Application of Expectation Models to Livestock and Crop Prices and Products

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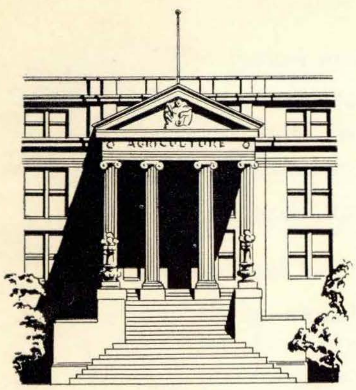

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CONTENTS

SUMMARY AND CONCLUSIONS

Fourteen different expectation models were formulated in this study and tested for efficiency of forecasting price and production outcomes. The main criterion of efficiency was the magnitude of the forecast errors. These models were selected because they were known to be used by farmers or because they appeared to be some of the more logical mechanical models which farmers can use with the knowledge at their command.

The models were tested for efficiency on both theoretical and empirical grounds. On theoretical grounds the models were applied to three suppositions about time series; the first, a generalized autocorrelated series; the second, a series with autocorrelation of positive unity; and the third, a random series. On empirical grounds the models were applied to selected time series of livestock and crop prices and to livestock yields.

The generalized autocorrelated series was useful in developing a set of formulas applicable to any autocorrelated series; the random series and the series with autocorrelations of positive unity are two particular cases of the generalized series. The application of the expectation models to a random series resulted in several conclusions. The most important of these was the efficiency and practicability of the moving-average model in forecasting. The series with autocorrelations of positive unity was less fruitful in its results. It was possible, however, to indicate the efficiency of the current-year model. The application of the models to the empirical data indicated the magnitude of the errors resulting from a series with parameters intermediate in value between those of the two hypothetical series.

On the basis of the theoretical and empirical evaluation of the models, three policy recommendations appear possible.

First, given a series with an imperfect degree of positive autocorrelation, individual farmers could be advised to use the current-year model or weighted-moving-average model as one with high efficiency and one simple to apply. In price series, the efficiency of these current-year models may be increased by supplementing them with farm outlook information. Since the outlook forecasts were indicated to be particularly accurate in forecasting large price changes, farmers could be advised to formulate expectations on the basis of the current-year or weighted-moving-average model and to shift to the outlook model whenever the latter indicated severe price changes. Utilizing farm outlook information would be particularly useful in reducing the number of extreme errors in the current-year model.

Second, for yield series which tend to approximate randomness, the 5-year moving-average model, from among the simple "rule of thumb" or "mechanical procedures," may be recommended for use by farmers.

Third, on the basis of the futures price model it is possible, with some reservations, to recommend that farmers sell their prospective crop on the cash rather than the futures market.

While these recommendations are based on the evaluation of the models made in this study, it must be remembered that the actual choice of a model by a farmer will depend on the manner in which uncertainty enters into his valuation pattern.

Application of Expectation Models to Livestock and Crop Prices and Products[1]

BY WILLIAM DARCOVICH AND EARL O. HEADY

Uncertainty—the prediction of the future and the making of decisions with imperfect knowledge—is one of the more complex problems facing Iowa farm operators. A relatively small amount of research has been devoted to this particular problem area. Two types of investigations are needed: (1) those showing how the economic structure can be changed to allow less extreme and abrupt change and less uncertainty and (2) those demonstrating methods of improved prediction and decision-making under uncertainty, since not all change and uncertainty can or should be removed.[2]

OBJECTIVES AND SOURCES OF DATA

A large body of economic theory has been developed in recent years which shows the effect of uncertainty in production on (1) the quantity of resources used by farmers and (2) on the efficiency of use of the existing quantity of resources. Empirical research, however has not kept pace with the developments in theory. The consequence has been that many theoretical concepts still remain unverified. This study is primarily empirical in nature and will be confined to the second aspect of uncertainty; it will attempt to evaluate different mechanical expectation models as a basis for efficient planning.

The purposes of this study are (1) to indicate some price and yield expectation models which appear logical for farmer use and (2) to indicate the magnitude of the expectation errors for each particular model. Two sections of analysis follow. The first involves a theoretical evaluation of expectation errors. The second includes an empirical evaluation of expectation errors plus an analysis of other simple measures of "expectation uncertainty."

An *expectation model* is a method of predicting a future price or yield. The errors of expectation for each model are determined by subtracting, for a given year, the expected price from the value actually realized. This operation is repeated for the whole period of time over which expectations are formulated. The "degree of uncertainty" in a given price or yield series is measured primarily by (1) the magnitude of the errors of expectation and, in addition, by (2) the percentage of extreme errors and by (3) the coefficient of the range. Hence, all three of these measures are used in the empirical evaluation of this study.

The models used in this study are tested on price and yield series which are believed to be applicable mainly to Iowa farm conditions. The series include five livestock prices, nine crop prices and three sets of livestock yields. Expectation models are tested for all of these series. The price series covers the 34-year period from 1917 to 1950 inclusive, except for the outlook model where data were available for only 27 years, and were taken from USDA statistics.[3] The three livestock yield series were obtained for 20 farms each from the Iowa Farm Business Association and the Iowa Dairy Herd Improvement Association. The poultry and hog data are records from the former source, and the dairy data are continuous records from the latter source. The period covered for livestock yields is 1924-50.

EXPLANATION OF MODELS USED

This part of the study explains the expectation models included in this study. Evaluation is made only of simple "mechanical" models which might be used by the majority of farmers with the estimating procedures and observations at their command.

It is possible, of course, to formulate a very large number of expectation models which might be used by farmers. To keep the study within manageable proportions, the number of models is limited to 14. The study is confined to "mechanical" models in which forecasts are made one period forward. Since the farmer usually has a greater knowledge of the yield than of price conditions, yield models are selected to stress the average value. Price models are selected to em-

[1] Project number 1199 of the Iowa Agricultural Experiment Station.

[2] For a selected bibliography of expectations dealing with outlook materials and farmer's subjective forecasts, see the bibliography at the end of this study.

[3] All prices are taken from agricultural statistics and are Iowa averages for livestock. Crop prices are averages for the United States.

phasize short-term trend and also the relationship between consecutive observations.

Only the simpler types of moving averages are used. In addition, short-term linear trends and linear regression are assumed to prevail in the series. A further degree of simplicity is achieved by using the same model expectations in the entire forecasting period. (Switches are not made back and forth between models.) This last procedure has a particular advantage for this study; the procedure provides a theoretical basis for the evaluation of the models, and theoretical values of the errors can be specified for the continuous period.

Confining the models to simple "mechanical" types represents a realistic farm condition. Most farmers are unlikely to use more than single characteristics of a series in formulating expectations. However, use of the same model throughout the entire forecasting period may represent some departure from reality. It assumes that farmers do not learn from experience. While no attempt is made to use all of the refined techniques of statistics and predictions, this step will be taken in a later study. Comparisons then will be made with the expectation errors devised from the simple models of this study.

The different mechanical expectation models evaluated in respect to forecasting accuracy are as follows: (1) the average, (2) normal, (3) cumulative, (4) random, (5) current year, (6) the 5-year moving average, (7) weighted 5-year moving average, (8) trend, (9) reverse trend, (10) trend from average, (11) reverse trend from average, (12) farm outlook, (13) parallel and (14) the futures price models. Nine of these models are empirically tested on price series and seven on yield series. In addition, a "futures price model" is tested on several series of crop prices.

AVERAGE PRICE AND YIELD MODEL

In this expectation model, the mean of the series is projected forward as the predicted value for every period into the future. The errors which arise are obtained by subtracting the mean of the period used for expectations from each of the individual values of the series (table 1, row 1). The main advantage of this model lies in the stability of the expected value. The only variability which arises is that of the individual observations themselves. However, this model is unable to utilize the relationship between consecutive observations or the short-term trend in the series of making predictions.

NORMAL MODEL

The normal model is a variant of the average model. It may be based on some period of "just" or "fair" or "parity" price, in terms of the 1910-1914 price relationship or in terms of minimum or maximum possible yield. A "normal" price is commonly used in valuation of farm resources such as land and buildings. In theoretical evaluation of the normal model, some constant value which differs from the mean is projected as the expected value for every period in the future (table 1, row 2). The error which occurs in the normal model is, *a priori,* larger than the error in the average model (table 3, rows 1 and 2). The increase in the error in the normal model over the average model will depend on the accuracy with which the average is estimated, or conversely, on the magnitude with which the normal value differs from the average value.

CUMULATIVE YIELD MODEL

In this model, the average yield experience of the farmer's entire farming period is projected as the predicted yield 1 year forward. This model is a logical outflow of the average model. In yields, some farmers may have little information about the average yield in the past but may build up this knowledge as their farming experience increases. The cumulative model is a representation of this "building up" process; for 2, 3, 4 or more years of farming, the moving average represents, respectively, the average experience for 2, 3, 4 or more years. In a series without pronounced trend, the moving average will tend to approach the average model. In a series with distinct trends, the value predicted from the cumulative averages will be too "heavily weighted" by the distant past to allow accurate forecasts. Hence, this model is not used for price series.

RANDOM PRICE AND YIELD MODEL

In this model, a value selected at random from the past observations of a series is projected as the predicted value for the future year (table 1, row 3). A farmer who has operated for 5 years, will have five observations from which to pick a value at random. It will be used as the predicted value for the sixth year. The confinement of the random selections to the values from past experience does not allow this model to utilize relationships between consecutive observations. Since the predicted value is based on a single observation, extreme errors are possible.

CURRENT-YEAR PRICE AND YIELD MODEL

The current price is projected forward as the predicted price for the following year for this model (table 1, row 4). Aside from its simplicity and its probable wide use by farmers,[4] there is a considerable amount of logic for the use of this model in formulating expectations. The model projects a current value 1 period forward. Hence, it utilizes the relationship between consecutive observations in forecasting future values. This advantage is greater for price than for yield

[4] Schultz, T. W. and Brownlee, O. H. Two trials to determine expectation models applicable to agriculture. Quart. Jour. Econ. 56:495. 1942. Williams, D. B. Price expectations and reactions to uncertainty by farmers in Illinois. Jour. Farm. Econ. 33:20-39. 1951.

series. In the former series, there tends to be continuity between consecutive observations arising out of the presence of momentum in economic activity.[5]

MOVING-AVERAGE PRICE AND YIELD MODEL

In this model the 5-year-moving-average value of a series is projected as the predicted value in the sixth year (table 1, row 5). A 5-year period appears to be a convenient[6] length of time over which the memory of many farmers extends. This type of model also has economic applicability; it allows for a flexible rather than a constant trend in a price series.[7] For yields, the trend feature allows recognition of technological changes.

WEIGHTED-MOVING-AVERAGE PRICE MODEL

This model is similar to the moving-average model in this sense: The average covers a period of 5 years. However, in place of equal weighting, the current year of the moving average is given a weight of 4 and each of the earlier years a weight of 1 (table 1, row 6). A greater weight for the current year is realistic from the viewpoint of momentum in economic phenomena; the current year affects the value of the following year more than do preceding years.[8] It is also realistic in this way: It helps minimize farmer memory error in respect to the earlier years. This model is not applied to yield series; they have less tendency to exhibit continuity between consecutive observations.

TREND AND REVERSE-TREND PRICE MODELS

For these models, the linear trend of the price between two consecutive years is (a) added to the price in the second year for the *trend model* (table 1, row 7) and (b) subtracted in the *reverse-trend model* (table 1, row 8). The resulting values are projected as the predicted prices for the third year. Thus, if the price rises by $1 between the first and second years of a price series, the price between the second and third years would be expected to rise by an additional $1 in the trend model. It would be expected to fall by an additional $1 in the reverse-trend model. These models use the concept of linear trend in the series and also the relationship between consecutive observations. Extreme errors are possible as the predicted prices are based on individual observations.

[5] This model is of importance in economic activity because the entrepreneurial behavior which it indicates is one of the basic assumptions for the existence of the cobweb phenomena in prices.

[6] In the study by Williams, op. cit., p. 26, it was noted that farmers tended to formulate their expectations in terms of convenient price figures such as $0.90, $1, $1.25, etc. From this it might be inferred that farmers also tend to use convenient time intervals in the formulation of expectations.

[7] Tintner, G. The variate difference method. Principia Press, Inc., Bloomington, Ind. p. 18-19. 1940.

[8] Keynes, J. M. The general theory of employment, interest and money. Harcourt Brace and Company, New York. 1936. pp. 50-51; 148.

TREND AND REVERSE-TREND-FROM-AVERAGE YIELD MODELS

In both of these models, the trend is obtained by subtracting the value of the yield in the sixth year from the average yield in the previous 5 years. This computed value of the trend is (a) added to the yield in the sixth year in the *trend-from-average model* (table 1, row 9) and (b) subtracted from the yield in the sixth year in the *reverse-trend-from-average model* (table 1, row 10). The resulting values are projected as the predicted yields for the seventh year for each respective model. These two models are analogous to the trend and reverse-trend models in prices except that they use the average; the former models use only single observations.

FARM OUTLOOK PRICE MODEL

In this model the predicted prices were determined on the basis of the annual farm outlook reports issued by the federal and state agencies. For livestock, national outlook reports were used for the period from 1924 to 1929 and those of Iowa State College for the period thereafter. For crops, national outlook reports alone were used.

In all cases, the predicted price was some proportion of the current price, the proportion being determined by the writers' judgment of the information contained in outlook reports. On the basis of these reports, four possible proportions or relationships between the current and next year's prices were established; prices next year were predicted to (1) be unchanged, (2) change 5 percent, (3) change 10 percent and (4) change 20 percent in relation to the current price.

It was necessary for the writers to read all of the farm outlook information over the period of years and to interpret it. Interpretation is complex since the level of price change is seldom indicated, except for the strength of the forces suggested for giving rise to price change.[9] If the outlook publications suggested "no," or "practically no," change in economic conditions, the year's price was projected to next year; if a "slight" change was suggested, next year's price was changed 5 percent; a "fairly large" change was taken as 10 percent and a "large" change was considered to mean 20 percent or more.

This procedure is one of many possible variants for the outlook model, all of which are subject to some arbitrary influences and the judgment of the person interpreting the information. This fact should be kept clearly in mind for later sections of this report. While each variant of an outlook model would be expected to yield somewhat different results, this disadvantage is not serious in evaluation of a particular outlook model. The usefulness of an outlook model lies largely in

[9] For similar analyses which tend to substantiate this study with respect to outlook models, see: John F. Heer. Accuracy of Iowa farm outlook information. Jour. Farm Econ. 36:143-47. Feb. 1954 and John D. Baker, Jr. An evaluation of the accuracy of federal economic forecasts. Unpublished Ph.D. thesis. Purdue University Library, LaFayette, Indiana.

accurate indication of the *direction* rather than *magnitude* of the predicted price change. The testing of some variant of the outlook model is of value in indicating the forecasting efficiency possible if farmers, with interpretation similar to those of persons making this study, were to utilize the best source of price information available.[10]

PARALLEL PRICE MODEL

In this model, the predicted price in a current period is determined on the basis of a price which existed in some parallel period. The logic for this type of a price model lies in the common belief that historical price periods tend to repeat themselves. Thus, it is assumed that each of the price periods in the interval under consideration in this study was paralleled by some previous price period.

In this model it is assumed that the years 1915-1918 were paralleled by the years 1861-1865 inclusive of the Civil War. Prices in the latter period rose about 25 percent per year;[11] it was predicted, therefore, that the price in 1918 would rise by 25 percent in comparison with the year 1917. For the years 1919-1923, the parallel period was assumed to be the post-Civil War years 1865-1871. For the years 1924-1929, the parallel period was assumed to comprise the years 1910-1914. For the years 1930-1934, the parallel period was assumed to be the depression years 1891-1896. For the years from 1935 to 1939, the parallel period was considered to be the 14 years from 1896 to 1910; for the years 1940-1946 which include most of the World War II period, the parallel was considered to be the 4-year period 1915 to 1919.

For the first 2 years of 1947-1950, the parallel period was assumed to be the post-World War I years 1919-1921. Prices fell by about 5 percent from 1919 to 1920, and this same rate of decline was predicted from 1946 to 1947. For 1949 and 1950 it was assumed that prices would continue to decline though somewhat more slowly, or about 20 percent per year. The assumption of declining prices for the last 2 years appears valid; in three empirical surveys farmers indicated they expect prices to decline until the end of the 40's and as far as the middle of the 50's.[12]

THEORETICAL EVALUATION OF EXPECTATION MODELS

Given certain assumptions about the nature of the parameters which arise in a time series, theoretical statements can be made with respect to the magnitude of the errors resulting from various expectation models. The theoretical errors are interpreted in terms of a long-term application of the models to particular series. The actual error may deviate widely from the theoretical errors for short periods. Alternatively, however, the theoretical errors may be interpreted as applying to a large group of farmers in 1 year. The theoretical magnitude of the errors then indicates the outcome if the whole group used a particular model.

Nine models presented on previous pages are evaluated in this section. No theoretical evaluation is made of the outlook or parallel models in prices nor of the cumulative model in yield. Theoretical evaluation is in terms of the magnitude of the errors inherent in each model. The measure of the magnitude is the expected error and the expected squared error. The latter measure mainly is used in this section because (1) it is adaptable to algebraic treatment and (2) its magnitude can be easily related to the expected error. The expected error, used more particularly in the following section, is more meaningful from the viewpoint of the farmer; he ordinarily is guided by the magnitude of the error, not by the square of the magnitude of the error.

The expected errors and expected squared errors of the various models are evaluated for three alternative assumptions in respect to the value of the parameters of this series. In the first case, it is assumed that the autocorrelation coefficients may take on any of all possible values. In the second case, the autocorrelations of the series are assumed to be at one extreme, or positive unity. In the third case, the series is assumed to be random, the autocorrelation coefficients and regression constant being zero.

A further assumption is possible with respect to the extreme values of the parameters which may arise in an autocorrelated series. The autocorrelation coefficients may be assumed to alternate between negative and positive unity. This represents a zig-zag series, or the opposite extreme to the series with autocorrelations of positive unity. In addition, further assumptions are possible with respect to the nature of the series itself; the series could be assumed to possess a more generalized type of trend; also various types of cyclical components could be assumed to be superimposed over the trend. Although these latter three assumptions would represent an approximation of reality in some situations, none of them is considered in this study.

AUTOCORRELATED SERIES

The descriptions of the measurement of error, the expected error and the expected squared error for the general case, namely when the autocorrelation coefficients may take on any of all possible values, are presented in tables 1, 2 and 3, respectively.

[10] See Heer and Baker, op.cit.

[11] The reference to price changes in the parallel periods is in terms of the Index of Farm Product Prices. See: U.S. Dept. of Agriculture. Agricultural outlook charts, 1947. p. 4.

[12] Elliott, R. T. Adjustments to risk and uncertainty in hog production. Unpublished M.S. thesis. Iowa State College Library, Ames, Iowa. 1947. p. 54-56; Ball, A. G. Expectations in the agricultural firm. Unpublished M.S. thesis. Iowa State College Library, Ames, Iowa. 1947. p. 68; Brownlee, O. H. and Gaines, W. Farmers' price expectations and the role of uncertainty in farm planning. Jour. Farm Econ. 31:269. 1949.

TABLE 1. ALGEBRAIC DESCRIPTION OF THE ERRORS WHEN THE SERIES IS AUTOCORRELATED.*

	Model	Error
(1)	Average	$x_t - u$
(2)	Normal	$x_t - u + c$
(3)	Random	$x_t - x_r$
(4)	Current year	$x_{t+1} - x_t + b$
(5)	Moving average	$x_{t+n} - [(x_{t+n-1} + b) + (x_{t+n-2} + 2b) + \dots + (x_t + nb)] / n$
(6)	Weighted moving average	$x_{t+n} - [(n-1)\ (x_{t+n-1} + b) + (x_{t+n-2} + 2b) + \dots + (x_t + nb)] / (2n-2)$
(7)	Trend	$x_{t+2} - [(x_{t+1} + b) + x_{t+1} - (x_t + b)]$
(8)	Reverse trend	$x_{t+2} - [(x_{t+1} + b) - x_{t+1} - (x_t + b)]$
(9)	Trend from average	$x_{t+n+1} - [x_{t+n} + b + \{x_{t+n} - \vert (x_{t+n-1} + b) + (x_{t+n-2} + 2b) + \dots + (x_t + nb) \vert / n\}]$
(10)	Reverse trend from average	$x_{t+n+1} - [x_{t+n} + b - \{x_{t+n} - \vert (x_{t+n-1} + b) + (x_{t+n-2} + 2b) + \dots + (x_t + nb) \vert / n\}]$

* The following is a description of the notation used: x_t represents a particular observation in the period t of a time series x, u is the mean of the time series x, and c is some constant which may be either added or subtracted from u; x_r represents a randomly selected observation from the time series x, b is a trend constant and n is the length of the moving average.

The usefulness of the formulas for the error, expected error and expected squared error in tables 1, 2 and 3 lies in their generality; they are applicable for all possible values of the autocorrelation coefficients and also various values of n, the length of the moving average of the particular expectation model. Given a particular series, the expected squared errors for the various expectation models may be obtained by calculating the regression constant and the required autocorrelation coefficients and also by indicating the particular length of the moving average of the model. Alternatively, the formulas may be evaluated by assuming specific values for the autocorrelation coefficients and the length of the moving average. The latter method will be adopted in this study; it will be assumed that the autocorrelation coefficients are either (1) positive unity or (2) zero. Also, it will be assumed that the length of the moving average n is 1, 5 and an infinitely large number of years. The evaluations which follow will be in terms of these two extreme values for the autocorrelation coefficients.

SERIES WITH AUTOCORRELATIONS OF POSITIVE UNITY

When the autocorrelation coefficients are of positive unity (table 4), the random element disappears and consecutive observations differ from each other only by the amount of the regression

TABLE 2. EVALUATION OF THE EXPECTED ERROR WHEN THE SERIES IS AUTOCORRELATED.

Model	General case	n = 5
	(1)	(2)
Average	0	0
Normal	c	c
Random	0	0
Current year	b	b
Moving average	$[\{n + (n-1) + \dots + (n-n+1)\} / n]\, b$	3b
Weighted moving average	$[\{n^2 - (n-2) + \dots + (n-n+1) + 1\} / (2n-2)]\, b$	(9/4)b
Trend	0	0
Reverse trend	2b	2b
Trend from average	$[\{(n-1) + \dots + (n-n+1)\} / n]\, b$	2b
Reverse trend from average	$[\{2n + (n-1) + \dots + (n-n+1)\} / n]\, b$	4b

TABLE 3. EXPECTED SQUARED ERROR WHEN THE SERIES IS AUTOCORRELATED.*

Model	Expected squared error
Average	σ^2
Normal	$\sigma^2 + c^2$
Random	$2\sigma^2$
Current year	$2\sigma^2 (1 - \rho_1) + b^2$
Moving average	$[\sigma^2 \{(n^2 + n) - 2 (\rho_1 + 2\rho_2 + \dots + n\rho_n)\} + \{n + (n - 1) + \dots + (n - n + 1)\}^2 b^2] / n^2$
Weighted moving average	$[\sigma^2 \{(5n^2 - 9n + 4) - 2 \vert (2n^2 - 6n + 5)\rho_1 + 2\rho_2 + \dots + (n - 1)\rho_{n-1} + (2n - 2)\rho_n \vert \} + \{n^2 - \vert (n - 2) + \dots + (n - n + 1) + 1 \vert \}^2 b^2] / (2n - 2)^2$
Trend	$6\sigma^2 - 2\sigma^2 (4\rho_1 - \rho_2)$
Reverse trend	$2\sigma^2 (1 - \rho_2) + 4b^2$
Trend from average	$[\sigma^2 (5n^2 + n) - 2 \vert (2n^2 + n - 1)\rho_1 + \dots + n\rho_n - n\rho_{n+1} \vert \} + \{(n - 1) + \dots + (n - n + 1)\}^2 b^2] / n^2$
Reverse trend from average	$[\sigma^2 \{(n^2 + n) + 2 \vert (n - 1)\rho_1 - 2\rho_2 - \dots - n\rho_n - n\rho_{n+1} \vert \} + \{2n + (n - 1) + \dots + (n - n + 1)\}^2 b^2 / n^2$

* ρ_m is the autocorrelation coefficient lagged m years, where $m = 1, \dots, n + 1$.

constant. This represents a simplified situation, and it is possible to extend the theoretical evaluation of the magnitude of the errors beyond that possible in the general case. To facilitate description, the models will be broken into two groups. The first group consists of the average, normal and random models. The second group consists of the remaining models. This split is made as the models in the first group, with the exception of the random, make no use of the autocorrelation coefficients or the regression constant in the series.

Average, normal and random models: These three models are classified together because their squared errors are independent of the autocorrelation coefficients and regression constant. Since they are all functions of σ^2, the variance of the series, some limited comparisons between them are possible. The squared error for the average model is σ^2, the smallest for the three models under consideration. The squared error of the random model is $2\sigma^2$, the second highest in this group (table 4, column 1). The magnitude of the squared errors of the normal model will remain unclassified, as it depends on how well the average value is estimated by farmers. Given a series with a small linear trend, this estimate may be accurately made, and the value of the squared error will likely be below that of the random model. However, given

TABLE 4. EVALUATION OF THE EXPECTED SQUARED ERROR WHEN $\rho_1 = \rho_2 = \dots = \rho_n = 1$, AND $n = 5$.

Model	Expected squared error	
	$\rho_1 = \rho_2 = \dots = \rho_{n+1} = 1$	$\rho_1 = \rho_2 = \dots = \rho_{n+1} = 1, n = 5$
	(1)	(2)
Average	σ^2	σ^2
Normal	$\sigma^2 + c^2$	$\sigma^2 + c^2$
Random	$2\sigma^2$	$2\sigma^2$
Current year	b^2	b^2
Moving average	$[\{n + (n - 1) + \dots + (n - n + 1)\} b]^2 / n^2$	$9b^2$
Weighted moving average	$[\{n^2 - (n - 2) + \dots + (n - n + 1)\} b]^2 / (2n - 2)^2$	$(81/16)\ b^2$
Trend	0	0
Reverse trend	$4b^2$	$4b^2$
Trend from average	$[\{(n - 1) + \dots + (n - n + 1)\} b]^2 / n^2$	$4b^2$
Reverse trend from average	$\{2n + (n - 1) + \dots + (n - n + 1)\} / n^2$	$16b^2$

a high value for the linear trend, the average may be estimated badly with the result that the squared error of the normal model may be greater than that of the random model.[13]

Remaining models: When the autocorrelations in the series become positive unity, the contribution of σ^2 to the squared error (table 3) is reduced to zero, and the squared errors become functions of b^2 and n. In the case of the trend model, the squared error will go to zero indicating that it is possible to make perfect forecasts. The remaining models may be further evaluated by letting $n = 5$. Then the value of their expected squared errors becomes a function only of regression constant b (column 2, table 4). The squared error of the current year model b^2 is least; it is followed by the reverse trend, the trend-from-average, weighted-moving-average, moving-average and the reverse-trend-from-average models which have squared errors of $4b^2$, $4b^2$, $(81/16)b^2$, $9b^2$ and $16b^2$, respectively. On the basis of these magnitudes, the models may be classed second to sixth in efficiency in relation to the current-year model.

The forecasting efficiency of the last six models depends on the degree with which each is tied to the past. The current-year model is tied most closely to the present, since the expectation for any one year is simply the extension of the price for the previous year. While it does not extend far into the past, it is the most efficient of these models. On the other hand, the moving-average and reverse-trend-from-average models extend further into the past, 3 and 4 years, respectively, and are the two most inefficient models. The greater weight given to the current year in the weighted-moving-average model, as compared with the moving-average and the reverse-trend models, reduces the tying of the forecasting value from 3 to 2¼ periods to the past and thereby improves its efficiency.

[13] The particular type of random model formulated in this study will have an expected squared error somewhat below $2\sigma^2$. The expected squared error of the ordinary random model $E(x_t - x_r)^2 = 2\sigma^2$ is derived on the assumption that x_t and x_r are independent of each other, or that $E(x_t x_r) = U^2$. This would be true in the case where x_r was picked at random from the entire series. For the random model in this study, x_r was picked at random only from the values which occurred in the "past farming experience of the farmer." In addition, with positive unity in the autocorrelation coefficients and also a finite series, x_t and x_r will not be independent of each other. As a result $E(x_t x_r)$ will be greater than U^2 giving an expected squared error which is somewhat below $2\sigma^2$. The ability of the random model to utilize the relationship between consecutive items does not require a series with autocorrelations of positive unity. This characteristic of the model also will be expressed in a series which has high positive values for the autocorrelation coefficients.

RANDOM SERIES WITH ZERO AUTOCORRELATION COEFFICIENT

In the case where the series is random, all the autocorrelation coefficients and the regression constant, b, become zero. Hence, this situation represents a particular case of the formulas used in table 3 for autocorrelated series. Also, it allows a further theoretical evaluation of the expected errors and expected squared errors presented in tables 2 and 3. Thus in table 5, the formulas for the description of the error (column 1) differ from the description in table 1 in that the regression constant b is equated with zero. The expected errors for the current-year, moving-average, weighted-moving-average, reverse-trend, trend-from-average and reverse-trend-from-average models which have positive values in table 2 (column 2) become zero in table 5 (column 2). Similarly the general formulas for the expected squared errors of table 3 are reduced to functions of σ^2 and the length of the moving average n (table 5, column 3).

The expected squared errors of table 5 (column 3) are evaluated in table 6 for various lengths of the moving average n. For all of the models which

TABLE 5. EXPECTED ERROR AND EXPECTED SQUARED ERROR WHEN THE SERIES IS RANDOM.

Model	Error	Expected error $b = 0$	Expected squared error $\rho_1 = \rho_2 = \ldots = \rho_n = 0$
	(1)	(2)	(3)
Average	$x_t - u$	0	σ^2
Normal	$x_t - u + c$	c	$\sigma^2 + c^2$
Random	$x_t - x_r$	0	$2\sigma^2$
Current year	$x_{t+1} - x_t$	0	$2\sigma^2$
Moving average	$x_{t+n} - (x_{t+n-1} + \ldots + x_t) / n$	0	$\sigma^2 (n^2 + n) / n^2$
Weighted moving average	$x_{t+n} - \{(n-1)(x_{t+n-1}) + \ldots + x_t\} / (2n-2)$	0	$\sigma^2 (5n^2 - 9n + 4) / (2n-2)^2$
Trend	$x_{t+2} - \{x_{t+1} + (x_{t+1} - x_t)\}$	0	$6\sigma^2$
Reverse trend	$x_{t+2} - \{x_{t+1} - (x_{t+1} - x_t)\}$	0	$2\sigma^2$
Trend from average	$x_{t+n+1} - \{x_{t+n} + \lvert x_{t+n} - (x_{t+n-1} + \ldots + x_t) / n \rvert\}$	0	$\sigma^2 (5n^2 + n) / n^2$
Reverse trend from average	$x_{t+n+1} - \{x_{t+n} - \lvert x_{t+n-1} - (x_{t+n-1} + \ldots + x_t) / n \rvert\}$	0	$\sigma^2 (n^2 + n) / n^2$

are dependent on a moving average, an increase in the length of the average serves to bring about an asymptotic decrease of the squared error to some constant value. Thus, as n becomes very large (column 3, table 6), the expected squared error approaches σ^2 for the moving-average model, $5\sigma^2$ for the trend-from-average model, $(5/4)\sigma^2$ for the weighted-moving-average model and σ^2 for the reverse-trend-from-average model. Conversely, if the length of the moving average is reduced to $n = 1$ (column 1), the expected squared errors of the moving-average, trend-from-average and reverse-trend-from-average models become equivalent to that of the current, the trend and the reverse-trend models, respectively. For the weighted-moving-average model, the expected squared error becomes indeterminate. When $n = 5$, (column 2) the length of the moving average used in this study, the expected squared error[14] for the moving-average, trend-from-average, reverse-trend-from-average and weighted-moving-average models become intermediate in value between these two extremes, namely $(6/5)\sigma^2$, $(26/5)\sigma^2$, $(6/5)\sigma^2$ and $(21/16)\sigma^2$, respectively.

Average model as a standard: One of the reasons for the consideration of the average model was its possible use as a standard for the comparison of errors in other models. In the case of an autocorrelated series, the average model was not suited for use as a standard. However, in the case of a random series, the average model is suited for this purpose. First, in a random series, the average model provides the smallest squared error of the models considered (table 6). This makes it a convenient standard from which to compare the errors of the other models. A more important consideration is that the squared errors of the various models are functions only of σ^2. This makes it possible to compare the various models with each other.

Assuming that the average value is estimated correctly, the squared error of the average model, σ^2 is the smallest of the 10 models under consideration (table 6). For the particular situation where $n = 5$ (column 2), the moving-average and the reverse-trend-from-average models, each of which have squared errors of $(6/5)\sigma^2$, rank next to the average model. Similarly, in relation to the average model, the weighted-moving-average model which has a squared error of $(21/16)\sigma^2$ is third least. The random, current-year and reverse-trend models, each of which have squared errors of $2\sigma^2$, are fourth least. Finally the trend-from-average and the trend models, which have squared errors of $(26/5)\sigma^2$ and $6\sigma^2$, respectively, are fifth least and highest in respect to the magnitude of the error. The normal model will remain unclassified as its squared error depends on the magnitude of the constant c; in a random series, it will likely fall between σ^2 and $2\sigma^2$.

Some Limitations in Theoretical Evaluation

The existence of two series, one with autocorrelations of positive unity on the one hand and one with a random series on the other, is a somewhat unrealistic assumption. An alternative is to assume that the middle ground, which allows for linear regression as well as some autocorrelation between the individual observations, is a closer approach to reality for all the price and many of the yield series. This study can make no theoretical statements with respect to the series which fall into this middle ground. Although the formulas indicated in table 1 represent a general situation, further application of these formulas for a particular series requires a knowledge of the re-

[14] Hereafter, the "expected squared error" will be referred to only as the "squared error."

TABLE 6. EVALUATION OF THE EXPECTED SQUARED ERROR IN A RANDOM SERIES FOR VARIOUS VALUES OF THE MOVING AVERAGE, n.

Model	Expected squared error		
	$n = 1$	$n = 5$	$n = \infty$
	(1)	(2)	(3)
Average	σ^2	σ^2	σ^2
Normal	$\sigma^2 + c^2$	$\sigma^2 + c^2$	$\sigma^2 + c^2$
Random	$2\sigma^2$	$2\sigma^2$	$2\sigma^2$
Current year	$2\sigma^2$	$2\sigma^2$	$2\sigma^2$
Moving average	$2\sigma^2$	$(6/5)\sigma^2$	σ^2
Weighted moving average	....	$(21/16)\sigma^2$	$(5/4)\sigma^2$
Trend	$6\sigma^2$	$6\sigma^2$	$6\sigma^2$
Reverse trend	$2\sigma^2$	$2\sigma^2$	$2\sigma^2$
Trend from average	$6\sigma^2$	$(26/5)\sigma^2$	$5\sigma^2$
Reverse trend from average	$2\sigma^2$	$(6/5)\sigma^2$	σ^2

TABLE 7. COMPARISON OF THE ABSOLUTE MEAN ERRORS OF THE PRICE EXPECTATION MODELS FOR LIVESTOCK.

	Out-look	Current year	Parallel	Weighted moving average	Trend	Moving average	Reverse trend	Random	Average
Steers (dollars)	2.96(1)*	3.08(2)	3.40(3)	3.41(4)	4.62(7)	4.27(6)	4.05(5)	6.80(9)	5.63(8)
Hogs (dollars)	2.24(2)	2.19(1)	2.36(3)	2.81(4)	3.16(5)	3.61(6)	3.63(7)	5.00(9)	4.67(8)
Lambs (dollars)	1.51(1)	1.64(2)	2.30(5)	2.20(3)	2.23(4)	2.77(7)	2.60(6)	3.76(8)	3.92(9)
Eggs (cents)	3.1(1)	4.0(2)	4.3(3)	4.6(4)	5.6(5)	6.0(6.5)	6.0(6.5)	9.1(9)	7.5(8)
Butterfat (cents)	5.3(1)	6.5(2)	6.7(3)	7.7(4)	11.6(8)	9.6(5)	10.9(6)	11.3(7)	12.5(9)
Sum of ranks	(6)	(9)	(17)	(19)	(29)	(30.5)	(30.5)	(42)	(42)
Rank of sums	1	2	3	4	5	6.5	6.5	8.5	8.5

* Numbers in parentheses indicate the ranks of the adjacent measures of the error.

gression constant and also of the required autocorrelation coefficients. The computation of these values is left for another study. A further approach to reality would require the extension of assumptions about the nature of the series and also about the nature of the models formulated. As indicated, a closer approach to reality will be made if the series are assumed to have a more generalized type of trend with a cyclical component superimposed over the trend.

EMPIRICAL EVALUATION OF EXPECTATION MODELS

The following parts of the study give the results of empirical application of the various expectation models to the prices and selected yields. For prices, each model is evaluated on the basis of its "average" efficiency for all the prices considered as a group. This procedure appears justified as all the prices covered the same period (1917 to 1950) and were subject to the same secular forces.

The absolute mean error[15] is used as the major index in the empirical evaluation of the magnitude of the error. It is more desirable than a related index, the squared error; the latter index, computed by squaring each of the individual errors, gives a larger mean error than that actually faced by the farmer.[16] It is believed that the former index is a more meaningful concept to the farmer than is the squared error. The error of each model also is evaluated in terms of two additional measures (1) the frequency of extreme errors and (2) the coefficient of the range. The frequency distribution makes possible a comparison of the proportion of the extreme errors in each model; the coefficient of the range makes possible a comparison of the range of the error in each model. A knowledge of the percentage of extreme errors and the range of the error is of importance for suggesting safety reactions on the part of farm operators.

Price Models for Livestock

The nine expectation models for the prices of steers, hogs, sheep, eggs and butterfat are compared in table 7 on the basis of the magnitude of the mean error. The outlook, current-year, parallel and weighted-moving-average models result in mean errors which rank first to fourth smallest in magnitude, respectively. The outlook model has a mean error of $2.96, $2.24, $1.51, 3.1 cents and 5.3 cents for the prices of steers, hogs, lambs, eggs and butterfat, respectively. These errors rank lowest in magnitude for all the prices except hogs; in the latter case, the errors rank second lowest. In comparison, for all prices except hogs, the current-year model has somewhat larger errors, namely $3.08, $1.64, 4 cents and 6.5 cents, respectively. These errors rank second least in comparison with corresponding figures for the outlook model; for the price of hogs, the error of $2.19 ranks least in magnitude.

The parallel and weighted-moving-average models have somewhat larger mean errors. In the parallel model, the errors of $3.40, $2.36, $2.30, 4.3 cents and 6.7 cents, respectively, are third least in magnitude for all prices except those of lambs; for the latter, the error of $2.30 ranks fifth in magnitude. Finally the errors for the weighted-moving-average model, $3.41, $2.81, $2.20, 4.6 cents and 7.7 cents, respectively, rank fourth least in magnitude for all prices except sheep; for the latter price, the error of $2.20 ranks third in magnitude. These models are also characterized by a high degree of consistency in ranks between the different prices. In each of the four models, the ranks are equivalent in all but one of the prices.

The remaining five models in table 7 are characterized by distinctly larger errors than those which arise in the first four models. This is particularly true for the average and random models. In the average model, the mean errors of $5.63, $4.67, $3.92, 7.5 cents and 12.5 cents are approximately from two to three times the magnitude of the corresponding errors in the outlook and current-year models. A similar comparison holds for the random model, as its errors are roughly equal to those of the average model. In the remaining models—namely the moving-average, the trend and reverse-trend models—the errors are intermediate in magnitude between those of the average and random models on the one hand, and the outlook, current-year and weighted-moving-average models on the other.

In addition to having errors of larger magnitude, the latter five models do not give as consistent a ranking of errors as do the first four models. Thus, the trend model results in mean errors which rank

[15] Hereafter the "absolute mean error" will be referred to as the "mean error."

[16] The square root of the squared error is approximately 1.2 times the mean error.

eighth in magnitude for the prices of butterfat, seventh for the prices of steers, fifth for the prices of hogs and eggs and fourth for the prices of lambs. This gives a range of ranks from fourth to eighth highest. The remaining four models give somewhat less inconsistent rankings; there is a range of three ranks for the reverse-trend, the moving-average and the random models, and a range of two ranks for the average model.

This inconsistency of rankings makes it difficult to evaluate the average efficiency of a model. The difficulty may be overcome to some extent by a summation of ranks of the errors. The average and random models are indicated to be equal in efficiency as each has a sum of ranks of 42. The trend, the reverse-trend and the moving-average models are also approximately equal in efficiency as they have sums of ranks of 29, 30.5 and 30.5, respectively. The first two models are, however, considerably less efficient than the last three.

Considering the nine models as a single group, the outlook, current-year, parallel and weighted-moving-average models, with sums of ranks of 6, 9, 17 and 19, rank first to fourth, respectively. The trend model ranks fifth, the reverse-trend and the moving-average models rank sixth, and the average and random models seventh in respect to the magnitude of their mean errors.

PERCENTAGE OF EXTREME ERRORS FOR LIVESTOCK PRICES

The percentage of extreme errors which occur in the various models for livestock is indicated in table 8.[17] The outlook, the current-year, the parallel and the weighted-moving-average models have the lowest average percentage of extreme errors, namely 9, 11, 15 and 18 percent, respectively. The sum of ranks of 7, 10.5, 14.5 and 20 for these models, respectively, gives further support to this ranking. The remaining five expectation models are somewhat more difficult to rank. The trend, the moving-average and the reverse-trend models have an average of 25, 27 and 28 percent of extreme errors, respectively. On this basis, it is possible to rank these models fifth, sixth and seventh, respectively. However, on the basis of the sum of ranks of 27.5, 31 and 29.5 these models rank fifth, seventh and sixth, respectively. As neither method appears conclusive, these models are considered equivalent with respect to the percentage of their extreme errors. Similarly, the average and random models with an average of 38 and 39 percent of extreme errors and a sum of ranks of 43 and 42 also are considered equivalent.

Considering the models as a single group, the outlook, current-year, parallel and weighted-moving-average models rank first to fourth respectively. The trend, the reverse-trend and the moving-average models rank fifth, and the average and random models rank sixth in respect to the percentage of their extreme errors. This ranking of the models is equivalent to that obtained on the basis of the absolute mean error in table 7.

COEFFICIENT OF THE RANGE

Table 9 provides a comparison of the coefficient of the range for the various expectation models. This measure indicates the range of the errors expressed as a percent of the mean of the series. Using the average coefficient for all prices, the outlook, the weighted-moving-average, the current-year and the parallel models, with coefficients

[17] An extreme error is defined as one which is 35 percent of the mean or greater. The percentage of extreme errors is the percentage of years in which the price differed by 35 percent or more of the expectation.

TABLE 8. COMPARISON OF THE PERCENTAGE OF EXTREME ERRORS IN PRICES FOR LIVESTOCK.

	Out-look	Current year	Parallel	Weighted moving average	Trend	Moving average	Reverse trend	Random	Average
Steers	11(1)*	12(2)	21(4)	14(3)	32(7)	25(5)	28(6)	42(9)	35(8)
Hogs	11(1)	18(2.5)	18(2.5)	21(4)	35(5.5)	36(7)	35(5.5)	43(8)	46(9)
Lambs	7(1)	12(2)	15(3)	21(5)	18(4)	27(7)	26(6)	33(8)	35(9)
Eggs	7(2)	6(1)	15(4)	10(3)	25(7)	24(6)	21(5)	49(9)	41(8)
Butterfat	7(2)	9(3)	6(1)	21(5)	13(4)	24(6)	28(7)	30(8)	35(9)
Average	9	11	15	18	25	27	28	39	38
Sum of ranks	(7)	(10.5)	(14.5)	(20)	(27.5)	(31)	(29.5)	(42)	(43)
Rank of sums	1	2	3	4	5	7	6	8	9

* Numbers in parentheses indicate the ranks of the adjacent measures of the error.

TABLE 9. COMPARISON OF THE COEFFICIENTS OF THE RANGE FOR LIVESTOCK PRICES (PERCENT).

	Out-look	Current year	Parallel	Weighted moving average	Trend	Moving average	Reverse trend	Random	Average
Steers	132(4)*	131(3)	121(1)	125(2)	174(7)	149(5)	161(6)	229(9)	198(8)
Hogs	137(3)	151(6)	112(1)	136(2)	150(5)	144(4)	202(7)	245(9)	210(8)
Lambs	97(1.5)	97(1.5)	128(5)	108(3)	129(6)	119(4)	130(7)	244(9)	199(8)
Eggs	80(1)	89(2.5)	97(4)	89(2.5)	105(5)	114(6.5)	114(6.5)	131(9)	122(8)
Butterfat	104(1.5)	104(1.5)	140(6)	107(3)	164(8)	131(5)	123(4)	143(7)	176(9)
Average	110	114	120	113	144	130	149	205	181
Sum of ranks	(11)	(14.5)	(17)	(12.5)	(31)	(24.5)	(30.5)	(43)	(41)
Rank of sums	1	3	4	2	7	5	6	9	8

* Numbers in parentheses indicate the ranks of the adjacent measures of the error.

TABLE 10. MAGNITUDE OF PREDICTED PRICE CHANGES AND ERRORS IN DIRECTION FOR THE OUTLOOK MODEL FOR THE VARIOUS PRICE SERIES.

Predicted price next year as a percent of current price*	Steers	Hogs	Lambs	Eggs	Butterfat	Total	Error as percent of total
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Unchanged							
Number of predictions	5	5	4	6	5	25	
Error in direction	4	4	3	3	3	17	68
Change 5 percent							
Number of predictions	10	4	16	11	14	55	
Error in direction	4	2	5	4	5	20	36
Change 10 percent							
Number of predictions	10	10	6	8	6	40	
Error in direction	3	5	0	1	1	10	25
Change 20 percent							
Number of predictions	2	8	1	2	2	15	
Error in direction	1	1	1	0	0	3	20
Total number of predictions	27	27	27	27	27	135	
Total errors in direction	12	12	9	8	9	50	

* In the unchanged category the prices of the current year were predicted for next year. In the 5-, 10- and 20-percent change categories prices next year were predicted to change by 5, 10 and 20 percent of the current-year price.

which range from 110 to 120, rank first to fourth in magnitude, respectively. There is little difference between the ranges of the current-year and weighted-moving-average models as indicated by the average coefficients of 114 and 113, respectively. The equivalence of their ranges is further indicated by the sums of ranks, which are 14.5 and 12.5, respectively. The coefficients of the range for the trend, the reverse-trend, the average and the random models (with average coefficients 144, 149, 181 and 205) rank sixth to ninth, respectively.

The rankings of the model on the basis of the range of the errors is in approximate agreement with the ranking of the models on the basis of the mean error and the extreme error. In general, it may be indicated that the models with the greatest mean error also have the highest percentage of extreme errors and usually, but not always, the highest range.

OUTLOOK AND PARALLEL MODELS

The favorable showing of the outlook model, in terms of the subjective evaluation made of it, is somewhat surprising in view of the large number of forecasts in which the predicted prices were wrong in direction (table 10). From the total of 27 forecasts for each price there were 12 errors in direction for the prices of steers and hogs, nine for the prices of lambs and butterfat and eight for the prices of eggs. In appraising these errors, some consideration should be given to the magnitude of the predicted price changes. For the five products there were a total of 25 forecasts in which the prices were predicted to remain unchanged (column 6); 17 of these forecasts were wrong since prices did change. The resulting errors were as large as those under the current-year model. In the eight forecasts which were correct in direction of price change, accuracy was no greater than for the current-year model.

In the "5-, 10- and 20-percent-change categories," a forecast using outlook which is wrong in direction results in errors which are greater than for the current-year model; on the other hand, forecasts which are right in direction result in errors which are smaller than those created by the current-year models.

A further important feature which is indicated in table 10 (column 7) for the outlook model is that an increase in forecasting accuracy arises with an increase in the magnitude of the forecasted price change. In the unchanged category, 17 out of 25 or 68 percent of the forecasts are wrong in direction.[18] In the 5-percent-change category, 20 out of 55 forecasts or 36 percent are wrong in direction. In the 10- and 20-percent-change categories, the number of errors which are wrong in the direction is reduced to 25 and 20 percent, respectively. Evidently those persons engaged in outlook preparation are best at predicting major economic changes. This feature of the model also has certain policy implications; farmers might follow the current-year model when small changes are predicted, but shift to farm outlook reports when they indicate a considerable price change.

The parallel model poses this problem: Assuming that history repeats itself, a difficulty lies in discovering the parallel periods. In view of these circumstances, the use of a parallel model is justified only on the ground that farmers continue to believe that parallel periods exist and not on whether such periods actually do or do not exist.

CURRENT-YEAR, REVERSE-TREND, WEIGHTED-MOVING-AVERAGE, MOVING-AVERAGE AND TREND MODELS

The empirical errors of the remaining models may be compared with the theoretical errors in an

[18] It should be remembered that empirical evaluation of the outlook model requires subjective interpretation of outlook discussions. As an indication that other subjective interpretations, from a somewhat longer series of data, result in somewhat similar predictions of forecasting accuracy for the outlook model, see Heer and Baker, op.cit.

"ideal" series.[19] It should be kept in mind, however, that theoretical evaluation was in terms of particular autocorrelation conditions—conditions which may not be paralleled in the "middle ground" of the actual series. The "ideal" series or theoretical evaluations can only represent a rough approximation of the actual series.

The actual series are not autocorrelated with positive unity, nor do they necessarily have linear trend. In table 2 (column 2), the expected errors of b, 2b, (9/4)b and 3b for the current-year, the reverse-trend, the weighted-moving-average and the moving-average models rank first to fourth in magnitude, respectively, for the "ideal" series.

The application of these models to the actual price series gives a somewhat different ranking. In table 7, the errors of the same respective models, have sums of ranks of 9, 30.5, 19 and 30.5 and rank one, three and one-half, two, and three and one-half in magnitude. Of the four models, only the reverse-trend model is seriously out of line with the corresponding ranking in the "ideal" series. (For the empirical series, this model ranks three and one-half; in the "ideal" series it ranks second.) Otherwise, the empirical results largely confirm the theoretical ranking, allowance being made for the approximate nature of the comparison.

In the "ideal" series with a correlation coefficient of 1, the error and squared error are zero for the trend model (table 4). Conversely, in a random series, the squared error of this model, $6\sigma^2$ (table 6), is the largest of the trend models under consideration. In the empirical series, the error of this model is intermediate in value between the theoretical values: its sum of ranks of 29 compares favorably with the moving-average and reverse-trend models in which the sum of ranks for each is 30.5.

AVERAGE AND RANDOM MODELS

The average and random models, with a sum of ranks of 42, are the most inefficient models considered. Theoretically, the squared error of the random model (table 3) is $2\sigma^2$ or twice the magnitude of the squared error of the average model.[20] The empirical mean error of the random model for all prices except steers is better than that indicated by theoretical evaluation. One reason for its favorable performance is likely because of its ability to utilize the autocorrelation in the series. Another reason may be the chance selection of a favorable set of predicted prices.

Livestock Yield Models

The livestock yield data are taken from samples of farms which do not necessarily serve as a refined basis for inferring to the total population of Iowa farms. The sources used provided the only data extending over a long period of years. In applying expectation models, each model was applied to each individual farm, and then the means were computed for each system; the data of tables which follow are means for 20 farms for each product.

In yields, the outlook, parallel and weighted-moving-average models are not considered; conversely, the cumulative model which was not considered in prices is considered in yields. Also the trend-from-average and the reverse-trend-from-average models in yields replace the trend and the reverse-trend models in prices. The remaining models in livestock yields are the same as those used for prices. The yield series for eggs laid per hen and 4-percent milk produced per cow are similar to the price series in that they are characterized by trends. For eggs laid per hen, the trend is distinctly upward; for milk produced per cow, the trend is less distinct. The yield series of pigs weaned per litter[21] approximate randomness.[22]

The major portion of the trend in the egg series is associated with the increased egg production which arose from the incentives of wartime, together with the simultaneous advancement in poultry breeding and nutrition. Most of the trend in the dairy series likely arose from the incentives to production created by membership in the Dairy Herd Improvement Associations. A few instances of a downward trend are difficult to explain. One possibility is that a few farmers in the particular sample may have gone out of commercial milk production or made feeding adjustments because of lower milk/feed price ratios.

EGGS LAID PER HEN AND MILK PRODUCED PER COW

Table 11 (row 1) presents the mean errors of the various expectation models for the egg series. The moving-average, current-year, reverse-trend, average, cumulative, random and trend-from-average models with mean errors of 31, 32, 34, 36, 38, 46 and 47 eggs per hen rank first to seventh, respectively. The ranking of the models on the basis of the percentage of extreme errors (row 2) is identical with the ranking on the basis of the mean error. The ranking of the models on the basis of the coefficient of the range (row 3) is similar, but not identical, to the ranking of the models on the basis of the mean error and extreme error. The noticeable deviation occurs in the case of the current-year model. On the basis of the coefficient of the range, it ranks fifth; on the basis of the mean error and extreme error, it ranks second. A somewhat smaller deviation in ranking occurs in the cumulative-yield model: On the basis of the mean error and the extreme error, it ranks fifth; on the basis of the coefficient of the range, it ranks third.

Table 12 (row 1) compares the errors which

[19] An "ideal" series refers to the series with autocorrelations of positive unity in the previous section.

[20] In the empirical comparisons the mean error of the random model should be approximately 1.4 times the mean error of the average model.

[21] Hereafter the series of "eggs laid per hen," "4-percent milk produced per cow" and "pigs weaned per litter" will be referred to as the "egg," "milk" and "pig" series.

[22] A test for randomness of the pig series was made by the rank correlation method. At the 5-percent level of significance none of the series differed from randomness.

TABLE 11. COMPARISON OF THE ABSOLUTE MEAN ERROR, PERCENTAGE OF THE EXTREME ERROR AND THE COEFFICIENTS OF THE RANGE FOR THE VARIOUS EXPECTATION MODELS FOR EGGS LAID PER HEN.

	Moving average	Current year	Reverse trend from average	Average	Cumulative	Random	Trend from average
(1) Absolute mean error (eggs per hen)	31(1)‡	32(2)	34(3)	36(4)	38(5)	46(6)	47(7)
(2) Percent extreme errors*	25(1)	30(2)	31(3)	32(4)	36(5)	45(6)	49(7)
(3) Coefficient of range†	123(1)	152(5)	124(2)	144(4)	130(3)	163(6)	193(7)

* Errors which are 35 percent or more of the mean.
† Range expressed as a percent of the mean.
‡ Numbers in parentheses indicate the ranks of the adjacent measures of the error.

TABLE 12. COMPARISON OF THE ABSOLUTE MEAN ERROR, EXTREME ERRORS AND THE COEFFICIENTS OF THE RANGE FOR THE VARIOUS EXPECTATION MODELS FOR MILK PRODUCED PER COW.

	Current year	Moving average	Average	Cumulative	Reverse trend from average	Random	Trend from average
(1) Absolute mean error (pounds per cow)	810(1)†	830(2.5)	830(2.5)	910(4)	950(5)	1,130(6)	1,290(7)
(2) Percent extreme errors*	3.8(1)	4.1(2.5)	4.1(2.5)	5.6(4)	7.5(5)	14.8(6)	17.4(7)
(3) Coefficients of range	42.0(1)	43.2(2)	47.0(5)	46.4(4)	46.2(3)	62.4(6)	72.1(7)

* Errors which are 25 percent or more of the mean.
† Numbers in parentheses indicate the ranks of the adjacent measures of the error.

TABLE 13. COMPARISON OF THE ABSOLUTE MEAN ERROR, PERCENTAGE OF EXTREME ERRORS AND THE COEFFICIENTS OF THE RANGE FOR THE VARIOUS EXPECTATION MODELS FOR PIGS WEANED PER LITTER.

	Average	Moving average	Reverse trend from average	Cumulative	Current year	Random	Trend from average
(1) Absolute mean error (pigs per litter)	0.85(1)†	0.93(2)	0.95(3.5)	0.95(3.5)	1.10(5)	1.19(6)	1.69(7)
(2) Percent extreme error*	16.4(1)	19.1(2)	20.5(4)	19.3(3)	25.3(5)	27.0(6)	47.9(7)
(3) Coefficients of range	75(1)	77(2)	78(3.5)	78(3.5)	92(5)	93(6)	123(7)

* Errors which are 25 percent of the mean or more.
† Numbers in parentheses indicate the ranks of the adjacent measures of the error.

arise from the application of the various models to the milk series. The current-year, the average, the moving-average, the cumulative, the reverse-trend-from-average, the random and the trend-from-average models, with mean errors of 810, 830, 830, 910, 950, 1,130 and 1,290 pounds of milk per cow, rank first to seventh, respectively, in the magnitude of their mean errors. An identical ranking of the models is indicated on the basis of the percent of extreme errors (table 12, row 2). A somewhat different ranking of the models results from the use of the coefficient of the range (row 3).

The tendency of the current-year model to result in several extreme errors is indicated by the high values of the coefficient of the range in both the egg and pig series. These high values are possible because the errors in the current-year model depend on differences between consecutive observations.[23]

PIGS WEANED PER LITTER

Table 13 (row 1) presents a comparison of the errors of the various expectation models for pigs weaned per litter. The average, moving-average, reverse-trend, cumulative, current-year, random and trend-from-average models rank first to seventh, respectively, in the magnitude of their mean errors, allowance being made for the equivalence of the mean errors of the cumulative and reverse-trend models. The ranking of the models on the basis of the percent of extreme errors (row 2)

[23] When the year-to-year variability is large as in the egg series, the current-year model can also lead to a large mean error: this is indicated by the lesser mean error and the lesser percentage of extreme errors which are present in the moving-average model (table 11, rows 2 and 3) in which the predicted value is based on the average.

and the range of the error (row 3) gives almost identical ranking in the first and identical ranking in the second situation.

Since it is likely that the series approximates randomness, the empirical errors may be compared with the theoretical errors which arise from the application of these models to a random series (one with a zero or small correlation coefficient as in the one phase of the theoretical evaluation). In a random series, the squared errors of the average, moving-average, current-year, random and trend-from-average models are σ^2, $(6/5)\sigma^2$, $2\sigma^2$, $2\sigma^2$ and $(26/5)\sigma^2$ (table 6, column 2). These models rank first to fifth in the magnitude of their errors if an allowance is made for the equivalence of the squared errors of the moving-average, the reverse-trend-from-average and the current-year and random models. The empirical errors for these same models of 0.85, 0.93, 1.10, 1.19 and 1.69 pigs per litter also rank first to fifth in magnitude, respectively, (table 13, row 1). On the whole they indicate close approximation to the theoretical errors in a random series.

Crop Prices

Results for selected crop prices are shown in tables 14, 15 and 16. Yield models are not presented for crops since those examined are on a state-wide basis and have less variability than yields on an individual farm basis.[24] Crops for which price models are tested include those important in the Iowa economy. However, other important national crops also have been included. These allow comparison of efficiency of mechanical expectation models for crops which have different uses and price-making forces. Since the models used are the same as for livestock, the findings and interpretations are presented in summary form.

The ranking of mean errors for crop prices are quite similar to those for livestock. However, the weighted-moving-average falls in first place, followed by the outlook, current-year and parallel models. The random, average, trend and reverse-trend give the poorest productions. The weighted-moving-average model likely has greater accuracy for crops than for livestock for this reason: Aside from potatoes, crops do not go through the short production cycles which characterize most livestock production; the same over-all trends from movements in the general price level are present, however. Still, the outlook model, as interpreted subjectively by the persons making this study, ranks first or second for all crops but soybeans, where it ranks third. Again it is obvious that models such as the random, reverse-trend or long-term average involve consistently large errors and are least dependable for planning—even though some farmers indicate that they use these methods or the fact that long-term average prices are sometimes used in valuation of farmland.

PERCENTAGE OF EXTREME ERRORS FOR CROP PRICES

In crops, as in livestock, the farm manager may be interested in models which give low extreme errors. He might be willing to accept a model which averages only third or fourth in average error, if it does not result in extreme errors which cause him to go bankrupt.

When the percentage of extreme errors are examined in table 15, the ranking of sums is similar to that for the absolute errors in table 14; the first two models occupy exactly the same ranks. The weighted-moving-average, followed by outlook, would be most efficient from the standpoint of the criteria in both tables 14 and 15. However, the weighted-moving-average occupies first place more consistently for all crops under the second measure.

COEFFICIENT OF THE RANGE

The coefficient of the range is presented for crop prices in table 16. While the weighted-moving-average still occupies first place, the outlook and current-year models now rank below the parallel and 5-year-moving-average models; the first two give smaller absolute errors and fewer extreme errors, but they occasionally have one or two very large errors. The trend, random and average models still rank low in efficiency, just as the theoretical evaluation suggests that they should under the types of autocorrelation encountered in these time series data.

[24] For an analysis of the same models applied to selected experimental yields, see: A.H.F. El-Attar. Expectations for primary production. Unpublished Ph.D. thesis. Iowa State College Library, Ames, Iowa. 1952.

TABLE 14. COMPARISON OF ABSOLUTE MEAN ERRORS OF THE PRICE EXPECTATION MODELS FOR CROPS (CENTS).*

	Weighted moving average	Out-look	Current year	Parallel	Moving average	Trend	Reverse trend	Average	Random
Corn	14.9(1)†	25.3(2)	26.3(3)	26.5(4)	28.2(5)	32.0(7)	35.0(8)	30.7(6)	41.1(9)
Oats	6.3(1)	10.1(2)	11.1(3)	13.3(5)	12.9(4)	15.0(7)	14.1(6)	16.1(8)	17.5(9)
Hay	177(2)	160(1)	285(3)	291(4)	353(7)	390(8)	348(6)	373(5)	575(9)
Wheat	19.3(2)	17.5(1)	24.6(3)	26.1(4)	39.1(7)	31.5(5)	38.1(6)	45.8(9)	63.6(8)
Potatoes	23.4(2)	21.9(1)	27.4(5)	26.1(4)	27.5(3)	36.0(9)	34.4(8)	32.7(6)	33.1(7)
Flax	38.2(2)	37.7(1)	58.8(4)	57.4(3)	70.0(6)	60.7(5)	91.6(8)	91.0(7)	104.0(9)
Cotton	2.5(1)	3.6(2)	4.3(4)	3.8(3)	4.9(5)	5.5(6)	5.7(7)	7.4(8)	9.8(9)
Soybeans	23.4(1)	31.2(3)	30.5(2)	33.7(4)	48.1(7)	36.5(5)	47.3(6)	63.6(8)	90.2(9)
Tobacco	3.2(1)	5.4(2)	5.3(3)	5.3(4)	7.6(6)	7.9(7)	5.6(5)	11.9(9)	8.1(8)
Sum of ranks	13	15	30	35	50	59	60	66	77
Rank of sums	1	2	3	4	5	6	7	8	9

* All measurements in reference to bushels or pounds except for hay which is tons.
† Numbers in parentheses indicate the ranks of the adjacent measures of the error.

TABLE 15. COMPARISON OF PERCENTAGE OF EXTREME ERRORS IN PRICES FOR CROPS.*

	Weighted moving average	Out-look	Parallel	Current year	Reverse trend	Trend	Moving average	Random	Average
Corn	9(1)†	30(2)	31(3)	34(4)	44(6)	35(5)	45(7)	57(9)	50(8)
Oats	12(1)	29(2)	30(3)	31(4)	41(5)	44(6)	48(8)	46(7)	56(9)
Hay	0(1)	19(2)	36(7)	20(3)	35(6)	32(4.5)	32(4.5)	51(9)	42(8)
Wheat	9(1)	11(2)	25(4)	14(3)	38(6)	29(5)	48(7)	54(9)	50(8)
Potatoes	3(1)	33(2)	42(4)	37(3)	47(7)	56(8)	45(6)	43(5)	67(9)
Flax	12(1)	27(3)	17(2)	29(4)	47(7.5)	29(5)	35(6)	57(9)	47(7.5)
Cotton	9(1)	30(4)	19(2)	29(3)	50(7)	38(5)	39(6)	54(8)	61(9)
Soybeans	6(1)	18(2)	17(3)	20(4)	29(5.5)	29(5.5)	42(7.5)	54(9)	42(7.5)
Tobacco	0(1)	17(4)	16(3)	20(5)	6(2)	35(7)	36(8)	33(6)	63(9)
Sum of ranks	9	23	31	33	50	51	60	71	75
Rank of sums	1	2	3	4	5	6	7	8	9

* Figures refer to percentage of years in which realized price exceeded expectation by 30 percent or more.
† Numbers in parentheses indicate the ranks of the adjacent measures of the error.

TABLE 16. COMPARISON OF COEFFICIENT OF THE RANGE FOR CROP PRICES (PERCENT).

	Weighted moving average	Moving average	Parallel	Out-look	Current year	Trend	Average	Reverse trend	Random
Corn	123(1)*	244(2)	265(4)	286(6)	287(7)	347(3)	265(5)	312(8)	319(9)
Oats	79(1)	149(4)	130(3)	87(2)	150(5)	158(6)	171(8)	168(7)	202(9)
Hay	55(1)	113(3)	105(2)	135(6)	125(4)	152(7)	127(5)	159(8)	214(9)
Wheat	72(1)	142(3)	179(5)	87(2)	209(6)	232(8)	167(4)	212(7)	276(9)
Potatoes	66(1)	133(4)	117(2)	134(5)	149(6)	208(8)	128(3)	168(7)	224(9)
Flax	100(1)	137(4)	175(2)	192(5)	180(3)	198(6)	202(7)	250(8)	308(9)
Cotton	75(1)	150(5)	135(3)	127(2)	140(4)	155(6)	176(8)	162(7)	251(9)
Soybeans	64(1)	136(4)	159(6)	250(8)	114(2)	117(3)	165(7)	154(5)	285(9)
Tobacco	36(1)	72(4)	87(6)	71(3)	70(2)	109(8)	129(9)	81(5)	98(7)
Sum of ranks	9	33	33	39	39	55	56	62	79
Rank of sums	1	2.5	2.5	4.5	4.5	6	7	8	9

* Numbers in parentheses indicate the ranks of the adjacent measures of the error.

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