A STATISTICAL ANALYSIS
OF
SOURCES OF VARIANCE OF INCOME ON SHEEP FARMS
IN NEW ZEALAND

by

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SUMMARY

This paper uses a variance partitioning technique to attempt to measure the relative contribution of several factors to variation in sheep farm incomes. The analysis covers individual farms, individual regions, and the sheep industry as a whole.

Although wool price fluctuations were identified as the principal source of variation in gross farm incomes, the results of this study confirm that the relative importance of product prices as a source of income variation increases as the scene shifts from the individual farm to the regional level and then to the industry level. This suggests that price smoothing may be more effective in terms of macroeconomic policy than as a palliative for the problems of income variation for individual farms.

1. INTRODUCTION

Recent discussion of New Zealand agricultural policy has emphasised questions of stabilisation of income and, more particularly, of farm product prices. This emphasis, illustrated by Zanetti et al. (1975), has also appeared in reviews of Australian agricultural policy (Harris et al., 1974).

The Zanetti Report has given considerable attention to product price stabilisation. This reflects an assumption that a smoothing of product prices will produce greater stability in gross farm incomes. With more stable gross farm incomes it is expected that farm investment and development programmes can be effected with greater efficiency and that greater farm investment stability from year to year will promote greater stability in the non-farm agricultural service industries and the economy as a whole.

This paper reports measures of the relative contribution of several sources of farm income variance. These measures are reported for several data series. They provide an index of the potential contribution of price smoothing schemes, as compared to stabilisation techniques associated with output, such as quota systems or irrigation development schemes.

Stabilisation policies may be aimed at different levels. Considerations of equity or of farm operating efficiency may indicate a concern with stabilisation of the incomes of individual farms, while management of the national economy is more likely to be influenced by the variability of aggregate farm income. At an intermediate level, certain stabilisation measures may have different regional impacts. In the current study we have examined farm incomes at the level of (a) individual farms, (b) economic regions, and (c) a national aggregate for the sheep industry. Data for each of these levels of aggregation have been obtained from the sheep farm surveys of the New Zealand Meat and Wool Boards' Economic Service.

2. METHODOLOGY

The measurement of the relative contributions of different sources of income variability followed procedures outlined by Burt and Finley (1968). Similar procedures have recently been illustrated in applications by Houck (1973) and by Harris et al. (1974).

Burt and Finley (1968) have demonstrated that Taylor's series expansions of multiplicative or additive identity functions may be used to express the variance of the function in terms of the means, variances, and covariances of the components. These terms measure the direct contributions of specific variables, and the contributions of the interactions among specific variables, to the variance of the function. For example, an expansion of the function

$$y = x_1 x_2$$

where y = total production

x_1 = crop acerage

x_2 = crop yield

results in the variance of y being partitioned as:

$$\text{var}(y) = \bar{x}_2^{\,2} \text{var}(x_1) + \bar{x}_1^{\,2} \text{var}(x_2) + 2\bar{x}_1 \bar{x}_2 \text{cov}(x_1, x_2)$$

where var(y) indicates the variance of y

$\text{cov}(x_1, x_2)$ indicates the covariance of x_1 and x_2

$\bar{x}_1$ is the mean of x_1

$\bar{x}_2$ is the mean of x_2

The present study has required an extension of the method of Burt and Finley (1968), since identities of a more complex form were of interest. Functions (1) to (6) list the identies (or definitions of income) which were considered here:

$$G = PW.QW + SP + NS \quad (1)$$

$$N = PW.QW + SP + NS - E \quad (2)$$

$$G = PW.QW + SP + CP + OI \quad (3)$$

$$N = PW.QW + SP + CP + OI - E \quad (4)$$

$$G = PW.QW + PL.QL + RS + NS \quad (5)$$

$$N = PW.QW + PL.QL + RS + NS - E \quad (6)$$

where

G	=	gross income ($)
N	=	net income ($)
PW	=	wool price ($ per kg)
QW	=	weight of wool sold (kg)
SP	=	sheep trading profit ($)
CP	=	income from cattle ($)
OI	=	income other than from sheep, wool or cattle ($)
NS	=	income other than from sheep or wool ($) (NS=CP+OI)
PL	=	lamb price ($ per head)
QL	=	number of lambs sold
RS	=	residual sheep trading profit; that is, sheep trading profit net of income from lambs ($)
E	=	expenditure

The development of an appropriate expansion is demonstrated for function (5) in Appendix 1. The terms of this expansion are listed in Table 1, which also indicates the effect or contribution that is measured by each term. A general formula for expansions relevant to identities of the class considered here has been developed and is reported in Appendix 2.

Table 1 illustrates only direct and first order interaction effects. Higher order interactions also exist but have not been considered explicitly here because:

(i) Burt and Finley (1968) and (1970) suggest that these higher order terms may be quite small and relatively unimportant; however, both these authors and Goldberger (1970) note the possibility of exceptional cases.

(ii) The direct and first-order interaction terms alone were found to provide a close approximation to the observed variance of farm incomes for the particular series studied here.

(iii) Major interest in the present study lies in assessment of the relative, rather than the absolute, roles of the major factors in the variance of farm incomes.

TABLE 1

Direct and First Order Terms of Expansion for Illustrative Function*, G = PW.QW + PL.QL + RS + NS

Variance of Gross Income =	Interpretation of term
$(\overline{QW})^2$ .var(PW)	Direct effect of PW
$+(\overline{PW})^2$ .var(QW)	" " " QW
$+(\overline{QL})^2$ .var(PL)	" " " PL
$+(\overline{PL})^2$ .var(QL)	" " " QL
+ var(RS)	" " " RS
+ var(NS)	" " " NS
$+2\overline{QW}.\overline{PW}$.cov(PW,QW)	Interaction of PW and QW
$+2\overline{QW}.\overline{QL}$.cov(PW,PL)	" " PW " PL
$+2\overline{QW}.\overline{PL}$.cov(PW,QL)	" " PW " QL
$+2\overline{QW}$.cov(PW,RS)	" " PW " RS
$+2\overline{QW}$.cov(PW,NS)	" " PW " NS
$+2\overline{PW}.\overline{QL}$.cov(QW,PL)	" " QW " PL
$+2\overline{PW}.\overline{PL}$.cov(QW,QL)	" " QW " QL
$+2\overline{PW}$.cov(QW,RS)	" " QW " RS
$+2\overline{PW}$.cov(QW,NS)	" " QW " NS
$+2\overline{QL}.\overline{PL}$.cov(PL,QL)	" " PL " QL
$+2\overline{QL}$.cov(PL,RS)	" " PL " RS
$+2\overline{QL}$.cov(PL,NS)	" " PL " NS
$+2\overline{PL}$.cov(QL,RS)	" " QL " RS
$+2\overline{PL}$.cov(QL,NS)	" " QL " NS
+2cov(RS,NS)	" " RS " NS

* Superscript bars indicate arithmetic means

Following Burt and Finley (1968), the relative contributions to variance have been reported in this study in terms of the ratios of specific effects to the sum of the direct effects. Hence, the resulting direct effects are all positive and sum to 1.0. The indirect or interaction effects may be of either sign (and do not sum to any meaningful value). Negative terms may be interpreted as interactions that reduce the variance of income.

3. DATA

All data for this study were drawn from the results of sheep farm surveys reported by the New Zealand Meat and Wool Boards' Economic Service. Three basic sets of data were examined.

(i) Individual income series for a sample of sixteen farms, two from each of the farm-type regions defined for Economic Service surveys of sheep farms. Appendix 3 identifies the eight regions in which the various farms were located. The sample farms were drawn at random from the set of farms which had been included in these surveys throughout the period 1958/59 to 1972/73. Data were extracted without identification of the farms from the survey records. Data were available for G, PW, PL, QL, SP, NS, RS and E (as defined on page 3).

(ii) Average farm income series for each of the eight farm-type regions. Data available from published survey results included the variables G, PW, QW, SP, CP, OI and E. (for example, see Anon (1974)).

(iii) The all-classes series from the same source as (ii); this is a weighted average income series which may be regarded as a proxy measure for aggregate income for the sheep farming sector; data referred to the same variables as in (ii).

As the North Island farm-type regions display poor correspondence with geographic boundaries, the 'regional' results discussed below refer to differences among types of farms but provide only crude indications of differences among regions in the locational sense.

The dissection of sheep trading profit (SP) into lamb income (PL.QL) and residual sheep trading profit (RS) components in functions (5) and (6) was considered desirable as a basis for indication of the potential role of price smoothing schemes for lamb, but must be accepted as an approximation only because of borderline allocations of livestock between the 'lamb' and 'other sheep' groups. Limitations of the published data dictated adoption of this dissection only for data series for individual farms.

For each set of data, the effects of previous stabilisation measures were removed, in that income equalisation contributions or withdrawals and sheep retention payments were excluded from the income series.

Following Burt and Finley (1968), the analyses were carried out with 'trend-free' data. For each series, simple linear regressions of the form

$$Y = b_0 + b_1 T \qquad (T = 1, 2, \ldots 15, \quad T = 1 \text{ for } 1958/59)$$

were fitted for each variable. For those variables for which trend was significant, in the sense that (b_1) differed significantly from zero ($p < 0.05$), a 'trend-free' series was computed as:

$$Y_T^* = \bar{Y} + (Y_T - b_0 - b_1 T)$$

That is, deviations from the (significant, linear) trends were expressed as deviations from the fifteen year mean. Following this transformation for basic variables, other variables were recomputed, as:

$$SP = PL.QL + RS \text{ (for individual farm data)}$$
$$G = PW.QW + SP + NS$$
$$N = G - E$$

Where there was no significant trend for basic variables the raw data series were used. Removal of trend meant that the effects of higher order interactions became relatively insignificant; for example, for function (1) the direct and first-order interaction terms together explained 95 <u>per cent</u> of the variance of gross incomes for the eight regions when raw data were analysed, but for trend-free data over 99% of variance was explained.

4. RESULTS

Table 2 provides a summary of results for functions (1) and (2): these functions provided the most detailed dissection of income that was feasible for all three levels of data aggregation. Results for individual farms and individual regions for function (1) are given in Appendices 4 and 5. A number of points of interest emerge from Table 2.

(i) As expected, the mean value for the eight regions are in close agreement with the results for the 'all-classes' aggregate. However, the standard deviations of regional results are relatively large, indicating the likelihood of substantial differences in the regional impacts of stabilisation measures directed towards specific components of farm income. For example, wool prices made up 85% of direct effects for the South Island high country (region 1) but only 39% for mixed cropping farms (region 8) (Appendix 5). Similarly, the standard deviations for values for the individual-farm results are large : specific stabilisation measures are likely to vary significantly in their effectiveness in reducing the variance of incomes on individual farms.

(ii) The direct effects of variance of wool prices, together with the interaction of wool prices and sheep trading profits, dominate the effects of other components of gross income at both regional and industry level. Stabilisation of wool prices would therefore appear to be a major focus for measures concerned with macro-economic stability. However, wool price variability is of less significance when the incomes of individual farms are considered. Hence wool price smoothing schemes may be expected to be only partially effective as devices for stabilising the incomes of individual farms.

(iii) Variation in sheep trading profits (reflecting variation in such factors as turnoff of lambs and other sheep, and lamb prices) has a major effect of stability of incomes

TABLE 2

Relative Variance Components* of Income at Farm, Regional and National Level

Source of Variation	Function (1) G = PW.QW + SP + NS			Function (2) N = PW.QW + SP + NS - E		
	Sixteen Farms	Eight Regions	All Classes	Sixteen Farms	Eight Regions	All Classes
DIRECT EFFECTS						
PW	0.203 (.113)	0.614 (.130)	0.648	0.152 (.085)	0.270 (.114)	0.278
QW	0.023 (.013)	0.015 (.006)	0.006	0.017 (.010)	0.007 (.004)	0.003
SP	0.623 (.107)	0.240 (.100)	0.251	0.473 (.122)	0.099 (.040)	0.107
NS	0.151 (.084)	0.131 (.144)	0.095	0.116 (.073)	0.049 (.038)	0.041
E				0.241 (.142)	0.576 (.145)	0.571
INTERACTION EFFECTS						
PW and QW	-0.025 (.041)	-0.044 (.038)	-0.052	-0.019 (.030)	-0.022 (.022)	-0.022
PW and SP	0.384 (.242)	0.571 (.184)	0.636	0.306 (.210)	0.243 (.086)	0.273
PW and NS	0.080 (.174)	0.232 (.173)	0.316	0.069 (.142)	0.098 (.081)	0.135
PW and E				-0.157 (.122)	-0.326 (.132)	-0.321
QW and SP	0.021 (.069)	-0.004 (.026)	-0.018	0.016 (.051)	-0.002 (.010)	0.008
QW and NS	-0.005 (.026)	0.021 (.023)	0.005	-0.004 (.019)	0.010 (.013)	0.002
QW and E				-0.007 (.034)	-0.006 (.012)	0.002
SP and NS	0.286 (.270)	0.166 (.096)	0.235	0.236 (.240)	0.078 (.063)	0.101
SP and E				0.151 (.290)	-0.164 (.062)	-0.180
NS and E				-0.077 (.111)	-0.094 (.066)	-0.110

* For farms and for regional groupings, the figures tabulated are means, and standard deviations over the sixteen farms or eight regions are presented in parentheses. Individual farm/region

of individual farms, although this variation is 'averaged out' when aggregate income over a region over all New Zealand sheep farms is considered.

(iv) The effect of variation in wool output is negligible at all levels.

(v) Variation in non-sheep income is of minor importance for most farms and for most regions (except the mixed cropping region of the South Island). However, interactions between wool prices and non-sheep income, and between sheep trading profit and non-sheep income, are non-trivial and positive.

(vi) When the variance of net, rather than gross, incomes is considered, the relative magnitude of effects associated with different income sources is not affected : the implication that stabilisation of wool prices is likely to be the most effective measure of income stabilisation in the production and marketing area is supported. However, variation in expenditure is observed to be a dominant factor in the variation of net incomes for aggregates of farms, although this component is relatively less important on an individual farm basis.

(vii) Negative interactions[1] between expenditure and each of wool price, sheep trading profit, and non-sheep income for the aggregates, regional or industry, support the general observation that the farming sector tends to stabilise net incomes by reducing expenditure when incomes fall, and by increasing expenditure when incomes rise.

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1 Note that expenditure entered the calculations as a negative value, so that correlation between expenditure and a variable such as wool price result in negative interaction terms in Table 2.

Results for functions (3) and (4), the functions in which cattle income is treated as a separate component, are summarised in Table 3. Appendix 6 gives the results for individual regions for function (3).

Table 3 shows that at the industry level most of the variation attributed to non-sheep income is derived from cattle income. At the regional level, 'other income' appears to be as important as cattle income. However, inspection of the individual regions results in Appendix 6 shows that cattle income contributes far greater variation that 'other income' for seven of the eight regions. The mean result for the eight regions is dominated by the large effect of 'other income' in region 8 (mixed cropping and fattening country).

Although, as indicated earlier, the dissection of sheep trading profits into lamb and other income is subject to some qualification, results presented in Table 4 for functions (5) and (6) provide an indication of the importance of lamb prices and lamb turnoff as factors in the variability of farm incomes. Appendix 7 gives the relative income variance components for individual farms for function (5).

Table 4 suggests that lamb income and turnoff of lambs explain only a minor proportion of the variance of sheep trading profits, or of income on the individual farm, although there has been a relatively wide variation between farms in the importance of both these factors. A price smoothing scheme for lamb would not appear to be likely to have a major impact on the variability of farm incomes : the direct effect of lamb prices is small, and the relatively small interaction effect for lamb prices and residual sheep trading profits suggests that variations in lamb prices have only limited impact on the size of other components of sheep trading profits.

Lamb turnoff appears to be as significant a factor in income variability as is lamb price. The negative correlation between lamb turnoff and residual sheep trading profit, however, suggests the possibility that the turnoff effect may be a result of classification errors, or that variations in sales of lamb may be offset by sales of older sheep (hoggets).

TABLE 3

Relative Variance Components* of Income at Regional and Industry Level

Source of Variation	Function (3) G = PW.QW + SP + CP + OI: Eight Regions	Function (3): All Classes	Function (4) N = PW.QW + SP + CP + OI - E: Eight Regions	Function (4): All Classes
DIRECT EFFECTS				
PW	0.614 (0.136)	0.668	0.270 (0.115)	0.281
QW	0.015 (0.006)	0.006	0.007 (0.004)	0.003
SP	0.241 (0.102)	0.258	0.100 (0.040)	0.109
CP	0.067 (0.060)	0.060	0.035 (0.037)	0.025
OI	0.063 (0.170)	0.008	0.013 (0.032)	0.003
E			0.576 (0.142)	0.579
INTERACTION EFFECTS				
PW and QW	-0.044 (0.038)	-0.054	-0.022 (0.022)	-0.023
PW and SP	0.572 (0.188)	0.655	0.244 (0.087)	0.276
PW and CP	0.150 (0.166)	0.236	0.079 (0.091)	0.099
PW and OI	0.080 (0.172)	0.090	0.019 (0.033)	0.038
PW and E			-0.327 (0.132)	-0.325
QW and SP	-0.005 (0.026)	-0.018	-0.002 (0.010)	-0.008
QW and CP	0.019 (0.023)	0.006	0.010 (0.012)	0.002
QW and OI	0.003 (0.005)	-0.000	0.001 (0.002)	-0.000
QW and E			-0.006 (0.012)	0.002
SP and CP	0.146 (0.103)	0.197	0.072 (0.063)	0.083
SP and OI	0.021 (0.039)	0.046	0.006 (0.011)	0.019
SP and E			-0.165 (0.063)	-0.182
CP and OI	-0.002 (0.024)	0.030	0.001 (0.006)	0.013
CP and E			-0.074 (0.079)	-0.086
OI and E			-0.020 (0.037)	-0.025

*For regional groupings, the figures tabulated are means, with standard deviations of the eight regions presented in parentheses. Individual region results appear in Appendix 6.

TABLE 4

Relative Variance Components* for Sixteen Farms

Function (5) : G = PL.QL + PW.QW + RS + NS and Function (6) : N = PL.QL + PW.QW + RS + NS - E					
Source of Variation	Partitioning of: G	Partitioning of: N	Source of Variation	Partitioning of: G	Partitioning of: N
DIRECT EFFECTS			INTERACTION EFFECTS (contd)		
PL	0.057 (.059)	0.043 (.052)	QL and QW	0.006 (.030)	0.006 (.020)
QL	0.056 (.048)	0.036 (.031)	QL and RS	-0.074 (.096)	-0.044 (.070)
PW	0.352 (.153)	0.221 (.109)	QL and NS	-0.002 (.083)	-0.004 (.062)
QW	0.040 (.022)	0.026 (.015)	QL and E		0.009 (.045)
RS	0.205 (.166)	0.136 (.142)	PW and QW	-0.044 (.067)	-0.026 (.042)
NS	0.292 (.199)	0.189 (.147)	PW and RS	0.081 (.234)	0.052 (.151)
E		0.350 (.200)	PW and NS	0.185 (.298)	0.130 (.223)
INTERACTION EFFECTS					
PL and QL	-0.018 (.049)	-0.016 (.037)	PW and E		-0.221 (.148)
PL and PW	0.136 (.110)	0.092 (.093)	QW and RS	0.031 (.053)	0.019 (.035)
PL and QW	-0.016 (.027)	-0.010 (.021)	QW and NS	-0.012 (.046)	-0.005 (.029)
PL and RS	-0.012 (.048)	-0.011 (.035)	QW and E		-0.010 (.051)
PL and NS	0.047 (.096)	0.034 (.081)	RS and NS	0.037 (.193)	0.021 (.124)
PL and E		-0.056 (.037)	RS and E		-0.095 (.172)
QL and PW	-0.006 (.063)	-0.007 (.043)	NS and E		-0.123 (.154)

* The figures tabulated are means, with standard deviations over the sixteen farms presented in parentheses. Individual farm results appear in Appendix 7.

It may be noted that there are minor discrepancies between Table 2 and Table 4 for variables which are common to both tables (see, for example, wool price). Specification of the function with aggregated terms (such as SP) rather than detailed components (such as PL.QL + RS) means that some intercorrelations are ignored, and hence that some interaction effects may be wrongly attributed to other effects. In applications, such as that reported here, where complete disaggregation of the component variables is not feasible, estimates by the method of Burt and Finley (1968) provide only approximate measures of the relative effects of the variables of interest. However, the relative stability of estimates between Table 2 and Table 4 suggests that the degree of approximation is acceptable.

Table 5 presents the average proportion of gross income contributed by different income sources for each of the eight regions and for the 'all classes' group over the 15 years. Table 6 gives a summary of the relative contributions of direct effects to gross income variance for functions (1) and (3). It could be inferred from Tables 5 and 6 that although income from wool only accounts for 38% of gross income at the national level, wool price variation accounts for 65-67 percent of the variation in gross farm income derived from direct effects. Sheep trading profits, income from cattle, and 'other income' all appear to contribute relatively less to income variation than to gross farm income itself. Exceptions to this general observation are in evidence : in the Hill Country of the South Island (region 2), sheep trading profits have contributed disproportionately to income variability.

TABLE 5

Relative Importance of Sources of Gross Income by Region and for the Sheep Industry

Region	Average Proportion of Gross Income from each Income Source Over 15 Years, 1958/59 to 1972/73: Wool Income	Sheep Trading Profit	Cattle Trading Profit	Other Income
1	.698	.188	.096	.018
2	.447	.374	.153	.026
3	.414	.254	.321	.011
4	.424	.318	.246	.012
5	.371	.376	.211	.042
6	.389	.418	.080	.113
7	.366	.445	.059	.130
8	.207	.253	.024	.516
All Classes	.383	.348	.163	.106

TABLE 6

Relative Importance of Source of Gross Income Variation, by Region and for the Industry

Function (1): G = PW.QW + SP + NS				
Region	Source of Variation			
	PW	QW	SP	NS
1.	.849	.013	.105	.034
2	.534	.016	.398	.052
3	.676	.018	.183	.124
4	.612	.025	.211	.152
5	.585	.012	.238	.165
6	.632	.019	.329	.020
7	.636	.007	.316	.041
8	.387	.009	.144	.460
All Classes	.648	.006	.251	.095

Function (3): G = PW.QW + SP + CP + OI					
Region	Source of Variation				
	PW	QW	SP	CP	OI
1	.852	.013	.105	.029	.001
2	.534	.016	.397	.051	.002
3	.674	.018	.182	.126	.000
4	.620	.026	.214	.139	.001
5	.596	.012	.242	.148	.002
6	.631	.019	.329	.012	.010
7	.645	.007	.320	.022	.006
8	.365	.008	.135	.008	.483
All Classes	.668	.006	.258	.060	.008

5. DISCUSSION

The method adopted in this study provides measures of the historical relative importance of various factors as sources of variance in farm incomes. These analyses provide an index of areas in which specific stabilisation policies may be expected to have significant effects on income stability, but do not provide a basis for forecasts of the variance of income after implementation of stabilisation policies. Such forecasts would require projections of the post-stabilisation covariances amongst the components of income. Appropriate bases for such projections are not available.

The results suggest that variability of wool prices has been the dominant factor in the variance of gross farm incomes for 'average' farms at both regional and national levels. Farm expenditures have been of major significance in the variance of net incomes, but appear to have fluctuated with changes in wool price and in other components of gross income. 'Price smoothing' or other policy measures directed towards stabilisation of wool prices would, therefore, appear to offer a potentially major contribution towards stabilisation of aggregate gross or net incomes for the farm sector, and so to be a useful tool of national economic policy.

National aggregate effects do disguise marked variability in the situation of specific regions, and even greater variability among individual farms. The potential lack of effectiveness of product price smoothing schemes in stabilising incomes of individual farms has recently been demonstrated in Chudleigh, Blackie and Dent (1976). If stabilisation policy is concerned with income distribution, or with the planning environment and operational efficiency of individual farms, measures directed at stabilisation of wool prices will need to be supplemented by other tools of policy.

While fluctuations in wool production and lamb turnoff appear to be of only moderate significance, and while lamb price stabilisation does not appear likely to have a major potential in stabilising the incomes of individual farms, sheep trading profits from sources other than lamb sales represent an important source of income variation.

The data that have been examined do not permit testing of hypotheses concerning the identification of the real source of this variation[2]. Further, the relationship or interactions between wool prices and sheep trading profits are complex : Appendix 7 (interaction of PW and RS) illustrates that price smoothing for wool may be associated with stabilisation of sheep trading profits for some farms but with destabilisation for other farms. The significance of the sheep trading profit term, combined with the variability (between farms) of the sign and magnitude of interaction effects between PW and RS, suggest that measures such as price smoothing for wool and for lamb will not eliminate the potential role for stabilisation measures that are based on whole-farm gross or net incomes, rather than on product prices.

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[2] One possible explanation is the use of dry sheep flocks as relatively liquid assets which can be used as a buffer against the effects of climatic variability.

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APPENDIX 1: EXPANSION OF FUNCTION TO DERIVE MEASURES OF VARIANCE CONTRIBUTIONS OF SPECIFIC VARIABLES

$$G = PW.QW + PL.QL + RS + NS \qquad \text{(A-1)}$$

can be written as a Taylor's expansion

$$\begin{aligned} G = {} & \overline{PW}.\overline{QW} + (PW-\overline{PW})\ \overline{QW} + (QW-\overline{QW})\ \overline{PW} \\ & + (PW-\overline{PW})\ (QW-\overline{QW}) + \overline{PL}.\overline{QL} + (PL-\overline{PL})\ \overline{QL} \\ & + (QL-\overline{QL})\ \overline{PL} + (PL-\overline{PL})\ (QL-\overline{QL}) \\ & + \overline{RS} + (RS-\overline{RS}) \\ & + \overline{NS} + (NS-\overline{NS}) \end{aligned} \qquad \text{(A-2)}$$

Taking the expectation of both sides

$$\begin{aligned} E(G) = {} & \overline{PW}.\overline{QW} + \mathrm{cov}(PW,QW) + \overline{PL}\ \overline{QL} \\ & + \mathrm{cov}(PL,QL) + \overline{RS} + \overline{NS} \end{aligned} \qquad \text{(A-3)}$$

$$\text{Now } \mathrm{var}(G) = E\{G - E(G)\}^2 \qquad \text{(A-4)}$$

So from (A-2) and (A-3)

$$\begin{aligned} \mathrm{var}(G) = {} & E\{(PW-\overline{PW})\ (\overline{QW}) + (QW-\overline{QW})\ (\overline{PW}) \\ & + +(PW-\overline{PW})\ (QW-\overline{QW}) + (PL-\overline{PL})\ (\overline{QL}) \\ & +(QL-\overline{QL})\ (\overline{PL}) + (PL-\overline{PL})\ (QL-\overline{QL}) \\ & +(RS-\overline{RS}) + (NS-\overline{NS}) - \mathrm{cov}(PW,QW) \\ & -\mathrm{cov}(PL,QL)\}^2 \end{aligned} \qquad \text{(A-5)}$$

Expanding (A-5) and discarding high order terms, then

$$\begin{aligned} \mathrm{var}(G) = {} & (\overline{QW})^2\ \mathrm{var}(PW) + (\overline{PW})^2\ \mathrm{var}(QW) + (\overline{QL})^2\ \mathrm{var}(PL) \\ & + (\overline{PL})^2\ \mathrm{var}(QL) + \mathrm{var}(RS) + \mathrm{var}(NS) \\ & + 2\ \overline{PW}\ \overline{QW}\ \mathrm{cov}(PW,QW) + 2\ \overline{QW}\ \overline{QL}\ \mathrm{cov}(PW,PL) \end{aligned}$$

$$
\begin{aligned}
&+\ 2\ \overline{QW}\ \overline{PL}\ \mathrm{cov}(PW,QL) + 2\ \overline{QW}\ \mathrm{cov}(PW,RS) \\
&+\ 2\ \overline{QW}\ \mathrm{cov}(PW,NS) + 2\ \overline{PW}\ \overline{QL}\ \mathrm{cov}(QW,PL) \\
&+\ 2\ \overline{PW}\ \overline{PL}\ \mathrm{cov}(QW,QL) + 2\ \overline{PW}\ \mathrm{cov}(QW,RS) \\
&+\ 2\ \overline{PW}\ \mathrm{cov}(QW,NS) + 2\ \overline{QL}\ \overline{PL}\ \mathrm{cov}(PL,QL) \\
&+\ 2\ \overline{QL}\ \mathrm{cov}(PL,RS) + 2\ \overline{QL}\ \mathrm{cov}(PL,NS) \\
&+\ 2\ \overline{PL}\ \mathrm{cov}(QL,RS) + 2\ \overline{PL}\ \mathrm{cov}(QL,NS) \\
&+\ 2\ \mathrm{cov}(RS,NS) \qquad \text{(A-6)}
\end{aligned}
$$

APPENDIX 2: GENERAL FORM OF DIRECT AND FIRST-ORDER INTERACTION COMPONENTS FOR VARIANCE OF A FUNCTION CONSISTING OF LINEAR AND CROSS-PRODUCT TERMS

The identities used to define income in the present paper represent sums of linear terms (incomes from certain sources) and cross-product terms (price times quantity for certain sources of income). The general form of these identities is shown in function (A-7).

$$Y = X_1X_2 + X_3X_4 + \ldots + X_{h-1}X_h + X_{h+1} + \ldots + X_m \qquad \text{(A-7)}$$

We wish to develop the (m + m(m-1)/2) terms of a Taylor's series expansion of the variance of Y, where these terms represent the direct and first-order interaction effects of the (m) variables.

Higher order interactions here are assumed negligible.

Let (U_i) be the mean of X_i, and let (U_{i*}) be the mean of the coefficient (in function A-7) of X_i. Note that terms $X_{h+1}, \ldots X_m$ have implicit coefficients of (+1.0), hence $(U_{i*} = 1.0)$ for $(i>h)$.

The (m) terms which measure the direct contributions of variables $(X_1, \ldots X_m)$ to the variance of Y will take the form (A-8)

$$(U_{i*})^2 \cdot var(X_i) \qquad \text{(A-8)}$$

where $var(X_i)$ is the variance of X_i.

The remaining (m(m-1)/2) terms, representing the interactions of variables (X_i) and (X_j) in contributing to the variance of Y will have the form (A-9)

$$2(U_{i*}) \cdot (U_{j*}) \cdot cov(X_i, X_j) \qquad \text{(A-9)}$$

where $cov(X_i, X_j)$ is the covariance of X_i and X_j

The forms presented as (A-8) and (A-9) are readily applied in a computer programme if an array is included to identify the sequence number of the variable which is a coefficient (in (A-7)) of variable (X_i); these sequence numbers may appear as zero for cases where (X_i) in (A-7) is a simple linear term.

Illustration

Consider a study involving ten variables $(X_1, \ldots X_{10})$, and a case where we use the identity:

$$Y = X_1X_7 + X_3X_9 + X_2 + X_{10} \qquad \text{(A-10)}$$

Let a main programme set:

M = 10 = total number of variables

NV = 6 = number of variables in the identity of interest

KTERM = (1, 7, 3, 9, 2, 10) = vector of sequence numbers of variables in the identity

KOEFF = (7, 1, 9, 3, 0, 0) = vector of sequence numbers of the coefficients of variables which are identified in the vector KTERM

U = a vector of the means of the 10 variables

VCV = an (M x M) = (10 x 10) variance-covariance matrix for the 10 variables (X_i).

The Fortran language computer subroutine listed below may be used to compute the direct and first-order interaction effects.

```
      SUBROUTINE VAR(M,NV,KTERM,KOEFF,U,VCV)
      DIMENSION  KTERM(NV), KOEFF(NV), U(M), VCV(M,M)
C         COMPUTE DIRECT EFFECTS
      DO 1 J = 1, NV
      K = KTERM(J)
      I = KOEFF(J)
      EFFECT = VCV(K,K) * (U(I)**2)
    1 WRITE(6,2)  K, EFFECT
    2 FORMAT(1H, 'DIRECT EFFECT OF VARIABLE ', I3,' = ',G20.4)
C         COMPUTE INTERACTION EFFECTS (FIRST ORDER)
      DO 3 J = 1, NV
      K = KTERM(J)
      I = KOEFF(J)
      JJ = J + 1
      DO 4 JA = JJ, NV
      KA = KTERM(JA)
      IA = KOEFF(JA)
      EFFECT = VCV(K,KA)*2.0
      IF(I.NE.0) EFFECT = EFFECT * U(I)
      IF(IA.NE.0) EFFECT = EFFECT * U(IA)
    3 WRITE(6,4) K, KA, EFFECT
    4 FORMAT(1H , 'INTERACTION EFFECT FOR VARIABLES ', I3,
     1        ' AND ', I3, ' = ', G20.4)
      RETURN
      END
```

Slight variations of the above subroutine could be used to store, rather than print, results for subsequent editing or calculations.

APPENDIX 3: EIGHT REGIONS FROM WHICH FARMS SELECTED

Region No.	Region	Farm Numbers Referred to in Text
1	High Country, South Island	1, 2
2	Hill Country, South Island	3, 4
3	Hard Hill Country, North Island	5, 6
4	Hill Country, North Island	7, 8
5	Intensive Fattening, Country, North Island	9, 10
6	Fattening-Breeding Country, South Island	11, 12
7	Intensive Fattening, Country, South Island	13, 14
8	Mixed Cropping and Fattening Country, South Island	15, 16

APPENDIX 4: RELATIVE VARIANCE COMPONENTS OF INCOME FOR INDIVIDUAL FARMS

FUNCTION: G = PW.QW + SP + NS

Variance Component	Farm No.							
	1	2	3	4	5	6	7	8
PW	0.367	0.080	0.195	0.474	0.078	0.194	0.061	0.202
QW	0.046	0.005	0.047	0.032	0.009	0.010	0.016	0.040
SP	0.557	0.688	0.515	0.392	0.657	0.696	0.610	0.706
NS	0.030	0.228	0.242	0.102	0.256	0.100	0.314	0.052
PW . QW	0.100	0.002	-0.056	-0.070	-0.012	-0.025	0.004	0.001
PW . SP	0.776	-0.024	0.468	0.472	0.140	0.368	0.311	0.657
PW . NS	-0.072	-0.092	0.067	-0.355	0.224	0.186	0.214	0.056
QW . SP	0.240	0.019	-0.019	-0.060	0.001	-0.034	0.042	0.056
QW . NS	0.015	0.011	0.023	0.033	0.001	-0.012	0.025	0.011
SP . NS	-0.071	0.584	0.225	-0.217	0.428	0.266	0.823	0.230

Variance Component	Farm No.							
	9	10	11	12	13	14	15	16
PW	0.250	0.159	0.182	0.101	0.227	0.275	0.108	0.298
QW	0.016	0.018	0.009	0.018	0.017	0.024	0.036	0.025
SP	0.561	0.615	0.734	0.838	0.601	0.518	0.717	0.566
NS	0.174	0.208	0.075	0.043	0.155	0.183	0.140	0.111
PW . QW	-0.043	-0.036	-0.051	-0.035	-0.018	-0.060	-0.043	-0.058
PW . SP	0.561	0.512	-0.166	0.411	0.545	0.656	0.051	0.074
PW . NS	0.237	0.310	-0.027	0.017	0.104	0.335	0.040	0.036
QW . SP	-0.014	-0.034	0.016	-0.002	0.056	-0.019	0.061	0.029
QW . NS	-0.020	-0.037	-0.005	-0.007	-0.009	-0.010	-0.043	-0.063
SP . NS	0.472	0.645	0.103	0.196	0.181	0.448	0.232	0.038

APPENDIX 5: RELATIVE VARIANCE COMPONENTS OF FARM INCOME FOR REGIONS

FUNCTION: G = PW.QW + SP + NS

Variance Component	Region No. 1	2	3	4	5	6	7	8
PW	0.849	0.534	0.676	0.612	0.585	0.632	0.636	0.387
QW	0.013	0.016	0.018	0.025	0.012	0.019	0.007	0.009
SP	0.105	0.398	0.183	0.211	0.238	0.329	0.316	0.144
NS	0.034	0.052	0.124	0.152	0.165	0.020	0.041	0.460
PW . QW	-0.035	-0.020	-0.112	-0.064	-0.042	-0.071	-0.017	0.011
PW . SP	0.483	0.812	0.464	0.538	0.555	0.749	0.719	0.247
PW . NS	-0.028	0.062	0.289	0.268	0.407	0.105	0.277	0.477
QW . SP	0.014	0.021	-0.012	0.015	-0.014	-0.057	-0.015	0.013
QW . NS	0.034	0.035	0.027	0.062	0.014	-0.010	-0.002	0.012
SP . NS	0.037	0.136	0.213	0.259	0.313	0.062	0.199	0.111

APPENDIX 6: RELATIVE VARIANCE COMPONENTS OF FARM INCOMES FOR REGIONS

FUNCTION: G = PW.QW + SP + CP + OI

Variance Components	Region No.							
	1	2	3	4	5	6	7	8
PW	0.852	0.534	0.674	0.620	0.596	0.631	0.645	0.365
QW	0.013	0.016	0.018	0.026	0.012	0.019	0.007	0.008
SP	0.105	0.397	0.182	0.214	0.242	0.329	0.320	0.135
CP	0.029	0.051	0.126	0.139	0.148	0.012	0.022	0.008
OI	0.001	0.002	0.000	0.001	0.002	0.010	0.006	0.483
PW . QW	-0.035	-0.020	-0.112	-0.065	-0.043	-0.071	-0.017	0.011
PW . SP	0.485	0.811	0.463	0.545	0.565	0.748	0.729	0.233
PW . CP	-0.063	0.056	0.289	0.269	0.401	0.110	0.186	-0.048
PW . OI	0.035	0.006	-0.001	0.002	0.014	-0.005	0.095	0.497
QW . SP	0.014	0.021	-0.012	0.015	-0.014	-0.057	-0.015	0.012
QW . CP	0.032	0.033	0.028	0.058	0.011	-0.010	0.002	-0.002
QW . OI	0.002	0.001	-0.001	0.005	0.003	0.000	-0.004	0.014
SP . CP	0.022	0.124	0.213	0.252	0.299	0.102	0.142	0.015
SP . OI	0.015	0.011	-0.001	0.011	0.020	-0.040	0.060	0.089
CP . OI	0.003	-0.001	-0.002	0.014	0.018	-0.001	0.014	-0.058

APPENDIX 7: RELATIVE VARIANCE COMPONENTS OF INCOME FOR INDIVIDUAL FARMS

FUNCTION; G = PL.QL + PW.QW + NS + RS

Variance Component	Farm No.															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
PL	0.000	0.000	0.067	0.086	0.007	0.033	0.006	0.014	0.106	0.104	0.035	0.024	0.221	0.108	0.073	0.024
QL	0.000	0.000	0.085	0.064	0.013	0.061	0.045	0.017	0.054	0.041	0.075	0.054	0.058	0.079	0.204	0.038
PW	0.567	0.179	0.261	0.410	0.201	0.481	0.138	0.479	0.447	0.327	0.484	0.139	0.334	0.452	0.170	0.562
QW	0.072	0.011	0.063	0.028	0.023	0.025	0.036	0.095	0.028	0.037	0.024	0.025	0.025	0.040	0.056	0.047
NS	0.046	0.512	0.324	0.088	0.662	0.248	0.711	0.124	0.310	0.430	0.198	0.059	0.228	0.300	0.220	0.209
RS	0.315	0.297	0.201	0.324	0.095	0.152	0.065	0.272	0.055	0.062	0.184	0.699	0.134	0.022	0.276	0.121
PL . QL	0.000	0.001	0.048	-0.039	-0.000	0.018	-0.005	0.028	-0.091	-0.055	0.022	0.027	-0.039	-0.112	-0.095	0.007
PL . PW	0.000	0.009	0.186	0.250	0.043	0.155	0.025	0.085	0.139	0.198	0.193	-0.004	0.365	0.289	0.084	0.164
PL . QW	0.000	0.000	-0.046	-0.005	0.001	-0.017	0.003	0.028	-0.074	-0.046	-0.041	-0.021	0.021	-0.022	-0.006	-0.028
PL . NS	0.000	-0.004	-0.003	-0.107	0.068	0.114	0.053	0.011	0.108	0.247	0.030	-0.005	-0.040	0.257	0.006	0.014
PL . RS	0.000	0.001	0.023	0.013	0.034	0.043	0.021	-0.026	-0.057	0.022	-0.080	-0.063	-0.118	-0.052	0.029	0.023
QL . PW	0.000	0.012	0.051	-0.069	0.004	-0.044	0.079	0.125	-0.067	-0.044	-0.032	-0.011	-0.051	-0.081	-0.056	0.095
QL . QW	0.000	0.001	0.076	0.028	-0.013	-0.003	-0.036	0.026	0.040	0.012	-0.019	-0.030	-0.012	0.015	0.057	-0.010
QL . NS	0.000	-0.007	-0.045	0.064	0.038	0.102	0.191	0.007	0.006	-0.060	0.031	-0.003	-0.046	-0.184	-0.059	-0.068
QL . RS	0.000	0.002	-0.076	-0.193	-0.022	-0.134	-0.061	-0.040	0.019	0.028	-0.140	-0.252	-0.020	0.045	-0.252	-0.082
PW . QW	0.155	0.005	-0.075	-0.060	-0.032	-0.063	0.008	0.003	-0.078	-0.075	-0.136	-0.048	-0.027	-0.098	-0.068	-0.109
PW . NS	-0.112	-0.206	0.089	-0.307	0.578	0.462	0.485	0.132	0.424	0.639	-0.073	0.023	0.153	0.549	0.063	0.068
PW . RS	0.755	0.015	0.100	0.222	0.058	0.209	0.044	-0.000	-0.048	-0.087	-0.295	0.340	-0.053	-0.130	0.049	0.123
QW . NS	0.023	0.026	0.031	0.029	0.002	-0.030	0.056	0.025	-0.036	-0.076	-0.012	-0.010	-0.013	-0.016	-0.068	-0.118
QW . RS	0.162	0.018	-0.019	-0.069	0.007	0.029	0.045	0.036	0.030	-0.027	0.098	0.056	0.075	0.020	0.012	0.029
NS . RS	-0.052	0.588	0.372	-0.208	0.026	-0.048	0.097	-0.074	0.008	-0.047	0.004	0.097	-0.035	-0.127	0.026	-0.034

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