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PROJECTING DAIRY FARM LIVESTOCK INVENTORIES

by

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Research and extension oriented literature stressing the need for detailed planning prior to expanding dairy farm businesses is abundant. Documentation exists which indicates expanding dairy farm managers should expect a decrease in milk production per cow, increased death losses among replacements, increased cull rates among the producing milk cows and a loss of reproductive efficiency. (Stoll) Most writers include the need for detailed prior planning high on their list of solutions to the expected problems.

The first step in planning for dairy expansion should be to construct an inventory of livestock numbers for the expanded herd. (Willett) There are two ways to do this: 1) The planner may project the makeup of the expanded herd by using the age distributions commonly found among existing herds. 2) The planner may base the calculations on the current inventories, expected purchases, known calving intervals, expected culling rate, and calf death losses. The speed of calculation and existence of guideline coefficients (Speicher) tend to make the first method more widely used. The second method has historically taken longer to calculate and requires identifying additional coefficients pertinent to the particular operation's operating characteristics. If such coefficients are obtainable, the second method has the potential for providing a more accurate projection on any individual herd. The model suggested below should reduce the calculation tasks while using the details of the second projection method. Better herd managers know their performance

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coefficients; guideline coefficients are suggested to help those without complete information. Accurate herd number projections and distributions by age will enable more accurate planning of building requirements, cash income projections, feed requirements, and expected quantities of manure.

The Dairy Herd Inventory Model

The dairy herd inventory model can be specified as:

(1) $Y_i = Y_{i-1} - a_{i-1} (Y_{i-1}) + P_{i-1} - b_{i-1} (P_{i-1}) + H_{i-1} - C_{i-1} (H_{i-1})$, where:

Y = Number of cows in the herd at the start of the year,

i = Year,

a = Cull rate or percent of cows in the milking herd which leave the herd during the year,

P = Number of purchased cows or bred heifers which enter the milking herd during the year,

b = Percent of purchased cows or bred heifers which enter the milking herd and also leave (are culled) the herd during the year,

H = Home grown first calf heifers entering the herd during the year, and

C = Cull rate or percent of home grown heifers entering the milking herd which also leave the herd during the year.

The number of milking cows on hand at the start of any year come primarily from cows on hand at the start of the previous year. The total is adjusted by cows and/or bred heifers purchased during the past year minus the animals removed (culled) from the herd in all previously mentioned categories. The value of H is computed as follows:

(2) $H_i = [g (X_{i-2}) + (1-g) (X_{i-3})](1-m)$, where:

g = The fraction of heifer calves born in year 1 which will freshen in year 3. This reflects the average freshening age of home grown first calf heifers. If the average freshening age is 24 months, then g = 1; all calves born in year 1, which survived and were on the farm, would freshen in year 3. If the average freshening age is 26 months, then g = .83. A heifer calf born in January, year 1 would freshen in March, year 3. Calves born in November and December, year 1, would freshen in January and February, respectively, year 4. Female calves born in the first 10 months of year 1 would freshen in year 3; the rest would freshen in year 4. The following formula calculates g:

(3) $$g = \frac{12 - (AFA-24)}{12}$$

where: $0 \leq g \leq 1$

and AFA = Average freshening age in months.

Some computed g values are:

Average freshening age in months	g Value
24	1.0
26	.83
28	.67
30	.50

(1-g) = The fraction of heifer calves born in year 1 which will freshen in year 4. It is assumed all female calves born that are kept and survive will freshen in either year i + 3 or year i + 4.

m = The fraction of heifer calves born on the farm which are born dead, sold or die before the average freshening age. The fraction of heifer calves which make it to freshen = (1-m).

X = number of heifer calves born (dead or alive) from all sources during the year.

All other variables as previously defined.

The number of home grown first calf heifers freshening during the previous year come from female calves born in earlier time periods. The number available to freshen in any given year is a function of the death losses incurred and the average age at freshening. The number of heifer calves born can be calculated as follows:

(4) $X_i = .5[j(Y_i - a_iY_i) + k(a_iY_i) + nP_i + H_i]$, where:

.5 = half of all calves born are assumed to be female,

j = calving rate for cows in the herd at the start of the year and that are still in the herd a year later. This fraction reflects the average calving interval of the herd. j = the ratio of one year to the calving interval. If the calving interval is 13 months, j = 12/13 = .92 while an 11 month calving interval would yield a 1.09 factor,

k = calving rate for cows removed during the year. It is assumed k = .3; this resulted from a case study done of the Michigan State University dairy herd where this factor ranged from .2 to .4 over a 6 year period. No other data was found pertaining to this statistic. It is specified as a variable because it is known that some herd managers have culling decision strategies that can be incorporated by varying k,

n = fraction of purchased cows and bred heifers which freshen during the year. If all purchased animals are to be purchased as bred heifers to freshen soon, then n = 1.0; if some are bred heifers and some are fresh cows at date of purchase, n will be less. The n range is: $0 \leq n \leq 1$,

All other variables as previously defined.

Heifer calves in any given year come from all births during the year, half of which should be female. For cows not culled, the number of births in a year depends on the average calving interval. Some culled cows will have calves during the year, but more than two thirds will not. Purchased animals giving birth on the farm depends on what is bought. First calf heifers, by definition, give birth during the year while cows may or may not. Furthermore, some managers may not keep any calves from some of the above categories.

Because equation (1) is recursive, special equations are needed to specify H in the first 3 years.

(5) $H_1 = (f)(F)(1-.5m)$, where:

f = fraction heifers greater than one year of age in inventory at the start of year one which will freshen during year one. The f range is: $0 \leq f \leq 1$. It depends on the average freshening age of heifers. The following assumed values are suggested:

Average Freshening Age in Months	f Value
24 to 26	.75
26 to 28	.65
28 to 30	.60

F = number of heifers greater than one year of age which are on hand at the start of year 1.

.5 = portion of death loss from birth to freshening applicable to heifers greater than 1 year of age.

All other variables as previously defined.

This is a time dependent model; what is on hand this year is a function of what took place in earlier years. Cows at the start of the year are partially a function of home grown first calf heifers freshening the year before, which in turn are a function of surviving females born 2 and 3 years before that. Consequently, the model cannot be self generating until the fourth year. Special equations must initially by used to define the starting point inventories and intended purchases to move the model through the first 3 years. The number of home grown first calf heifers freshening during year 1 depends on the number of heifers over one year of age which are on hand at the start of year 1 and the fraction which will freshen during the first year. For H in year 2:

(6) $H_2 = [(1-f)(F)(1-.5m) + (g)(G)(1-m)]$, where:

G = number of heifers one year or less of age which are in inventory at the start of year 1,

All other variables as previously defined.

Home grown first calf heifers freshening during year 2 can only come from heifers which were on hand at the start of year one assuming the average age of freshening for first calf heifers is 24 months or more. For those heifers which were initially over one year of age, any that didn't freshen in year one are assumed to do so during year 2. In addition, a portion of those one year or less of age at the start of year 1 will freshen during year 2. For heifers freshening in year 3:

(7) $H_3 = (1-m)[(1-g)\ (G) + (g)\ (X_1)]$, where:

H_3 = Number of home grown first calf heifers freshening during year 3,

All other variables as previously defined.

Home grown first calf heifers freshening in year 3 come from heifers one year or less on hand at the start of year one which did not freshen year 2 and from heifer calves born during year 1. Both sources are adjusted for death and other losses. The model will be self-generating for year 4 and later.

Stability, Death Losses and Cull Rates

Stable herd size is an objective of many dairy farmers. The cull rate of milking cows and the availability of replacements are key variables in stability. The model can indicate the acceptable levels of one variable given the values of all other variables. The dairy industry is currently concerned about calf death losses. If the desired cull rate is given and assuming all heifer calves born can be raised for replacements, what is the maximum death loss of replacement heifers which can be tolerated and still maintain a stable herd size? Assuming a calving interval of 13 months and an average age of 28 months for freshening first calf heifers, the model was solved for m, the death loss (or removal rate) for replacements which could be tolerated while retaining a minimum herd size. This means all replacements come from births within the herd; purchases are at zero level.

The minimum cull rate observed in herds is 15 to 20 percent. Assuming it is 15 percent, m is about .65; as many as 65 percent of female animals born can die and still get enough first calf heifers to maintain a stable herd size. If the cull rate is .4, then m is about .003 or about 0. Given the above assumptions, the following equation results:

(8) $L = 1.-2.5Z$, where:

L = maximum death loss among replacements if herd size is stable,

Z = cull rate of all milking animals.

The coefficient of Z will change if the exogenous variables are modified.

Equation (8) indicates managers who maintain lower cull rates can maintain a stable herd size over time, even with a high death loss of calves. However, the economic loss would be high; the minimum opportunity cost would be the lost sales of one day old calves. Managers who agressively cull the milking herd to increase milk sales per cow must keep calf death losses low or purchase replacements to maintain herd size.

Verification of the Model

Michigan farm account records indicates replacement death losses average about 14 percent on all dairy farms. On farms with over 100 cows, calf losses average 16 percent (Nott, 1974). It can reach 50 percent on individual farms. Production records from the Southeastern United States indicate the average cull rate for farms on test was 32 and 28 percent in 1973 and 1974, respectively. (Butcher) Equation (8) indicates the typical manager achieving a 32 percent cull rate and a 14 percent calf mortality could maintain herd size and gradually expand without purchasing replacements. Such expansion has been recorded on individual farms (Nott, 1968) indicating the model does approximate reality.

The model was set up for computer computation of inventory movements over a 20 year period. While checking the calculations for equation (8) we noted a range of 1.00 to 1.10 calves born per cow per year. This range contains the 1.01 average of calves born per cow reported for all sizes of Michigan dairy farms in 1973. (Nott, 1974) This indicates model results are consistent with farm accounting project data.

Expansion Planning

The model can predict problems which may result from inadequate planning. Farmer A has a 50 cow herd with the usual number and age distribution of replacements. He plans to expand to 100 cows by investing in buildings and purchasing 50 heifers to freshen during 1975. He hopes to maintain his management strategies which have resulted in a 22 percent cull rate, 10 percent calf death loss, 13 month calving interval and heifers freshening at 28 months of age. Assuming all female calves are kept for replacements and no additional purchases, the model projects:

Year	Cows at Start of Year
1975	50
1976	90
1977	88
1978	99
1979	112

It will be over 3 years before his herd size actually achieves 100 cows or more. A low point in milking cow numbers will be reached during the second year. If gross cash income projections assume 100 cows will be present each year, available cash will be overestimated.

Several studies have indicated management practices in a dairy growth situation often result in poorer performance levels than those achieved in the smaller, stable herd size. (Stoll) To predict what would be typically expected to happen with Farmer A, the cull rate was increased to 33 percent the first year, 30 percent the second year, 25 percent the third year and held constant at 22 percent thereafter. The calf death loss was doubled to 20 percent and the calving interval lengthened to 14 months. Heifer freshening age was not changed.

The model projects:

Year	Cows at Start of Year
1975	50
1976	79
1977	71
1978	79
1979	88
1980	94
1981	101

With this performance, it will take Farmer A nearly 6 years to reach 100 milking cows. Gross cash income could be overestimated during the first six years. Use of the model and alternative projections could help Farmer A identify problem areas and managerial priorities.

Use in Computer Programs

The dairy herd growth model has potential as a subroutine in several larger computerized models such as farm management games, programmed growth models and whole farm simulators. The advantages of the model include its equation format which can be set up for computer calculations. The exogenous variables specified allow users to simulate expected impact of problems which occur in expansions. Disadvantages include the necessity of special equations during the first 3 years of the model and specification of the necessary exogenous variables.

SUMMARY

This paper presented a recursive, deterministic growth model with the capability of calculating dairy livestock inventories. It was verified with farm accounting and DHIA summary statistics. The exogenous variables were designed so that better herd managers could readily define them using existing production records. The model was presented in 7 equations; anyone familiar with dairy farm management should be able to work through the equations with a pocket calculator. The model results are useful in analyzing the interaction among livestock inventories, replacement (calf) death losses and milking herd cull rates. Extension personnel will find it a useful tool in helping dairy persons do forward planning for expansion.

REFERENCES

Butcher, K. R., State and Regional DHI Averages for the 1973-74 Testing Year. Southern Regional Dairy Records Processing Center: North Carolina State University, Raleigh, N.C. 1975.

Nott, S. B. and L. H. Brown. Business Analysis Summary for Specialized Michigan Dairy Farms. Agricultural Economics Report 273. Michigan State University: E. Lansing, MI. 1974.

Nott, S. B., Economic Restrictions to the Expansion of New York Dairy Farms. Ph.D. Thesis, Cornell University: Ithaca, N.Y. 1968.

Speicher, J. A. and L. H. Brown. A Dairy Budget Guide. Dept. of Diary Science D-211. Michigan State University: E. Lansing, MI. 1969.

Stoll, Thomas Lee. An Analysis of the Effect of Expansion on Cash Flow, Management Income and Various Management Factors. M.S. Thesis. Michigan State University, E. Lansing, MI. 1974

Willett, G. S., W. T. Howard and R. N. Weigle. Planning for Dairy Farm Expansion. Depart. of Agricultural Economics A 2449. University of Wisconsin: Madison, WIS, 1972.