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Decision Models for California Turkey Growers

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CALIFORNIA AGRICULTURAL EXPERIMENT STATION

The general objective of this study is to provide answers to questions concerning internal adjustments and decisions for turkey producing firms in California. One question concerns the economic scale of operation. The average total production cost (ATC) estimated for two broods of 5,000 turkeys was \$0.229 per pound. Increasing the size to two broods of 100,000 turkeys resulted in an ATC of \$0.218 per pound—a decline of 5 per cent. However, average total costs varied markedly with different mortality rates and with different rates of feed efficiency.

Parameters of the price, mortality, and income distributions were estimated and the question of whether to produce as independent or produce under a contract was examined using modern statistical decision theory. The results indicated that independent production would be preferred by growers attempting to maximize expected monetary returns. However, for producers of only *medium* efficiency, the expected returns from contracting are almost as high with much less risk. Growers able to reach high efficiency levels, achieve significantly higher incomes but with much greater risk. The results also indicated that a grower using an intelligent price predicting model might increase his average income somewhat by shifting between independent and contract production from year to year based on his price forecast.

Two attempts were made to simulate the potential financial progress of a grower over a ten-year period, starting initially with a 20,000-bird operation, and a net worth of \$30,000. First, the firm was not permitted to grow in size, and any excess capital generated was therefore invested outside of agriculture. The results simulated over a ten-year period indicated that net worth would remain about the same through time under contracting. New worth would grow, on the average, to about \$75,000 over ten years under independent production. However, the probability of the firm being forced out of business because of unfavorable prices is somewhat higher under independent production.

Secondly, the firm was permitted to grow in size through capital investment in additional turkey housing facilities. Results were obtained using a multistage chance-constrained linear programming model. Growth rates in net worth were found to be extremely sensitive to product prices, feeding efficiency levels, and the borrowing policies of the firm.

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DECISION MODELS FOR CALIFORNIA TURKEY GROWERS[1]

INTRODUCTION

THIS IS THE SECOND of two studies attempting to assess the competitive economic position of California turkey growers resulting from marked changes in production and marketing technology in the turkey industry. The first study was concerned with predicting future locational changes of the industry in the short and long run (Bawden, *et al.*, 1966). This study relates to the adjustments and decisions internal to the individual turkey producing firm in California. Particular attention is centered on questions of economic size and growth of the operation, and on alternative financial and contractual arrangements under conditions of risk and uncertainty.

Structural changes in the turkey industry

The turkey industry has experienced a number of changes in recent years. At the grower level changes concerned ration formulation, development of labor saving feed handling equipment, improved disease control, and the development of numerous off-farm grower financing arrangements. Changes at the industry level included those in the volume of turkey meat produced, the relative importance of the several producing regions, the number of producers, the typical size of enterprise, and the marketing of turkey meat.

The volume of turkey meat production in the United States has been increasing at a rapid rate since 1950. The number of turkeys raised increased from 44.4 million in 1950 to 108.1 million in 1961, declined to 92.4 million in 1962, and increased steadily again through 1965. Table 1 shows that the trend in California production has closely paralleled this national trend. California producers have accounted for 15.1 to 19.4 per cent of the national output in each of the years 1950–1965, making the State either first or second in turkey production during each of the 16 years. The annual average live weight prices declined rapidly during the early 1950's for both the United States and California.

Turkeys are raised in each of the 50 states. Bawden, *et al.* (1966) showed that turkey production in the East and West North Central areas of the United States has been expanding more rapidly than other areas of the country. During the 1956–1961 period, production in these two areas expanded 66 and 81 per cent, respectively, in the West only by 37 per cent and in the South Central by 26 per cent. In the North and South Atlantic regions, production decreased 21 and 10 per cent, respectively. The study also indicated that future turkey production is likely to shift to the Midwest and South, with the West (includ-

[1] Submitted for publication, December 27, 1967.

TABLE 1

NUMBER OF TURKEYS RAISED AND AVERAGE FARM LEVEL PRICES FOR THE UNITED STATES AND CALIFORNIA 1950–1965

Year	Number of turkeys raised		Percentage of U. S. total raised in California	Average price per pound at farm level	
	U. S.	California		U. S.	California
	thousand		*per cent*	*cents*	
1950	44,393	7,202	16.22	32.9	28.5
1951	53,298	9,507	17.84	37.5	36.7
1952	62,327	11,123	17.85	33.6	31.0
1953	59,822	9,899	16.55	33.7	31.1
1954	67,693	10,196	15.06	28.8	26.4
1955	65,598	10,196	15.54	30.2	28.8
1956	76,741	12,643	16.47	27.2	26.9
1957	81,104	14,666	18.07	23.4	21.9
1958	78,349	13,639	17.41	23.9	22.7
1959	84,493	13,047	15.44	23.9	24.9
1960	84,772	14,536	17.15	25.4	25.5
1961	108,131	17,765	16.43	18.9	19.4
1962	92,365	17,963	19.45	21.6	20.5
1963	93,370	15,082	16.15	22.3	21.7
1964	99,678	15,737	15.79	21.0	20.8
1965	104,740	15,667	14.96	22.2	22.9

SOURCE: California Crop and Livestock [1908–1958, 1959–1966].

ing California) declining. This interregional study was based on representative costs of production and processing for each area of the country, and suggests that in future years only the most efficient turkey growers will compete successfully in California.

While the number of turkeys raised in California has been increasing, production has been shifting toward fewer, but larger flocks. Table 2 shows the number and percentage of total for California flocks of different sizes for the years 1954, 1959, and 1961. Flock size is defined as the number of turkeys slaughtered for one firm. These data show a sharp decrease in both the number and relative importance of smaller flocks, while larger flocks increased in both these categories. By 1961 the total number of producers had declined to 638, less than one-half the total seven years before.

The number of turkeys marketed by size of flock and the proportion of total turkeys marketed by size of flock from July 1, 1960–June 30, 1961 (referred to hereafter as 1961) are reported in the final two columns of table 3. These data indicate that the 20.9 per cent of producers, raising less than 2,000 turkeys per year, accounted for only 0.6 per cent of California's production, while the 8.9 per cent in the 50,000-plus flock size produced 59.0 per cent of the marketed turkeys.

The number of turkeys marketed by size of flock and type of producer are also shown in table 3 for 1961. Most growers were classified as either independent or contract growers. Those producers raising a portion of their turkeys under contract and the remainder under their own financing were classified as combination growers. The financial and contractual arrangements of some, referred to as unidentified growers, could not be determined. These data show that

TABLE 2
NUMBER AND PERCENTAGE OF CALIFORNIA TURKEY PRODUCERS BY SIZE OF FLOCK*

Size of flock	1954		1959		1961	
	Number	Percentage	Number	Percentage	Number	Percentage
100– 1,999	418	30.2	135	17.2	133	20.9
2,000– 4,999	391	28.2	133	17.0	101	15.8
5,000– 9,999	332	24.0	191	24.5	129	20.2
10,000–14,999	110	8.0	92	11.8	71	11.1
15,000–19,999	50	3.6	83	10.6	49	7.7
20,000–29,999	48	3.5	63	8.1	53	8.3
30,000–49,999	17	1.2	46	5.9	45	7.1
50,000 plus	18	1.3	38	4.9	57	8.9
TOTAL number of producers	1,384	100.0	781	100.0	638	100.0

* Source for 1954 and 1959 data: California Department of Agriculture (1962, Table 3, p. 23). Source for 1961 data: "Monthly Reports of Turkeys Received for Processing," deposited with the California Department of Agriculture.

contract growers tended to be larger than independent growers.[2]

The number of growers by size of flock and type of producer is summarized in table 4. Assuming that the unidentified producers were divided between independent and contract production in the same proportion as the identified producers, 31.8 per cent of the growers produced 45.3 per cent of California's 1961 turkey crop under contract, while 66.5 per cent raised 50.3 per cent of total production as independent growers.

The rapid expansion of turkey meat production in other areas of the country, the apparent competitive disadvantage of California turkey growers, and the rapid shift of California growers to larger operations and to financing by nonfarm firms raises a number of economic questions concerning the optimum organization of turkey meat production firms. What are the economies of size in turkey meat production? Are they great enough to enable large California growers to overcome other cost disadvantages and to compete successfully with the smaller operations typical of many competing areas? How is the production cost level affected by certain indicators of managerial efficiency, such as the rate of feed conversion and mortality rate? How much year-to-year income variability is faced by the turkey grower? Which organizational strategies are most effective in combating this variability? How should the alternative methods of financing be utilized? How will the alternative methods of financing affect the rate of firm expansion over time?

Objectives of the study

The general objective of this study is to provide answers to some of the above questions concerning the economic organization of the turkey meat producing firm in California. More specifically, this study estimates the economies of size facing California turkey growers by using a random variable, the mortality rate, so that a probability distribution is attached to the cost level at any specified output. The study then applies decision theory to the annual decision about the

[2] A chi-square test of homogeneity was used to determine if the actual distribution of growers by type of operation differed from the distribution for all types of production. The observed chi-square value indicated the differences would occur less than 1 per cent of the time due to chance.

TABLE 3

TURKEYS MARKETED BY SIZE OF FLOCK AND TYPE OF PRODUCER*

Size of flock	Independent growers		Contract growers		Combination growers		Unidentified growers		All growers	
	Number of turkeys	Per-centage	Number of turkeys	Per-centage	Number of turkeys	Per-centage	Number of turkeys	Per-centage	Number of turkeys	Per-centage
0– 1,999	68,550	1.1	14,530	0.2	800	0.1	2,520	0.1	86,400	0.6
2,000– 4,999	147,300	2.4	111,450	2.0	14,250	2.1	67,610	2.7	340,610	2.3
5,000– 9,999	453,500	7.2	259,050	4.6	15,690	2.4	208,140	8.4	936,380	6.2
10,000–14,999	456,540	7.2	276,650	4.9	0	0.0	134,110	5.4	867,300	5.7
15,000–19,999	579,160	9.2	143,770	2.5	0	0.0	156,130	6.3	879,050	5.8
20,000–29,999	715,090	11.4	469,820	8.3	22,040	3.3	134,980	5.5	1,341,930	8.9
30,000–49,999	959,660	15.2	601,150	10.6	0	0.0	180,640	7.3	1,741,450	11.5
50,000 plus	2,916,320	46.3	3,791,150	66.9	613,540	92.1	1,580,540	64.3	8,910,550	59.0
TOTAL	6,296,120	100.0	5,667,570	100.0	666,320	100.0	2,478,670	100.0	15,103,680	100.0
Percentage of TOTAL	41.7		37.5		4.4		16.4		100.0	

* Independent growers were those who met all three of the following criteria: (a) furnished or purchased all inputs and, if financing was necessary, arranged for it himself; (b) made all production and marketing decisions; and (c) had the responsibility for risk. A contract producer is one who had entered into a written agreement with an off-farm firm in connection with the production or marketing of turkeys which violated one or more of the criteria for an independent producer. A combination producer raised part of his turkeys under contract and part as an independent producer. An unidentified producer was one who could not be classified as one of the other three types.

SOURCE: Compiled from "Monthly Reports of Turkeys Received for Processing," deposited with the California Department of Agriculture, 1961. Information on the type of financial arrangement was obtained from County Farm Advisors.

TABLE 4

NUMBER OF GROWERS BY SIZE OF FLOCK AND TYPE OF PRODUCER*

Size of flock	Independent growers		Contract growers		Combination growers		Unidentified growers		All growers	
	Number of growers	Percentage	Number of growers	Percentage	Number of growers	Percentage	Number of growers	Percentage	Number of growers	Percentage
0– 1,999	110	30.1	20	11.5	1	9.1	2	2.3	133	20.9
2,000– 4,999	43	11.8	33	19.0	4	36.3	21	23.9	101	15.8
5,000– 9,999	61	16.7	36	20.7	2	18.2	30	34.1	129	20.2
10,000–14,999	38	10.4	22	12.6	0	0.0	11	12.5	71	11.1
15,000–19,999	32	8.8	8	4.6	0	0.0	9	10.2	49	7.7
20,000–29,999	28	7.7	19	10.9	1	9.1	5	5.7	53	8.3
30,000–49,999	26	7.1	15	8.6	0	0.0	4	4.5	45	7.1
50,000 plus	27	7.4	21	12.1	3	27.3	6	6.8	57	8.9
TOTAL	365	100.0	174	100.0	11	100.0	88	100.0	638	100.0
Percentage of TOTAL	57.2		27.3		1.7		13.8		100.0	

* The definitions of types of operations are given in the footnote of table 3.

SOURCE: Compiled from "Monthly Reports of Turkeys Received for Processing," deposited with the California Department of Agriculture, 1961. Information on the type of financial arrangement was obtained from County Farm Advisors.

choice between the type of contract or independent production, based on both the expected value and the variability of net returns. The study further employs a price forecasting model and evaluates several alternative decision rules by analyzing the results of a simulation model. It also uses simulation to evaluate the growth in the firm's net worth over time using each of the decision rules, but assuming no expansion in the size of the firm. Finally, the study analyzes, with a multistage linear programming model, the influence of alternative strategies, feed efficiency levels, credit restrictions, and price levels on the potential growth rate of the firm.

The findings of this study should be useful in advising California turkey growers on the improved organization and operation of their firm. The study should also be interesting from a methodological point of view, because it applies a number of quantitative techniques to the question of decision making under risk and uncertainty—probability distributions, price forecasting equations, simulation techniques, and chance-constrained programming.

ECONOMIES OF SCALE IN TURKEY MEAT PRODUCTION

The concept of economies of scale is commonly illustrated with reference to the shape of the long-run average cost curve of a firm producing a single homogeneous product. The long-run average cost (LRAC) is derived as the envelope of a series of short-run average cost curves (SRAC) as shown in figure 1. The short-run curves show the minimum cost for producing each level of output with one or more factors of production taken as given or fixed. The fixed factor usually represents the size of plant such as the brooding facilities in the case of turkey production. The short run is assumed to be sufficiently long to alter the amount of any variable production factors (e.g., the number of poults, the amount of feed fed, etc.), but not long enough to alter the amount of the fixed factors. The long run is considered sufficiently long so that all factors or production, including the size of plant, can be varied. Thus, the long-run average curve (LRAC) in figure 1 can be derived as the envelope to the series of short-run curves (SRAC) for successively larger fixed plants.

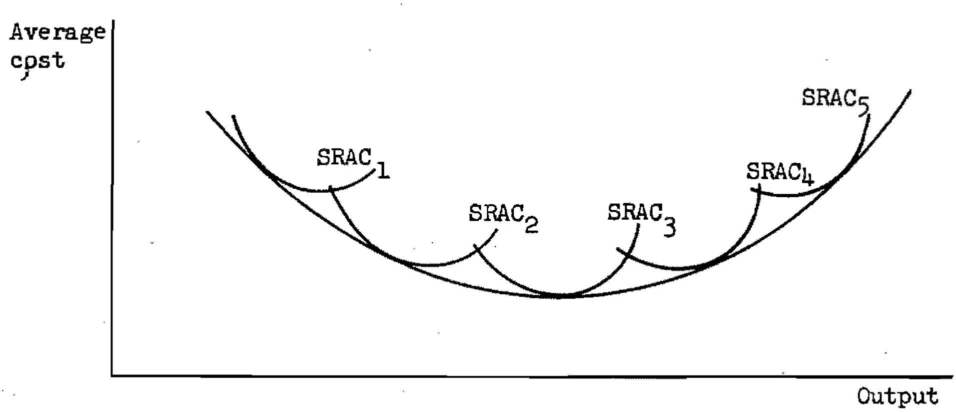

Fig. 1. Theoretical Shape and Position for the Short-Run and Long-Run Average Cost Curves of a Typical Firm

Short-run average cost curves are conventionally considered to be "U"-shaped; i.e., first decreasing with the spreading of fixed costs over more units of output, but finally increasing as a result of diminishing marginal physical product as more of the variable factors are combined with the fixed factors. In turkey production, overcrowding of poults in brooding facilities can be expected to lead to rapidly increasing mortality rates and, consequently, eventually increasing short-run average costs.

As the scale of plant is increasing, the minimum average cost of production may be at successively lower levels, resulting in economies of scale; may be at the same level, resulting in constant returns to scale; or it may be at successively higher levels of costs, resulting in diseconomies of scale. Figure 1 shows all three phases of this sequence, resulting in a "U"-shaped long-run average cost curve. The reasons underlying a "U"-shaped long-run average cost curve are usually summarized in terms of net internal and external economies and diseconomies of scale (Viner, 1952). Our study considers only internal economies and diseconomies Net internal economies arise primarily from the reduction in technological coefficients as factors are combined more efficiently with larger sizes, or as prices paid for factors of production decrease (e.g., quantity discounts on feed or poult purchases). After an initial portion of declining average production costs, all available technological and pecuniary economies are probably exploited, and the long-run average costs may remain approximately constant over a wide range of output. At some size, net internal diseconomies may appear because of increasing average cost of supervision, higher incidence of disease, or other factors. In most empirical studies, net internal diseconomies are extremely difficult to measure meaningfully.

We derived the empirical estimates of the short- and long-run average cost curves from budgeting the production costs of various sizes of turkey meat production operations. We synthesized the combinations of fixed and variable inputs in these operations, based on engineering estimates of the physical quantities of these factors needed and their market prices. The advantage of the synthesis technique is that it allowed us to "construct" fixed plants with the optimum combination of inputs for the specified plant capacity and to synthesize as many of these plants as necessary to estimate the total range of the long-run average cost curve. The long-run average cost curve can then be fitted as an envelope curve to the synthesized short-run average cost curves.

Estimates of short-run and long-run cost curves

Based on the cost components developed in Appendix A, two general equations are given representing short-run average total costs (ATC) for producing turkeys, assuming "high" and "average" growth rates, respectively.

$$ATC^{*}_{ij} = \frac{F.C._{ij} + (K_1 + K_{2j} + K_{3j})S}{YS} \qquad (1)$$

$$ATC_{ij} = \frac{F.C._{ij} + (K_1 + K_{2j} + K_{3j})S}{ZS} \qquad (2)$$

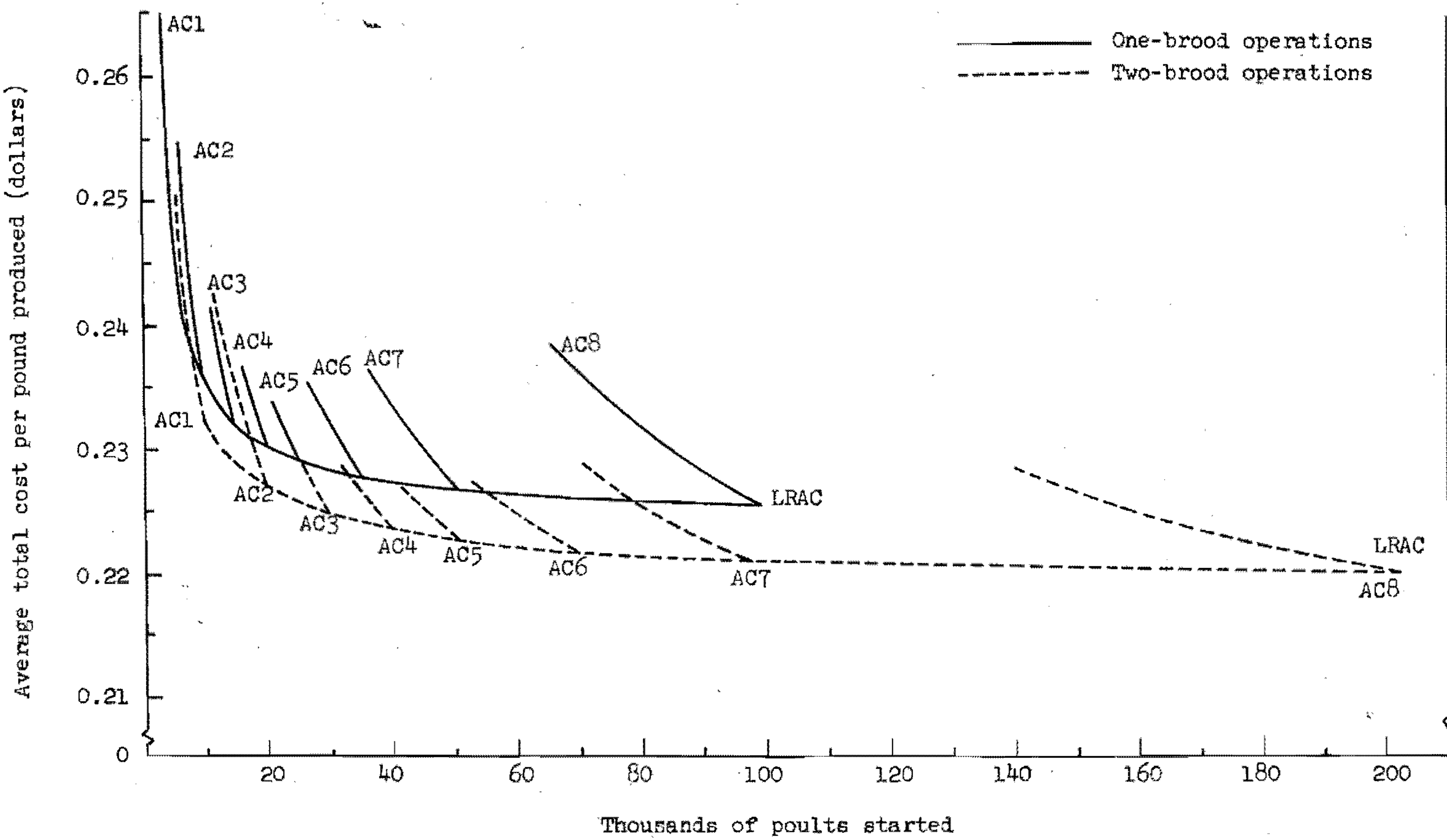

Fig. 2. Average Cost Curves for Eight Sizes of One- and Two-Brood Operations and the Long-Run Planning Curve Assuming 9.75 per cent Mortality and Medium Rate of Gain

Where i = number of broods (i = 1 or 2);

j = capacity per brood in thousands (j = 5, 10, 15, 20, 25, 35, 50, and 100);

$F.C.$ = annual fixed costs as given in table A-4;

K_1, K_{2i}, K_{3j} = components of total variable costs as discussed in Appendix A and their numerical values are presented in table A-12;

Y = predicted pounds of turkey meat per 1,000 poults started using the "high" growth rate (equation A-31);

Z = predicted pounds of turkey meat per 1,000 poults started using the adjusted or "average" growth rate (equation A-32); and

S = size of enterprise in thousands of poults.

Based on equations (1) and (2), total and average costs per pound of turkey produced are derived and presented in tables A-13, A-14, and A-15 for operations of different sizes. Results are presented for one-brood turkey meat enterprises assuming both high and medium growth rates for 4.00, 9.75, and 20.50 per cent mortality, respectively. Corresponding summaries for two-brood enterprises are presented in tables A-16, A-17, and A-18.

Effects on costs of one brood versus two broods per year.—Although cost comparisons from growing turkeys in single broods versus two broods per year can be made for any of the mortality and growth rates assumed, we illustrate the results only for the situation where mortality is fixed at 9.75 per cent and a medium growth rate is assumed. Figure 2 presents this comparison of short- and long-run cost curves based on cost summaries in tables A-14 and A-17. In the theoretical discussion presented earlier, the long-run average cost curve (LRAC) is obtained by connecting the points of lowest cost for each of the "fixed plants." Here, LRAC is derived as the locus of lowest costs at capacity for each of the short-run curves AC1 to AC8. Note that for the smallest plant size (AC1) the one-brood operation at capacity (5,000 birds), shows costs exceeding that for the two-brood operation by \$0.0099 (\$0.2418 versus \$0.2319) per pound of turkey. This difference declines to \$0.0053 when comparing one- and two-brood operations for the large plant (AC8). A second comparison may be made by considering the difference in the average cost of production of raising the same number of turkeys by a one- or two-brood operation. Raising 10,000 turkeys in one brood using building Component II (i.e., AC2) results in a production cost of \$0.2342 per pound while two broods of 5,000 birds can be raised with building Component I at an average total cost of \$0.2319 per pound. Likewise, raising 100,000 turkeys in one brood with building Component VIII results in an average total cost of \$0.2254 per pound, while raising two broods of 50,000 birds each with building Component VII has an average cost of production of \$0.2208 per pound.

Effects of mortality level on costs. — Figure 3 shows the effects of three mortality levels on short-run and long-run cost curves for the two-brood medium-growth rate case, based on costs summarized in tables A-16, A-17, and A-18. The results indicate that for the 4 per cent mortality level, the average production cost declines from \$0.2239 to \$0.2128 per pound as the size of operation increases from 10,000 poults to 200,000 poults started per year. With a 9.75 per cent mortality rate, approximately an average death loss, the average production cost declines from \$0.2319 to \$0.2201 per pound over the same size range. For the 20.50 per cent mortality, the minimum average cost of production declines from $0.2500 to $0.2366 over the range considered. Hence, increasing the mortality rate from 4.00 per cent to 9.75 per cent increases the cost of production $0.0070 per pound and a further increase from 9.75 per cent to 20.50 per cent increases the cost of production an additional $0.0170 per pound. The three mortality rates used in figure 3 were selected because they represent a lower limit to the mortality rate a grower may expect, the expected mortality rate, and a mortality rate which should rarely be exceeded.

Effects of growth rate on costs.—Comparison of short-run and long-run cost curves for the high and medium growth rate assuming the "most likely" situation of two broods and 9.75 per cent mortality is shown in figure 4, based on costs summarized in table A-17. For the medium growth rate, LRAC declines from $0.2319 for 10,000 birds (two broods of 5,000 birds) to $0.2201 per pound for 200,000 birds started (two broods of 100,000 birds). The comparable costs for the high-growth-rate curve are $0.2182 and $0.2071, respectively—the difference between the two growth rates accounting for about $0.0130 per pound.

Effects of contracting on costs.—The influence of contracting, if any, on production costs of California turkey growers is difficult to assess. Six off-farm concerns offering contracts to California turkey growers in 1963 were interviewed to gain information about the provisions of the turkey meat production contracts, the effect of large volume purchases of poults, and other inputs on the prices contractors pay for inputs, and the general experience of contractors with this

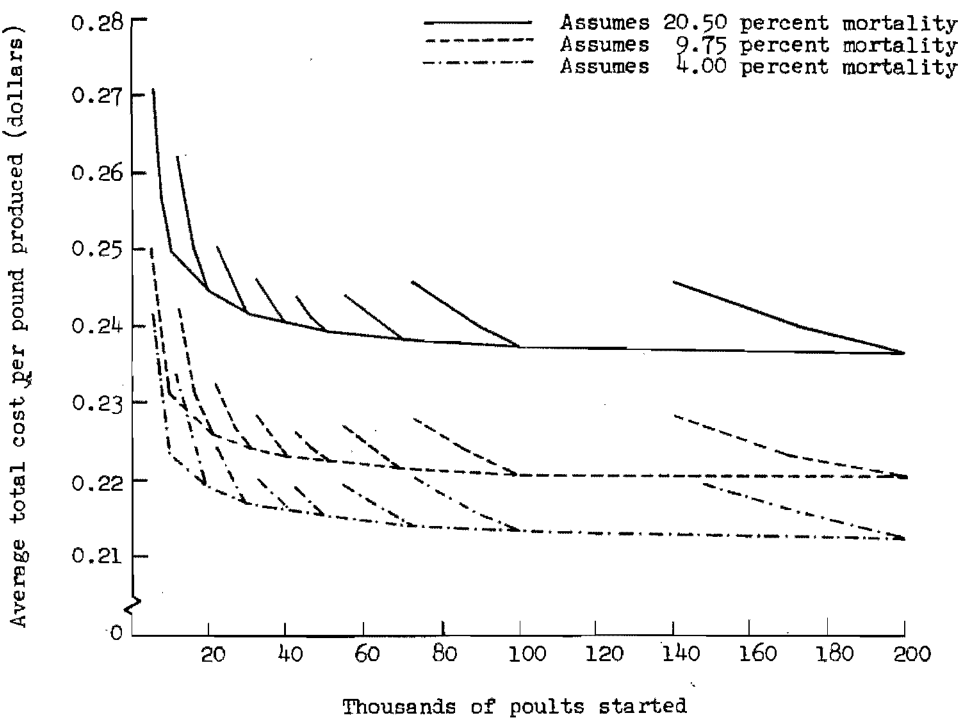

Fig. 3. Average Cost Curves for Eight Sizes of Two-Brood Operations and the Long-Run Planning Curve Using the Medium Growth Rate and Three Alternative Mortality Rates

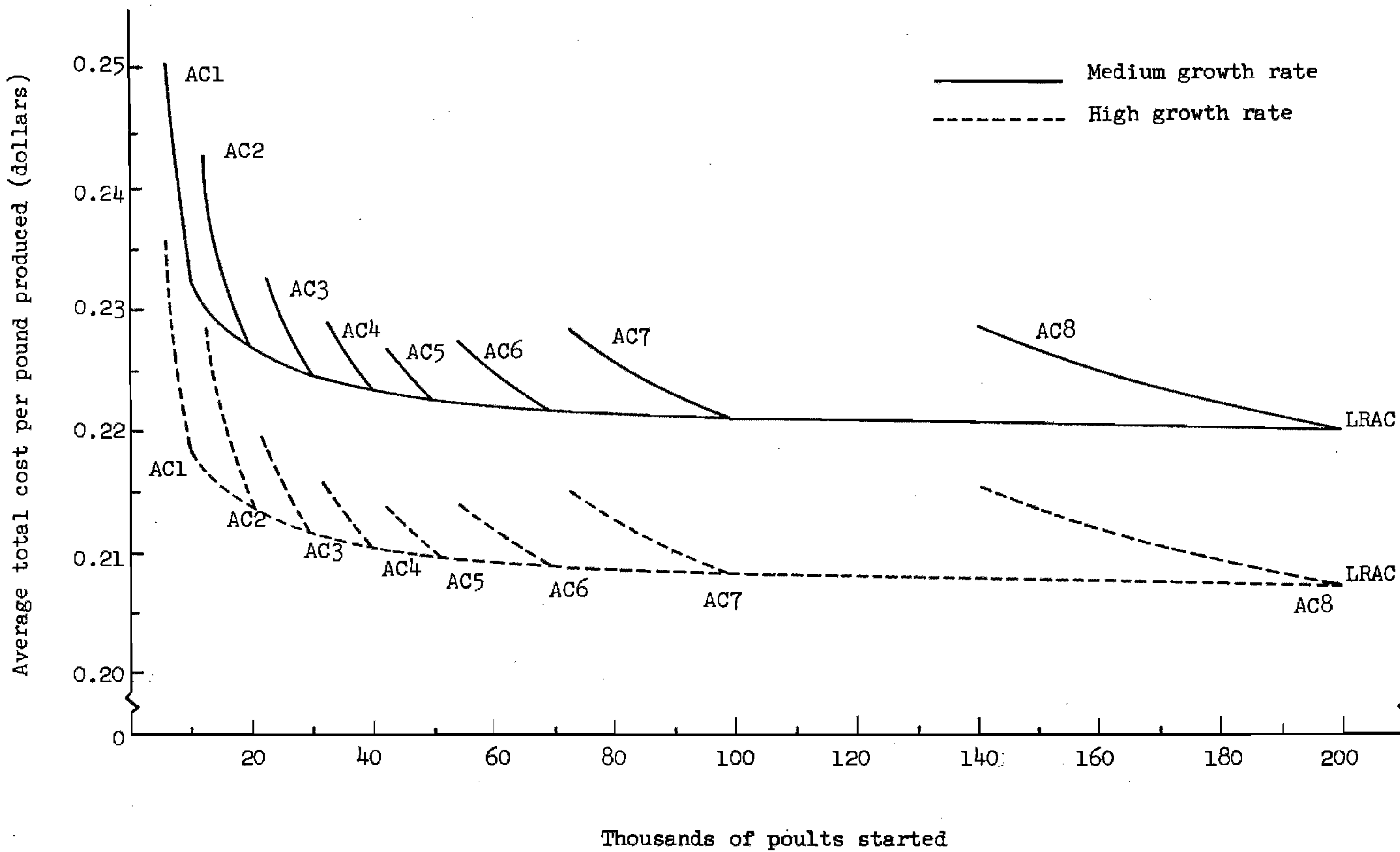

Fig. 4. Short- and Long-Run Average Cost Curves for Two-Brood Operations with Alternative Growth Rates (9.75 per cent mortality rate assumed)

endeavor. Of the six concerns interviewed, five were offering contracts to turkey growers in 1964. The discussion which follows relates to the provisions of the contracts offered in 1964.

The provisions of the contracts available to California turkey meat producers tend to be uniform, and typically relate to the ownership of the flock, furnishing of inputs, care and marketing of the turkeys, and the determination of the payments growers will receive. The contracts of the firms interviewed either specified the amount of building and equipment space as a part of the contract or had a similar list of requirements which must be met before the contract was offered to the grower. These requirements were essentially identical with the physical requirements specified for building, pen, feeder, and water space specified in developing the annual cost data in the initial portion of this section. The cleaning and sanitation procedures required for all buildings, equipment, and facilities used in turkey production prior to placement of the poults were also included. The contracts typically inincluded the feeding program to be followed and the procedures to be followed in daily care of the growing turkeys. The contractor (the off-farm firm) furnished the poults, feed, grit, vaccines, litter, brooder fuel, insurance on the poults, sanitation products, and, consequently, maintained ownership of the flock. The grower was required to furnish all land, buildings, equipment, water, labor, and facilities to care for the growing turkeys. All of the contracts established the right of the contractor's field representative to inspect the flock at any time and make recommendations which the grower must follow, or allowed the contractor to hire other labor to care for the turkeys on the grower's premises. Finally, the contracts established a method of computing the growers' payment and a procedure for paying it. The payment procedures varied somewhat among companies, and will be examined in detail later in this monograph.

It seems reasonable that contractors, by purchasing poults, feed, medication supplies, litter, and fuel in quantity, might obtain lower input prices. We investigated the input prices furnished by contractors through personal interviews with representatives of the contracting concerns, and verified them by studying the prices charged to contract growers' accounts. The poult prices charged to contractors are apparently the same as those charged independent growers. The Fair Trade Laws prohibit different price discounts on a given size of feed order delivered to a contract producer as compared to an independent grower. The other inputs furnished by the contractor are typically purchased locally by the grower and charged to the contracting concern. Consequently, it does not appear that inputs for contract growers are purchased at lower prices than those purchased by independent growers.

Because contracting does not influence either the purchase prices of inputs or the quantity of inputs required for a "given level of management," perhaps the major influence of contracting on average production cost is on the "level of management" or the "amount of the managerial input." The field representatives of the contracting concerns should be able to provide managerial assistance for growers not following acceptable practices. However, it is doubtful if the field representatives can improve greatly the performance of "efficient growers." Obviously, the influence on average production cost of the managerial assistance provided by the contracting concern will depend largely on the individual grower. An analysis of this effect, a sizeable independent study, will not be attempted here. Moreover, this study assumes that we are dealing with growers who can raise turkeys for meat production efficiently as either independent or contract growers.

Therefore, the average total cost of production (including all fixed and variable inputs) for independent and contract growers is considered to be identical for any given size of enterprise. However, under contract production the grower furnishes only the fixed inputs, his labor, and machinery operating expense. That is, he furnishes the items included in the annual fixed cost and the item included in K_{2j} of the development of average total cost (see equation (1)). The contractor furnishes all variable inputs included in K_1 and K_{3j}. Obviously, the capital requirement for contract growers is a good deal less than for independent growers, even though the average total cost of production is the same in either case.

The next section deals with a detailed comparison of the expected returns from contracting versus independent production and the risk or income variability associated with each. It considers two specific types of contracts: (1) *Base Payment Plus Bonuses Contract,* which closely follows the terms outlined above and (2) *Guaranteed Price Contract,* which stipulates the time of delivery and price to be paid the producer, but leaves the grower independent with respect to other aspects of his operation. More information on these contracts is provided later in this monograph when they are analyzed in detail.

CHOICE BETWEEN INDEPENDENT AND CONTRACT PRODUCTION UNDER CONDITIONS OF UNCERTAINTY

The previous section developed the economies of scale relationships in terms of static analysis, assuming that all input quantities, prices, and mortality rate were known with certainty. We turn now to the problem of decision making under uncertainty. More specifically, given the uncertainties of turkey prices and mortality, how should a grower with a specified size of operation decide between independent and contract production? We have used the concepts of modern decision theory as a framework for analyzing this question. This section first briefly outlines some relevant decision theory concepts, then develops the needed probability distributions of prices, mortality, and income, and finally presents the empirical choice problems in a decision framework.

Elements of decision theory

Modern decision theory provides a useful framework for analyzing the desirability of independent versus contract turkey production. The main ideas used empirically in this study are briefly outlined here. More detailed discussions of decision theory can be found in such standard sources as Chernoff and Moses (1959) and Luce and Raiffa (1957).

Decision problems under uncertainty can be presented in terms of a gains (loss) table such as table 5, which shows the consequences (the gains or net incomes) of following a given plan (action a_i) when a particular event (state of nature θ_i) occurs. Let action a_1 represent independent turkey production, and actions a_2 and a_3 represent two alternative types of contract production. The states of nature (θ_i) represent possible combinations of the random variables—turkey prices and mortality.

A number of criteria for choice among alternative actions have been proposed in the literature. Several of these criteria assume either that probabilities of the

TABLE 5
PAYOFFS (NET INCOMES) OF ALTERNATIVE ACTIONS UNDER VARIOUS STATES OF NATURE

Values of random variables		States of nature	Actions			$P(\theta_i)$*
Price	Mortality		a_1	a_2	a_3	
			dollars			
Low	High	θ_1	−12.0	0.0	2.0	0.1
Low	Low	θ_2	− 4.0	8.0	4.0	0.1
Medium	High	θ_3	2.0	0.0	2.0	0.3
Medium	Low	θ_4	8.0	8.0	4.0	0.3
High	High	θ_5	14.0	0.0	2.0	0.1
High	Low	θ_6	20.0	8.0	4.0	0.1
Expected value		..	4.8	4.0	3.0	...

* Assumed probabilities of low, medium, and high prices are 0.2, 0.6, and 0.2, respectively, probabilities of high and low mortality are 0.5 in both cases, and price and mortality are assumed to be independent.
SOURCE: Hypothetical data.

θ_i cannot be derived or that an extreme unique probability distribution characterizes each decision problem. An extremely conservative criterion of this type, the *minimax gain* criterion, assumes that the worst will happen, i.e., that the most unfavorable θ_i will occur with probability 1.0, then selects the action a_i which is most favorable for that θ_i. In table 5 the *minimax gain* criterion would recommend action a_3, since this action gives the greatest income ($2) if the worst state of nature (θ_1, with low prices and high mortality) should occur. Conversely, the *maximax gain* criterion, a very optimistic criterion, assumes that the most favorable state of nature (θ_6) will occur with probability 1.0, then selects the action (a_1) which gives the greatest income ($20) for θ_6.

In cases where the probabilities of the θ's are unknown, it has sometimes been suggested that the decision maker assume that all θ's are equally likely, then simply select that action which gives the greatest average income. This criterion has been called *the principle of insufficient reason*. In table 5 this criterion would recommend a_1 because its simple average value of 4.67 exceeds those for a_2 and a_3.

The above decision rules and several others, such as the *pessimism-optimism* index, have been suggested for cases in which the probability distribution of the states of nature is unknown. All of these criteria have severe defects as shown by Luce and Raiffa (1957) in their chapter 13. Furthermore, it is difficult to conceive of decision problems in which the decision maker has *no* information, either objective or subjective, regarding the probabilities of the θ_i. Thus, recent emphasis in decision theory has moved toward the use of so-called Bayes strategies. The basic Bayes approach has several variations. The simplest case is where probabilities of the θ_i are estimated either from empirical data or subjectively by the decision maker, then used as weights in calculating expected values from each action. These probabilities are called *d; s;* probabilities. In this case, the optimal Bayes strategy is the single action with the maximum expected value, i.e., action a_1 in table 5 with an expected value of 4.8.

The optimal Bayes strategy described above concentrates on only one parameter of the probability distribution for each action, i.e., the mean or expected value. No attention is paid to the dispersion of income about the expected value. Two alternatives can be proposed to incorporate more information about the probability distribution into the decision criterion. The most satisfying alternative, theoretically, is to derive the decision maker's utility function for wealth using the standard techniques available (Chernoff and Moses, 1959, pp. 350–352), then substitute utility values for monetary values in table 5. The optimal Bayes strategy would then be that action which maximizes expected utility. However, derivation of utility functions would be a formidable task for any sizeable number of growers. Thus, as a second simple alternative for decision making with nonlinear utility functions, we will adopt the following criterion: Select that strategy which maximizes expected monetary value, subject to the restriction that net returns exceed some minimum absolute "disaster" level with a specified probability. In our example, suppose that the minimum absolute level of income (maximum allowable loss) is $\$-10$ with a probability of 0.1. That is, the decision maker wishes to maximize expected income subject to the restriction that there is no more than a one in ten chance of losing more than \$10. In that case, action a_2 would be selected because action a_1 permits a one in ten chance of losses of \$12. Alternatively, suppose that the decision maker is willing to take a two in ten chance of losing \$10. Then action a_1 is the optimum decision. Such decision criteria will be used in the empirical sections to follow.

Another aspect of Bayes strategies is the use of additional "outside" information in calculating revised probabilities of the θ's for a particular decision period. In decision theory terms, this corresponds to use of *posterior* rather than *prior* probabilities of the θ's. Problems using only *prior* probabilities are called "no data" problems, whereas those using *posterior* probabilities are called "data" problems. Suppose, for example, that we had a price forecasting model which was completely accurate for our example in table 5. This forecasting model would predict low, medium, and high prices accurately and with probabilities of 0.2, 0.6, and 0.2, respectively. We would then select a_2 when the model forecasted low prices because action a_2 gives an expected value of 4 as compared with -8 and 3 for action a_1 and a_3 when low prices occur. Likewise, when the model forecasted medium or high prices, one would select action a_1. Our expected income would then be $.1\ (0) + .1\ (8) + .3\ (2) + .3\ (8) + .1\ (14) + .1\ (20) = 7.2$. Thus, a "perfect" price forecasting model would increase our expected income from 4.8 to 7.2—an increase of 2.4.

In practice, a forecasting model will not be completely accurate. However, such a model may allow some increase in expected income over using the same action for all years. This increase in expected income from using the "data" rather than the "no data" model is sometimes called the "value of additional information" or the "value of an experiment." In the empirical work to follow, we will test the "value" of a set of price forecasting equations in this way.[3]

Estimation of mortality, price, and income variability

The decision theory concepts outlined above emphasize the need for probability distributions of turkey prices and mortality. In the empirical work to follow, these two probability distribu-

[3] For an example of deriving the "value of an experiment" from the "data" versus "no data" problem in another agricultural setting, see, Dean, *et al.* (1966, Appendix B).

tions are combined into a single distribution of net income for the various production alternatives. Actually, production costs and net income for a given size of flock vary considerably because of several other factors. For example, the input prices and the amount of labor required for a given size of enterprise may vary from one grower to another. However, the analysis assumes that growers have a thorough knowledge of the market prices for inputs and also have a physical layout which permits efficient labor usage. Another source of income variation is weather. Cool, damp spring weather delays the date on which poults can be moved from brooder houses to growing pens, while extremely hot weather during the final part of the growing period reduces daily feed consumption, resulting in slower rates of gain and higher feed conversion ratios.

The above sources of income variability, while of some significance for California growers, are relatively minor when compared with the variability in mortality rates and market prices. Variation in the mortality rate reflects influence of weather, disease, and predatory animals. Hence, it represents the composite effect of several sources of uncertainty facing the grower and may be considered a random variable from the individual producer's point of view. Certainly the management practices followed will affect the expected level and the standard deviation of the mortality rate. But even a manager following accepted management practices will experience variable mortality rates over a period of years due to uncontrollable factors.

Likewise, an independent grower has little control over the price he receives for the turkey meat produced. Hence, his income variability stems both from price and mortality variability. A contract grower, on the other hand, experiences income variability primarily because of variations in mortality rates. Under the contract arrangements studied, market prices either are guaranteed in the contract or do not specifically enter the contract terms.

Mortality variability.—Because the production costs estimated previously assumed that currently recommended management practices were being followed, it was essential that the data used for estimating mortality variability also reflect this high level of management practices. The observations used to estimate the probability distribution of the mortality rate were taken from growers' records from a feed company and the California Extension Service. The feed company's records covered the results of contract turkey growers who had been screened prior to placement of the poults and then carefully supervised by company fieldmen to insure adherence to specified management practices. The independent growers in the sample worked closely with a California Extension Specialist, insuring that the currently accepted management practices were followed in each of these cases. Consequently, both sources of sample data provided observations of the mortality rates experienced by producers closely following accepted management practices.

It has sometimes been suggested that disease outbreaks follow a cyclical pattern and hence that the parameters describing the probability distribution of the mortality rate may vary in a cyclical manner. The growers interviewed indicated that veterinary services are now readily available to diagnose and treat disease outbreaks, thus nullifying cyclical effects which were once important. The lack of severe spring and summer storms in central and southern California and the use of sprinkler systems to prevent losses on days of extreme temperature also suggest little dependence of expected death loss in a given year on weather conditions. Consequently, there appears to be little year-to-year effect on the probability distribution of mortality rates facing a grower. Hence, cross-section data—observations for a group of growers during one year—appeared satisfactory for estimating the parameters of this distribution.

The 1963 mortality rates were obtained from 47 turkey growers. Of these, 25 were contract growers with a feed company and 22 cooperated in a cost study with the California Agricultural Extension Service. The number of sample observations by percentage of mortality class is given in table 6. The range in the sample of mortality rates is 4.5 to 25.8 per cent. The modal class is 7.0 to 7.9 per cent mortality and the distribution appears to have a significant positive skew, i.e., it is skewed to the larger mortality rates. Although a number of theoretical distributions permit positive skewness, we selected the lognormal distribution. Fitting a normal curve to the logarithmic transformations of the original observations permits the use of all properties applicable to the normal distribution, making the function relatively easy to handle in analysis. The mean and variance are somewhat more difficult to compute because they must be derived from the transformed observations, but the mean and variance completely describe the distribution. The logarithm of zero and negative numbers are not defined. Consequently, the lognormal distribution realistically describes a variable (such as mortality) which must be greater than zero and positively skewed. The maximum likelihood method was used to estimate the parameters of the distribution. Consequently, the estimate of the mean of log M is unbiased but the antilog of this estimate is not an unbiased estimate of the mean of M. The estimate of the variance of the logarithmic distribution is not unbiased but it is consistent.[4]

TABLE 6
SAMPLE MORTALITY DATA

Percentage of mortality	Number of observations
0.0– 3.9	0
4.0– 4.9	2
5.0– 5.9	4
6.0– 6.9	5
7.0– 7.9	8
8.0– 8.9	4
9.0– 9.9	3
10.0– 10.9	3
11.0– 11.9	2
12.0– 12.9	3
13.0– 13.9	1
14.0– 14.9	2
15.0– 15.9	1
16.0– 16.9	2
17.0– 17.9	1
18.0– 18.9	3
19.0– 19.9	0
20.0– 20.9	1
21.0– 21.9	1
22.0– 24.9	0
25.0– 25.9	1
26.0–100.0	0
	TOTAL 47

SOURCE: 1963 mortality rates experienced by 47 growers; 25 were contract growers with a feed company, 22 cooperated in a cost study of the California Agricultural Extension Service.

The estimated values of the mean and standard deviation of the logarithmic transformation of mortality are given by equations (3) and (4), respectively.

$$\bar{M}_{log} = 0.98890 \qquad (3)$$

$$\hat{\sigma}_{log} = 0.19329 \qquad (4)$$

A positively skewed lognormal distribution has a mean exceeding the median which, in turn, is larger than the modal value. The estimated values of these three parameters of the mortality distribution are given by equations (5), (6), and (7), respectively.

[4] Alternative methods of estimating the parameters of the lognormal distribution are discussed in Aitchison and Brown (1957, pp. 37–54).

$$\text{Mean} = 9.75 \text{ per cent} \quad (5)$$

$$\text{Median} = 9.32 \text{ per cent} \quad (6)$$

$$\text{Mode} = 8.54 \text{ per cent} \quad (7)$$

A chi-square test of goodness of fit, utilizing the actual and theoretical frequencies of the mortality distribution, indicated that the hypothesis that the sample is drawn from a lognormally distributed parent population cannot be rejected at the 5 per cent level. Consequently, the probability distribution of mortality rates will be assumed lognormal with the parameters given by equations (3) and (4).

Using the logarithmic values of the median and the standard deviation and letting M represent the percentage of mortality for an individual grower in a specified year, the following probability statements can be made:

$$P(M < 3.30) = P(M > 26.28) = .01 \quad (8)$$

$$P(M < 4.48) = P(M > 19.37) = .05 \quad (9)$$

$$P(M < 5.27) = P(M > 16.48) = .10 \quad (10)$$

$$P(M < 9.32) = P(M > 9.32) = .50 \quad (11)$$

$$P[M < E(M)] = P(M < 9.75) = .54 \quad (12)$$

The above probability distribution of mortality is used as a component in deriving probability distributions of net incomes later in this section. Also, the probability distribution of mortality can be used to provide added meaning to the economies-of-scale curves developed previously. For example, the upper scale curve shown in figure 3 represents a mortality rate of 20.5 per cent. According to the mortality distribution derived, actual costs would be less than or equal to this level (for the appropriate set of fixed inputs and number of poults started) approximately 96 per cent of the time.

Price variability.—Turkey prices fluctuate considerably during the year as well as among years. Therefore, to estimate price variability, we must establish typical marketing dates within the year. California growers commonly start one brood during March and the second in May or June. Starting the first brood prior to March is impractical because poults generally are not available during January and because market prices for poults started in February approach a seasonal low. Considerations of disease control require that the brooder house remain empty for about six weeks between broods. The resulting production schedule is summarized in table 7. The grower is assumed to raise two broods of equal size and death loss.

Table 8 includes time series data on hen prices in the marketing months of August and November and tom prices during the marketing months of September and December. Analysis of the price data reveals two central facts: (1) Prices trended downward sharply during the first part of the period, as indicated by a drop in the average prices from 1950–1956 to 1957–1964 of from about 6 to

TABLE 7

PRODUCTION AND MARKETING SCHEDULE FOR TWO-BROOD TURKEY OPERATIONS

Brood	Date poults are started	Date poults are placed in growing pens	Marketing date	
			Hens	Toms
1..........	March 20	May 15	August 1	September 4
2..........	June 26	August 21	November 6	December 11

SOURCE: Assumed by authors on basis of typical industry pattern.

TABLE 8

TURKEY PRICES AND RELATED DATA USED IN PRICE FORECASTING EQUATIONS

Year	Hen prices per pound live weight*			Tom prices per pound live weight*			Ratio of inventory holdings†	Ratio of turkey hens on farms‡
	January	August	November	January	September	December		
	dollars							
1950	.3020	.3448	.3327	.2534	.2708	.2621	2.5097	1.0388
1951	.3755	.3596	.4076	.3027	.3500	.3510	.8678	.9789
1952	.3533	.3071	.3340	.3486	.2898	.2989	.9696	1.1540
1953	.3521	.3201	.3607	.2949	.2910	.2849	1.3733	.8560
1954	.4004	.2752	.3119	.3023	.2343	.2290	.8331	.9788
1955	.3119	.2941	.3161	.2249	.2892	.2824	.9905	.9732
1956	.3284	.2711	.2544	.3031	.2466	.2769	.7906	1.0561
1957	.2615	.2132	.2376	.2650	.2036	.1924	1.7059	1.1333
1958	.2384	.2551	.2286	.1910	.1967	.2114	1.0904	.9254
1959	.2364	.2128	.2765	.2422	.2163	.3121	.9169	1.0977
1960	.2908	.2401	.2822	.2848	.2310	.2535	.9205	.9085
1961	.2576	.2059	.2043	.2326	.1622	.1689	1.0732	1.2711
1962	.1816	.1962	.2469	.1647	.1896	.2070	1.6433	.9052
1963	.2400	.2124	.2491	.2138	.2053	.2119	.7727	1.0107
1964	n.a.	.1994	.2219	.2072	.1950	.2102	n.a.	n.a.
1950–56 avg.	.3462	.3103	.3310	.2900	.2817	.2836	......	......
1957–64 avg.	.2438	.2169	.2434	.2252	.2000	.2209	......	......
1950–64 avg.	.2950	.2605	.2843	.2554	.2381	.2502	......	......

* Monthly average prices paid per pound live weight at the farm in the San Joaquin Valley of California, Federal-State Market News Service (1950–1963).

† The pounds of inventory holdings used to compute these ratios are reported in U. S. Agricultural Marketing Service, Annual Reports (1949–1962). The method of computing the ratios is discussed in the text.

‡ The number of turkey hens on farms used to compute these ratios are reported in U. S. Department of Agriculture Statistical Bulletin 305, (1962, p. 104) and U. S. Statistical Reporting Service (1962 and 1963). The method of computing these ratios is discussed in the text.

10 cents per pound and (2) prices fluctuated considerably from year to year, irrespective of long-term trends.

The central issue here is to obtain an estimate of the price variability which an independent turkey grower could expect to face in the future. Because the general *level* of prices has been relatively stable for the 1957–1964 period, at about 23 cents per pound for hens and 21 cents per pound for toms, these price *levels* are projected for the future. Perhaps the best estimate of the variability of prices for the future is the variability of prices around the long-term trend of prices. Thus, quadratic trend equations were fit to the time series data of table 8 and the results summarized in the top portion of table 9. The residuals of these equations provide the appropriate variance and covariance of prices used in estimating net income variability.

The price variabilities estimated as above are relevant for an independent grower who had no information concerning the prices which might be forthcoming in a particular year. As pointed out in the decision theory discussion, however, a grower might use some "outside" information in attempting to predict *which* level of price is most likely *this* year. Of course, to the extent that his price anticipations model is inaccurate, the grower will still experience some random variation about his expected price. Still, his price anticipation model may help him to decide which years he should contract turkey production and

TABLE 9

REGRESSION EQUATIONS FOR HEN AND TOM TURKEY PRICES

Equation	Constant term	Regression estimates and their t values for the independent variables: Time (T)	Time (T^2)	Hens on farms (H)	Cold storage inventories (I)	R^2
	Equations for no "data" problem					
Hen price:						
August	0.3794	−0.0212	0.0006	.....	.....	.90
	(22.74)	(−4.41)	(2.09)			
November	0.4022	−0.0222	0.0007	.....	.....	.72
	(13.77)	(−2.64)	(1.41)	.....	.....	
Tom price:						
September	0.3354	−0.0173	0.0005	.....	.....	.70
	(12.61)	(−2.26)	(1.06)			
December	0.3141	−0.0092	0.0001	.....	.....	.42
	(8.39)	(−0.85)	(0.18)			
	Equations for "data" problem					
Hen price:						
August	0.5034	−0.0238	0.0007	−0.0889	−0.0198	.96
	(13.35)	(−6.36)	(3.31)	(−2.71)	(−2.34)	
November	0.6096	−0.0268	0.0009	−0.1434	−0.0346	.87
	(8.71)	(−3.89)	(2.31)	(−2.36)	(−2.22)	
Tom price:						
September	0.5097	−0.0230	0.0008	−0.1046	−0.0393	.87
	(8.32)	(−3.78)	(2.15)	(−1.96)	(−2.86)	
December	0.4802	−0.0168	0.0005	−0.0774	−0.0498	.62
	(4.64)	(−1.64)	(0.81)	(−0.86)	(−2.14)	

which years he should remain independent, thereby increasing his expected income over continuous independent or contract production.

Outlined below is an attempt to develop such price forecasting equations for hen and tom prices in the relevant marketing months.

A turkey price forecasting model, to be useful, must utilize data available by about January of year (T) because by this time the grower must start making decisions about contracting, number of poults to order, etc., for the coming year. By the end of January, a number of important variables affecting prices are available. An analysis of factors influencing the supply and demand for turkey meat suggest that a reasonable price forecasting model might contain the variables in equation (13). Equation (13) states that market prices (P) depend on T = time trend, H = the number of breeder hens on farms at the start of

$$P = f(T, T^2, H, I, U) \qquad (13)$$

the year relative to the number one year earlier, I = cold storage inventories at the start of the year relative to those of the previous year, and U = the unexplained residual.

The two variables H and I reflect expected changes in the supply of turkey meat for the coming year relative to those of the previous year. The trend variables allow for the gradual shift in demand because of changes in population, consumer income, and taste.

Because the grower markets hen turkeys during both August and November and tom turkeys during September and December, we are interested in four separate price forecasting equations. The lower portion of table 9 summarizes the coefficients and relevant statistics for these four price forecasting equations fit in linear form. The R^2 values increase substantially over the corresponding time trend equations, all coefficients have the expected sign, and most are significant at generally accepted probability levels. The residuals from these equations represent the variation an intelligent grower utilizing outside information might expect around his forecasted price.

In decision theory terms, the top set of equations in table 9 refers to the "no data" problem where the decision maker does not attempt to made a specific price forecast each year apart from a simple extrapolation of trend. His *prior* distribution of the states of nature is based simply on the observed residuals about the trend line over the past 15 years. On the other hand, the bottom set of equations in table 9 refers to the "data" problem where the decision maker uses the price forecasting equations to make a particular price forecast for each year based on observed values of the independent supply variables H and I. His *posterior* distribution of the states of nature is based on the observed residuals from the price forecasting equations observed over the past 15 years.

We have assumed throughout the analysis that the grower raises two equal sized broods and that he markets one-half of the hen turkeys and one-half of the tom turkeys from each brood. The price variability for hens in year T can then be estimated from the general expression given in equation (14), where (r_{AN}^H) is the correlation of hen prices in August and November in the same year

$$\mathrm{Var}(P^H) = (1/2)^2 \mathrm{Var}\, P^{HA} + (1/2)^2 \mathrm{Var}(P^{HN}) + 2(r_{AN}^H)\, \frac{(\sigma_A^H)}{2}\, \frac{(\sigma_N^H)}{2} \qquad (14)$$

(see derivation in Appendix B). An expression for the variance of tom prices in each year can be derived in a similar manner.

One further statistical measure of price variability needed in computing total price variability and, ultimately, income variability, is the covariance of hen and tom prices as shown in equation (15). (See derivation in Appendix B.)

$$\begin{aligned} \mathrm{Cov}(P^T, P^H) = {} & q_1q_4\mathrm{Cov}(P^{HA}, P^{TD}) + q_2q_3\mathrm{Cov}(P^{HN}, P^{TS}) \\ & + q_2q_4\mathrm{Cov}(P^{HN}, P^{TD}) + q_1q_3\mathrm{Cov}(P^{HA}, P^{TS}). \end{aligned} \tag{15}$$

The empirical estimates of the relevant variances and correlation coefficients required to estimate equations (14) and (15) are given in tables 10 and 11. Table 11 indicates the reduction in the variance (or standard deviation) of the residuals as the decision maker moves from the "no data" to the "data" problem. For hens, the standard error of prices is reduced from 2.09 cents per pound to 1.15 cents per pound, while for toms it is reduced from 3.16 cents to 2.30 cents per pound.

Income variability.—The estimates of mortality and price variability from the previous sections are now combined into estimates of income variability associated with three principal methods of financing California turkey production:

(1) independent production,
(2) a guaranteed price plan, and
(3) a base payment plan with bonuses based on physical production factors.

These plans are representative of the major independent and contracting arrangements available to California turkey growers. They do not, of course, represent all contractual arrangements currently being used. Estimates of income variability are provided for two-brood operations of three sizes: 10,000, 20,000, and 35,000 poults started per brood. Alternative estimates also are provided for producers attaining either medium or high growth standards. Since primary emphasis in this section is on *variability* of returns, the definition of returns used is total revenue minus variable costs only, expressed in terms of 1,000 birds. Fixed costs are constant and do not affect the variance estimates

TABLE 10
VARIANCE-COVARIANCE MATRIX OF REGRESSION RESIDUALS

	No data problem				Data problem			
	P^{HA}	P^{HN}	P^{TS}	P^{TD}	P^{HA}	P^{HN}	P^{TS}	P^{TD}
P^{HA}	0.000301	0.000263	0.000323	0.000291	0.000130	−0.000022	0.000063	0.000023
P^{HN}		0.000922	0.000694	0.000845		0.000445	0.000256	0.000388
P^{TS}			0.000765	0.000857			0.000344	0.000395
P^{TD}				0.001513				0.000983

TABLE 11
VARIANCE ESTIMATES OF TURKEY PRICES

	σ_H^2	σ_T^2	Cov(H,T)	σ_H	σ_T
No data problem	0.000437	0.000998	0.000538	0.020905	0.031591
Data problem	0.000133	0.000529	0.000183	0.011533	0.023000

However, in the empirical decision section to follow, net incomes are expressed in terms of the entire operation with both variable and fixed costs deducted in computing grower incomes.

Independent Production. The independent turkey producer purchases all inputs, makes all decisions, arranges his own financing, and assumes all of the risk. His variability in income depends both on the variation of total revenue (gross returns) and the variation in production cost. Gross returns simply equal the market price multiplied by the pounds of turkey produced and, hence, fluctuate in response to changes in both prices and mortality. Production costs fluctuate only because of variability in mortality since input prices are assumed constant.

Let Z_{TA} and Z_{HA} represent the pounds of tom and hen turkey produced per 1,000 poults started, using the adjusted (medium) growth standards developed earlier. Likewise, let Z_{TH} and Z_{HH} represent like quantities for the high growth standard. M represents the percentage (decimal form) of mortality. Using the

$$Z_{TA} = 12{,}575 - 13{,}341\ M \qquad (16)$$

$$Z_{HA} = 6{,}625 - 6{,}221\ M \qquad (17)$$

$$Z_{TH} = 13{,}361 - 14{,}161\ M \qquad (18)$$

$$Z_{HH} = 7{,}039 - 6{,}604\ M \qquad (19)$$

variable cost components K_1, K_{2j}, and F_j defined earlier (all variable costs except interest on operating capital), equations (20), (21), and (22) are used in computing expected returns (R_{1A}, R_{2A}, and R_{3A}) and variances for an independent producer with brood sizes 10,000, 20,000, and 35,000, respectively, and using the adjusted (medium) growth standard. A similar set of equations is

$$R_{1A} = P_H Z_{HA} + P_T Z_{TA} - (3{,}597 - 1{,}917\ M) \qquad (20)$$

$$R_{2A} = P_H Z_{HA} + P_T Z_{TA} - (3{,}584 - 1{,}916\ M) \qquad (21)$$

$$R_{3A} = P_H Z_{HA} + P_T Z_{TA} - (3{,}577 - 1{,}916\ M) \qquad (22)$$

used in computing returns R_{1H}, R_{2H}, and R_{3H} for growers reaching the high growth standard.

To estimate the expected returns and the variance of expected returns, we generalize the above equations to the form shown in equation (23), where the letters a through f represent the corresponding six numerical coefficients.

$$R = P_H(a-bM) + P_T(c-dM) - (e-fM) \qquad (23)$$

Well-known mathematical definitions concerning the expected value and the variance of a random variable defined as a linear combination of other random variables were used to obtain the expected value and the variance of R_{1A}, R_{2A}, and R_{3A}. (The variances for R_{1H}, R_{2H}, and R_{3H} were assumed to approximate those for the adjusted growth rate.) Using these rules, expected returns per 1,000 poults started would be given by equation (24) where $\bar{R}$ refers to the expected returns using the expected prices ($\bar{P}_T$ and $\bar{P}_H$) estimated by the regression model and the expected level of mortality ($\bar{M}$).

$$\bar{R} = \bar{P}_H(a-b\bar{M}) + \bar{P}_T(c-d\bar{M}) - (e-f\bar{M}) \qquad (24)$$

The variance of R is by definition equation (25). Substituting equations (23) and (24) into equation (25),

$$\mathrm{Var}R = E(R - \bar{R})^2 \qquad (25)$$

and assuming that mortality is independent of prices, the resulting expression is equivalent to equation (26). (See Appendix C for derivation.) Hence, the variance of R for any of the three brood

$$\begin{aligned}\mathrm{Var}R = {} & a^2\sigma_H^2 + c^2\sigma_T^2 + f^2\sigma_M^2 + b^2\,[(\sigma_H^2)(\sigma_M^2 + \bar{M}^2) + \bar{P}_H^2\sigma_M^2] \\ & + d^2[(\sigma_T^2)(\sigma_M^2 + \bar{M}^2) + \bar{P}_T^2\sigma_M^2] - 2ab(\sigma_H^2\bar{M}) + 2ac\sigma_{HT} \\ & - 2(ad + bc)(\sigma_{HT}\bar{M}) + 2bd\sigma_{TH}(\sigma_M^2 + \bar{M}^2) + 2bd\sigma_M^2\bar{P}_H\bar{P}_T \\ & - 2bf(\bar{P}_H\sigma_M^2) - 2cd\sigma_T^2\bar{M} - 2df(\bar{P}_T\sigma_M^2)\end{aligned} \tag{26}$$

sizes and growth rates can be expressed in terms of the variance, covariance, and expected value of the three random variables (price of toms, price of hens, and mortality) and the appropriate constants in the returns equation.

Using equations (24) and (26), it is possible to estimate both expected returns and the variance of these returns for the independent grower, both with and without a price forecasting model. However, prices in both cases are normally distributed while mortality is lognormally distributed. What, then, is the form of the resulting probability distribution of returns? A Monte-Carlo simulation technique was used to approximate the form of this distribution. Three samples of 1,000 normal random deviates were selected. The first and second samples were used to transform the value of expected prices and the standard error of prices to form a series of 1,000 tom and hen prices having the specified variances and covariance. The third sample of random deviates was transformed using the median and standard deviation of the lognormal distribution. The antilogs of these values were used as the 1,000 observations for M. Hence, the Monte-Carlo technique was used to generate 1,000 sets of estimates of (P_{Hi}, P_{Ti}, M_i) where P_{Hi} and P_{Ti} have the specified covariance estimated previously, but both are independent of the value of M_i. Returns equation (24) was solved using each of the 1,000 sets of estimates for price and mortality. The resulting frequencies of returns approximated the theoretical frequencies of a normal distribution with the same mean and variance, as indicated by a chi-square goodness of fit test.[5]

The above procedures were used to establish the expected value, variance, and form of the returns distribution per 1,000 poults started under independent production. The left-hand portion of table 12 provides estimates of the expected returns, standard error of returns, and the level of returns (per 1,000 poults) associated with the 5 per cent point on the lower tail of the probability distribution of returns. The parameters are presented for both the "no data" (no price forecast) and "data" (with price forecast) problems. The standard error of returns, given the price forecast, is, of course, less than the standard error of returns without a forecast. These results, along with similar estimates for the two contract alternatives, form the basic information to be used in the decision models to follow. The implications of these results are discussed in more detail at that time.

Guaranteed Price Contract. Raising turkeys for a guaranteed price per pound is one alternative to independent production in California. In this contractual arrangement, the off-farm firm agrees prior to the starting of the poults to purchase all turkeys at market weight for a specified price per pound. The grower agrees to furnish all of the financing for the operation and must sell the

[5] Eidman (1965) presents the actual numerical results for the frequencies by size class and the chi-square test.

TABLE 12

ESTIMATED PARAMETERS OF THE DISTRIBUTION OF RETURNS PER 1,000 POULTS STARTED UNDER INDEPENDENT PRODUCTION ("DATA" AND "NO DATA" PROBLEMS), A GUARANTEED PRICE CONTRACT AND A BASE PAYMENT PLUS BONUSES CONTRACT

Growth standards	Brood size two broods per year	Parameter of return distribution estimated	Independent production: "no data" problem	Independent production: "data" problem, for alternative price forecasts								Guaranteed price contract	Base payment plus bonuses
				P_H = .16 P_T = .14	P_H = .18 P_T = .16	P_H = .20 P_T = .18	P_H = .22 P_T = .20	P_H = .24 P_T = .22	P_H = .26 P_T = .24	P_H = .28 P_T = .26	P_H = .30 P_T = .28		
MEDIUM	10,000	Expected returns...	343	− 868	− 522	−176	170	516	801	1,207	1,553	169	231
		Std. error of return.	480	315	319	324	330	337	345	354	364	104	49
		Returns at 5 per cent lower level..	−447	−1,386	−1,047	−708	−372	− 38	233	625	954	− 35	148
	20,000	Expected returns...	355	− 856	− 510	−164	182	528	813	1,219	1,565	181	241
		Std. error of return.	480	315	319	324	330	337	345	354	364	104	49
		Returns at 5 per cent lower level..	−435	−1,374	−1,034	−697	−360	− 26	245	637	966	− 23	159
	35,000	Expected returns...	363	− 848	− 502	−156	190	536	821	1,227	1,573	189	249
		Std. error of return.	480	315	319	324	330	337	345	354	364	104	49
		Returns at 5 per cent lower level..	−427	−1,336	−1,026	−689	−352	− 18	253	645	974	− 15	167
HIGH	10,000	Expected returns...	597	− 690	− 322	46	413	781	1,149	1,516	1,884	392	285
		Std. error of return.	509	334	338	343	350	357	366	376	386	116	49
		Returns at 5 per cent lower level..	−240	−1,239	− 878	−518	−163	194	547	897	1,249	165	204
	20,000	Expected returns...	609	− 678	− 310	58	425	793	1,161	1,528	1,896	405	295
		Std. error of return.	509	334	338	343	350	357	366	376	386	116	49
		Returns at 5 per cent lower level..	−228	−1,227	− 866	−506	−151	206	559	909	1,261	178	215
	35,000	Expected returns...	617	− 670	− 302	66	433	801	1,169	1,536	1,904	413	303
		Std. error of return.	509	334	388	343	350	357	366	376	386	116	49
		Returns at 5 per cent lower level..	−220	−1,219	− 858	−498	−143	214	567	917	1269	186	223

turkeys to the buyer at market time or pay a substantial fine for failure to perform the contract. The guaranteed prices per pound for 1964 agreements were 20 cents and 22 cents for tom and hen turkeys, respectively. The grower may raise no more than two broods per year to be eligible for this arrangement. If only one brood is raised per year, the above guarantees are reduced by 1¾ cents per pound. Under this agreement, a grower has obviously shifted all price variability to the off-farm firm and maintains only the income variability due to mortality. The grower incurs the same fixed and variable costs as an independent grower and maintains ownership of the turkeys throughout the growing period.

Returns per 1,000 poults started for two-brood operations with brood sizes of 10,000, 20,000, and 35,000 are defined by equations (27), (28), and (29), respectively, using the adjusted (medium) growth standard. Equations (30), (31), and (32) provide similar estimates using the high growth standard. The center

$$R_{1A} = 375 - 2{,}120\,M \tag{27}$$

$$R_{2A} = 388 - 2{,}121\,M \tag{28}$$

$$R_{3A} = 396 - 2{,}121\,M \tag{29}$$

$$R_{1H} = 624 - 2{,}368\,M \tag{30}$$

$$R_{2H} = 637 - 2{,}369\,M \tag{31}$$

$$R_{3H} = 644 - 2{,}369\,M \tag{32}$$

portion of table 12 shows the expected returns, standard error of returns, and returns at the lower 5 per cent level for various sizes of operations using the two alternative growth standards. Expected returns from this contract are somewhat lower than for independent production, but income variability is also much less because of the guaranteed price.

Base Payment Plus Bonuses Contract. The second major type of contract available to California turkey growers requires the grower to furnish only the fixed inputs (land, buildings, and equipment), and the labor and machinery operating expenses (the variable inputs represented by K_{2j}). The off-farm concern furnishes the remainder of the variable inputs, including feed, maintains ownership of the flock, and makes the major production and marketing decisions.

The provisions stipulating payments to be made to the growers are written to apply to flocks of either sex or mixed flocks. Because all of the analysis in this study is based on mixed flocks, only the payment provisions applying to them will be quoted.

When the flock has been marketed, the grower receives a base payment for all live birds marketed (except culls and condemnations) calculated on the basis of (1) 2 cents per bird per week from day old through 8 weeks plus, (2) 1 cent per bird per week from 9 weeks through 25 weeks plus, and (3) 1½ cents per bird per week from 26 weeks to market time. In addition a bonus is paid for livability. Livability is defined as the ratio of total birds marketed to the total birds started. A bonus of 1 cent or fraction thereof per bird marketed is paid for each 1 per cent or fraction thereof that livability exceeds 89 per cent. No bonus (or penalty) applies when livability falls below 89 per cent.

A second bonus is paid for feed conversion, i.e., the pounds of feed required to produce 1 pound of live turkey at marketing time. The bonus schedule for mixed flocks with an average weight per bird marketed of more than 18 pounds but less than 20 pounds is given in table 13.

In this contractual arrangement, the grower has again shifted the portion of income variability due to price fluctuations to the contractor. Only mortality

TABLE 13
FEED CONVERSION BONUS FOR BASE PAYMENT PLAN

Pounds of feed fed per pound of live turkey marketed	Bonus per bird marketed
	cents
over 4.19	.00
4.19–4.10	.01
4.09–4.00	.02
3.99–3.90	.03
3.89–3.80	.05
3.79–3.70	.07
3.69–3.60	.09
3.59–3.50	.11
3.49–3.40	.14
less than 3.40	.17

SOURCE: Adapted from contracts of major contracting concerns.

affects the income variability of the grower. In addition to shifting the price variability to the contractor, this contract also requires the off-farm firm to provide the financing for all of the variable inputs except labor and machinery operating expenses.

The relationship of returns over the range of mortality rates from 0 to 100 per cent is in actuality discontinuous rather than continuous because of the ranges in mortality to which certain bonus rates apply. However, these discontinuities were found to be of relatively minor importance in the analysis. Consequently, the analysis assumes that the relationship of net returns to mortality is satisfactorily approximated by a continuous distribution. The returns per 1,000 poults started can be computed as the base payment plus the bonus for livability, plus the bonus for feed conversion minus the labor and machinery operating expenses (value for K_{2j}). This is summarized by equation (33) where R_j refers to the returns per 1,000 poults for the brood size j (10,000, 20,000, or 35,000). Feed conversion bonus b_i takes a value b_1 when the adjusted (medium) growth standard is used, and a value b_2 for the high growth standard. The resulting probability distribution of returns is lognormally distributed since it is a linear transformation of the log of the random variable mortality (M). The

$$R_j = .27(500 - 470M) + .32(500 - 530M) + .01X(1{,}000 - 1{,}000M) + b_i(1{,}000 - 1{,}000M) - K_{2j} \qquad (33)$$

where

$\$0.27$ = base payment per hen turkey marketed at 19 weeks.
$\$0.32$ = base payment per tom turkey marketed at 25 weeks.
$X = 11 - M$ when $0 \leqq M < 11$ per cent and
$X = 0$ when $M \geqq 11$ per cent.
b_1 = bonus per bird from table 33 applicable for the feed conversion computed as

$$3.4635 + \left(\frac{18{,}858}{19{,}200 - 19{,}405M}\right) M .$$

b_2 = bonus per bird from table 33 applicable for the feed conversion computed as $\frac{b_1}{1.0625}$. That is, the high growth standard gives 6.25 per cent greater output from the same feed inputs as the adjusted (medium) growth standard.

right-hand portion of table 12 provides estimates of the expected returns, standard error of returns, and returns at the lower 5 per cent level of returns for this contract. The system of bonuses reduces the variability of returns below that for the other contract system studied. Using the medium growth standard it also has a higher expected return. However, at the high growth standard, the guaranteed price contract has a higher expected return per 1,000 poults. A more complete comparison among alternative plans is given in the next section.

Empirical decision models for contract versus independent production

The previous sections developed measures of income variability per 1,000 poults for turkey growers. This section expresses these results in terms of the entire turkey operation—a more realistic basis for grower decisions. Tables 14, 15, and 16 present the income distributions for contract and independent producers of various sizes using the high growth standards. Later tables show similar results for producers attaining the adjusted (medium) growth standards. Table 14 will be analyzed first in some detail to indicate clearly the decision procedures followed. Other tables can be analyzed similarly. The tables in this section summarize the results in a convenient form for our purposes by showing the returns which accrue to the grower at specified points on the probability distribution of returns for each action.

The data in table 14 are defined as net returns to the grower's capital, management, and operator and family labor. That is, they represent all variable and fixed costs except family labor (valued at $2,600 per year based on $1.50 per hour) and interest on fixed capital. It is assumed that the grower has 100 per cent equity in his operation. That is, he owns all buildings, land, machinery and equipment, valued at $30,000—approximately the average investment over the life of the capital items. However, the grower is considered to have little cash on hand for operating costs, and therefore borrows approximately $65,000 for a period of six months, requiring almost $2,000 in interest payments. This $2,000 is deducted in arriving at the figures in table 14, while interest on the long-term capital items (approximately $1,800) is not deducted, because it is not a cash cost. Thus, the income figures in table 14 (and the subsequent tables in this section) represent the cash income to the grower after paying all cash costs and providing for maintenance and replacement of existing capital items. If turkey production provides the only income of the grower, the amounts in table 14 represent the income available for family living expenses, savings, and any investment in an expansion of the business.

Consider first the case presented in table 14 of a grower producing 20,000 birds (two broods of 10,000 each) and achieving the high growth rate. Columns (1), (2), and (3) of table 14 are the only actions relevant for the solution of the "no data" decision problem. They are relevant to the producer who has no price forecasting model, and who will therefore choose either independent production, Contract A, or Contract B continuously over time.

Assuming a linear utility function and the Bayes criterion, independent production would be selected in this case because it provides an expected income of $5,670 compared with $2,210 and $1,920 for the contract alternatives. However, the income variances for contract production are much less than for independent production, and have only somewhat lower expected values. Thus, if the incomes in these two columns could be converted to utility values, a producer revealing a decreasing marginal utility for money might select Contract B over independent production. The alternative to this procedure is to adopt the Bayes criterion subject to a minimum absolute income (maximum loss) at an "acceptable" probability level such as 5 per cent. To illustrate, assume the case of a producer whose equity posi-

Table 14

PAYOFF TABLE (NET RETURNS)* FOR INDEPENDENT TURKEY PRODUCTION AND TWO ALTERNATIVE CONTRACTS (10,000 BIRDS PER BROOD, TWO BROODS PER YEAR), USING *HIGH* GROWTH STANDARDS

Points on the probability distribution	Contract A: guaranteed price	Contract B: base plus bonus	Independent production: no price forecast	Independent production: given specified price forecasts							
				P_H = .16 P_T = .14	P_H = .18 P_T = .16	P_H = .20 P_T = .18	P_H = .22 P_T = .20	P_H = .24 P_T = .22	P_H = .26 P_T = .24	P_H = .28 P_T = .26	P_H = .30 P_T = .28
	dollars per year										
	1	2	3	4	5	6	7	8	9	10	11
.01	−5,810	− 920	−18,020	−35,590	−28,690	−21,310	−14,300	− 7,260	− 320	6,550	13,430
.05	−2,550	180	−11,080	−31,040	−23,810	−16,630	− 9,530	− 2,400	4,670	11,680	18,690
.10	−1,170	440	− 7,380	−28,610	−21,350	−14,140	− 6,980	200	7,330	14,410	21,500
.20	210	700	− 2,000	−25,670	−18,380	−11,120	− 3,900	3,340	10,550	17,720	24,890
.50	2,210	1,920	5,670	−20,050	−12,690	− 5,350	1,990	9,350	16,710	24,050	31,390
.80	3,590	2,740	14,240	−14,430	− 7,000	420	7,880	15,360	22,870	30,380	37,890
.90	4,130	3,080	18,720	−11,490	− 4,030	3,440	10,960	18,500	26,000	33,690	41,280
.95	4,510	3,300	22,420	− 9,060	− 1,570	5,930	13,510	21,100	28,750	36,420	44,090
.99	5,070	3,660	20,360	− 4,510	3,040	10,610	18,280	25,960	33,740	41,550	49,350
Expected value	1,990	1,780	5,070	−20,050	−12,690	− 5,350	1,990	9,350	16,710	24,050	31,390

* Net returns defined as return to management, operator, labor, and capital.

Source: Compiled from previous tables.

Table 15

PAYOFF TABLE (NET RETURNS)* FOR INDEPENDENT TURKEY PRODUCTION AND TWO ALTERNATIVE CONTRACTS (20,000 BIRDS PER BROOD, TWO BROODS PER YEAR), USING *HIGH* GROWTH STANDARDS

Points on the probability distribution	Contract A: guaranteed price	Contract B: base plus bonus	Independent production: no price forecast	Independent production: given specified price forecasts							
				P_H = .16 P_T = .14	P_H = .18 P_T = .16	P_H = .20 P_T = .18	P_H = .22 P_T = .20	P_H = .24 P_T = .22	P_H = .26 P_T = .24	P_H = .28 P_T = .26	P_H = .30 P_T = .28
	dollars per year										
	1	2	3	4	5	6	7	8	9	10	11
.01	−12,540	−2,830	−36,950	−72,100	−57,760	−43,540	−29,520	−15,450	− 1,570	12,190	25,940
.05	− 6,020	− 630	−23,070	−63,000	−48,540	−34,190	−19,980	− 5,710	8,410	22,440	36,460
.10	− 3,260	− 110	−15,680	−58,140	−43,630	−29,200	−14,890	− 520	13,730	27,900	42,070
.20	− 500	370	− 6,720	−50,930	−37,680	−23,170	− 8,740	5,760	20,170	34,520	48,860
.50	3,500	2,810	10,420	−41,020	−26,300	−11,620	3,050	17,780	32,490	47,180	61,860
.80	6,260	4,490	27,560	−31,110	−14,920	− 70	14,840	29,800	44,810	59,840	74,860
.90	7,340	5,170	36,520	−23,900	− 8,970	5,900	20,990	36,080	51,260	66,460	81,650
.95	8,100	5,610	43,910	−19,040	− 4,060	10,950	26,080	41,270	56,570	71,920	87,080
.99	9,220	6,330	57,790	− 9,940	5,160	20,300	35,020	51,010	66,550	82,170	97,780
Expected value	3,050	2,570	10,420	−41,020	−26,300	−11,620	3,050	17,780	32,490	47,180	61,860

* Net returns defined as return to management, operator, labor, and capital.
Source: Compiled from previous tables.

TABLE 16

PAYOFF TABLE (NET RETURNS)* FOR INDEPENDENT TURKEY PRODUCTION AND TWO ALTERNATIVE CONTRACTS (35,000 BIRDS PER BROOD, TWO BROODS PER YEAR), USING *HIGH* GROWTH STANDARDS

Points on the probability distribution	Contract A: guaranteed price	Contract B: base plus bonus	Independent production: no price forecast	Independent production: given specified price forecasts							
				P_H = .16 P_T = .14	P_H = .18 P_T = .16	P_H = .20 P_T = .18	P_H = .22 P_T = .20	P_H = .24 P_T = .22	P_H = .26 P_T = .24	P_H = .28 P_T = .26	P_H = .30 P_T = .28
	dollars per year										
	1	2	3	4	5	6	7	8	9	10	11
.01	−21,840	− 4,840	−64,630	−126,150	−101,040	−76,160	−51,610	−26,990	− 2,700	21,360	45,420
.05	−10,430	− 990	−40,340	−110,210	− 84,910	−59,800	−34,910	− 9,960	14,770	39,300	63,840
.10	− 5,600	− 80	−27,400	−101,720	− 76,320	−51,070	−26,010	− 880	24,070	48,870	73,660
.20	− 770	760	−11,720	− 91,430	− 65,910	−40,510	−15,230	10,110	35,340	60,440	85,540
.50	6,230	5,030	18,270	− 71,750	− 45,990	−20,300	5,390	31,150	56,910	82,600	108,290
.80	11,060	7,900	48,260	− 52,070	− 26,070	− 90	26,010	52,190	78,480	104,760	131,040
.90	12,950	9,090	63,940	− 41,780	− 15,660	10,470	39,490	63,180	89,750	116,330	142,920
.95	14,280	9,930	76,880	− 33,290	− 7,070	19,200	45,690	72,260	99,050	125,900	152,740
.99	16,240	11,190	101,170	− 17,350	9,060	35,560	61,390	89,290	116,520	143,840	171,160
Expected value	5,390	4,610	18,270	− 71,750	− 45,990	−20,300	5,390	31,150	56,910	82,600	108,290

* Net returns defined as return to management, operator, labor, and capital.
SOURCE: Compiled from previous tables.

tion is such that a loss of \$10,000 would force him out of business. Suppose the producer is willing to accept the risk of this occurring with a chance of 5 out of 100. In other words, the criterion now is: Select that action which gives maximum expected value subject to the restriction that the income at the lower 5 per cent point on the income distribution is not less than \$−10,000 (a loss of \$10,000). Table 14 indicates that Contract A would be selected in this case. Independent production has a higher expected value but does not meet the side condition—it allows a loss of \$−11,080 at the 5 per cent level, which exceeds the \$10,000 maximum "permissible" loss. Of course, other combinations of absolute "permissible" losses and probability levels would be relevant for producers in other financial circumstances and with different attitudes toward risk. Given the specifications, the recommended action for such cases can be derived directly from the data in table 14.

Thus far we have assumed that the producer has no price forecasting model and is operating with a "no data" problem. Suppose now that he uses the price forecasting equations to predict prices. On the basis of the price forecast, he decides whether to contract production or produce as an independent. Thus, he is operating with a "data" problem where the price forecast represents the outside information incorporated each year. The right-hand portion of table 14 shows *posterior* distribution of returns, given various price forecasts as indicated in the heading of each column. In this case, application of the unrestricted Bayes criterion would suggest that the producer should remain independent in those years in which he predicts prices of about 22 cents for hens (20 cents for toms) or higher, and employ Contract A or B when predicted prices are lower. In other words, the relevant actions for the "data" problem consist of columns (1), (2), and the columns (4) to (11) representing the specific price forecast for year T.

Suppose the producer could develop completely accurate predictions of price so that he could always select that form of production (independent or contract) which would maximize his profit (minimize losses) in a given year. The value of this "perfect predictor" would have averaged about \$2,700 per year over the 15-year period 1950–1964. That is, average income from a flexible plan would have increased income \$2,700 per year over continuous independent production. If a producer has used the price forecasting equations presented earlier, the "value of experiment" would have averaged about \$600 per year over the same period. These results suggest that a producer who is flexible as between independent and contract production could expect to increase his average income somewhat over time if his price forecasting model were sufficiently accurate to forecast extreme prices in either direction from mean price levels.

A major implication drawn from table 14 is that a small turkey operation of 20,000 birds (two broods of 10,000) provides extremely low expected incomes at price levels prevailing in recent years even when the operation is efficient in terms of achieving high growth rates. It is difficult to see how a family operation of this size, relying entirely on income from turkey production, could have prospered over this period. Of course, turkey production requires operator and family labor primarily over a six- to eight-month period. Therefore, some operators might obtain additional income from other jobs during the idle season. In other cases, turkey production may be only one enterprise on a multiple enterprise farm, such that low turkey profits may not be disastrous for the operator.

Tables 15 and 16 show that expected income and income distributions for operations of 40,000 and 70,000 birds per year follow a pattern similar to that for a 20,000-bird operation summarized in table 14. Even though there are approximately constant average costs beyond a 20,000-bird operation, the larger volume of production in these cases provides more satisfactory income levels. Independent production provides higher expected incomes than Contract A or B, but nonlinear utility functions (or side restrictions on absolute losses and probability levels) would likely suggest Contract B as a preferred alternative for some producers.

The above results suggest that, at recent prices, the expected income for turkey producers achieving *high* growth rates are quite modest. Approximately one-half of the producers in the 1963 sample achieved growth rates above the *medium* level; several achieved rates above the *high* standard. Rapid adoption of new technology has been an outstanding characteristic of the turkey industry. Hence, it is likely that in the years since 1963 further increases in growth rates have been achieved by growers. For this reason, the *high* growth standards outlined above may now be relevant for a fairly substantial proportion of California turkey growers. However, a number of producers still have operations achieving only the *medium* growth standards. Results for this situation are presented in tables 17, 18, and 19.

Substantially lower incomes are obtained with the *medium* growth standard. Expected income from independent production is \$980, \$1,040, and \$1,850 for operations of 20,000, 40,000, and 70,000 birds, respectively (tables 17, 18, and 19). At the medium growth standard, the base plus bonuses Contract B is clearly preferred to the guaranteed price Contract A because it provides a high expected income with less variance. In addition, Contract B would probably be preferred to independent producer by most growers in this situation because it provides an expected income almost as great as independent production with far less risk.

Shifting to the "data" problem where a price forecast is available, tables 17, 18, and 19 indicate that the "breakeven" price, below which contract production would have a higher expected income, is about 23 cents per pound for hens (21 cents for toms). This is about 1 cent higher than the "breakeven" price for the grower achieving *high* growth rates.

A major conclusion of this section is that producers able to reach *high* growth standards in their operations are more likely to produce turkeys independently than those reaching only *medium* growth standards. The level of expected returns from turkey production under *high* growth standards, at recent average prices, is sufficiently high to induce resources to remain in turkey production. However, it is difficult to see why a producer achieving only the *medium* growth standard would remain in production over an extended period at recent average prices—the income levels achieved in this case are simply too low.

Simulated capital accumulation through time from independent and contract production

The previous sections suggest that the prospects for capital accumulation over time for California turkey producers are poor if their birds reach only the medium growth standard. This is true regardless of whether production is independent or contract. However, at the high growth standard, there appeared to be some possibility of capital accumulation and growth in net worth through times. The purpose of this section is to simulate the growth (or decline) in net worth through

Table 17

PAYOFF TABLE (NET RETURNS)* FOR INDEPENDENT TURKEY PRODUCTION AND TWO ALTERNATIVE CONTRACTS (10,000 BIRDS PER BROOD, TWO BROODS PER YEAR), USING *MEDIUM* GROWTH STANDARDS

Points on the probability distribution	Contract A: guaranteed price	Contract B: base plus bonus	Independent production: no price forecast	Independent production: given specified price forecasts							
				$P_H = .16$ $P_T = .14$	$P_H = .18$ $P_T = .16$	$P_H = .20$ $P_T = .18$	$P_H = .22$ $P_T = .20$	$P_H = .24$ $P_T = .22$	$P_H = .26$ $P_T = .24$	$P_H = .28$ $P_T = .26$	$P_H = .30$ $P_T = .28$
	dollars per year										
	1	2	3	4	5	6	7	8	9	10	11
.01	−9,490	−1,800	−21,360	−37,890	−31,150	−24,470	−17,830	−11,250	− 4,680	1,800	8,250
.05	−6,550	− 940	−14,810	−33,590	−26,810	−20,050	−13,330	− 6,660	20	6,620	13,210
.10	−5,330	− 400	−11,320	−31,300	−24,400	−17,700	−10,930	− 4,210	2,530	9,200	15,800
.20	−4,090	− 160	− 7,100	−28,530	−21,680	−14,840	− 8,030	− 1,240	5,560	12,310	19,060
.50	−2,290	840	980	−23,230	−16,310	− 9,390	− 2,470	4,430	11,370	18,270	25,190
.80	−1,070	1,620	9,060	−17,980	−10,940	− 3,940	3,090	10,100	17,180	24,230	31,320
.90	− 570	1,940	12,400	−15,160	− 8,130	− 1,080	5,990	13,070	20,210	27,340	34,520
.95	− 250	2,160	16,770	−12,870	− 5,810	1,270	8,390	15,520	22,720	29,920	37,170
.99	250	2,500	23,320	− 8,570	− 1,470	5,690	12,890	20,110	27,420	34,740	42,130
Expected value	−2,470	700	980	−23,230	−16,310	− 9,390	− 2,470	4,430	11,370	18,270	25,190

* Net returns defined as return to management, operator, labor, and capital.
Source: Compiled from previous tables.

Table 18

PAYOFF TABLE (NET RETURNS)* FOR INDEPENDENT TURKEY PRODUCTION AND TWO ALTERNATIVE CONTRACTS (20,000 BIRDS PER BROOD, TWO BROODS PER YEAR), USING *MEDIUM* GROWTH STANDARDS

Points on the probability distribution	Contract A: guaranteed price	Contract B: base plus bonus	Independent production: no price forecast	Independent production: given specified price forecasts							
				P_H = .16, P_T = .14	P_H = .18, P_T = .16	P_H = .20, P_T = .18	P_H = .22, P_T = .20	P_H = .24, P_T = .22	P_H = .26, P_T = .24	P_H = .28, P_T = .26	P_H = .30, P_T = .28
	dollars per year										
	1	2	3	4	5	6	7	8	9	10	11
.01	−19,900	−4,590	−43,630	−76,700	−63,230	−49,850	−36,570	−23,420	−10,290	2,670	15,580
.05	−14,060	−2,870	−30,540	−68,110	−54,530	−41,020	−27,570	−14,230	− 880	12,330	25,510
.10	−11,620	−1,790	−23,570	−63,530	−49,890	−36,310	−22,780	− 9,340	4,130	17,470	30,800
.20	− 9,140	−1,350	−15,120	−57,990	−44,280	−30,610	−16,970	− 3,410	10,200	23,700	37,200
.50	− 5,540	650	1,040	−47,380	−33,540	−19,700	− 5,860	7,940	21,820	35,620	49,460
.80	− 3,060	2,250	17,200	−36,770	−22,800	− 8,790	5,250	19,290	33,440	47,540	61,720
.90	− 2,100	2,890	25,650	−31,230	−17,190	− 3,090	11,060	25,220	39,510	53,770	68,120
.95	− 1,420	3,330	32,620	−26,650	−12,550	1,620	15,850	30,110	44,520	58,910	73,410
.99	− 425	4,010	45,710	−18,060	− 3,850	10,450	24,850	39,300	53,930	68,570	83,340
Expected value	− 5,860	410	1,040	−47,380	−33,540	−19,700	− 5,860	7,940	21,820	35,620	49,460

* Net returns defined as return to management, operator, labor, and capital.
Source: Compiled from previous tables.

TABLE 19

PAYOFF TABLE (NET RETURNS)* FOR INDEPENDENT TURKEY PRODUCTION AND TWO ALTERNATIVE CONTRACTS (35,000 BIRDS PER BROOD, TWO BROODS PER YEAR), USING *MEDIUM* GROWTH STANDARDS

Points on the probability distribution	Contract A: guaranteed price	Contract B: base plus bonus	Independent production: no price forecast	Independent production: given specified price forecasts							
				P_H = .16 P_T = .14	P_H = .18 P_T = .16	P_H = .20 P_T = .18	P_H = .22 P_T = .20	P_H = .24 P_T = .22	P_H = .26 P_T = .24	P_H = .28 P_T = .26	P_H = .30 P_T = .28
	dollars per year										
	1	2	3	4	5	6	7	8	9	10	11
.01	−34,700	−7,920	−76,330	−134,180	−110,620	−87,210	−63,970	−40,960	−17,970	6,180	27,310
.05	−24,500	−4,910	−53,420	−119,150	− 95,390	−71,750	−48,220	−24,880	− 1,510	22,640	44,680
.10	−20,510	−3,020	−41,220	−111,140	− 87,280	−63,510	−39,830	−16,310	7,270	31,420	53,930
.20	−15,890	−2,250	−26,430	−101,440	− 77,460	−53,530	−29,670	− 5,930	17,890	42,040	65,140
.50	− 9,590	1,250	1,850	− 82,880	− 58,660	−34,440	−10,220	13,930	38,220	62,370	86,590
.80	− 5,250	3,980	30,130	− 64,320	− 39,800	−15,350	9,230	33,790	58,550	82,700	108,040
.90	− 3,570	5,100	44,920	− 54,620	− 30,040	− 5,370	10,390	44,170	69,170	93,320	119,250
.95	− 2,380	5,940	57,120	− 46,610	− 21,930	2,870	27,780	52,740	77,950	102,100	128,500
.99	− 630	7,130	80,030	− 31,580	− 6,700	18,330	43,530	68,820	94,410	118,560	145,870
Expected value	−10,220	830	1,850	− 82,880	− 58,660	−34,440	−10,220	18,930	38,220	62,370	86,590

* Net returns defined as return to management, operator, labor, and capital.
SOURCE: Compiled from previous tables.

time for a 20,000-bird operation attaining the high growth rate (i.e., the operation summarized earlier in table 14). It is assumed, as specified previously, that the grower has a net worth of $30,000 initially. Family consumption expenditure is assumed to be $2,600 annually. Thus, net worth at the end of each year is calculated as follows: net worth at the beginning of the year, plus total revenue, minus total variable costs, minus total fixed costs (excluding interest on owned capital), minus family consumption expenditure, and either plus interest on savings or minus interest on loans against the original $30,000 of equity. If a particular year shows a loss which cannot be covered by savings, it is assumed that the grower must borrow against his $30,000 of equity.

Six alternative strategies were simulated. The first three are of the "no data" type employing a single action through time: (1) Select independent production each year; (2) select Contract A production each year; and (3) select Contract B production each year. The other three strategies are variations of the "data" type, where the action taken each year depends on the prices predicted by the price-predicting equations: (1) Given the price prediction each year, select that action (independent, Contract A, or Contract B) which gives the greatest expected value. As before, this strategy involves selecting independent production if the price forecast is higher than $0.22 per pound for hens ($0.20 for toms) and Contract B when the price forecast is lower. (2) Given the price prediction, select that action which gives the greatest expected value, subject to the constraint that returns exceed $-5,000 with a probability of 0.95. As can be seen approximately by examining the second row and last row of table 14, this is equivalent to raising turkeys as an independent when predicted prices exceed $0.2328 per pound for hens and raising turkeys under Contract A at lower predicted prices. (3) Given the price prediction, select that action which gives the greatest expected returns subject to the constraint that returns exceed zero dollars with a probability of 0.95. A grower using this strategy raises turkeys as an independent when predicted prices exceed $0.2469 for hens; if predicted prices are below this level, the grower selects Contract B.

Simulation procedure.—One could hypothesize a number of other strategies. However, those specified should allow an interesting set of comparisons in the financial position of the firm over time between the first three single action ("no data") strategies and the last three multiple action ("data") strategies. The comparisons are made from the results of a series of simulations of firm growth over time using each of the six alternative strategies.

Thirty individual runs of 10 years each were simulated for each strategy. Three hundred paired values of actual price, predicted price, and mortality rate were generated from the appropriate distributions for use in the simulation procedure. The following procedure was used to obtain the values for a given year: The actual price was computed as the weighted mean price ($0.2172) over the 1957–1964 period plus a random normal deviate times the standard deviation of prices over this period ($0.0243). Having the "actual" price for the year, the "predicted" price was estimated as the actual price plus a second random normal deviate times the standard error of the price prediction model ($0.0166). The mortality rate (in logs) was computed as the mean (in logs) plus a third random normal deviate times the standard error of mortality (in logs). The antilog of this result provided the observation of the mortality rate. Nine hun-

TABLE 20

FREQUENCY OF ENDING NET WORTH AND MINIMUM NET WORTH RESULTING FROM THIRTY SIMULATION RUNS FOR EACH OF SIX ALTERNATIVE GROWER STRATEGIES

Range in net worth	Frequency of ending net worth						Frequency of minimum net worth					
	"No data" strategies			"Data" strategies			"No data" strategies			"Data" strategies		
	Independent production	Contract A	Contract B	Strategy 1	Strategy 2	Strategy 3	Independent production	Contract A	Contract B	Strategy 1	Strategy 2	Strategy 3
thousands of dollars	*number of years*											
−5 to 5	0	0	0	0	0	0	1	0	0	0	0	0
5 to 15	0	3	0	0	0	0	2	2	0	0	0	0
15 to 25	0	10	8	0	0	0	9	15	12	6	5	1
25 to 35	4	11	22	0	0	1	7	13	18	13	15	21
35 to 45	1	6	0	1	1	3	8	0	0	8	7	4
45 to 55	1	0	0	1	3	8	3	0	0	3	3	4
55 to 65	7	0	0	4	3	1	0	0	0	0	0	0
65 to 75	5	0	0	5	5	5	0	0	0	0	0	0
75 to 85	2	0	0	5	6	3	0	0	0	0	0	0
85 to 95	1	0	0	4	2	3	0	0	0	0	0	0
95 to 105	2	0	0	2	3	3	0	0	0	0	0	0
105 to 115	3	0	0	3	2	0	0	0	0	0	0	0
115 to 125	1	0	0	2	3	2	0	0	0	0	0	0
125 to 135	2	0	0	2	1	1	0	0	0	0	0	0
135 to 145	1	0	0	1	0	0	0	0	0	0	0	0
145 to 155	0	0	0	0	1	0	0	0	0	0	0	0
155 to 165	0	0	0	0	0	0	0	0	0	0	0	0
165 to 175	0	0	0	0	0	0	0	0	0	0	0	0
175 to 185	0	0	0	0	0	0	0	0	0	0	0	0
	dollars											
Lower limit	25,985	9,521	19,065	44,173	42,874	25,773	4,330	8,699	18,597	16,600	20,586	22,464
Upper limit	142,471	42,210	34,066	136,133	147,481	130,040	53,825	30,959	29,319	53,825	53,825	53,825
Mean	75,480	27,174	26,599	87,197	83,803	71,240	29,740	23,298	24,938	40,954	32,541	32,401

dred random normal deviates were used to provide the 300 paired observations. For each paired value (the data for one year) the predicted and actual prices are related as they would be using the price prediction equation. The mortality rate is independent of both prices. The same set of observations on these three variables was used to investigate changes in the firm's financial position for each of the six strategies. Therefore, differences observed in the results are not due to selection of alternate sets of random variables, but are comparable in the sense that the values of prices and mortality were the same for each strategy.

Simulation results.—Because financial growth is a goal of most managers, growth in net worth over the simulated ten-year period is selected as the basis for comparing the six alternative strategies. The frequency of ending net worth for each strategy is presented in the left-hand portion of table 20. Recall that the starting net worth of the firm was $30,000. Thus, on the average over the 30 simulated 10-year periods, Contracts A and B did not maintain the original net worth (i.e., mean ending net worth dropped to $26,599 and $27,174, respectively). Continuous independent production, on the other hand, produced substantial growth, averaging $75,480 at the end of the 10-year period. The right-hand portion of table 20, however, indicates the relative risk associated with the various strategies by showing the minimum net worth position experienced by the grower at some time during the ten-year period. Compared with the two contract strategies, independent production has a substantially higher number of cases in which net worth dropped at some time during the ten-year period to less than $15,000.

Table 20 also allows a comparison between the three "data" strategies (those using price forecasts) and the "no data" strategies. The least conservative of the "no data" strategies is Strategy 1 which selects the action each year which maximizes expected income for the given price forecast. The table shows that Strategy 1 is a substantial improvement over the "no data" strategies in all respects: It has a higher mean ending net worth ($87,197 versus $75,480 for continuous independent production), a higher mean minimum net worth ($40,954 versus $29,746 for independent production), and a higher minimum net worth experienced during the ten-year period ($16,600 versus $4,330 for independent production). In fact, the distribution of minimum net worth for Strategy 1 is more favorable than for either of the two contract alternatives. Thus, Strategy 1 permits greater growth than continuous independent production with less risk of going out of business than contract production.

"Data" Strategies 2 and 3 are progressively more conservative than Strategy 1 in that they require a more favorable price forecast before the grower is willing to go independent. As expected, therefore, the mean ending net worths drop progressively ($83,803 and $71,240 compared with $87,197 for Strategy 1) while the minimum level of net worth experienced during the ten years increased progressively ($20,586 and $22,464 compared with $16,600 for Strategy 1). Thus, compared with Strategy 1, the safer growth of Strategies 2 and 3 is attained at some sacrifice in average growth. A grower's choice between "data" Strategies 1, 2, and 3 would be dictated by his attitude toward risk. However, regardless of risk preference, one of the "data" strategies would always be preferred to any of the "no data" strategies.

DYNAMIC PRODUCTION AND INVESTMENT PLANNING

Growth and expansion of the firm is often a primary means by which the manager accumulates capital and improves his net worth position. In this section, we construct a normative growth model which demonstrates, for a 20,000-bird turkey operation in the initial period, the accumulation of net worth and the pattern of capital allocation and cash expenditures over five- and ten-year planning periods. Our preceding analysis suggests that a growth model for turkey growers should allow a choice between independent and contract production because of the difference in level of inputs required by growers over time as well as the difference in expected returns. Recognition also should be given to any scale economies existing for either method of production. Further, the model should allow the grower the option to invest in additional facilities to increase capacity either with internally generated capital or with borrowed capital based on adequate restraints. The multistage or dynamic linear programming model modified slightly to solve problems involving mixed integer solutions provides the basic analytical framework to incorporate the above conditions for whatever planning period that is relevant (Loftsgard, *et al.*, 1960, Edwards, 1963, Candler, 1960, Cocks, 1965).

Multistage linear programming model

The general model is depicted in table 21 without slack variables. It is assumed that the turkey grower's objective is to maximize his terminal net worth for a "T"-year planning period ($k = 1, \cdots, T$). The initial condition is, as discussed previously, that the turkey grower has a given amount of operating capital (b_1^1) and a complement of real estate and equipment adequate for turkey production of a specified scale. The relevant alternatives available to the grower in the k^{th} year ($k = 1, \cdots, T$) can be represented by the following seven activities:

X_1^k = turkey growing as an independent operator, two broods of 500 birds or 1,000 birds per year;

X_2^k = turkey growing under Contract A, two broods of 500 birds or 1,000 birds per year;

X_3^k = short-term capital borrowing which must be paid back at end of year plus interest;

X_4^k = long-term capital borrowing which is amortized over a specified time period;

X_5^k = an activity to construct additional brooding and growing facilities adequate for 500 birds (enables two broods or 1,000 birds per 40-week period to be grown);

X_6^k = same as X_5^k except at a different cost level which is effective only after a given size of operation; and

X_7^k = invest capital off-farm for a single year at a specified interest rate.

Activity X_8^k is a "dummy" which is forced to zero or one controlling the *choice* between contract and independent production for a given year. X_0^T accounts for surplus capital available at the end of the final planning year which is incorporated into terminal net worth.

There are eight restraints on production in each of the n years. In addition, there is a single restraint (b_0^T) ensuring that the grower can meet all cash debts at the terminal year. The eight restraints for the k^{th} year are:

b_1^k = amount of operating capital available at the start of the year;

b_2^k = permission to borrow short-term capital in terms of a fixed amount per 1,000 turkeys raised only as independent grower;

b_3^k = amount of long-term borrowing permitted;

$\left.\begin{array}{l} b_4^k \\ b_5^k \\ b_6^k \end{array}\right\}$ = three restraints forcing a choice between independent and contract product;

b_7^k = housing available at the start of the year; and

b_8^k = maximum amount of housing that may be constructed of the type specified by X_5^k.

The objective function is to maximize the accumulated value of *net* investments at the planning horizon as given in equation 34. For example, C_4^1 represents the unpaid balance at the T^{th} or terminal year from borrowing \$1 in Year 1 based

$$\text{Max} \qquad \sum C_j^k X_j^k + C_0^T X_0^T \tag{34}$$

$$k = 1, \cdots, T$$

$$j = 1, \cdots, 8$$

on a specified interest rate and amortization schedule. C_5^1 and C_6^1 represent the remaining equity (original cost less depreciation) in the T^{th} year for one building unit of either X_5 or X_6 constructed in Year 1. ($C_T^0 = 1$) represents the value of a unit (dollars) or surplus capital to terminal worth of the firm.

The first constraint (Year 1) ensures that the capital used in production (either X_1^1 or X_2^1), saving (X_0^1), and building construction (X_5^1 and/or X_6^1) does not exceed the initial capital on hand (b_1^1) plus that borrowed (X_3^1 and/or X_4^1). The second constraint places a limit on the *short-term* borrowing capacity of the independent grower which states that he can borrow up to X_3^1 dollars for each unit of X_1^1 (1,000 turkeys grown). Long-term borrowing capacity in Year 1 is fixed at b_3^1 and determined exogenously, presumably on the basis of the grower's equity position, previous experience, standing in the community, etc.

Constraints 5, 6, and 7 (Year 1) and activities X_1^1, X_2^1, and X_8^1 use the principles of integer programming to force the program to select either independent or contract production and place upper limits on capacity for each. Independent production (X_1) cannot exceed a_{48}^{11} and only enters the program if the dummy variable $X_8^1 = 1$. If $X_8^1 = 0$, contract production may enter the program but cannot exceed b_5^1. Note that $b_5^1 = a_{58}^{11}$.

The seventh restraint in Year 1 states that the initial capacity for housing plus housing built must be greater than the capacity required for birds grown as independent or on contract production. The final restraint limits the amount of "low cost" housing which can be built.

The constraint on operating capital at the start of the second year ensures that the *gross* returns from turkey sales in Year 1 (X_1^1 or X_2^1), capital invested or saved in Year 1 plus interest [i.e., $a_{17}^{21} = -(1 + i)$ where i = rate of return], and capital borrowed short or long term in Year 2, (X_3^2, X_4^2) must be equal to or exceed the capital required for production, savings, and building construction in the second year plus payoff on short- and long-term loans contracted in Year 1 and yearly payment of cash fixed costs on original assets (b_1^2) and new building constructed in the first year.

Similarly, long-term borrowing capacity in any subsequent years is equal to the initial limit (i.e., $b_3^1 = b_3^2 = \ldots, b_3^T$)

TABLE 21

MATRIX FOR MULTISTAGE LINEAR PROGRAM TO MAXIMIZE TERMINAL NET WORTH IN n YEAR PLANNING PERIOD

Objective Function — Maximize ⟶		C_1^1	C_2^1	C_3^1	C_4^1	C_5^1	C_6^1	C_7^1	C_8^1	C_1^n	C_2^n	C_3^n	$(-)C_4^n$	C_5^n	C_6^n	C_7^n	C_8^n	$C_0^T = 1$
Restrictions	Basis	X_1^1	X_2^1	X_3^1	X_4^1	X_5^1	X_6^1	X_7^1	X_8^1	X_1^n	X_2^n	X_3^n	X_4^n	X_5^n	X_6^n	X_7^n	X_8^n	X_0^T
		Turkey indept.	Turkey contract	Borrow short	Borrow long	Construct housing (1)	Construct housing (2)	Lend capital	Dummy	Turkey indept.	Turkey contract	Borrow short	Borrow long	Construct housing (1)	Construct housing (2)	Lend capital	Dummy	Payoff
Operating capital (start of Year 1)	b_1^1	a_{11}^{11}	a_{12}^{11}	$(-)a_{13}^{11}$	$a_{14}^{11}=-1$	a_{15}^{11}	a_{16}^{11}	$a_{17}^{11}=1$										
Permission to borrow short-term capital (Year 1)	$b_2^1=0$	$a_{21}^{11}=-1$		$a_{23}^{11}=1$														
Maximum long-term borrowing (Year 1)	b_3^1				$a_{31}^{11}=1$													
Maximum capacity for independent	$b_4^1=0$	$a_{41}^{11}=1$							$(-)a_{48}^{11}$									
or	b_5^1		$a_{52}^{11}=1$						a_{58}^{11}									
Contract production (Year 1)	$b_6^1=1$								$a_{68}^{11}=1$									
Available housing (start of Year 1)	b_7^1	$a_{71}^{11}=1$	$a_{72}^{21}=1$			$a_{75}^{1}=-1$	$a_{76}^{1}=-1$											
Limit for housing at cost level 1	b_8^1					$a_{85}^{1}=1$												
Operating capital (start of Year 2)	b_1^2	$(-)a_{11}^{21}$	$(-)a_{12}^{21}$	a_{13}^{21}	a_{17}^{21}	a_{15}^{21}	a_{16}^{21}	$(-)a_{17}^{21}$										
Operating capital (start of Year n)	b_1^n				a_{14}^{n1}	a_{15}^{n1}	a_{16}^{n1}			a_{11}^{nn}	a_{12}^{nn}	$(-)a_{13}^{nn}$	$a_{14}^{nn}=-1$	a_{15}^{nn}	a_{16}^{nn}	$a_{17}^{nn}=1$		
Permission to borrow short term (Year n)	$b_2^n=0$									$a_{21}^{nn}=-1$		$a_{23}^{nn}=1$						
Maximum long-term borrowing (Year n)	b_3^n				a_{34}^{n1}	$(-)a_{35}^{n1}$	$(-)a_{36}^{n1}$											
Maximum capacity for independent	$b_4^n=0$									$a_{41}^{nn}=1$							$(-)a_{48}^{nn}$	
or	b_5^n										$a_{52}^{nn}=1$						a_{58}^{nn}	
Contract production (Year n)	$b_6^n=1$																$a_{68}^{nn}=1$	
Available housing (Year n)	b_7^n					$a_{75}^{n1}=-1$	$a_{76}^{n1}=-1$			$a_{71}^{nn}=1$	$a_{72}^{nn}=1$			$a_{75}^{nn}=-1$	$a_{76}^{nn}=-1$			
Limit for housing at cost level 1 (Year $1-n$)	b_8^n					$a_{85}^{n1}=1$								$a_{85}^{nn}=1$				
Payoff (end of Year n)	b_0^T				a_{04}^{T1}	a_{05}^{T1}	a_{06}^{T1}			$(-)a_{01}^{Tn}$	$(-)a_{02}^{Tn}$	a_{03}^{Tn}	a_{04}^{Tn}	a_{05}^{Tn}	a_{06}^{Tn}	$(-)a_{07}^{Tn}$		$a_{00}^{TT}=1$

TABLE 22

EXAMPLE MATRIX OF THE EMPIRICAL LINEAR PROGRAMMING GROWTH MODEL*

	Objective Function — Maximize	$c_j \longrightarrow$	0	0	0	−0.9410	1,781.0	2,028.0	0	0	0	0	0	−0.9713	1,922.0	2,192.0	0	0	1
0	Restrictions	Basis	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}
			Turkey indept.	Turkey contract	Borrow short	Borrow long	Construct housing (1)	Construct housing(2)	Lend capital	Dummy	Turkey indept.	Turkey contract	Borrow short	Borrow long	Construct housing (1)	Construct housing(2)	Lend capital	Dummy	Payoff
							Year 1												
1	Operating capital (start of Year 1)	5,000	1,699	67.5	−1,500	−1.0000	2,063.0	2,356.0	1										
2	Permission to borrow short-term capital (Year 1)	0	− 1		1														
3	Maximum long-term borrowing (Year 1)	15,000				1.0000													
4	Maximum capacity for independent	0	1							−200									
5	*or*	50		1.0						50									
6	Contract production (Year 1)	1								1									
7	Available housing (start Year 1)	20	1	1.0			− 1.0	− 1.0											
							Year 2												
8	Operating capital (start of Year 2)	− 2,792	− 2,399	− 308.9	1,590	0.0837	139.6	139.6	−1.035		1,699	67.5	−1,500	−1.0000	2,063.0	2,356.0	1.000		
9	Permission to borrow short term (Year 2)	0									− 1		1						
10	Maximum long-term borrowing (Year 2)	15.000				0.9713	− 961.0	−1,096.0						1.0000					
11	Maximum capacity for independent	0									1							−200	
12	*or*	50										1.0						50	
13	Contract production (Year 2)	1																1	
14	Available housing (Year 2)	20					− 1.0	− 1.0			1	1.0			− 1.0	− 1.0			
15	Limit for housing at cost level 1 (Year 1 − 2)	80					1.0								1.0				
16	Payoff (end of Year 2)	− 2,792				0.0837	139.6	139.6			−2,399	−308.9	1,590	0.0837	139.6	139.6	−1.035		1

* This example is limited to only two years for reasons of space. The empirical problems were solved for either 5- or 10-year planning periods.

plus some ratio of the equity established in building constructed in previous years.

The final constraint at the end of Year T is an accounting device to ensure that yearly payments on previously contracted debts, including Year T cash fixed costs on the original assets and subsequent housing and equipment, can be met with production returns in Year T plus capital accrued in saving with interest. Any excess of returns over cash obligations is accounted for in terminal net worth through activity X_0^T.

This program makes the simplifying assumption that the grower removes all labor income from the enterprise and uses it for family living expenditures, but does not require the enterprise to furnish any capital for family living expenditures in excess of that amount. While some turkey producers with a specified size of operation may depend solely on the returns of this enterprise as their source of income and might need to withdraw additional capital for family consumption, others have other enterprises on the farm, and still others have off-farm employment to furnish capital for family consumption.

Example matrix

The empirical counterpart of the general *LP* growth model is provided in table 22. This example matrix is formulated for a two-year planning period but illustrates the data requirements for extending the model to any number of years.

The first seven coefficients in the basis vector represent opportunities and resources available at the planning moment. The second seven represent comparable opportunities and resources which will be available after one year.

Restraint 1 represents $5,000 of operating capital available at the start of Year 1. This figure is chosen because it gives the grower roughly enough cash to fill his available housing units under independent growing plus enough to undertake a modest expansion program without making any long-term borrowings. This cash will be completely allocated by the program among growing, building, and lending activities in the first year. The comparable figure for operating capital available at the start of Year 2 (8, 0) is $−2,792. There are 20 units of housing available on the farm at the planning moment (7, 0) and if we assume that the farm *will* be operated over the two-year period, then the farmer must pay the taxes, maintenance, and insurance costs ($139.60 per unit) associated with these 20 units. Thus, $2,792.00 (20 × $139.60) is a cash fixed cost which must be paid at the end of both the first year and second year (16, 0) of the planning period.

Because the 20 units of housing (1 unit equals 1,000 birds per 40 weeks) initially available are also available in Year 2, the restraint 7 is repeated as the restraint 14. If these 20 units were assumed to be of an age where part of their capacity was becoming unavailable each year, then the element (14, 0) would have to be reduced.

In the initial state, prior to making any decisions, the farmer has not created any permission to borrow short term against the turkeys he will run in Year 1—(2, 0) equals 0. Similarly, before deciding on his production activities for Year 2, the farmer cannot claim as an asset unused permission to borrow short at that time. Such permission is generated only by growing turkeys independently—each unit of turkeys giving permission to borrow $1,500 against anticipated returns. Similarly, for Year 2 (9, 0) is zero.

At the planning moment, however, the farmer does have an asset represented by permission to borrow up to $15,000 (3, 0) as a long-term loan. This represents a first mortgage equal to half the value of opening land and buildings. Unless the farmer can increase his equity in land plus structural assets, he will still be unable to borrow more than $15,000 in the second year (10, 0). We built into the program the requirement that if part of this sum is borrowed in Year 1, then only the residue can be borrowed in Year 2. Against this, if the farmer acquires equity on additional structural assets he will be able to increase his borrowing limit. We will allow for this, but at the planning moment long-term borrowing is restricted to $15,000.

Conditions imposed by the contracting company on a farmer growing birds under contract generally forbid him to simultaneously grow turkeys independently. The amount of contract growing is limited to 50 units (5, 0) whereas the farmer himself imposes a limit of 200 units grown independently. As a purely methodological device, restraints 4, 5, and 6 are introduced into the initial state vector to ensure that the program achieves these limits in Year 1. Similarly, restraints 11, 12, and 13 achieve the same end in Year 2. Restraint 15 is a limitation on the amount of cheap housing built, and represents an opportunity which can be taken up at the start of either the first year or the second year, or some mixture thereof. The restraint generated by this limitation implies that if the farmer runs more than 100,000 birds (an extra 80 units of housing), the cost of housing then increases from an outlay of $2,063 to $2,356 per 1,000. This restraint is a recognition of the fact that housing costs, which include the costs of associated installations and machinery, are not directly proportional to the number of additional birds run. Because of the machinery complement already on hand with a 20,000-bird installation, the costs of providing for an additional 80,000 birds are, on average, $2,063 per 1,000. These savings are no longer available past 100,000 birds when the capital-sharing effect of the opening machinery complement is exhausted.[6] Table 23 shows the average outlay required per 1,000 extra birds (a) up to 80,000 (100,000 total flock) and (b) above 80,000 (over 100,000 flock size).

TABLE 23

AVERAGE FACILITY OUTLAY PER 1,000 BIRDS FOR TWO RANGES OF TOTAL FLOCK SIZE (dollars)

Item	20,000–100,000 birds	> 100,000 birds
	dollars	
Brooder houses (500 sq. ft.)	625	625
4 Range shelters	600	600
10 Round range feeders	280	260*
4 Waterers	101	90*
3.5 Sprinklers	70	70
25 Fencing (rods)	87	87
0.6 Acres	300	300
0.025 Tractors	...	94
0.025 Self-unloading wagons	...	62
0.1 Bulk feed bins	...	168
TOTAL (rounded)	2,063	2,356

* Slight reduction due to quantity discounts.

[6] The increase in average outlay per 1,000 birds at levels greater than 100,000 birds is not to be interpreted as a diseconomy of size. As noted earlier, slight economies are associated with increasing bird numbers but by assuming that the average *marginal* cost of increasing flock size from 20,000 to 35,000 birds holds for increases from 20,000 to 100,000 birds, it becomes possible to treat a considerably extended planning period. An alternative approach to the expansion problem would be to define activities corresponding to each of a number of flock sizes and require that these enter, if at all, at integer magnitudes. This would enable a direct allowance for decreasing costs and was, in fact, the way that this program was initially formulated.

Consider now the activities open to the farmer over the two-year planning period assumed in the example matrix. Some of these have nonzero coefficients in the goal function indicating that they directly contribute to or diminish the value of terminal net worth.

For example, a unit of cheap housing erected in Year 1 costs $2,063 [element (1, 5)]—the money being drawn from opening operating capital (1, 0) or borrowed money (1, 3) or (1, 4). If we assume that the components of the composite input called housing each depreciate linearly to zero over the periods given in table 24, we can calculate the total annual depreciation of each unit of cheap housing. As tabulated, this is approximately $142. Thus, in one year a unit of housing depreciates to $1,922 and in two years to $1,781. This terminal value of a housing unit is an asset which will contribute directly to terminal net worth at the end of the planning period. Whether it is financed with borrowed money or not, this contribution will remain the same. However, if borrowed money is used, a corresponding debit will have to be taken into account in calculating terminal net worth—a debit which is accounted for in the program with an entirely separate borrowing activity. Similarly, a unit of ordinary housing erected in Year 1 depreciates by $164 from $2,356 to $2,192 in one year and to $2,028 in two years. Housing of either type, as previously mentioned, has annual cash maintenance costs of $139.60 in each year. These are withdrawn from available operating capital at the end of each year.

Not only do house building activities contribute to terminal net worth but they also augment the volume of long-term borrowing which can be drawn upon. The assumption is that 50 per cent of the current value of additional erected buildings can be borrowed in addition to the initial sum of $15,000. Hence, a building worth $2,063 when erected at the start of Year 1 and worth $1,922 after one year adds $961 (half of $1,922) to the maximum permissible term loan. To avoid the suspicion that the farmer is obtaining something for nothing, if buildings are purchased with borrowed money, note that an outstanding debt will be affecting the borrowing power stemming from additional buildings. Nevertheless, in a long-term context, the

TABLE 24
ANNUAL DEPRECIATION OF A UNIT OF HOUSING
(dollars)

Item	Life in years	Annual depreciation (rounded)	
		Cheap housing	Ordinary housing
		dollars	
Brooder houses (500 sq. ft.)	20	31	31
4 Range shelters	10	60	60
20 Round range feeders	10	26	26
4 Waterers	10	9	9
3.5 Sprinklers	10	7	7
25 Fencing (rods)	10	9	9
0.6 Acres	..	..	..
0.025 Tractors	10	..	9
0.025 Self-unloading wagons	10	..	6
0.1 Bulk feed bins	25	..	7
TOTAL depreciation	..	142	164

effect of adding buildings would eventually have a substantial effect on borrowing power.

Long-term borrowing activities (X_4) and (X_{12}) can be initiated at the beginning of either year. The assumption is that mortgage moneys have to be amortized in equal installments over 20 years at a 5½ per cent interest rate.

Thus, considering a sum of $1 borrowed, we can calculate the following:

Year	*Unpaid balance beginning of year*	*Total payment at end of year*	*Interest component*	*Principal component*
1.........	1.0000	0.0837	0.0550	0.0287
2.........	0.9713	0.0837	0.0534	0.0303
3.........	0.9410	0.0837	0.0518	0.0319
4.........	0.9091	0.0837	0.0500	0.0337
		and so on.		

A sum of $1 borrowed at the beginning of Year 1 requires payments of $0.0837 at the end of Year 1 and at the end of Year 2. If these payments are made, the unpaid balance will be $0.9410 at the end of Year 2 and this is a liability directly affecting terminal net worth at that date. Thus, $−0.9410 is entered into the objective function. By calculating the outstanding debt after two years, we can build a 20-year activity into a two-year program.

Short-term borrowing activities [(X_3) and (X_{11})] are interpreted as follows: A unit of independent turkey growing "creates permission" [elements (2, 1) and (9, 9)] for short-term borrowing to be undertaken. A unit of short-term borrowing is $1,500 and this is entered as an input in the appropriate operating capital row. Short-term loans have to be repaid with 6 per cent interest after one year—a total of $1,590 per unit. These repayments are also drawn out of the appropriate operating capital row.

The only other activity contributing directly to terminal net worth is titled "payoff" (X_{17}). It draws all surplus operating capital at the end of Year 2 into the objective function [(0, 17) = 1]. This surplus is the algebraic sum of fixed cash and cash costs and returns which result at the end of Year 2.

The lending activities [(X_7) and (X_{15})] take $1 at the beginning of a year and contribute $1.035 at the end of that year, i.e., they return 3½ per cent simple interest. They ensure a productive outlet for any cash not capable of being used more effectively on the farm itself.

The grower has a choice between growing turkeys independently or under contract, but not both. Both activities [(X_1) and (X_2) in Year 1, (X_9) and (X_{10}) in Year 2] draw on operating capital and housing facilities at the beginning of the year and contribute operating capital at the end of the year. Contracting, however, is a low capital operation ($67.50 compared to $1,699.00) being financed largely by the contracted buyer. The operating capital coefficient for independent production includes feed, cost of poults, labor, machinery operating expenses, medication, litter, insurance of growing birds, electricity, and fuel. These costs are sensitive only to mortality, and a mortality rate of 0.0975 has been assumed in this program in deriving the capital requirement. For contract production the only outlay required is labor. Although capital requirements are much higher for independent production, they can be largely financed through short-term borrowing.

Returns from contracting are guaranteed and the cash flow coefficients of $−308.90 [(8, 2) and (16, 10)] are the sum of a gross margin of $241.40 and labor costs of $67.50 based on a medium growth rate assumption.

Returns from independent production are based on an assumed price of 25 cents per pound for hens and 23 cents per pound for toms; for convenience this is referred to as an average price of 24 cents per pound. Again, a medium growth rate and a mortality of 0.0975 are assumed. The cash flow figures $−2,399 [(8, 1) and (16, 9)] are the sums of the gross margin per 1,000 birds ($700) and the opening cash requirements ($1,699).

The dummy activities, (X_8) and (X_{16}), can take only the magnitudes zero or one in the solution and they can be interpreted by considering the consequences of these two possibilities.

If (X_8) comes in at level one, then contract growing is "illegal" for the 50 units in the basis (5, 0) and is now balanced by 50 units in (5, 8). The restraint is violated at any positive level for the contract activity (X_2). Simultaneously, the element (4, 8) provides "permission" to grow 200 units of turkeys independently.

If (X_8) comes in at level zero, then no "permission" for independent growing is generated and 50 units of contract permission remain available for use. Thus, independent growing is "illegal" and contract growing is "legal." Restraint 6 ensures that integers greater than zero will not be considered.

The general pattern of the program can be summarized: Cash flows in at the beginning of Year 1 from that on hand and from borrowing activities. It is allocated among competing activities and these provide cash flows at the end of the year. This generated cash is immediately allocated among Year 2 activities and these in turn generate cash for allowing the payoff column to be activated. Noncash assets and liabilities are interrelated with but independent of the cash aspects of activities and, broadly, noncash effects enter directly into the objective function.

Chance-constrained programming model

The multistage programming model, discussed above, assumes that all elements of the matrix are known with certainty. At the time production plans are formulated for a given year, it is reasonable to assume that for the independent and contract production activities, the net returns are the elements having greatest variability. The amount of capital available in any period $(k + n)$ depends on the actual value of the returns for the previous periods (k) through $(k + n + 1)$. Hence, the items of greatest variability in the multiperiod model are the returns for the turkey production activities in each period and the quantity of capital available in the second through the n^{th} period.

The appropriate method of modifying the model depends on the way in which income variability enters the decision maker's utility function. The method used assumes the grower is interested in maximizing terminal net worth subject to a requirement that his liabilities will not exceed a specified percentage of assets even if returns drop to an improbably low level. Hence, the grower attempts to maximize terminal net worth subject to the constraint that he will not be forced out of business in a given year of low returns or in a succession of a specified number of low-return years, depending upon the exact constraint specified.[7] In this analysis it is necessary to assume that the grower knows (or at least has estimates of) both the anticipated returns (R_j) and the variance of these anticipated returns (σ_j^2) for each alternative production activity he can choose. If the grower combines two or more activities having an income variance, the total variance (σ_T^2) can be written for n activities as equation (35), where r_{ij} is the correlation between returns of activities i and j, σ_i, and σ_j are

[7] This method implies a producer utility function which is discontinuous for increasing values of income variability at a specified level. That is, it assumes little or no disutility to increasing risk up to some critical level of income variance, but an infinite disutility for the marginal unit of income variability which exceeds the critical level specified. For a discussion of chance-constrained programming, see Charnes and Cooper (1959).

$$\sigma_T^2 = \sum_{i=j}^{n} X_i^2\sigma_{ij}^2 + 2 \sum_{\substack{i,\,j \\ i>j}}^{n} X_iX_jr_{ij}\sigma_i\sigma_j \qquad i, j = 1, 2, \cdots, n \tag{35}$$

the square roots of the income variances for activities i and j, respectively, and the level of activity i and j is denoted by X_i and X_j, respectively.

The linear programming model assumes additivity and linearity. Total income variance equation (35), takes a quadratic form. However, the institutional constraints facing turkey producers prohibit more than one of the real production activities entering the optimal solution for any given year. By assuming that either the activities for contract or those for independent production contribute to income variance, the total income variance for any period K of the program can be written as $(X_j^2\ \sigma_j^2)$ where j takes an only *one* value, $j = 1, 2, \cdots$, or n for a program with n real production activities. For the problem outlined, j takes the value 1 or 2. While the variance of income increases by the square of the level of the activity, the standard deviation of the income is the product of the level of that activity and the standard deviation of the returns $(X_j\sigma_j)$, and is introduced as a linear equation in the programming model. If the distribution of deviations from the expected return is known, statements can be made about the probability of returns lying within specified intervals and/or above specified minimal levels.

The specific strategy which is optimal depends on the decision maker's aversion to risk. Only two of the many possible strategies are incorporated into the numerical results, and these are discussed in the following section.

Empirical results from variations in parameters and policies.—The linear programming model is a powerful and versatile technique for examining the economic consequences of different combinations of activities in which the grower can engage. These activities are defined as "units" which associate invariate quantities of input, financial or physical, and invariate quantities of outputs, again financial or physical. The implication is that the grower can select the number of units of each activity which he desires to implement but he cannot change the ratio between input and output levels, nor will this ratio deviate from that implied in the defined activity due to the impact of causes beyond the grower's control.

Unfortunately, the grower does not have the necessary information to define activities for which this implication is valid, and he is forced to consider the possible consequences should the activities which become open to him in the real world differ from the activities assumed in defining the linear programming model.

One way of taking some account of this planning hazard is to run a number of linear programs, each differing with respect to certain key parameters in the model. In this way the farmer may be able to pinpoint strategic aspects of his operations to which he should pay particular attention, i.e., those aspects of his operations which if not implemented in accordance with the assumed activities will have large effects on his achieved results. In turkey growing, for instance, where feed is a large part of the variable costs, the efficiency of feed conversion achieved may make all the difference between large profits and significant losses. This possibility can be checked by running one program in which the defined turkey growing activities assume highly efficient feed conversion and another in which average feed efficiency is assumed. If results differ widely, the grower can be fairly sure that his results are sensitive to feed efficiency and he will take particular note of this phase of his business.

It is also possible that the grower's achievements will be sensitive to factors outside his control—turkey prices, for example. If turkey prices are likely to be low, the grower should run programs which differ with respect to assumed turkey price and see how the results vary. He cannot alter turkey prices, but if he finds that low prices would be disastrous, then he may decide to devote fewer resources to turkey growing and follow a less risky enterprise, or perhaps switch from independent growing to contracting with its assured prices. A third possibility is to select programs into which a requirement is built such that even if prices drop to an improbably low level, his balance sheet will remain healthy insofar as his liabilities will not exceed an acceptable percentage of his assets.

Running a number of linear programming models of a situation has another advantage besides the identification of sensitive coefficients in the model. It enables the farmer to compare markedly different policies which he might follow. Often such comparisons can be made internally by building one big program but it may also be convenient to run separate programs. Two such policies might differ—for example, in the attitude assumed towards expansion. Is it better to erect extra facilities and use them as soon as money or credit becomes available, or to be more conservative and only finance such expansion out of surpluses?

Another problem which involves a choice of policy is the length of the period over which plans should be made. Should one plan five or ten years ahead? Perhaps if we could accurately value resources which might be on hand at some future date this problem would not exist, and plans for both periods would be the same over the first two years. But often the only way in which we can value resources is to define the use to which they will be put and this involves planning over longer periods. However, the major advantage of planning over a longer rather than a shorter period is that, using our best forward estimates of the values of different resources, planned activities change with the length of the planning period, even in those intervals which are common to both planning periods. A simple example will illustrate this fallacy. A capital-intensive high-profit activity will become feasible one year after the end of some suggested planning period. Unless the grower has the necessary money put aside, he will not be able to take advantage of this opportunity. Unless terminal liquid capital is heavily weighted in the objective function, the program solution may imply that the farmer should divert liquid assets into fixed assets which generate good profits in the short run. By planning over a longer period, the farmer avoids short-run gains at the expense of long-run opportunity losses.

Summary of variations studies.—We now present the results of a series of linear programming models designed to study the effects of some important changes and combinations of changes in the planning environment. The variations studied are as follows:

(1) Turkey prices of 20, 22, 24, and 26 cents per pound—an average price taken over tom and hen prices.

(2) Average and high growth rates for birds as defined previously.

(3) Conservative and "loan using" expansion policies. It is assumed in one case that the farmer may expand by borrowing up to a maximum permitted level specified as a

TABLE 25

SUMMARY OF RESULTS FROM VARIATIONS IN PARAMETERS AND POLICIES

Program number*	Conservative (C) or loan-based (L) expansion	Assumed growth rate high (H) or average (A)	Assumed turkey price	Length of planning period	Bird numbers in last year of planning period (nearest 1,000)	Terminal net worth (nearest $100)	Average rate of capital accumulation
			cents/pound	*years*		*dollars*	*percent/year*
1	L	A	22	10	20,000	41,900	1.8
2	L	A	24	10	210,000	311,400	24.6
3	L	A	26	10	676,000	1,452,300	45.1
4	L	H	22	10	138,000	165,800	16.8
5	L	H	24	10	504,000	1,016,600	40.1
6	L	H	26	10	1,531,000	3,888,000	60.2
7	C	A	22	10	20,000	41,800	1.8
8	C	A	24	10	104,000	213,600	19.8
9	C	A	26	10	281,000	765,500	36.1
10	C	H	22	10	76,000	129,900	13.9
11	C	H	24	10	218,000	565,800	32.1
12	C	H	26	10	582,000	1,809,500	48.4
13	L	A	20	5	20,000(C)†	35,200	0.0
14	L	A	22	5	20,000	38,400	1.9
15	L	A	24	5	74,000	108,300	25.3
16	L	A	26	5	123,000	252,100	48.4
17	L	H	20	5	20,000(C)†	41,000	3.2
18	L	H	22	5	61,000	74,700	17.0
19	L	H	24	5	110,000	208,200	42.8
20	L	H	26	5	174,000	426,800	64.9
21‡	L	A	24	5	71,000	106,000	25.0
22§	L	A	24	5	30,000(C/1)¶	75,000	16.6

* Programs 1–12 allow only independent growing; programs 13–22 include the options of independent or contract growing.
† Contract production.
‡ Assets at the end of any year always at least equal to liabilities.
§ Assets at the end of any year always at least twice liabilities.
¶ Contract and independent production mixed.

percentage of equity, and using generated and borrowed moneys to erect extra buildings and perhaps run more birds. In the second case, it is assumed that the farmer never borrows and expands only by using moneys generated by the business.

(4) Planning periods of two different lengths are studied—five years and ten years.

(5) A second form of conservative expansion policy is studied by the use of chance-constrained programming. This requires that the programs maximize terminal net worth subject to the requirement that at the end of *each* of the five years of the planning period liabilities are less than or equal to value of assets obtained if (a) gross returns for the year eventuate at a level which is exceeded by chance with probability 0.95 and (b) gross returns in previous years have taken their anticipated values. A variation of this decision rule was also used, i.e., liabilities less than or equal to half the value of assets at the end of each year.

In comparing programs which include the above assumptions in different combinations, we make use of three indications of the rate of expansion:

(1) The average rate of capital accumulation (γ) given by equation (36):

$$\gamma = \text{antilog}\left[\frac{1}{n}\log\frac{T}{35{,}000}\right] - 1.0 \qquad (36)$$

where

n is the length of the planning period in years;

T is the terminal net worth at the end of the planning period; and

\$35,000 is the capital value of the enterprise at the planning moment.

This formula is obtained by simple manipulation of the formula for the terminal value of an outlay earning interest for n years, compounded annually.

$$T = 35{,}000\ (1 + \gamma)^n$$

(2) Terminal net worth of the enterprise as given by the program solution plus a correction for the depreciated value of opening fixed assets (= \$3,200 for a ten-year planning period and \$18,600 for a five-year planning period).

(3) Number of birds run in the last year of the planning period.

Summary of results.—The results of the various programs are summarized in table 25. A number of points are worth noting with respect to this table.

(1) Program results are extremely sensitive to differences in turkey prices, especially when high growth rates can be obtained. The average of the average rates of capital accumulation per annum (p.a.) in the twelve decade models varied with price as follows:

22 cents— 8.6 per cent p.a.
24 cents—29.1 per cent p.a.
26 cents—47.4 per cent p.a.

(2) The achieved production growth rate is also important in determining the terminal net worth. Over the 12 ten-year programs, the average capital accumulation for six high and six average production growth rates were:

Average—21.5 per cent p.a.
High —35.2 per cent p.a.

(3) The expansion policy adopted affects capital growth rates as follows:

Conservative expansion—
25.3 per cent p.a.
Loan-based expansion—
31.4 per cent p.a.

(4) Capital accumulation rates tended to be only slightly higher for five-year than for ten-year planning periods. This similarity was due to the fact that opportunities remained constant from year to year. The small difference was the effect of introducing a linear depreciation of opening assets into a calculation of a compounded rate of growth.

(5) The effect of introducing restraints on the asset-liability ratios can be seen by comparing programs in which these restraints are introduced, but price, period, and growth rate are held constant (24 cents, five years, and average growth rate).

Restrained	*Unrestrained*
25.0 per cent (assets equal liabilities)	25.3 per cent
16.6 per cent (assets equal twice liabilities)	25.3 per cent

It would appear that assets have to be kept greater than liabilities before there is any depression of growth rate. The price of requiring an equity of 67 per cent is that the growth rate is reduced from 25.3 per cent to 16.6 per cent. An equity of 50 per cent imposes hardly any depression of growth rate.

(6) The five year programs allowed a choice between contract and independent growing. In the absence of equity restraints, the price had to fall to somewhere between 20 and 22 cents before contract growing became the preferred activity. It is interesting to note that when an equity of 67 per cent was de-

manded the program included both contract and independent growing —the high returns with high variance of independent growing being balanced by the stability of lower contract returns. Such a composite of activities is not, of course, allowable in practice.

SUMMARY AND CONCLUSIONS

Turkey meat production in California has been shifting toward fewer, but larger flocks. The number of turkey growers declined from 1,384 in 1959 to 638 in 1961. During the same period, California growers marketing less than 10,000 turkeys per year declined both in numbers and relative importance, those marketing 10,000 to 20,000 birds declined in numbers but gained in relative importance, while those marketing in excess of 20,000 turkeys per year gained in both numbers and relative importance.

During this period, contracting became an important new method of financing California turkey production. This study indicates that in 1961, 32 per cent of the growers raised 45 per cent of California's turkeys under contract; 66 per cent produced one-half of the turkeys as independent growers; and the remainder used a combination of independent and contract production.

The general objective of the study is to provide answers to some of the questions concerning the economic organization of the individual turkey production operation in California. One question regards the economic scale of operation. Long-run average cost functions were synthesized based on turkey farms ranging from two broods of 5,000 to 100,000 birds per year. Using an average feed efficiency rate (i.e., the feed efficiency rate for growers of average efficiency), the average total production cost estimated for two broods of 5,000 turkeys was $0.229 per pound. Increasing the size to two broods of 100,000 turkeys resulted in an average total cost of production of $0.218 per pound, or a decline of 5 per cent in the average total cost of production. Of the 5 per cent decline in average total cost, approximately 4 per cent is available to an enterprise as large as two broods of 20,000 and the average total cost of production is relatively constant for operations with two broods of 50,000 or more.

The position of the long-run average cost curve was very sensitive to mortality rates and to rates of feed efficiency achieved. For example, an operation of 10,000 poults had average costs ranging from $0.2239 to $0.2500 per pound when the mortality rate was varied from 4 to 20 per cent. For the same operation, costs dropped from $0.2319 to $0.2182 per pound if the grower could achieve the higher feed efficiency rate rather than the average rate with his flock.

An investigation of the effect of contracting on production costs suggests that contracting neither reduces the quantity nor the price of inputs used by efficient independent growers and hence does not reduce the average total cost of production. The contractor furnishes all of the variable inputs except labor and the machinery operating expense. Thus, contracting greatly reduces the amount of capital a grower needs to produce turkeys. The managerial assistance provided by contractors through their fieldmen may significantly reduce the average cost of production for some "less efficient" growers. Consequently, the effect of contracting on the average cost of production will vary from grower to grower. It will not affect the economies of scale curve for the typical efficient firm in the industry.

However, given the risk and uncertainty in prices and mortality rates in turkey production, an important question facing growers is whether to produce as independent or produce under a contract. Parameters of the price, mortality, and income distributions were estimated and the question of independent versus contract production was examined using modern statistical decision theory. The results indicated that independent production would be preferred by growers attempting to maximize expected monetary returns. However, for producers of only *medium* efficiency, the expected returns from contracting are almost as high with much less risk. Growers able to reach high efficiency levels, on the other hand, achieve significantly higher incomes but with much greater risk. Even a highly efficient grower, if he desired to avoid risks, might select contract production. The results also indicated that a grower using an intelligent price predicting model might increase his average income somewhat by shifting between independent and contract protion from year to year based on his price forecast.

Growers are also concerned about the long-run financial potential of their firms. Two general attempts were made to evaluate the potential financial progress of a grower over a ten-year period, starting initially with a 20,000-bird operation, and a net worth of $30,000. In the first attempt, the firm was not permitted to grow in size, and any excess capital generated was therefore invested outside agriculture at 6 per cent interest. The results simulated over a ten-year period indicated that net worth would remain about the same through time under contracting. Net worth would grow, on the average, to about $75,000 over ten years under independent production. However, the probability of the firm being forced out of business because of unfavorable prices is somewhat higher under independent production. Greater growth in net worth with less risk is possible by an intelligent grower using outside information to forecast prices and switching between contract and independent production accordingly.

The second attempt to evaluate the financial potential of the firm permitted growth in the size of the firm through capital investment in additional facilities for turkeys. Results were obtained using a multistage chance-constrained linear programming model. Growth rates in net worth were found to be extremely sensitive to product prices, feeding efficiency levels, and the borrowing policies of the firm. For example, a product price of 24 cents rather than 22 cents permitted an increase in per annum growth in net worth from 8.6 to 29.1 per cent. The high feeding efficiency level increased per annum growth in net worth from 21.5 to 35.2 per cent.

APPENDIX A

ESTIMATING PROCEDURES FOR ECONOMIES OF SCALE RELATIONSHIPS

The data used in estimating the cost curves were obtained from a variety of sources. Used were personal interviews with extension specialists working with turkey growers, representatives of feed manufacturing firms, turkey growers, published summaries of turkey growers' records, unpublished growers' records obtained from contracting firms, and published feeding standards. Specific references to the sources are made in the relevant portions of this section.

Fixed cost

The complement of land, buildings, and equipment necessary for the production of a given number of turkeys is considered fixed in the short run. All of the items included in this group—land, brooder houses, range shelters, feeders, waterers, sprinklers, fence, tractor, feed wagon, and feed storage bins—are durable items in the sense that they may be used for more than one year's production. Hence, the annual cost of using this complement of equipment is the fixed charge appropriate for any year's service. The annual cost or fixed charges to the producer includes depreciation, interest on the investment, maintenance, taxes, and insurance.

California turkeys are typically grown in drylot pens rather than in confinement or on open range. Day-old poults are purchased and placed in the brooder house. At six to nine weeks of age (depending on the season of the year) the poults are moved to drylot pens. Feeding and watering in brooder houses is done with automatic equipment. Range feeders are typically filled using a tractor and a self-unloading feed wagon. Drylot pens generally allow 15 to 20 square feet per turkey and contain approximately 2 square feet of shade per bird, automatic waterers, and a sprinkler system to settle dust and cool the turkeys on hot days. The turkeys remain in the pens until marketed. In the past, many California producers have attempted to produce turkeys on a year-round basis, raising three to four broods per year. Year-round use of brooding facilities encourages disease buildup and heavy mortality rates. Consequently, production currently is typically carried out using brooding facilities for two broods per year and growing pens for one brood per year. This allows facilities to stand idle a sufficient length of time between broods to prevent the effects of disease buildup.

The annual cost for fixed inputs has been derived for eight alternative brood sizes (5,000, 10,000, 15,000, 20,000, 25,000, 35,000, 50,000, and 100,000). These eight brood sizes were selected as those representative of the range in size of the majority of commercial California turkey producers. Growers raising 10,000 birds per year (two broods of 5,000 birds) or less would need to have alternative employment for their labor not required by the turkey enterprise. Hence, it seemed essential to have minimum brooder facilities of 5,000-bird-capacity (10,000 birds per year with two broods). A turkey operation with 20,000 to 25,000 birds produced per year would provide relatively full employment for one man. Two men working full time can feed and care for 50,000 turkeys per year; three men can handle 100,000 birds per year.

The complement of equipment developed for the eight brood sizes assumes that the brooding facilities are used twice per year and the growing pens once. The annual

TABLE A-1

QUANTITY OF BUILDING SPACE AND EQUIPMENT REQUIRED BY SIZE OF OPERATION AND NUMBER OF BROODS

Investment item	Unit	Size I		Size II		Size III		Size IV		Size V		Size VI		Size VII		Size VIII	
		5,000 birds		10,000 birds		15,000 birds		20,000 birds		25,000 birds		35,000 birds		50,000 birds		100,000 birds	
		1 Brood	2 Broods	1 Brood	2 Broods	1 Brood	2 Broods	1 Brood	2 Broods	1 Brood	2 Broods	1 Brood	2 Broods	1 Brood	2 Broods	1 Brood	2 Broods
Brooder house with feeding equipment	1,000 sq. ft.	5	5	10	10	15	15	20	20	25	25	35	35	50	50	100	100
22′ × 26′ range shelters	numbers	20	40	40	80	60	120	80	160	100	200	140	280	200	400	400	800
Round range feeders	numbers	50	100	100	200	150	300	200	400	250	500	350	700	500	1,000	1,000	2,000
8′ automatic waterers	numbers	20	40	40	80	60	120	80	160	100	200	140	280	200	400	400	800
Sprinklers	numbers of nozzles	17	35	35	70	52	105	70	140	87	175	122	245	175	350	350	700
Fencing	rods	125	250	250	500	375	750	500	1,000	625	1,250	875	1,750	1,250	2,500	2,500	5,000
Tractors	numbers	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2
Self-unloading wagon	numbers	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2
24 ton bulk feed bins	numbers	2	4	2	4	2	4	2	4	2	4	2	4	3	5	6	10
Land	acres	3	6	6	12	9	18	12	24	15	30	21	42	30	60	60	120

SOURCE: Adapted from Asmundson and Kratzer (1951).

TABLE A-2

PURCHASE PRICES FOR INVESTMENT ITEMS*

Investment item	Quantity	Price per unit
	units	*dollars*
Brooder house with automatic feeding equipment	5,000 sq. ft. or larger	1.25
22′ × 26′ range shelters	10 or more	150.00
Round range feeders	50–299 units	28.00
	300–599 units	26.00
	600 or more units	22.00
8′ automatic waterers	20–124 units	25.80
	125–249 units	22.50
	250 or more units	18.00
Sprinklers	15 or more nozzles	20.00
Fencing	100 rods or more	3.47
Tractor (30 h. p.)	1	3,750.00†
Self-unloading wagon	1	2,500.00‡
24 ton bulk feed bins	2–5 units	1,680.00‡
Land	3–60 acres	500.00§

* Prices quoted were obtained from commercial concerns supplying these items to California turkey growers.
† Based on A. D. Reed (1964, p. 2).
‡ Based on Horace T. Strong, *et al.* (1956, p. 22).
§ The price of land used in turkey production varies from $300.00 to $1,000.00 per acre. The figure of $500.00 per acre is used as an average value.

TABLE A-3

METHOD OF COMPUTING ANNUAL COSTS

Item	Depreciation: Years expected life	Depreciation: Value	Interest (based on ave. value)*	Maintenance (based on new cost)†	Property tax per $100.00 ave. value‡	Fire and extended insurance per $100.00 ave. value§
	years	*per cent*			*dollars*	
Brooder house with feeding equipment	20	5	6	4	1.79	0.60
22′ × 26′ portable range shelters	10	10	6	6	1.79	0.60
Round range feeders	10	10	6	6	1.79	0.60
8′ automatic waterers	10	10	6	6	1.79	0.60
Sprinklers	10	10	6	6	1.79	0.60
Fencing	10	10	6	6	1.79	0.60
Tractors	10	10	6	¶	1.79	0.60
Self-unloading wagon	10	10	6	¶	1.79	0.60
24 ton bulk feed bins	25	4	6	1	1.79	0.60
Land	..	..	6	..	1.79	....

* Average value is computed as the depreciated value of the asset in the median year of its expected life.
† The percentage values for buildings and range equipment are based on a study by Jolliff and Sutter, (1962, p. 21).
‡ The $1.79 tax rate is based on an average California tax rate of $7.80 per $100.00 assessed value, and an average ratio of assessed to full cash value of assessed property of 0.23 as reported by California State Board of Equalization (1962, pp. 9–12).
§ Insurance rates are based on statewide commercial rates of $0.42 to $0.59 for fire and $0.10 for extended coverage. An assumed rate of $0.50 for fire and $0.10 for extended coverage per $100.00 of average value is used.
¶ Maintenance charges for this item are based on the hours of annual use.

costs for only one brood per year have also been computed for the eight brooder-house sizes mentioned above. In this case only one-half the amount of range equipment used for two broods is needed.

Amounts and prices of fixed inputs.—The size and quantity of buildings and equipment assumed by size of operation is given in table A-1. These quantities were recommended by V. S. Asmundson, Professor of Poultry Husbandry, Davis, and are typical of the equipment used by efficient turkey growers (Asmundson and Kratzer, 1951). Assumed are 1 square foot of floor space per poult in the brooder house, 2 square feet of shade per poult on range, 50 linear feet of watering space per 1,000 birds in growing pens, and 10 circular range feeders per 1,000 birds in drylot. Numbers of sprinklers by size of operation are based on recommendations by Schroeder and Rooney (Schroeder and Rooney, 1961). Fencing requirements are based on the assumption that 10,000 turkeys in drylot are kept in a pen 100 feet by 1,700 feet which is partitioned into five equal sized pens holding 2,000 turkeys each. This provides 17 square feet of space per turkey. Feeding on range is done with a tractor and power take off operated self-unloading wagon. Storage bins of sufficient capacity to hold a truckload of feed are provided for all sizes of enterprise considered. Four feed bins are required for two broods of turkeys because hens and toms on range are fed different levels of protein, and with two broods, four different feeds are used during several weeks of the growing season. Three acres of land are specified for brooding, growing, and for storage of feed and equipment for each 5,000 turkeys produced. The prices used for fixed inputs are given in table A-2. These purchase prices are based on the prices of new items available to growers in the Central Valley area of California or the construction cost (including labor costs of the item). These prices and discounts given for quantity purchases were obtained from firms supplying the items to California turkey growers.

Annual fixed costs.—The method of computing the annual costs for one and two broods for the eight sizes of operation is summarized in table A-3. Annual costs include depreciation, interest on the investment, maintenance, property taxes, and insurance. Total investment and annual costs for the eight buildings and equipment combinations are shown in table A-4.

Variable costs

Variable cost items change with the number of turkeys grown. The variable inputs in turkey meat production are feed, labor, poults, machinery operating expenses and repairs, medication, litter, insurance on the poults, electricity and fuel, miscellaneous items, and interest on the capital necessary to finance these variable cost items.

Growers' records from feed companies and from the California Extension Service were used to provide the cost items for some of the variable factors mentioned above and were used as "bench marks" to check other synthesized values (Schroeder, 1964). The ten variable-cost items can be divided into two groups on the basis by which they were derived. The feed cost, labor cost, and machinery-operating costs were synthesized using feeding standards, labor-use standards, and the purchase prices of these items. The remaining variable-cost items were computed as the average values paid by growers.

Feed costs.—Estimation of feed costs relate directly to assumptions of consumption, growth rate, mortality, and feed prices. Weekly feed consumption and average

TABLE A-4
TOTAL INVESTMENT AND ANNUAL COST BY SIZE OF OPERATION

Building code	Brood size	Total investment*		Annual cost†	
		1 Brood	2 Broods	1 Brood	2 Broods
	number	*dollars*			
I	5,000	23,050	33,620	3,288	4,866
II	10,000	36,510	54,269	5,381	8,226
III	15,000	49,949	73,922	7,474	11,386
IV	20,000	63,409	94,240	9,566	14,678
V	25,000	76,848	114,558	11,659	17,972
VI	35,000	102,586	151,132	15,700	23,739
VII	50,000	144,128	212,025	21,941	33,422
VIII	100,000	282,455	424,050	42,051	66,846

* The total investment represents the total quantity of all fixed inputs shown in table A-1 valued at the appropriate prices given in table A-2.
† The method of deriving the annual cost is given in table A-3.

cumulative weight for broad-breasted bronze hen and tom turkeys, as shown in table A-5, are based upon Feed Consumption Standards developed by M. L. Scott, Cornell University (Schroeder, 1963). Feed consumption by weeks is noted in table A-5 because protein requirements of turkeys decline with age. Major commercial feed companies recommend 28 to 30 per cent protein content for day-old poults as compared to 14 to 16 per cent for birds in the final feeding period prior to marketing. Moreover, the protein level fed to hens is ordinarily decreased at an earlier age than for tom turkeys, because hens mature more rapidly. For the analysis, we assume six discrete time periods with varying protein levels as shown in table A-6.

The sample growers' records show that California producers typically market hen turkeys at 18 to 20 weeks of age and tom turkeys at 23 to 25 weeks of age. The decision on the exact marketing age, once the birds reach a marketable weight, may vary somewhat from grower to grower due to market conditions at that time and the grower's short-term price expectations. This study assumes that all hen turkeys are marketed at the end of the nineteenth week of the growing period and all tom turkeys at 24 weeks of age.

Assuming that each 1,000 turkey poults are composed of 500 hen poults and 500 tom poults, the information in tables A-5 and A-6 can be used to compute the pounds of each of the six feeds fed per 1,000 turkeys. However, one more factor—mortality during the growing period—must be incorporated into the analysis in order to estimate accurately the feed consumption by a brood of turkeys.

Mortality affects feed consumption in two ways. First, the distribution of mortality over the growing period is important because a poult which dies during the first few weeks consumes little feed, while one dying near market time consumes almost as much feed as a marketed turkey. Secondly, the level of mortality is important, because, for any given distribution of death loss over the growing period, a flock having higher mortality will consume less feed for each 1,000 poults started. The distribution of mortality over the growing period can be represented by equation (A-1) where m_i is the cumulative proportion of the total mortality

$$m_i = aw^b \qquad \text{(A-1)}$$
$$i = 1, 2, \cdots, 24$$

which has occurred through week i, i takes on the values of the weeks of the growing period, w represents week and takes the values 1, 2, $\cdots$, 24, and a and b are constants to be estimated. This form was selected for the mortality equation because it requires the regression line to run through the origin (i.e., at age zero, no mortality has occurred) and because the usual mortality pattern over the growing period shows heavy losses during the initial few weeks of the growing period, followed by declining mortality rates. If we define M as the total mortality rate for the entire growing period, then the rate of mortality which has occurred up to week i is equal to m_iM.

The coefficients of equation (A-1) were estimated as given in equation (A-2)

$$m_i = 40.623w^{0.27590} \qquad R^2 = 0.855 \tag{A-2}$$

based upon data from growers' records. Mortality by week was converted to the cumulative percentage of total mortality which had occurred through the given week. The predicted values of equation (A-2) are converted from percentage values to decimal values for use in the feed consumption formulas.

Because the proportion of turkeys lost is equal to m_iM, the proportion alive (P_a) and eating feed in any week i can be represented by equation (A-3). If we

$$P_a = (1 - m_iM) \tag{A-3}$$

TABLE A-5

FEED CONSUMPTION AND GROWTH RATE OF BROAD BREASTED TURKEYS

Age in weeks	Hens: Feed per bird	Hens: Average weight of hens	Toms: Feed per bird	Toms: Average weight of toms
	pounds			
1	0.18	0.27	0.20	0.30
2	0.35	0.53	0.40	0.60
3	0.57	0.90	0.60	1.00
4	0.70	1.40	0.90	1.60
5	1.00	1.90	1.30	2.40
6	1.30	2.50	1.40	3.20
7	1.50	3.30	1.90	4.20
8	2.10	4.20	2.10	5.20
9	2.70	5.20	3.30	6.40
10	3.40	6.30	4.10	7.70
11	3.30	7.50	4.40	9.00
12	3.30	8.50	4.40	10.40
13	3.10	9.40	4.50	11.80
14	3.50	10.40	4.80	13.20
15	2.50	11.30	4.70	14.70
16	4.10	12.20	4.80	16.00
17	4.10	13.00	4.70	17.30
18	4.10	13.70	4.40	18.60
19	4.10	14.40	4.60	19.90
20	....	.....	4.80	21.20
21	....	.....	5.20	22.50
22	....	.....	6.30	23.80
23	....	.....	6.50	25.10
24	....	.....	6.80	26.40

SOURCE: Adapted from Schroeder (1963).

TABLE A-6

PROTEIN LEVELS ASSUMED FOR BROAD-BREASTED BRONZE TURKEYS AT VARIOUS STAGES OF GROWTH

Protein content	Age of hens	Age of toms
per cent	*weeks*	
28	1 to 4	1 to 4
24	5 to 8	5 to 8
20	9 to 11	9 to 13
18	12 to 14	14 to 18
16	15 to 17	19 to market
14	18 to market	

SOURCE: Recommendations of major commercial feed companies.

define F_{iT} as the number of pounds of feed consumed by 500 live tom turkeys in week i, and F_{iH} as the number of pounds of feed consumed by 500 live hen turkeys in week i, then equation (A-4) gives total feed consumed (F_{ci}) in week i per 1,000 turkeys started.

$$F_{ci} = (1 - m_iM)F_{iT} + (1 - m_iM)F_{iH} \tag{A-4}$$

It was assumed above that all hen turkeys are sold at the end of the nineteenth week. During weeks 1, 2, · · ·, 12, the grower is losing half hen and half tom turkeys, but all turkeys lost in weeks 20 through 24 are tom turkeys. Hence, equation (A-4) only holds for weeks 1, 2, · · ·, 19. The proportion of live tom turkeys (P_{Ta}) in any week i = 20, 21, · · ·, 24 is given by equation (A-5)[8].

$$P_{Ta} = 1 - (m_i - 0.5m_{19})(M) \tag{A-5}$$

Using the above relationships to account for death loss, and representing by Q_j the pounds of feed with protein level j per 1,000 poults started, equations (A-6) to (A-11) are the feed-consumption equations for each of the six protein feed levels.

$$Q_{28} = \sum_{i=1}^{4} (1 - m_iM)F_{iH} + \sum_{i=1}^{4} (1 - m_iM)F_{iT} \tag{A-6}$$

$$Q_{24} = \sum_{i=5}^{8} (1 - m_iM)F_{iH} + \sum_{i=5}^{8} (1 - m_iM)F_{iT} \tag{A-7}$$

$$Q_{20} = \sum_{i=9}^{11} (1 - m_iM)F_{iH} + \sum_{i=9}^{13} (1 - m_iM)F_{iT} \tag{A-8}$$

$$Q_{18} = \sum_{i=12}^{14} (1 - m_iM)F_{iH} + \sum_{i=14}^{18} (1 - m_iM)F_{iT} \tag{A-9}$$

$$Q_{16} = \sum_{i=15}^{17} (1 - m_iM)F_{iH} + (1 - m_{19}M)F_{19T} \tag{A-10}$$

$$+ \sum_{i=20}^{24} [1 - (m_i - 0.5m_{19})M]F_{iT}$$

$$Q_{14} = \sum_{i=18}^{19} (1 - m_iM)F_{iH} \tag{A-11}$$

Simplifying each of these equations by gathering terms and inserting the values for m_i, F_{iH}, and F_{iT}, the quantity of feed consumed at each of the six protein levels for any given total mortality rate M is given by equations (A-12) to (A-17) below.

$$Q_{28} = 1{,}950 - 999.29255\ M \tag{A-12}$$
$$Q_{24} = 6{,}300 - 4{,}230.09000\ M \tag{A-13}$$
$$Q_{20} = 15{,}050 - 11{,}615.00000\ M \tag{A-14}$$
$$Q_{18} = 16{,}650 - 14{,}146.80150\ M \tag{A-15}$$
$$Q_{16} = 22{,}450 - 14{,}000.72200\ M \tag{A-16}$$
$$Q_{14} = 4{,}100 - 3{,}697.11350\ M \tag{A-17}$$

[8] Total hen turkeys lost = $0.5m_{19}(M)$. The cumulative death loss of tom turkeys for any week i = 20, · · ·, 24 is $m_i(M) - 0.5m_{19}(M) = (m_i - 0.5m_{19})M$. This follows because m_iM represents total rate of death loss through week i. By subtracting the hen turkeys lost ($0.5m_{19}M$), the remainder represents the loss of tom turkeys.

A list of the prices charged, delivery charges, and quantity discounts available to California turkey growers were obtained from each of the commercial feed companies interviewed. As expected, these prices varied greatly among companies for any given protein level feed and among seasons of the year. The prices adopted for this study are modal values of the prices charged for each of the six protein level feeds delivered to the farm 30 miles from the feed company. The price lists obtained were applicable for the first six weeks of 1964. Quantity discounts, while not always explicitly stated, appeared to be incorporated in the quoted feed prices. These discounts apply to orders for full truckloads of 12 tons and double trailer truckloads of 20 to 24 tons. Generally, a 3-ton order was the minimum order that would be delivered without additional charge. A discount of $1.00 per ton was available for a 12-ton truckload, and a $1.40 per ton discount was available for trailer loads. The assumed prices paid by turkey growers for feed delivered to the ranch in bulk are given in table A-7. The prices are generally quoted as net due within 30 days.

Feed prices are based on the number of tons for a given delivery, feed costs were therefore calculated under the assumption that the feed for each brood is purchased separately. For example, a grower requiring 8 tons of the 28 per cent protein feed for each of two broods is assumed to purchase 8 tons at two times, rather than 16 tons at one time and storing half of it for the second brood. Table A-8 gives the feed prices assumed for each of the eight brood sizes considered in this study.

Using the feed consumption equations (A-12) to (A-17) and the feed costs of table A-8, total feed-cost equations for the eight sizes of operation are developed and shown in equations (A-18) to (A-22). F_j is the feed cost in dollars per 1,000

$$F_5 = 2{,}637.72 - 1{,}919.73\,M \qquad \text{(A-18)}$$

$$F_{10} = 2{,}634.40 - 1{,}917.03\,M \qquad \text{(A-19)}$$

$$F_{15} = 2{,}632.61 - 1{,}915.79\,M \qquad \text{(A-20)}$$

$$F_{20} = 2{,}632.22 - 1{,}915.59\,M \qquad \text{(A-21)}$$

$$F_{20} = F_{25} = F_{35} = F_{50} = F_{100} \qquad \text{(A-22)}$$

TABLE A-7

MODAL PRICES PAID BY TURKEY GROWERS FOR BULK FEEDS DELIVERED TO THE RANCH

Type of feed	Size of delivery		
	3 to 10 tons*	11 to 20 tons†	21 of more tons‡
per cent protein	*dollars per cwt.*		
28	5.89	5.84	5.82
24	5.15	5.10	5.08
20	3.95	3.94	3.92
18	3.88	3.83	3.81
16	3.76	3.71	3.69
14	3.63	3.58	3.56

* The 28 per cent protein feed is assumed to contain 4 pounds of antibiotic per ton; the 24 per cent protein feed 2 pounds of antibiotic per ton.
† Assumes quantity discount of $1.00 per ton.
‡ Assumes quantity discount of $1.40 per ton.
SOURCE: Modal prices for 30-mile deliveries of major feed companies.

TABLE A-8

FEED COSTS PER HUNDREDWEIGHT ASSUMED FOR THE EIGHT BROOD SIZES*

Type of feed	Brood size (in thousands)			
	5	10	15	20 to 100
per cent protein	*dollars per cwt.*			
28	5.89	5.89	5.84	5.82
24	5.10	5.08	5.08	5.08
20	3.92	3.92	3.92	3.92
18	3.81	3.81	3.81	3.81
16	3.69	3.69	3.69	3.69
14	3.63	3.58	3.56	3.56

* Based on the prices quoted in table A-7 and incorporate discounts for quantity purchases where appropriate.

poults started for brood size j, where j takes the values 5, 10, 15, 20, 25, 35, 50, and 100 for the eight brood sizes.

Labor costs.—Labor requirements and costs by type of operation for the eight brood sizes are shown in table A-9, based on estimates provided by extension specialists, growers, and the fieldmen of contracting concerns. These labor requirements were further verified by interviews with a sample of turkey growers representative of the eight brood sizes.

Machinery operating costs.—The cost of maintaining and operating the tractors and self-unloading wagons for each of the eight brood sizes as shown in table A-10 are directly related to the hourly requirements for feeding given in table A-9. Reed (1964, p. 2) gives the hourly cash operating cost for a 30-horsepower tractor as $0.57 for fuel and $0.38 for repairs. A similar study gives the hourly cash operating cost of a feed wagon as $0.50 (Strong, *et al.*, 1956, p. 22). Hence, the cash operating cost of the tractor and feed wagon is assumed to be $1.45 per hour. Table A-10 gives the cash operating cost per 1,000 turkeys for each of the eight brood sizes.

Poult costs.—Contracts with hatcheries, with feed firms which purchase poults for contract growers, and with independent growers verified that the purchase price of a broad-breasted bronze poult of good quality is $0.55 or more in California. Sexing poults so that the hens and toms may be separated and raised in separate pens to improve feeding efficiency, costs an additional $0.015 per poult. Quantity discounts for larger orders are not commonly available. The only discount ordinarily available on the purchase price of poults occurs in the event that a hatchery has an order cancellation and another grower cannot be found to take the poults at the standard price. Hence, the cost per 1,000 poults started is assumed at $565.00 (1,000 birds at $0.565 per bird) regardless of the size of operation.

Other variable costs.—The cost per 1,000 poults started for medication, litter, insurance, electricity and fuel, and miscellaneous items was obtained from the records of contract growers as summarized in table A-11. In the absence of any evidence of quantity discounts, the cost for these items is assumed to be constant regardless of the size of operation.

Interest on operating capital.—Interest on the amount of money necessary to finance the variable-cost items represents a cost of doing business and, hence, is included as a variable cost in the analysis. Operating capital for turkey production is generally available at simple 6 per cent interest per year to growers who have some equity in their operation. Because rearing a brood of turkeys covers approximately six months, the interest charge used in this study is 3 per cent of the cost for all the variable inputs. If all the capital is borrowed, the interest is paid as a cash cost. However, if a grower is using his own capital, the interest charge represents interest foregone on his own capital, and is therefore an opportunity cost rather than a direct cash cost.

Total variable-cost equation.—The total variable-cost equation per 1,000 poults is obtained by aggregating the input costs per 1,000 poults of each of the ten variable-cost items discussed above. Multiplying this equation by the size of the enterprise (S) in thousands of poults started will give the total variable cost for any enterprise size. To simplify the analysis, the ten variable-cost items can be combined into three groups. Combination of the terms will reduce the length of the equation and simplify the empirical work.

TABLE A-9

LABOR REQUIREMENTS AND COSTS BY BROOD SIZE

Type of labor	Brood size							
	5,000	10,000	15,000	20,000	25,000	35,000	50,000	100,000
	hours per 1,000 poults							
Purchasing poults*	4.0	3.0	2.7	2.5	2.4	2.3	2.2	2.1
Preparing houses and equipment†	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Daily care								
1st week‡	9.2	8.9	8.7	8.4	8.1	7.6	6.7	5.0
2nd–8th week (7 weeks)‡	32.2	31.2	30.5	29.4	28.4	26.6	23.4	17.5
9th–market (16 weeks)§	22.4	22.4	22.4	22.4	22.4	22.4	22.4	22.4
Feeding in dry lot (16 weeks)¶	11.2	10.6	9.6	8.6	8.3	8.0	7.7	7.5
Marketing turkeys‖	4.0	3.0	2.6	2.5	2.4	2.3	2.2	2.1
TOTAL hours per 1,000 turkeys	91.0	87.1	84.6	81.8	80.0	77.2	72.6	64.6
	hours per brood							
TOTAL hours per brood	455.0	870.1	1,268.2	1,636.8	1,999.2	2,702.0	3,631.5	6,462.0
	dollars per brood							
TOTAL labor cost per brood (at $1.50 per hr.)	682.50	1,305.15	1,902.38	2,455.20	2,998.88	4,053.00	5,447.25	9,693.00

* Ordering and transporting poults to the ranch is assumed to require ten hours regardless of the size of operation; placing poults in the brooder house two hours per 1,000 poults.

† From Jolliff and Sutter (1962).

‡ According to extension specialists, one man and supplementary family labor can care for 20,000 turkeys; two men and supplementary family labor for 50,000 during the second through the eighth weeks. The hourly requirements were developed assuming a man provides ten hours of labor per day and his family two hours per day and using straight line interpolation between operations of different sizes.

§ The labor required for cleaning the feeders, waterers, removing dead birds, and general flock surveillance is two hours per 10,000 birds per day, or 1.4 hours per 1,000 birds per week.

¶ Feeding on range with a tractor and self-unloading feed wagon is assumed to require 30 minutes for each two-ton load.

‖ Contacting turkey buyers and getting bids on the flock is assumed to require ten hours. Two hours per 1,000 turkeys are assumed necessary to catch the turkeys and load them on trucks.

SOURCE: Estimates from extension specialists, growers, and fieldmen of contracting companies.

TABLE A-10

MACHINERY OPERATING COSTS FOR TURKEY OPERATIONS OF VARIOUS SIZES

Item	Brood size							
	5,000	10,000	15,000	20,000	25,000	35,000	50,000	100,000
	hours per 1,000 poults							
Machine operating time*	11.20	10.56	9.60	8.64	8.32	8.00	7.68	7.52
	dollars per 1,000 poults							
Machine operating costs (at $1.45 per hour)†	16.36	15.31	13.92	12.53	12.06	11.60	11.14	10.90

* The hours of machinery operation are based on the hours required for drylot feeding in table A-9.

† The machinery cost for fuel and repairs is based on the costs of $0.95 for a 30-horsepower tractor and $0.50 for a feed wagon (Reed, 1964 and Strong, 1956).

Six of the variable inputs have been considered as constant per 1,000 poults started, regardless of brood or enterprise size. These six items, poult cost (P), medication cost (Me), litter (Li), insurance cost (In), electricity and brooder fuel (E), and miscellaneous items (Mi) can be combined into a constant, K_1, as shown

$$K_1 = P + Me + Li + In + E + Mi \qquad \text{(A-23)}$$

in equation (A-23). Total cost of these items for any enterprise size can then be represented as K_1S, where S is the enterprise size in thousands of poults started.

Two of the variable-cost items per 1,000 poults started, labor (La) and machinery operating cost (Ma), are a function of the brood size and are combined as shown in equation (A-24). In this equation K_{2j} represents the cost of labor and machinery

$$K_{2j} = La_j + Ma_j \text{ where } j = 5, 10, 15, 20, 25, 35, 50, \text{ or } 100 \qquad \text{(A-24)}$$

per 1,000 poults started for brood size j. The cost for any enterprise size S is given by $K_{2j}S$. This represents the total cost of labor and machinery for enterprise size S where the turkeys are raised in facilities with capacity per brood of j.

The interest charge per 1,000 poults for brood capacity j is given by equation (A-25). The interest charge for an enterprise of size S where the turkeys are reared

$$I_j = 0.03(K_1 + K_{2j} + F_j) \text{ where } j = 5, 10, 15, 20, 25, 35, 50, \text{ or } 100 \qquad \text{(A-25)}$$

in facilities with capacity per brood of j is given by I_jS. For any given j, the interest equation (A-25) becomes a linear function of the total mortality for the season. Consequently, the interest equation is combined with the equation for feed cost and defined as K_{3j} as shown in equation (A-26). The total feed and interest charge

$$K_{3j} = F_j + I_j = F_j + 0.03(K_1 + K_{2j} + F_j) \qquad \text{(A-26)}$$
$$\text{where} \quad j = 5, 10, 15, 20, 25, 35, 50, \text{ or } 100$$

for an enterprise of size S reared in facilities with a brood capacity of j is given by $K_{3j}S$.

Table A-11

COST OF OTHER VARIABLE INPUTS IN TURKEY PRODUCTION

Input	Cost per 1,000 poults started
	dollars
Medication	149.00
Litter	17.00
Insurance	34.00
Electricity and brooder fuel	33.00
Miscellaneous	19.00
TOTAL	252.00

Source: Adapted from records of growers raising turkeys under contract with a commercial feed company.

Table A-12

COEFFICIENTS FOR THE TOTAL VARIABLE COST EQUATION IN TURKEY PRODUCTION

Brood size	Cost coefficient		
	K_1	K_{2j}	K_{3j}
	dollars per 1,000 poults started		
5,000	817.00	152.74	2,745.94–1,977.32M
10,000	817.00	145.82	2,742.32–1,974.54M
15,000	817.00	140.74	2,740.32–1,973.26M
20,000	817.00	135.23	2,739.75–1,973.06M
25,000	817.00	132.02	2,739.66–1,973.06M
35,000	817.00	127.40	2,739.52–1,973.06M
50,000	817.00	120.08	2,739.30–1,973.06M
100,000	817.00	107.83	2,738.93–1,973.06M

Source: The assumptions and method of computation are given in the text.

The total variable-cost equation for enterprise size S reared in facilities with brood capacity j is given as equation (A-27). Because K_{3j} includes feed cost,

$$\text{T.V.C.}_{j} = K_1S + K_{2j}S + K_{3j}S \qquad \text{(A-27)}$$

which is a function of mortality rate, the value of K_{3j} itself is a function of the total mortality for the enterprise. Consequently, equation (A-27) gives the total variable cost as a linear function of the brood size, enterprise size, and the amount of mortality. The numerical values for K_1, K_{2j}, and K_{3j} are given by brood size in table A-12.

Pounds of turkey produced

The pounds of turkey meat produced by a given size of operation must be estimated to compute the average cost of production. The level of mortality (M) affects the number of turkeys and, hence, the pounds of turkey marketed. As indicated, marketing toms five weeks later than hens results in a loss of more tom than hen turkeys, which must be taken into account when computing the pounds of turkey produced. Assuming that each 1,000 turkey poults started are composed of 500 hen turkeys and 500 tom turkeys, and that the distribution of mortality over the growing period is given by equation (A-1), the number of hen turkeys alive (H_a) at the end of 19 weeks is given by equation (A-28).[9] Using equation (A-1), the value for m_{24} if 0.97628, i.e., about 98 per cent of total death loss has

$$H_a = (0.5 - 0.45767M)\ 1{,}000 \qquad \text{(A-28)}$$

occurred during the 24 weeks of the growing period. The remaining 2 per cent of the death loss is accounted for by birds dead on arrival or condemned at the processing plant. Assuming that the birds dead on arrival and condemned ($D.O.A.$) are divided equally between hen and tom turkeys, equation (A-29) gives the number of hen turkeys (H_S) which are sold. The number of tom turkeys sold (T_S) is derived using the relationship given in equation (A-30).

$$\begin{aligned} H_s &= (0.5 - 0.45767M - 0.01186M)\ 1{,}000 \qquad \text{(A-29)} \\ &= (0.5 - 0.46953M)\ 1{,}000 \end{aligned}$$

$$\begin{aligned} T_s &= [0.5 - m_{24}M + 0.5m_{19}M - 0.5(D.O.A.)]\ 1{,}000 \qquad \text{(A-30)} \\ &= (0.5 + 0.53047M)\ 1{,}000 \end{aligned}$$

Two methods are used to compute the pounds of turkey produced. The first method assumes the growth standards given in table A-5. Using these standards, hens marketed at 19 weeks and toms at 24 weeks would average 14.4 pounds and 26.4 pounds, respectively. Combining these coefficients with equations (A-29) and (A-30), the pounds of turkey meat produced per 1,000 poults started (Y) is given by equation (A-31). The pounds of turkey produced for any size operation can be predicted by YS.

$$Y = 20{,}400 - 20{,}765.64M \qquad \text{(A-31)}$$

Only two of the 36 operations whose records were used in this study reported an average market weight greater than or equal to the standards for hens given in table A-5, while only eight of the 35 operations with tom turkeys reported average

[9]Using equation (A-1), $m_{19} = 0.91534$ and $0.5m_{19} = 0.45767$.

market weights greater than or equal to these standards. Consequently, using the growth rates of table A-5 and the quantity of turkey meat produced given by equation (A-31) provided estimates of economy-of-scale curves indicative of a "high" or above average level of feed conversion for the brood sizes specified.

As a comparison, it may be useful to compute the cost relationships for growers who attain an average level of feed efficiency. Consequently, a second method of computing market weights, and "adjusted" or "medium" growth rate standard, is also developed and presented for comparison. This adjustment was made by computing the mean age and weight for the hens and toms from the sample records. Then, preserving the same curvature as the standard growth curve over the marketing period, the growth curve was shifted downward so as to run through the mean values of the record data. By preserving the same curvature of the growth curve, the marketing ages of 19 weeks for hens and 24 weeks for toms remain optimum. The results of the adjusted standards indicated an average marketing weight of 13.25 pounds for hens at 19 weeks and 25.5 pounds for 24 week toms. The predicted pounds of turkey meat per 1,000 poults started using the adjusted growth standard (Z) is given by equation (A-32). The total quantity of turkey meat marketed for any size of enterprise using the adjusted growth standard is given by ZS.

$$Z = 19{,}200 - 19{,}562.593M \qquad \text{(A-32)}$$

TABLE A-13

BUDGETED COSTS FOR ONE BROOD TURKEY MEAT PRODUCTION ENTERPRISES ASSUMING 4 PER CENT MORTALITY

Building component	Number of poults started	Total fixed cost	Total variable cost	Total cost	High rate of gain			Medium rate of gain		
					Average fixed cost	Average variable cost	Average total cost	Average fixed cost	Average variable cost	Average total cost
	1,000 birds	*dollars*			*dollars per pound*					
I.......	1	3,288	3,636	6,925	0.1681	0.1858	0.3539	0.1785	0.1975	0.3760
	3		10,910	14,198	0.0560		0.2418	0.0595		0.2570
	5		18,182	21,472	0.0336		0.2194	0.0357		0.2332
II.......	6	5,381	21,757	27,138	0.0458	0.1853	0.2311	0.0487	0.1969	0.2456
	8		29,009	34,390	0.0344		0.2197	0.0365		0.2334
	10		36,262	41,643	0.0275		0.2128	0.0292		0.2261
III.......	11	7,474	39,810	47,284	0.0348	0.1849	0.2197	0.0369	0.1965	0.2334
	13		47,048	54,522	0.0294		0.2143	0.0312		0.2277
	15		54,287	61,761	0.0255		0.2104	0.0271		0.2236
IV.......	16	9,566	57,808	67,376	0.0306	0.1846	0.2152	0.0324	0.1962	0.2286
	18		65,035	74,602	0.0272		0.2118	0.0289		0.2250
	20		72,261	81,827	0.0244		0.2091	0.0259		0.2221
V.......	21	11,659	75,804	87,463	0.0284	0.1845	0.2128	0.0301	0.1960	0.2261
	23		83,024	94,683	0.0259		0.2104	0.0275		0.2235
	25		90,244	101,902	0.0238		0.2083	0.0253		0.2213
VI.......	27	15,700	97,334	113,036	0.0297	0.1842	0.2139	0.0316	0.1957	0.2273
	31		111,754	127,456	0.0259		0.2101	0.0275		0.2232
	35		126,174	141,876	0.0229		0.2071	0.0244		0.2201
VII.......	36	21,941	129,508	151,450	0.0312	0.1838	0.2150	0.0331	0.1953	0.2284
	44		158,288	180,230	0.0255		0.2093	0.0271		0.2224
	50		179,872	201,814	0.0224		0.2062	0.0238		0.2191
VIII.......	65	42,651	233,014	275,666	0.0335	0.1832	0.2167	0.0356	0.1946	0.2302
	80		286,787	329,438	0.0272		0.2104	0.0290		0.2236
	100		358,484	401,136	0.0218		0.2050	0.0232		0.2178

SOURCE: Compiled from data in previous tables.

TABLE A-14

BUDGETED COSTS FOR ONE BROOD TURKEY MEAT PRODUCTION ENTERPRISES ASSUMING 9.75 PER CENT MORTALITY

Building component	Number of poults started	Total fixed cost	Total variable cost	Total cost	High rate of gain: Average fixed cost	High rate of gain: Average variable cost	High rate of gain: Average total cost	Medium rate of gain: Average fixed cost	Medium rate of gain: Average variable cost	Medium rate of gain: Average total cost
	1,000 birds	*dollars*			*dollars per pound*					
I.......	1	3,288	3,522	6,812	0.1790	0.1917	0.3707	0.1902	0.2037	0.3939
	3		10,568	13,857	0.0597		0.2514	0.0634		0.2671
	5		17,614	20,903	0.0358		0.2275	0.0381		0.2418
II.......	6	5,381	21,076	26,457	0.0488	0.1912	0.2400	0.0519	0.2031	0.2550
	8		28,101	33,482	0.0366		0.2278	0.0389		0.2420
	10		35,126	40,508	0.0293		0.2204	0.0311		0.2342
III.......	11	7,474	38,556	46,036	0.0370	0.1908	0.2278	0.0393	0.2027	0.2420
	13		45,574	53,048	0.0313		0.2221	0.0333		0.2360
	15		52,585	60,059	0.0271		0.2179	0.0288		0.2315
IV.......	16	9,566	55,994	65,560	0.0325	0.1905	0.2230	0.0346	0.2024	0.2370
	18		62,992	72,560	0.0289		0.2194	0.0307		0.2331
	20		69,992	79,558	0.0260		0.2165	0.0276		0.2300
V.......	21	11,659	73,422	85,081	0.0302	0.1903	0.2205	0.0321	0.2022	0.2343
	23		80,414	92,074	0.0276		0.2179	0.0293		0.2315
	25		87,408	99,066	0.0254		0.2157	0.0270		0.2292
VI.......	27	15,700	94,272	109,972	0.0317	0.1900	0.2217	0.0336	0.2019	0.2355
	31		108,238	123,938	0.0276		0.2176	0.0293		0.2312
	35		122,204	137,904	0.0244		0.2144	0.0259		0.2278
VII.......	36	21,941	125,424	147,366	0.0332	0.1896	0.2228	0.0352	0.2015	0.2367
	44		153,296	175,238	0.0271		0.2167	0.0288		0.2303
	50		174,200	196,142	0.0239		0.2135	0.0254		0.2269
VIII.......	65	42,651	225,640	268,292	0.0357	0.1889	0.2246	0.0379	0.2007	0.2387
	80		277,711	320,362	0.0290		0.2179	0.0309		0.2316
	100		347,139	389,790	0.0232		0.2121	0.0247		0.2254

SOURCE: Compiled from data in previous tables.

TABLE A-15

BUDGETED COSTS FOR ONE BROOD TURKEY MEAT PRODUCTION ENTERPRISES ASSUMING 20.5 PER CENT MORTALITY

Building component	Number of poults started	Total fixed cost	Total variable cost	Total cost	High rate of gain: Average fixed cost	High rate of gain: Average variable cost	High rate of gain: Average total cost	Medium rate of gain: Average fixed cost	Medium rate of gain: Average variable cost	Medium rate of gain: Average total cost
	1,000 birds	*dollars*			*dollars per pound*					
I.......	1	3,288	3,310	6,599	0.2037	0.2051	0.4088	0.2165	0.2179	0.4344
	3		9,930	13,220	0.0679		0.2730	0.0722		0.2901
	5		16,552	19,840	0.0407		0.2458	0.0433		0.2612
II.......	6	5,381	19,802	25,184	0.0556	0.2044	0.2600	0.0590	0.2173	0.2763
	8		26,402	31,784	0.0417		0.2461	0.0443		0.2616
	10		33,004	38,385	0.0334		0.2378	0.0354		0.2527
III.......	11	7,474	36,229	43,702	0.0421	0.2040	0.2461	0.0448	0.2168	0.2616
	13		42,816	50,290	0.0356		0.2396	0.0379		0.2547
	15		49,403	56,877	0.0309		0.2349	0.0328		0.2496
IV.......	16	9,566	52,600	62,166	0.0371	0.2036	0.2407	0.0394	0.2164	0.2558
	18		59,175	68,742	0.0330		0.2366	0.0350		0.2514
	20		65,750	75,316	0.0297		0.2333	0.0315		0.2479
V.......	21	11,659	68,968	80,627	0.0344	0.2034	0.2378	0.0366	0.2162	0.2528
	23		75,536	87,196	0.0314		0.2348	0.0334		0.2496
	25		82,104	93,764	0.0289		0.2323	0.0307		0.2469
VI.......	27	15,700	88,544	104,246	0.0361	0.2031	0.2392	0.0383	0.2159	0.2542
	31		101,662	117,363	0.0314		0.2345	0.0333		0.2492
	35		114,780	130,481	0.0278		0.2309	0.0295		0.2454
VII.......	36	21,941	117,788	139,730	0.0377	0.2027	0.2404	0.0401	0.2154	0.2555
	44		143,964	165,905	0.0309		0.2336	0.0328		0.2482
	50		163,595	185,536	0.0272		0.2299	0.0289		0.2443
VIII.......	65	42,651	211,854	254,505	0.0406	0.2019	0.2425	0.0432	0.2146	0.2578
	80		260,743	303,394	0.0330		0.2349	0.0351		0.2497
	100		325,928	268,580	0.0264		0.2283	0.0281		0.2427

SOURCE: Compiled from data in previous tables.

TABLE A-16

BUDGETED COSTS FOR TWO BROOD TURKEY MEAT PRODUCTION ENTERPRISES ASSUMING 4 PER CENT MORTALITY

Building component	Number of poults started	Total fixed cost	Total variable cost	Total cost	High rate of gain: Average fixed cost	High rate of gain: Average variable cost	High rate of gain: Average total cost	Medium rate of gain: Average fixed cost	Medium rate of gain: Average variable cost	Medium rate of gain: Average total cost
	1,000 birds	*dollars*			*dollars per pound*					
I.......	6	4,866	21,820	26,685	0.0415	0.1858	0.2273	0.0440	0.1975	0.2415
	8		29,092	33,958	0.0311		0.2169	0.0330		0.2305
	10		36,366	41,231	0.0249		0.2107	0.0264		0.2239
II.......	12	8,226	43,514	51,740	0.0350	0.1853	0.2203	0.0372	0.1969	0.2341
	16		58,018	66,244	0.0263		0.2116	0.0279		0.2248
	20		72,523	80,749	0.0210		0.2063	0.0223		0.2192
III.......	22	11,386	79,620	91,006	0.0265	0.1849	0.2114	0.0281	0.1965	0.2246
	26		94,098	105,483	0.0224		0.2073	0.0238		0.2203
	30		108,574	119,960	0.0194		0.2043	0.0206		0.2171
IV.......	32	14,678	115,618	130,296	0.0235	0.1846	0.2081	0.0249	0.1962	0.2211
	36		130,070	144,749	0.0209		0.2055	0.0221		0.2183
	40		144,522	159,201	0.0188		0.2034	0.0199		0.2161
V.......	42	17,972	151,610	169,582	0.0218	0.1845	0.2063	0.0232	0.1960	0.2192
	46		166,048	184,021	0.0199		0.2044	0.0212		0.2172
	50		180,488	198,460	0.0183		0.2028	0.0195		0.2155
VI.......	54	23,739	194,670	218,409	0.0225	0.1842	0.2067	0.0239	0.1957	0.2196
	62		223,510	247,249	0.0196		0.2038	0.0208		0.2165
	70		252,350	276,089	0.0173		0.2015	0.0185		0.2142
VII.......	72	33,422	259,016	292,440	0.0238	0.1838	0.2076	0.0252	0.1953	0.2205
	88		316,576	349,999	0.0194		0.2032	0.0207		0.2160
	100		359,746	393,168	0.0171		0.2009	0.0182		0.2135
VIII.......	140	66,846	501,878	568,724	0.0244	0.1832	0.2076	0.0260	0.1946	0.2206
	170		609,423	676,269	0.0201		0.2033	0.0214		0.2160
	200		716,968	783,814	0.0171		0.2003	0.0182		0.2128

SOURCE: Compiled from data in previous tables.

TABLE A-17

BUDGETED COSTS FOR TWO BROOD TURKEY MEAT PRODUCTION ENTERPRISES ASSUMING 9.75 PER CENT MORTALITY

Building component	Number of poults started	Total fixed cost	Total variable cost	Total cost	High rate of gain: Average fixed cost	High rate of gain: Average variable cost	High rate of gain: Average total cost	Medium rate of gain: Average fixed cost	Medium rate of gain: Average variable cost	Medium rate of gain: Average total cost
	1,000 birds	*dollars*			*dollars per pound*					
I.......	6	4,866	21,137	26,002	0.0441	0.1917	0.2358	0.0469	0.2037	0.2506
	8		28,183	33,048	0.0331		0.2248	0.0352		0.2389
	10		35,228	40,094	0.0265		0.2182	0.0282		0.2319
II.......	12	8,226	42,152	50,378	0.0373	0.1912	0.2285	0.0397	0.2031	0.2428
	16		56,202	64,428	0.0279		0.2191	0.0298		0.2329
	20		70,252	78,478	0.0223		0.2135	0.0238		0.2269
III.......	22	11,386	77,124	88,510	0.0281	0.1908	0.2189	0.0300	0.2027	0.2327
	26		91,147	102,533	0.0238		0.2146	0.2053		0.2280
	30		105,170	116,556	0.0206		0.2114	0.0220		0.2247
IV.......	32	14,678	111,988	126,666	0.0249	0.1905	0.2154	0.0265	0.2024	0.2289
	36		125,986	140,664	0.2219		0.2126	0.0236		0.2260
	40		139,984	154,663	0.0199		0.2104	0.0212		0.2236
V.......	42	17,972	146,844	164,817	0.0233	0.1903	0.2136	0.0247	0.2022	0.2269
	46		160,830	178,802	0.0212		0.2115	0.0226		0.2248
	50		174,815	192,788	0.0195		0.2098	0.0208		0.2230
VI.......	54	23,739	188,543	212,282	0.0239	0.1900	0.2139	0.0254	0.2019	0.2273
	62		216,476	240,215	0.0208		0.2108	0.0222		0.2241
	70		244,408	268,148	0.0185		0.2085	0.0196		0.2215
VII.......	72	33,422	250,848	284,271	0.0253	0.1896	0.2149	0.0268	0.2015	0.2283
	88		306,592	340,016	0.0207		0.2103	0.0219		0.2234
	100		348,400	381,824	0.0182		0.2078	0.0193		0.2208
VIII.......	140	66,846	485,994	552,840	0.0260	0.1889	0.2149	0.0277	0.2007	0.2284
	170		590,136	656,982	0.0214		0.2103	0.0227		0.2234
	200		694,278	761,124	0.0182		0.2071	0.0194		0.2201

SOURCE: Compiled from data in previous tables.

TABLE A-18

BUDGETED COSTS FOR TWO BROOD TURKEY MEAT PRODUCTION ENTERPRISES ASSUMING 20.5 PER CENT MORTALITY

Building component	Number of poults started	Total fixed cost	Total variable cost	Total cost	High rate of gain: Average fixed cost	High rate of gain: Average variable cost	High rate of gain: Average total cost	Medium rate of gain: Average fixed cost	Medium rate of gain: Average variable cost	Medium rate of gain: Average total cost
	1,000 birds	*dollars*			*dollars per pound*					
I.......	6	4,866	19,862	24,728	0.0502	0.2051	0.2553	0.0534	0.2179	0.2713
	8		26,482	31,348	0.0377		0.2427	0.0401		0.2580
	10		33,103	37,968	0.0301		0.2352	0.0321		0.2500
II.......	12	8,226	39,604	47,830	0.0425	0.2044	0.2469	0.0451	0.2173	0.2624
	16		52,806	61,032	0.0319		0.2363	0.0338		0.2511
	20		66,007	74,233	0.0255		0.2299	0.0270		0.2443
III.......	22	11,386	72,458	83,844	0.0321	0.2040	0.2361	0.0341	0.2168	0.2509
	26		85,632	97,018	0.0271		0.2311	0.0289		0.2457
	30		98,806	110,192	0.0235		0.2275	0.0250		0.2418
IV.......	32	14,678	105,200	119,879	0.0284	0.2036	0.2321	0.0302	0.2164	0.2466
	36		118,350	133,029	0.0253		0.2289	0.0269		0.2433
	40		131,500	146,179	0.0228		0.2264	0.0242		0.2406
V.......	42	17,972	137,936	155,908	0.0266	0.2034	0.2300	0.0282	0.2162	0.2444
	46		151,073	169,046	0.0242		0.2276	0.0257		0.2419
	50		164,210	182,182	0.0223		0.2257	0.0237		0.2399
VI.......	54	23,739	177,090	200,829	0.0273	0.2031	0.2304	0.0289	0.2159	0.2448
	62		203,325	227,064	0.0238		0.2269	0.0252		0.2411
	70		229,560	253,300	0.0211		0.2242	0.0223		0.2382
VII.......	72	33,422	235,576	269,000	0.0287	0.2027	0.2314	0.0306	0.2154	0.2460
	88		287,927	321,350	0.0235		0.2262	0.0250		0.2404
	100		327,190	360,613	0.0207		0.2234	0.0220		0.2374
VIII.......	140	66,846	456,300	523,146	0.0296	0.2019	0.2315	0.0314	0.2146	0.2460
	170		554,078	620,924	0.0244		0.2263	0.0259		0.2405
	200		651,858	718,703	0.0207		0.2226	0.0220		0.2366

SOURCE: Compiled from data in previous tables.

APPENDIX B

METHOD OF ESTIMATING PRICE VARIABILITY

The variance of H where $H = q_1A + q_2N$ (where q_1 and q_2 are the proportions of A and B, respectively, used to make up H) is given by definition in equation (B-1) where r_{AN} is the correlation of A and N. A similar derivation for σ_T^2 where

$$\begin{aligned}\sigma_H^2 &= E[(q_1A + q_2N) - E(q_1A + q_2N)]^2 \qquad \text{(B-1)}\\ &= q_1^2E(A - EA)^2 + q_2^2E(N - EN)^2 + 2q_1q_2E(A - EA)(N - EN)\\ &= q_1^2\sigma_A^2 + q_2^2\sigma_N^2 + 2q_1q_2\mathrm{Cov}\,AN\\ &= q_1^2\sigma_A^2 + q_2^2\sigma_N^2 + 2q_1q_2r_{AN}\sigma_A\sigma_N,\end{aligned}$$

$T = q_3S + q_4D$ results in equation (B-2).

$$\sigma_T^2 = q_3^2\sigma_S^2 + q_4^2\sigma_D^2 + 2q_3q_4r_{SD}\sigma_S\sigma_D \qquad \text{(B-2)}$$

Likewise, σ_p^2 where $p = q_5H + q_6T$ can be expressed as equation (B-3). However,

$$\sigma_p^2 = q_5^2\sigma_H^2 + q_6^2\sigma_T^2 + 2q_5q_6r_{HT}\sigma_H\sigma_T \qquad \text{(B-3)}$$

we have defined $H = q_1A + q_2N$ and $T = q_3S + q_4D$. Hence, σ_p^2 may also be defined as equation (B-4). Then the covariance of T and H in terms of the original four

$$\begin{aligned}\sigma_p^2 &= E[q_5(q_1A + q_2N) + q_6(q_3S + q_4D) - Eq_5(q_1A + q_2N) \qquad \text{(B-4)}\\ &\qquad - Eq_6(q_3S + q_4D)]^2\\ &= q_5(q_1^2\sigma_A^2 + q_2^2\sigma_N^2 + 2q_1q_2r_{AN}\sigma_A\sigma_N) + q_6^2(q_3^2\sigma_S^2 + q_4^2\sigma_D^2 + 2q_3q_4r_{SD}\sigma_S\sigma_D)\\ &\qquad + 2q_5q_6(q_1q_3r_{AS}\sigma_A\sigma_S + q_1q_4r_{AD}\sigma_A\sigma_D + q_2q_3r_{NS}\sigma_N\sigma_S + q_2q_4r_{ND}\sigma_N\sigma_D)\end{aligned}$$

variables, A, N, S, and D may be derived by subtracting equation (B-1) and equation (B-2) from equation (B-4) and dividing the remainder by $2q_5q_4$. The result is shown in equation (B-5).

$$\mathrm{Cov}TH = q_1q_3r_{AS}\sigma_A\sigma_S + q_1q_4r_{AD}\sigma_A\sigma_D + q_2q_3r_{NS}\sigma_N\sigma_S + q_2q_4r_{ND}\sigma_N\sigma_D \qquad \text{(B-5)}$$

This method was used to derive the turkey price variability estimates given in tables 10 and 11, where the letters A, N, S, and D represent hen turkey prices in August and November, and tom turkey prices in September and December, respectively.

APPENDIX C

METHOD OF ESTIMATING INCOME VARIABILITY

Define returns (R) as a linear function of the price of hen turkeys (P_H), the price of tom turkeys (P_T), and the proportion of mortality (M) as in equation (C-1). P_H is normally distributed with known mean ($\bar{P}_H$) and variance (σ_H^2), P_T is

$$R = P_H(a - bM) + P_T(c - dM) - (e - fM) \tag{C-1}$$

also normally distributed with known mean ($\bar{P}_T$) and variance (σ_T^2) and mortality is lognormally distributed with mean ($\bar{M}$) and variance (σ_M^2). We further assume that both prices are independent of mortality, but are positively correlated with each other with known covariance (σ_{TH}). Using bars over the variables to denote expected values, expected returns ($\bar{R}$) is given by equation (C-2).

$$\bar{R} = \bar{P}_H(a - b\bar{M}) + \bar{P}_T(c - d\bar{M}) - (e - f\bar{M}) \tag{C-2}$$

The variance of returns (σ_R^2) is by definition equation (C-3). Substituting equa-

$$\sigma_R^2 = E(R - \bar{R})^2 \tag{C-3}$$

tion (C-1) and equation (C-2) into equation (C-3) and expanding the square results in equation (C-4).

$$\begin{aligned}\sigma_R^2 = E[&a^2(P_H - \bar{P}_H)^2 + b^2(P_HM - \bar{P}_H\bar{M})^2 + c^2(P_T - \bar{P}_T)^2 \\ &+ d^2(P_TM - \bar{P}_T\bar{M})^2 + f^2(M - \bar{M})^2 - 2ab(P_H - \bar{P}_H)(P_HM - \bar{P}_H\bar{M}) \\ &+ 2ac(P_H - \bar{P}_H)(P_T - \bar{P}_T) - 2ad(P_H - \bar{P}_H)(P_TM - \bar{P}_T\bar{M}) \\ &+ 2af(P_H - \bar{P}_H)(M - \bar{M}) - 2bc(P_HM - \bar{P}_H\bar{M})(P_T - \bar{P}_T) \\ &+ 2bd(P_HM - \bar{P}_H\bar{M})(P_TM - \bar{P}_T\bar{M}) - 2bf(M - \bar{M})(P_H - \bar{P}_H) \\ &- 2cd(P_T - \bar{P}_T)(P_TM - \bar{P}_T\bar{M}) + 2cf(P_T - \bar{P}_T)(M - \bar{M}) \\ &- 2df(P_TM - \bar{P}_T\bar{M})(M - \bar{M})]\end{aligned} \tag{C-4}$$

Using the definitions of the variance of a variable Y given in equation (C-5), the covariance of two variables X and Y given in equation (C-6), making the appropriate substitutions into equation (C-4) and collecting terms, the resulting expression for the variance of returns is given by equation (C-7).

$$\sigma_Y^2 = E(Y^2) - \bar{Y}^2 \tag{C-5}$$

Hence $$E(Y^2) = \sigma_Y^2 + \bar{Y}^2$$

$$\begin{aligned}\sigma_{XY} &= E(Y - \bar{Y})(X - \bar{X}) \\ &= E(YX) - \bar{Y}\bar{X}\end{aligned} \tag{C-6}$$

Hence $$E(YX) = \sigma_{XY} + \bar{Y}\bar{X}$$

$$\begin{aligned}\sigma_R^2 = {}&a^2\sigma_H^2 + c^2\sigma_T^2 + f^2\sigma_M^2 + b^2[(\sigma_H^2)(\sigma_M^2 + \bar{M}^2) + \bar{P}_H^2\sigma_M^2] \\ &+ d^2[(\sigma_T^2)(\sigma_M^2 + \bar{M}^2) + \bar{P}_T^2\sigma_M^2] - 2ab(\sigma_H^2\bar{M}) + 2ac\sigma_{HT} \\ &- 2(ad + bc)(\sigma_{HT}\bar{M}) + 2bd\sigma_{TH}(\sigma^2 + \bar{M}^2) + 2bd\sigma_M^2\bar{P}_H\bar{P}_T \\ &- 2bf(\bar{P}_H\sigma_M^2) - 2cd\sigma_T^2\bar{M} - 2df(\bar{P}_T\sigma_M^2)\end{aligned} \tag{C-7}$$

The variance of returns has been expressed in terms of the variance of the variables, P_T, P_H, and M, the expected values of these three variables, the covariance of the two prices, and the coefficients of the returns equations.

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