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Analysis of agricultural production instability in the Gezira scheme

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Abstract The study was conducted to measure the extent of instability and contribution of different components to change in mean production of the main crops grown in the Gezira scheme. The study used time series data covering the period before the adoption of liberalization policy (1970/71 to 1991/92) and the period after the adoption of liberalization policy (1992/93 to 2007/08). The main crops included in the study were sorghum, wheat, cotton and groundnuts. The instability of area, yield and production were determined, in addition to the analysis of different components of the sources of change in the mean production of crops.

The findings of the study showed that sorghum, wheat and cotton witnessed a continuous increase in instability over the two periods, whereas there was a decrease in the instability of groundnuts production during post-liberalization period. The instability in area and yield of all crops moved in the same direction and their increasing/decreasing trend resulted in increase/decrease in instability. The decomposition analysis of sources of change in mean production of crops indicated that changes in mean yield accounted for large shares of the change in mean production of wheat and sorghum but change in mean area contributed largely in cotton and groundnuts. Furthermore, the analysis showed that changes in the variance of yield accounted for large share of changes in the variance of production for sorghum, while for wheat the large share was due to variance of area. The changes in the residual term were important in explaining the changes in the variance of production in the case of groundnuts. Programs and policies such as rehabilitation of irrigation canals, provision of inputs and strengthening the agricultural research

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and extension can play a vital role in achieving stability in the agricultural production in the Gezira scheme.

1. Introduction

The agricultural sector dominates the economy of Sudan, it provides livelihood for over 80% of the population, accounts on average, for about 45% of Gross Domestic Product (GDP) and provides a big share of inputs for the country's agro-industries (Bank of Sudan, 2003). The total arable land in Sudan is estimated at 84 million ha, and only about 7.14 million ha are utilized in agricultural production (Ministry of Agriculture and Forestry, 2006). The agricultural sector is divided into two main sub-sectors, namely, irrigated sub-sector and rain-fed sub-sector. The area of the irrigated sub-sector is about 1.8 million ha and includes Gezira, Rahad, New Halfa, Elssuki, White Nile and Blue Nile schemes. Gezira, Rahad and New Halfa schemes are considered the most important schemes in the sub-irrigated sector and the most important crops grown in these schemes are cotton, groundnuts, wheat, sorghum and vegetables. The agricultural sector's share of exports declined from 73.4% in 1998 to only 8% in 2006 due to decline in agricultural production and increase in the petroleum export (Ministry of Finance and National Economy, 2006).

Gezira scheme is one of the biggest irrigated farms in the world under one management. It covers 50% of the irrigated sub-sector and its total area is 0.882 million ha (Elmagboul, 2004).

The productivity of crops in irrigated agricultural sub-sector is low and fluctuating due to low producer prices, lack of foreign currency and import regulations which have limited the availability of vital production inputs and spare parts (IFAD, 1992). The spatial variations have been an important dimension of the spectacular growth of agriculture in Sudan caused by differences in agro-climatic situations, levels of infrastructural facilities and inherent socio-economic characteristics of different regions of the country (Mahir, 2004). The instability of economic phenomena is generally understood as the departure from what may be considered to be a stable passage through time (FAO, 1998). Its measurement has been developed in order to quantify the risk of insecurity resulting from fluctuating levels of economic phenomena such as production, trade, income, prices, etc. Instability measurement with respect to agricultural production is of interest to food issues or to issues arising from the influence of fluctuations in output on agricultural prices and returns to the producers (FAO, 1998).

In 1992, the government of Sudan liberalized its economy to correct the growing internal and external imbalances and achieve desirable growth in the different sectors of the economy. The main components of the liberalization policy included price liberalization, privatization, removal of government subsidies, cuts in public expenditures, relaxation of foreign exchange control, increase of interest rates to real levels, withdrawal of protectionism measures and tight control of credit. Despite these efforts, the response from the agricultural sector has been insufficient.

The objectives of this paper were to measure the extent of instability in the production of the principal crops in the Gezira scheme and to measure the contribution of different components to agricultural production instability during two periods (pre-prices liberalization policy 1970/71 to 1991/92 and post-prices liberalization policy 1992/93 to 2007/08).

2. Methodology

The study used secondary data covering the period from 1970 to 2008. The sources of the data were the Ministry of Agriculture and Forestry, Department of Statistics in the Gezira scheme. The standard deviation and coefficient of variation were used by many economists for estimating the instability in agricultural production. Hazell (1982) estimated the instability in Indian food production using the coefficient of variation, Farih (1996) adopted the standard deviation and coefficient of variation for studying the instability in agricultural production in Sudan. Singh (1989) and Gangwar and Singh (1991) used the coefficient of variation when investigating agricultural instability and farm poverty in India.

The contribution of different components to agricultural production variation was analyzed following Goodman (1960) and Bohrnstedt and Goldberger (1969), the variance of agricultural production $V(P)$, can be expressed as

$$V(P) = \overline{A}^2 V(Y) + \overline{Y}^2 V(A) + 2\overline{A}\,\overline{Y}\mathrm{cov}(A, Y) - \mathrm{cov}^2(A, Y) + R \quad (1)$$

where $\overline{A}$ and $\overline{Y}$ denote the mean area and yields and R is a residual term. Clearly, a change in any one of these components will lead to a change in $V(P)$ between two periods in time. Similarly, average production, $E(P)$ can be expressed as:

$$E(P) = \overline{A}\,\overline{Y} + \mathrm{cov}(A, Y) \quad (2)$$

It is affected by changes in the covariance between area and yield and by changes in mean area and mean yield. The objective of the decomposition analysis is to partition the changes in $V(P)$ and $E(P)$ between the first and the second periods into constituent parts, which can be attributed separately to changes in the means, variances and covariances of area and yield.

2.1. Method of decomposition of average production

Using Eq. (2), average production in the first period is

$$E(P_1) = \overline{A}_1\overline{Y}_1 + \mathrm{cov}(A_1, Y_1) \quad (3)$$

and in the second period is

$$E(P_2) = \overline{A}_2\overline{Y}_2 + \mathrm{cov}(A_2, Y_2) \quad (4)$$

Each variable in the second period can be expressed as its counterpart in the first period plus the change in the variable between the two periods. For example,

$$\overline{A}_2 = \overline{A}_1 + \Delta\overline{A}$$
$$\overline{Y}_2 = \overline{Y}_1 + \Delta\overline{Y}$$
$$\mathrm{Cov}(A_2, Y_2) = \mathrm{Cov}(A_1, Y_1) + \Delta\mathrm{Cov}(A, Y)$$

Eq. (4) can, therefore be rewritten as:

$$\begin{aligned} E(P_2) &= (\overline{A}_1 + \Delta\overline{A})(\overline{Y}_1 + \Delta\overline{Y}) + \mathrm{Cov}(A_1, Y_1) \\ &\quad + \Delta\mathrm{Cov}(A, Y) \\ &= \overline{A}_1\overline{Y}_1 + \overline{A}_1\Delta\overline{Y}_1 + \overline{Y}_1\Delta\overline{A}_1 + \mathrm{Cov}(A_1, Y_1) \\ &\quad + \Delta\mathrm{Cov}(A, Y) \end{aligned} \tag{5}$$

The change in average production, $\Delta E(P)$ is then obtained by subtracting Eq. (3) from Eq. (5). Thus,

$$\begin{aligned} \Delta E(P) &= E(P_2) - E(P_1) \\ &= \overline{A}_1\Delta\overline{Y} + \overline{Y}_1\Delta\overline{A} + \Delta\overline{A}\Delta\overline{Y} + \Delta\mathrm{Cov}(A, Y) \end{aligned} \tag{6}$$

which can be arranged as in Table 1.

2.2. Methods of decomposition of the changes in variance of production

In this section, we will construct a method to partition the changes in variance of production ($V(P)$) between the first and the second periods into its constituent parts.

As shown in Eq. (1), the variance of production, $V(P)$ can be expressed as,

$$V(AY) = \overline{A}^2V(Y) + \overline{Y}^2V(A) + 2\overline{A}\,\overline{Y}\mathrm{Cov}(A, Y) - \mathrm{Cov}^2(A, Y) + R$$

Using Eq. (1), variance of production in the first period is

$$\begin{aligned} V(P_1) &= \overline{A}_1^2V(Y_1) + \overline{Y}_1^2V(A_1) + 2\overline{A}_1\overline{Y}_1\mathrm{cov}(A_1, Y_1) \\ &\quad - \mathrm{cov}^2(A_1, Y_1) + R_1 \end{aligned} \tag{7}$$

and in the second period is

$$\begin{aligned} V(P_2) &= \overline{A}_2^2V(Y_2) + \overline{Y}_2^2V(A_2) + 2\overline{A}_2\overline{Y}_2\mathrm{cov}(A_2, Y_2) \\ &\quad - \mathrm{cov}^2(A_2, Y_2) + R_2 \end{aligned} \tag{8}$$

each variable in the second period can be expressed as its counterpart in the first period plus the change in the variable between the two periods, i.e.,

Sources of change	Symbol	Components of change
Change in mean yield	$\Delta\overline{Y}$	$\overline{A}_1\Delta\overline{Y}$
Change in mean area	$\Delta\overline{A}$	$\overline{Y}_1\Delta\overline{A}$
Interaction between changes in mean yield and mean area	$\Delta\overline{A}\Delta\overline{Y}$	$\Delta\overline{A}\Delta\overline{Y}$
Change in area–mean covariance		$\Delta\mathrm{cov}(A, Y)$

Table 1 Components of change in average production.

$$\overline{A}_2 = \overline{A}_1 + \Delta\overline{A}$$
$$\overline{Y}_2 = \overline{Y}_1 + \Delta\overline{Y}$$
$$V(A_2) = V(A_1) + \Delta V(A)$$
$$V(A_2) = V(A_1) + \Delta V(A)$$
$$V(A_2) = V(A_1) + \Delta V(A)$$
$$V(Y_2) = V(Y_1) + \Delta V(Y)$$
$$\mathrm{Cov}(A_2, Y_2) = \mathrm{Cov}(A_1, Y_1) + \Delta\mathrm{cov}(A, Y)$$

Eq. (8) can, therefore, be rewritten as

$$\begin{aligned} V(P_2) &= \{\overline{A}_1 + \Delta\overline{A}\}^2\{V(Y_1) + \Delta V(Y)\} + \{\overline{Y}_1 \\ &\quad + \Delta\overline{Y}\}^2\{V(A_1) + \Delta V(A)\} + 2\{\overline{A}_1 + \Delta\overline{A}\}\{\overline{Y}_1 \\ &\quad + \Delta\overline{Y}\}\{\mathrm{Cov}(A_1, Y_1) + \Delta\mathrm{cov}(A, Y)\} \\ &\quad - \{\mathrm{Cov}(A_1, Y_1) + \Delta\mathrm{cov}(A, Y)\}^2 + \{R_1 + \Delta R\} \end{aligned} \tag{9}$$

which can be expressed as

$$\begin{aligned} V(P_2) &= \overline{A}^2V(Y_1) + 2\overline{A}_1\Delta\overline{A}V(Y_1) + \Delta\overline{A}^2V(Y_1) \\ &\quad + \overline{A}_1\Delta V(Y) + 2\overline{A}_1\Delta\overline{A}\Delta V(Y) + \Delta\overline{A}^2\Delta V(Y) \\ &\quad + \overline{Y}_1^2V(A_1) + 2\overline{Y}_1\Delta\overline{Y}V(A_1) + \Delta\overline{Y}^2V(A_1) \\ &\quad + \overline{Y}_1^2\Delta V(A) + 2\overline{Y}_1\Delta\overline{A}\Delta V(A) + \Delta\overline{A}^2\Delta V(A) \\ &\quad + 2\overline{A}_1Y_1\mathrm{Cov}(A_1, Y_1) + 2\overline{A}_1\Delta\overline{Y}\mathrm{Cov}(A_1, Y_1) \\ &\quad + 2\Delta\overline{A}_1, \overline{Y}_1\mathrm{Cov}(A_1, Y_1) + 2\Delta\overline{A}\Delta\overline{Y}\mathrm{Cov}(A_1, Y_1) \\ &\quad + 2\overline{A}_1, \overline{Y}_1\Delta\mathrm{cov}(A, Y) + 2\overline{A}_1\Delta\overline{Y}\Delta\mathrm{Cov}(A, Y) \\ &\quad + 2\Delta\overline{A}\overline{Y}_1\Delta\mathrm{cov}(A, Y) + 2\Delta\overline{A}_1\Delta\overline{Y}\Delta\mathrm{Cov}(A, Y) \\ &\quad - \mathrm{Cov}^2(A_1, Y_1) - 2\mathrm{Cov}(A_1, Y_1)\Delta\mathrm{cov}(A_1, Y_1) \\ &\quad - \mathrm{cov}^2(A, Y) + R_1 + \Delta R \end{aligned} \tag{10}$$

The change in variance of production, $\Delta V(P)$ is then obtained by subtracting Eq. (7) from Eq. (10). Thus

$$\begin{aligned} \Delta V(P) &= V(P_2) - V(P_1) \\ &= 2\overline{A}_1\Delta\overline{A}V(Y1) + \Delta\overline{A}^2V(Y_1) + \overline{A}_1^2\Delta V(Y) \\ &\quad + 2\overline{A}_1\Delta\overline{A}\Delta V(Y) + \Delta\overline{A}^2\Delta V(Y) + 2\overline{Y}_1\Delta\overline{Y}V(A_1) \\ &\quad + \Delta\overline{Y}^2V(A_1) + \overline{Y}_1^2\Delta V(A) + 2\overline{Y}_1\Delta\overline{A}\Delta V(A) \\ &\quad + \Delta\overline{A}^2\Delta V(A) + 2\overline{A}_1\Delta\overline{Y}\mathrm{Cov}(A_1, Y_1) \\ &\quad + 2\Delta\overline{A}_1, \overline{Y}_1\mathrm{Cov}(A_1, Y_1) + 2\Delta\overline{A}\Delta\overline{Y}\mathrm{Cov}(A_1, Y_1) \\ &\quad + 2\Delta\overline{A}_1, \overline{Y}_1\mathrm{Cov}(A, Y) + 2\Delta\overline{A}_1, \overline{Y}\mathrm{cov}(A, Y) \\ &\quad + 2\Delta\overline{A}, \overline{Y}_1\mathrm{Cov}(A, Y) + 2\Delta\overline{A}\Delta\overline{Y}\Delta\mathrm{cov}(A, Y) \\ &\quad - \mathrm{Cov}(A_1, Y_1)\Delta\mathrm{cov}(A, Y) - \Delta\mathrm{cov}^2(A, Y) \\ &\quad + \Delta R \end{aligned} \tag{11}$$

which can be arranged as in Table 2.

3. Results and discussion

3.1. Measurement of instability in area and yield

Instability in production of principal crops is expected to be caused by instability in area and productivity. If the instability in both components declined, the instability in production has to be declined. The standard deviations (SD) of area and productivity of principal crops were computed and is presented

Table 2 Components of change in the variance of agricultural production.

Source of change	Symbol	Components of change
Change in mean yield	$\Delta\overline{Y}$	$2\overline{A}_1\Delta\overline{Y}\text{cov}(A_1, Y_1) + \{2\overline{Y}_1\Delta\overline{Y} + (\Delta\overline{Y})^2\}V(A_1)$
Change in mean area	$\Delta\overline{A}$	$2\overline{Y}_1\Delta\overline{A}\text{cov}(A_1, Y_1) + \{2\overline{A}_1\Delta\overline{A} + (\Delta\overline{A})^2\}V(Y_1)$
Change in yield variance	$\Delta V(Y)$	$\overline{A}_1^2\Delta V(Y)$
Change in area variance	$\Delta V(A)$	$\overline{Y}_1^2\Delta V(A)$
Interaction between changes in mean yield and mean area	$\Delta\overline{Y}\Delta\overline{A}$	$2\Delta\overline{Y}\Delta\overline{A}\text{cov}(A_1, Y_1)$
Change in area–yield covariance	$\Delta\text{cov}(A, Y)$	$\{2\overline{A}_1\overline{Y}_1 - 2\text{cov}(A_1, Y_1)\}\Delta\text{cov}(A, Y) - \{\Delta\text{cov}(A, Y)\}^2$
Interaction between changes in mean area and yield variance	$\Delta\overline{A}\Delta V(Y)$	$\{2\overline{A}_1\Delta\overline{A} + (\Delta\overline{A})^2\}\Delta V(Y)$
Interaction between changes in yields and area variance	$\Delta\overline{Y}\Delta V(A)$	$\{2\overline{Y}_1\Delta\overline{Y} + (\Delta\overline{Y})^2\}\Delta V(A)$
Interaction between changes in mean area and yield and changes in area–yield covariance	$\Delta\overline{Y}\Delta\overline{A}\Delta\text{cov}(A, Y)$	$\{2\overline{Y}_1\Delta\overline{A} + 2\overline{A}_1\Delta\overline{Y} + 2\Delta\overline{A}\Delta\overline{Y}\}\Delta\text{cov}(A, Y)$
Change in residual	ΔR	$\Delta(AY)$ − sum of the other components

Table 3 Instability in area and productivity of principal crops in the Gezira scheme (percent).

Crop	Period I	Period II
Sorghum		
A[a]	21.28	28.52
Y[b]	21.20	26.96
Wheat		
A	33.28	26.05
Y	41.24	41.41
Cotton		
A	14.28	28.38
Y	28.28	43.50
Groundnuts		
A	72.65	15.71
Y	19.09	24.31

Source: Author's calculations.
[a] Area.
[b] Yield.

in Table 3. It is interesting to observe that instability in area and productivity in some of the crops fluctuated in the same direction, i.e., if there is an increase/decrease in instability in the area of particular crop, the instability in productivity also increases/decreases. It has been observed that the instability in the area and productivity of sorghum and cotton in Gezira increased simultaneously from period I to period II. Some crops showed fluctuations in the opposite direction, i.e., if there is an increase/decrease in instability in the area of a particular crop, the instability in productivity decreases/increases. The instability in area of wheat and groundnuts in Gezira decreased in period II, while instability of productivity increased in the same period.

Table 4 Instability in crop production in the Gezira scheme during the two periods (percent).

Crop	Period I	Period II
Sorghum	41.53	51.04
Wheat	33.45	52.53
Cotton	33.09	46.68
Groundnuts	57.02	34.27

Source: Author's calculations.

As discussed earlier, the instability in area and productivity generally move in the same direction, but area instability is generally lower than the productivity instability for most crops.

3.2. Measurement of instability in production

Instability in production of principal crops is expected to be caused by instability in area and productivity. Table 4 indicates that the standard deviation of sorghum production was estimated to be 41.53% in the first period, and increased to 51.04% in the second period. Fluctuations in wheat production was lower than that in sorghum, it recorded 33.45% and 52.53% during the first and the second period, respectively. Fluctuations in cotton production increased from 33.09% to 46.68% in the second period. Fluctuations of groundnuts production declined in period II from 57.02 to 34.27.

On the basis of the above results, it may be concluded that crop production fluctuation declined in the second period in groundnuts while fluctuations increased in other crops during the second period. Groundnuts was the only crop that its fluctuations decreased in the second period. Sorghum and wheat instability increased during the second period.

3.3. Sources of changes in mean production

The decomposition analysis identified four sources of change in the mean production. These sources were change in mean yield, change in mean area, interaction between changes in mean yield and mean area, and change in area–yield covariance. The magnitude of change in mean production after the adoption of prices liberalization policy and the relative contribution of different sources to change in mean production in Gezira are presented in Table 5. The increase in production was observed in sorghum, wheat and groundnuts. Cotton witnessed a decrease in average production in the second period. The decrease in production of cotton was mainly attributed to decrease in area. The increase in area and yield, increased the production of groundnuts. The increase in production of wheat was mainly attributed to increase in yield. The contribution of change in area–yield covariance in growth of production was very small. The contribution of interaction between changes in mean yield and mean area was negative in case of sorghum and positive in case of wheat, groundnuts and cotton.

Table 5 Components of change in the mean production of individual crops in the Gezira scheme during the study period (percent).

Source of change	Sorghum	Wheat	Cotton	Groundnuts
Change in mean yield	163.74	409.77	8.32	8.50
Change in mean area	−39.87	−452.38	90.78	80.05
Change in area–yield covariance	−18.28	−41.10	−3.52	2.94
Interaction between changes in mean yield and mean area	−5.59	183.71	4.41	8.50

Source: Author's calculations.

Table 6 Components of change in the variance of production of individual crop in the Gezira scheme during the study period (percent).

Source of change	Wheat	Cotton	Groundnuts	Sorghum
Change in mean yield	−26.03	2.94	−19.87	305.14
Change in mean area	9.35	59.27	−26.23	−49.95
Change in yield variance	4.27	27.31	−60.12	327.12
Change in area variance	129.13	−0.13	151.13	−25.82
Interaction between changes in mean yield and mean area	−0.23	−0.51	0.08	−10.25
Change in area, yield covariance	−69.10	46.93	−167.90	−199.88
Interaction between change in mean area and yield covariance	−0.81	−18.22	−48.63	−68.99
Interaction between change in mean yield and area covariance	24.59	0.01	11.28	−29.11
Interaction between change in mean area and yield and change in area yield covariance	1.29	−20.97	−67.33	−59.57
Change in residual	27.55	3.36	327.61	−88.68

Source: Author's calculations.

3.4. Source of change in variance of production

Table 6 shows the components of change in variance of production of individual crops, which have been obtained by using the equations in Table 2. Changes in the variance of yield accounted for large shares of the changes in variance of production for sorghum. It accounted for 327.12% of increase in the variance of production of sorghum. This large share of change in variance of production was also consistent with large increase in the standard deviation of yield of sorghum production as depicted in Table 5. Changes in mean area accounted for 59.27% in cotton production, 9.35% in wheat production. The contribution of change in mean area for groundnuts and sorghum was negative, it accounted for −26.23% and −49.95%, respectively. The change in mean area had little effect on the stability of production of wheat but it acted to reduce the variability in case of groundnuts and sorghum. Changes in mean yields accounted for large shares in sorghum and had little effect on the stability of production of cotton but they acted to reduce the variability in case of wheat and groundnuts. Changes in variance of area accounted for large shares of the changes in variance of production for wheat and groundnuts. They accounted for 129.13% and 151.13%, respectively but they acted to reduce the variability in case of cotton and sorghum. Changes in the covariances between areas and yield had stabilizing effect on the production of wheat, groundnuts and sorghum. However, changes in area–yield covariances, accounted for about 46.93% of the increase in variance of cotton production. Table 6 further reveals that the interaction terms were not important in explaining the changes in the variance of production. Interaction between changes in mean yield and area covariance in wheat accounted for 24.59% and in groundnuts (11.28%). Finally, changes in the residual terms were important in explaining the changes in the variance of crop production in case of groundnuts (327.61%), and in case of sorghum it reduced the variability of production.

4. Conclusion

The study of instability indicated that the principal crops, sorghum, wheat and cotton witnessed a continuous increase in instability over the two sub-periods under study. The instability in groundnut production witnessed a decrease during post-liberalization period.

It is also worth pointing out that the instability in area and yield of almost all crops moved in the same direction and their increasing/decreasing trend resulted in increase/decrease in instability. Hence, it may be said that the increase in production of a particular crop due to a spectacular increase in area and productivity would accompany the increase in instability also, but an increase in production largely due to the increase in yield would help declining production instability.

The decomposition analysis of sources of change in mean production of principal crops in Gezira, indicated that changes in mean yield accounted for large shares of the change in mean production of wheat and sorghum, but change in mean area contribution was large in case of cotton and groundnuts.

The analysis of decomposition also indicated that changes in the variance of yields accounted for large shares of the changes in variance of production for sorghum. Changes in the variance of area accounted for large shares for wheat. The changes in the residual term were important in explaining the changes in the variance of production in case of groundnut. It is clear from the above discussion that the change in the base (mean area and mean yield), yield variability and simultaneous changes in area and yield led to increase in the absolute production instability (variance). Individually, yield variability was an important source of instability in most of the crops. The changes in yield might have caused the changes in area and this led to higher area-yield covariability. The larger contribution of interaction terms indicated that the simultaneous changes in area and yield further accentuated the production instability. In order to achieve stability in agricultural production, the study recommended rehabilitation of irrigation canals, provision of inputs and strengthening the agricultural research and extension.

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