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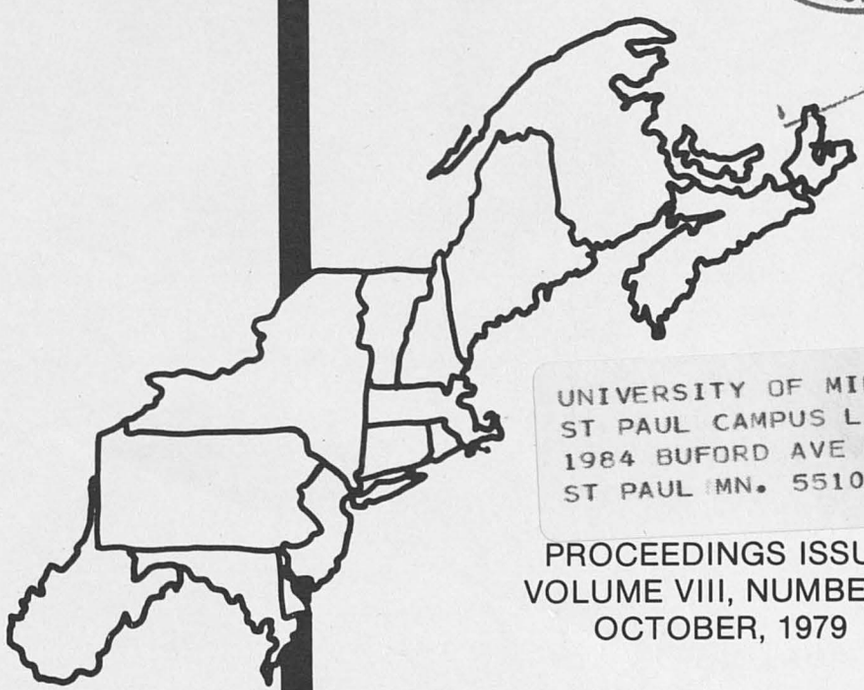

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USE OF MARKOV PROCESSES IN PREDICTING DAIRY FARM SIZE DISTRIBUTION CHANGES

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During the past several decades, a number of research publications have used Markov chain processes to predict changes in number of farm firms, the average size of farms and labor resource productivity in farm production (Conneman, Harris and Wilson, Judge and Swanson, Kottke, Seyala, Willett and Saupe, Wysong and Seyala). The Markov method assumes that the pattern of change exhibited in the past will continue into the future. This method provides information on historical changes by frequency distribution categories as well as for the whole cohort, and allows for projection of these changes into the future. Previous studies have used mainly short-run periods of up to 5 years as the primary data base. This study has considered the use of longer-run base periods of 10 to 20 years combined with periodic updating of sample data in projecting long-term trends in numbers and sizes of dairy farms and revising such projections through time.

Objectives

Objectives of this paper are: 1) to present the Markov chain predictions of numbers and sizes of dairy farms based on a periodically updated Maryland panel of farms and 2) to describe and analyze the causes of the difference in projected and actual numbers.

Brief Review of Literature and Hypotheses

Conneman compared the application and results of the Markov processes with three other methods of agricultural supply analysis on dairy farms in the New York milkshed from 1960 to 1964. The four sets of techniques

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compared by Conneman were: 1) the representative farm, 2) analysis of average relationships, 3) multiple regression analysis and 4) the Markov process. The first approach, the representative farm, basically "consists of selecting a farm to represent each distinct resource situation in an area or region, then deriving supply functions for these farms, and aggregating the individual firm supply functions to provide an estimate of the aggregate supply." (Seyala, p. 117)

"The analysis of average relationships method involves the classification of data into groups on one factor (the independent variable) and determining the corresponding average for a second factor (the dependent variable) for these groups." (Seyala, p. 117)

"The multiple regression analysis method requires the fitting of a mathematical equation showing the quantitative relationship between a dependent variable such as milk production, and a set of independent variables, such as number of cows, production of milk per cow and other variables." (Seyala, p. 118)

"The Markov process method assumes that the pattern of change exhibited in the past period will continue into the future. This method provides information on changes in farm numbers by size distribution categories as well as for the cohort for the past, and projects these changes into the future in a systematic, explicit manner." (Seyala, p. 118)

One of Conneman's conclusions was: "Of the methods investigated, the Markov process seemed to best represent the long-run tendency of the process of change in the industry despite the apparently changing transition probabilities." (p. 215) By using longer-term data collected from a farm panel, this study attempts to apply the implications of the earlier Conneman research specifically to the Maryland dairy industry which was part of the original Conneman study area during the early 1960's.

The addition of new data through time improved the accuracy and usefulness of the estimates of the more distant future "size distribution states." The actual direction and magnitude of change in the means and distributions of dairy farm cow herd sizes was determined from a periodically continuing long-term farm survey sample of the total dairy population in the Central Piedmont area of Maryland.

Procedures and Source of Data

A farm panel of 203 dairy farms in the Central Piedmont area of Maryland was selected and interviewed in 1957 using a stratified, random cluster sampling design. This farm survey panel was used for cross-sectional analysis within years and longitudinal analysis of characteristics over time (Appendix Table 1). In addition to the 1956 data base, those farms which stayed in the milk production business were interviewed in 1966, 1971, and 1976 (Wysong, 1968 and 1969 and Wysong and Seyala, 1977 and 1978). The actual data collected from those four years of personal interviews were used in these Markov chain analyses of different time spans for predicting and analyzing future projections of numbers and sizes of herds in Maryland. Previously existing and enumerated dairy

farms in the 1956 base survey were allowed to reenter the sample. Dairy farms not in the original survey were not added during the 20-year period. This could slightly bias the downward declines in dairy farm numbers when expanded to the six county aggregates or the State of Maryland.

Projected vs. Actual Changes

Using the changes during the 10-year period 1956-66, the numbers and distributions of farms for 1971, 1976 and 1986 were predicted in 1969 using the Markov technique. The predicted 1971 Markov number of 103 farms was substantially higher than the actual number of 90 farms resurveyed in 1971. The predicted 1976 Markov value of 86 farms, based on changes between 1956-66, was markedly higher than the actual number of 73 farms in 1976. The use of the most recent 1966-71 base period as a projection base in 1973 resulted in a projection of 70 farms for 1976. Therefore, use of the 1966-71 base period for projections compared favorably with the actual 1976 figure of 73 farms.

There was not much difference in the projections of farms with 60 or more cows in 1976 using the two different base periods for the predictions. The differences were mainly for the farms falling in herd size classes of fewer than 60 cows.

For 1986, the projection of farm numbers was 65 farms using the 1956-66 base period, compared with only 51 farms using the 1956-71 base period. When the actual changes in dairy farm numbers and sizes between 1971 and 1976 were used as transition probabilities, the projected number of farms was 61 in 1981 and 53 farms in 1986. Net farm exits over the 1956-76 period were entirely farms with herds of fewer than 60 cows. Farms with fewer than 40 cows declined most rapidly between 1956 and 1966. A major exodus of farms with 40-59 cows occurred between 1966 and 1976. Declines in the 60-99 size groupings are projected for 1986. The numerical increase will come in the 100 or more cow category in 1986 (Appendix Table 3). This group increased from 5 in 1956 to 9 in 1966 and 16 in 1971 before reaching 21 farms in 1976. In 1986, 25 farms are projected with 100 or more cows and 24 farms with fewer than 100 cows.

The projected number and distribution was 49 farms for 1986 using actual 1966-76 changes in numbers and sizes (Appendix Tables 4 and 5). This was lower than the projected 51 farms using the 15-year, 1956-71 base and the 65 farms projected using the 1956-66, 10-year period. So the major contribution to projection accuracy by using the longer base periods and the most recent base periods was the result of showing how the mean size of cow herd on dairy farms has actually increased over time as dairymen sought to use more capital inputs to improve their average labor productivity as reflected in cows handled per man and milk sold per man.

Types of Exogenous Changes Which Distort Markov Projections

The differences in the predicted farm numbers using alternative base

periods is dependent on the following basic assumption in the Markov technique: that changes will continue at the same rates in the future as in the past. However, during the latter part of the sixties and early 1970's, the general economy and the labor employment situation was favorable for off-farm work. Jobs off-farm were generally available at higher than farm wage rates; prices of farm real estate especially in the three counties closest to Washington, D.C. and Baltimore, Maryland, were increasing rapidly; farm prices of whole milk were rising slowly; and two drought years in 1966 and 1967 caused some farmers to leave the milk production industry (Wysong, 1965, 1967, 1969). Since 1971, these factors have changed somewhat. Prices of feeds and milk both increased substantially between 1971 and 1976, but feed prices rose relatively more than milk prices during 1973 and 1974. Real estate prices have continued to rise up to the present time. Off-farm jobs generally have been available within reasonable commuting distances. On balance, changes in the factors affecting the dairy industry since 1971 have caused some dairy farmers to stay in business who otherwise would have left the industry under the set of conditions prevailing in the late 1960's. We expect that a few dairy farmers who shifted to other types of farming may come back into dairying if alternative uses of labor and capital decline in profitability and remain depressed until the 1981-86 projection periods become actualities.

In summary, the Markov process gives an explicit prediction. Detailed distributions of actual sizes of herds periodically over time have to be taken into account if the process is to be used effectively in the prediction of farm numbers and sizes. This method does not account for changes in the exogenous factors causing the long-term trend downward in farm numbers and upward in size of cow herds. It cannot and does not give accurate estimates under rapidly changing conditions which cause significant deviations from past trend relationships.

There were 42 Maryland farms with more than 200 milk cows in 1974 according to U.S. Census of Agriculture data. In addition, there were 251 Maryland farms with 100-199 cows, and 1,874 farms with fewer than 100 cows but more than 10 cows in 1974. Farms with 100 or more cows have increased since 1974. Some labor-saving milking systems such as the static herringbone design with pipelines are now being used in Maryland. Data from this research panel over the 1956-76 period have indicated that levels of labor resource utilization could be nearly double the average of 33 cows per man observed in this study if labor-saving, capital intensive technology becomes widely adopted on a commercial basis in the future. In 1976, farms with 150 or more cows averaged over 42 cows per man-equivalent (Wysong and Seyala, 1977, p. 8).

Conclusions

Substantial possibilities exist for adjustments toward larger but fewer dairy farms in 1986. Improved labor resource use with wider adoption of improved types of mechanical technology already used on Maryland

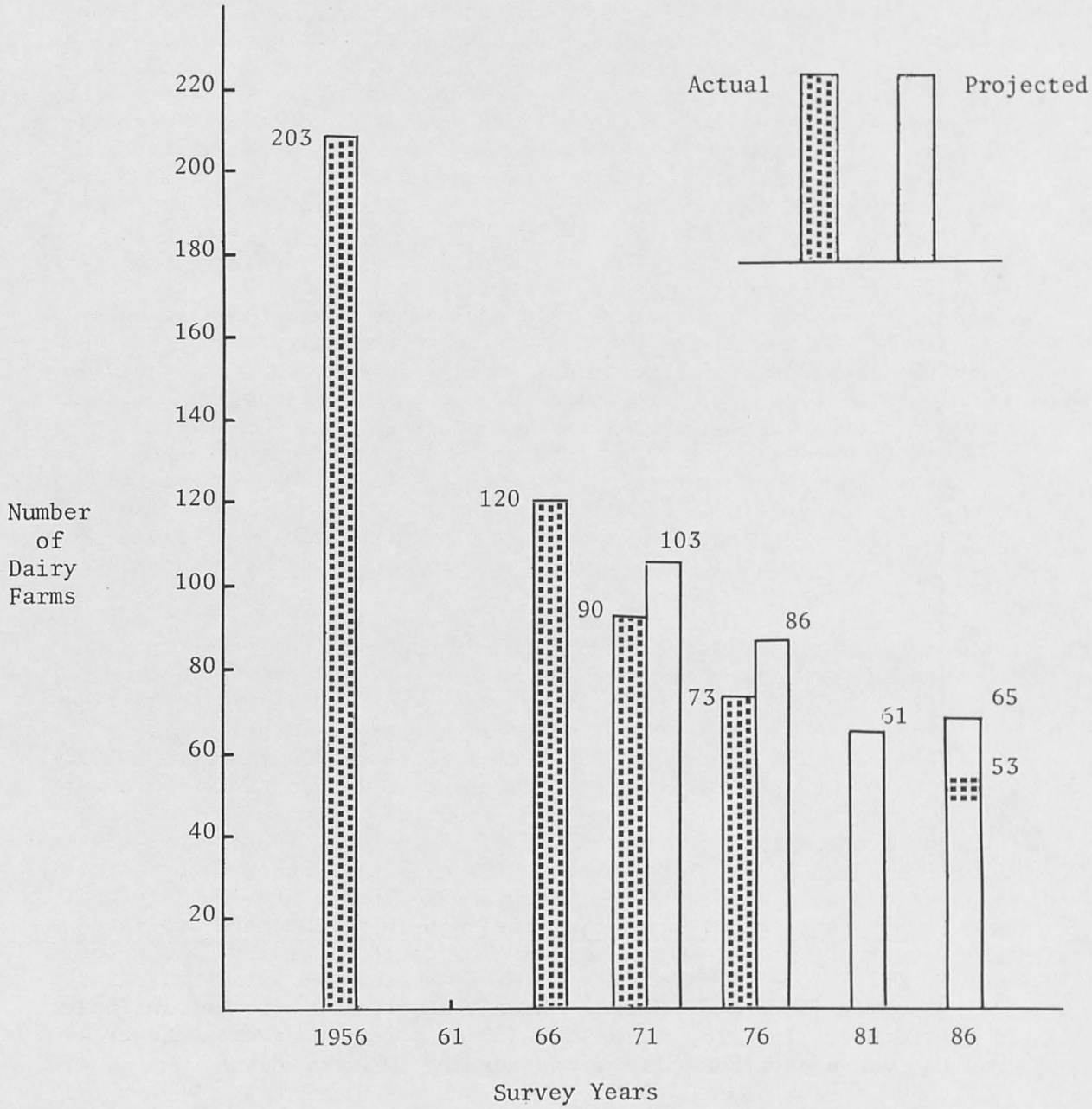

Fig. 1: Actual Numbers of Dairy Farms, Maryland, 1956-76 and Markov Chain Projections for 1971, 1976, 1981 and 1986.

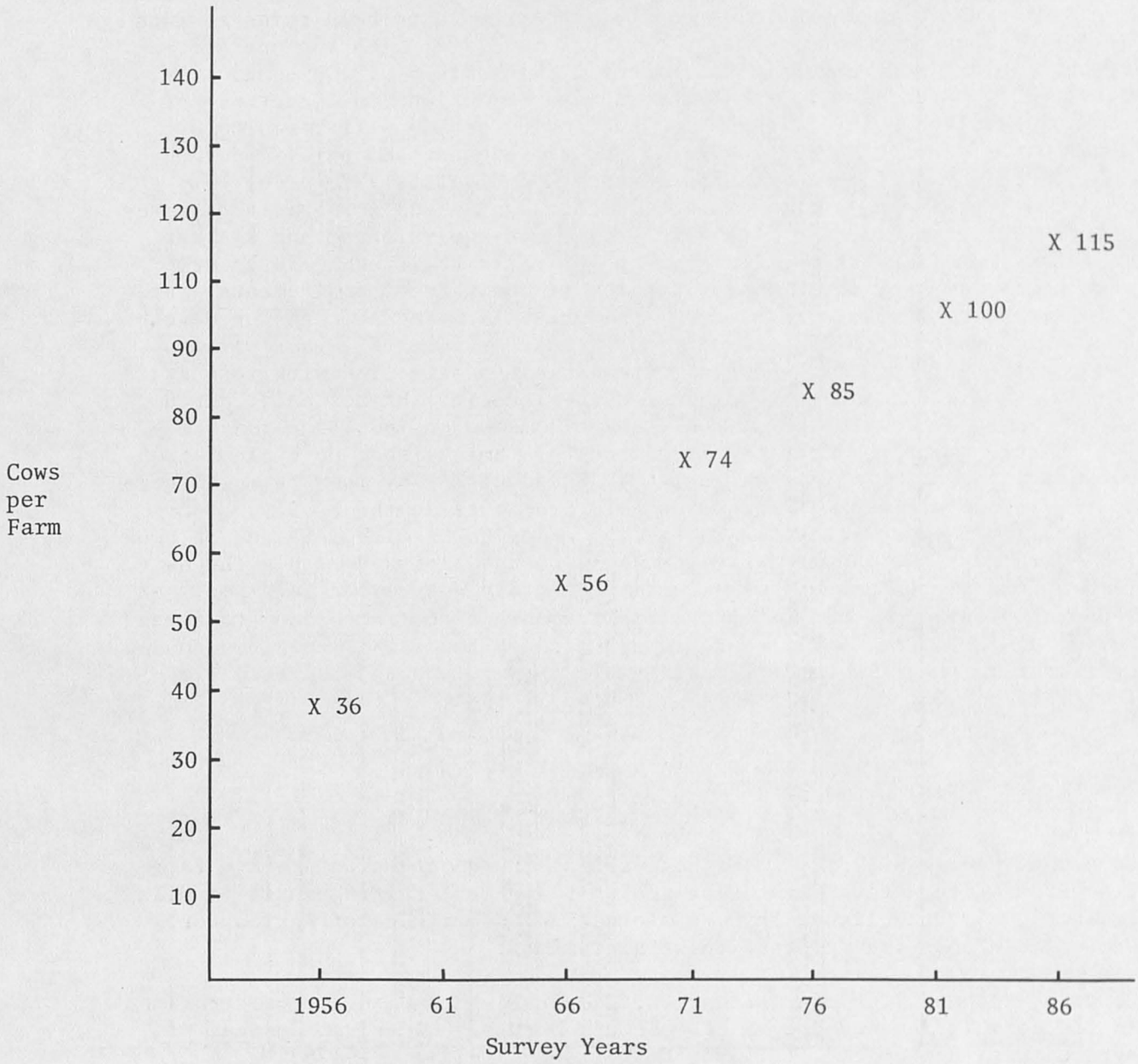

Figure 2. Actual Mean Sizes of Cow Herds, 1956-76 and Projected Mean Sizes 1981 and 1986, Maryland Central Piedmont Dairy Farms.

dairy farms can be observed from the Markov chain analyses and projections. Maryland dairymen and their competitors in other areas of the United States are projected to make new fixed capital investments to help raise average levels of labor use toward the 50 cows per man level with top operators reaching 65 or more cows per man employed (Willett, p. 12, Wysong, 1959, pp. 21-23). According to the Markov chain projections, a larger proportion of Maryland dairy farms during the coming decade will have 100 or more cows. The 150 to 199 cow farms had the highest economic efficiency in 1976 in terms of most measures (Wysong and Seyala, 1977, p. 6).

This Markov projection assumes 1) that typical dairy farm labor force numbers will range from 1.5 to 4 full-time man-equivalents, and 2) that most Maryland dairy farms will continue to raise their own milk cow replacements and provide the major portion of their feed requirements. Some Maryland dairy farms in this study are currently being operated or developed which exceed the 200 cow size that three to four efficient workers can operate effectively. However, the long-term situation with respect to the recruitment and management of higher quality, higher paid, hired labor cannot be determined at the present time on an industry-wide basis.

In the past, the critical importance of family labor on typical two-man dairy farms was in part a result of the decision by many farm managers to try to operate with little or no help from outside the family. Some flexibility in work schedules is sacrificed on farms with only one or two full-time workers. These Markov projections and analyses assume the dairy farm sector of the economy will continue to rely heavily on self-employed labor and managerial resources at least through 1986. According to these Markov projections, family operated and managed farms will continue to characterize the milk production industry in Maryland as mean herd size increases to 100 cows in 1981 and 115 cows in 1986.

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Appendix Table 1. Twenty-five Years of Change on Dairy Farms, Maryland (Panel of 204 Central Piedmont Farms. 1956-76, with estimates for 1981)[a]

Item	Production and marketing year ending				
	1956	1966	1971	1976	Estimated 1981[a]
No. of Farms Surveyed	204	123	90	73	60
Average Man-Equivalent per farm	1.9	2.1	2.1	2.6	2.5
Average No. of Cows	36	56	74	85	100
Annual Mild Sold per Cow					
4% F.C.M.	7,241	9,325	10,476	10,691	11,800
Actual 3.7%	7,702	9,775	11,203	11,265	12,500
Annual Milk sold per farm					
4% F.C.M.	259,000	522,000	781,000	908,000	1,180,000
Actual 3.7%	270,000	554,000	819,000	957,000	1,250,000
Annual Milk sold per man					
4% F.C.M.	141,800	246,700	374,600	352,500	472,000
Lbs. of TDN harvested per man	130,000	223,000	320,000	472,000	600,000
Lbs. of TDN harvested per crop acre	2,700	3,100	3,800	4,700	5,000
Milk sold per crop acre (4%)	2,685	3,395	4,305	3,638	4,500
Cows per man-equivalent	19	26	35	33	40
Crop acres per man	54	73	86	97	120
Crop acres per farm	106	155	181	250	300
Crop acres per cow	2.8	2.8	2.4	2.9	3.0
Blend Price per cwt. (3.7%)	$ 4.99	$ 5.22	$ 6.79	$10.12	$12.00
Gross receipts from milk					
Per farm	$13,089	$28,420	$55,622	$96,824	$150,000
Per man	6,853	12,663	26,644	37,587	60,000
Per cow	384	510	760	1,143	1,500

[a]Estimated by the author.

Appendix Table 2. Projected Changes in the Numbers and Sizes of Dairy Cow Herds in 1986 (Base of 88 Central Piedmont Maryland Dairy Farms, 1971; Based on the Changes Between 1956 and 1971)[a]

Size of Herd Milk Cow Numbers	No. of farms in 1971	Out of business in 1986	Size of Herd Categories and No. of Farms Projected for 1986									
			10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100 or more
10-19	1	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20-29	3	2	0.0	0.2	0.7	0.2	0.1	0.1	0.1	0.0	0.0	0.1
30-39	20	7	0.0	0.0	3.5	2.2	2.6	1.3	1.7	0.0	0.5	1.7
40-49	12	9	0.0	0.0	0.0	0.4	0.9	0.9	0.4	0.4	0.0	0.4
50-59	13	8	0.0	0.0	0.0	0.8	0.8	0.0	0.0	0.0	0.8	2.5
60-69	10	4	0.0	0.0	0.0	0.0	1.1	2.2	0.0	0.0	0.0	2.2
70-79	8	6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0
80-89	2	1	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0
90-99	3	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0
100 or more	16	0	0.0	0.0	0.0	0.0	0.0	3.2	0.0	3.2	0.0	9.6
60 or more	39	11	0.0	0.0	0.0	0.0	1.1	5.4	1.0	3.2	3.0	13.8
All farms	88	37	0	0	4	4	6	8	3	3	4	19

[a]Some Columns and rows are rounded to even numbers.

Appendix Table 4. Projected Changes in Numbers and Sizes of Dairy Cow Herds in 1986 (Base of 73 Piedmont Dairy Farms, 1976; Based on the Actual Changes Between 1966 and 1976)[a]

	Farms in 1976	No. of exits	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100 or more	Total
No. of Reentries			.5				.7						1.2
10-19	1	1											
20-29	5	3		.9	1.4								
30-39	5	2		.4	.4	1.3	.7	.2	.2				
40-49	11	6		.5		1.5	1.0			1.5			
50-59	9	4				.4	.8	1.2	2.5			.4	
60-69	6	3						.4	.4			2.2	
70-79	8	3						1.1		1.1		2.3	
80-89	7	1								2.0		4.0	
90-99	0	0											
100 or more	21	2								2.1		16.8	
60 or more	42	9						1.5	.4	5.2		25.3	
All farms	73	25											
Estimated Farms in 1986			1	2	2	3	3	3	3	7	0	25	49

[a]Some columns and rows are rounded to even numbers.

Appendix Table 5. Relationships Between Cows Per Farm and Cows Per Man, and Pounds of Milk Sold Per Man, Central Piedmont, Maryland, Survey Years, 1956, 1965-66, 1970-71, and 1975-76 and Projected 1986.

Cows per farm	Number of farms					Average Cows per man					Average lbs. of milk sold per man (000)				
	(Year)														
	1956	1966	1971	1976	1986[a]	1956	1966	1971	1976	1986[a]	1956	1966	1971	1976	1986[a]
10-29	92	12	4	6	3	14	19	20	17	20	96	165	199	142	240
30-39	46	27	20	5	2	20	21	27	23	27	148	183	264	206	310
40-49	28	22	12	11	3	20	23	28	23	28	150	204	272	233	325
50-59	16	22	13	9	3	26	25	30	27	32	223	222	319	254	375
60 or more	21	37	41	42	38	27	31	40	37	43	196	309	427	403	495
100 or more	5	9	16	21	25	30	35	43	39	50	188	370	473	434	600
All farms	203	120	90	73	49	19	26	35	33	40	142	247	375	352	480

[a]1986 farm numbers estimated by the authors using Markov Chain method from Appendix Table 4.