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Agronomic structural transformation in Africa: The role of external finance

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ABSTRACT
This study examines the impact of diverse sources of external finance, including official development aid (ODA), foreign direct investment (FDI), external debt, and remittances, on agronomic transformation in African economies from 2000 to 2022. Data is obtained from the World Development Indicators, and a plethora of estimation approaches is used, such as the Driscoll-Kraay, the fully generalized least squares, the quantile regression, and the generalized method of moments type sequential regression techniques. The outcomes reveal ample evidence of an augmenting effect of external debt and remittances on agronomic transformation in Africa. However, sub-regional comparisons demonstrate that the influence of remittances is insignificant for East African economies, while external debt has a negative impact on North African economies. Furthermore, FDI negatively affects agronomic transformation but fails to be significant for East and Southern African economies. Finally, ODA was generally positive but insignificant. External finance sources variably influence agronomic transformation, with outcomes shaped by regional contexts. The heterogeneity underscores the need for nuanced, region-specific policy frameworks. Policymakers should prioritize remittance channels and debt management to foster agronomic transformation while tailoring strategies to sub-regional dynamics. East and Southern Africa require cautious ODA utilization, and FDI policies should be redesigned to align with agricultural development goals.

Contribution/Originality: This study stands out through its analysis of regional disparities in Africa's agronomic transformation using multi-method econometrics, revealing divergent impacts of external finance sources.

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1. INTRODUCTION
The consistently increasing trend of the world population is one of the most worrisome and problematic issues for global stakeholders regarding how to meet the food demands of these incessant increments. Pivotal in reconciling these challenging issues is the enhancement of the agronomic sector to boost production and improve future supply. The World Bank (2014) highlighted that the most effective approach to target food scarcity and feed the global population, which is forecasted to be about 9.7 billion, and enhance shared prosperity by 2050, will require the development of the agricultural sector. Structural transformation of the agricultural sector has remained a policy target of the Millennium and Sustainable Development Goals to fight hunger and reduce poverty globally. Extended literature has continually certified that structural change in the agronomic sector within an economy remains a key pillar to achieving sustainable development (Dedewanou & Kpekou Tossou, 2022; Ndjidda, Amoa, & Nourou, 2022; Olumo, Byaruhanga, & Mungai, 2023). While developed economies have long understood this rhetoric and acted accordingly, their developing

counterparts are still struggling to catch up regarding structural transformation, be it in the agricultural, industrial, or service sectors. Structural change, especially in the agronomic sector, remains a vital tool in attaining the sustainable development goals of zero hunger, reduced poverty, and decreased inequality (goals 1, 2, and 10, respectively). While the process of structural transformation in the agronomic sector is advancing in most developing economies, the pace of Africa in general and sub-Saharan Africa (SSA) in particular remains a cause for concern. The SSA sub-region accounts for about 13 percent of the world population, and with this population projected to reach 22% or 2.1 billion by 2050, undernourishment has remained a key problem in this sub-region (World Food Programme, 2015). Though the rate of undernourishment reduced from 33% from 1990 to 1992 to 23% in 2024, the comparative proportion of undernourishment remains the highest among other developing countries. Boosting agronomic transformation is one of the most vital tools in combating hunger, reducing poverty, and improving the welfare of developing economies, especially those of the African continent. However, the process of agronomic transformation requires high amounts of capital investment, given that it necessitates the adoption of modern agronomic technologies and practices to enhance productivity and sustainability.

Developing countries in general and Africa in particular have been lagging behind other regions with regard to modern agronomic technologies and practices (Bachewe, Berhane, Minten, & Taffesse, 2018; Mukasa, Woldemichael, Salami, & Simpasa, 2017). A key reason that can explain such drawbacks within the African context is limited capital, which constrains investment in modern agricultural technologies (Mukasa & Simpasa, 2024). Africa Economic Outlook (AEO, 2024) research forecasts that, by 2030, Africa needs to eliminate an annual financial shortfall of $402.2 billion (approximately 13.7% of its estimated 2024 GDP) to speed up its structural transformation. External sources of finance are among the major cradles wherein African economies can source the required capital needed to transform their domestic agricultural sectors and enhance the general value chain on the continent (UNCTAD, 2023). In terms of external finance inflow into Africa, there has been a consistent increase in the inflow of remittances, foreign direct investment (FDI) and official development aid (ODA) into Africa during the past decades. However, Africa still falls behind its developing Asian counterparts (Yeboua & Cilliers, 2024). Equally, Africa's external debt has risen to about 1.152 trillion dollars in 2023, and this is equally accompanied by the highest interest rates (AfDB, 2024). This demonstrates that external finance has generally been on a constant rise on the African continent during the past decades. Understanding the role played by these different sources of external finance in shaping agronomic structural transformation amid limited domestic capital and technologies has increasingly become the subject of global concern.

This study examines the role of the major sources of external finance, which are external debt, ODA, FDI and remittances, on the progress of agronomic transformation in Africa. Most extant literature has focused on examining the role of different unique sources of external finance on either agricultural production (Ojo & Ojo, 2022; Olumo et al., 2023; Tian, 2023), growth (Ndjidda et al., 2022; Sogah, Mawutor, Ofoeda, & Gborse, 2024) and yields (Gunasekera, Cai, & Newth, 2015; Mohamed, Xu, Inglett, Rayas-Duarte, & Palmquist, 2005). This current study contributes to extant literature in different ways. Firstly, it exploits the concept of agronomic transformation and not agricultural productivity or growth, as has been common within the literature. Secondly, it makes a general comparison of how different sources of external finance impact agronomic transformation within African economies. Furthermore, comparative analyses on how specific sources of external finances shape the agronomic transformation within five regional blocs of Africa are equally accounted for. Finally, the adoption of robust and current empirical techniques makes the conclusive arguments more realistic and good for policy inferences.

The rest of the paper is organized as follows. Section 2 presents an overview of the literature on how different sources of external finance influence agronomic structural transformation. Section 3 discusses the estimation methodologies, including variable descriptions, sources, stylized facts, and estimation approaches. Sections 4 and 5 present the results and conclude by noting the policy implications.

2. LITERATURE REVIEW

In this section, we present the literature perspective linking agronomic structural transformation to the four sources of external finance, notably external debt, foreign direct investment, official development aid, and the influence of remittances.

2.1. Literature Linking External Debt and Agronomic Transformation

From a theoretical standpoint, the dependency theory (Prebisch, 1950; Singer, 1950) asserts that developing nations are ensnared in a cycle of reliance on rich nations, and as such, dependencies are always worsened by external debt. This dependency can curb structural transformation in all sectors through unequal power relations and resource flow. This shows that when developing countries, due to factors like capital, are constrained to seek foreign options (especially external debt) to fill the existing domestic gap, this can negatively influence structural changes in different sectors, like agronomic structural transformation. Therefore, external debt can be detrimental to agronomic structural change. Furthermore, the debt trap theory (Sachs, 1989) establishes that countries may be trapped in a cycle of debt wherein funds that could be used for investment purposes are diverted to service high debt. This will insinuate that when debt stock increases, with an accompanied increase in debt burden, financial resources that could be used for financing structural transformation will be diverted to debt servicing. Nonetheless, the financial development theory (Goldsmith, 1969; Schumpeter, 1911) posits that financial system development can enhance growth and structural transformation (agricultural, service or industrial). External debt directly influences financial development through its role in credit availability, financial stability and interest. This shows that through the financial sector, external debt can enhance agronomic structural transformation. The theoretical arguments show that external debt can either be an enhancing stimulus or a degrading factor in agronomic transformation.

Empirical studies have equally been considered within the past decades; however, the outcomes have remained controversial, with some authors observing positive impacts (Olumo et al., 2023; Sogah et al., 2024) while others observing negative effects (Mohamed et al., 2005; Yeshineh, 2018). In investigating the effect of foreign debt on the agricultural sector, Olumo et al. (2023) concluded that external debt enhanced the performance of the agricultural sector for the Kenyan economy over the period 2012 to 2020. On a similar note, Sogah et al. (2024) examine the role of external debt on Ghanaian agricultural GDP growth over the period 1980 to 2019. The empirical outcome demonstrates that external debt boosts agricultural GDP growth in Ghana. Sikandar, Erokhin, Wang, Rehman, and Ivolga (2021) examined the role of different sources of foreign capital on poverty and agricultural development for 14 developing countries from the world, excluding those from Africa and concluded, among others, that remittances, ODA and FDI increase poverty while external debt reduces poverty. Furthermore, the outcome equally shows that, but for remittance, ODA, FDI and external debt increase agricultural development. Empirical outcomes in some studies have equally pointed toward a detrimental impact. Yeshineh (2018) examined the role of external debt on the agricultural and service sectors of the Ethiopian economy and settled on the degrading effect of debt on agricultural sector development in Ethiopia. Mohamed et al. (2005) showed that, using data from the Sudanese economy, external debt stock and inflation negatively impact agricultural productivity.

2.2. Literature Linking FDI and Agronomic Transformation

The proponents of the dependency theory have elucidated that foreign direct investment (FDI) has the potential to strengthen ties of dependency while simultaneously fostering technological transfer and capacity growth, which can result in agricultural transformation. Nevertheless, authors of the modernization theory rather point out that developing nations can advance toward industrialization and modernization with the correct external investments, such as foreign direct investment (FDI), and regulations. These brief theoretical perceptions buttress that the role of FDI can be both beneficial and detrimental to the growth and advancement of developing economies.

Authors have equally sought to examine the empirical relationship between FDI and agricultural sector development and transformation. Nugroho, Bhagat, Magda, and Lakner (2021) examined the role of economic globalisation on agricultural value added for 17 developing countries within the 2006 and 2018 period. Their outcomes showed, among others, that FDI positively drives agricultural value added. Similarly, Ojo and Ojo (2022) empirically showed, using the autoregressive distributive lag (ARDL) model for the Nigerian economy, that FDI has a positive effect on various agricultural production sectors (crop, fishery and livestock). Limited investment in agriculture was identified by Gunasekera et al. (2015) as a factor limiting productivity, and in a bid to address this, the authors examined the role of FDI in African agriculture. They settled on the views that enhanced land productivity and augmenting FDI inflow would boost Africa's share in global agricultural output. Similar outcomes were equally established by authors like Akinwale, Adekunle, and Obagunwa (2018) and Edeh, Eze, and Ugwuanyi (2020). Analogously, in his thesis, Martin-Odoom (2021) examined FDI in Ghana's agricultural sector and found that FDI enhances agricultural production in the short run and reduces it in the long term. This demonstrates that FDI crowd in more agronomic transformation within Ghana's domestic economies, however, such benefits is crowded out in the long. According to Mamba, Gniniguè, and Ali (2020) FDI inflows had no appreciable impact on agricultural value added within the West African economic and monetary union countries. Rufai and Celine (2013) argued, for the Nigerian economy, that there is unidirectional causality from FDI to agricultural productivity in the short run, and there is no significant impact of FDI on agricultural output during the period 1960 to 2008.

2.3. Literature Linking ODA and Agronomic Transformation

The theoretical relationship linking ODA and agronomic transformation can be factored within the framework of the modernisation theory. The theory explains that developing economies can drive towards structural transformation and modernisation using the right policy and foreign assistance, including ODA (Bernstein, 1971). This implies that ODA can serve as a source of capital that is needed for technological adoption, investment and transformation of economic structures. However, looking at the arguments of the dependency theory, such aid can equally lead to the continuous dependence of developing countries, driving them towards a dependency cycle that can be detrimental for structural transformation and subsequent development.

The empirical perspective has equally been under scrutiny by scholars over the past decade, with controversial outcomes observed. Ndjidda et al. (2022) utilised the general equilibrium modelling approach to examine how ODA impacts agricultural growth in Cameroon. The multifaceted analyses' outcomes showed that any rise in ODA stocks allocated to the agriculture sector results in more agricultural output and ultimately higher economic growth. Similarly, Norton, Ortiz, and Pardey (1992) empirically concluded from a panel of eight developing economies that ODA enhances the development of the agricultural sector and improves the standard of living in these economies. In the same vein, Alabi (2014) showed, using the generalised method of moments (GMM) for SSA economies, that an increasing direction of ODA towards growth sectors enhances productivity. A similar argument for SSA was put forth by Akpokodje, Omojimite, and BU (2008) using the instrument variable technique, where augmenting the inflow of agricultural ODA boosts agricultural growth. Tian (2023) opines empirically that agricultural ODA enhances the flow of FDI in the agricultural sectors. Some authors have shown that ODA is detrimental to the development and transformation of the agricultural sector. Proponents of this outcome explain that when ODA is channelled to unproductive activities, it will be detrimental to the growth and development of the agronomic sector. Dillon and Sofia (2010) showed empirically that aid does not have an impact on agricultural productivity. Tony (2024) demonstrated, using 69 developing economies, that ODA has no significant effect on total factor productivity. However, further

outcomes demonstrate that ODA in the agronomic sector significantly enhances human capital, GDP and employment for low-income economies.

2.4. Literature Linking Remittances and Agronomic Transformation

The new economics of labour migration stands out as one of the key theories that correlate remittances with agricultural sector development. The theory elucidates that migration is vital for households' decision-making (Stark & Taylor, 1989). The flow of funds from migrants can boost household income, driving them towards investment and structural transformation. Such a structural change will enhance agricultural productivity. This implies that remittances can reduce the revenue gap of developing countries, necessary to venture into agronomic transformation and technological adoption in different sectors of the economy. On the empirical front, several arguments have been established linking remittances and agronomic activities, with obvious divergence in suppositions arrived at.

Dedewanou and Kpekou Tossou (2022) used the Bayesian instrumental variable model and investigated the nexus between remittances and agricultural productivity in Burkina Faso. Total production, total production per unit of land, and total production per unit of labour were the three metrics of agricultural productivity that they took into consideration. The findings show a strong negative correlation between remittances and agricultural productivity, regardless of the metric applied. De Brauw (2010) empirically pointed out that remittances enhance agricultural productivity and boost welfare in the rural areas of Vietnam through an increase in household income. Rozelle, Taylor, and DeBrauw (1999) empirically showed within the Chinese economy that migration negatively affects yields through a reduction in the labour force; however, this negative effect is compensated by increased revenues through remittance inflows from the migrants. Similar arguments have equally been put forth by Taylor, Rozelle, and De Brauw (2003) and Li, Wang, Segarra, and Nan (2013). Abbas, Selvanathan, and Selvanathan (2023) employed the panel VAR on 95 developing economies and concluded, among others, that there is no long-run relationship between remittances and structural transformation, and no causal relationship exists between the variables. However, GDP and urbanisation granger cause structural transformation.

A synthetic appraisal of the aforementioned literature linking various sources of external finance and agronomic transformation establishes a number of gaps within the literature. Regardless of the sources of external finance (FDI, ODA, remittances, and external debt), their effects are all controversial with no clear direction. Secondly, the literature has been more focused on productivity, with limited strands of studies examining agronomic transformation. Furthermore, comparative analyses within different regional blocs, especially in Africa, which will produce specific policy directions, have not been given consideration. The examination of the joint effect of these sources of finance on agronomic transformation remains limited within existing studies. Based on these backdrops, this study fills a vital empirical gap by examining how external finance is shaping agronomic transformation on the African continent.

3. ANALYTICAL FRAMEWORK AND MODEL

3.1. The Model

This study developed and adopted an econometric model where agronomic structural change is the independent variable, while the four key sources of external finance (Word Bank, 2014) notably remittances, ODA, FDI and external debt, are the key independent variables. The model equally includes GDP and domestic investment as control variables, along with an error term that encapsulates the elements excluded from the model. The adopted model is an ameliorated model to that of Sikandar et al. (2021). The adopted model is defined in equation 1.

$$LAGST_{it} = \delta_0 + \delta_1 LXDBT_{it} + \delta_2 LFDI_{it} + \delta_3 LODA_{it} + \delta_4 LREMIT_{it} + \delta_5 LDINV_{it} + \delta_6 LGDPC_{it} + \omega_{it} \quad (1)$$

With $LAGST_{it}$ denoting the log agronomic transformation for country i at time t, $LXDBT_{it}$ stands for the log external debt stock, $LFDI_{it}$ is the log of net FDI inflow, $LODA_{it}$ stands for the log of net inflow of foreign aid, $LREMIT_{it}$ denotes the log of the inflow of remittances, $LDINV_{it}$ and $LGDPC_{it}$ respectively stand for the logs of domestic investment and GDP per capita, ω_{it} is the error term, δ_i are the parameters of the model to be estimated.

3.2. Data, Variables and Measurability

The empirical assessment is based on macroeconomic data for African economies, built from the World Bank (2023) database. The data spans from 2000 to 2022, and this timeframe captures the period of the establishment of the Millennium Development Goals (MDGs) through the recent Sustainable Development Goals. The study also constitutes a panel of 38 African economies (see Appendix 5). The paragraphs that follow present the definition of the key variables and some stylized views of these variables.

3.2.1. Dependent Variable

The dependent variable, which is agronomic transformation, is measured using agricultural value added. It is defined as the total output of a sector (such as agriculture, forestry, hunting, fishing, and raising livestock) after deducting intermediate inputs from the total output. This captures the changes in the value of goods and services at each stage of production. An increasing value added frequently denotes advancements in management techniques, technology, and inputs that result in higher output per unit of input.

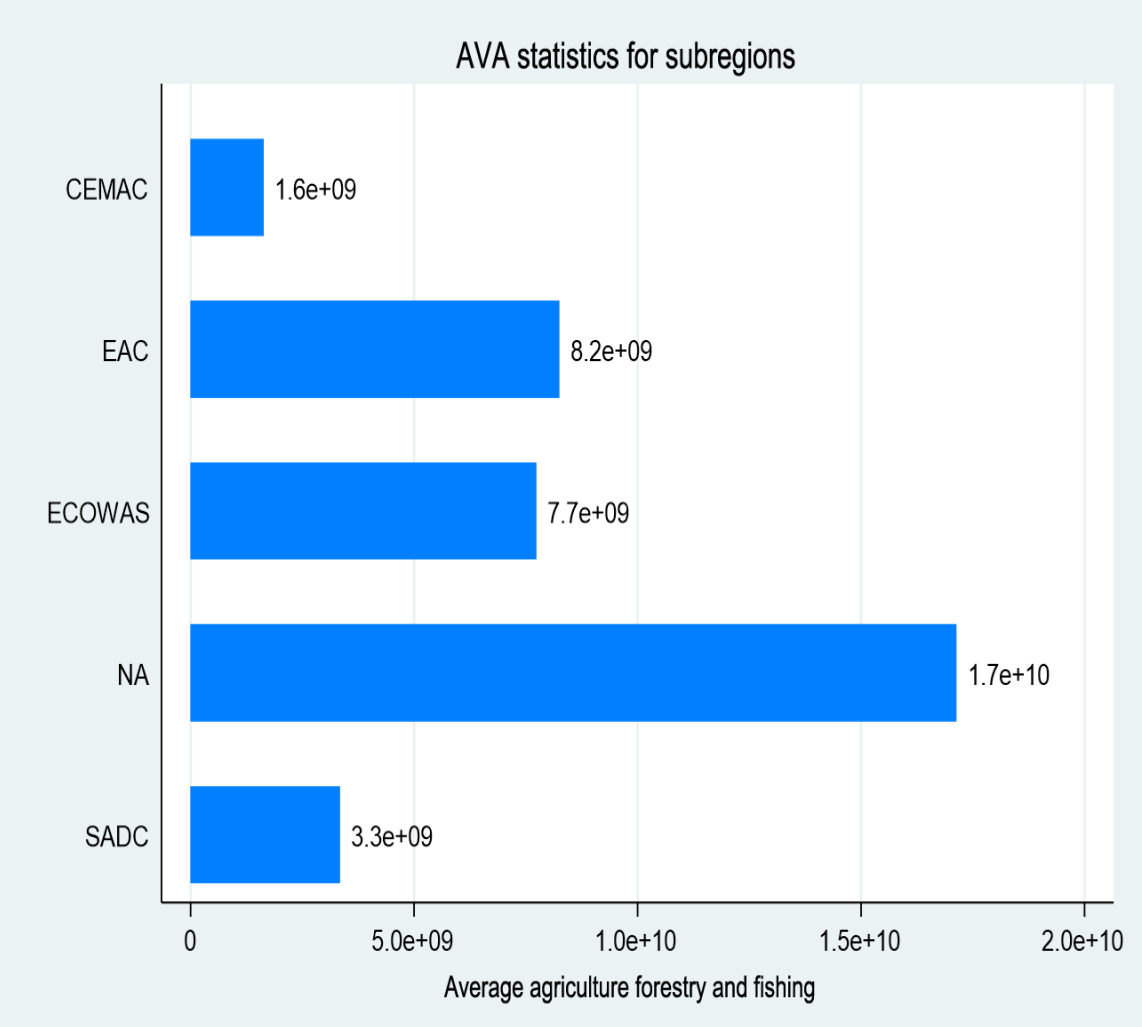

Figure 1. Average regional agronomic transformation.

Figure 1 presents the average agronomic structural transformation for different sub-regional blocs in Africa. On average, the performance trend of agronomic transformation demonstrates that North African economies, considered within the framework of this study, perform relatively better than their counterparts in Central, West, Southern, and East Africa. This is evident given that African growth statistics demonstrate a generally dominant trend for North Africa (African Development Bank, 2023). Figure 1 further shows that East and West Africa, on average, perform better in terms of agronomic transformation during the period from 2000 to 2022 than the Southern and Central African economies. Central Africa shows the lowest performance average during the period under consideration.

3.2.2. Independent Variables

With regard to the four sources of external finance considered in this study, FDI is measured using the net inflow of foreign direct investment in current US dollars. This measurement aligns with the approach adopted by Emmanuel et al. (2023) and Dinga (2023). ODA is captured by net official development aid received per capita in current US dollars. The adopted measurement is per extant studies (Ndjidda et al., 2022; Tian, 2023). External debt is defined by total external debt stock, which is the sum of publicly guaranteed and privately nonguaranteed long-term debt, short-term debt, and the utilization of IMF financing and is captured in terms of current US dollars. Such an approach has been utilized by different authors recently (Olumo et al., 2023; Sogah et al., 2024). Remittance is captured by any current monetary or in-kind transfers made or received by resident households to or from non-resident households and measured in current US dollars. This aligns with the adopted measure by authors such as Li et al. (2013) and Abbas et al. (2023).

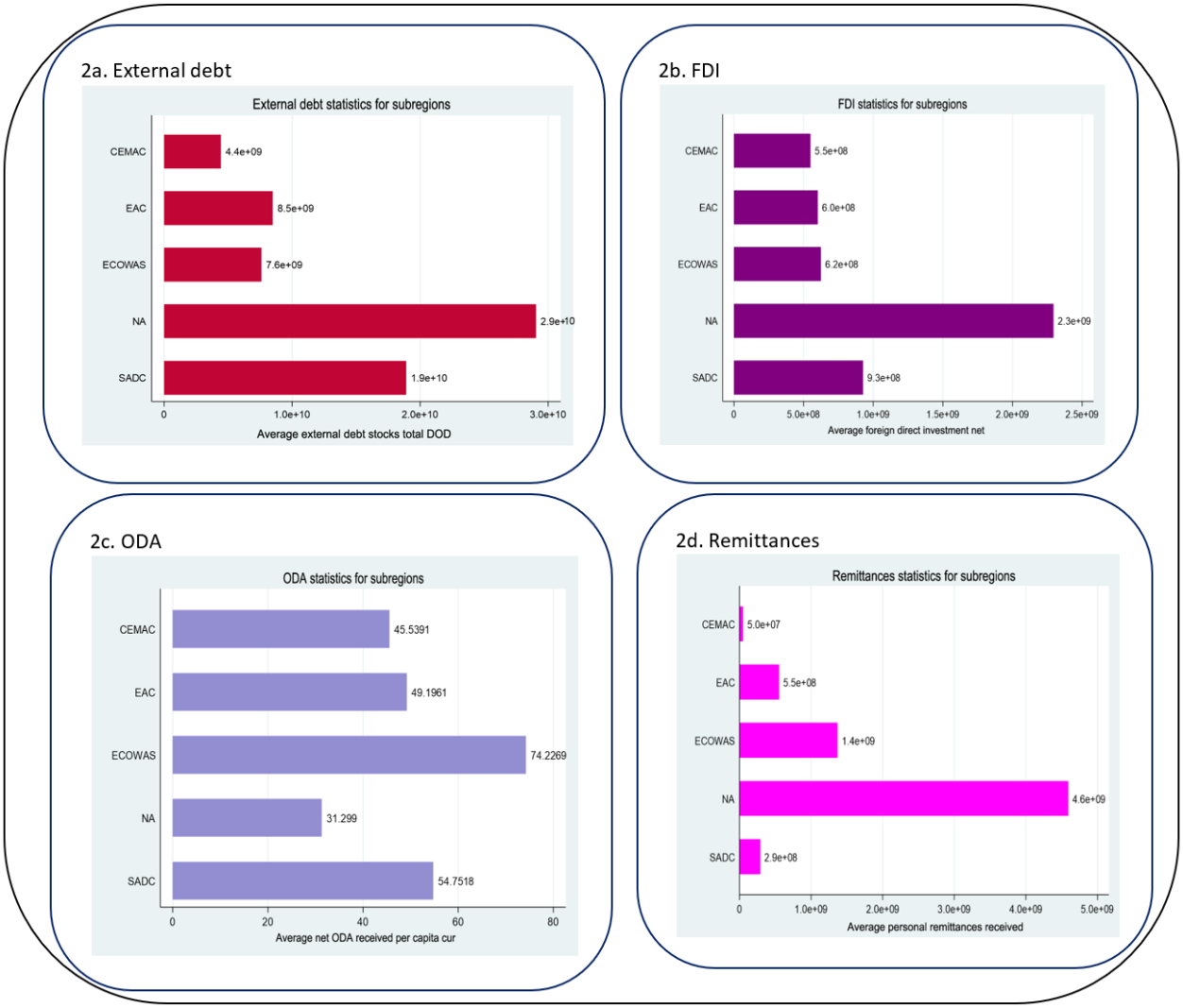

Figure 2. Sub-regional average values of external finance sources.

The average statistics of FDI, remittances, external debt, and ODA during the period 2000 to 2022 are presented in Figure 2. The statistics show a significant disparity in terms of sources of external finance and the sub-regions. The statistics presented indicate that, comparatively, for Figure 2a, more external debt flows to North Africa than to any other subregion. This can be indicative of the fact that North African economies are more trustworthy to international lenders. Southern African economies demonstrate the second-highest average debt stock, followed by East Africa, West Africa, and Central Africa, respectively. This disparity can be due to socioeconomic factors (like country risk ratings, repayment history, and fiscal balance, among others) that guide international lenders on where their capital can flow. Figure 2b equally demonstrates that FDI inflow on average peaks in North Africa, followed by Southern Africa, West Africa, East Africa, and Central Africa, correspondingly. This can entail that foreign investors judge North and Southern Africa as the sub-regions in Africa with favorable economic, political, and social conditions that could permit their capital to thrive.

The average statistics of ODA per African subregions presented in Figure 2(sub c) demonstrate that West African economies considered within the framework of this study had the highest proportion of ODA received. Comparatively, they are followed in order by Southern Africa, East Africa, Central Africa, and North Africa, respectively. The low level of development aid in North Africa can be attributed to the higher income levels of most North African economies, resource wealth, and high diversification, which make them less reliant on aid. Finally, the sub-regional average of remittances is primarily dominated by North African economies, followed by West Africa, East Africa, Southern Africa, and lastly, Central Africa.

3.2.3. Control Variable

Within the scope of this study, we adopt two key control variables, namely domestic investment to account for domestic capital mobilisation and gross domestic product per capita to account for economic conditions. Domestic investment is measured by gross fixed capital formation in constant 2015 US dollars, and GDP per capita is measured in constant 2015 US dollars.

3.3. Empirical Approach

Estimating equation 1 can be subject to several econometric problems defined within extant literature, such as cross-sectional dependence, unit roots, serial correlation, heteroscedasticity, and cointegration, among others. Before estimating the equation, key preliminary tests, such as unit roots, cross-sectional dependence (CD), slope homogeneity, and cointegration, will be examined. The Driscoll and Kraay (DK) estimation technique is employed in this study to examine the baseline model. The Driscoll and Kraay technique offers a robust and efficient way to estimate standard errors in panel data models (Driscoll & Kraay, 1998). The DK technique is advantageous, given that it addresses common econometric problems such as CD, heteroskedasticity, and autocorrelation. This approach equally improves inference through the usage of the DK standard errors, making outcomes more accurate. The DK equally renders efficiency within both large and small panels, especially when the time dimension is relatively larger (Dinga, 2023). The DK equally produces three variant estimations, which are the fixed effect (FE), random effect (RE), and the pooled estimations, which give insight into how the individual-specific effect and time-specific effect affect the strength and efficiency of outcomes. Furthermore, the study equally adopts the fully generalized least squares (FGLS) technique to check the robustness of the preliminary outcomes. To examine the effect of external finance on the conditional distribution of agronomic transformation, the quantile regression technique for panel data is employed equally in this study. Finally, to ensure that our empirical outcome is equally free from the problem of endogeneity, this study further employs the sequential regression technique following the generalized method of moments (GMM) approach. The approach performs sequential estimators for linear panel models using Kripfganz and Schwarz (2019) analytical second-stage standard error correction algorithm. This permits the correction of endogeneity within the panel; the sequential regression technique corrects for endogeneity.

4. EMPIRICAL OUTCOME

We present and discuss the estimates of the effect of external finance on agronomic transformation in Africa while controlling for domestic fixed capital and the growth performance of the African economies. We first commence with the fitted line graph between agronomic transformation and the four dimensions of external finance. Figure 3 illustrates the four (3a, 3b, 3c, and 4d) fitted line graphs related to the variables. The graph outcome shows that there is a direct relationship between agronomic transformation and external debt, FDI, and remittances. This *a priori* representation of the data demonstrates a positive link between these variables, indicating that an increase in external debt, FDI, and remittances enhances agronomic transformation. On the other hand, a mild indirect relationship is established between ODA and agronomic transformation. However, the fitted line graph just gives *an a priori* view and, as such, the effect of these external finance sources on agronomic transformation can only be established using regression analyses.

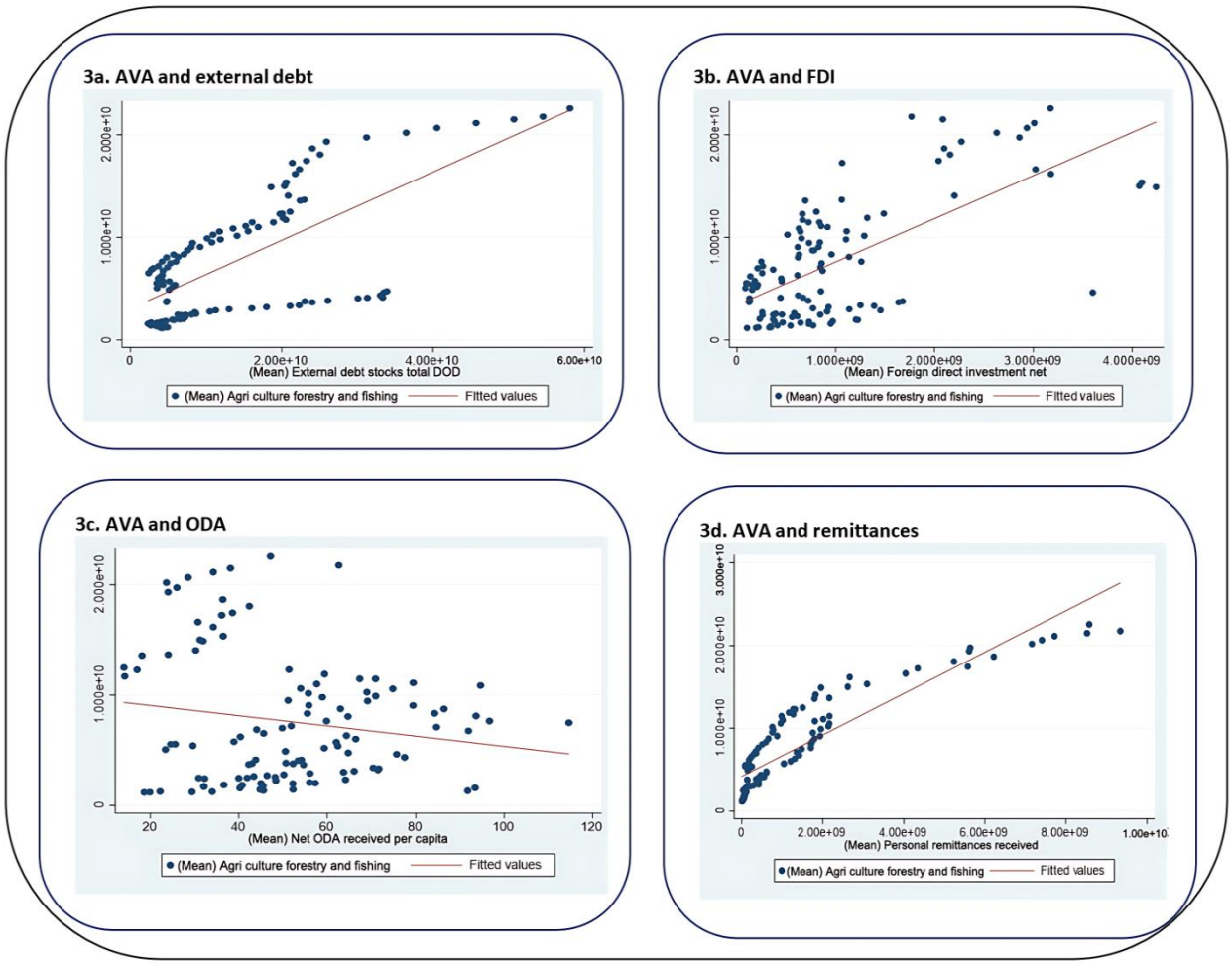

Figure 3. Fitted line graph of agronomic transformation (AVA) and external finance sources.

Before proceeding with empirical analyses, the model was first tested for CD, slope homogeneity, and cointegration, and each variable was examined for unit roots (See Appendices 1, 2, 3, 4). The baseline model in this study is examined using the Driscoll-Kraay (DK) technique. Before the estimation of the baseline model, the Breusch and Pagan Lagrangian multiplier test (BPLMT) was used to select the efficient estimator between random effects and pooled estimates, and equally, the Hausman test was employed to select between the fixed effects and random effects. The outcome of the preliminary selection test is reported in Table 1 and reveals that the null hypothesis of the BPLMT test, that the variance of the random effects is zero, was rejected. This implies that the random effects estimation is efficient when compared with the pooled estimate. The Hausman test results comparing the fixed and random effects outcomes reveal that the null hypothesis, that the random effects model is efficient, is rejected, implying that the fixed effects model is efficient. Therefore, within the framework of this study, we interpret the fixed effects.

Table 1. Baseline regression using the fixed effect Driscoll-Kraay technique.

Variables	(1)	(2)	(3)
	FE	RE	Pooled
Dependent variable : Agronomic transformation			
LXDBTTOT	0.0761**	0.113**	0.232***
	(0.0342)	(0.0467)	(0.0268)
LFDII	-0.0475***	-0.0322**	0.0239
	(0.0151)	(0.0117)	(0.0161)
LODA	0.000315	-0.00275	-0.151***
	(0.00894)	(0.0169)	(0.0160)
LREMIT	0.0212***	0.0289***	0.106***
	(0.00744)	(0.00589)	(0.00879)
LDINV	0.127***	0.170***	0.523***
	(0.0189)	(0.0227)	(0.0155)
LGDPC	0.621***	0.305***	-0.681***
	(0.127)	(0.0316)	(0.0303)
Constant	13.50***	13.47***	7.970***
	(0.372)	(0.362)	(0.374)
Observations	727	727	727
R-squared	0.6084	0.4059	0.860
F statistics	7435.07		87450.42
	[0.000]		[0.000]
Wald Chi2		27424.14	
		[0.000]	
Number of groups	35	35	35
Hauman test/BPLM	189.94		3664.73
	[0.000]		[0.000]

Note: Standard errors in parentheses.
*** p<0.01, ** p<0.05.

The baseline DK-FE (Driscoll and Kraay fixed effect) results in Table 1 reveal that external debt exerts a positive and significant effect on agronomic transformation in Africa. This outcome aligns with the theoretical arguments of the financial development theory that explains how external debt enhances agronomic transformation through credit availability, financial stability, and interest. The result equally accords with the empirical outcomes of Olumo et al. (2023) and Sogah et al. (2024). The results further show that there is a negative and significant impact of FDI on agronomic transformation in Africa. This points to the fact that FDI crowds out the pace of development of the agricultural sector. The result is in alignment with the empirical works of Martin-Odoom (2021), who noted empirically that FDI hurts Ghana's agricultural sector development in the long run. ODA inflow to the African continent is positive but not statistically significant. This demonstrates the weak effect of ODA on the development of the agronomic sector in Africa. The outcome buttresses the empirical views of Dillon and Sofia (2010) and Tony (2024), who all concluded that ODA does not significantly influence agricultural productivity. A strong and significant effect of remittance inflow on the transformation of the African agronomic sector is observed. This demonstrates that migrants from Africa significantly enhance the development of the agricultural sector in Africa. This can be explained on the basis that most of this finance is sent directly to family members and, as such, has an enhanced direct effect on agronomic sector development. This result supports the empirical work of De Brauw (2010) and theoretical views of the new economics of labor migration that posit that migration is essential in reducing the revenue gap and bringing forth household development through increased revenue and investment in production activities such as agriculture.

The outcome further shows that the control variables, GDP per capita and domestic investment, significantly enhance agronomic transformation within Africa. The F-statistics are equally significant, and this demonstrates the global fitness of the model under consideration.

Within the framework of this article, we reexamine our baseline model for each subregion within Africa (Central Africa (CEMAC), East Africa (EAC), West Africa (ECOWAS), North Africa (NA), Southern Africa (SADC), and sub-Saharan Africa (SSA)). The outcome of this comparative appraisal is presented in Table 2.

The outcome demonstrates that external debt inflow enhances agronomic transformation within the CEMAC, EAC, ECOWAS, SADC, and SSA generally; however, the outcome is not significant for ECOWAS. External debt has a deleterious effect on agronomic transformation in North Africa. These outcomes demonstrate that SSA and its sub-regional blocs are benefiting from debt-source external financing. The negative effect of North Africa may be due to the high level of external debt that comes with higher debt servicing costs, which may harm the transformation of the agronomic sector. FDI outcomes point to the fact that there is generally a negative effect of FDI on agronomic transformation for all the subregions within Africa. However, the outcome is not significant for the EAC and SADC zones. ODA outcomes demonstrate disparity in terms of signs and effects for each sub-region. ODA is positive for CEMAC, ECOWAS, and NA, but not statistically significant. EAC and SADC demonstrate a significant negative effect of ODA on agronomic transformation. Remittances demonstrate unity in terms of signs for all sub-regions, and they are statistically significant for all the sub-regions. This further shows that remittances are very beneficial for the advancement of the agronomic sector for all subregions within Africa. Concerning the control variables, domestic investment positively and significantly enhances agronomic structural transformation for all subregions; however, for North Africa, the outcome is negative. Per capita GDP is negative for CEMAC and SADC but positive and significant for all the other sub-groupings.

Table 2. Baseline regression for sub-regions using the fixed effect Driscoll-Kraay technique.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	CEMAC	EAC	ECOWAS	NA	SADC	SSA
Dependent variable : Agronomic transformation						
LXDBTTOT	0.181***	0.0666***	0.00427	-0.225***	0.172***	0.0981**
	(0.0393)	(0.00816)	(0.0295)	(0.0473)	(0.0452)	(0.0421)
LFDII	-0.464***	-0.0539	-0.396***	-0.102*	-0.0187	-0.0415**
	(0.150)	(0.111)	(0.0767)	(0.0548)	(0.0172)	(0.0178)
LODA	0.0172	-0.0349**	0.0206	0.00445	-0.0232***	-0.00243
	(0.0105)	(0.0141)	(0.0211)	(0.0108)	(0.00678)	(0.00623)
LREMIT	0.0509***	0.00193	0.0436***	0.116***	0.0174***	0.0138***
	(0.0126)	(0.00323)	(0.0123)	(0.0267)	(0.00414)	(0.00439)
LDINV	0.404***	0.140***	0.181***	-0.0856***	0.221***	0.230***
	(0.0392)	(0.0191)	(0.0378)	(0.0137)	(0.0181)	(0.0195)
LGDPC	-0.471	0.465***	1.038***	1.843***	-0.123	0.320***
	(0.541)	(0.0592)	(0.120)	(0.106)	(0.182)	(0.0874)
Constant	21.31***	16.01***	18.71***	15.96***	13.79***	12.83***
	(1.653)	(2.519)	(2.185)	(1.465)	(0.501)	(0.521)
Observations	65	99	282	92	189	635
R-squared	0.7638	0.9368	0.7971	0.7612	0.6816	0.6843
F statistics	383.54	621.01	1308.94	272.93	6333.58	11756.71
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Number of groups	3	5	13	4	10	31

Note: Standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1.

Table 3. Regression using the panel fully generalised least square approach.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	GLOBP	CEMAC	EAC	ECOWAS	NA	SADC	SSA
Dependent variable : Agronomic transformation							
LXDBTTOT	0.194***	0.393***	0.00281	0.210***	-0.0336	0.201***	0.197***
	(0.0174)	(0.124)	(0.0341)	(0.0353)	(0.103)	(0.0266)	(0.0195)
LFDII	-0.000124	-0.732	-0.629***	0.457**	1.266***	-0.0115	-0.0585*
	(0.0346)	(0.762)	(0.208)	(0.223)	(0.282)	(0.0310)	(0.0329)
LODA	-0.122***	-0.119	-0.450***	0.0802**	-0.274***	-0.0432	-0.0379*
	(0.0179)	(0.0850)	(0.0311)	(0.0386)	(0.0572)	(0.0291)	(0.0204)
LREMIT	0.0948***	0.402***	0.00669	0.0182	0.153***	0.000876	0.0624***
	(0.00663)	(0.0655)	(0.00873)	(0.0168)	(0.0498)	(0.0103)	(0.00738)
LDINV	0.565***	0.0967	0.816***	0.481***	0.283***	0.514***	0.557***
	(0.0163)	(0.168)	(0.0367)	(0.0201)	(0.0572)	(0.0290)	(0.0190)
LGDPC	0.700***	-0.462***	-0.175***	-0.174***	-0.773***	-0.676***	-0.729***
	(0.0144)	(0.104)	(0.0515)	(0.0552)	(0.125)	(0.0211)	(0.0140)
Constant	8.695***	23.92	21.71***	-2.439	-8.124	11.13***	10.59***
	(0.776)	(15.78)	(4.480)	(4.739)	(5.444)	(0.682)	(0.716)
Observations	727	65	99	282	92	189	635
Wald chi2	10283	399	9506	3226	208	5872	9356
Number of COUNTY	35	3	5	13	4	10	31

Note: Standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1.

The FGLS was further employed for robustness purposes and for comparative intentions regarding the estimation technique that accounts for CD and those that do not. The outcome of the FGLS presented in Table 3 shows that the external debt outcome is all positive and only negative for NA. This outcome confirms what was initially obtained for the DKFE model. Remittances are generally positive for all models but vary in terms of the levels of significance. This can be attributed to the fact that the FGLS model does not account for CD among the economies of the study. FDI and ODA are both negative for the global African model; however, there is a disparity in terms of signs when compared with the baseline models estimated using the DKFE. The control variables, domestic investment and GDP per capita, equally demonstrate complementarity and differences with the baseline DKFE model. These differences in terms of sign and significance can partially be explained by the non-consideration of CD in the FGLS model. This further supports the arguments presented by authors like Pesaran (2007) that the non-consideration of CD may lead to biased outcomes and conclusions. Therefore, considering techniques that account for CD is vital in obtaining efficient outcomes.

Additionally, the effect of external finance on the conditional distribution of agronomic transformation in Africa is examined using the panel quantile technique. The outcomes of the quantile regression are presented in Table 4 and demonstrate that external debt positively and significantly boosts agronomic transformation from the lowest quantile (10^{th}) to the highest quantile (90^{th}). In the same vein, remittances are positive and statistically significant for the nine quantiles considered. FDI is generally negative from the 10^{th} to the 40^{th} quantile and positive from the 50^{th} to the 90^{th} quantile. However, the results are not significant. ODA is negative for all quantiles but statistically significant only from the 30^{th} to the 90^{th} quantile. This outcome validates the initial baseline outcome of the DKFE model and equally demonstrates that external finance has a disparity in terms of the conditional distribution of agronomic transformation. Domestic investment is generally positive, and GDP per capita is generally negative across all quantiles.

Endogeneity is equally vital in a panel model. Authors like Alabi (2014), Kapetanios and Marcellino (2010), and Roodman (2009) have noted that without accounting for endogeneity within a panel, estimated outcomes can be biased. To account for endogeneity, we employ the sequential linear panel data estimation technique using the GMM approach. The outcome presented in Table 5 shows that the main Africa panel model (column 1, GLOBP) outcome reveals and confirms the positive effect of external debt on agronomic transformation amidst endogeneity control. Equally, amid endogeneity, remittances reaffirm a positive effect on agronomic transformation. This demonstrates that the initial outcome for external debt and remittances on agronomic transformation is confirmatory and robust to the problem of endogeneity. Furthermore, ODA is still significantly negative, and FDI is positive and not statistically significant. This confirms the DKFE outcome amidst endogeneity. Since the GMM-type sequential regression requires large individual units, instead of the sub-regional comparison, we consider five simulation cases wherein at least one sub-regional grouping is eliminated to see if this will alter the main results in column 1. In column 2, wherein NA is not considered, external debt and remittances positively boost agronomics, while FDI and ODA are negative, but only FDI is significant. This shows that the significant degrading effect of ODA on agronomic transformation is mostly from North Africa. In column 3, where CEMAC economies are partial, column 4 with no EAC economies, column 5 with no ECOWAS economies, and column 6 with no SADC economies, the outcomes are all consistent with the outcome in column 1. This shows that a major disparity exists between North Africa and SSA in terms of how external sources of finance shape agronomic transformation. The different models equally show that there is no first- or second-order autocorrelation, and equally, the Hansen test is insignificant, showing that the instruments are valid.

Table 4. Regression using the panel quantile regression approach.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	10th	20th	30th	40th	50th	60th	70th	80th	90th
Dependent variable : Agronomic transformation									
LXDBTTOT	0.249***	0.244***	0.240***	0.236***	0.232***	0.228***	0.225***	0.222***	0.216***
	(0.0539)	(0.0430)	(0.0353)	(0.0304)	(0.0282)	(0.0301)	(0.0338)	(0.0391)	(0.0503)
LFDII	-0.0813	-0.0555	-0.0341	-0.0151	0.00473	0.0258	0.0415	0.0575	0.0853
	(0.108)	(0.0862)	(0.0709)	(0.0610)	(0.0568)	(0.0604)	(0.0678)	(0.0784)	(0.101)
LODA	-0.0372	-0.0660	-0.0899**	-0.111***	-0.133***	-0.157***	-0.174***	-0.192***	-0.223***
	(0.0636)	(0.0507)	(0.0419)	(0.0361)	(0.0337)	(0.0357)	(0.0399)	(0.0461)	(0.0593)
LREMIT	0.0906***	0.0978***	0.104***	0.109***	0.115***	0.121***	0.125***	0.129***	0.137***
	(0.0197)	(0.0157)	(0.0129)	(0.0111)	(0.0104)	(0.0110)	(0.0123)	(0.0143)	(0.0183)
LDINV	0.543***	0.538***	0.534***	0.531***	0.527***	0.523***	0.521***	0.518***	0.513***
	(0.0476)	(0.0379)	(0.0311)	(0.0268)	(0.0249)	(0.0265)	(0.0298)	(0.0345)	(0.0444)
LGDPC	-0.668***	-0.671***	-0.673***	-0.675***	-0.677***	-0.679***	-0.681***	-0.682***	-0.685***
	(0.0454)	(0.0362)	(0.0297)	(0.0256)	(0.0238)	(0.0253)	(0.0285)	(0.0329)	(0.0424)
Observations	727	727	727	727	727	727	727	727	727

Note: Standard errors in parentheses.
*** p<0.01, ** p<0.05.

Table 5. Regression using the system GMM sequential regression approach.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	GLOBP	SSA	NOCEMAC	NOEAC	NOECOWAS	NOSADC
Dependent variable: Agronomic transformation						
LXDBTTOT	0.232**	0.232***	0.217**	0.233**	0.208*	0.331***
	(0.0936)	(0.0744)	(0.0948)	(0.0991)	(0.112)	(0.127)
LFDII	0.0239	-0.101*	0.0769	0.0149	0.00528	0.341
	(0.102)	(0.0594)	(0.110)	(0.104)	(0.0921)	(0.338)
LODA	-0.151**	-0.0174	-0.135**	-0.148**	-0.205***	-0.218***
	(0.0612)	(0.0638)	(0.0639)	(0.0656)	(0.0576)	(0.0739)
LREMIT	0.106***	0.0700**	0.0765**	0.115***	0.127***	0.116**
	(0.0348)	(0.0330)	(0.0309)	(0.0422)	(0.0389)	(0.0532)
LDINV	0.523***	0.541***	0.541***	0.504***	0.518***	0.472***
	(0.0874)	(0.0740)	(0.0882)	(0.0900)	(0.119)	(0.0986)
LGDPC	-0.681***	-0.732***	-0.629***	-0.659***	-0.708***	-0.709***
	(0.0650)	(0.0611)	(0.0879)	(0.0729)	(0.0597)	(0.0936)
Constant	7.970***	10.92***	6.856**	8.219***	9.051***	-0.0879
	(2.723)	(1.552)	(2.984)	(2.751)	(2.618)	(6.923)
Observations	727	635	662	628	445	538
Number of COUNTY	35	31	32	30	22	25
AR(1)	-1.8571	-1.6042	-1.6307	-1.4598	-1.8762*	-1.7824
AR(2)	0.6489	0.3955	0.7479	0.6507	0.9981	0.5042
Hansen test	21.6475	21.3052	24.3316	23.7574	10.9435	20.6659
	[0.3599]	[0.3794]	[0.2282]	[0.2532]	[0.9477]	[0.4170]

Note: Standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1.

5. CONCLUSION AND RECOMMENDATIONS

This study examined the role of external finance sources in shaping agronomic transformation on the African continent. The study examines the concepts of agronomic transformation and how it has been affected by different sources of external finance from 2000 to 2022 within a panel of 38 economies. In this light, data is obtained from the World Development Indicators, and we use a plethora of estimation approaches such as the Driscoll-Kraay, the fully generalized least squares, the quantile regression, and the generalized method of moments-type sequential regression techniques. The outcome revealed ample evidence of an augmenting effect of external debt and remittances on agronomic transformation in Africa. Furthermore, FDI demonstrated a negative effect, while ODA is positive but insignificant. A sub-regional comparison between the outcomes shows consistency in the positive effect of remittances across the five regional blocs considered. However, the regional comparison revealed that the effect of ODA, FDI, and external debt on agronomic transformation demonstrates disparity in terms of signs and significance levels. Further outcomes revealed that controlling for econometric problems like endogeneity and cross-sectional dependence within models brings some disparities in the outcomes.

Based on the established results, we put forth the following policy proposals. ODA should be channeled toward capacity-building activities that benefit local farmers and agricultural cooperatives. ODA should be utilized to increase food security by providing training, resources, and market access to support sustainable agricultural methods. Regarding external debt, governments should ensure that external debt is allocated specifically to agricultural projects with the potential for substantial returns. Debt should be directed toward investments in infrastructure, irrigation systems, and technology to enhance agricultural productivity. This focused approach can help limit the risks associated with debt accumulation while maximizing the advantages to the agriculture industry.

To boost the effect of FDI in driving a positive agronomic transformation, by promoting collaborations with private investors, governments can exploit FDI to promote innovative agricultural technologies and practices that enhance production. Remittances are an important source of funding for household agricultural investments. Policymakers can encourage the use of remittances for agricultural purposes by offering financial literacy programs that educate beneficiaries on agricultural investment prospects. Establishing effective monitoring and evaluation frameworks is critical for determining the impact of external loans, ODA, FDI, and remittances on agricultural transformation. This will allow governments to make data-driven judgments and alter policies as necessary.

Finally, a study of this magnitude cannot be void of some caveats that could be considered for further studies. Firstly, the study period and the number of African countries can be increased to verify the robustness of the current outcomes over time. Other estimation techniques exist that scholars could consider for further study.

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APPENDIXES

Appendix 1. Descriptive statistics.

Variables	Obs	Mean	Std. dev.	Min	Max
AVA	1012	6.517e+09	1.413e+10	59509906	1.217e+11
External debt	966	1.260e+10	2.360e+10	1.256e+08	1.907e+11
FDI	1012	8.526e+08	2.087e+09	-7.397e+09	4.066e+10
ODA	1012	57.814	56.357	-11.967	627.346
Remittances	989	1.095e+09	3.717e+09	0	3.149e+10
Domestic investment	864	9.807e+09	1.931e+10	36402660	1.571e+11
GDP per capita	1012	1924.713	2167.026	255.1	14222.549

Appendix 2. Pairwise correlations.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) LAVA	1.000						
(2) LXDBTTOT	0.733	1.000					
(3) LFDII	0.259	0.263	1.000				
(4) LODA	-0.421	-0.384	-0.010	1.000			
(5) LREMIT	0.555	0.439	0.375	-0.087	1.000		
(6) LDINV	0.766	0.862	0.249	-0.394	0.481	1.000	
(7) LGDPC	-0.070	0.429	0.124	-0.199	0.165	0.450	1.000

Appendix 3. Cross-sectional dependence and unit root test.

Pesaran 2015 residual CD test			
Test statistics	3.245		
P value	0.001		
Pesaran CIPS unit root test			
Variables	Level test statistics	First difference test statistics	Decision
LAVA	-2.485		I(0)
LXDBTTOT	-1.148	-3.869	I(1)
LFDII	-2.349		I(0)
LODA	-2.487		I(0)
LREMIT	-0.613	-3.765	I(1)
LDINV	-1.475	-3.741	I(1)
LGDPC	-1.650	-3.845	I(1)

Appendix 4. Westerlund cointegration test.

Statistic	Value	Z-value	P-value
Gt	-1.977	-1.474	0.070
Ga	-5.127	2.455	0.993
Pt	-11.460	-1.869	0.031
Pa	-5.136	-1.353	0.088

Appendix 5. List of countries.

Angola	Congo, Dem. Rep.	Kenya	Senegal
Benin	Congo, Rep.	Lesotho	Sierra Leone
Botswana	Cote d'Ivoire	Madagascar	South Africa
Burkina Faso	Equatorial Guinea	Mali	Tanzania
Burundi	Eswatini	Mauritius	Togo
Cabo Verde	Gabon	Mozambique	Uganda
Cameroon	Gambia, The	Namibia	Zambia
Central African Republic	Ghana	Niger	Zimbabwe
Chad	Guinea	Nigeria	
Comoros	Guinea-Bissau	Rwanda	