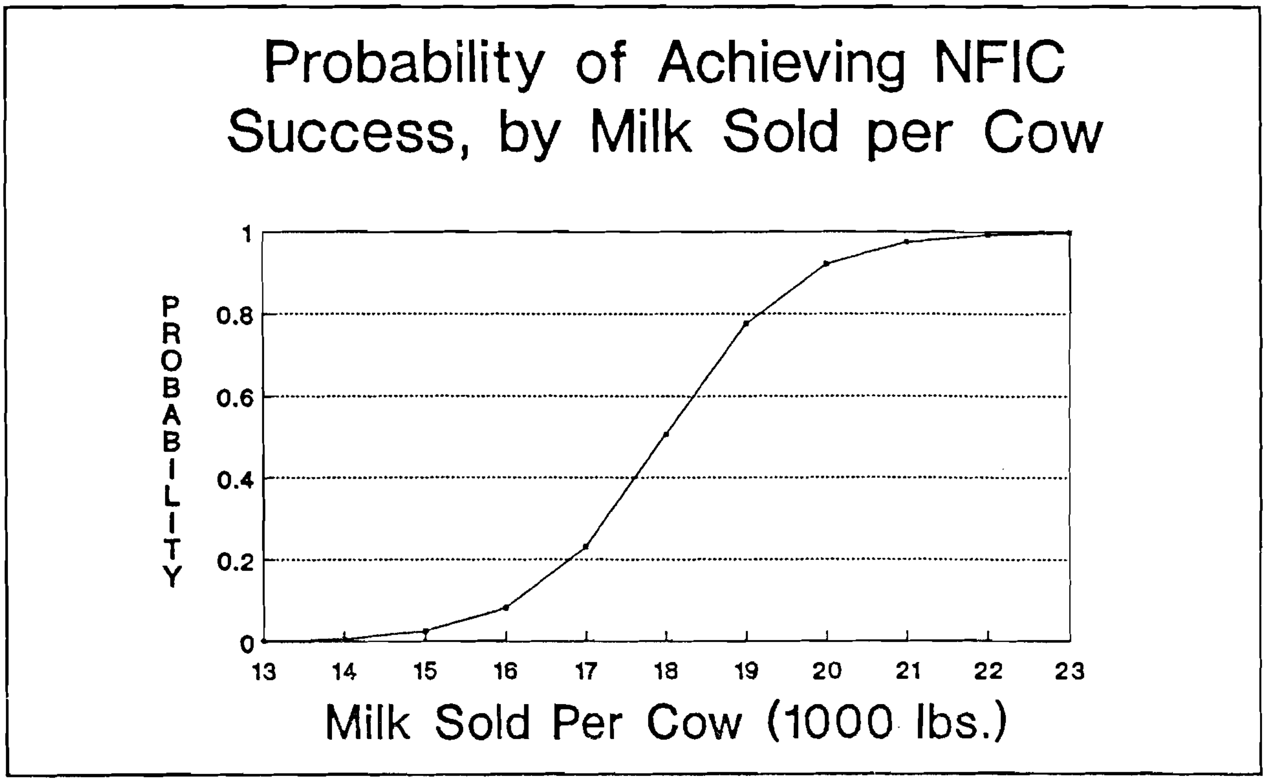

Figure 3.

gross dairy receipts as a percentage of total farm receipts were the most consistently important variables in explaining variation in financial success across all four models. The capital investment and age of principal operator variables were important in three of the four logit equations. Several variables, including herd size, debt-to-asset ratio, veterinary expense and sole proprietorship, were statistically significant in only one or two of the models.

From a farm management perspective, this analysis points to those variables which are most influential in attaining financial success. Region within New York state had no bearing on achieving financial success. More modern technology, reflected in the utilization of milking parlors, freestall barns and haylage production, had no impact on the probability of achieving financial success as measured by these four scale-neutral profitability indicators. Finally, the axiom of "get better, before getting bigger" held true in this analysis as increased milk sold per cow was consistently more important than larger herd size in achieving financial success.

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