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TB102: A Markov Analysis of Structural Change and Output Prediction in the New England Egg Industry

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PREFACE

In recent years there has been a noticeable trend toward a small number of large farms and declining output in the New England egg industry. This study examines changes in the size distribution of egg farms as a Markov process in the three-state region consisting of Connecticut, Massachusetts and New Hampshire. In addition, the future size distribution of egg farms, total number of layers, and egg output are projected. This information should be of interest to input supply firms, farm cooperatives, agricultural policy makers and others interested in the characteristics and trends of the egg industry.

This report is based directly on a portion of the author's doctoral dissertation [8]. As such it is part of a broader study of production response and structural change in the New England egg industry. The author is grateful for the cooperation received from many New England egg producers. Special appreciation is extended to his advisers, Dr. Stanley K. Seaver, Dr. T.C. Lee and Dr. George Ecker, of the Department of Agricultural Economics and Rural Sociology at the University of Connecticut in Storrs. All made a positive contribution through their careful review, critical comments, and helpful suggestions of the author's doctoral dissertation. Also, the thorough review and helpful comments made by Dr. Edward Micka of the Department of Agricultural and Resource Economics at the University of Maine in Orono were very much appreciated. The research reported in this publication was supported in part by funds made available through the U.S.D.A. under the provisions of PL 89-106.

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by

Steven P. Skinner*

INTRODUCTION

The egg industry remains an important part of New England's agricultural economy. However. in recent years there has been a noticeable trend toward a small number of large farms and declining output. The purpose of this study is to examine changes in the size distribution of egg farms as a Markov process in the three-state region consisting of Connecticut, Massachusetts, and New Hampshire. In 1978 these three states together received cash receipts of 83 million dollars from egg sales.

In addition to examining the size distribution of farms, the occurrence of a marked structural change in the egg industry during the period 1967 to 1978 is statistically tested. Also, the future size distribution of egg farms, total number of layers, and egg output are projected. This information should be of interest to input supply firms, farm cooperatives, agricultural policy makers, and others interested in the characteristics and trends of the egg industry.

METHODOLOGY

General Overview

Analysis of the regional egg industry structure was conducted by using the Markov chain technique. Past patterns and changes in the distribution of egg farm numbers by size class were examined. Also, the future industry structure and output were projected by the Markov technique.

This technique has been employed in a variety of ways by economists. For instance, Adelman [1] used Markovian analysis to examine the size distribution of firms within the steel industry. Several other studies have used farm numbers as projected by Markov analysis as weights in the determination of aggregate output levels. For instance, Gates and Kottke [5] weighted and aggregated representative farm step-supply

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functions generated by recursive linear programming to estimate annual milk supply functions for southeastern New England. Milk supply in England and Wales was projected by Coleman and Leech [4] by forecasting the number of producers in each production class. Milk output by farm size class was computed by multiplying the average farm output of each class by the projected number of farms in each class. These class outputs were then summed to determine aggregate milk output. A similar procedure will be employed in the present study. This methodology has the advantage of explicitly considering annual changes in the number of farms in each size class, thus adding a dynamic element to the determination of output.

Markov Chain Model

A general discussion of Markovian analysis is presented here; specific applications will be detailed in later parts of this study.

A stochastic process refers to any sequence of experiments that can be subjected to probability analysis. A discrete-time Markov chain is a stochastic process that satisfies the following three restrictions. First, it must be a discrete-time process. Second, only processes that have a countable or finite state space will be considered. Third, the process must satisfy the Markov property which requires that the outcome of a given experiment depends only on the outcome of the immediately preceding experiment.

A more formal mathematical statement of the above is given by the following definition:

Definition: A finite stochastic process with outcome functions $f_0, f_1, \ldots, f_n$ is a Markov chain process if the starting state, given by f_0, is fixed and

(1) $Pr[f_n=t \mid f_{n-1}=s) \wedge (f_{n-1}=r) \wedge \ldots \wedge (f_1=a)]=Pr[f_n=t \mid f_{n-1}=s]$

(2) $Pr[f_n=t \mid f_{n-1}=s]=Pr[f_m=t \mid f_{m-1}=s]$

for all $m \geq 1$, $n \geq 2$, and any possible sequence of outcomes $a, \ldots, s, t$ [6:148].

The above definition states that a given experiment's outcome depends solely on the immediately preceding experiment's outcome and that this dependence is the same at all stages in the sequence of experiments. An equivalent definition is given below:

> Definition: A Markov chain process is determined by specifying the following information: There is given a set of states $(s_1, s_2, \quad . \quad , s_n)$. The process can be in one and only one of these states at a given time and it moves successively from one state to another. Each move is called a step. The probability that the process moves from s_i to s_j depends only on the state s_i that it occupied before the step. The transition probability, p_{ij}, which gives the probability that the process will move from s_i to s_j is given for every ordered pair of states. Also, an initial starting state is specified at which the process is assumed to begin [6:148].

The probabilities, p_{ij}, that the process will move from state s_i to s_j in the next step can be depicted in the form of a (n x n) transition probability matrix. All entries of this matrix are non-negative and the sum of the probabilities in any row is one. Therefore, each row of the matrix is a probability vector and the transition matrix is a stochastic matrix. A Markov chain process is completely defined by specifying both the transition matrix and an initial starting state vector.

Assume that:

1. The initial size distribution of farms in the industry is given by the following vector:

   $W^0 \quad (w_1, w_2, \qquad , w_n)$,

   W^0 the initial starting state vector of size (1 x n),

   w_i the number of farms in each size category i, where $i = 1, 2, \qquad , n$.

2. The transition probability matrix is:

$$P = \begin{array}{c} \\ s_1 \\ \hline s_2 \\ \cdot \\ \cdot \\ \cdot \\ s_{n-1} \\ s_n \end{array} \left[\begin{array}{c|ccc} s_1 & s_2 & s_{n-1} & s_n \\ p_{1,1} & p_{1,2} & p_{1,n-1} & p_{1,n} \\ \hline p_{2,1} & p_{2,2} & p_{2,n-1} & p_{2,n} \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & & \cdot & \cdot \\ p_{n-1,1} & p_{n-1,2} & p_{n-1,n-1} & p_{n-1,n} \\ p_{n,1} & p_{n,2} & p_{n,n-1} & p_{n,n} \end{array} \right] \quad \left[\begin{array}{c|c} A & C \\ \hline B & D \end{array} \right]$$

where:

- s_1 state for exit and potential entrant farms
- s_i Markov state (farm size class), where $i = 2, \ldots, n$
- P the $(n \times n)$ transition probability matrix
- p_{ij} = probability of moving from state i to state j in one time period
- i row, $i \quad 1, \ldots, n$
- j column, $j \quad 1, \ldots, n$
- $A = p_{11}$
- B = the $[(n-1) \times 1]$ exit vector
- C = the $[1 \times (n-1)]$ entry vector
- D the $[(n-1) \times (n-1)]$ transition matrix excluding the entry and exit vectors.

3. $\sum_{j=1}^{n} p_{ij} = 1$, for $i \quad 1, 2, \ldots, n$

   and

   $p_{ij} \geq 0$ for all i and j

The computation of the transition matrix is straightforward except for the first row, which is the entry vector C. The determination of the elements of this row raises the important matter of how to adequately consider farms that are potential entrants.[1] The farm survey procedure, discussed later in this study, provided an acceptable method for surmounting this potential problem.

Once the initial starting state vector and the transition matrix are known, it is possible to determine what the size distribution of the industry will be in the m^{th} step, or after m periods have elapsed. This process is shown in the following formula:

$$W^{(m)} \quad W^{(0)} P^m$$

where:

$W^{(m)}$ the (1 x n) vector of industry size distribution after the m^{th} period

$W^{(0)}$ = the (1 x n) initial starting state vector of industry size distribution

P^m = the m^{th} power of the transition matrix

m = the number of elasped periods.

Therefore, to determine the vector $W^{(m)}$, whose elements are the number of farms in each of the states after m steps, multiply the vector $W^{(0)}$ by the m^{th} power of the transition matrix P

Estimation and Inference

Six layer size categories, or Markov states, as shown in Table 1, were used to classify sample farms. The first class represents the Markov state that farms leaving the industry join as well as the one from which new firms enter the industry. The second class was designated to begin at 1,600 birds rather than at a smaller number in order to exclude individuals who keep chickens only for non-commercial use. A larger number was not chosen since farms planning to go out of business often decrease the size of their flocks to approximately two to three thousand layers for a few periods prior to actually leaving the industry. Thus, if a larger number were used, some farms still operating commercially might well be excluded as active farms in assessing industry structure.

[1]The reader is referred to an article by Stanton and Kettunen [9] for a complete discussion of the problem posed by potential farm entrants when using Markov analysis for projection purposes.

Table 1. The 1967 Sample Farm Distribution

Markov State	Farm Size Class (no. layers)		Ave. Class Size* (no. layers)	Sample Farms Per Class (no. farms)	Sample Farm Distributio (in percent
1	--		--	12	--
2	1,600	9,999	5,500	362	72.1
3	10,000	19,999	13,500	92	18.3
4	20,000	49,999	27,300	37	7.4
5	50,000	99,999	68,100	8	1.6
6	100,000 or larger		--	3	0.6

*The average class size was determined from a detailed analysis of sample farm sizes. The reader interested in the procedure employed is referred to Skinner [8:33-37].

Movements of individual sample farms among various Markov states for successive years were used to estimate elements of both annual and average transition probability matrices. The maximum likelihood estimates of the elements of the annual transition probability matrices were calculated based on the following formula:[2]

$$(1) \quad \hat{p}_{ij}(t) \quad n_{ij}(t) / \sum_{j=1}^{r} n_{ij}(t)$$

where $\hat{p}_{ij}(t)$ is the estimated probability of moving from state i to state j in one time period and $n_{ij}(t)$ denotes the number of farms that moved from state i in time period (t-1) to state j in time period t. After calculating annual matrices for each successive pair of years from 1967-1968 through 1977-1978, weighted average matrices for the periods 1967-1973 and 1973-1978 were computed. The elements of these matrices were calculated from the following formula:

$$(2) \quad \hat{p}_{ij} \quad \sum_{t} n_{ij}(t) / \sum_{t} \sum_{j} n_{ij}(t)$$

where the summations are over t=1, 2,...,T, and j 1, 2,...,r.

To determine whether annual matrices differed significantly from an average probability matrix, the null hypothesis, H_0: $\hat{p}_{ij}(t) \quad \hat{p}_{ij}$,

[2]For the derivations and details of formulae see Anderson & Goodman [2].

for t 2, ..., T, was tested by calculating a chi-square statistic according to the following formula:

$$(3) \quad \chi^2 \quad \sum_{i}^{r} \sum_{j}^{r} \sum_{t}^{T} n_i \, (t-1)[\hat{p}_{ij}(t) \quad \hat{p}_{ij}]^2/p_{ij}$$

with r(r-1) (T-1) degrees of freedom.

Finally, a transition matrix was tested to see if it was the same as a certain given matrix $[p^*_{ij}]$. The null hypothesis, H_0: $\hat{p}_{ij} \quad p^*_{ij}$, for i, j 1, 2, ..., r. was tested by calculating a chi-square statistic according to the following formula:

$$(4) \quad \chi^2 \quad \sum_{i=1}^{r} \sum_{j=1}^{r} n_i \frac{(\hat{p}_{ij} \quad p^*_{ij})^2}{p^*_{ij}}$$

with r(r-1) degrees of freedom.

FARM SURVEY

A sample survey of egg farms in Connecticut, Massachusetts, and New Hampshire was conducted in order to obtain annual individual farm size data. In addition, information related to production technology employed, marketing arrangements, and characteristics of farmers exiting from the industry was collected. A twelve year period, 1967 to 1978, was used to examine the size distribution of farms and patterns of structural change. This time period was of sufficient length to allow patterns of economic change to develop and thus permit an accurate assessment of industry structure and trends.

A population of 721 egg farms in operation during 1967 was compiled for Connecticut, Massachusetts, and New Hampshire.[3] Optimally, information on annual farm sizes for 1967 to 1978 was desired for every farm in the population. Since the Markov analysis required a large number of farm observations to be accurate, the sampling procedure was simply to contact as many producers as possible.

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[3]Complete lists of egg farms in business during 1967 in Connecticut, Massachusetts, and New Hampshire were obtained, respectively, from the Marketing Division of the Connecticut Agricultural Department, Hartford; Massachusetts Agricultural Department, Boston; and University of New Hampshire, Durham. In addition to the 1967 producer lists, the Farm Bureau Federation provided a 1978 list of member producers for Connecticut, Massachusetts and New Hampshire. Also, the U.S.D.A. furnished 1973 and 1978 lists of egg farms that were producer-packers.

The Connecticut Agricultural Department made available data which yielded 107 individual farm size records for the study period. Also, mail questionnaires and a telephone follow-up procedure were used to gather information on an additional 395 farms. Careful sampling procedure requires that questionnaire information be obtained from non-respondents to insure that their farm characteristics do not differ markedly from respondents. The telephone follow-up procedure revealed that farm sizes and production techniques did indeed differ substantially between respondents and non-respondents. The latter group contained an extremely high percentage of farmers who kept only three to seven thousand layers. Also, a large number of these individuals had gone out of business. These sources together yielded usable records on 502 of the 721 population farms, a very sizable, representative sample.

In addition, more recently dated producer lists were compared with the 1967 farm population to identify new entrants into the egg industry. A new entrant is defined as either a farm that has been out of operation for at least a year and which later resumes production, or a newly built farm which is not an expansion of an already existing farm. Note that the unit of inquiry is the farm itself, not the operator. Any operators appearing only on the more current lists were contacted to ascertain whether their farms qualified as new entrants. This procedure identified 12 new entrants into the industry during the study period. Therefore, this study was based on a sample of 514 farms.

ANALYSIS OF EGG INDUSTRY STRUCTURE

The Markov analysis required calculating both annual and average transition probability matrices for the study period. In general, the elements of a probability matrix depict the probabilities of a farm moving from state i during period t to state j at time t+1. More specifically, the elements of the annual transition matrices were estimated from micro data describing the movements of individual sample farms among various size classes for successive years. For example, the 1967-68 annual matrix depicts the probability of an individual farm moving from its 1967 size class to that of any size in 1968, including remaining in its present size class.

After calculating annual matrices for each successive pair of years from 1967-68 through 1977-78, an average matrix for the study period, 1967-78, was computed. This matrix is an average or composite of the 11 annual matrices, 1967-68 through 1977-78, and is shown in Table 2.[4]

Average Transition Probability Matrix

An examination of the average matrix for 1967-78 (Table 2) provides useful information on the dynamic patterns of change in the regional egg industry. Note that elements on the diagonal of the transition matrix are all larger than the other probabilities in each row. This indicates that the strongest tendency is for producers to remain in the same size class from one period to the next. For example, there was approximately an 87 percent probability that farms in classes 2 and 3, respectively, would remain in their present size classes the following period (given $\hat{p}_{22}$ 0.8653 and $\hat{p}_{33} = 0.8715$). This probability increases to over 90 percent for larger farms in states 4, 5, and 6. In particular, producers with more than 100,000 layers have almost a 98 percent probability of remaining in that size class with only about a 2 percent chance of decreasing to a smaller size or going out of business.

Table 2. Regional Egg Industry Average Transition Probability Matrix for 1967-78*

Markov States (time t)	Markov States (time t + 1)					
	1	2	3	4	5	6
1	0.9927	0.0006	0.0011	0.0045	0.0011	0
2	0.1086	0.8653	0.0218	0.0043	0	0
3	0.0736	0.0304	0.8715	0.0234	0.0012	0
4	0.0177	0.0044	0.0199	0.9095	0.0442	0.0044
5	0.0135	0	0	0.0207	0.9054	0.0541
6	0.0120	0	0	0.0120	0	0.9759

*Based on annual sample farm size data for the period 1967-1978.

[4]A computer program written by Dr. T.C. Lee, Professor of Agricultural Economics and Rural Sociology, University of Connecticut, was used to make all Markov Chain Calculations.

The relatively high probability of farms remaining in the same size class from year to year is due in part to the number of size classes and their widths as selected for use in this study. A larger number of classes would permit narrower class widths which in turn would allow detection of smaller period-to-period shifts in farm size. Nevertheless, the general tendency is for producers to annually house approximately the same number of layers.

Markov state 1 represents the class that farms going out of business join, as well as the one from which new farms enter the industry. As revealed by the elements of the first row, there was less than a 1/2 percent chance of a farm entering the egg industry at any size. By far the greatest tendency was for farms leaving the industry never to return and for new farms to enter the industry with only a very small probability.

Further examination of this matrix reveals that farms in state 2 have almost an 11 percent chance of exiting from the industry ($\hat{p}_{21}$ 0.1086) from year to year In contrast, they have only a 2.6 percent probability of expanding their size by one or two classes. Farms in the 10,000 19,999 class, state 3, also only have about a 2 1/2 percent chance of increasing their size by one or two classes. They have a 3 percent probability of decreasing their size by one class and over a 7 percent probability of going out of business.

Producers in state 4 have almost a 5 percent probability of expanding in size and slightly over a 4 percent chance of contracting in size or exiting from the industry. Similarly, farms in state 5 have approximately a 5 percent probability of moving to state 6 in the next period and only a 3 1/2 percent chance of decreasing in size or going out of business.

In contrast to the smaller size operations, farms in state 6 ($\geq$ 100,000 layers) almost universally remain in that size class as evidenced by $\hat{p}_{66}$ 0.9759.

Annual Transition Probability Matrices

Examination of the average transition matrix revealed general patterns of movement among different farm size classes over the period 1967-1978. Additional insights into the egg industry structure can be obtained by considering the annual transition matrices, shown in Table 3.

Table 3. Regional Egg Industry Annual Transition Probability Matrices for 1967-68 to 1977-78*

Markov States (time t)	Markov States (time t+1)					
	1	2	3	4	5	6
			1967-68			
1	0.8333	0	0.0833	0.0833	0	0
2	0.0994	0.8867	0.0110	0.0028	0	0
3	0.0652	0.0435	0.8587	0.0326	0	0
4	0	0	0	0.9459	0.0541	0
5	0	0	0	0	0.8750	0.1250
6	0	0	0	0	0	1.0000
			1968-69			
1	1.0000	0	0	0	0	0
2	0.0862	0.8923	0.0185	0.0031	0	0
3	0.0476	0.0238	0.9048	0.0238	0	0
4	0.0250	0	0.0250	0.8500	0.0500	0.0500
5	0	0	0	0	1.0000	0
6	0	0	0	0	0	1.0000
			1969-70			
1	0.9529	0	0	0.0235	0.0235	0
2	0.0753	0.8767	0.0377	0.0103	0	0
3	0.0361	0.0120	0.9036	0.0482	0	0
4	0.0270	0.0270	0.0270	0.8378	0.0811	0
5	0.0909	0	0	0	0.7273	0.1818
6	0	0	0	0	0	1.0000
			1970-71			
1	0.9907	0	0	0.0093	0	0
2	0.0698	0.8915	0.0349	0.0039	0	0
3	0.0345	0.0115	0.9310	0.0230	0	0
4	0.0250	0	0.0250	0.9000	0.0500	0
5	0	0	0	0	0.9231	0.0769
6	0.1250	0	0	0	0	0.8750
			1971-72			
1	0.9769	0	0.0077	0.0154	0	0
2	0.0823	0.8831	0.0260	0.0087	0	0
3	0.0440	0.0330	0.9011	0.0220	0	0
4	0	0	0.0250	0.9500	0.0250	0
5	0	0	0	0.1429	0.8571	0
6	0	0	0	0	0	1.0000

Table 3. Regional Egg Industry Annual Transition Probability Matrices for 1967-68 to 1977-78* (Concluded)

Markov States (time t)	Markov States (time t+1)					
	1	2	3	4	5	6
			1972-73			
1	0.9867	0	0	0.0133	0	0
2	0.0966	0.8792	0.0193	0.0048	0	0
3	0.0667	0.0333	0.8889	0.0111	0	0
4	0.0217	0	0.0435	0.8913	0.0435	0
5	0	0	0	0	1.0000	0
6	0	0	0	0	0	1.0000
			1973-74			
1	1.0000	0	0	0	0	0
2	0.1351	0.8486	0.0162	0	0	0
3	0.0930	0.0233	0.8605	0.0233	0	0
4	0.0222	0	0	0.9333	0.0444	0
5	0	0	0	0	1.0000	0
6	0	0	0	0	0	1.0000
			1974-75			
1	1.0000	0	0	0	0	0
2	0.1950	0.7862	0.0126	0.0063	0	0
3	0.1558	0.0390	0.7922	0.0130	0	0
4	0.0227	0.0227	0.0455	0.8864	0.0227	0
5	0	0	0	0.0588	0.8824	0.0588
6	0	0	0	0	0	1.0000
			1975-76			
1	0.9960	0.0040	0	0	0	0
2	0.2171	0.7674	0.0155	0	0	0
3	0.1385	0.0462	0.8000	0.0154	0	0
4	0.0238	0	0	0.9524	0.0238	0
5	0	0	0	0.0625	0.8750	0.0625
6	0	0	0	0	0	1.0000
			1976-77			
1	1.0000	0	0	0	0	0
2	0.1553	0.8252	0.0194	0	0	0
3	0.0926	0.0556	0.8148	0.0185	0.0185	0
4	0	0	0.0238	0.9286	0.0476	0
5	0	0	0	0	0.9333	0.0667
6	0	0	0	0	0	1.0000
			1977-78			
1	1.0000	0	0	0	0	0
2	0.1250	0.8523	0.0227	0	0	0
3	0.0638	0.0213	0.8936	0.0213	0	0
4	0.0250	0	0	0.9250	0.0500	0
5	0.0588	0	0	0	0.8824	0.0588
6	0	0	0	0.0909	0	0.9091

*Based on annual sample farm size data for the period 1967-1978.

A time series for each individual calculated $\hat{p}_{ij}$ can be constructed from the 11 annual matrices. For example, beginning with the 1967-68 matrix, there is nearly a 10 percent probability of a farm in state 2 exiting from the industry ($\hat{p}_{21}$ 0.0994). By considering successive annual $\hat{p}_{21}$'s for the entire study period, the pattern of farm exits is more saliently portrayed than if one considered merely the average matrix value of $\hat{p}_{21}$ from 1967 to 1978 (p_{21} 0.1086).

Note that the annual values of $\hat{p}_{21}$ remained within a 7 to 10 percent range during the period 1967-68 through 1972-73. However, beginning in 1973-74, the probability of exit for a state 2 farm increases to 13.5 percent. This rate of exit continues to climb to 19.5 percent and 21.7 percent for the periods 1974-75 and 1975-76, respectively. Thereafter, the rate begins to shift back to earlier levels with 15.5 percent and 12.5 percent rates of exit calculated for the years 1976-77 and 1977-78, respectively.

An examination of the annual $\hat{p}_{31}$'s (rate of exit probabilities for a state 3 farm) reveals a similar trend of increasing probabilities of exit between 1973-77, with a leveling off by 1977-78. Although similar trends of exit prevail between the state 2 and state 3 farms, the probabilities of exit for the latter size farm are invariably smaller. For example, in 1974-75 the rate of exit for a class 3 farm peaked at 15.5 percent whereas in the same time period a state 2 farm experienced a 19.5 percent exit rate, with a peak of 21.7 percent not occurring until the 1975-76 period. Reciprocally, during the periods of high exit rates for state 2 and 3 farms, the probabilities of remaining at the same size or expanding to a larger size diminished. However, even during the period in which these smaller farms exhibited the greatest probabilities of expanding, 1969-70, only 4.8 percent increased their size by one or more classes.

In contrast, larger size farms were characterized by greater stability and significantly less tendency to reduce size or exit from the industry. This is especially evident when contrasted with the period of high exit for size 2 and 3 farms, 1973-74 through 1976-77. During this period, farms in size class 4 averaged about a 2 percent probability of exit whereas those in classes 5 and 6 evidenced zero probabilities of exit.

While averaging approximately a 5 percent probability of expanding to sizes 5 and 6 over the entire study period, farms in size class 4 experienced their lowest expansion probability of 2.3 percent in 1974-75 and their greatest expansion probability, 10 percent, in 1968-69. A similar trend prevailed for farms in class 5, averaging 5.5 percent over the 1967-78 period, with a peak expansion rate of 18 percent in 1969-70 and a zero probability of expanding from 1971-74. Farms in class 6 are by far the most stable. In 9 of the 11 transition periods, no farm in this class reduced its flock size below 100,000 birds.

STRUCTURAL CHANGE IN THE EGG INDUSTRY

A Statistical Examination

The rapid increases in the rates of exit for state 2 and 3 farms during the period 1973 to 1977 suggested a dramatic shift in the size distribution of the region's egg farms. In order to support the hypothesis of a structural change during the period 1967 to 1978, average transition probability matrices were calculated for the two periods 1967-1973 and 1973-1978 and statistically compared.

Tables 4 and 5 depict the average probability matrices for the periods 1967-1973 and 1973-1978, respectively. A stationarity test was first performed on each of these matrices using formula (3). The calculated chi-square values of 101.3 for 1967-1973 and 45.6 for 1973-1978 with 180 and 150 degrees of freedom, respectively, support the hypothesis of stationarity within each period at the 1 percent significance level.[5] Therefore the average transition matrices represent the stationary Markov chain for the corresponding periods.

[5]For degrees of freedom n greater than 30, chi-square values are not available in most statistical tables. However, the transformed variable $z \quad \sqrt{2x^2} \quad \sqrt{2n - 1}$ is approximately distributed as a standard normal. In the stationarity tests, the z values are -47.1 and -7.74 respectively, and their absolute values are greater than the standard normal table value of 2.58 at 1 percent significance level.

Table 4. Regional Egg Industry Average Transition Probability Matrix for 1967-1973*

Markov States (time t)	Markov States (time t+1) 1	2	3	4	5	6
1	0.9777	0	0.0037	0.0149	0.0037	0
2	0.0854	0.8854	0.0239	0.0054	0	0
3	0.0493	0.0266	0.8975	0.0266	0	0
4	0.0167	0.0042	0.0250	0.8958	0.0500	0.0083
5	0.0147	0	0	0.0294	0.8971	0.0588
6	0.0270	0	0	0	0	0.9730

*Based on annual sample farm size data for the period 1967-1973.

Table 5. Regional Egg Industry Average Transition Probability Matrix for 1973-1978*

Markov States (time t)	Markov States (time t+1) 1	2	3	4	5	6
1	0.9992	0.0008	0	0	0	0
2	0.1672	0.8148	0.0166	0.0015	0	0
3	0.1125	0.0365	0.8298	0.0182	0.0030	0
4	0.0188	0.0047	0.0141	0.9249	0.0376	0
5	0.0125	0	0	0.0250	0.9125	0.0500
6	0	0	0	0.0217	0	0.9783

*Based on annual sample farm size data for the period 1973-1978.

The hypothesis of structural change was then tested by using formula (4) to compare the two stationary transition matrices. Each matrix was tested against the other matrix for a significant difference. The conclusion remained the same regardless of whether the 1967-1973 or 1973-1978 matrix was considered given. The calculated chi-square values are 131.3 and 122.9, respectively, and are greater than the table value of 50.9 with 30 degrees of freedom. The hypothesis that the two stationary transition matrices are the same thus is rejected at the 1 percent significance level. Therefore, the existence of a significant structural change occurring within the period 1967 to 1978 is statistically confirmed. Moreover. this change in the regional egg industry structure began to evolve in 1973.

A Descriptive Analysis

A comparison of the matrices for these two periods reveals substantially different average probabilities of movement for state 2 and 3 farms. Specifically, the probability of a state 2 farm leaving the industry increased from $\hat{p}_{21}$ 8.5 percent during the 1967-1973 period to $\hat{p}_{21}$ 16.7 percent in 1973-1978. Similarly, farms in class 3 exhibited a pattern of increased exit from the industry. During the years 1967-1973 the probability of going out of business was $\hat{p}_{31}$ 4.9 percent. This rate of exit more than doubled to $\hat{p}_{31}$ 11.2 percent in the 1973-1978 period.

Whereas major divergences between the calculated probabilities of movement for the two time periods exist for state 2 and 3 farms, the larger farm sizes evidence a greater degree of stability over the entire study period. In a comparison of matrices, probabilities of movement calculated for the years 1967-1973 and 1973-1978 for farms in classes 4, 5, and 6 differ far less in magnitude. For instance, farms in size class 4 over the years 1967-1973 experienced a 5.8 percent average probability of increasing one or more size classes; over the years 1973-1978 a slight dampening of this rate of expansion resulted in a 3.8 percent average probability.

The increased exit rate of farms in classes 2 and 3 during the period 1973 to 1977 suggested the presence of some element(s) of instability in the egg industry. A review of all potential causes of structural change, including changes in key economic, social, and institutional variables, indicated that feed price had markedly increased. Egg price also increased at the same time, although at a relatively slower rate than feed price. For example, the average prices of laying mash during the periods 1967-1972 and 1973-1978 were \$3.82 and \$6.98, respectively. This represented an 83 percent increase. In contrast, egg prices averaged 34 1/2¢ and 54¢ per dozen during the same periods, respectively. This amounted to only a 57 percent increase. Thus the dramatic rise in feed price was considered to be the major catalyst of structural change. The effect of this feed price increase is indicated by questionnaire responses from farmers who had exited from the industry. Most cited low economic returns, and in many cases specifically the feed price increase, as their primary reason for leaving the industry.

Several events contributed to this price rise. First, a generally tight feed grain situation occurred as a result of poor crops and strong demand due to markedly expanded grain exports. Second, in the fall of 1973, the Organization of Petroleum Exporting Countries initiated an oil embargo against the United States which sharply raised not only oil prices, but also contributed to the approximate doubling of the price for fertilizer. a petroleum-based product. This in turn raised the price of grain products. Together, these events boosted the price of feed to record levels.

Another important factor placing pressure on state 2 and 3 farmers to exit was the type of production technology utilized by them. Over 90 percent of all exit farms employed older floor-type laying houses, with the remainder being cage-type systems. The adoption of the more modern cage-type laying house has progressively reduced the cost of producing a dozen eggs as compared to the floor system. It has greatly reduced labor requirements, especially the fully-automated house, while dramatically increasing the number of layers housed within a given floor space. These factors have placed pressure on farmers with floor-type operations in need of replacement to either modernize their facilities or leave the industry. Many of these producers had decided, prior to the 1973 grain price increase, to remain at their present size and technological state of production and then eventually either retire or find off-farm work. However, the sudden and dramatic increase in feed prices resulted in many producers leaving the industry at a much earlier date than planned.

Two large farm operations, each housing more than 100,000 layers, were also observed to decrease their operations significantly. Both were characterized by older, labor-intensive, floor-type laying houses. Due to their heavy reliance upon an abundant supply of cheap labor and its growing scarcity, their operations were greatly curtailed. This eventually led to one producer exiting from the industry in 1971. In addition, the other operator was adversely affected when part of his land complex was zoned out of farm use. The pressures of urban-industrial expansion along with the absence of a satisfactory source of labor thus served to reduce this farm's size to the 20,000 49,999 class. In contrast, most farms housing more than 100,000 layers employ more technologically advanced laying houses as part of a vertically integrated operation, therefore either maintaining or expanding production.[6]

Characteristics of Exit Farms

Based on questionnaire responses, a profile of the distinguishing characteristics of exit farms can be formed. Between the years 1967 and 1979, 327 of the 514 farms sampled went out of business, leaving only 187 sample farms still in production during 1979. As noted in Table 6, 96.7 percent of all exit farms were in size classes 2 and 3. More specifically, over 77 percent were in class 2 and approximately 19 percent in class 3. Though some farms reduced their flock size from larger classes before going out of business, most size categories from which farms exited represented their maximum farm capacity.

Table 6. Distribution of Exit Farms by Size Class

	Farm Size Class					
	2	3	4	5	6	Total
Number of Exiting Farms	253	63	8	2	1	327
Percent Distribution	77.4	19.3	2.4	0.6	0.3	100
Type of Laying House:						
Floor System	253	39	5	1	1	299
Cage System		24	3	1		28

Table 6 also depicts that in addition to most exit farms being of small size, 299 or 91 percent were floor-type laying operations. In contrast, only 28 exit farms were cage-type systems.

[6]It is not the intention of this study to address all factors affecting egg industry structure. For a comprehensive treatment of this topic the reader is referred to an excellent article by Rogers [7].

Although it may be useful to examine the type of marketing outlets employed by exiting farms, many had several markets for their eggs, making it very difficult to define the exact percentage of their production sold in each. For instance, a typical state 2 or 3 farm may market its eggs primarily through a wholesaler or dealer, as well as directly retailing a portion of its output. Therefore, Table 7 gives only a general indication of the relative importance of various marketing outlets. Wholesale and retail outlets were most common, while approximately one-third of all producers marketed eggs through a cooperative. Only a small number of exit farms were contract producers.

Table 7. Market Outlets of Exit Farms*

(in percent)	
Wholesale (dealer)	47
Retail	41
Cooperative	31
Contract Producer	9

*Percent distribution will not total 100 since many farms have several market outlets.

The ages of operators who went out of business were not evenly distributed, as shown in Table 8. Approximately 84 percent of operators were over 50 years of age; 59.1 percent were over 60 years old. In contrast, farmers under the age of 50 comprised only 16 percent of the exit operations.

Table 8. Exit Farmer Age Distribution

(in percent)

Age Category	Percent Distribution
20 29	2.3
30 39	4.5
40 49	9.1
50 59	25.0
60 and Over	59.1
	100.0

Farmers were asked to rank in order of importance their reason(s) for going out of business. These responses are listed in Table 9, with primary and secondary reasons for exiting noted in columns (1) and (2), respectively. The most frequently cited prime reason for leaving the egg industry was a low economic return. Retirement was the next most common reply, followed by sickness, labor problems, off-farm job and lack of sufficient market outlet. Secondary reasons for leaving the industry are found in column (2). Note that a more balanced, even distribution prevailed among these reasons. Interestingly, the most frequently reported secondary reason for going out of business was to take an off-farm job. This was followed in importance by low economic return, insufficient market outlet, and labor problems. In neither case was lack of capital to expand business cited as an important reason for exiting.

Table 9. Producer Reasons for Exiting From the Egg Industry

(in percent)

	(1) Primary Reason	(2) Secondary Reason
Low Economic Return	36.7	23.4
Retirement	30.6	10.5
Sickness	10.2	--
Labor Problems	8.2	12.2
Took Off-Farm Job	8.2	26.3
No Market Outlet	4.1	21.5
Lack of Capital to Expand	2.0	6.1
	100.0	100.0

In summary, exit farms were generally of small size and used older, outmoded production techniques. A large number of these farms marketed their product through wholesalers and cooperatives. Many also retailed a portion of their output; only a small number. however, were contract producers. Over 80 percent of the operators were more than 50 years old. The most commonly cited primary reasons for going out of business were a low economic return and retirement. Secondary reasons noted were a lack of a sufficient market outlet and off-farm job opportunities.

PROJECTION OF FARM NUMBERS

The recursive relation of the Markov process, $n(t) \quad n(t-1)P$, where $n(t)$ is a distribution vector in period t and P is a transition probability matrix, was used to project the number of egg farms in each size class. In order to project future farm numbers, the initial distribution of farms by size class must be known. Although the regional egg farm population (farms housing more than 1,600 layers) in 1967 was 721 farms, the size distribution of farms was unknown. Therefore, to determine the initial state vector for 1967 it was assumed that the population of farms had the same percentage distribution as farms in the sample.[7] This distribution is shown in the last column of Table 1.

The farm number projections for the period 1967-1988 are shown in Table 10. The 1967-1973 transition matrix was used to make projections for that period whereas the 1973-1978 matrix was employed to project farm numbers from 1974 to 1979 and selected future years. This projection procedure appeared reasonable given the occurrence of structural change beginning in 1973.

The most marked shifts in farm numbers were projected for classes 2 and 3 over the years 1967 to 1988, with rapid declines from 520 to 22 and 132 to 16 farms, respectively. The number of farms in class 4, in contrast, rises slowly from 1967 to 1973, and then slowly decreases. The class 5 population shift is characterized by an initial slow growth in the number of farms through 1977, followed by a period of zero growth through 1982, and a slow downward trend beginning in the mid 1980's. This slow decrease in farm numbers may reflect the movement of some state 5 farms into size class 6, with a slower rate of entrance into class 5 from smaller classes to offset the upward movement of these expanding farms. An invariant increase in farms of size greater than 100,000 birds is observed over the entire period, 1967-1988.

[7]The adequacy of both the sample size and the precision and reliability of individual sample estimates are assessed in Skinner [8:114-17]. Based on this evaluation it appeared reasonable to use the 1967 sample distribution of farm sizes to infer the population distribution.

Table 10. Projection of Regional Egg Farm Numbers, By Size Class, 1967-1979, 1982, 1985 and 1988

Year	Class 1 Exit Entry Pool	Class 2 1,600- 9,999	Class 3 10,000- 19,999	Class 4 20,000- 49,999	Class 5 50,000- 99,999	Class 6 More Than 100,000
1967	12	520	132	53	12	4
1968	64	464	132	55	13	5
1969	110	415	131	56	15	6
1970	150	371	130	58	17	7
1971	187	332	127	60	18	9
1972	219	298	124	62	20	10
1973	247	267	121	65	22	11
1974	307	222	106	63	23	12
1975	357	185	92	62	24	13
1976	399	155	81	60	24	14
1977	435	130	70	58	25	15
1978	467	109	61	56	25	15
1979	492	92	53	54	25	16
1982	550	55	36	48	25	19
1985	587	34	24	43	24	21
1988	611	22	16	38	23	23

Despite a slight increase in class 6 farms, the total farm population decreased dramatically. By 1976 the three-state egg industry consisted of less than one-half the number of farms operating in 1967 This trend is projected to continue into the future with only 25.4 percent and 16.9 percent as many farms remaining in business in 1982 and 1988, respectively. In addition, there is a marked change in the number of farms in each size class over time. For instance, in 1967 state 2 farms comprised 72 percent of the farm population; by 1988 this class is projected to account for only 18 percent of total farm numbers. In contrast, class 6 farms represented only 0.5 percent of all farms in 1967. However. by 1988 they are predicted to make up 19 percent of the population.

PROJECTION OF LAYER NUMBERS AND EGG OUTPUT

The annual numbers of layers in size classes 2 through 5 were determined by multiplying the number of farms in each class, as projected by the Markov analysis, by the average layer size of each class (shown in column 3 of Table 1). This method could not be used to project layer numbers for class 6 because it is defined as an open interval with no upper bound ($\geq$ 100,000 layers) and thus has no meaningful class mid-point. Instead, the total number of farms in this class and their annual sizes for the period 1967-1978 were determined from confidential records and interviews. Regression analysis then was used to predict class 6 layer numbers for 1979, 1982, 1985 and 1988. The projected layer numbers for farm size classes 2 through 6 were then summed to obtain the projected regional total number of layers for each study year. These layer projections by size class are shown in Table 11.

The projection procedure used for classes 2 through 5 is reasonable since changes in individual farm size usually result from either an expansion or contraction in capacity by a large enough increment to cause reclassification of the farm into another size class. Also, this method of output determination closely conforms to and reflects the actual ongoing process by which changes in industry output occur. That is, although many farms remain at the same size for a number of years, some choose to either expand or contract their capacity, while still others leave the industry. It is the net effect of these individual farm changes that causes industry output to vary.[8]

Underlying this process of change is the role played by technology; its adoption is often cited as the major reason for increases in output. According to Cochrane, "technological advance is the dynamic force in agriculture, being involved in almost all production adjustments and explaining net increase in output on individual farms and in the aggregate" [3:1168]. In Cochrane's view the typical farmer seldom adds more of the same type of capital; rather the producer adopts an improved resource mix based on new technology. This process accurately characterizes the egg industry where technological progress has been rapid, although its adoption has been at a differential rate.

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[8] In this study, output also changes due to the assumed increases in the rates of lay over the study period and the regression analysis prediction of class 6 layer numbers.

Table 11. Projection of Regional Egg Output and Total Number of Layers by Size Class, 1967-1979, 1982, 1985 and 1988

Year	Size Class					Total Layer Numbers		Percent	Rate of Lay**	Egg Output Projected
	2	3	4	5	6	Projected	USDA*	Deviation	(eggs/year)	(million dozens)
	(1,000 layers)									
1967	2,860	1,782	1,447	817	563	7,469	7,933	- 5.8	221	137.6
1968	2,552	1,782	1,502	885	823	7,544	7,818	- 3.5	221	138.9
1969	2,283	1,769	1,529	1,022	1,022	7,625	8,006	- 4.8	220	139.8
1970	2,041	1,755	1,583	1,158	1,322	7,859	7,895	- 0.5	222	145.4
1971	1,826	1,715	1,638	1,226	1,115	7,520	7,353	+ 2.3	225	141.0
1972	1,639	1,674	1,693	1,362	1,205	7,573	7,641	- 0.9	232	146.4
1973	1,469	1,634	1,775	1,498	1,313	7,689	7,754	- 0.9	229	146.7
1974	1,221	1,431	1,747	1,566	1,358	7,323	7,111	+ 2.6	232	141.6
1975	1,018	1,256	1,693	1,634	1,627	7,228	6,923	+ 4.2	236	142.2
1976	853	1,094	1,638	1,634	1,902	7,121	6,783	+ 5.0	238	141.2
1977	715	959	1,583	1,703	2,082	7,042	5,990	+17.3	238	139.7
1978	600	837	1,529	1,703	2,139	6,808	6,076	+11.8	240	136.2
1979	506	716	1,474	1,703	2,321	6,720	--	--	243	136.1
1982	303	486	1,310	1,703	2,807	6,608	--	--	249	137.1
1985	187	324	1,174	1,634	3,292	6,611	--	--	255	140.5
1988	121	216	1,037	1,566	3,778	6,718	--	--	261	146.1

*Agricultural Statistics, U.S.D.A.

**The rates of lay for 1967 through 1978 are the weighted averages of figures for Connecticut, Massachusetts and New Hampshire reported in Agricultural Statistics, U.S.D.A. The weights are the number of layers in each state and are approximately 65 percent, 25 percent and 15 percent for Connecticut, Massachusetts and New Hampshire respectively. The rates of lay for 1979 through 1988 are linear projections on an increment of two eggs per year

Table 11 indicates that when annual layer projections for 1967-1978 are compared with layer totals reported by the U.S.D.A., the calculated values range within 0.5 percent to 5.8 percent of the U.S.D.A.'s for the years 1967-1976, An unexplained marked decrease in layer numbers reported by the U.S.D.A. for 1977 and 1978 accounts for the larger discrepancies with projected numbers for these years.

An examination of Table 11 indicates that layer numbers for the years 1979, 1982, 1985, and 1988 will stabilize at an approximate level of 6.6 to 6.7 million birds. Although layer numbers are projected to stabilize, the distribution of layers by farm size class will continue to shift. For example, in 1967 farms in states 2 and 3 housed approximately 62 percent of all layers; farms in states 5 and 6 only 18 percent. By 1978 this situation had reversed with state 2 and 3 farms housing only 18 percent of all layers while farms 5 and 6 housed 60 percent. This trend is expected to continue with state 5 and 6 farms projected to house 80 percent of all layers by 1988. Thus production responses of farms in these classes can be expected to noticeably affect future regional output. Also external events affecting the egg industry must be interpreted through the responses of these larger-size farms.

Egg output, shown in the last column of Table 11, was calculated by multiplying the projected number of layers by the rate of lay. In general, egg output parallels trends in projected layer numbers. Egg output was projected to reach a peak of 146.7 million dozens in 1973. Although output exhibits a fluctuating pattern of increase for the years 1967 to 1973, a steady downward trend was observed beginning in 1975 and continuing through 1979. In the 1980's egg output is predicted to show slight increases from approximately 137 to 146 million dozens, due primarily to increased rates of lay.

SUMMARY AND CONCLUSION

Markov chain analysis was employed in order to determine past trends in industry structure, as well as to project future farm size distribution. An examination of the annual transition probability matrices revealed structural change in the regional egg industry coincident with the abrupt increase in feed prices beginning in 1973-1974. For example, the probability of a state 2 farm leaving the industry increased from $\hat{p}_{21}$ 8.5 percent during the 1967-73 period to $\hat{p}_{21}$ 16.7 percent in 1973-78. Similarly, farms in class 3 exhibited a pattern of increased exit from the industry. During the years 1967-73, the probability of going out of business was $\hat{p}_{31}$ 4.9 percent. This rate of exit more than doubled to $\hat{p}_{31} = 11.2$ percent in the 1973-78 period. Whereas major divergences between the calculated probabilities of movement in the matrices for the two time periods occurred for class 2 and 3 farms, the larger farm sizes demonstrated a greater degree of stability over the entire study period.

In order to support the observation of structural change occurring in the egg industry in 1973-74, the study period was divided into the two periods 1967-73 and 1973-78 and an average transition probability matrix calculated for each. A statistical comparison of these two matrices revealed that they were significantly different at the one percent level. This confirmed the results of a visual inspection and comparison of the annual matrices which showed marked differences in the values of several $\hat{p}_{ij}$'s.

Based on questionnaire responses it was noted that approximately 97 percent of all exit farms were in size classes 2 and 3. These farms were typically older and employed inefficient production techniques. More than 80 percent of these producers were over 50 years of age. The most frequently cited reasons for exiting were a low economic return and retirement. However. many producers specifically singled out the sudden and dramatic increase in feed price as the major factor causing them to leave the industry. Essentially, the 1973 feed price increase was the catalyst, acting in concert with a number of other factors, that brought about the marked shift in the size distribution of farms.

Annual farm numbers in each class were determined for the years 1967-73 using the average transition matrix based on those years. Farm numbers for the years 1974-78 and selected future years were projected on the basis of the 1973-78 matrix. The most marked shifts were projected for farms in classes 2 and 3 over the years 1967-1988, with rapid declines from 520 to 22 farms and 132 to 16 farms, respectively.

The number of farms in class 4, in contrast, rose slowly from 1967 to 1973, and then slowly decreased beginning in 1974. The class 5 population shift was characterized by an initial slow growth through 1982, and a slow downward trend beginning in the mid-1980's. An invariant increase in farms of size $\geq$ 100,000 was observed over the entire study period 1967 to 1988.

Regional egg output during the period 1967-1988 was characterized by a peak production of 146.7 million dozen in 1973. Although output exhibited a fluctuating pattern of increase and decrease for the years 1967-1973, a steady downward trend was observed to begin in 1974 and to continue through 1982. In the 1980's the total number of layers is projected to stabilize at about 6.6 to 6.7 million birds and egg output is predicted to show increases from approximately 136 to 146 million dozen eggs, due primarily to increased rates of lay over time.

Since the foregoing analysis has projected that 80 percent of all layers will be housed on farms larger than 50,000 layers by 1988, it can be concluded that the integration of production with input-supplying and marketing functions can be expected to continue. In addition, since fewer but larger, more technologically advanced farms are predicted, it is reasonable to expect that the egg industry would not respond to adverse economic events with the same pattern of dramatically increased exit rates observed during the period 1973-1975. However, the trend toward more vertical integration within the egg industry will continue to have impacts upon input-supply industries and egg pricing practices.

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