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Articles in the field of agricultural economics, suitable for publication in the journal, will be welcomed.

Articles should have a maximum length of 10 folio pages (including tables, graphs, etc.), typed in double spacing. Contributions, in the language preferred by the writer, should be submitted in triplicate to the Editor, c/o Department of Agricultural Economics and Marketing, Pretoria, and should reach him at least one month prior to date of publication.

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# Risk and uncertainty in agriculture

by

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The farmer has to make decisions in extremely unstable and insecure circumstances. This is an important difference between the farmer and the industrialist, who has some control over the conditions under which he produces. In an enterprise where it is possible to control production, as in the poultry and mushroom industries, soil is less important as a production factor. These industries can really be classified as factory enterprises.

When choosing an enterprise, a farmer should aim for the maximum expected profit. (Expected profit = expected profit - expected loss.) This concept may be illustrated with a simple example. Suppose a farmer's income per hectare from a certain crop is R100, his current costs R80, and his profit therefore R20 and suppose he has a crop failure once every five years and then makes nothing from the crop. His expected profit per hectare will be  $R20 \times \frac{4}{5} = R16$ , and his expected loss  $R80 \times \frac{1}{5} = R16$ . So the expected profit is nil, and in the longrun he makes no profit. The risk factor differs for various enterprises and should be taken into account when choosing an enterprise. The risk factor is therefore taken into account in simulation programming techniques.<sup>1)</sup> If the farmer had complete knowledge of future yields from products, and product and factor prices, he could complete his planning down to the finest details, but the elements of risk and uncertainty make planning difficult. Some farmers may prefer a lower expected income and more security. Another consideration is that the farmer's financial position determines whether he would be able to weather a setback during a particular year.

One may gain an idea of the degree of uncertainty and risk by analysing the variability of production figures, and product and factor prices. The aim of this article is to provide such an analysis on a macro-basis. The degree of variability of production for a certain crop differs from region to region, and a single overall figure may therefore be misleading. For example, maize production is more unstable in the North Western Cape or Northern Transvaal than in the Western Transvaal. One should also bear in mind that overall production may look fairly stable from year to year, but there may be

very good crops in some parts and crop failures in others.

## (a) PRODUCTION VARIATION

Table 1 shows the coefficients of variation for various crops, based on the period 1917/18 to 1968/69. The coefficient of variation is defined as the standard deviation provided by the arithmetic average for production. The production of most crops has increased during the past 50 years. This increase should be ascribed to technological factors rather than to production variation. Production variation may therefore be regarded as the deviation of the yields obtained from the expected yields. The coefficient of variation is therefore taken from the ratio  $Y/\bar{Y}$  where  $Y$  = yield obtained and  $\bar{Y}$  = estimated yield. Yields are estimated with time as the only variable in a rectilinear, logarithmic and quadratic function.

As far as the three summer crops go maize production is the most stable and groundnut production the least stable. The production of the winter cereals wheat and oats was also more stable than that of the summer cereals. This may be ascribed partly to the cultivation of winter crops in both summer and winter rainfall areas. This factor can have a stabilising effect on the total production of winter crops. The coefficient of variation for potatoes was 18 per cent, which is very good. This may be ascribed to the fact that potatoes are also grown under irrigation.

Heady referred to coefficients of variation for wheat ranging from 9 to 92 per cent in parts of the U.S.A.<sup>2)</sup> The coefficients for maize and oats, based on experimental data collected in Ames, Iowa, were 25 per cent. The coefficient for potatoes in Aroostok, Maine, was 19 per cent. Although these calculations are based on micro-data, they show a similarity to South African statistics.

Whereas the industrialist can control the production of secondary and tertiary goods, the farmer has little control over his primary production. To some extent the livestock industry is a stabilising element. Variability in production in agriculture is due chiefly to changes in weather conditions, although price instability is also partly to blame.

\* The writer is indebted to Mr J.A. Fletcher for the calculations contained in Tables 2, 5 and 7

1) Donaldson, C.F. and Webster, J.P.G. An operating procedure for simulation farm planning. Department of Economics, Wye College, Ashton, Kent, 1968

2) Heady, E.O. Economics of agricultural production and resource use. Prentice-Hall, Englewood Cliffs, 1960

TABLE 1 - Coefficients of production variation for various South African crops, 1917/18 - 1968/69

Maize	Grain sorghum	Groundnuts	Potatoes	Sugar-cane	Wheat	Oats
%						
28,4*	37,9*	99,3***	17,8*	23,6*	23,4*	20,5*
32,6**	74,0**	122,6**	51,5**	65,2**	53,0**	23,6**

\* Variation calculated from a quadratic function

\*\* Variation calculated from a straight line

\*\*\* Variation calculated from a logarithmic function

Table 2 further illustrates the uncertainty and complexity of farming production decisions. This information gives the farmer an idea of what to produce in order to reduce his risk. Livestock products are at the top of the list and show relatively small variations in comparison with field crops. Pastoral products show an average annual variation of 3,9 per cent and field crops an average of 16,8 per cent. The figures in Table 2 refer to the 40 years from 1918 to 1967, excluding the periods 1931 to 1934 and 1939 to 1945. In only seven of these 40 years has maize production shown deviations of between 0 and 5 per cent from the previous year's crop. In 11 of the 40 years the deviation was over 40 per cent. Wheat production showed deviations of 0 to 5 per cent in 7 years, but in 5 years the deviations were over 40 per cent. The average variation in maize production was 27,8 per cent, which was only a little more than the variation of 25,4 per cent for wheat production. In the case of horticultural production the variation was only 5,9 per cent. This may be ascribed to the perennial nature of the crops and the fact that they are grown under irrigation.

for the future on a fairly rational basis. It is doubtful whether it is possible for the farmer to plan rationally in the case of certain crops. Decisions on matters such as the amount that can be spent on fertiliser, etc., with additional expenses still being covered by additional income, are very difficult and depend partly on guesswork.

It appears from Table 3 that production in South Africa is far more subject to extreme variations than production in the U.S.A. The order of variability of the products shows the same pattern in both countries, with field crops low on the list. The fact that the variation is greater in South Africa can be ascribed partly to the larger area used for agriculture, with various types of climate, in the U.S.A. The area used for agriculture is 736 million hectares in the U.S.A., as against 90 million hectares in South Africa.<sup>3)</sup> The larger changes in production in South Africa may also be ascribed partly to the more changeable climate and the fact that crops are grown in marginal areas. The average percentage changes in the U.S.A. and South Africa are 13 and 25 per cent respectively in the case of wheat and

TABLE 2 - Year by year fluctuations in the production of certain commodities in South Africa, 1918 - 1967

Commodity	Fluctuations in total production as a percentage of the previous year's production											Average annual percentage change
	+41 and over	+26 to +40	+16 to +25	+11 to +15	+6 to +10	0 to +5	-6 to -10	-11 to -15	-16 to -25	-26 to -40	-41 and over	
	%											
Pastoral products <sup>a)</sup>	0	0	1	0	5	34	0	0	0	0	0	3,9
Poultry and poultry products	0	1	0	0	5	33	1	0	0	0	0	4,9
Sheep and goats slaughtered	0	0	1	2	9	23	5	0	0	0	0	5,1
Horticultural products <sup>b)</sup>	0	0	1	3	8	18	0	0	0	0	0	5,9
Fresh milk and dairy products	0	0	0	2	13	24	1	0	0	0	0	6,2
Cattle slaughtered	0	0	3	2	6	26	1	2	0	0	0	7,3
Wool	0	0	2	2	11	20	3	2	0	0	0	9,4
Pigs slaughtered	0	0	4	4	9	16	3	3	1	0	0	11,0
Field crops <sup>c)</sup>	2	2	3	3	9	11	2	4	3	1	0	16,8
Potatoes	3	2	6	5	2	9	5	2	5	1	0	19,1
Wheat	5	5	4	3	2	7	1	4	3	6	0	25,4
Maize <sup>d)</sup>	8	2	2	4	5	7	2	1	1	5	3	27,8

a) Includes slaughtering of cattle, pigs, sheep and goats, as well as wool, mohair, fresh milk, dairy products, poultry and poultry products

b) Fruit, vegetables and wine

c) Maize, wheat, other winter cereals, potatoes, tobacco, groundnuts, hay, sweet potatoes and grain sorghum

d) Production on White farms

In all the livestock enterprises the variation was between 0 and 10 per cent in 80 per cent of cases, which means that the farmer can plan

3) Food and Agriculture Organisation of the U.N.O. Production yearbook (Vol. 21) 1967, Rome, pp. 3-10

16 and 28 per cent in the case of maize. In the U.S.A. these crops are grown under more favourable conditions as the yields per hectare in the U.S.A. and South Africa show - maize 47,3 and 13,5 bags per hectare respectively and wheat 19,1 and 7,2 bags per hectare respectively. These figures are averages for the five-year period 1962 to 1966.<sup>5)</sup>

TABLE 3 - Comparison of the average annual percentage changes in production: South Africa and the U. S. A.

Commodity	South Africa 1918-1967	United States* of America, 1910-1949
	%	
Poultry and poultry products	4,9	4,1
Sheep slaughtered	5,1	6,7
Fresh milk and dairy products	6,2	2,1
Cattle slaughtered	7,3	4,6
Pigs slaughtered	11,0	8,6
Potatoes	19,1	14,5
Wheat	25,4	13,1
Maize	27,8	16,1

\* Heady, E. O. Economics of agricultural production and resource use, 1960, p. 462

According to Table 4 the annual production variation was smaller during the more recent period 1946 to 1967 than it was during the period 1918 to 1939. The years 1931 to 1934 were again excluded.

The greater stability in production during the more recent period is probably partly the result of greater price stability. From 1930 to 1935 the local prices of industrial milk products, maize, tobacco, slaughter stock and wheat were supported by the authorities.<sup>6)</sup>

One of the primary aims of the Marketing Act of 1937 was greater price stability. The average annual fluctuation in production in respect of maize during the period 1918 to 1939 was 38 per cent, as against 15 per cent for the period 1946 to 1967. The variation in wheat production dropped from 29 to 17 per cent. Modern cultural practices and the use of drought-resistant varieties also reduced the production risk considerably. The production variation for potatoes remained about the same.

Apparently the Marketing Act has achieved greater stability not only in respect of prices but also in respect of production. The reduction of the risk factor enables farmers to plan more rationally.

#### (b) PRICE VARIATION

The prices of certain products are available only for the period since 1936/37, so the degree to which prices have been stabilised was not investigated. In Table 5, however, the period has been arbitrarily subdivided into the periods 1936/37 to 1953/54 and 1953/54 to 1966/67. Prices have been far more stable during the more recent period, and this may be ascribed to abnormal conditions during the Second World War and to measures aimed at stabilising prices.

Potato prices were subject to great fluctuations, whereas the prices of field crops, maize and wheat, have been fairly stable during the past 13 years. Price fluctuations in the livestock enterprises were moderate, except in the case of wool, where there was great variation. For example, merino wool prices rose from 88c per kg in 1949/50 to 194c per kg in 1950/51 and then fell to 99c per kg the next year.

One danger of price stability that is often cited is that it makes income unstable.<sup>7)</sup> A certain

TABLE 4 - Average annual percentage variation in production for the periods 1918-1939 and 1946-1967<sup>4)</sup>

	Pastoral	Poultry and poultry products	Sheep and goats slaughtered	Horticulture	Fresh milk & dairy products	Cattle slaughtered	Wool	Pigs slaughtered	Field crops	Potatoes	Wheat	Maize
	%											
1918-1939	1,8	0,6	2,6	0,9	3,3	4,4	8,2	4,2	13,9	18,1	28,8	38,1
1946-1967	0,4	0,5	1,9	0,6	2,7	4,7	4,4	8,8	8,3	17,8	16,9	14,6

4) Average percentage changes were adjusted to a long-term growth rate that reflects expansion in production or technological improvement

5) Food and Agriculture Organisation of the U.N.O., *op. cit.*

6) Department of Agricultural Economics and Marketing: Report of the National Marketing Council on the control boards under the Marketing Act for the period 1950/51 to 1963/64. Government Printer 1965, p. 2

degree of price variation is therefore necessary, in accordance with the elasticity in the demand for the product. In the case of cereals the demand

7) Shepherd, G.S.: Agricultural price and income policy. The Iowa State University Press. Ames, Iowa, 1952

TABLE 5 - Average annual percentage change in product prices for the periods 1936/37-1953/54 and 1953/54-1966/67

	Poultry and poultry products	Sheep and goats slaughtered	Dairy products	Cattle slaughtered	Wool	Pigs slaughtered	Potatoes	Wheat	Maize
	%								
1936/37-1953/54	10,3	10,1	9,4	8,1	29,5	11,5	31,5	8,8	17,3
1953/54-1966/67	3,2	7,9	3,1	8,1	16,1	9,1	25,3	2,1	5,6
1936/37-1966/67	6,9	8,3	6,5	7,8	22,9	10,1	28,1	5,8	11,7

Source: Division of Agricultural Marketing Research

Supplementary data to the Abstract of Agricultural Statistics, South Africa, 1958, 1969

TABLE 6 - Average annual percentage differences in the gross values of certain agricultural products, 1947/48-1966/67

Poultry and poultry products	Sheep slaughtered	Cattle slaughtered	Pigs slaughtered	Dairy products and fresh milk	Wool	Potatoes	Wheat	Maize
%								
8,7	10,5	8,6	10,6	6,8	26,3	21,2	22,9	26,1

is so inelastic that the free market cannot be allowed to find its own level, because of the great fluctuations in both prices and incomes and the irrational source allocation that would arise. Both incomes and prices could be made reasonably stable through judicious price manipulation from year to year. This is more or less the policy followed by the Maize Board. One possibility is to force the demand elasticity<sup>8)</sup> between -1 and -00 i.e. somewhere between complete price stability and complete income stability.

#### (c) INCOME VARIATION

The wool, potato, wheat and maize industries were subject to great variations in incomes. Moreover, the changes in net income were even greater than the changes in gross income because of the stability of total production costs. Suppose for example the production cost is 50 per cent of the gross income. A drop of 25 per cent in the gross income will then mean a drop of 50 per cent in net income.

As one might expect, the variations in income in the pastoral industries are slight, except in the case of wool. This is because the changes in prices and production are moderate from year to year. In addition the elasticity in the local

demand for these products is about -1. These factors help to make the pastoral industries basically sound economically, and prevent surpluses on account of the fairly free market conditions that prevail.

#### (d) VARIATION IN FACTOR PRICES

If Tables 5 and 7 are compared, it is clear that the prices of production factors changes less from year to year than the prices of farm products. Because of the protracted production period production decisions are taken chiefly on the basis of expected prices. Because farmers are more certain of expected factor prices, one might expect a change in factor prices to affect decisions on production to a greater extent than a similar change in product prices.<sup>9)</sup>

When deciding on policy in respect of factor subsidies such as subsidies on fertiliser and support measures in respect of product prices, it is therefore important to know how farmers will react. In a managerial survey<sup>10)</sup> in the U.S.A.,

8) If the price of a product always remains the same, the demand for the product is completely elastic. The local demand for cereals is inelastic, but the demand elasticity as it affects the farmer may be increased through exports

9) The permanent component of the factor price is larger than that of the product price and it is assumed that the changeable component does not influence decisions. Friedman uses changeable and permanent components of income to explain the consumption function. Friedman, M. A theory of the consumption function. Princeton Univ. Press, 1957

10) Bayne, D.H. and Johnson G.L. A partial evaluation of static theory from results of the interstate managerial survey. Jour. Farm Econ. 40: 458-469. 1958

TABLE 7 - Average annual percentage change in factor prices for the periods 1939-1953 and 1954-1967

	Tractors	Imple- ments	Lorries	Spares	Building material	Stock feed	Fuel	Fertiliser
	%							
1939- 1953	4,8	5,3	7,9	7,9	8,2	5,2	7,3	10,5
1954- 1967	1,2	2,1	1,5	1,4	1,5	1,6	1,3	2,9

51 per cent of the farmers said that that a change in input prices affected production and 41 per cent reacted to changes in product prices. Other research workers<sup>11)</sup> have concluded that farmers showed the same reaction to changes in factor and product prices.

However, the stability of factor prices complicates the farm problem. When there are fluctuations in product prices and constant factor prices, the variation in net farm income is far greater than when factor prices rise and fall with product prices.

(e) COMPARISON OF THE COEFFICIENTS OF VARIATION OF INCOME, PRODUCTION AND PRICES FOR THE PERIOD 1947/48 TO 1967/68

According to Table 8 the uncertainty attached to income is greater than the uncertainty attached to production or prices. It is interesting that even in the livestock enterprises, where marketing conditions are fairly free, income variation is greater than production variation. Price therefore do not have much of a stabilising effect on income.

Table 8 also reflects the greater stability in the livestock enterprises, apart from the wool industry. Factor prices were more stable than producer prices. It also seems that the Maize Board and Wheat Board cannot be accused of causing instability in income through their price policy. The ratio of income variation to production variation was more favourable in these enterprises

than in other enterprises. In the potato industry production was less uncertain, but the income variation was considerably greater than in the maize and wheat industries.

Production variations in yields per hectare were also calculated in respect of the most important maize and wheat areas. The coefficients of variation for the three maize areas, the Transvaal Highveld, the Western Transvaal and the North-Western Free State, were 16,8, 25,1 and 32,0 per cent respectively. The variations for the two wheat areas, Swartland and Rûens, were 10,3 and 10,6 per cent respectively. It is interesting to note that the variations in yield per hectare are considerably smaller for wheat than for maize. Of the three maize areas the Transvaal Highveld had the smallest production variation.

According to Table 8 there were great variations in potato prices, which indicates that the demand for this product is inelastic. The income variation of the product was 33 per cent and the production variation only 13 per cent.

Price, production and income were most stable in the pastoral enterprises apart from wool. Wool production was relatively stable, but great variations in prices led to great income variations in this industry. As far as the pastoral industries go, the risk was the smallest in the case of dairy

TABLE 8 - Coefficients of variation in income, production and prices, expressed as percentages, 1947/48-1967/68 (Variation calculated from a quadratic function)

	Poultry & poul- try pro- ducts	Sheep slaugh- tered	Cattle slaugh- tered	Pigs- slaugh- tered	Dairy products & fresh milk	Wool	Potatoes	Wheat	Maize
	%								
Produc- tion	12,2	9,1	5,6	10,5	2,6	3,6	13,0	17,7	19,7
Gross in- come	13,7	14,8	8,2	11,3	5,1	31,2	32,9	18,5	21,2
Prices	3,4	10,9	9,3	6,9	6,4	27,8	23,6	5,5	7,9
	Tractors	Imple- ments	Lorries	Spares	Building material	Stockfeed	Fuel	Fertiliser	
	%								
Prices	5,6	5,2	5,4	6,0	5,4	4,4	4,8	6,8	

11) Heady, E.O. and Yeh, M.H. National and regional demand functions for fertiliser. Jour. Farm Econ. 41: 332-348. 1959

products and fresh milk. The risk attached to cattle slaughtered was less than the risk attached to sheep slaughtered.



## CONCLUSIONS

The choice of enterprise is affected by the risk attached to the production of, income from and prices for the various products. An attempt has been made in this article to compare a few of the important products from the point of view of risk.

The risk attached to production, prices and income was considerably higher in respect of field crops than in the livestock enterprises. Pastoral products show an average annual variation of 4 per cent and field crops an average variation of 17 per cent. The average annual variation in the maize crop was 28 per cent for the period 1918 to 1967 (the years 1931 to 1934 and 1939 to 1945 excluded). During these 40 years the total maize crop showed deviations of less than 5 per cent in comparison with the previous year's crop in 7 years, but in 11 years the deviations were over 40 per cent. In the livestock enterprises the production deviations were between 0 and 10 per cent in 80 per cent of the years, which makes it possible for these farmers to plan fairly rationally.

It has been found that the risk attached to gross income is greater than the risk attached to production. Under free market conditions, and with a demand elasticity of about one, the variation in income should be relatively small, however. The production variation in respect of the uncontrolled potato industry was less than in the

case of the wheat and maize industries, but the income variation for the potato industry was considerably greater than in the other two industries. A possible reason for this is that the stabilisation of the price of a product for which the demand is inelastic has a stabilising effect on income. In the major maize-producing areas the production variation, in yield per hectare, was also considerably greater than the variation in the most important wheat-producing parts.

The uncertainty attached to product prices was greater than that attached to factor prices, which may mean that farmers pay more attention in planning to a 5 per cent change in input prices, for example, than to a 5 per cent change in product prices.

Production uncertainty differs from area to area and from crop to crop within each area. It is hoped that this article will stimulate research on the risk attached to enterprises in individual areas. Farm planning is of little value if this risk is not taken into account. The importance of this factor in South Africa can be confirmed by examining the maize production per hectare in a major maize-producing area, the North-Western Free State, for the recent period 1947/48 to 1967/68. During the six years 1947/48 to 1952/53 production (kg per hectare) was as follows: 1 154, 434, 932, 1 123, 360 and 1 133. For the periods 1962/63 to 1964/65 and 1966/67 to 1967/68 the annual yields were 1 843, 964, 1 620, 2 372 and 762 kg per hectare respectively.