Does Improving Agricultural Productivity Reduce Poverty? A Computable General Equilibrium Approach for Guinea-Bissau

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Abstract
This paper aims to analyze the effects of productivity improvements on economic outcomes, especially on poverty reduction in Guinea-Bissau for the period 2014-2030. We analyze the evolution of agricultural production over the last three decades and econometrically estimate the agriculture investment allocation parameter. Through a dynamic recursive CGE model, we find that improvements in agricultural productivity through a 4% increase in investment in this sector positively impact GDP growth, sector output, and job opportunities for rural and urban workers. There are long-term positive welfare effects from rising real income and household consumption in rural and urban settings. The rural household welfare gains are due to direct effects and a drop in the consumer price index. The decline in food prices propagated the indirect impacts on urban household welfare. The poor benefited the most. We suggest an agricultural development agenda as a measure that would help to improve the poorer living standard in this country.
Keywords: Agricultural productivity. Poverty reduction. Guinea-Bissau economy.

Resumo
Este estudo tem como objetivo analisar os efeitos das melhorias de produtividade nos resultados econômicos, especialmente na redução da pobreza na Guiné-Bissau no período 2014-2030. Analisamos a evolução da produção agrícola nas últimas três décadas e estimamos econometricamente o parâmetro de alocação do investimento. Por meio de um modelo EGC recursivo dinâmico, encontramos que as melhorias na produtividade agrícola por meio de um aumento de 4% no investimento neste setor impactam positivamente o crescimento do PIB, a produção do setor e as oportunidades de emprego para trabalhadores rurais e urbanos. Existem efeitos positivos de bem-estar a longo prazo decorrentes do aumento da renda real e do consumo das famílias em ambientes rurais e urbanos. Os ganhos de bem-estar das famílias rurais devem-se a efeitos diretos e à queda no índice de preços ao consumidor. A queda nos preços dos alimentos propagou os impactos indiretos sobre o bem-estar das famílias urbanas. Os pobres se beneficiaram mais. Sugerimos uma agenda de desenvolvimento agrícola como medida que pode ajudar a melhorar o padrão de vida dos mais pobres do país.
Palavras-chave: Produtividade agrícola. Redução da pobreza. Economia da Guiné-Bissau.
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1. Introduction

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Guinea-Bissau is a West African country with about 2 million inhabitants, of whom 60% live in rural areas and 40% in small urban cities. This country is characterized by low macroeconomic performance and a high level of poverty. The gross domestic product (GDP) per capita and the Human Development Index are US$ 600 and 0.424, respectively. The life expectancy at birth is about 46 years, while about 69 percent of the population live in absolute poverty (World Bank, 2019). Moreover, Guinea-Bissau has an agriculture-based economy since much of the national production is directly related to agricultural activities. For instance, from 2010 to 2017, the farm sector represented nearly 42% of the output and absorbed 61% of the labor force (ILO, 2019).

The governments of Guinea-Bissau have carried out since the mid-1980s several economic reforms oriented for agriculture sector development. In 2015, they budgeted $1 billion US dollars to promote agricultural productivity, boost economic growth, and generate resources for extreme poverty reduction policies (Guinea-Bissau, 2015). However, given the precariousness of fiscal instruments, about 95% of these investments are loans from international partners, such as World Bank, European Union, and African Union, and only 5% from own revenues. As a result, the cost of debt in the medium and long term can be too high. The lack of mechanism of control and accountability may raise uncertainties about whether this budget will be fully allocated for the initial purposes. The internal or regional political and institutional instabilities can make it harder to implement the desired measures.

However, even with such possible costs, improved agriculture productivity can benefit the poor (Korkmaz and Korkmaz, 2017). Past works show that agriculture productivity contributes to increase sector output and boost economic growth (Rudolf and Zurlinden, 2010), increase capital employment (Alani, 2012), income (Gollin, Lagakos, and Waugh, 2014), and trade (Alcalá and Ciccone, 2003). Ehui and Pender (2005) show that the performance of agriculture has long remained the indicator of well-being for families in Sub-Saharan Africa, where 60 percent of the individuals are agricultural population, and 80 percent are poor. This paper explores the relative importance of agricultural sector improved productivity in explaining poverty reduction in a setting with heterogeneous workers for Guinea-Bissau. The motivation is that poverty alleviation occurred in the period of agricultural productivity growth. For example, in 2002, agricultural productivity decreased by about 0.12%, and poverty incidence rates enlarged by about 23%. The poverty incidence rates decreased by about 15% in 2017, following up a 0.9% agricultural sector productivity growth in the previous year (Faostat, 2019; Word Bank, 2019).

Since the seminal work by Johnston and Mellor (1961) on the role of agriculture in inclusive economic development, a plethora of empirical studies has examined pro-poor agricultural productivity growth. For instance, Datt and Ravallion (1998) used microdata to estimate the impacts of agricultural productivity on India's rural poor. They found evidence that increased agricultural productivity by 1% contributes to decreasing absolute poverty by about 12%. The relative poverty has decreased by about 5% due to 1% reduction in food price. Moreover, 1% increase in GDP growth coming from agriculture leads to about 10% reduction in poverty. Ravallion and Chen (2007) in turn used annual poverty data over 21 years to estimate the effect of sectoral growth on the poverty rate in China. They found evidence that agriculture impact poverty reduction by about 3.5 times larger than either the secondary or tertiary sectors.

In an across-developing region study, Thirtle et al. (2003) estimated the impact of research on agricultural performance and poverty. They found that increased agriculture productivity (value-added per worker) by 1% resulted in a drop of about 0.65 in poverty in Africa, Asia, and the Americas. De Janvry and Sadoulet (2010) used an autoregressive vector model to examine poverty's response to agricultural productivity impulses. They found evidence that agricultural productivity growth by 1% decreases world poverty by about 2.2%. Irz et al. (2001) estimated the impact of productivity growth on the poverty headcounts alleviation in a pair of countries, of which about two-thirds are African. Among the findings, they observed that 1% increase in agricultural yields causes a reduction in extreme poverty by about 0.37%. These results are statistically significant even at 1%.

Meanwhile, Minten and Barrett (2008) estimated the link between agricultural performance and rural poverty alleviation in Madagascar and found that poverty reduction in communities has occurred because of the drop in food prices of about 0.258 due to improved food production technology. Demery (2007) estimated the effect of sectorial growth on the headcount poverty rate for selected African countries. Comparatively to the impact of GDP growth coming from non-agriculture sectors, they found evidence that overall GDP growth originating from agriculture is 2.7 times more effective in reducing extreme poverty (1$/day). Bravo-Ortega and Lederman (2005) estimated the effect of an increase in sectoral labor productivity on GDP growth and the income of the poor in developing countries. They found evidence that overall GDP growth due to agricultural labor productivity, on average, impacts by about 2.9 times more the income of the poorest quintiles than the GDP growth related to non-agricultural labor productivity.

De Janvry and Sadoulet (2001) examined through a computable general equilibrium model (CGE) the direct and indirect impacts of improved agricultural technology on poverty in Africa, Latin America, and Asia. They found that targeting technical change on the land held by small and medium farmers gives rise to an aggregate growth effect of about 2.6%. Conversely, indirect effects are the only source of real income gains for large farmers since they face lower prices for their crops without having the beneficial effect of technology. As a result, they observed that the urban poor are the main beneficiaries, with real income gains being three times larger than those of the rural poor, 0.7% vs. 0.2%.

Sarris (2001) simulated through a CGE model the effects of increasing agriculture productivity on poverty alleviation. They found that for any given degree of openness, 1% increase in the values of the agricultural TFP (total factor productivity) elasticity contributes to an increase by about 3.8% the growth of the real incomes of the poor. This is a scenario where the aggregate saving rate is kept at 0.2. Pauw and Thurlow (2011) used a dynamic recursive GCE model to analyze the effects of agricultural growth on poverty and hunger reduction in Tanzania. They found evidence of pro-poverty growth elasticity of about -1.32 due to a 4.09% agricultural production growth, which would confirm the broad-based agricultural growth in alleviating poverty.

The impact of increased production on labor demand may depend on the intensity of labor used by the sector. If the output from the agricultural sector increases, it is expected that demand for rural workers and their labor income will increase as well. In this case, Loayza and Raddatz (2010) draw attention to the importance of the composition of growth when the analysis focuses on the labor market. In a cross-countries study, including seventeen countries from Africa, they observed that it is not just the size of growth that matters for poverty reduction for sectors intensives in the use of unskilled labor, such as agriculture and construction. In agriculturally based-economies, agricultural output growth will increase the incomes of the poorest rural households and demand for goods and services produced outside the rural environment and urban income will increase as well (Lin et al., 2001). The increase in comparative advantage is due to agricultural productivity impacts on production, resulting in higher aggregated income, either through international trade or employment opportunities.

This study aims to provide macro and micro level evidence showing how improved agricultural productivity impacts poverty reduction in Guinea-Bissau using a dynamic recursive

CGE model. The base year is 2014 and we analyze the effects of improved productivity on economic outcomes over a 16-year window, i.e., from 2014 to 2030. The effects of policies at time t (i.e., year 2014) start to manifest themselves at time t+1. The initial projection that generated the baseline solution is BAU (business as usual) simulation, where it is assumed 2 % growth corresponding to the growth of the stock of capital in the economy in the last three decades.

This paper builds on, and contributes to, these past studies in several ways. First, we analyze the implications for poverty reduction by comparing household income gains and long-term consumption before and after the productivity shocks. The households are partitioned into four rural and urban categories to analyze the individual's *ex-ante* socioeconomic status influences on *ex-post* economic outcomes. This disaggregation is crucial for the design of policies to mitigate the poverty traps in developing countries. This is an important innovation from previous works that study the effect of productivity on economic outcomes irrespective of *ex-ante* family conditions. The focus on rural and urban households also brings enormous advantages as we can provide evidence to support the elaboration of public policies consistent with the reality of each family across and within settings.

Second, it used Faostat data on agricultural production from 1990 to 2017 to calculate the productivity growth rate to understand the relative importance of each micro-sector in the economy in terms of its contribution to output growth and job creation. The use of Faostat in this study is important because agriculture is intensive in the employment of poor workers in Guinea-Bissau. Previous work by De Janvrey and Saboulet (2010) shows that, in such a context, agricultural productivity growth tends to be more inclusive. Thus, together with World Bank facilities indicators, we estimate the productivity parameters by sector and then use an updated 22 sectors social accounting matrix (SAM) of Guinea-Bissau from IFPRI (International Food Policy Research Institute) to simulate productivity growth on the households' economic outcomes applying parameters previously estimated through an econometric model to calibrate allocation of investment to agriculture. Improved agricultural productivity comes from a 4% increase in new capital investment in this sector. This shock size corresponds to the average growth rate of capital, proxied by the quantity of machinery, from 1990 to 2017. Third, the simulations are accomplished by a CGE model, the first to be applied for this economy, to the best of our knowledge. Finally, agricultural productivity externalities and their implication on poverty reduction are not been explicitly modeled by past studies. This work is a first attempt to fills this theoretical gap.

We find several key results. First, in line with a large literature that documents that agriculture productivity growth impacts economic outcomes (e.g., Gayathr et al., 2018; Gabaix, 2011; Fernald, 2014; Nakamura, Kaihatsu, and Yagi, 2019), we find that improved agricultural productivity increase job opportunities for workers in rural and urban environments. The agricultural productivity improvements have increased the household incomes. The benefited the most. We observe that, while the increase in rural household income is due to labor income growth, the increase in urban household income is related to capital income gains. The wealth accumulation by type of households over time has increased their consumption and long-term well-being.

The remainder of the paper is structured as follows. Section 2 builds an agricultural-based CGE model. Section 3 presents results. Section 4 concludes.

2. Theoretical framework

We develop Guinea-Bissau economy-based CGE model. The foundations of this model stems from neoclassical microeconomic assumptions in the tradition of Dervis, De Melo, and Robinson (1982). Particularly, we develop a dynamic recursive CGE model consistent with PEP

(Partnership for Economic Policy) framework. As this is a detailed model, we refer interested reader to Decaluwé, Lemelin, Robichaud, and Maisonnave (hereinafter, DLRM, 2012).

The key assumption of our model is that productivity generates economic outcomes capable of reducing the level of poverty. Let

$$VA_{j,t} = B_j^{va}\left[\beta_j^{va} Ldc_{j,t}^{-\rho_j^{va}} + \left(1-\beta_j^{va}\right) Kdc_{j,t}^{-\rho_j^{va}}\right]^{\frac{1}{\rho_j^{va}}} \quad (1)$$

denoting a typical value-added equation, where $Ldc_{j,t}$ and $Kdc_{j,t}$ are the industry j demand for composite labor and composite capital at time t, respectively; B_j^{va}, β_j^{va} , and ρ_j^{va} are the CES-value added scale, share, and elasticity parameters, respectively. The industry j productivity ($\theta_{j,t}$) has the following functional form:

$$\theta_{j,t} = \left(\frac{INV_t}{INV_{t-1}}\right)^{\varepsilon_i} \quad (2)$$

and represents productivity effect on economic outcomes. It is set as a function of the ratio of current stock of composite investment (INV_t), i.e., at time $t,$ over composite previous investment (INV_{t-1}), and ε_i is an agricultural subsector-specific elasticity. Equation (2) is consistent with past works by Savard (2010) and Boccanfuso et. al. (2014) on the externalities of public investments on the level of economic activity.

$\theta_{j,t}$ variations can be induced as in Hicks sense due to the natural resources discovery and technology changes, or it can be induced by investment policies incentives. As we discussed below, despite the efforts made in favor of agricultural production, the productivity of the sectors did not grow that much, so scale up agriculture investment can result in an important change in $\theta_{j,t}$. We introduce the induced-productivity effect on the model variables as follows:

$$VA_{j,t} = \theta_{j,t} B_j^{va}\left[\beta_j^{va} Ldc_{j,t}^{-\rho_j^{va}} + \left(1-\beta_j^{va}\right) Kdc_{j,t}^{-\rho_j^{va}}\right]^{\frac{1}{\rho_j^{va}}} \quad (3)$$

The mechanisms of transmission are as: at macro level, if the current investment stock is greater than the previous investment, productivity grows. Positive $\theta_{j,t}$ shock is expected to increase the level of economic activity through each sector value added. For a given production technology, the industry production should increase as well as total aggregate output at time t. Given the direct link between the level of economic activity and GDP, the economy should grow from one period to the next. The investment effect on GDP is likely to continue until capital depreciates.

The positive macro impacts are due to efficiency gains. A productivity growth implies decrease in the factor requirement per unit of sector product. Although the aggregate labor factor demand is declining in the short-run (see Hanson and Rose, 1997), over long term, however, it is expected that the adjustments in the market factor will lead to the primary factors, labor-capital, substitution towards full employment that reduce the initial negative impact on employment.

It is precisely in job opportunities creation that the first micro-level effects of productivity growth occur. Let $Ldc_{j,t}$ and $Kdc_{j,t}$ be the demand for labor and capital:

$$Ldc_{j,t} = \left[\frac{\beta_j^{va}}{1-\beta_j^{va}}\frac{RC_{j,t}}{WC_{j,t}}\right]^{\sigma_j^{va}} Kdc_{j,t} \quad (4)$$

$$Kdc_{j,t} = B_j^{Kd}\left[\sum_k \beta_{k,j}^{Kd} Kd_{k,j}^{-\rho_j^{Kd}}\right]^{-\frac{1}{\rho_j^{Kd}}} \quad (5)$$

where $RC_{j,t}$ is the rental rate of industry j composite capital at time t; $WC_{j,t}$ is the wage rate of industry j composite labor at time t; σ_j^{va} is the CES-value added elasticity of transformation, $0 < \sigma_j^{va} < \infty$; $Kd_{k,j}$ is the demand for type *k* capital by industry *j;* and ρ_j^{Kd} is the CES-composite capital elasticity parameter; $-1 < \rho_j^{Kd} < \infty$.

The effect of increased productivity on employment is carried from one period to another through the scale parameter, β_j^{va}. If the scale parameter of current production increases more than its value in the previous period, then investments in agriculture imply an increase in the sector's production and in the demand for labor. Given the slack in the labor market, employment opportunities grow for households in both rural and urban settings. This means that households' consumption may increase as the product supply and labor income grow.

This assumption is consistent with past work by Gollin (2010), who shows that improved agricultural productivity leads to growth in total product. Recent evidence points to the existence of a price-effect associated with increased agricultural production (e.g., Irz et al. 2001). As the industry product supply increases, the price of the product should decrease, and households now can consume more units of the goods than before.

Household demand is a Linear Expenditure System (LES). We assume household to maximize a Stone-Geary utility function for each commodity subject to the budget constraints, so that:

$$PC_{i,t}C_{i,h,t} = PC_{i,t}C_{i,h,t}{}^{MIN} + \gamma_{i,h}{}^{LES}\left(CTH_{h,t} - \sum_{ij} PC_{ij,t}C_{ij,h,t}{}^{MIN}\right) \tag{6}$$

where $PC_{i,t}$ is the purchaser price of composite commodity i (including all taxes and margins) at time t; $C_{i,h,t}$ is the consumption of commodity i by type h households at time t; $C_{i,h,t}{}^{MIN}$ is the minimum consumption of commodity *i* by type *h* households at time t; $\gamma_{i,h}{}^{LES}$ is the marginal share of commodity *i* in type *h* household consumption budget; and $CTH_{h,t}$ is the consumption budget of type *h* households at time t.

Note that in Equation (6), we do not impose restrictions on cross-price elasticities, instead we assume that these elasticities can be zero across all pairs of commodities. This is consistent with many utility functional forms in CGE modeling (e.g., see DLRM, 2012). Thus, by combining this with the assumption that income elasticities for all available commodities can be zero, our model is flexible enough to accommodate the substitution possibilities in response to relative price changes.

The dynamic in the model is introduced as usual with capital accumulation rule given by equation (7):

$$Kd_{k,j,t+1} = Kd_{k,j,t}(1 - \delta_{k,j}) + Ind_{k,j,t} \tag{7}$$

where $Kd_{k,j,t+1}$ is the stock of type *k* capital in industry *j* at time $t + 1$; $Kd_{k,j,t}$ is the stock of type *k* capital in industry *j* at time *t;* $Ind_{k,j,t}$ is the volume of new type *k* capital investment to sector *j* at time *t;* and $\delta_{k,j}$ is the depreciation rate of capital *k* used in industry *j*. Equation (7), then, states that stock of type *k* capital in industry *j* in time $t + 1$ is equal to the capital stock in time *t*, minus depreciation, plus the volume of capital investment in the current period.

The evolution of capital stock is modeled through the investment demand functions (Equation 8), where the volume of new type of capital allocated to agriculture-sector is proportional to the new capital investment. The proportion varies according to the ratio of the rental rate ($R_{k,i,t}$) over the user cost of that capital ($U_{k,i,t}$- Tobin's q).

$$Ind_{k,j,t} = \phi_{k,i}\left[\frac{R_{k,j,t}}{U_{k,j,t}}\right]^{\sigma_{k,j}{}^{INV}} Kd_{k,j,t} \tag{8}$$

where $\phi_{k,j}$ is the scale parameter (allocation of investment to agriculture) and $\sigma_{k,j}{}^{INV}$ the elasticity of private investment demand relative to Tobin's q, which in turn depends on the price of new capital (or replacement cost of capital - ${PK_t}^{new}$), the rate of interest ($IR_{k,t}$), and the rate of depreciation (Equation 9).

$$U_{k,j,t=} = {PK_t}^{new} \left(\delta_{k,j} + IR_{k,t}\right) \tag{9}$$

$$Lcs_{t+1} = Lcs(1+n) \tag{10}$$

The dynamic specification is complete through by setting the update variables that grow at a constant rate per period, governed by official population growth rates over time which enters the model as a free parameter *n*. We use this parameter to introduce the labor force growth (Lcs_{t+1}) as usual (Equation 10).

2.1 Data and Empirical strategy

We use a 22 sectors SAM for Guinea-Bissau from IFPRI and Faostat data on agricultural production and capital investment in agriculture to calibrate and simulate productivity growth. One possible concern may be that a CGE model assumes a competitive economy and optimizing agents, so that a country with GDP per capita of 600 USD may not be well represented through these types of models. Moreover, in a CGE model, any exogenous productivity shock will raise GDP, sectoral activity, labor income, etc. So, the results obtained may be obvious and very easy to model with any CGE. The interesting question would be what kind of policies allow raising productivity. For instance, it should be noted that modeling a sectoral productivity shock without explaining where it comes from contributes little to the literature.

These concerns, however, can be allayed by the inclusion of the informal sector in SAM and appropriate treatment of origin of productivity growth. Thus, first, we compute value-added and informal and formal activities shares by sector. Table 1 reports an example of how this is done for the agricultural sectors. Since the SAM contains formal activities, the consideration of informal activities includes only the weighted values in Column I*III, defined as the proportion of informality in a sector activity multiplied by its share in the value-added. This is built on the work by Thiele and Piazolo (2003).

Table 1 – Share of formal and informal activities in the agricultural sectors, 2014

Sector	Informal activity	Formal activity	VA share	Weighted informal	Weighted formal
	I	II	III	I*III	II*III
1. Millet	0.793	0.207	0.201	0.159	0.042
2. Sorghum	0.793	0.207	0.154	0.122	0.032
3. Rice	0.793	0.207	0.191	0.151	0.04
4. Maize	0.793	0.207	0.110	0.087	0.023
5.Other agr.	0.793	0.207	0.344	0.273	0.071

Sources: The Authors'. Note: *Sector* is the number and sector; *Informal activity* is the share of informal activity in that sector, *formal activity* is the share of formal activity in that sector; *VA share* is the sectorial share of all agricultural activities; *Weighted informal* is the weighted share of the informal activities; *Weighted formal* is the weighted share of the formal activities (source: National Research Institute, INEP); *VA share* is the sector share in agricultural value added (Source: Faostat - crops production; and World Bank Development indicators, WBDI –Value added by macro sector).

Second, it is used the 2014 official minimum wage to disaggregate households in four urban and four rural types (Table 2) and then emerge the resulting shares with every row and column in the SAM so as to obtain a new level of consumption and income for every household, generating an updated 2014 SAM.

Table 2 – Household disaggregation by minimum wage

Household type	Rural	Urban	Wage limit	Wage in Franco CFA	Share
Household 1	HR1	HU1	≤ 1 minimum wage	\$ 50,000*	0.053
Household 2	HR2	HU2	≤ 2 minimal wages	\$ 100,000	0.105
Household 3	HR3	HU3	≤ 4 minimal wages	\$ 200,000	0.211
Household 4	HR4	HU4	≤ 6 minimal wages	\$ 600,000	0.632

Source: Authors elaboration. Note: Household type is household classification by effective received wage. Type of HR1 Household 1 is rural household receiving up to one minimum wage. Its urban counterpart is HU1. *Wage limit* is the maximum amount the household can receive. In general, we observe that each household receives wage below this bound. *Wage in Franco CFA* is the current official wage in 2014 (source: INEP, 2014). * *50,000*(=\$ US 93) is the minimum wage. The wage below the minimum is 10,000 CFA Francs (=\$US 19). Individuals in this category (HR1 and HU1) are said to live in extreme poverty as defined by the World Bank. HR1and HU1 is the rural and urban household that receives at most a minimum wage, respectively. HR2 and HU2 is the rural and urban household that receives at most two minimal wages, respectively. HR3 and HU3 is the rural and urban household that receives at most four minimal wages, respectively. HR4 and HU4 is the rural and urban household that receives at most six minimal wages, respectively. *Share* is the proportion of the household wage in total wage.

The individual economic conditions in the sample are classified in terms of initial earnings from extreme poverty to not-so-poor. In general, poorer in rural areas receive up to a minimum wage, which is equivalent to less than \$2 per day, while non-poor individuals receive a minimum wage above this amount, which ranges from \$4 to \$20 per day. By observing the sources of each household income gains in SAM, we interrelated the labor market and factor market. Specially, we link labor supply in terms of unskilled and skilled workers in rural and urban settings to each household economic condition in terms of several poor and non-poor households in both rural and urban environments. The reason for disaggregating workers (or households) in several types is that it allows visualizing which sector demands more the labor offered by poor households, for example. By computing the share of sectorial labor demand for the type of worker from the SAM flows, it is observed that the agricultural sectors demand more unskilled labor from the rural environment. In contrast, the industrial and service sectors require more skilled one.

Finally, we estimate the TFP by industry ($TFP_{j,t}$) as a function of capital (cap_{it}) and labor ($labor_{it}$) and infrastructure ($Infra_{it}$), and sectoral fixed effects (γ_i) - Equation 11. This specification is consistent with the usual econometric model on productivity determinants (e.g., Key and McBride, 2003; Mawson et al., 2003).

$$TFP_{it} = \delta_0 + \delta_1 cap_{it} + \delta_2 labor_{it} + \delta_3 Infra_{it} + \gamma_i + e_{it} \quad (11)$$

where e_{it} is the well-behaved error term. The capital stock is proxied by the quantity of machinery in agriculture (Source: Faostat), labor is the employed population over 15 years (Source: ILO), and infrastructure includes quality of infrastructure and logistic performance indexes (source: WBDI).

The econometric model details are given in Appendix A. Table 3 reports the estimates found through the generalized least square regression. It observed that 1% increase in capital employed in agriculture increases by about 0.35 percentage points the total productivity. This effect is statistically significant at 10%. In calibration, it is set $\varphi_{k,i} = 0.35$, which is sectorial investment allocation in the base year. This value is considered timid since, according to Tobin's investment theory, the equilibrium investment allocation equals 1 (see, DLRM, 2012).

Table 3 - Random-effects GLS regression for TFP

Independent variables	Dependent variable: total factor productivity
Capital	0.3507
	(0.147)*
Labor	-0.2369
	(0.092)*
Infrastructure	1.115
	(0.022)***
Coefficient	-6.085
	(0.466)***
R-sq:	0.8211
Wald chi2(3)	2910.61
Prob > chi2	0.0000
Observations	638

Source: The Authors. * p < 0:10; ** p < 0:05; *** p < 0:01.

The final demand for investment purposes (${Inv_i}^0$) is calibrated as:

$$ {Inv_i}^0 = \frac{{\gamma_i}^{Inv0} {IT_i}^0}{{PC_i}^0} \tag{12} $$

where ${\gamma_i}^{Inv0}$ is the share of commodity i in total expenditures on goods and services; ${IT_i}^0$ is the total investment expenditures; ${PC_i}^0$ is the purchaser price of composite commodity *i* (including all taxes and margins). The ${IT_i}^0$ is calibrated to be equal to the investment in agriculture weighted by current public investment in the sector, which is about 3.3% of the initial \$1 billion package. IT_i is a policy variable that increases the amount of capital investment. The shock size over IT_i is equal to the machinery investment growth rate in agriculture, which is approximately 4.3% between 1990 and 2017 (Faostata, 2019). Therefore, the simulations are based in increasing IT_i, which generates productive externalities, captured by equation (2). In this scenario, new investment IT_i is set to be exogenous.

The implications of investment in agriculture on households' long-term outcomes are measured by welfare indicators. Like De Janvry and Sadoulet (2002), a household welfare q is measured by real income, which is nominal income y divided by the consumer price index pc.

$$ q = \frac{y}{PC}, y = ({pc_a}^z z_z - c_a) + z_{-a} \tag{13} $$

where pc_a is the producer price, z_z is the production level, c_a is the production costs in agriculture, and z_{-a} is the non-agricultural income of the household.

Equation (13) indicates that, given the nominal income level, household welfare increases as consumer price index decreases. For a given price level, we should expect the household welfare to decrease. The three welfare components are written as:

Direct (within) effect:

$$ ({pc_a}^z z_z - c_a) - ({pc_a}^{z0} {z_a}^0 - {c_a}^0) + ({pc_a}^z - {p_a}^{z0}) min({x_a}^0 - {z_a}^0) + (wL - w^0 L^0) \tag{14} $$

Indirect income (between) effect:

$$ y_a - {y_{-a}}^0 - (wL - w^0 L^0) \tag{15} $$

Indirect price (substitution) effect:

$$ y\left(1 - \frac{pc_a}{pc}\right) \text{-} ({pc_a}^z - {p_a}^{z0}) min({x_a}^0 - {z_a}^0) \tag{16} $$

where x_a, w, L are the consumption of agricultural product, wage, and employ in agriculture by type of worker, respectively, and the superscript a indexes the value of variables before the productivity change due to agricultural investment. Direct effects are calculated in terms of changes in household income from agricultural sector, change in the agricultural cost of capital investment, change in consumption of agricultural production, change in agricultural self-employment. The between or indirect income effect comes from change in nominal income from all sources other than self-employment in agricultural production. The substitution or indirect price effect comes from the change in the consumer price index, discounted by the consumption opportunity cost of agricultural food products.

3. Results

This section presents the results of the improved agriculture productivity from increased new capital investment in the sector. We first discuss the macroeconomic and then turn to the sectoral and household level productivity effects. As the BAU reproduces the behavior of the model variables in the absence of the shock, the numerical values after policy simulations (i.e., agriculture investments) are interpreted as being variations relative to the BAU.

The first general observations of the results is that there are positive impacts of agriculture investments shocks on aggregate variables, such as real GDP, agricultural production, non-agricultural production, and household real income and real consumption (Table 4).

Table 4 – Macro effects of improved agricultural productivity (%)

Variable	Result
Real GDP	6.199
Total agricultural production	36.138
Total non-agricultural production	19.146
Aggregate exports	12.061
Exchange rate	-1.091
Unskilled agricultural employment	6.677
Skilled aggregate agricultural employment	1. 596
Unskilled aggregate non-agricultural employment	4.452
Skilled aggregate non-agricultural employment	2.394
Rural aggregate real income	42.954
Urban aggregate real income	13.468
Consumer price index	-0.062
Rural aggregate real consumption	15.555
Urban aggregate real consumption	5.62

Source: The Authors.

Specially, improved productivity through an increase in agricultural investment by approximately 4% immediately impacts aggregate real GDP by about 6 percent. The agricultural total output grew by about 36 percent, and the non-agricultural sector production increased by about 19 percent. Exports increase by nearly 12 percent due to increased production and falling real exchange rate by about 1 percent. Unskilled and skilled workers' aggregate employment in agriculture sector grew by approximately 7 and 1.5 percent, and by about 4 and 2 percent in the non-agricultural sectors, respectively. The rural and urban households' real incomes increased by about 43 and 13 percent, respectively. The increase in aggregate income and the drop in the consumer price index implied a rise in the aggregate households' consumption in rural and urban environments.

At the sector level, there are positive impacts of improved productivity on sectorial output due to the externalities coming from agricultural investment. We observe that a 4% increase in agricultural investment generates positive externalities in the agriculture and non-agriculture sectors. The agricultural production increases more as the externalities in the agricultural sectors are relatively greater. However, the non-agricultural sectors, such as the food processing industries, have benefited from the current policy as their production increased substantially. The impacts of positive externalities, coming from the increased investment in agriculture sectors, on the production were magnified through the scale parameter, β_j^{va}, which accumulated these effects from one period to another. As a result, the long-term sectoral outcomes are propagated by positive current and lagged direct and indirect externalities effects of investment on production.

Table 5 – Industry value added and externalities at the end of simulation (% in 2030)

Sector	Externalities ($\theta_{j,t}$)	Valued added ($VA_{j,t}$)
Millet	2.747	6.726
Sorghum	4.342	7.648
Rice	3.124	7.018
Maize	1.504	3.312
Cotton	0.483	2.8
Fonio	0.229	1.75
Other agricultural sectors	1,736	3.842
Cashew nut	1.051	3.042
Breeding and hunting	0.574	2.604
Forestry	0.203	1.312
Fishery products	0.084	0.462
Mining industries	0.14	1.016
Food	2.703	6.296
Other Industries	0.621	2.044
Electricity and water	0.552	1.244
Construction	1.098	2.804
Trading and repair	0.182	1.12
Hotels and restaurants	0.058	0.853
Transport and communication	0.023	0.448
Financial services	0.023	0.641
Services to firms	0.07	0.906
Public administration	0.034	0.774

Source: The authors.

Table 6 reports the implications of agricultural investment on employment. The results from Columns 2 to 9 (USK1-SK4) are percentage changes in the job by type of worker, in Columns 9 and 10 (Total and capital) are the aggregate labor and capital employment changes that rise from the current policy in agriculture. We observe that investment in agriculture has increased the unskilled and skilled workers' jobs. The effects are more significant across poor workers due to the increased demand in agricultural sectors intensive in unskilled labor. The aggregate labor employment grew by about 24 percent, and aggregate capital employment grew by about 37 percent. The demand for the factor capital has grown more due to the increase in the wage, the fall in the rental capital price, and the rise in investment capital return in agriculture.

Table 6 – Aggregate employment at the end of simulation (% in 2030)

Sector	USK1	USK2	USK3	USK4	SK1	SK2	SK3	SK4	Total	Capital
	4.244	3.396	2.963	2.752	1.493	1.194	1.091	1.01	24.358	37.085

Source: The Authors. Note: USK1 and SK1 is the rural and urban household that receives at most a minimum wage and offers unskilled and skilled labor, respectively. USK2 and SK2 is the rural and urban household that receives at most two minimal wages and respectively offers unskilled and skilled labor. USK3 and SK3 is the rural and urban household that receives at most four minimal wages and offers unskilled and skilled labor, respectively. USK4 and SK4 is the rural and urban household that receives at most six minimal wages and offers unskilled and skilled labor, respectively.

At household level, we present the household income and consumption results, then return to the direct, indirect, and price effects discussion by type of household and their distributive implications. The rural and urban real incomes rise with improved productivity originating from agricultural investment. The values ranged from nearly 8 to about 15 percent for rural households and 3 to approximately 4 percent for their urban counterparts (Table 7). Thus, the current investment policy has significantly increased more rural households' incomes. The rural household with relatively lower *ex-ante* wages has benefited the most. The rural households' real incomes have increased due to the increase in labor income, while about 37.5 percent of urban households' earnings is related to the return to capital investment, which benefited more those with the highest *ex-ante* minimal wages. Thus, in urban settings, the income increased more across the not-so-poor households. However, consumption has increased most between the poorer in both rural and urban environments. In other words, the rural households' consumption increased due to the increase in labor income and to a lesser extent by capital income. Government transfers are little importance in explaining these results. Urban households consume more because of higher capital income gains, and labor income has little or no significant impact on their consumption. The households' accumulated wealth was responsible for explaining the growth in aggregate consumption in both settings.

Table 7 – Household real income and consumption at the end of simulation (% in 2030)

	Rural households				Urban households			
Variable	HR1	HR2	HR3	HR4	HU1	HU2	HU3	HU4
Real income	15.007	11.924	8.090	7.933	3.063	3.164	3.022	4.219
Consumption	5.785	5.404	2.289	2.077	2.417	1.624	1.083	0.496

Source: The Authors. Note: HR1and HU1 is the rural and urban household that receives at most a minimum wage, respectively. HR2 and HU2 is the rural and urban household that receives at most two minimal wages, respectively. HR3 and HU3 is the rural and urban household that receives at most four minimal wages, respectively. HR4 and HU4 is the rural and urban household that receives at most six minima wages, respectively. HRT and HUT is the total consumption of rural and urban household, respectively.

The direct and consumer price index effects dominate the rural households' income gains, especially the poorest, while the indirect effects further increase the poor urban households' income gains. In aggregate terms, productivity improvements due to a four percent increase in investment in agriculture enhance more rural households' income. In the rural environment, the poor households' income gains are due to the positive effect of the consumer price index. A household minimum consumption can come from own-farm production, and a drop in the food price would not have as much impact on income gains as a decrease in the other off-farm good prices. Conversely, the income gains of poor urban households increase because of falling food prices since the poor urban households' consumption depends on processed food.

We observe that about 78 of poor rural household income gains come from direct effects. The share of direct impact in urban households' income gains ranges from 0.67 to about 4 percent, being smaller across the poorest. On average, about 96 percent of urban household income gains come from indirect impacts of improved productivity due to changes in agricultural investment.

Table 8 – Household welfare components (%)

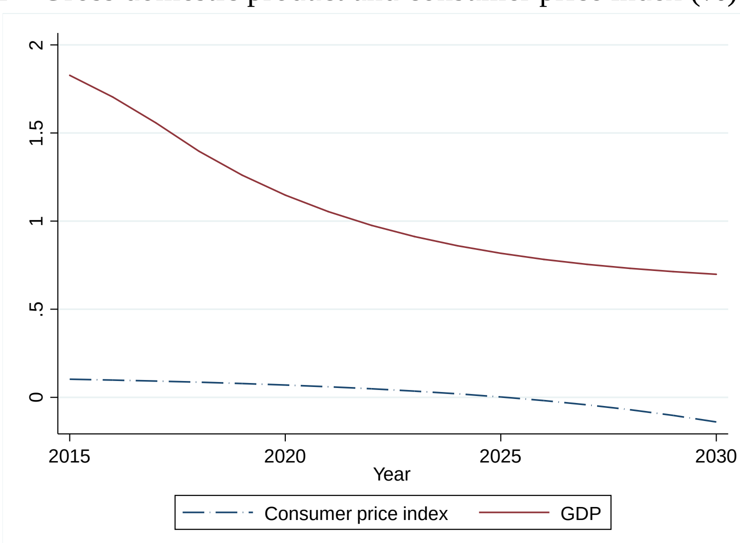
Type of effect	Rural household				Urban household			
	HR1	HR2	HR3	HR4	HU1	HU2	HU3	HU4
Direct effect	21.007	19.662	7.479	5.031	0.045	0.063	0.074	0.075
Nom.income indirect effect	2.020	2.640	2.753	3.010	5.774	5.041	2.918	2.010
Consumer price effect	3.753	3.848	1.824	1.033	0.883	0.352	0.040	0.005
Total effects	26.780	26.150	12.056	9.074	6.702	5.456	3.032	2.090
Food price effect	0.750	1.275	1.337	1.333	6.820	6.131	3.628	2.900
Share of direct effect*	78.443	75.189	62.036	55.444	0.671	1.155	2.441	3.589
Share of indirect effect*	21.557	24.811	37.964	44.556	99.329	98.845	97.559	96.411

Source: The Authors.

The dynamic effect on GDP and consumer price index of improved productivity by increased investment in agriculture is reported in Figure 1. The first general observation is that there are positive effects of this policy on GDP growth. Although being immediately higher, this macro result propagates through the simulation period (i.e., from 2014 to 2030). Second, the positive effects until 2030 indicate the persistence of improved productivity on GDP long-term growth. Finally, the downward trend is due to capital depreciation, which tends to smooth the productivity results on GDP over time.

The long-term results at the household level are also related to this macro effect that rises from the current policy, as economic growth has increased job opportunities for workers in rural and urban environment. The effect of real income on welfare is *magnified* by the drop in the consumer price index which, after the initial positive impact, has substantially reduced over time, even when GDP growth is still high.

Figure 1 – Gross domestic product and consumer price index (%)



Source: The Authors.

Although in a different context, the results of this study are consistent with past works. The existing literature has pointed out the importance of improved agricultural productivity on economic outcomes (e.g., Korkmaz and Korkmaz, 2017; Gollin et al., 2014; Alani, 2012; De Janvry and Sadoulet, 2010; among others). Investments generate positive productivity externalities (Boccanfuso et al., 2014), cause GDP growth (Gollin, 2010), and can lead to the food price reduction favoring the poor (Irz et al. 2001). As in the work by Lin et al. (2001), the propagation effects of improved agriculture productivity are emphasized in terms of non-agricultural employment and export growth.

De Janvry and Sadoulet (2010) found evidence that a 1% increase in agricultural productivity leads to a 2.2% reduction in world poverty. We find that improved agricultural productivity due to a 4% increase in investment in this sector has increased the poor welfare the most. Minten and Barrett (2008) found that poverty reduction in Madagascar was due to a 0.258% drop in food prices originating from improved food production technology. In the present study, poor urban households have benefited more from falling food prices. In contrast, the fall in the consumer price index helped more low-income families in rural areas. In addition, we find the poorest households who receive lower *ex-ante* minimal wages to gains more incomes. The improved agriculture productivity implies welfare gains as households' long-term income and consumption have risen. This result is also consistent with previous pro-poor policy CGE models simulation (e.g., De Janvry and Sadoulet, 2002; Sarris, 2001; Pauw and Thurlow, 2011).

4. Conclusion

This study aimed to analyze the impacts of improved productivity on economic outcomes for Guinea-Bissau for the period 2014-2030, using a dynamic recursive CGE model. We econometrically estimate an agriculture investment allocation parameter to calibrate the initial investment stock in the economy. Total investment expenditures on agriculture are measured in terms of the amount of invested capital weighted by the current public investment budget in the sector. The improved productivity comes from a simulated shock of new capital investment in agriculture based on capital growth rate over the last three decades.

We found that productivity improvements in agriculture from a four percent increase in agricultural investment positively impact sectoral output, long-term GDP growth, and employment in the agricultural and non-agricultural sectors. Rural workers benefited from the increase in aggregate employment in the agricultural sectors, while their urban counterparts profited from the increase in aggregate employment in the non-agricultural sectors. The poor workers are the most beneficiaries in both environments. There are long-term welfare gains associated with increases in labor income for rural households and capital income for rural households, which implied in the long-term consumption increases for households in both rural and urban settings.

Improved productivity has direct, indirect, and price effects that contribute to rising individual welfare. Direct results were predominant across the poor rural households' income gains, and indirect effects account for most of the income gains of the poor in urban settings. While the direct effect was magnified by the fall in the consumer price index, the food price decrease has magnified the indirect impact on poor urban households' gains.

It is suggested a development program for the agriculture sector to create job opportunities in the country and promote policies to alleviate extreme poverty. However, the improved productivity effects on household welfare should not be thought out in isolation but with other pro-poor policy instruments that can further reduce poverty. The complementary policies can magnify the positive effects of productivity improvements. As there are still no studies that have done what is proposed here, this can be a first step towards finding joint poverty reduction policies for Guinea-Bissau.

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Appendix A - Details of the econometric model

The FAOSTAT database starts in 1989 so as not to nullify the 1990 observation when growth rate for each variable is calculated. Note that data from service sectors is not observable, rather the added value of the macro-sectors such as agriculture, services, industry, and manufacture production. Thus, to obtain the productivity growth rates, some data desegregations were made. The values of service sectors production were obtained as follows: (i) calculate the share of each of these four sectors in the total value added and (ii) emerge the resulting values with the total production of the agricultural sectors[4].

[4] Production data taken from FAOSTAT refer only to the agricultural sectors. But since we already know the share of the agricultural sector (the sum of all agricultural sectors), the industry and the services sectors in the composition of

The same criterion was used to disaggregate the amount of labor and capital (machinery-credit) by sector. For instance, the share of employment (between 15- and 65-year working age) for the four macro-sectors was calculated. Since data on agricultural employment are already available, the shares corresponding to the missing sectors were used to extract the employment series in these sectors.

To obtain a joint series of productivity, that is, the total factor productivity, the labor and capital productivity was calculated by dividing each sector output by the labor and capital factors. Therefore, aggregate of the two variables corresponds to the observed total productivity of the sectors in the period in question. Table A1 just below reports descriptive statistics on the variables of the econometric model.

Table A1 - Descriptive statistics

Variable	Observations	Mean	Std. Dev.	Min	Max
Productivity	638	14.576	1.111	12.013	16.010
Capital	638	0.368	0.822	0.000	2.681
Labor	638	1.197	1.328	0.000	1.907
Infrastructure	638	0.743	0.185	0.444	0.985

Source: The authors.

Estimates (Equation 11):

We also find that 1% increase in the quantity of labor reduces productivity by about 0.24 percentage points. An increase in infrastructure quality by one unit causes an increase of about 1.11 percentage points in total factor productivity. The effects of primary factors on productivity are statistically significant at 10%, while the impact of infrastructure on productivity is significant even at 1%. The R-squared of 0.82 indicates that the independent variables have a high explanatory power on productivity.

Appendix B: Factor supply by type of worker (%)

Factors of production: The factors were classified into two types according to their current use, labor (L) and capital (K). In this economy, there are four types of unskilled and skilled workers, and two types of capital, agricultural and non-agricultural. unskilled labor supply is employed more in agricultural sectors and skilled labor is predominant in non-agricultural sectors.

Figure B.1 – Factor account

Initial SAM	Final SAM	Header	Factor supply in agricultural sector (%)	Factor supply in non-agricultural sector (%)
Unskilled labor	USK1	L	0.860	0.140
	USK2	L	0.800	0.200
	USK3	L	0.710	0.290
	USK4	L	0.630	0.370
Skilled labor	SK1	L	0.170	0.830
	SK2	L	0.110	0.890
	SK3	L	0.080	0.920
	SK4	L	0.050	0.950
Non-agricultural Capital	NCAP	K	0.000	1.000
Agricultural Capital	CAP	K	1.000	0.000

value added, we calculate the each macro sector shares and then use them to open up the other sectors whose data are not initially disaggregated.

Source: The authors. Information from IFPRI SAM for Guinea-Bissau.

Appendix C – Model calibration: elasticities

The calibration process requires additional data, such as trade and production elasticities, household consumption elasticities, interest rate, and population growth rate. While the latter two are from the World Bank, the production, trade, and substitution elasticities have not yet been estimated for Guinea-Bissau. We consider it possible to resort to the already estimated elasticities for Tanzania, which is an economy with the production technology very similar to Guinea-Bissau.

Table C1– Investment elasticities

Industry/elasticities	Depreciation rates		Investment demand elasticity		New public investment elasticities
	Capital	Land	Capital	Land	zeta
Millet	0.02	0.00	2.00	2.00	0.0403
Sorghum	0.02	0.00	2.00	2.00	0.0142
Maize	0.02	0.00	2.00	2.00	0.00125
Rice	0.02	0.00	2.00	2.00	0.0403
Fonio	0.02	0.00	2.00	2.00	0.0165
Cotton	0.02	0.00	2.00	2.00	0.0251
Other agriculture	0.02	0.00	2.00	2.00	0.0512
Cashew nut	0.02	0.00	2.00	2.00	0.0521
Breeding-hunting	0.02	0.00	2.00	2.00	0.0533
Forestry	0.02	0.00	2.00	2.00	0.0543
Fishery products	0.02	0.00	2.00	2.00	0.0553
Mining industries	0.02	0.00	2.00	2.00	0.0564
Food and bever	0.02	0.00	2.00	2.00	0.0576
Other industries	0.02	0.00	2.00	2.00	0.0567
Electricity-water	0.02	0.00	2.00	2.00	0.0556
Construction sector	0.02	0.00	2.00	2.00	0.0567
Trading and repair	0.02	0.00	2.00	2.00	0.0623
Hotels-restaurants	0.02	0.00	2.00	2.00	0.0635
Transport	0.02	0.00	2.00	2.00	0.0644
Financial services	0.02	0.00	2.00	2.00	0.0655
Real estate	0.02	0.00	2.00	2.00	0.0657
Publ. administration	0.02	0.00	2.00	2.00	0.0524

SOURCE: The authors. The model default parameters.

Table C2 – Free parameters

Frisch	n	IR	sh0O	tr0O	ttdh0O	ttdf0O
-2.00	0.02	0.07	0.02	0.02	0.02	0.02

Source: The authors. Frisch: The same value has been assigned to the Frisch parameter for every household, urban and rural; n: population growth rate, being the same for every simulation time; IR: interest rate; sh0O: Intercepts of household savings function; tr0O: intercept of the household transfers to government function; andttdf0O and ttdf0O: households' and firms' income tax function intercepts.