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The potency of horizontal and vertical expansion on food output growth in Sudan: A causality analysis, 1962-2000

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ABSTRACT

Against the background of the persistent low productivity and yield in Sudanese agriculture, this paper assesses the performance of various medium-tem plans and programs encapsulated in the national development strategies between 1962 and 2000 vis-à-vis the declared objective of achieving national food security through horizontal and vertical expansion in food production. For this purpose, Hsiao (1979,1981) procedure is used, which combines Granger (1969) causality test procedure and Akaike (1969) final prediction error criterion, to test for causality between growth in output on one hand and growth in area (horizontal expansion) and growth in yield (vertical expansion) on the other hand for three major food crops in Sudan, namely, sorghum, wheat and millet. The results reveal that, in the case of sorghum, it is growth in yield (and not expansion in area) which causes growth in output, while in the case of wheat, neither growth in yield nor expansion in area cause growth in output. The best results are obtained for millet, a crop grown mainly in the traditional sector, where a two-way causality is found between output growth on one hand and growth in yield and expansion in area on the other hand. These results provide the important policy lesson that development strategies should focus more on vertical expansion. Agricultural production and productivity could be increased through the allocation of more investment resources to the sector, not only for the promotion of human capital via the improvement of education, health, and extension services as well as management skills, but also for the provision of adequate infrastructure such as roads, irrigation, research, and markets. It is also argued that such a strategy of vertical expansion is not only viable from an economic point of view since it considerably reduces production cost and improves profitability and international competitiveness, but is also sound in so far as the sustainability of the resources and the environment is concerned.

INTRODUCTION

Owing to its importance in economic structure and food security, the development of the agricultural sector in developing economies plays an exceptionally vital role in establishing the appropriate framework for industrialization and take-off into self-sustained growth. Thus, for instance, agriculture in these countries must generate a steadily rising surplus of food production over and above subsistence levels of farmers to provide food for a growing urban (industrial) population so that starvation is not a threat to the industrial labour force. To achieve this end, the alternatives available for policyrmakers include increasing land under cultivation (horizontal expansion),improving land yield and agricultural labour productivity (vertical expansion), and controlling population growth. Given social ethics that prevail in developing countries, the option of adopting a population policy that aims at controlling population growth may seem to be implausible and unattractive. Furthermore, although a significant improvement of agricultural labour productivity and/or land yield constitutes the most crucial and indispensable priority in so far as long-term development strategy is concerned, yet most developing countries have failed to realize such an objective. Thus, in practice, governments in these countries are left with the easy option of increasing output via horizontal expansion in area under cultivation.

In the Sudan, almost all development strategies have focused on both horizontal and vertical expansion of agriculture with the implicit objective of establishing the appropriate framework for industrialization and take-off into self-sustained growth. In practice, however, while tremendous increases in area under cultivation has been achieved, little or no progress has been made in improving land yield and/or labour productivity with a view of generating a steadily growing agricultural surplus.

The present paper assesses the relative importance of horizontal and vertical expansion to food output growth in Sudan over the last four decades (1962-2000). The analysis will focus on output growth of sorghum, wheat, and millet as they constitute the most important staple food crops for the majority of Sudanese people. For each of these crops we examine causality between output growth on one hand and each of the policy variables on the other hand, viz. horizontal expansion (as measured by growth in area under cultivation) and vertical expansion (as measured by the growth in land yield).

In line with the current trend in the literature, we adopt a rather simple and straightforward approach for data analysis. In particular we apply Granger-type of causality methods to annual time-series data covering the period 1962-2000 to examine the causality between any. of these policy variables and output growth. The results reveal that neither the expansion in area nor the growth in yield per feddan causes growth in wheat output, a crop mainly grown in the modern sector. In contrast, the expansion in area and growth in yield per feddan each causes growth in the output of millet, a crop grown mainly in the neglected traditional sector. More importantly, the expansion in area does not cause growth in the output of sorghum, by far the for dominant food crop. Therefore, it is not surprising that millet plantation, which is a predominantly small holders' crop, performed better than sorghum, which is a large plantation crop. These results suggest that large- scale plantations are not rewarding in so far as output growth is concerned. Instead, horizontal expansion may have negative impact human health and the environment at large, since such plantations create the right environment for the spread of water-borne diseases which affect human health and reduce labour productivity.

A background on agricultural productivity in Sudan

Sudan is the largest country in Africa with a total area of 597 million feddans (equivalent to 251 million hectares), of which nearly 86.0 million feddans (14.4%) are arable land. Despite its abundant water endowments, it is estimated that up to 1998/99, only 31.1 million feddans.(36.4%) of the total arable land were under cultivation (Bank of Sudan Annual Report, 1999). Despite this, the agricultural sector remains the backbone of the Sudanese economy. Currently contributes nearly 49.0% of the country's gross domestic product and accounts for over 62% of export revenues. Furthermore, agriculture provides employment opportunities for over 70% of the labour force and constitutes the main source of income for over 80% of the population. In addition, the sector supplies nearly all the raw materials for Sudanese agro-industries such as sugar, textile and food processing, and plays a vital role in national food security.

Characteristic of the Sudan is its huge endowments of natural resources. Notwithstanding, Sudan has suffered from a food insecurity problem since mid 1970s. Efforts have been made as part of the national development strategies to combat the problem. During the 1960s and 1970s, these strategies encapsulated various medium-term plans and programs, including the Ten-Year plan (1961-1970), the Five-Year Plan (1970/71-1974/75), and the Six-Year Plan (1975/76-1980/81). Over the 1980s and early 1990s, these programs included the First Three-Year Investment Program (1979/80-1981/82), the Second Three- Year Investment Program (1982/83-1984/85), and the Four-Year Salvation and Recovery Program (1988/89-1991/92), and more recently the Comprehensive National Strategy (1990/91-2002). A central national objective of these plans and programs has been the realization of self-sufficiency in food via both horizontal and vertical expansion.

Table 1 displays land distribution by major crops (excluding gum Arabic) for three relatively recent agricultural seasons. We observed that sorghum is the most dominant crop, occupying on average 47.1% of the total area under the main crops while millet and wheat occupy 23.3% and 1.4%, respectively. The three crops together occupy nearly 72.0% of the total area, typifying the importance attached to horizontal expansion in these cereals for national food security.

Table 1. Land distribution by major crops, 1998-2000 (000 ha).

Crop	Annual average	Share (%)
Millet	2655	23.3
Sorghum	5383	47.1
Wheat	163	1.4
Other	3220	28.2
Total	11420	100.0

Source: Own calculations based on data from Bank of Sudan Annual Reports.
The category 'Other' includes sesame, groundnuts, and sunflower.

With regard to the type of technology adopted, the agricultural sector in the Sudan is divided into three sub-sectors, viz. modern irrigated, mechanized rainfed, and traditional rainfed (which includes livestock) sub-sectors. The modern irrigated subsector produces cotton, groundnut, sorghum, wheat, and sugarcane, in addition to vegetables and horticultural crops. The mechanized rainfed sector extends horizontally along the Savanna belt to include parts of the eastern, central and western states. The main crops grown in this subsector are sorghum and sesame, with almost equal shares in total area of the sector. The traditional rainfed sector produces millet, sorghum, sesame, groundnut, and gum Arabic, in addition to livestock raising. In terms of geographical coverage, the sector is pervasive and is found in almost all parts of the Sudan.

Based on its inherent low labour productivity and land yield, it is often argued that the agricultural sector in the Sudan is far from being an economically viable sector. The evidence in this regard suggests that yield per hectare in Sudanese agriculture falls well below that of highest-yield countries. For example, the data in Table 2 indicate that yield per hectare of wheat and sorghum represents, respectively, 30% and 10.2%% of that in Egypt. Furthermore, yield per hectare of millet represents 12.8% of that in China. The weighted average yield for millet, sorghum, and wheat in Sudan during 1998-2000 represents only 27.0% of that in highest-yield countries during 2000-2002.

Table 2. Yield in Sudanese agriculture relative to highest yield countries (kg/ha).

Crop	Sudan average (1998-2000)	Highest yield average		Sudan as % of highest yield
		(2000-2002)	Country	
Millet	226.7	1764.9	China	12.8
Sorghum	579.2	5654.2	Egypt	10.2
Wheat	1880.2	6235.2	Egypt	30.2
Weighted average	1460.1	5416.8		27.0

Source: Own calculations based on data from Bank of Sudan Annual Reports.

In the context of agricultural development strategies, various governments have consistently declared the objective of achieving self-sufficiency in food. In addition to economy wide and sector-specific policies, expansion in cultivated area characterized the set of policy instruments that have been adopted towards realizing this objective. The available evidence suggests that while area under food crops has increased, little or no effort has been made to bring about the expected increase in land yield and/or labour productivity. The question posed in this paper is whether this horizontal expansion has been more important to food output growth than vertical expansion.

STATISTICAL METHODOLOGY AND DATA

According to Granger (1969), the procedure of testing for causality between two variables, say (Y) and (X), involves estimating the following regression equations:

$$Y_t = \theta + \sum_{j=1}^{h} \beta_j Y_{t-j} + \sum_{i=1}^{k} \alpha_i X_{t-j} + \varepsilon_t \qquad (1)$$

$$X_t = \emptyset + \sum_{i=1}^{p} \delta\, Y_{t-j} + \sum_{i=1}^{q} \lambda_i\, X_{t-i} + \xi_t \qquad (2)$$

Where ε_t and ξ_t are white-noise error processes and h, k, p and q denote the number of lagged variables in the regressions. Granger procedure is based on obtaining the ordinary least squares estimates of the parameters of equations (1) and (2) and applying the conventional Wald F-test of joint statistical significance. For purposes of detecting the existence and direction of Granger causality, three cases are distinguished. The first is the case of unidirectional causality, which involves two sub-cases: Either causality from (X) to (Y), or vise versa. One-way causality from (X) to (Y) is indicated if the estimated coefficients of the lagged (X) variable in Equation (1) are significantly different from zero as a group ($\sum \alpha_i \neq 0$) and the estimated coefficients on the lagged (Y) variable in Equation (2) are not significantly different from zero as a group ($\sum \delta_j = 0$). Conversely, unidirectional causality from (Y) to (X) exists if the estimated coefficients of the lagged (X) variable in Equation (1) are not statistically different from zero as a group ($\sum \alpha_i = 0$) and the estimated coefficients on the lagged (Y) variable in Equation (2) are statistically different from zero as a group ($\sum \delta_{j \neq 0}$). Second, bilateral (feedback) causality exists when the coefficients of lagged (Y) and (X) variables are statistically different from zero in both regressions. More formally, causality from (Y) to (X) coexists with causality from (X) to (Y) if the hypotheses $\sum \alpha_i \neq 0$ and $\sum \delta_j \neq 0$ are accepted for both equations. Third, independence of the two variables is suggested when the coefficients of lagged variables (Y) and (X) are not statistically different from zero in both regressions ($\sum \alpha_i = 0$ and $\sum \delta_j = 0$).

It has been a common practice in many causality studies not only to select the lag length on ad hoc basis, but also to restrict all variables in the regression to the same lag order. Hsiao (1979, 1981) and Thornton and Batten (1985), however, produced an evidence suggesting that the results of Granger procedure for testing causality are sensitive to the selected lag structure (i.e., number of lags) of the independent variables and that an ad hoc choice of such a structure can give rise to misleading results. For this reason, Hsiao (1979, 1981) proposed an alternative test procedure that combines Granger (1969) causality test and the final prediction error criterion as developed by Äkahke ('1969). In the absence of prior knowledge of the lag order and their combinations in an equation, this procedure has the advantage over Granger's method in that it allows the data to determine the optimal lag length for each variable.

According to Hsiao's (1979, 1981) procedure, we first assume that (Y) is the only output of the system and then perform a series of autoregressive regressions on (Y) beginning with one lag and adding one more lag in each successive regression. Suppose that these regressions range from one up to some order, say n. For each of these autoregressive regressions, calculate the final prediction error (FPE) using the formula:

$$FPE(n) = [(T+n+1)/(T-n-1)][RSS(n)/T]$$

where T is the sample size, and RSS(n) is the conventional residual sum of squares with (n) lags. The optimal lag order (n*) is the one corresponding to the autoregressive regression with the minimum FPE(n*). Secondly, take the equation for (Y) with (n*) lags and perform regressions with lagged values of (X) added sequentially. Suppose that there are (m) such regressions. For each regression, compute the final prediction error using the formula:

$$FPE(n^*, m) = [(T + n^* + m + 1)/(T - n^* - m - 1)][RSS(n^*.m)/T]$$

From these regressions, the optimal lag (m*) for the manipulated variable (X) is defined as the one which produces the smallest FPE(n*, m*). Having done so, testing for causality is a straightforward exercise which involves a comparison between FPE(n*) and FPE(n*, m*). In particular, if FPE(n*, m*) is smaller than FPE(n*), it is said that (X) Granger-causes (Y), while if the converse is true, then (X) does not Granger-cause (Y). Repeating the same procedure with (X) as the controlled variable and (Y) as the manipulated variable, we can test whether (Y) causes (X) or not. This is the statistical methodology that is adopted in this paper.

Because the presence of serial correlation in time series data of variables on both sides of an equation can give rise to biased results (Granger and Newbould, 1974), it has become a common practice to pre-filter the data series. According to Nerlove (1964), Sims (1972) and Kraft and Kraft (1977), a filter that is quite sufficient to produce a series of uncorrelated residuals takes the form (1 - Kδ) v, where K equals 0.75, $\delta = X_{t-1}/X_{t,}$ and v = 1,2, or 3, However, since no problem of serially correlated residuals has been detected in the series for each crop, we have used the original time series data for our purposes. Moreover, since the causality test requires stationarity in the data while time series data is hardly stationary, we transformed the dynamic series by using the growth rates of variables in the regressions. Indeed, a number of linear transformations such as differencing and log transformations have been attempted with no significant change in the results. According to Pierce and Haugh (1977), such linear transformations do not remove any causal relationship if it exists in the original series. Finally, to produce zero means of the jointly covariance stationary processes, a constant term has been included in the regression equations. The data employed in the analysis are annual time-series for the period 1962-2000 obtained from various issues of the Bank of Sudan annual reports.

RESULTS AND DISCUSSION

The first step in our analysis is to determine the lag structure of all variables over the entire sample. For this purpose, one-dimensional autoregressive regressions were estimated with an upper bound of 5 lags for each variable, after which the final prediction error (FPE) started to rise. The results reported in Tables 1, 3 and 5 give the best FPEs of the one-dimensional autoregressive processes for sorghum, wheat and millet, respectively.

The second step of the analysis is to fix the number of lags in the controlled variable, as has been determined in the first step, and perform regressions with lagged values of the manipulated variable added sequentially to determine the final prediction error of the bivariate regressions. A summary of these results is given in Tables 2, 4 and 6 for sorghum, wheat and millet, respectively. For all crops, the

Table 3. FPEs of one-dimensional autoregressive processes for output, area and land yield of sorghum.

	Final prediction error of controlled variables		
n	Y	N	y
1	0.462856	0.050763*	0.135326
2	0.427819*	0.051258	0.118381*
3	0.454464	0.055014	0.129098
4	0.472901	0.056692	0.139873
5	0.513017	0.061016	0.152672

Sources. Own calculations. Stars denote the minimum prediction error of the autoregressive process, (n) denotes the lag order.

Table 4. Summary of causality results for sorghum.

Controlled variable	Manipulated variable	FPE (n*)	FPE (n* , m*)	Causality results
Y (2)	N (1)	0.427819	0.445752	Area does not cause output
N (1)	Y (2)	0.050763	0.050754	Output causes area
Y (2)	Y (1)	0.427819	0.417658	Yield causes output
Y (2)	Y (1)	0.118381	0.124988	Output does not cause yield

Source: Own calculations. Figures in parentheses are the optimal lag orders of variables.

Table 5. FPEs of one-dimensional autoregressive processes for output, area and yield of wheat.

	Final prediction error of controlled variables		
n	Y	N	y
1	0.161287	0.269347	0.063464
2	0.175198	0.282161	0.061227
3	0.190988	0.307793	0.066735
4	0.203024	0.277265	0.065240
5	0.222257	0.300564	0.070038

Sources. Own calculations. Stars denote the minimum prediction error of the autoregressive process, (n) denotes the lag order.

F-statistic indicates the significance of the autoregressive processes and bivariate regressions, while the Durbin-Watson test statistic is estimated around the value 2.00 for all regressions, suggesting the absence of auto-correlation in either the autoregressive processes or the bivariate regressions.

Table 6. Summary of causality results for wheat.

Controlled variable	Manipulated variable	FPE (n*)	FPE(n* m*)	Causality results
Y (1)	N (1)	0.161287	0.169996	Area does not cause output
N (1)	Y (1)	0.269347	0.278651	Output does not cause area
Y (1)	Y (1)	0.161287	0.169417	Yield does cause output
Y (2)	Y (2)	0.061227	0.061995	Output does not cause yield

Source: Own calculations. Figures in parentheses are the optimal lag orders of variables.

In view of the results in Tables 3 and 4 for sorghum, we observe the existence of a one-way causality running from output growth (Y) to expansion in area (N). However, the results also indicate that the expansion in area (N) does not Granger-cause growth in output of sorghum (Y), the dominant food crop in Sudan. Thus, while growth in sorghum output causes expansion in area, the latter does not significantly cause the former. In conclusion, these results provide a strong evidence for the contention that vertical expansion in sorghum is the all important for growth in output of that crop.

With regard to wheat, the results in Tables 5 and 6 suggest the absence of any causality between output growth (Y) and expansion in area (N), or vice versa. The reasons behind these results may be traced back to the strong belief among farmers and policymakers alike that the environmental conditions in the areas where wheat is grown are not conducive for the plantation of this crop. Thus, as long as these conditions persist, neither horizontal expansion nor vertical expansion will pay off in so far as the growth in wheat output is concerned.

The best causality results are obtained for millet, as reported in Tables 7 and 8. In contrast to wheat, these results indicate the existence of causality between variables in all directions. Thus, a two-way causality is detected between the expansion in area and growth in millet output as well as between growth in yield and growth in output.

Table 7. FPEs of one-dimensional auto regressive processes for output, area and yield of millet.

n	Final prediction error of controlled variables		
	Y	N	y
1	0.739798	0.256295	0.217669
2	0.698501	0.229099	0.235818
3	0.556709	0.213944	0.255525
4	0.584872	0.231344	0.273758
5	0.612983	0.250652	0.293831

Source: Own calculations. Stars denote the minimum final prediction error of the autoregressive process, (n) denotes the lag order.

Table 8. Summary of causality results for millet.

Controlled variable	Manipulated variable	FPE (n*)	FPE (n ,m*)	Causality results
Y(3)	N(6)	0.556709	0.365463	Area causes output
N(3)	Y(3)	0.213944	0.193189	Output causes area
Y(3)	Y(3)	0.556709	0.363307	Yield causes output
Y(1)	Y(3)	0.217669	0.211713	Output causes yield

Source: Own calculations. Figures in parentheses are the optimal lag orders variables.

The most important policy lesson that these results provide is best argued by Schultz (1964), who made it clear that strategies for sustainable agricultural development should focus more on vertical expansion. Owing to the inherent characteristics of traditional agriculture as manifested in the very low rates of return at the margin additional quantities of existing inputs (including expansion in land acreage) will achieve nothing. The most practical and economical approach to realizing a sizeable increase in agricultural productivity lies in enhancing the efficiency of the existing agricultural economy through improvements in the quality of inputs, and by the application of advances in knowledge and modern technology. Thus, with the cultivation of high-yield varieties in a given area of land, the scope for yield increases and the rates of return on investment in new technologies and high-yield varieties become high. Transforming the traditional methods in agriculture, however, is not simply a matter of introducing new inputs. What matters most in the transformation process is the role of economic policy that provides the right incentives for the application of new inputs and for agriculture to attract an adequate share of investment. These resources are vital for agriculture research, for the improvement of human capital (health, education, and extension services), as well as for the development of adequate infrastructure such as transportation, irrigation canals, and management skills.

CONCLUSION

The empirical results suggest that expansion in land acreage does not cause growth in output of two major food crops, namely sorghum and wheat. On the other hand, the results for millet, a crop gown mainly in small-size plantations, indicate the existence of causality between all variables in all directions. These results provide an important policy lesson that strategies for sustainable agricultural development should focus more on vertical expansion. Such a strategy is not only viable from an economic point of view since it considerably reduces production cost and improves profitability and international competitiveness, but is also sound in so far as the sustainability of the resources and the environment is concerned.

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