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**EMPIRICAL MEASURES OF RISK FOR SELECTED
FIELD AND HORTICULTURAL CROPS***

Gene A. Mathia

INTRODUCTION

Farm planning and enterprise selection have been studied by agricultural economists for many years. Detailed methodology has been developed to analyze the economic situation of farm firms and to project optimum combinations of resources used in producing selected enterprise activities. Programming techniques have been used extensively. They provided planning guidelines, with quality dependent on availability of data and completeness of the programming format.

One area of concern arising from many programming efforts is that resource utilization and, ultimately, enterprise selection do not accurately project the general patterns of production observed in a specific area. Furthermore, there is little observable indication that farmers tend to move toward the programming solution. This problem is apparent when more variable enterprises are programmed with traditionally less variable enterprises.¹ The more variable enterprises are frequently indicated to be profitable in the programming solutions, but farmers are not very interested in growing them.

A plausible explanation is that farmers are risk averters. Risks which farmers take into consideration are often not sufficiently incorporated into programming analyses. Nieuwoudt, Bullock and Mathia [4]

showed that risks are important in enterprise selection. The degree of risk aversion varies by geographic location. This study and others [5, 2] demonstrate that farmers do consider crop variability in selecting enterprise combinations.

Very little effort has been directed toward generating risk coefficients. The purpose of this paper is to provide estimates of risk coefficients associated with product prices and yields.² In addition, combined effects of price and yield variations are measured by analyzing variation in total sales per acre of selected enterprises.

PROCEDURE FOR RISK MEASUREMENT

Four sources of variation can be identified in an analysis of time series data. These sources are due to secular trends, cyclical movements, seasonal fluctuations and a component which remains after the first three have been taken into account. The first three are systematic. The last one is frequently referred to as the random component of total variation. Farmers must deal with both systematic and random variations in prices and yields of alternative crops. They frequently lack information about both sources of variation. The magnitude of the random component relative to total variation should be useful information in farm planning.³

Gene A. Mathia is Professor, Department of Economics and Business, North Carolina State University, Raleigh, North Carolina. The author is indebted to colleagues at North Carolina State for their helpful comments and suggestions.

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¹ High variance enterprises in this case refer to those that have relatively high variabilities in expected yields and/or prices. An approach for incorporating variability among enterprises in a programming format is demonstrated in Nieuwoudt, Bullock and Mathia [4] and others [2, 5]. A variation of the above approach, followed by the Southern Regional Vegetables Committee members (Sm-46) in accounting for the variabilities of field crops and vegetables, is to restrain the programming solution by the indirect cost of sales variability given the frequency distribution of occurrence of unfavorable seasons.

² Other sources of risks are input prices and availability, acres planted, the availability of product markets and transportation facilities and services. Measurement of these risks is beyond the scope of this analysis.

³ For example, an enterprise with a high ratio of random variation relative to total variation would likely be discounted more heavily by farmers than one with a lower ratio, if total variation were equal for both enterprises.

The objective of this study is to develop risk coefficients for both random and total variations for selected enterprises grown in North Carolina.⁴ The variate difference method is used to separate systematic and random elements of variation.⁵ This technique utilizes historical data series to calculate variance estimates. The fundamental assumption of the variate difference method is that time series of the relevant variables consists of two additive parts. The first is the mathematically expected or systematic component of the series, in which consecutive observations are positively correlated. The second is the random or unpredictable component, where consecutive items are assumed not to be autocorrelated or correlated with the systematic component [7].

The variate difference method separates random and systematic components by a finite differencing transformation process. Finite differencing eliminates the systematic component of variation, leaving the random component. The procedure involves calculating the variance of the original series as well as the series of successive finite differences. The difference between variances of successive series of finite differences is compared with its standard error.⁶

Total and random indexes of variability in prices, yields and total sales per acre of selected enterprises are empirically estimated by using the following two expressions.⁷

$$\text{Total variability index} = \frac{\sqrt{\text{variance}}}{(1971-1973) \text{ average}} \times 100 \quad (1)$$

$$\text{Random variability index} = \frac{\sqrt{\text{variance}^*}}{(1971-1973) \text{ average}} \times 100 \quad (2)$$

Variances were estimated from North Carolina data provided by the Statistical Reporting Services of the U.S. Department of Agriculture [8, 9, 10, 11, 12, 13, 14, 15]. The period 1939-1973 was selected for

study. These indexes expressed the standard deviation as a percentage of recent average levels (1971-1973) of price, yield and sales-per-acre data.⁸ The $\sqrt{\text{variance}^*}$ is an estimate of the standard deviation of the random portion of the time series data.

The theoretical setting for yield and price variations in farm planning relates to how farmers may view shifts in the cost and revenue functions, resulting from possible random and total variations in prices and yields—relative to some projected yield or price levels. Variations in yield would be expected to affect per-unit cost functions associated with growing a particular enterprise. For example, negative yield variations relative to some projected yield would be expected to bring about upward shifts in average and marginal costs of production. The opposite would be expected for positive yield variations.

Variations in price of the product would affect total and marginal revenue relationships for a product. Negative price variations relative to some projected price would be expected to bring about downward shifts in average and marginal revenue relationships. Again, the opposite would be expected for positive price variation.

SELECTION OF CROPS

Total and random variability indexes associated with prices, yields, and total sales per acre are estimated for the major field and horticultural crops grown in North Carolina. The field crops are corn, wheat, oats, barley, sorghum, soybeans, rye, peanuts, cotton and tobacco. These are grown under the assumption that marketing outlets are available.

Horticultural crops include spring, summer and fall snap beans and cabbage, summer sweet corn, spring cucumbers, late summer tomatoes, summer peppers, watermelons, strawberries, white potatoes and sweet potatoes. These are all grown for the fresh market, but available marketing outlets are much more limited for many of these products than for the

⁴ Another researchable objective would be the estimation of probabilities of occurrence associated with these annual fluctuations. However, this type of analysis is beyond the scope of the study.

⁵ See Tintner [6]. The method was used several years ago in a study by H. O. Carter and G. W. Dean [1]. Other methods for separating random variation from total variation are available, but it was not the purpose of this study to evaluate alternative methods.

⁶ The general rule set out by Tintner [6, p. 68] is that variance is reasonably stable when the standard error ratio for successive finite differences becomes numerically smaller than three and stays more or less so, i.e., the probability is fairly great that differencing has been carried out far enough to yield a valid variance estimate of the random component.

⁷ The "total variability index" in (1) differs from the usual "coefficient of variation" only in that the mean is defined as the average of 1971-1973 levels rather than the mean of the entire series. The "random variability index" of (2) differs from the coefficient of variation in that the variance refers to the random portion of variation in time series data as computed by the variate differences method and the mean is computed as the average of the 1971-73 levels.

⁸ Recent levels of prices, yields and total sales per acre (1971-1973) are considered to be more meaningful base periods for future farm planning and decision-making than the entire series means. The basis for this assumption is that farmers' recall of historical patterns in prices and yields is limited to rather recent events. This also tends to reduce the effects of long-term systematic trends in the data series.

field crops. Local markets in the farming area, including pick-your-own operations for horticultural crops, are very common. Indexes are also calculated for cucumbers and snap beans for the processing market. Most processing cucumbers and snap beans are produced under contracts which specify production practices and prices.

The following section will first present total and random yield variation estimates for the two types of

crops. Yield variations are followed by sections on prices and total sales.⁹

RISK COEFFICIENT ESTIMATES

Yield Variability

Variability indexes for selected field and horticultural crops are presented in Table 1. Random variability indexes for the field crops (upper part of

TABLE 1. YIELD VARIABILITY INDEXES FOR SELECTED FIELD AND HORTICULTURAL CROPS, NORTH CAROLINA, 1939-1973

Enterprise	Variability indexes	
	Total	Random
(percent)		
I. FIELD CROPS		
Rye	18.8	8.6
Oats	18.5	9.1
Sorghum ^a	30.9	9.8
Wheat	24.4	10.4
Barley	20.0	10.6
Soybeans	22.0	10.8
Corn	25.3	13.7
Tobacco	19.8	7.7
Peanuts	21.4	11.6
Cotton (lint)	18.7	18.7
II. HORTICULTURAL CROPS		
Sweet potatoes	22.6	6.2
White potatoes	21.0	7.5
Green peppers	10.3	10.3
Summer snap beans	15.2	10.5
Summer cabbage	16.1	10.9
Spring cucumbers	17.0	13.6
Watermelons ^b	40.0	15.5
Fall cabbage	17.2	17.2
Fall snap beans	26.0	20.5
Spring snap beans	17.8	17.8
Spring cabbage	18.7	18.7
Summer sweet corn ^b	42.4	25.7
Strawberries	34.5	34.5
Late summer tomatoes ^c	37.5	37.5
Cucumbers (proc.)	16.1	13.9
Snap beans (proc.)	20.4	20.4

^aCalculated for the period of 1945-1973. ^bCalculated for the period of 1949-1973. ^cCalculated for the period of 1957-1973.

⁹Variability indexes, mean values and standard deviations for yields, prices and sales are presented in more detail in [3].

Table 1) ranged from a low of about eight percent for tobacco to almost 19 percent for cotton lint. Indexes for all but cotton centered around ten. Random variation accounted for around 50 percent of total variation for several crops. Random and total variation indexes were equal for cotton lint, but only about one-third for sorghum and tobacco.

The yield variability indexes for horticultural crops are included in the lower part of Table 1. Indexes for yields of fresh market horticultural crops varied from a low of about six percent for sweet potatoes to a high of almost 38 percent for late summer tomatoes. Strawberries also exhibited a relatively high random variability index of about 35 percent, equal to the total variability index.

Yield variability indexes tended to be greater for the horticultural crops observed than the field crops. Other than sweet potatoes, peppers, early snap beans, early summer tomatoes and summer cabbage, horticultural crops would have higher random yield variabilities than field crops. These might be discounted more heavily than field crops by the risk averse farmer in developing his farm plan, since per-unit costs would likely fluctuate over a wider range than similar costs for field crops.

Random yield variability coefficients for processing cucumbers and snap beans were 14 and 21 percent, putting them in the median to high range in yield variability. There was little systematic variation noted for snap beans, in that the random component equalled the total variation index. Snap beans might be discounted more by the farmer because of the wider range of yield variation during any given production period, i.e., average and marginal costs could fluctuate more than similar costs for processing cucumbers.

Price Variability

Real farm prices data were used to estimate price variability. The index of prices for all crops (1967=100) were used for deflation.¹⁰

Price variability indexes measure only annual variations. It is possible that intra-seasonal variations in prices could be greater than annual variations. This is especially true for the horticultural crops. However, if we assume that farmers ship throughout the season, price misrepresentation may not be too great.

Another problem deals with possible effects on price variation of selected government programs and institutional regulations. For some of the field crops, government price and production programs may have played an important role in determining the sizes of

the total variability indexes. Tobacco, peanuts, cotton, wheat and most of the other field crops may have had some institutional price manipulation during some of the 1939-1973 period. Expected effects of either price supports or controls would be to reduce the magnitude of the price variability indexes. In North Carolina, peanut and tobacco programs would be expected to reduce price variability indexes for the two crops.

Indexes of prices for the field crops are presented in the upper part of Table 2. The random and total indexes for peanuts were both around ten percent. Random variation in peanut prices is almost equal to total variation. The same is true for tobacco, in which total and random variability indexes were both slightly greater than 14 percent. Oats and soybeans also are not subject to wide random fluctuations in annual real prices. Wheat, sorghum and rye are rather minor crops in North Carolina. They are subject to rather wide fluctuations in prices, but only sorghum has a great deal more total than random fluctuations. The total variation index for sorghum was 43 percent relative to a random variation index of 26 percent.

Variability indexes associated with prices of horticultural crops are presented in the lower part of Table 2. Prices might be expected to fluctuate more widely for horticultural crops than for field crops, because of their greater perishability and their relatively inelastic demands. U.S. government programs to stabilize prices during the 1939-73 period would not be expected to greatly affect any horticultural crops except, possibly, white potatoes. A marketing order for white potatoes was in effect for a couple of years, but it did not appear very effective in stabilizing prices.

The random variation indexes for real prices of fresh market crops ranged from a low of 11 percent for fall and summer snap beans to a high of 34 percent for fall cabbage. Total variations were the same as random variations for spring and fall cabbage, but more than double the random variation in the case of fall snap beans. White potatoes, green peppers, summer cabbage, spring cucumbers and strawberries also exhibited similar and relatively high random and total variation indexes of over 20 percent. The random and total indexes for sweet potatoes of 12 were relatively low for the horticultural crops. Late summer tomatoes exhibited a 15-percent random variation and an 18-percent total variation. However, yield variability indexes for late summer tomatoes were relatively high at almost 38 percent (see Table 1). The latter would tend to dampen any

¹⁰ Real prices were chosen because deflation would aid in eliminating one source of systematic variation in prices. However, deflation would not be expected to greatly affect the variability indexes.

TABLE 2. PRICE VARIABILITY INDEXES FOR SELECTED FIELD AND HORTICULTURAL CROPS, NORTH CAROLINA, 1939-1973

Enterprise	Variability index	
	Total	Random
	(percent)	
I. FIELD CROPS		
Soybeans	12.1	11.8
Oats	27.3	10.6
Barley	23.1	14.3
Wheat	30.7	23.6
Rye	30.3	21.0
Sorghum ^a	42.7	25.5
Corn	19.7	14.2
Tobacco	14.6	14.4
Peanuts	10.1	9.3
Cotton Lint	15.7	15.7
II. HORTICULTURAL CROPS		
Sweet potatoes	12.4	12.4
White potatoes	27.8	27.8
Green peppers	28.0	28.0
Summer snap beans	29.9	11.6
Summer cabbage	21.1	21.1
Spring cucumbers	24.0	24.0
Watermelons ^b	40.2	30.8
Fall cabbage	34.2	34.2
Fall snap beans	32.5	11.2
Spring snap beans	28.2	17.3
Spring cabbage	32.8	32.8
Summer sweet corn ^b	37.6	14.8
Strawberries	23.8	23.4
Late summer tomatoes ^c	18.3	15.4
Cucumbers (proc.)	22.8	15.3
Snap beans (proc.)	16.5	16.5

^aCalculated for the period of 1945-1973. ^bCalculated for the period of 1949-1973. ^cCalculated for the period of 1957-1973.

efforts to expand late summer tomato production.

For the processing vegetables, random indexes for both cucumbers and snap beans were relatively low, as expected when one considers that producer-processor contracts regarding prices are usually negotiated before the harvest season. Evidently, the contracts have been somewhat effective in reducing both random and total variations in prices, thus yield fairly predictable revenue levels. However, limited contract possibilities in North Carolina for these two

crops prevent farmers from responding to rather stable prices and revenues.

Sales Variability

Total and random variation indexes associated with gross sales-per-acre harvested in constant dollars (1967=100) for field and horticultural crops are presented in Table 3. These variability coefficients combine the variability effects of yields and real farm prices for crops grown in North Carolina. Since costs

TABLE 3. REAL SALES PER ACRE VARIABILITY INDEXES FOR SELECTED FIELD AND HORTICULTURAL CROPS, NORTH CAROLINA, 1939-1973

Enterprise	Variability coefficients	
	Total	Random
	(percent)	
I. FIELD CROPS		
Soybeans	21.0	10.6
Oats	13.6	11.1
Barley	16.3	15.2
Wheat	17.1	16.0
Rye	14.4	14.4
Sorghum ^a	31.6	15.0
Corn	21.6	13.4
Tobacco	25.5	12.7
Peanuts	24.3	10.7
Cotton lint	22.4	22.4
II. HORTICULTURAL CROPS		
Sweet potatoes	24.0	9.8
White potatoes	31.4	30.1
Green peppers	24.1	24.1
Summer snap beans	32.9	12.2
Summer cabbage	23.2	22.7
Spring cucumbers	24.7	20.4
Watermelons ^b	37.7	15.6
Fall cabbage	31.1	31.1
Fall snap beans	38.8	23.4
Spring snap beans	32.8	16.9
Spring cabbage	28.3	28.3
Summer sweet corn ^b	36.8	12.4
Strawberries	44.1	44.1
Late summer tomatoes ^c	44.4	35.8
Cucumbers (proc.)	28.5	17.7
Snap beans (proc.)	29.8	29.8

^aCalculated for the period of 1945-1973. ^bCalculated for the period of 1949-1973. ^cCalculated for the period of 1957-1973.

are not taken into account, the coefficients do not represent an index of relative profitability.

Field crops exhibited a random sales-per-acre variation ranging from a low of 11 percent for peanuts to a high of 22 percent for cotton lint. Soybeans fluctuated widely in total variation, but about the same as others in random terms. Total variation amounted to about the same as others in random terms. Total variation amounted to about 32 percent, with a 15-percent random variation for sorghum.

Random and total variation indexes of tobacco sales were 13 and 26 percent, respectively. Peanuts, another crop with government price regulations, fluctuated by 11 percent in random terms and about 25 percent in total terms. Real price variations (Table 2) were considerably lower for these two crops. Yield variations (Table 1) were relatively high.

Many of the crops exhibited similar sales, yield and price indexes. Variations in yields and prices tended to offset each other, yielding no observable multiple effects on sales variation.

Sales variability indexes for the horticultural crops are shown in the lower part of Table 3. Strawberries showed wide random and total variations in total sales per acre of about 44 percent. This is considerably more than either the yield or price index for strawberries. Sweet potatoes showed a relatively low random variation of ten percent but a total variation of 24 percent.

Variability indexes of sales per acre of most horticultural crops fell between the associated yield and price indexes. An exception was summer sweet corn, which exhibited a random yield index of 26 percent (Table 1), a price variation index of 18 (Table 2), but only a random sales index of 15 percent (Table 3). This was not true for total variation indexes of summer sweet corn.

SUMMARY

This analysis of random and total yield, price and sales-per-acre variabilities provides some indication of why farmers may not plant selected crops, even though budget data and programming analyses may indicate that they are profitable.

Level of price, yield or sales-per-acre indexes of certain crops reflect possible ranges of favorable and unfavorable changes during a particular crop year. Several crops, mainly horticultural ones, exhibited rather high random and/or total yield indexes. Watermelons, fall snap beans, spring and fall cabbage, summer sweet corn, strawberries and late summer tomatoes were examples of crops which farmers would tend to discount heavily, in that shifts in marginal costs of production could be relatively high. This would result from relatively large yield variability indexes.

Crops with larger random and/or total real price variability coefficients were barley, sorghum, rye and cotton lint in the field crops area and more than half the horticultural crops.

Total real sales-per-acre indexes indicated that price and yield variabilities tend to offset each other for most crops. Sales indexes were not much greater than either yield or price indexes taken independently. Processing snap beans, strawberries and late summer tomatoes are exceptions, in that sales indexes are considerably greater than either price or yield indexes.

Farmers are apparently aware of the variability associated with many of these crops. Introduction of these variability coefficients into farm programming analysis should provide more reliable estimates of farm plans. At least, it is easy to visualize why farm plans can shift when gross returns per acre are appropriately discounted by their sales-per-acre indexes, e.g. sales per acre of late summer tomatoes could be discounted by 45 percent while returns per acre of sweet potatoes might be discounted by only 24 percent. Farmers would not likely discount crops this heavily unless they were assigning a probability of one to the likelihood of the occurrence of a particularly unfavorable year. Failure to take into consideration the difference in variability of crops might lead to farm plans and enterprise combinations which differed considerably from actually observed patterns and from those developed from appropriately discounted revenue estimates.

Use of these indexes is limited by a lack of information about the probability of incurring the various levels of variation from the alternative sources. Further work is needed to establish the probability of occurrence of at least the extreme ranges of price, yield and sales-per-acre variations.

Further research is also suggested to determine how closely variability indexes calculated from aggregate state data may approximate the variation indexes of individual farmers. Effects of farmer's experience, size of farm holding, level of income, soil capacity, capital situation (ability to assume risk) of the individual farmer and many other factors on variability indexes are unresolved issues.

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