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THE CONSEQUENCES OF SMALL RICE FARM MECHANIZATION PROJECT

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THE DECOMPOSITION OF DIFFERENCES IN OUTPUT BETWEEN TWO GROUPS OF FARMS

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Introduction

Decomposition analysis is a technique for quantitatively partitioning an aggregate into its component elements. An example is the partitioning of a change in output into the effects of changes in yield, cropping intensity and area. Use of inputs, such as labor, may be decomposed in a similar manner. Such a partitioning may be useful since it reduces a complex of changes to an apparently simple basis and may also give guidance as to the relative importance of the factors underlying the observed change.

Given such potential, it is not surprising to find that the concept of decomposition has been applied to a wide variety of problems. Among the early studies, Minhas and Vaidyanatham (1965) have used decomposition to evaluate the various causes of yield increases which accompanied the spread of irrigation and adoption of better crop rotations. The causes studied included the extension of cultivation to new areas, due to reclamation of virgin land and deforestation, and increases in cropping intensity. Solow (1957) used decomposition to investigate the effects of technological change on output growth and Sondhi and Singh (1975) applied it to comparative analysis of the pre-Green Revolution periods in India. The underlying concepts can also be observed in more diverse areas. For example, Theil (1961) has shown how his U statistic, a statistic designed to compare predictions of change from an econometric model with those actually observed in the economy, can be decomposed into three components to assist in identification of the causes of inaccurate projections.

More recent studies have used decomposition to analyze the differences in output between farms using traditional and modern technologies (Bisaliah, 1977) between small and large farms (Binswanger, 1978; Rathore, 1979) and growth due to changes in relative prices and yields of different crops (Sagar, 1977). It was also used to quantify employment effects of technical change (Krishna, 1974) and to measure total change in employment between new and old technology farms (Bisaliah, 1978).

Decomposition analysis can be used to evaluate the effects of mechanization on production (Binswanger, 1978) and employment (Krishna, 1974). The technique is designed to allocate the observed output and employment differences between farms "before and after" or "with and without" certain machines into cropping intensity, yield, cropping pattern and price effects. This partitioning amplifies the relative importance of the component effects and may be used as a guide to the

identification of the potentially most fruitful areas for further research. However the technique does not imply causality. This must still be specified by the researcher.

As with any other technique, acceptability of the decomposition methodology depends largely on the interpretation that one can place on the results. If empirical application frequently suggests an effect then we should be seriously concerned about the technique. Secondly the technique should be capable of producing consistent results, irrespective of the manner in which the data are analyzed. This property will be examined in greater detail when we develop a graphical representation of decomposition. However at this point it should be sufficient to note that little confidence can be placed in the results of a decomposition analysis, if vastly different results can be obtained by simple switches in the ordering of the data.

Derivation of the Decomposition Equations

The general framework of the decomposition models will be formulated as a synthesis of the approach of Raj Krishna (1974) and Hans Binswanger (1978). It starts with the output identity:

$$Q = C \sum_i A_i Y_i \qquad (1)$$

where:

Q = value of output per hectare of operated area;

C = cropping intensity defined as the gross cropped area divided by operated area;

A_i = proportion of the gross cropped area under crop i, the sum of which defined the cropping pattern (and hence the area effect); and

Y_i = yield of crop i in money terms.

Output from two groups of farms, A and B, denoted as Q^1 and Q^0 respectively may be compared as follows. The difference in output of the two groups is given by:

$$Q^1 - Q^0 = C^1 \sum_i A_i^1 Y_i^1 - C^0 \sum_i A_i^0 Y_i^0 \qquad (2)$$

The derivation of the general formula for the decomposition model employs a commonly-used mathematical device, i.e. the addition and subtraction of the same terms.

Adding and subtracting $C^0 \sum_i A_i^1 Y_i^1$

$$Q^1 - Q^0 = C^1 \sum_i A_i^1 Y_i^1 - C^0 \sum_i A_i^0 Y_i^0 + C^0 \sum_i A_i^1 Y_i^1 - C^0 \sum_i A_i^1 Y_i^1 \tag{3}$$

and collecting common terms results in:

$$Q^1 - Q^0 = (C^1 - C^0) \sum_i A_i^1 Y_i^1 + C^0 (\sum_i A_i^1 Y_i^1 - \sum_i A_i^0 Y_i^0) \tag{4}$$

In order to simplify the notation, differences in output (Q), yield (Y), area (A), and cropping intensity (C) will be now written in terms of delta (Δ) such that,

$$\Delta Q = Q^1 - Q^0$$

$$\Delta Y = Y^1 - Y^0$$

$$\Delta A = A^1 - A^0$$

and $$\Delta C = C^1 - C^0$$

Expanding the second expression in the right hand side of (3), using Identity I from Appendix A, will lead to:

$$\Delta Q = \Delta C \sum_i A_i^1 Y_i^1 + C^0 (\sum_i \Delta A_i Y_i^1 + \sum_i A_i^0 \Delta Y_i)$$

$$\Delta Q = \underbrace{\Delta C \sum_i A_i^1 Y_i^1}_{\text{cropping intensity effect}} + \underbrace{C^0 \sum_i \Delta A_i Y_i^1}_{\text{area effect}} + \underbrace{C^0 \sum_i A_i^0 \Delta Y_i}_{\text{overall yield effect}} \tag{5}$$

This is the formula for decomposition without a residual[1/] as used by Binswanger (1979) to decompose the output differences between large and small farms.

So far it has been assumed that all farms face identical prices. If not, the price effect might also be important. With yield equation (5) expressed in value terms, and defined as price (P) times quantity (X), the overall yield effect may be rewritten as:

$$C^0 \sum_i A_i^0 \Delta Y_i = C^0 \sum_i A_i^0 (X_i^1 P_i^1 - X_i^0 P_i^0) \qquad (6)$$

where X_i is the physical yield of crop i; and

P_i is the price of crop i.

Repeating the addition and subtraction procedure used earlier, we obtain:

$$C^0 \sum_i A_i^0 \Delta Y_i = C^0 \sum_i A_i^0 (X_i^1 P_i^1 - X_i^0 P_i^0 + X_i^1 P_i^0 - X_i^1 P_i^0) \qquad (7)$$

which may be grouped and simplified to:

$$C^0 \sum_i A^0 \Delta Y_i = C^0 \sum_i A_i^0 X_i^1 \Delta P_i + C^0 \sum_i A_i^0 P_i^0 \Delta X_i \qquad (8)$$

[1/] Binswanger (1978; pp. 87-89) describes a calculus based technique for decomposition which includes a term R. This he ascribes to a "residual" or "interaction" effect and notes to be generally due to approximation errors. Binswanger (1979) has presented an alternative formulation, based on the output identity used here, to produce a decomposition without residual The residual or interaction term referred to by Binswanger is different to the interaction term described later in this paper. As shown in the derivation and graphical explanation our interaction terms are embedded in Binswanger's area and yield effects.

From equation (5) the decomposition model, including the price variable, may now be written as:

$$\Delta Q = \Delta C \sum_i A_i^1 P_i^1 X_i^1 + C^0 \sum_i \Delta A_i P_i^1 X_i^1 + C^0 \sum_i A_i^0 X_i^1 \Delta P_i + C^0 \sum_i A_i^0 P_i^0 \Delta X_i \quad (9)$$

cropping intensity effect	area effect	price effect	pure yield effect

At this stage we introduce the concept of interaction terms into the decomposition model. These interaction terms reflect the changes in output occurrring because of simultaneous changes in two or more of the main effects and they are dependent on the magnitude of changes in both or more of these effects. Interaction terms, which are explained more fully by the graphical approach in the next section, are implicit in the second, third and fourth expressions on the right hand side of (9). We now proceed to expand the model to include explicitly these interaction terms. Using Identity II from Appendix A to combine the area, price and pure yield effects, equation (9) can be rewritten as:

$$\Delta Q = \Delta C \sum_i A_i^1 P_i^1 X_i^1 + C^0 \left(\sum_i A_i^1 P_i^1 X_i^1 - \sum_i A_i^0 P_i^0 X_i^0 \right) \quad (10)$$

Adding and subtracting $\Delta C \sum A_i^0 P_i^0 X_i^0$ yields:

$$\Delta Q = \Delta C \sum_i A_i^1 P_i^1 X_i^1 + \Delta C \sum_i A_i^0 P_i^0 X_i^0 - \Delta C \sum_i A_i^0 P_i^0 X_i^0 + C^0 \left(\sum_i A_i^1 P_i^1 X_i^1 - \sum_i A_i^0 P_i^0 X_i^0 \right) \quad (11)$$

$$\Delta Q = \Delta C \sum_i A_i^0 P_i^0 X_i^0 + \Delta C \left(\sum_i A_i^1 P_i^1 X_i^1 - \sum_i A_i^0 P_i^0 X_i^0 \right) + C^0 \left(\sum_i A_i^1 P_i^1 X_i^1 - \sum_i A_i^0 P_i^0 X_i^0 \right) \quad (12$$

Using Identity III from Appendix A, to expand the parenthesized expressions leads to the final decomposition equation.

$$\begin{aligned} \Delta Q = {} & \Delta C \sum_i A_i^0 P_i^0 X_i^0 + \Delta C \{ \sum_i A_i^0 P_i^0 \Delta X_i + \sum_i \Delta A_i P_i^0 \Delta X_i + \sum_i \Delta A_i P_i^0 X_i^0 + \sum_i \Delta A_i \Delta P_i \Delta X_i \\ & + \sum_i \Delta A_i \Delta P_i X_i^0 + \sum_i A_i^0 \Delta P_i \Delta X_i + \sum_i A_i^0 \Delta P_i X_i^0 \} + C^0 \{ \sum_i A_i^0 P_i^0 \Delta X_i \\ & + \sum_i \Delta A_i P_i^0 \Delta X_i + \sum_i \Delta A_i P_i^0 X_i^0 + \sum_i \Delta A_i \Delta P_i \Delta X_i + \sum_i \Delta A_i \Delta P_i X_i^0 \\ & + \sum_i A_i^0 \Delta P_i \Delta X_i + \sum_i A_i^0 \Delta P_i X_i^0 \} \end{aligned} \quad (13)$$

Rearranging the terms:

$$\Delta Q = \Delta C \Sigma A_i^0 P_i^0 X_i^0 \quad - \text{ cropping intensity effect}$$

$$+ C^0 \Sigma A_i^0 P_i^0 \Delta X_i \quad - \text{ pure yield effect}$$

$$+ C^0 \Sigma \Delta A_i P_i^0 X_i^0 \quad - \text{ cropping pattern effect}$$

$$+ C^0 \Sigma A_i^0 \Delta P_i X_i^0 \quad - \text{ price effect}$$

$$\left.\begin{array}{l} + \Delta C \Sigma A_i^0 P_i^0 \Delta X_i \\ + \Delta C \Sigma \Delta A_i P_i^0 X_i^0 \\ + \Delta C \Sigma \Delta A_i^0 \Delta P_i X_i^0 \\ + C^0 \Sigma \Delta A_i \Delta P_i X_i^0 \\ + C^0 \Sigma \Delta A_i P_i^0 \Delta X_i \\ + C^0 \Sigma A_i^0 \Delta P_i \Delta X_i \end{array}\right\} \text{ first-order interaction terms}$$

$$\left.\begin{array}{l} + \Delta C \Sigma \Delta A_i P_i^0 \Delta X_i \\ + \Delta C \Sigma \Delta A_i \Delta P_i X_i^0 \\ + \Delta C \Sigma A_i^0 \Delta P_i \Delta X_i \\ + C^0 \Sigma \Delta A_i \Delta P_i \Delta X_i \end{array}\right\} \text{ second-order interaction terms}$$

$$+ \Delta C \Sigma \Delta A_i \Delta P_i \Delta X_i \quad - \text{ third-order interaction term}$$

This is an extension of decomposition without residual as reported by Binswanger (1979). The degree of the interaction terms expressed the number of component elements that are allowed to change simultaneously in the model. The first-order interactions refer to the simultaneous effects of the component elements taken two at a time. The second-order interactions refer to the simultaneous effects of the component elements taken three at a time, and the third-order interaction reflect the simultaneous effect of the four components considered together.

Graphical Representation of Decomposition

The analyses developed in the previous section may be explained using graphs. In order to simplify the exposition, let us start with the case of decomposing output into only two effects, namely cropping intensity (c) and yield (y). The identity relating these to output (Q) may be written as:

$$Q = cY \qquad (14)$$

This is equivalent to equation (1) for a single crop and no area effect. In figure 1 the relationships between quantity of output (Q), the two alternative cropping intensities (c_o and c_1) and the two yields (Y_o and Y_1) are shown by the lines OC_0 and OC_1. The procedure for decomposition without interactions may then be explained as follows.

W_0 is the point on the line representing cropping intensity c_0 where yield Y_0 produces output Q_0 and similarly W_1 is the point on the line representing intensity c_1 where yield Y_1 produces output Q_1. To decompose the difference in output, Q_0Q_1, starting from W_0 and following the order defined above we first define the change in output arising from increase in yield at constant cropping intensity. This is Q_0B_1. Second we define the change in output arising from a shift in cropping intensity given the yield Y. This is B_1Q_1. The reverse decomposition, from X_1 to X_0 produces a yield effect Q_1B_0 and a cropping intensity effect B_0Q_o. These results are clearly inconsistent since the values of B_0Q_0 and B_1Q_1 depend upon the relative value of A_1A_0 as well as the difference between c_0 and c_1. Moreover:

$$Q_0B_1/Q_1B_0 \neq B_1Q_1/B_0Q_0$$

and hence the results of the decomposition are dependent on the order by which it is computed.

The case of two component decomposition with interactions is shown in Figure 2. This is an extension of Figure 1 to incorporate the lines $O_1'c_1'$ parallel to O_{c_1} and passing through W_1, and $O_0'C_1'$ parallel to O_{c_0} and

passing through W_0. Decomposition from W_0 to W_1 produces a yield effect Q_0B_1, an interaction effect, B_1c_1, and an intensity effect c_1Q_1. The value B_1c_1 is designated as the interaction effect since it is jointly dependent on the value of Y_0Y_1 and also the difference between c_0 and c_1. Working from X_1 back to X_0 we get an area effect , Q_1B_0, an interaction effect, B_0c_0',[2] and a cropping intensity effect, c_0Q_0. The method with interactions is considered superior to the one without since the cropping intensity effect is independent of the value of A_0A_1. However, it is still possible, and very likely that:

$$\frac{Q_0B_1}{Q_1B_0} \neq \frac{B_1C_1}{B_0C_0} \neq \frac{C_1Q_1}{C_0Q_0}$$

Extension of the principle to three dimensions is conceptually simple, but more complex to represent graphically. The identity for output, given a single crop may be written as:

$$Q = cAY \tag{15}$$

where Q is the quantity of output, c is the cropping intensity, A is the area of the crop and Y is the yield per unit area. Figure 3 illustrates the situation for two cropping intensities c_0 and c_1. The horizontal axis, OY, represents increasing yield per unit area, the horizontal axis, OA, represents increasing area and the vertical axis, YQ, measures quantity of output. Into this framework insert the plane OYQ_0A to represent the range of production possibilities given cropping intensity c_0 and define a point, W_0, to specify a particular production relationship. We now superimpose a second plane, OYQ_1A, which represents the range of production possibilities given croppingintensity c_1 and define a point, W_1, to specify a second production relationship.

The objective is to illustrate the decomposition of the change in level of output between W_0 and W_1. This is achieved as follows. Construct a line through W_0 such that the height of the line above the base is constant and its distance from OY is constant. At the point where this line intersects the vertical plane $Y_1A_1W_1$, as shown in Figure 3, construct a vertical line to intersect the plane OYQ_0A. Two lines are then drawn on the plane $Y_1W_1A_1$ and parallel to Y_1A_1 to degine the points W_0' and Y'. The vertical intersection of A_1W_1 with the plane OYQ_0A defines the point A'. The decomposition is then given by:

$W_0'W_1$	=	$W_0'Y$	+	$Y'A'$	+	$A'W_1$
		change due to increase in Y (yield)		change due to increase in A (area)		change due to increase in c (cropping intensity)

[2] Note that in this case the interaction effect is always negative, since $Q_1Q_0 = Q_1B_0 + B_0C_0 + C_0Q_0$.

Extension of the three dimensional model to include interactions is too complex to represent graphically.

A Program to Carry Out Decomposition

A program has been written in BASIC to carry out the decomposition analysis. It is interactive and prompts the user to supply the data in the order required.

There is a choice of methodology, using either Binswanger (1979) or the methodology incorporating interaction terms. There is also a choice as to whether yield and price data are available, or only yields. The program automatically requests the relevant data when the type of data available has been indicated.

Figure 4 shows the outline flowchart. The calculations are carried out on a crop-by-crop basis and the results are printed as they are calculated. There is a final computational check to reassure the user that the correct quantities have been allocated amongst the different effects.

Table 1 shows an example output from the program. Wet-season rice and dry-season rice were the only crops under cultivation. Two-wheel tractors gave a massive increase in output, and the major part of this increase is seen to come from an increase in intensity.

Appendix B shows a complete listing of the program. Appendix C gives a list of the variables used, together with their interpretation.

An Example of Decomposition with and without Interactions

In this section results of a decomposition analysis with and without interaction terms are presented. The implications of these results are compared and conclusions drawn as to the validity of the models. The example has been taken from Tan (1981).

Table 2 shows the results of decomposition of output change, between overall yield, area and cropping intensity effects without an interaction term, a sample of 42 farms using draft animals for land preparation and a sample of 52 farms using two-wheel tractors for land preparation. These results clearly suggest the cropping intensity effect to be the most important, followed by the yield effect. The area effect is relatively unimportant. If the interaction terms are included, the results shown in Table 3 are obtained. The yield effect is the most important and the cropping intensity effect is now much less important. Of the interaction effects only the one for cropping intensity-yield is of any importance. It is the separation out of this effect which has caused the change in emphasis. The reason for this was shown by the difference between equations (9) and (13).

These results reinforce the need to consider interaction effects explicitly in decomposition analysis. Although it should not be expected that they are so important in all analyses, the possibility of their having a significant effect on the results should not be ignored. Moreover the computational burden of this extra work is not so great, particularly if a programmable calculator or mico-computer is available.

Conclusions

In this paper we have described the derivation, interpretation, estimation and application of decomposition analysis. The technique is intuitively appealing since it requires only limited computational facilities, and the change in output is reduced to a few additive and multiplicative effects. However, some notes of caution are required.

It has been shown both graphically and empirically that errors may occur in the results unless interaction terms are considered explicitly. Since this does not constitute a major, extra computation, we would urge future researchers to also include these.

We have shown graphically that the results of decomposition analysis are dependent on the direction in which the decomposition is undertaken. Hence conflicting results may be obtained. In handling this problem, we suggest that there are two distinct types of decomposition problem, viz. the uni-directional problem and the bi-directional problem. A typical case of the uni-directional problem is the mechanization issue, where the shift is clearly from non-mechanized to mechanized. Regardless of other considerations we should decompose in this direction. The comparison of small and large farms provides an example of a bi-directional problem. There is no logical reason for favoring one direction over another. The most satisfactory solution in this case is to decompose in both directions and hence to establish boundaries on the relative importance of the various effects. We prefer not to use the pragmatic approach suggested by Binswanger (1978) where the direction of the decomposition is based on the farm group growing the largest number of crops. The only advantage of such an approach is computational convenience.

Finally it should be emphasized that the theoretical basis of decomposition analysis is not well established. Yet it does appear to be an area in which further research may be fruitful.

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Table 1. Example output from the production decomposition program

Decomposition of Difference in Output
****

- between non-mech and mech farms.
- using Binswanger's methodology.
- with output expressed in money terms.

DATA
****

	non-mech	mech
-groups		
-intensity	1.36	1.92
-area:		
wet rice	1.44	1.24
dry rice	0.72	1.20
-yield per unit area:		
wet rice	2587.22	4105.72
dry rice	3058.17	4154.02
-price per unit yield:		
wet rice	1.05	1.18
dry rice	1.15	1.16
-output	8763.90	22636.60

R E S U L T S
****

	Intensity	Area	Yield	Price	Total	% of output difference
wet rice	3364.19	-1317.77	3122.52	1045.28	6214.23	44.79
dry rice	3238.14	3145.62	1234.01	40.68	7658.46	52.21
Totals	6602.34	1827.85	4356.54	1085.96	13872.70	100.00
% of output	47.59	13.18	31.40	7.83	100.00	

Computational Check:
calculated difference = 13872.7
allocated difference = 13872.7
mean output = (8763.9 + 22636.6)/2 = 15700.2

Table 2. Decomposition analysis (without interaction terms) of output difference between 2-wheel tractor and draft animal using farms.

EFFECTS	ABSOLUTE CHANGE	PERCENTAGE SHARE
Sources of output difference		
overall yield effect	5442.50	39.23
area effect	1827.85	13.18
cropping intensity effect	6602.34	47.59
Total change in output	13872.70	100.00

Table 3. Decomposition analysis (with interaction terms) of output difference between 2-wheel tractor and draft animals using farms.

EFFECT	ABSOLUTE CHANGE	PERCENTAGE SHARE
Sources of changes in output		
A. Individual effects		
yield effect	5442.50	39.23
area effect	1556.92	11.22
cropping intensity	3608.66	26.01
B. First-order interaction effects		
yield and area	270.93	1.95
cropping intensity and area	641.08	4.62
cropping intensity and yield	2241.03	16.15
C. Second-order interaction effect		
cropping intensity, area and yield	111.56	0.82
Total change in output	13872.70	100.00

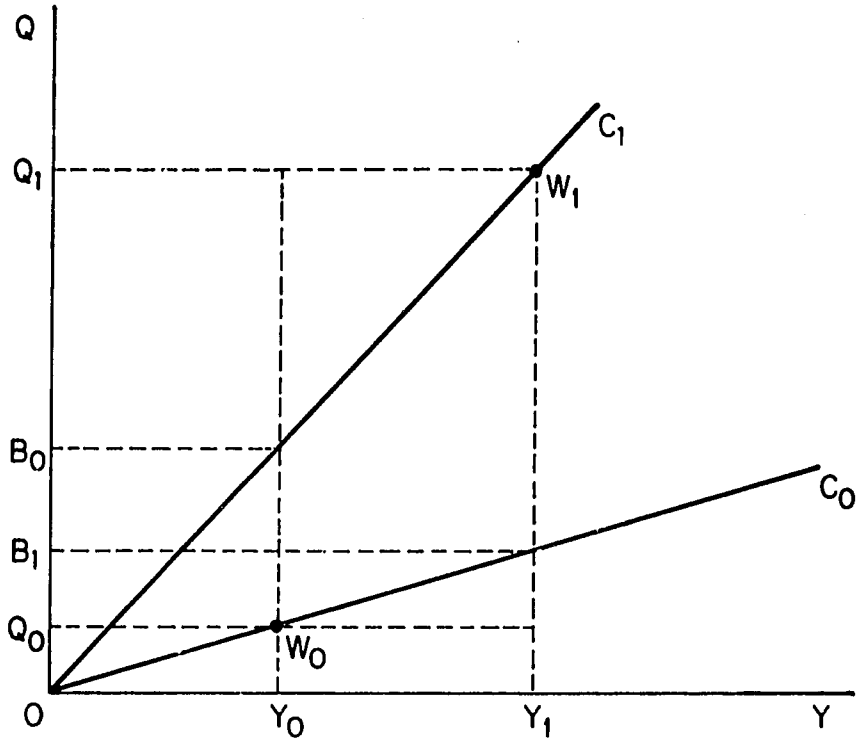

Figure 1. Graphical representation of two component decomposition without interactions.

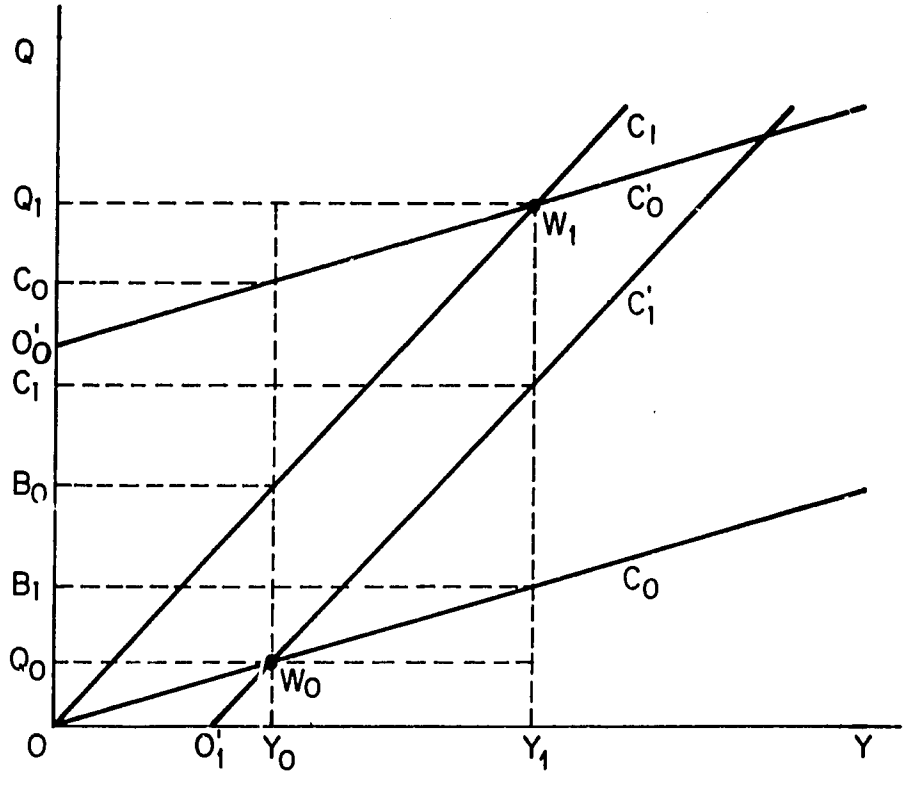

Figure 2. Graphical representation of two component decomposition with interactions.

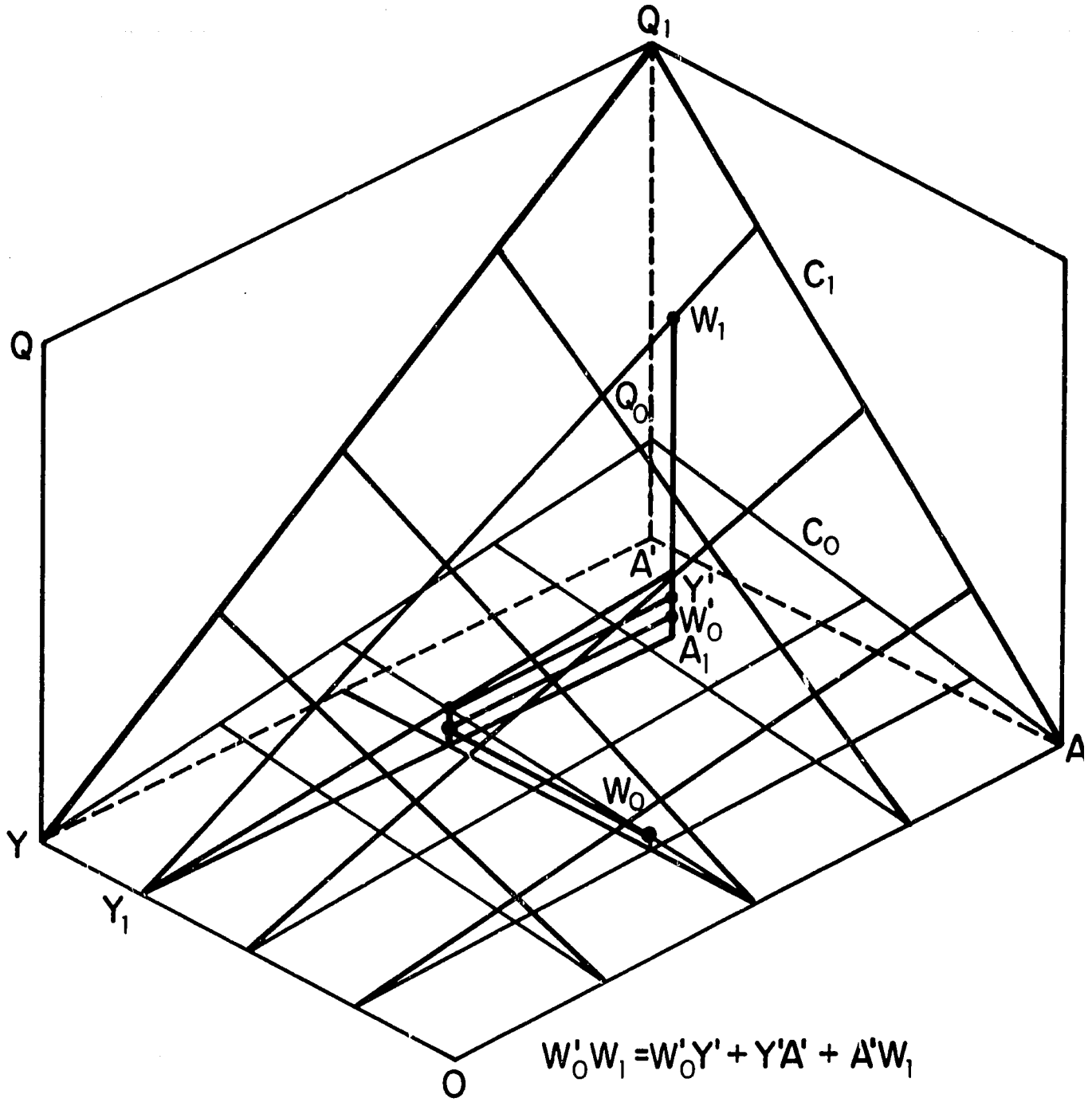

Figure 3 Graphical representation of three component decomposition.

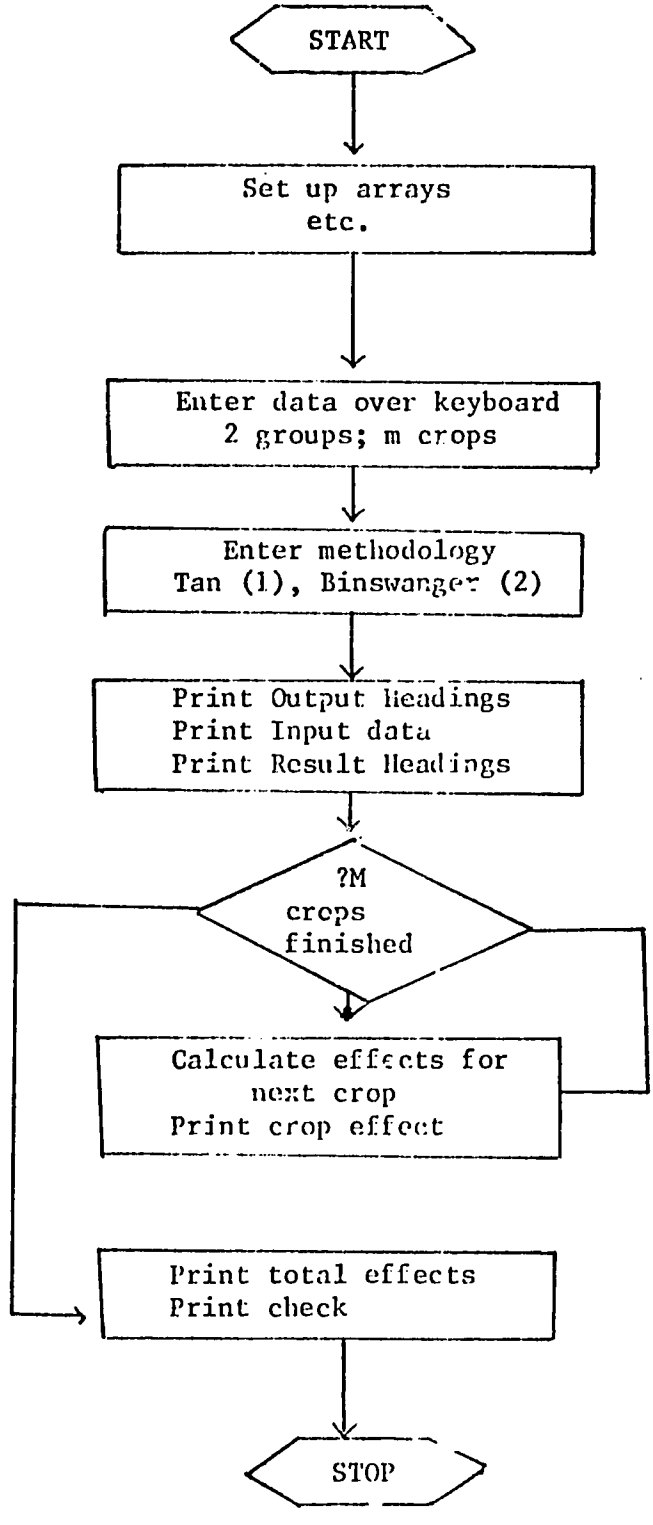

Fig. 4. Flowchart for decomposition program.

APPENDIX A

Derivation of Identities

Identity I

$$\left(\sum_i A_i^1 Y_i^1 - \sum_i A_i^0 Y_i^0\right) = \sum_i \Delta A_i Y_i^1 - \sum_i A_i^0 \Delta Y_i$$

Derivation:

$$\sum_i A_i^1 Y_i^1 - \sum_i A_i^0 Y_i^0 = \sum_i A_i^1 Y_i^1 - \sum_i A_i^0 Y_i^0 + \sum_i A_i^0 Y_i^1 - \sum_i A_i^0 Y_i^1$$

$$= \sum_i (A_i^1 - A_i^0) Y_i^1 + \sum_i A_i^0 (Y_i^1 - Y_i^0)$$

$$= \sum_i \Delta A_i Y_i^1 + \sum_i A_i^0 \Delta Y_i \qquad \text{Q.E.D.}$$

Identity II

$$\left(\sum_i A_i^1 P_i^1 X_i^1 - \sum_i A_i^0 P_i^0 X_i^0\right) = \sum_i \Delta A_i P_i^1 X_i^1 + \sum_i A_i^0 \Delta P_i X_i^1 + \sum_i A_i^0 P_i^0 \Delta X_i$$

Derivation:

$$\sum_i A_i^1 P_i^1 X_i^1 - \sum_i A_i^0 P_i^0 X_i^0 = \sum_i A_i^1 P_i^1 X_i^1 - \sum_i A_i^0 P_i^0 X_i^0 + \sum_i A_i^0 P_i^1 X_i^1 - \Sigma A_i^0 P_i^1 X_i^1$$

$$= \sum_i (A_i^1 - A_i^0) P_i^1 X_i^1 + \sum_i A_i^0 (P_i^1 X_i^1 - P_i^0 X_i^0)$$

$$= \sum_i \Delta A_i P_i^1 X_i^1 + \sum_i A_i^0 (P_i^1 X_i^1 - P_i^0 X_i^0 + P_i^0 X_i^1 - P_i^0 X_i^1)$$

$$= \sum_i \Delta A_i P_i^1 X_i^1 + \sum_i A_i^0 \Delta P_i X_i^1 + \sum_i A_i^0 P_i^0 \Delta X_i \qquad \text{Q.E.D.}$$

Identity III

$$(\sum_i A_i^1 P_i^1 X_i^1 - \sum_i A_i^0 P_i^0 X_i^0) = \sum_i A_i^0 P_i^0 \Delta X_i + \Sigma \Delta A_i P_i^0 \Delta X_i + \Sigma \Delta A_i P_i^0 X_i^0$$

$$+ \sum_i \Delta A_i \Delta P_i \Delta X_i + \sum_i \Delta A_i \Delta P_i X_i^0$$

$$+ \sum_i A_i^0 \Delta P_i \Delta X_i + \sum_i A_i^0 \Delta P_i X_i^0$$

Derivation:

$$\sum_i A_i^1 P_i^1 X_i^1 - \sum_i A_i^0 P_i^0 X_i^0 = \sum_i A_i^1 P_i^1 X_i^1 - \sum_i A_i^0 P_i^0 X_i^0 + \sum_i A_i^0 P_i^1 X_i^1 - \sum_i A_i^0 P_i^1 X_i^1$$

$$= \sum_i (A_i^1 - A_i^0) P_i^1 X_i^1 + \Sigma_i A_i^0 (P_i^1 X_i^1 - P_i^0 X_i^0)$$

$$= \sum_i \Delta A_i P_i^1 X_i^1 + \sum_i A_i^0 (P_i^1 X_i^1 - P_i^0 X_i^0 + P_i^0 X_i^1 - P_i^0 X$$

$$= \sum_i \Delta A_i P_i^1 X_i^1 + \sum_i A_i^0 (P_i^1 - P_i^0) X_i^1 + \sum_i A_i^0 P_i^0 (X_i^1 - X_i^0$$

$$= \sum_i \Delta A_i P_i^1 X_i^1 + \sum_i A_i^0 \Delta P_i X_i^1 + \sum_i A_i^0 P_i^0 \Delta X_i$$

$$+ \sum_i \Delta A_i P_i^0 X_i^0 - \sum_i \Delta A_i P_i^0 X_i^0$$

$$= \sum_i \Delta A_i (P_i^1 X_i^1 - P_i^0 X_i^0) + \sum_i A_i^0 \Delta P_i X_i^1 + \sum_i A_i^0 P_i^0 \Delta X_i$$

$$+ \sum_i \Delta A_i P_i^0 X_i^0$$

$$= \sum_i \Delta A_i \Delta P_i X_i^1 + \sum_i \Delta A_i P_i^0 \Delta X_i + \sum_i A_i^0 \Delta P_i X_i^1$$

$$+ \sum_i A_i^0 P_i^0 \Delta X_i + \sum_i \Delta A_i P_i^0 X_i^0$$

$$= (\sum_i \Delta A_i \Delta P_i X_i^1 + \sum_i \Delta A_i \Delta P_i X_i^0 - \sum_i \Delta A_i \Delta P_i X_i^0)$$

$$+ \sum_i \Delta A_i P_i^0 \Delta X_i + (\sum_i A_i^0 \Delta P_i X_i^1 + \sum_i A_i^0 \Delta P_i X_i^0)$$

$$- \sum_i A_i^0 \Delta P_i X_i^0) + \sum_i A_i^0 P_i^0 \Delta X_i + \sum_i \Delta A_i P_i^0 X_i^0$$

$$= \sum_i \Delta A_i \Delta P_i X_i^0 + \sum_i \Delta A_i \Delta P_i (X_i^1 - X_i^0) + \sum_i \Delta A_i P_i^0 \Delta X_i$$

$$+ \sum_i A_i^0 \Delta P_i X_i^0 + \sum_i A_i^0 \Delta P_i (X_i^1 - X_i^0) + \sum_i A_i^0 P_i^0 \Delta X_i$$

$$+ \sum_i \Delta A_i P_i^0 X_i^0$$

$$= \sum_i A_i^0 P_i^0 \Delta X_i + \sum_i \Delta A_i P_i^0 \Delta X_i + \sum_i \Delta A_i P_i^0 X_i^0 + \sum_i \Delta A_i \Delta P_i \Delta X_i$$

$$+ \sum_i \Delta A_i \Delta P_i X_i^0 + \sum_i A_i^0 \Delta P_i \Delta X_i + \sum_i A_i^0 \Delta P_i X_i^0 \qquad \text{Q.E.D.}$$

APPENDIX B

Listing of the Computer Program for Decomposition Analysis

```
10 CLS
20 PRINT "   Decomposition of Differences in Output between 2 Groups of Farms"
30 PRINT "   ****************************************************************"
40 PRINT "                    Tan, Webster & Wicks, IRRI, Dec 1980.  "
50 PRINT
100 '
110 DIM II(20),A(2,20),AA(20),Y(2,20),YY(20),P(2,20),PP(20)
120 DIM F(6,20),FIRST(20),S(4,20),SEC(20),THIRD(20),TT(20)
140 '*******  Definition of variables
150 '  I,II     Intensity
160 '  A,AA     Area
170 '  Y,YY     Yield
180 '  P,PP     Price
200 '  FIRST,SEC and THIRD contain the interactive effects
210 '  TT       Total effects
220 '  C$       has the names of the crops
230 '  M        no. of crops
260 '  Prefix T has the total effect   e.g. TI is the total intensity effect
270 '
275 F$ = "######.##      "
280 I$(0) = "output"
290 I$(1) = "yield"
300 I$(2) = "Binswanger's"
310 I$(3) = "Tan, Webster & Wicks' interaction"
320 I$(4) = "physical"
330 I$(5) = "money"
331 R$(1) = "yield & price"
332 R$(2) = "area & price"
333 R$(3) = "area & yield"
334 R$(4) = "intensity & yield"
335 R$(5) = "intensity & price"
336 R$(6) = "intensity & area"
337 S$(1) = "area, price & yield"
338 S$(2) = "area, price & int."
339 S$(3) = "yield, price & int."
340 S$(4) = "area, yield & int."
345 '**********  Determine mode of entry
350 INPUT "Data entry over the keyboard(1) or is it already in the program(0)";Z2
360 IF Z2<>0 AND Z2<>1 THEN 350
370 IF Z2 = 0 THEN GOSUB 4000 ELSE GOSUB 3000
380 '*****   Clear the interaction arrays and totals
390 FOR J = 1 TO M
400 FOR I = 1 TO 6
410 F(I,J) = 0
420 NEXT I
460 FIRST(J) = 0
```

```
470 FOR I = 1 TO 4
480 S(I,J) = 0
490 NEXT I
510 SEC(J) = 0
520 THIRD(J) = 0
530 NEXT J
540 TI = 0
550 TA = 0
560 TY = 0
570 TP = 0
574 FOR I = 1 TO 7
575 T1(I) = 0
576 NEXT I
580 FOR I = 1 TO 5
585 T2(I) = 0
590 NEXT I
600 T3 = 0
610 GT = 0
620 Q1 = 0
630 Q2 = 0
640 '*****   Find the overall output for checking
650 FOR J = 1 TO M
660 Q1 = Q1 + I(1) * A(1,J) * Y(1,J) * P(1,J)
670 Q2 = Q2 + I(2) * A(2,J) * Y(2,J) * P(2,J)
680 NEXT J
690 '*****   revised
700 D = Q2 - Q1
710 '*****   D is the difference in output for the two groups of farms
715 MD = (Q1 + Q2)/2
720 '
725 PRINT
730 INPUT "Analysis with interaction terms: Tan (1) or without: Binswanger (0)";Z
740 IF Z<>0 AND Z<>1 THEN 730
750 '
760 '*****   Print output headings
770 '
780 LPRINT CHR$(12)
790 LPRINT:LPRINT:LPRINT:LPRINT:LPRINT
800 LPRINT TAB(45) "Decomposition of Differences in Output"
810 LPRINT TAB(45) "*************************************"
820 LPRINT:LPRINT TAB(40) "- between ";G$(1); " and ";G$(2); " farms."
830 LPRINT TAB(40) "- using ";I$(Z+2); " methodology."
840 LPRINT TAB(40) "- with output expressed in ";I$(Z1+4); " terms."
850 LPRINT
860 '
870 '*****   Print the data
880 '
890 LPRINT:LPRINT:LPRINT:LPRINT
```

```
900 LPRINT TAB(62) "DATA"
910 LPRINT TAB(35) STRING$(54,"_")
920 LPRINT:LPRINT TAB(40) "groups";TAB(66);G$(1);TAB(80);G$(2)
925 LPRINT TAB(35) STRING$(54,"_"):LPRINT
930 LPRINT:LPRINT TAB(35) "-intensity"; TAB(65) USING "####.##";I(1);
940 LPRINT TAB(80) USING "####.##";I(2)
950 LPRINT TAB(35) "-area:"
960 FOR J = 1 TO M
970 LPRINT TAB(45); C$(J);TAB(65) USING "####.##";A(1,J);
980 LPRINT TAB(80) USING "####.##";A(2,J)
990 NEXT J
1000 LPRINT TAB(35) "-yield per unit area:"
1010 FOR J = 1 TO M
1020 LPRINT TAB(45); C$(J); TAB(64) USING "#####.##";Y(1,J);
1030 LPRINT TAB(79) USING "#####.##";Y(2,J)
1040 NEXT J
1050 IF Z1 <> 1 THEN 1110
1060 LPRINT TAB(35) "-price per unit yield:"
1070 FOR J = 1 TO M
1080 LPRINT TAB(45); C$(J); TAB(65) USING "####.##";P(1,J);
1090 LPRINT TAB(80) USING "####.##";P(2,J)
1100 NEXT J
1110 LPRINT:LPRINT TAB(35) "-output";TAB(64) USING "#####.##";Q1;
1120 LPRINT TAB(79) USING "#####.##";Q2
1130 LPRINT CHR$(12)
1140 LPRINT:LPRINT:LPRINT
1150 LPRINT TAB(57) "R E S U L T S"
1160 LPRINT TAB(57) "*************"
1170 '
1180 '*****   Do the calculations for crops 1 to M
1190 '
1200 DI = I(2) - I(1)
1210 FOR J = 1 TO M
1220 '    the differences
1230 DA = A(2,J) - A(1,J)
1240 DY = Y(2,J) - Y(1,J)
1250 DP = P(2,J) - P(1,J)
1260 IF Z = 1 THEN 1330
1270 '*****   the effects without interactions
1280 II(J) = DI * A(2,J) * Y(2,J) * P(2,J)
1290 AA(J) = DA * I(1) * Y(2,J) * P(2,J)
1300 YY(J) = DY * I(1) * A(1,J) * P(1,J)
1310 PP(J) = DP * I(1) * A(1,J) * Y(2,J)
1320 GOTO 1670
1330 '*****   the effects with interactions
1340 ' --  main effects
1350 II(J) = DI * A(1,J) * Y(1,J) * P(1,J)
1360 AA(J) = DA * I(1) * Y(1,J) * P(1,J)
```

```
1370 YY(J) = DY * I(1) * A(1,J) * P(1,J)
1380 PP(J) = DP * I(1) * Y(1,J) * A(1,J)
1390 ' --  interactions
1400 F(1,J) = I(1) * DP * DY * A(1,J)
1410 F(2,J) = I(1) * DP * DA * Y(1,J)
1420 F(3,J) = I(1) * DA * DY * P(1,J)
1430 F(4,J) = DI * A(1,J) * P(1,J) * DY
1440 F(5,J) = DI * A(1,J) * Y(1,J) * DP
1450 F(6,J) = DI * P(1,J) * Y(1,J) * DA
1460 FIRST(J) = F(1,J) + F(2,J) + F(3,J) + F(4,J) + F(5,J) + F(6,J)
1470 S(1,J) = DA * DP * DY * I(1)
1480 S(2,J) = DA * DP * DI * Y(1,J)
1490 S(3,J) = DI * DY * A(1,J) * DP
1500 S(4,J) = DI * DY * P(1,J) * DA
1510 SEC(J) = S(1,J) + S(2,J) + S(3,J) + S(4,J)
1520 THIRD(J) = DI * DA * DY * DP
1530 ' --  totals
1540 FOR I = 1 TO 6
1550 T1(I) = T1(I) + F(I,J)
1560 NEXT I
1570 T1(7) = T1(7) + FIRST(J)
1610 FOR I = 1 TO 4
1620 T2(I) = T2(I) + S(I,J)
1630 NEXT I
1640 T2(5) = T2(5) + SEC(J)
1660 T3 = T3 + THIRD(J)
1670 TI = TI + II(J)
1680 TA = TA + AA(J)
1690 TY = TY + YY(J)
1700 TP = TP + PP(J)
1710 TT(J) = II(J) + AA(J) + YY(J) + PP(J) + FIRST(J) + SEC(J) + THIRD(J)
1720 GT = GT + TT(J)
1730 NEXT J
1735 MD = (Q1 + Q2)/2
1740 LPRINT:LPRINT:LPRINT TAB(10) STRING$(50,"_");
1745 LPRINT TAB(60) STRING$(46,"_")
1750 LPRINT:LPRINT TAB(10) "Effects"; TAB(35);
1755 FOR J = 1 TO M
1760 LPRINT USING "\              \";C$(J);
1770 NEXT J
1780 LPRINT "  Total        % of allocated    % of mean"
1785 LPRINT TAB(83) "output          output"
1788 LPRINT TAB(10) STRING$(50,"_");
1789 LPRINT TAB(60) STRING$(46,"_")
1790 LPRINT:LPRINT:LPRINT TAB(10) "Intensity";TAB(35);
1800 FOR J = 1 TO M
1810 LPRINT USING F$;II(J);
1820 NEXT J
```

```
1830 LPRINT USING F$;TI;
1835 LPRINT USING F$;TI*100/GT;
1840 LPRINT  USING F$;TI*100/MD
1850 LPRINT:LPRINT TAB(10) "Area";TAB(35);
1860 FOR J = 1 TO M
1870 LPRINT USING F$;AA(J);
1880 NEXT J
1890 LPRINT USING F$;TA;
1895 LPRINT USING F$;TA*100/GT;
1900 LPRINT USING F$;TA*100/MD
1910 LPRINT:LPRINT TAB(10) "Yield";TAB(35);
1920 FOR J = 1 TO M
1930 LPRINT USING F$;YY(J);
1940 NEXT J
1950 LPRINT USING F$;TY;
1955 LPRINT USING F$;TY*100/GT;
1960 LPRINT USING F$;TY*100/MD
1970 IF Z1 <> 1 THEN 2040
1980 LPRINT:LPRINT TAB(10) "Price";TAB(35);
1990 FOR J = 1 TO M
2000 LPRINT USING F$;PP(J);
2010 NEXT J
2020 LPRINT USING F$;TP;
2025 LPRINT USING F$;TP*100/GT;
2030 LPRINT USING F$;TP*100/MD
2040 IF Z <> 1 THEN 2410
2050 LPRINT:LPRINT TAB(10) "Interaction"
2060 LPRINT TAB(12) "First order"
2070 FOR I = 1 TO 6
2080 LPRINT TAB(14) R$(I);TAB(35);
2090 FOR J = 1 TO M
2100 LPRINT USING F$;F(I,J);
2110 NEXT J
2120 LPRINT USING F$;T1(I);
2121 LPRINT USING F$;T1(I)*100/GT;
2125 LPRINT USING F$;T1(I)*100/MD
2130 NEXT I
2140 LPRINT:LPRINT TAB(16) "Total";TAB(35);
2150 FOR J = 1 TO M
2160 LPRINT USING F$;FIRST(J);
2170 NEXT J
2180 LPRINT USING F$;T1(7);
2185 LPRINT USING F$;T1(7)*100/GT;
2190 LPRINT USING F$;T1(7)*100/MD
2200 LPRINT:LPRINT TAB(12) "Second order"
2210 FOR I = 1 TO 4
2220 LPRINT TAB(14) S$(I);TAB(35);
2230 FOR J = 1 TO M
```

```
2240 LPRINT USING F$;S(I,J);
2250 NEXT J
2255 LPRINT USING F$;T2(I);
2260 LPRINT USING F$;T2(I)*100/GT;
2265 LPRINT USING F$;T2(I)*100/MD
2270 NEXT I
2280 LPRINT:LPRINT TAB(16) "Total";TAB(35);
2300 FOR J = 1 TO M
2310 LPRINT USING F$;SEC(J);
2320 NEXT J
2330 LPRINT USING F$;T2(5);
2335 LPRINT USING F$;T2(5)*100/GT;
2340 LPRINT USING F$;T2(5)*100/MD
2350 LPRINT:LPRINT TAB(12) "Third order";TAB(35);
2360 FOR J = 1 TO M
2370 LPRINT USING F$;THIRD(J);
2380 NEXT J
2390 LPRINT USING F$;T3;
2395 LPRINT USING F$;T3*100/GT;
2400 LPRINT USING F$;T3*100/MD
2410 LPRINT:LPRINT:LPRINT TAB(10) "Total";TAB(35);
2420 FOR J = 1 TO M
2430 LPRINT USING F$;TT(J);
2440 NEXT J
2450 LPRINT USING F$;GT;
2460 LPRINT SPC(15) USING F$;GT*100/MD
2470 LPRINT:LPRINT TAB(10) "as % of allocated diff";TAB(35);
2480 FOR J = 1 TO M
2490 LPRINT USING F$; TT(J)*100/GT;
2500 NEXT J
2510 LPRINT SPC(15) USING F$;GT*100/MD
2515 LPRINT TAB(10) STRING$(50,"_");
2516 LPRINT TAB(60) STRING$(46,"_")
2520 LPRINT:LPRINT:LPRINT:LPRINT TAB(10) "Computational check:"
2530 LPRINT TAB(14) "calculated difference = ";Q2-Q1
2540 LPRINT TAB(14) "allocated difference = ";GT
2550 LPRINT TAB(14) "mean output = (";Q1;"+";Q2;")/2 = ";MD
2560 '*****  another problem ?
2570 PRINT:INPUT "Another problem (1) or stop (0)";Z5
2580 IF Z5 <> 0 AND Z5 <> 1 THEN 2570
2590 IF Z5 = 1 THEN 350
2595 LPRINT CHR$(12):LPRINT
2600 LPRINT "****** End of program. Written by J.P.G.Webster, IRRI, Dec. 1980 "
2605 LPRINT "       Y. L. Tan, J. P. G. Webster & J. A. Wicks "
2606 LPRINT "       IRRI, December 1980 "
2620 END
3000 '**********  Data entry over keyboard
3010 '
```

```
3020 PRINT:PRINT
3030 PRINT "What are the names of the two groups of farms to be compared ?"
3040 INPUT "   Group 1 ";G$(1)
3050 INPUT "   Group 2 ";G$(2)
3055 PRINT
3060 INPUT "Is there separate yield and price data (1), or only yields (0)";Z1
3070 IF Z1<>0 AND Z1<>1 THEN 3060
3080 PRINT:INPUT "How many crops are there ";M
3090 PRINT:PRINT "What are their names ?"
3100 FOR J= 1 TO M
3110 PRINT "   Crop ";J;
3120 INPUT C$(J)
3130 NEXT J
3140 PRINT:PRINT "What are the cropping intensities, 2 numbers, ";G$(1);
3150 PRINT " followed by ";G$(2):INPUT I(1),I(2)
3160 PRINT:PRINT "What are the crop areas ? 2 numbers; area for "G$(1);
3165 PRINT " then area for ";G$(2)
3170 FOR J = 1 TO M
3180 PRINT " for ";C$(J);
3190 INPUT A(1,J),A(2,J)
3200 NEXT J
3210 PRINT:PRINT "What are the crop yields ?"
3220 FOR J = 1 TO M
3230 PRINT " for ";C$(J);
3240 INPUT Y(1,J),Y(2,J)
3250 NEXT J
3260 FOR J = 1 TO 2
3270 FOR K = 1 TO M
3280 P(J,K) = 1
3290 NEXT K
3300 NEXT J
3310 '********   Set P's to 1
3320 IF Z1 = 0 THEN 3400
3330 '*****   Note that if there is no separation of yields and prices, prices
3340 '*****   are all set to 1.0 and calculations proceed using similar formulae
3350 PRINT:PRINT "What are the crop prices ?"
3360 FOR J = 1 TO M
3370 PRINT " for ";C$(J);
3380 INPUT P(1,J),P(2,J)
3390 NEXT J
3400 RETURN
4000 '
4010 '*****   Decide which example to run
4020 '
4030 RESTORE:PRINT
4040 PRINT "Which example : Patel(1), Binswanger(2), Tan1(3), Tan2(4), Tan3(5),"
4045 INPUT "                Tan4(6) or <BREAK>";Z3
4050 IF Z3<1 OR Z3>6 THEN 4040
```

```
4060 Z4 = 0
4070 '
4080 '*****   Subroutine for data entry within the program
4090 '
4100 READ G$(1),G$(2),Z1,M,I(1),I(2)
4110 FOR J = 1 TO M
4120 P(1,J) = 1
4130 P(2,J) = 1
4140 READ C$(J),A(1,J),A(2,J),Y(1,J),Y(2,J)
4150 IF Z1 = 1 THEN READ P(1,J),P(2,J)
4160 NEXT J
4170 Z4 = Z4 + 1
4180 IF Z4<>Z3 THEN 4100
4190 PRINT
4200 RETURN
4210 '
4220 '*****   Example data follows
4230 '
4240 'N.T.Patel, "Farm Tractorization", Economic Times, Oct. 20, 1980
4250 DATA Bullock,Tractor,0,6,1.31,1.72
4260 DATA Paddy,1.26,2.28,1970,2304.6
4270 DATA Wheat,.91,2.92,2262.5,3289.0
4280 DATA Jowar,1.69,3.41,881,1222.5
4290 DATA Mustard,0.82,2.09,1435,1855
4300 DATA Bajra,1.92,3.84,1480,2085
4310 DATA Cotton,.7,.96,4250,5200
4320 '***  NB output/ha is not split into yield and price;
4325 '     it goes into Y and P is set to 1.
4330 'Binswangers
4340 DATA GROUP1,GROUP2,0,2,1,2
4350 DATA CROPONE,.5,.333,1,1.5
4360 DATA CROPTWO,.5,.667,2,1.5
4370 'non-mech vs. 2-wheel farms
4380 DATA non-mech,2-wheel,1,2,1.363,1.923
4390 DATA wet rice,1.439,1.24,2587.22,4105.72,1.049,1.175
4400 DATA dry rice,0.72,1.2,3058.17,4154.02,1.15,1.157
4410 'non-mech vs. 2+4-wheel
4420 DATA non-mech,2+4-wheel,1,2,1.363,1.972
4430 DATA wet rice,1.439,.798,2814.2,3773.7,1.049,1.053
4440 DATA dry rice,.72,.805,3408.4,4114.2,1.15,1.081
4450 'non-mech vs. 2-wheel ; no prices
4460 DATA non-mech,2-wheel,0,2,1.363,1.923
4470 DATA wet rice,1.439,1.24,2587.22,4105.72
4480 DATA dry rice,0.72,1.2,3058.17,4154.02
4490 'non-mech vs. 2+4-wheel ; no prices
4500 DATA non-mech,2+4-wheel,0,2,1.363,1.972
4510 DATA wet rice,1.439,0.798,28[illegible]4.198,3773.694
4520 DATA dry rice,0.72,0.805,3408.388,4114.244
```

APPENDIX C

List of Variables in the Decomposition Program

A(2,20)	Crop areas 2 groups, up to 20 crops
AA (20)	Cropping pattern, or area, effect by crop.
C$(20)	Crop names
D	Difference in output per hectare between the 2 groups
DA	Difference in area for a given crop
DI	Difference in intensity
DP	Difference in price for a given crop
DY	Difference in yield for a given crop
FIRST (20)	First order interactions by crop
C$(2)	Group names
GT	Grand total of effects
I(2)	Cropping intensities by group
II(20)	Intensity effect by crop
I$(5)	Miscellaneous captions
M	Number of crops
P(s,20)	Prices by group and crop
PP(20)	Price effects by crop
Q1	Total output for group 1
Q2	Total output for group 2
SEC(20)	Second order interactions by crop
T1	Total first order interactions
T2	Total second order interactions
T3	Total third order interactions
TA	Total cropping pattern effect
TI	Total intensity effect
TP	Total price effect
TY	Total yield effect
THIRD(20)	Third order interactions by crop
Y(2,20)	Yields by group and crop
YY(20)	Yield effects by crop

CONSEQUENCES OF SMALL RICE FARM MECHANIZATION PROJECT

Working Papers

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