Quantifying the Spillover Effect of Agricultural Productivity and Macroeconomic Variables on Nutritional Outcomes in Selected African Countries

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ABSTRACT
Reduced food production, hunger, and malnutrition remain enormous challenges for African economies. These problems have been exacerbated by a rising trend in population density, which has occurred in the absence of increases in agricultural productivity. While international forums have emphasized the importance of agricultural productivity in alleviating hunger and malnutrition through increased on-farm income and market participation, the positive effects of agriculture and macroeconomic policies on malnutrition reduction are not well understood. This study used geo-epidemiological and econometric tools to identify African countries at risk of malnutrition (hotspots), and a dynamic spatial Durbin model to assess the direction and magnitude of the direct and spillover effects of agricultural productivity and macroeconomic variables on malnutrition in selected African countries. It illuminates whether increased agricultural productivity and sound macroeconomic policies result in improved nutritional outcomes. The study discovered clear evidence of clustering in the prevalence of undernourishment in African countries, with 29.6% and 25.9%, respectively, in the hotspot and coldspot zones. Furthermore, the study found evidence of local and global spillover effects of agricultural value added, economic growth, and financial development on the prevalence of undernourishment in the African population, both directly and indirectly. Our findings indicate that agriculture's positive effect on nutritional outcomes is not consistent across countries, and that nutritional improvements are likely to occur only in countries trapped in low agricultural productivity traps. Agriculture productivity has a less visible positive effect over time. Furthermore, macroeconomic factors such as GDP per capita, financial development, trade openness, and individual internet access all have a significant impact on malnutrition. Population growth, as expected, puts additional strain on nutritional outcomes. As part of the recommendation, subsistence farmers' access to credit and microfinance to grow crops rich in micronutrients should be enhanced. This will boost household nutrition outcomes as opposed to dependency on already processed and unavoidable diets at food markets. The significant spillover effect of agricultural value added compared to other variables in the model also suggests that enriching agricultural products in Africa is one of the panaceas or strategies that could be used to alleviate community malnutrition as efforts to achieve Sustainable Development Goal 2 (SDG-2) continue.

INTRODUCTION
Undernutrition, overnutrition, and micronutrient deficiencies are the three dimensions of malnutrition, which is a complex problem; resulting in enormous human and economic development loss at both individual and aggregate levels (Sebastian Mary, 2018; Black et al., 2013; World Bank, 2017). The Sustainable Development Goals recognized the need for action and set the objective of zero hunger by 2030. An adult with a body mass index of less than 18.5 kg/m^2 and children with Z-score values of less than –2 compared with the WHO Anthropometric reference on three metrics of height-for-age, HAZ (stunted); weight-for-height, WHZ (wasted) and weight-for-age WAZ (underweight) are termed as undernourished (Andrew M. Prentice, 2018). Though Malnutrition is considered public health of global concern, its rapport with macroeconomic factors, household levels variables, and socio-economic characteristics of the cross-country cannot be mistaken This paper bothers on the application of the dynamic

Durbin spatial model to quantify the direct and spillover effects of macroeconomic variables on malnutrition, proxy by the prevalence of undernourishment, in selected African countries.

LITERATURE REVIEW

Several academics had looked into how agriculture may reduce world hunger in order to achieve the SDG-2 target (Chamberlin et al., 2014; Headey and Ecker, 2013). Though, the impact of agriculture on nutrition appears to be universal in both theory and reality. Increased agricultural productivity has been touted as the key factor in combating undernourishment (Chegere and Stage, 2020; Haddad, 2016; Kadiyala et al., 2014). In theory, agriculture can affect the household's nutritional status by; production for household self-consumption, income from agricultural activities, the diversity and nutritional value of food supply, reduction in prices of more nutritious foods, and women-empowerment. Meanwhile, empirical research on the relationship between agricultural production and nutrition has produced conflicting results. Studies such as Chegere et al. (2020) showed that agriculture has a positive impact on nutrition, however, recent studies have found no evidence of a link between agriculture and nutrition. For example, Johnson et al. (2018) revealed that time restrictions with home food preparation may be a factor in how negatively women's expanding engagement in agriculture affects nutritional outcomes.

In addition, the availability of credit to private business owners is an impetus for the growth of Small and Medium Scale businesses (SMEs) and this has the potential to assist subsistence farmers. The idea is that because foods that are high in nutrients are free to the household, food expenditure would decrease and calorie and micronutrient deficits will be reduced. It is an undeniable fact that Women contribute a lot to family nutrition through producing, processing, and selecting purchased foods, as well as seeking and providing care for their family members. The United Nations Report (1997) submitted that 67% of the total labour force in agriculture in developing countries are Women and that rural Women are responsible for 55% and 70% of food grown worldwide and in African regions, respectively. Women tend to spend a higher proportion of their income directly on the purchase of goods and services that promote the nutrition, health, and general well-being of their families. Consequently, increasing women's income has had a greater effect on those outcomes than increasing men's income. The effect of improving Women's access to credit or microfinance was demonstrated in a program tagged "Freedom from Hunger's Credit' conducted in Ghana. In the intervention program, village banking services and business training for rural women were combined with education in appropriate breastfeeding, child nutrition, treatment and prevention of diarrhea, immunization, and family-planning practices. The program lasted for three years, and the results showed that the nutritional status and health of one-year-old children whose mothers participated were significantly better than those of such children's mothers from groups in the intervention communities who did not participate or from control communities (K. M. Kurz and C. Johnson-Welch, 2001).

The impact of access to agricultural cropland on the nutritional outcomes of the population of the Democratic Republic of the Congo (DRC) at the household level was examined by Janvier MK and Muzabedi E (2020). Their findings indicated that access to farmland is an important factor in determining how diverse a child's diet is across the entire sample, so that, the discrete change from non-access to access to farmland is associated with 0.15 significant variation in the dietary diversity score. Dividing the data into male and female headed households, they noted that access to farmland influences positively and significantly the children dietary diversity score in female headed households with an associated marginal effect of 0.34, whereas there was no discernible impact in homes led by men. A report by the Global Panel on Agriculture and Food Systems for Nutrition (2016) highlighted that food systems in Africa and Asia would be affected by the combined factors of population growth and climate change because there would be an additional two billion people in the regions by 2050; which was in tandem with Thomas Malthus theory on population. One can come to the conclusion that imbalanced food distribution, poverty, bad infrastructure, and instability caused by war, pandemics, etc., rather than overpopulation, are the main causes of hunger (Alex Ruthrauff, 2011, Mercy crops, 2015). Hunger will be conquered if food is made available consistently to everyone who needs it. It is essential to note that using calorie production as a justification for food supply may be misleading because not all of those calories are used to feed people. A third of calories are utilized to feed animals, while up to one third are squandered in the food chain and about 5% of calories are used to make biofuels (*The New York Times, 2013)*.

The gap in the above cited articles are that majority of them are purely descriptive while the few ones that adopted empirical models failed to incorporate space or space-time components into their specifications. The motivation of the current study is to assess and quantify both the direct and indirect (spillover) effects of these variables on undernutrition. In the next section, spatial autocorrelation test, dynamic spatial econometric model specification and measurement of direct & indirect impacts are discussed.

DYNAMIC SPATIAL ECONOMETRICS MODEL

Spatial interactions can be dynamic. The dynamic nature can be accounted for by building on the static specification such that the time lags are introduced on the response variable as well as its spatial lag. Suppose that the value of an observation at a given location i in time t depend on the values taken by the observations close to i in the previous period, the econometrics representation takes the form;

$$y_{it} = \tau y_{it-1} + \rho W y_{it} + \eta W y_{it-1} + \beta X_{it} + P Z_{it}\theta + \alpha_i + \delta_t + v_{it} \qquad (1)$$

This specification assumed that v_{it} is a normally distributed error term, α_i is the individual fixed or random effect, δ_t is the time specific effect and each of W and P are the spatial weight matrix for the spatially lagged endogenous and exogenous variables, respectively. It is clear that spatial autocorrelation can be taken into account in multiple ways – by lagged, dependent or explanatory spatial variables.

In most empirical studies, the spatial weight matrix is hardly different for the two potential spatial terms. Thus, if $W = P$ equation (1) yields;

$$y_{it} = \tau y_{it-1} + \rho W y_{it} + \eta W y_{it-1} + \beta X_{it} + W Z_{it}\theta + \alpha_i + \delta_t + v_{it} \qquad (2)$$

MEASUREMENT OF DIRECT AND INDIRECT IMPACTS

Lesage and Pace (2009) opined that the result by direct point estimate may be biased and formulated partial derivative method to calculate direct and spatial spillover effects. The matrix expression of (2) can be expressed

$$y_t = (I_N - \rho W_n)^{-1}(\tau y_{t-1} \eta W_N y_{t-1}) + (I_N - \rho W_n)^{-1}(x_t\beta + W_N x_t \theta) + (I_N - \rho W_n)^{-1}(\alpha_i + \delta_t + u_{it} \qquad (3)$$

The partial derivative of the expected value of y_t with respect to the Kth explanatory variable X at time t is given as;

$$\left[\frac{dE(y)}{dx_{1k}}, \dots, \frac{dE(y)}{dx_{nk}}\right]_t = (I_N - \rho W_N)^{-1}(\beta_k I_N - \theta_k W_N) \qquad (4)$$

These partial derivatives reflect the effect of a change affecting an explanatory variable for an observation i on the explained variable of all other observations in the short term only. Long-term effects are defined by:

$$\left[\frac{dE(y)}{dx_{1k}}, \dots, \frac{dE(y)}{dx_{nk}}\right]_t = [(1-\tau)I_N - (\rho + \eta)W_N]^{-1}(\beta_k I_N - \theta_k W_N) \qquad (5)$$

The direct effects consist of diagonal elements of the term to the right of Equation 4 or Equation 6 and indirect (spillover) effects such as the sum of the lines or columns of the non-diagonal elements of these matrices

RESULT AND DISCUSSION

The LISA scatter plot matrix displayed in figure 1 showed that 8(29.6%) of the countries considered in the study are in the hotspot (risk) zone of prevalence of undernourishment. Figure 2 shows the spatial distribution of the prevalence of undernourishment. The different color bands were used to depict the level of prevalence of undernourishment in the selected countries. The highest prevalence of undernourishment is from 27.6%-38.2% while the lowest range from 3.4%-5.4%. The direct and indirect effects resulting from the dynamic spatial Durbin model are presented in Table 1, which shows that the short-term direct effect of agriculture value added (AGVD) is negative and significant while its long-term direct effect is positive and insignificant. The negative and significant short-term direct effect indicates that the boosting of agricultural productivity would produce a decline in the prevalence of malnutrition in the local country. This result implies that agriculture has a significant negative intra-country spillover effect on the prevalence of malnutrition. Equally, the spillover effect of agriculture value added is significant in the short term but insignificant in the long term, though they both indicate a negative impact. The negative and significant short-term indirect effect implies that agriculture's value added has a spatial spillover effect and that its increase will reduce the prevalence of malnutrition in other or neighboring countries.

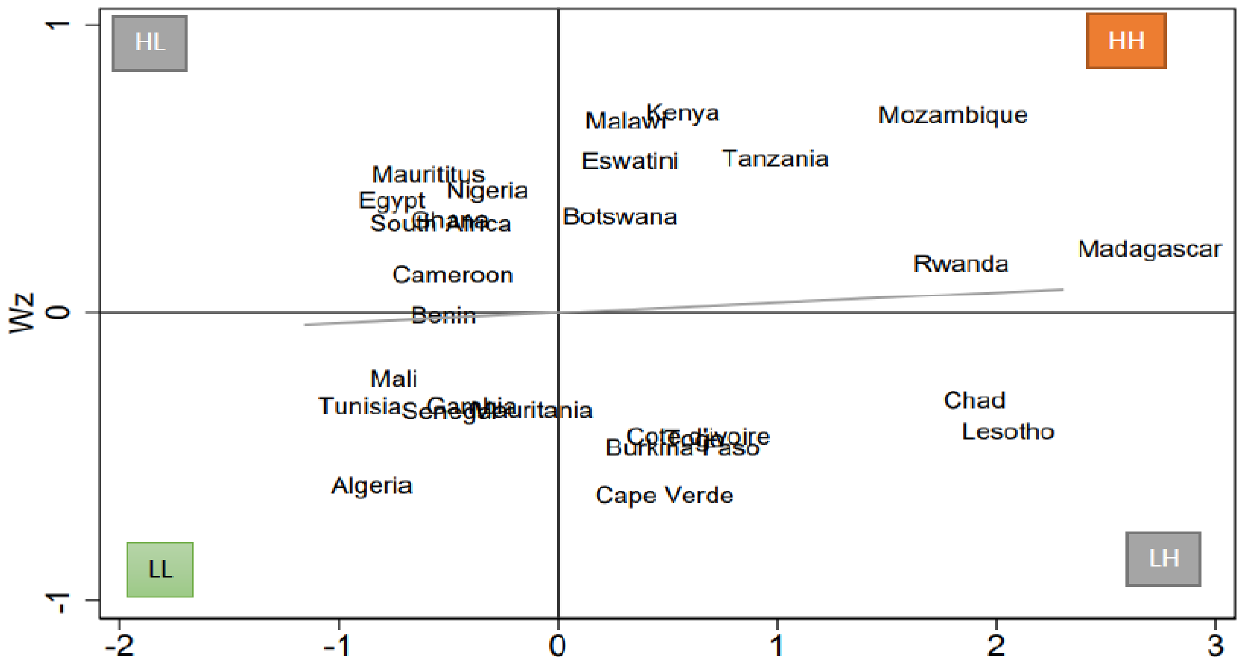

Figure 1: LISA scatter plot matrix for prevalence of undernourishment

Interestingly, we observe that both the direct and indirect effects of the variables under investigation are not found to be statistically significant in the long run; only the total effects are statistically significant. Moreover, the total effects observed in the short- and long-run did not appear to differ statistically. This is indicative that the total effects of agricultural productivity, GDP, financial development, arable land, population, and internet use are consistent across time horizons. There is strong evidence that agricultural productivity has the strongest impact on the level of undernutrition. We find that a 1% increase in agricultural productivity tends to decrease the prevalence of undernutrition by 0.118% and 0.294% in the long and short runs, respectively. Looking at both the short-run total effects, we observe that macroeconomic factors including GDP per capita, financial development, trade openness and individual access to internet significantly decrease the level of undernutrition. As expected, population size increases pressure on nutritional outcomes.

The short-term direct effects of agricultural productivity, GDP per capita, financial development, land area, access to arable land, urban population, and primary school enrolment are negative and statistically significant, while the impact of population size and trade openness is positive and significant. Also, the short-term indirect effect (spillover) of agricultural productivity, GDP per capital, financial development, trade openness, proportion of land area, access to arable land and internet access are negative and significant while population size and urban population are positive and significant. We find that improvements in agricultural productivity, financial development, and the proportion of arable land can diminish the level of undernutrition in a specific country as well as its neighbours in the short run. By looking at the magnitude of the indirect effects in the short term, one might claim that the spillover effect of agricultural productivity are the largest, followed by trade openness and GDP per capita. In summary, agricultural productivity, economic growth, and population size affect nutritional outcomes in the local region in the short term

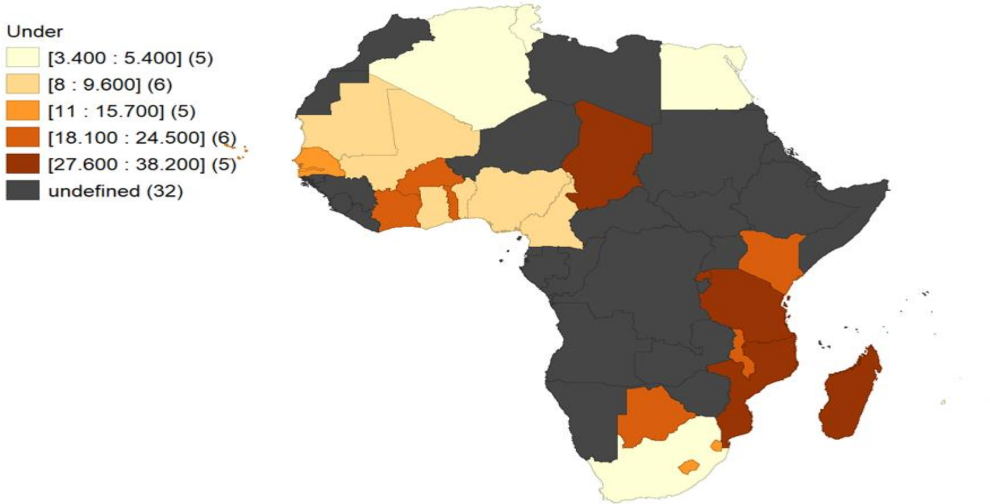

Figure 2: Spatial Distribution of Prevalence of Undernourishment in Selected Africa Countries

We find evidence that the spatial spillover effect of agricultural productivity, economic growth, trade openness, and population size do not persist in the long run. An important finding is that agricultural productivity displays the largest spillover effect in the short run. This shows that improving agricultural productivity can be accepted as part of the solution to improving nutritional outcomes in Africa.

Table 1: Analysis of short-run dynamics of Direct, Indirect and Total Effects

Model	AGVD	GDPpc	DCR	GCF	TRD	LAAR	ARLD	POP	URPOP	PSCE	INAC
SHORT RUN DYNAMICS											
Direct	-0.149^{***}	-0.189^{***}	-0.111^{***}	0.045	0.184^{***}	-0.111^{***}	-0.0935^{***}	0.302^{***}	-0.173^{***}	-0.0127	0.032
Indirect	-0.132^{*}	-0.0817	-0.126^{*}	-0.0085	-0.0358^{*}	-0.258^{***}	-0.110^{*}	0.345^{***}	0.0338^{*}	-0.256	-0.178^{***}
Total	-0.281^{***}	-0.271^{***}	-0.237^{***}	0.0365	0.148^{***}	-0.369^{***}	-0.204^{***}	0.647^{***}	-0.139^{***}	-0.268	-0.146^{**}
LONG RUN DYNAMICS											
Direct	9.476	20.08	1.573	4.341	-33.07	-9.704	6.953	-10.25	36.13	-37.15	-27.18
Indirect	-10.13	-20.71	-2.128	-4.254	33.41	8.84	-7.429	11.76	-36.45	36.52	26.84
Total	-0.656^{***}	-0.631^{***}	-0.555^{***}	0.0866	0.348^{***}	-0.864^{***}	-0.476^{**}	1.511^{***}	-0.326^{***}	-0.631	-0.343^{**}

Notes: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. AGVD: agricultural value added; GDPpc: real per capita gross domestic product; DCR: domestic credit to private sector; GCF: gross capital formation TRD: trade openness; LAAR: land area; ARLD: arable land; POP: population density; URPOP: urban population; PSCE: primary school enrollment; INAC: Internet use

CONCLUSION

The purpose of this study is to look into the effects of macroeconomic variables on nutrition outcomes in a few African countries. It established the possibility of policies that improve agricultural productivity, GDP per capita, financial development, and arable land as a way out of the local country's current malnutrition, albeit in the short term. It also shows that agricultural productivity, GDP per capita, and trade openness have a negative and significant short-term spillover effect on nutrition outcomes. This suggests that macroeconomic policies that promote agricultural productivity, GDP per capita, and trade openness will reduce hunger not only in the home country but also in neighboring countries.

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