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RESEARCH ARTICLE

Potential Economic Impacts of Agricultural Growth in Africa: Evidence from Guinea-Bissau

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Abstract
This paper examines the potential effects of agricultural investment on economic outcomes in Guinea-Bissau (2014–2030). Through a dynamic computable general equilibrium (CGE) model, we found that improved agricultural performance will positively impact economic growth, sector output, and job opportunities for rural and urban workers. The decline in food prices will propagate indirect impacts on urban household welfare, while rural households will benefit from direct and indirect effects through the decline in the consumer price index. Poverty alleviation suggests agriculture's crucial role in supporting ongoing industrialization and food security in Africa with attenuated income inequality.

Keywords: African economies; Agricultural investment; Applied economics; Poverty alleviation; PEP model

JEL classifications: C68; J43; Q18

1. Introduction

One of the most common and important issues in economic studies concerns the role of agriculture in economic development. Kuznets (1957), Lewis (1954), and Johnston and Mellor (1961) were among the early development economists to approach the problem from the modern integrated market perspective. They showed that the agricultural sector complements the industrial sector as an economy moves toward industrialization with the change in relative prices operating against agriculture. Several past works found that the agricultural sector contributes to development because improved agricultural production may boost overall output and economic growth (Rudolf and Zurlinden, 2010), creating job opportunities (Alani, 2012), which impact income positively (Gollin et al., 2014) and negatively poverty incidence (Tiberti and Tiberti, 2015).

This paper attempts to document the potential implications of agricultural investment on economic outcomes in Guinea-Bissau, identifying the channels through which agricultural performance affects poverty alleviation in the country. In fact, it has been few years since those insights were made that policymakers in developed and developing countries have recognized the importance of agriculture to national economies and individual welfare. Stablishing the United Nations Development Program in 1965 was a milestone of leaders recognizing that industry alone would not generally account for globally shared prosperity capable of spurring growth and contributing to poverty reduction in each region. Improved agricultural production may bring significant economic outcomes, especially in agricultural-based economies where about 60% of household incomes are driven from agricultural activities (De Janvry and Sadoulet, 2010; Minten

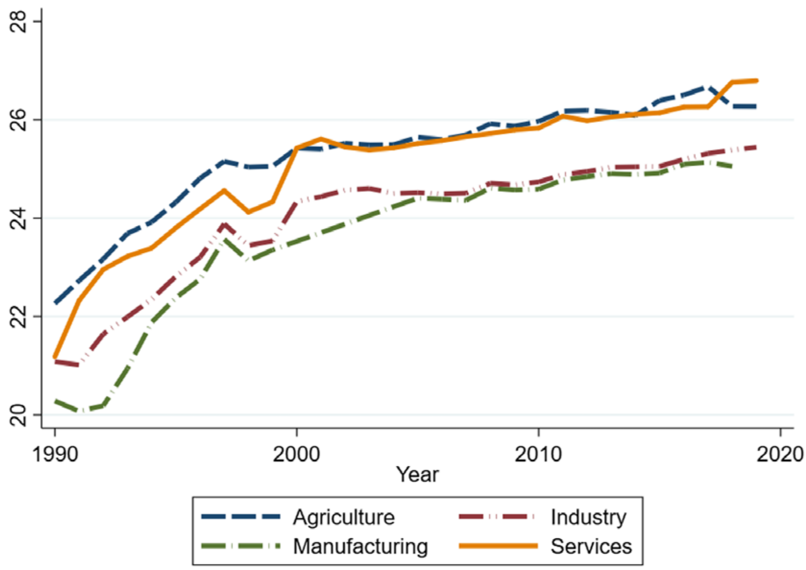

Figure 1. Value-added by macro sector in Guinea-Bissau (1990–2020). Source: The authors. World Bank Development Indicators.

and Barrett, 2008). In such countries, agricultural value-added is generally higher than in developed regions where industry value-added share is steadily high.

The present paper examines the potential economic impacts of improved agricultural production in Guinea-Bissau using a computable general equilibrium (CGE) model. 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. As the farm sector represents nearly 42% of the output and absorbs about 61% of the labor force (ILO, 2019), several central governments have devoted part of the budget to programs to improve this sector's performance. Thus, unlike countries in developed regions, where the role of agriculture in the economy is relatively minor and decreasing, in Guinea-Bissau, there is a predominance of agriculture as a vital sector in the economy (Figure 1), and so for macro stability, economic growth, and improved welfare of the population. Moreover, poverty incidence rates declined during periods of increased agricultural productivity. For instance, agricultural productivity decreased by about 0.12% in 2002, and poverty incidence rates increased by approximately 23%. A decrease of 15% in poverty incidence rates was observed in 2017 following a growth in agricultural sector productivity of 0.9% in the previous year (FAOSTAT, 2021; World Bank, 2021). The economic impact of these results, however, has not yet been well documented.

We build on and contribute to a growing literature on agriculture's role in inclusive economic development (e.g., Ravallion and Chen, 2007; Christiaensen et al., 2011; Loayza and Raddatz, 2010; Brzeska et al., 2012; Bustos, et al., 2020). For instance, Ravallion and Chen (2007) used annual poverty data over 21 years to estimate the effect of sectoral growth on poverty rates in China. They found that agriculture impacts on poverty reduction was about 3.5 times larger than the secondary or tertiary sectors. However, unlike us, the authors studied an economy in which agriculture's share in GDP has been decreasing. Additionally, Guinea-Bissau is a typical example of an agricultural-based economy, so its productive structure differs from emerging economies.

A previous work by Christiaensen et al. (2011) examined the effect of agricultural sectoral growth on the headcount poverty rate in selected African countries. Comparatively to the impact of GDP growth from nonagricultural sectors, they found evidence that GDP growth originating from agriculture is 2.7 times more effective at reducing extreme poverty (1 USD dollar/day).

However, their study was conducted from a partial equilibrium perspective. It did not examine the spillover and feedback effects of agricultural sector production improvement over time.

There has been a growing application of CGE models to evaluate economic-wide outcomes of several reforms in Africa (e.g., Cockburn et al., 2010; Maisonnave and Mamboundou, 2022; Savard and Adjovi, 1998). For instance, Pauw and Thurlow (2011) used a recursive dynamic CGE 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. Among the closest-related literature to ours are Chitiga et al. (2016), Vanduzai and Chitiga (2017) for South Africa, and Sangare and Maisonnave (2018) for Nigeria. Like us, they applied the recursive dynamic CGE model in the tradition of Partnership for Economic Policy (PEP) (see Decaluwé et al., 2012) to evaluate the *ex ante* impacts of different economic policies in an African economy.

We contributed to these previous studies in several directions. First, in Guinea-Bissau, agricultural sectors are more labor-intensive than others, so how agricultural investment affects labor income through the labor market may depend on the degree to which changes in economic activity impact the demand curve by type of labor. We provide a contribution to the existing literature by including into the present model multiproduct industries and various types of rural and urban workers with cross-sector labor mobility. Categorizing workers and households into groups will make it possible to assess the potential effects of agricultural investment at the household level in terms of job opportunities and income generation. In addition, it will allow us to evaluate the distributional and welfare implications of current policy as to provide policy recommendations for deliberate intervention in the sector aimed at alleviating poverty in the country.

Second, we focus on one sector that has been crucial to answering several emerging challenges, such as the housing shortage and food insecurity. Agriculture plays a critical role in socioeconomic development, since Guinea-Bissau's population is approximately 60% rural, with almost 90% working on agricultural crops, especially cashew nuts, peanuts, rice, and palm oil extraction. Household earnings in rural areas are largely determined by the sale of agricultural products through intermediaries. An intermediary is typically an individual from the city who purchases products from the countryside and sells them to qualified international traders. As a result, the agricultural sector is vital to the livelihood of a large majority of the population. For instance, the improvement of housing conditions in the country has been primarily due to the reinvestment of gains from agricultural activities in the construction of new homes. Consequently, future urbanization in Guinea-Bissau may require agriculture innovations, particularly in the agricultural production chain, since Guinea-Bissau does not have industries that process agricultural products, and most agricultural commodities exported abroad are of low value-added. Producers and intermediaries may be able to increase their earnings through the creation of processing industries. As a net importer of many food items, expanding the processing industry can also contribute to strengthening food security in the country.

Third, this paper contributes to the debate on how governments can rationalize revenues from the comparative advantage sector to boost productive investment in developing countries (see, for example, Sangare and Maisonnave, 2018). Agriculture taxes account for approximately 40% of Guinea-Bissau's government revenue (Guinea-Bissau, 2010), suggesting a dependence on public funding for development programs on the performance of the agricultural sector. Historically, there has been a coexistence between external funding and internal resources for development policies.[1] However, in the absence of external financing, macro-stabilization and development measures, especially those designed to reduce poverty, depend entirely on agricultural production.

[1]These development policies include the Structural Adjustment Program in 1986, I and II National Poverty Reduction Strategies (DENARPs), respectively, in 2007 and 2011, and Infrastructure Investment Program in 2014 (see Cateia et al., 2023).

Finally, we provide methodological value to the above literature in that we attempt to model public agricultural investments' externalities and their implications for poverty reduction in a developing country. Unlike the existing literature, we use FAOSTAT data on agricultural production to estimate a production equation to conceptualize investment allocations in the base year. Governments initiate investment in the economy, while private agents may invest in sectors with high returns.

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 developed a Guinea-Bissau economy-based CGE model. We build especially on Decaluwé et al. (2012), who described the PEP dynamic model. It is an open economy with various industries that produce various products. The institutions that conduct transactions are the government, the rest of the world (ROW), households, and firm. The government collects taxes and carries out expenditures and investments but does not optimize. We assume that the government may incur debt, or it may save. The government can invest in sectors other than agriculture, but we only deal with agricultural investments; that is, we model only the share of total public investment allocated to agriculture. We will refer to this type of investment as new public investment or total public investment allocated to agriculture. There is complementarity between public and private investments. The behavioral functions of the ROW are derived implicitly. So, this section attempts to identify the implications of public agricultural investment on productive structure and individuals' welfare by setting the relevant functional forms of firm's and households' behavior.

2.1. Production Side

Firms operate in a competitive environment. A representative firm in each industry strives to maximize profits by taking prices as given. The study by Fereira and Cateia (2023) discusses the geometry of the production function, which results in a nested optimization scheme at several levels. The model algebra is shown below. Decaluwé et al. (2012) provide a more detailed description of this model. Let $VA_{j,t}$ denote the value-added equation with the following constant elasticity of substitution (CES) form (Equation 1):

$$VA_{j,t} = A_j \theta_{j,t} \left[B_j L_{j,t}{}^{-\rho_j} + \left(1 - B_j\right) K_{j,t}{}^{-\rho_j} \right]^{\frac{1}{\rho_j}} \tag{1}$$

where, at time t, A_j is technical change, $\theta_{j,t}$ is public agricultural investment sectoral-specific externality, $L_{j,t}$ and $K_{j,t}$ are the industry j demand for composite labor and composite capital, respectively, B_j is CES value-added share, and ρ_j is the elasticity parameter, $-1 < \rho_j < \infty$.

The assumption in Equation (1) is that capital and labor are substituted for each other. As a result, the proportion of each factor in the sector's production will depend on the degree of substitution between the two factors. The firm employs both skilled and unskilled workers. A demand for labor by type l ($L_{l,j,t}$) is determined by the wage rate of composite labor ($W_{j,t}$) and the wage rate paid by j for each l in time t ($WT_{l,j,t}$):

$$L_{l,j,t} = \left[\frac{B_{l,j}{}^{L} W_{j,t}}{WT_{l,j,t}} \right]^{\sigma_j} \left(B_j{}^{L}\right)^{\sigma_j - 1} L_{j,t} \tag{2}$$

where $B_{l,j}{}^{L}$ is the share parameter, and σ_j is the CES value-added elasticity of transformation, $0 < \sigma_j < \infty$.

Capital demand is set symmetrically, with the return on capital performing a similar role to the wage rate in each industry. The law of capital motion in an economy will be defined later.

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In the production of a good of sector $j(y_{j,i,t})$, the firm combines value-added and intermediary inputs in a fixed share. According to (Equation 3), the total output at time t ($Y_{j,t}$) is as follows:

$$Y_{j,t} = B_j \left[\sum_i B_{j,i} y_{j,i,t}{}^{\rho_j} \right]^{\frac{1}{\rho_j}} \tag{3}$$

where $B_{j,\,i}$ is the share parameter.

2.2. Demand Side

Institutions such as governments, households, and the ROW operate on the demand side. The sum of public and private investment is demanded by a group of agents called investors. It is important to note that investment demand includes gross fixed capital formation and inventory changes. There is also a demand for margin, which reflects the payments for transport, retail, and wholesale trade services to supply commodities to the final consumer (see Cateia et al., 2023).

Public consumption of good i at time t ($\mathrm{Cgov}_{i,t}$) is set as (Equation 4):

$$\mathrm{Cgov}_{i,t} = \gamma_i{}^G G_{i,t} \tag{4}$$

where $G_{i,\,t}$ is the current government expenditures on goods and services at time t and $\gamma_i{}^G$ is the share of good i in total public expenditures.

Agents in the domestic market pay for foreign goods and services. ROW receives these payments, which vary according to the exchange rate. The difference between what the ROW receives from Guinea-Bissau and what it pays corresponds to external savings ($S_{\mathrm{row},t}$). In open macroeconomics, ROW's savings equal the current account balance ($\mathrm{CAB}_{\mathrm{row},t}$) in equilibrium with an inverted sign (Equation 5):

$$S_{\mathrm{row},t} = -\mathrm{CAB}_{\mathrm{row},t} \tag{5}$$

The household's demand requires a more formal treatment due to behavioral parameters governing the length of expenses incurred during each period. We assume a heterogeneous h group of rural and urban households demanding final goods for consumption. Under budget constraints, the individual maximizes the Stone–Geary function. Based on the first-order conditions of this problem, the following demand function (Equation 6) is obtained:

$$p_{i,t} c_{i,h,t} = p_{i,t} c_{i,h,t}{}^{\mathrm{MIN}} + \gamma_{i,h}{}^{\mathrm{LES}} \left(\mathrm{cb}_{h,t} - \sum_{ij} p_{ij,t} c_{ij,h,t}{}^{\mathrm{MIN}} \right) \tag{6}$$

where, at time t, $p_{i,\,t}$ is the purchaser price of composite good $i; c_{i,h,t}$ and $c_{i,h,t}{}^{\mathrm{MIN}}$ is the consumption of good i and the minimum consumption of good i by type h household, respectively, $\gamma_{i,h}{}^{\mathrm{LES}}$ is the marginal share of good i in h consumption budget, and $\mathrm{cb}_{h,t}$ is the consumption budget of each h.

To purchase the good i at time t, h has a total income $Y_{h,\,t}$, the sum of labor income ($YL_{h,\,t}$), capital income ($YK_{h,\,t}$), and transfers from other agents ($YTR_{h,\,t}$). The total income expression is specified as (Equation 7):

$$Y_{h,t} = YL_{h,t} + YK_{h,t} + YTR_{h,t} \tag{7}$$

Public investment impact on household income is transmitted via the labor market through the adjustment of demand factors by each industry. Considering that labor and capital are defined as functions of wage rates and capital rental rates, a policy that increases demand for labor (capital) will increase wages (return on capital) in the industry. Given the transfers, household income should increase. It is important to note that the extent to which households will benefit from rising factor prices depends on both the labor intensity of the industry and the composition of their

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ex ante wealth. A wage increase in labor-intensive industries will benefit workers offering labor, while an increase in capital return will increase the income of capital owners. Furthermore, this model considers all transfers to be exogenous across institutions. These flows are identified in the SAM in the base year. Governments and ROWs transfer resources to households in the form of social assistance.

Consumption budget of households ($C_{h,t}$) depends on disposal income ($Yd_{h,t}$), savings ($S_{h,t}$), and transfers from each household to nongovernmental agents ($\sum_{\text{nag}} Tr_{\text{nag},h,t}$) that set as follows (Equation 8):

$$C_{h,t} = Yd_{h,t} - S_{h,t} - \sum_{\text{nag}} Tr_{\text{nag},h,t} \tag{8}$$

2.3. Supply Functions and International Trade

The PEP model sets country characteristics relative to the ROW. It also sets the characteristics of the product offered and the supply functions of locally produced goods for foreign and domestic markets. Based on the assumption that Guinea-Bissau has a small, open economy, the world supply is infinitely elastic, and the world price is normalized to one.

The firm's output is sold on the market at the basic price of *j*'s production of good *i* at time *t* ($p_{j,i,t}$). Assuming these prices as given, producers aim to maximize their sales revenue subject to their total output. Equation (9) specifies the individual supply functions resulting from first-order conditions:

$$y_{j,i,t} = \frac{Y_{j,t}}{(B_j)^{1+\sigma_j}} \left[\frac{p_{j,i,t}}{B_{j,i} p_{j,t}}\right]^{\sigma_j} \tag{9}$$

where, at time t, $y_{j,i,t}$ is good i of j and $p_{j,t}$ is the j unit cost.

The assumption that governs Guinea-Bissau's interaction with the ROW, in terms of the supply of national products and the demand for foreign products, is that goods are differentiated according to their origin. Production can be sold on the domestic or external markets, and local consumers can purchase products from overseas. Foreign and domestic productions are, however, imperfect substitutes.

2.4. Price System

The relative prices play an important role in the instantaneous adjustment of markets to an investment shock in the economy. Several types of prices were considered, including factor prices, production prices, and final product prices. Consumer price index is one type of price index, but there are others as well, including public investment price index and private investment price index.

2.5. Market Clearing

In an equilibrium market, there is neither excess demand nor excess supply across all markets. To illustrate, the sum of the supplies of a particular product by local producers must equal the demand for that particular product on the domestic market (Equation 10):

$$Q_{i,t} = \sum_h \mathrm{Cb}_{i,h,t} + G_{i,t} + \mathrm{INV}_{i,t} + \mathrm{VSTK}_{i,t} + \mathrm{INT}_{i,t} + \mathrm{MRG}_{i,t} \tag{10}$$

where, at time t, $Q_{i,t}$ is the composite good, $\mathrm{INV}_{i,t}$ is the final demand for investment, $\mathrm{VSTK}_{i,t}$ is the inventory change of good i, $\mathrm{INT}_{i,t}$ is the total intermediate demand for good i, and $\mathrm{MRG}_{i,t}$ is the demand for margin.

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2.6. Public investment and dynamics

Equation (1) is a modified version of the value-added equation specified by Decaluwé et al. (2012). We plug theta into this equation to capture the effect of public investment externality on economic activity. Savard and Adjovi (1998) and Savard (2009) discuss the underlying economic theory. Studies by Boccanfuso et al. (2014), Estache et al. (2012), and Cateia et al. (2023) model public investment externalities. In works by Chitiga et al. (2016), Vanduzai and Chitiga (2017), and Sangare and Maisonnave (2018) using the PEP model, the externality of some public investment in the economy was also propagated via the value-added equation. The functional form of $\theta_{j,t}$ is the following (Equation 11):

$$\theta_{j,t} = \left(\frac{Kg_t}{Kg_{t-1}}\right)^{\varepsilon_i} \tag{11}$$

and represents productivity effect on economic outcomes. It is set as a function of the ratio of current stock of public capital (Kg_t) at time t over previous investment (Kg_{t-1}), and ϵ_i is the sector-specific elasticity.

The transmission mechanism is as follows: at the macro level, productivity increases when the current investment stock is greater than the previous investment. A positive $\theta_{j,t}$ shock is expected to increase economic activity through a rise in sectoral value-added. At time t, industrial production and total aggregate output should increase for a given production technology. In light of the direct connection between economic activity and the GDP, it is expected that the economy will grow from one period to another. It is likely that the impact of investment on GDP will continue until capital depreciates.

Efficiency gains cause favorable macro impacts. The increase in productivity leads to a decrease in the amount of input required per unit of sector product. Even though the aggregate labor factor demand is declining in the short term, the market factor adjustments are expected, over the long term, to lead to the primary factors of labor-capital substitution toward full employment, thereby reducing the initial negative impact on employment.

The externality length, however, depends on public capital investment elasticities, which vary by sector. Additionally, since elasticities vary according to each country's structural characteristics, it is expected that public investment may have a different impact on economic activity depending on these characteristics.

The dynamics of capital accumulation in the economy is modeled as follows (Equation 12):

$$K_{k,j,t+1} = K_{k,j,t}(1 - \delta_{k,j}) + \mathrm{Ind}_{k,j,t} \tag{12}$$

where $K_{k,j,t+1}$ is the stock of type k capital in industry j at time $t+1$, $K_{k,j,t}$ is the stock of k in j at time t, $\mathrm{Ind}_{k,j,t}$ is the volume of new type k capital investment to industry j, and $\delta_{k,j}$ is the depreciation rate of capital k used in industry j.

Capital stock and new capital investment can be either public or private in the PEP model. Here, public and private investments are assumed to be complementary. When the government allocates government investments to the agricultural sector, private agents may demand private investments based on their perceptions of the return on capital. Because of time-structure underpinning dynamic specification, capital stock reflects the most recent investment (Savard, 2010). It is a *putty-clay type* of capital, which can be allocated to any industry but is fixed once it has been allocated to that industry (Decaluwé et al., 2012). Equation (13) provides the investment demand functions by industry j:

$$\mathrm{Ind}_{k,j,t+1} = \phi_{k,j}\left(\frac{R_{k,j,t}}{U_{k,j,t}}\right)^{\sigma_{k,j}} K_{k,j,t} \tag{13}$$

where, at time t, $R_{k,j,t}$ is the rental rate and $U_{k,j,t}$ is the user cost of type k capital (Tobin's q), $\sigma_{k,j}$ is the elasticity of private investment demand relative to Tobin's q, and $\varphi_{k,j}$ is the allocation of investment to industry j.

We will discuss policy scenarios for allocating public investments to agriculture in the next subsection. We will estimate the private investment allocation parameter using an econometric model to fix sectoral allocation of this investment at the beginning of the simulation. Fixing private investment in the base year implies that the government is responsible for the initial investment in the economy. As mentioned, it is also possible for private agents to invest in sectors with higher capital returns in the future as there is a complementarity between the two types of investments. This reflects evidence that, in developing countries, private agents can be cautious when making investment decisions. If the return on investment is uncertain, such as in agricultural investments, they may not invest, unless they see some noticeable signs that it is worth investing in.

Despite the inclusion of public capital stock and new government investment capital in expressions (12) and (13), respectively, we can explicitly specify the dynamic of public capital in the economy as in Equation (14) and conceptualize government investment:

$$K_{g,t} = K_{g,t-1}(1 + g_{kg})^t \left(1 - \delta_g\right)^t + \mathrm{IT}_{g,t-1}(1 - \delta_g)^{t-1} \tag{14}$$

where, at time t, $K_{g,\,t}$ is the current stock of public capital, the sum of public capital stock of the previous period, which grows at a rate of the level of investment required to maintain the capital stock (g_{kg}), and public investment in new capital of the previous period ($\mathrm{IT}_{g,t-1}$), both terms associated with a discount factor, the depreciation rate of public capital (δ_g).

Conceptually, government investment is a resource from tax collected, but it may also borrow from private institutions to make investment. It will be discussed later that if the government raises taxes to finance its investment in the present, it will have fewer investable resources in the future unless economic growth results in some improvement in tax collection. In the same way, if investment is financed by borrowing, government debt may increase over time. Thus, the public account may not be balanced at every date. We follow Boccanfuso et al. (2014) to specify the new public capital investment ($\mathrm{IT}_{g,t}$) as (Equation 15):

$$\mathrm{IT}_{g,t} = S_{g,t} + \mathrm{Def}_{g,t} \tag{15}$$

where, at time t, $S_{g,\,t}$ and $\mathrm{Def}_{g,t}$ are the government savings and debt, respectively.

It is worth noting that the expression (15) refers only to public investment allocated to agriculture as the government can invest in other sectors. Furthermore, this expression does not necessarily mean savings and debt must be used completely to finance agricultural investments. Taxes related to agricultural activities, or a share of public debt, can be adjusted to change the amount of investable funds.

As a final step in the dynamic specification, the update variables are set to grow at a constant rate per period. The growth rates of the population over time (n_t) govern these exogenous variables. For instance, in equilibrium, demand for type l labor in time t is equal to supply of type l labor in t ($\mathrm{Ls}_{l,t}$). Labor supply is a nonprice variable that grows exogenously as n_t. Thus, as in Boccanfuso et al. (2014), a labor supply in $t + 1$ ($\mathrm{Ls}_{l,t+1}$) is modeled using n_t as (Equation 16):

$$\mathrm{Ls}_{l,t+1} = \mathrm{Ls}_{l,t}(1 + n_t) \tag{16}$$

2.7. Data and empirical Strategy

This study relied on the SAM for Guinea-Bissau, which was initially developed by Cabral (2015) from the African Growth and Development Policy Modeling Consortium (AGRODEP) with the support of the International Food Policy Research Institute (IFPRI) and provided comprehensive economic information in 2007. The matrix was updated for 2014 by Cateia et al. (2023), taking into account informal activities as described by Thiele and Piazolo (2003). An example of how this is accomplished in the agricultural sector is provided in Table 1. Because the SAM contains formal activities, informal activities are considered only by taking into account the weighted values in

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

Sector	Informal activity I	Formal activity II	VA share III	Weighted informal I*III	Weighted formal 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).

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: *Wage limit* is the maximum amount the household received. *Wage in Franco CFA* is the current official wage in 2014 (source:INEP, 2014. **50,000*(= $ US 93) is the minimum wage. *Share* is the share of the household wage in total wage.

Column I*III, defined as the percentage of informality in a sector activity multiplied by its share in the value-added.

The SAM consists of 22 sectors, 9 production factors, and 85 accounts, which are classified into the following 6 macro accounts: factors, institutions, activities, domestically sold commodities, export commodities, and accumulations. Each account represents agents' relationships determining the economy dynamics in 2014.

There are nine factors in the original matrix, including skilled and unskilled labor, agricultural capital, and nonagricultural capital, as well as five types of land for various crops. We are interested in studying the impact of public agricultural investments in Guinea-Bissau on heterogeneous household groups. To achieve this objective, skilled and unskilled workers were disaggregated into four types using 50,000 Franco CFA (roughly USD 93) as the threshold for identifying potential groups living in extreme poverty. In accordance with the World Bank's definition of extreme poverty, individuals earning wages equal to the minimum wage (HR1 and HU1) live in poverty (Table 2). In both rural and urban areas, HR2 and HU2 are households that receive at most two minimal wages per month. HU3 and HR3 are rural and urban households earning at least four minimal wages, respectively. HR4 and HU4 are rural and urban households that receive at most six minimal wages. Share of household wage is the proportion of household wage to total wage. Composite capital was formed by combining capital and land. In both urban and rural areas, we can identify the labor supply based on the type of households and capital owners.

Production factors are offered on the market, and their practical use for production represents costs in terms of wages and rent. Producers remunerate factors conventionally based on marginal productivity. Revenues are transferred to households through an institutional account as factor income. Households also receive transfers from other agents. After receipts, households consume, pay taxes, and save.

Firms and the ROW are also agents in the institutional account. There is only one representative firm in the SAM, which is responsible for private investments. Payments received by the firm are capital income. Meanwhile, the firm transfers resources to households in the form of social assistance and capital rent. It pays taxes and saves an investable fund.

Additionally, public and private capital were separated in the matrix along with the disaggregation of factors and households. Government revenue is the sum of taxes, government capital income, and transfers from minus transfers to nongovernmental agents. The government consumes public goods, transfers, and saves. Public investments can be financed by government savings.

The third account is activity. In this economy, there are 22 sectors of activity, including 12 agricultural sectors. Value-added, intermediate consumption, and value-added taxes are recorded in this activity account. Product and export accounts provide information about sales and purchases of production to domestic and foreign markets, respectively. Accumulation accounts and their interconnections with other matrix vectors complete the interconnection of flows.

In addition to trade and production elasticities, household consumption elasticities are also required to calibrate the model. Based on a CGE model applied to Guinea-Bissau's economy by Cateia et al. (2023), we determine these elasticities. Public investment elasticities are sector-specific (Table A1 in Appendix A). In general, elasticities are defined differently across sectors. Some of these elasticities were subjected to sensitivity analyses (Table B1 in Appendix B). Free parameters include savings, interest rate, and population growth rates (Table A2) obtained from the World Bank (World Bank, 2021).

To calibrate private investment sectoral allocation (D), it is necessary to know the value of private capital allocation across sectors in the base year (${\varphi_{k,i}}^{\mathrm{PRIV}}$). As we cannot obtain this parameter using only SAM flows, we estimate it using a partial equilibrium econometric model. The estimated parameter is then fed into the CGE model through Equation (13).

We estimate an extended production function (Y_{it}) as a function of capital (cap_{it}) and labor (labor_{it}), infrastructure (Infra_{it}), and sectoral fixed effects (γ_i), as shown in Equation (17):

$$Y_{it} = \delta_0 + \delta_1 \mathrm{cap}_{it} + \delta_2 \mathrm{labor}_{it} + \delta_3 \mathrm{Infra}_{it} + \gamma_i + e_{it} \tag{17}$$

where e_{it} is the well-behaved error term.

Agricultural capital is determined by the quantity of machinery in agriculture (source: Faostat), labor by the number of people employed over a period of 15 years (source: ILO), and infrastructure by quality of infrastructure and logistic performance indexes (source: WBDI). Appendix A contains details of the economic model.

The work conducted by Olley and Pakes (1996) is regarded as a milestone in the estimation of the production function. Since they assume a monotonic relationship between inputs and productivity, they invert a production function in the telecommunications sector to reflect productivity, while maintaining capital constant over time. There is a growing interest in estimating production functions in several areas of economics, particularly in development economics (e.g., Gobel et al., 2012). This paper does not discuss in detail the consistency of estimators or measurement errors, among other econometric issues, since we are only concerned with determining the size of the investment allocation parameter. Detailed discussions of such issues are presented, for example, by Ackerberg et al. (2015) and Kim et al. (2016).

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 production. This effect is statistically significant at 10%. In calibration, it is set $\varphi_{k,\,i} = 0.35$,

Table 3. Random-effects GLS regression for agricultural production

Independent variables	Dependent: total factor productivity
Capital	0.3507 (0.147)*
Labor	−0.2369 (0.092)*
Infrastructure	1.115 (0.022)***
Coefficient	−6.085 (0.466)***
R-squared	0.8211
Wald $chi^2(3)$	2910.610
Prob > chi^2	0.000
Observations	638

Source: The authors.
*$p < 0{:}10$; ***$p < 0{:}01$.

the sectoral investment allocation in the base year. This value is considered small since, according to Tobin's investment theory, the equilibrium investment allocation equals 1 (see Decaluwé et al., 2012).

An analysis of agricultural investment implications at the household level entails determining whether household consumption and real income will change because of an investment shock. This paper also measures the income direct effect, income indirect effect, and price effect of this investment as to take into account its social impacts (see De Janvry and Sadoulet, 2002). Direct effects are calculated in terms of changes in household income from the agricultural sector. They also include changes in agricultural capital investment cost, consumption of agricultural production, and agriculture self-employment. A change in nominal income from all sources other than self-employment in agricultural production constitutes an indirect income effect. Changes in consumer prices are discounted by the consumption opportunity cost of agricultural food products to determine the price effect of agricultural investment.

2.8. Policy Scenarios, Closures, and Baseline Projection

Since the 1980s, when droughts hit rural areas and reduced crop production by nearly half, the government has perceived agriculture as a sector that can bring economic growth and improve individual well-being. The drought resulted in a drop in GDP, delays in civil servant payments, and increased poverty. In 1984, the central government implemented agricultural modernization programs by increasing public investment in the sector and lowering taxes on agricultural machinery imports (Cateia et al., 2018).

The policy scenario is based on the continuity of government measures adopted in 2014 to modernize the agricultural sector to fight persistent poverty incidences. The objective was to boost Guinea-Bissau's economic development on several fronts, including promoting agricultural productivity through public investment (Cateia et al. , 2022; Guinea-Bissau, 2015). However, the country does not produce agricultural machinery. Production equipment in this sector is imported from abroad. Therefore, agriculture physical capital per head depends on machinery import tariffs. We assume that the government may adopt an agricultural investment financing strategy based on revenues allocation to agriculture through savings or debt adjustment. If the government cuts taxes to increase machinery imports, current savings fall and debt rises. However, future savings will necessarily rise as future taxes are paid back. Recent work by Fereira and Cateia (2023) adopted a similar public investment financing mechanism.

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Table 4. Policy scenario of agricultural investment in Guinea-Bissau

Business as usual	Growth of 2% per year for the 2015–2030 period (from t to $t + 16$)
Policy scenrio	Scaling-up public investment in agriculture in 4.3% funded by government revenues

Source: The authors.

A quantitative measure of public incentives to the agricultural sector (IT_i) is agricultural machinery growth rate, which is approximately 4% from 1990 to 2017 (FAOSTAT, 2021). The simulation is based on increasing IT_i, which produces productive externalities, which are captured by equation (11) and dispersed throughout the economy by the value-added equation. The Business as Usual (BAU) scenario is without interventions. Basically, this is a baseline or reference scenario (Table 4). In the next section, numerical values will be reported as changes in percentage points over BAU.

We set a dynamic closure of the model. Our base year is 2014, and we project investment levels for the period up to 2030 while taking into consideration lags, adjustment dynamics, and the spread of agricultural investments over time. The current government expenditures, changes in the capital stock inventory, the minimum consumption, labor supply, income taxes, as well as world prices are exogenously determined. Savings or government debt vary over time, while new public investments are considered exogenous. The BAU projection assumes that exogenous variables grow at the same rate as population growth, which is 2%. A sensitivity analysis was conducted by changing the exogenous variables growth rate from 2% to 1 and 3%. As compared to the BAU scenario, the results do not differ significantly (Table B2).

Following calibration, the model was checked for consistency by performing staggered shocks of 5 and 10% of the *numeraire*. Exogenous variables increased at the same rate as population growth. In contrast, relative prices remained at BAU levels, suggesting that the model is well calibrated in the sense that only relative prices matter according to Walras institutional assumption.

3. Results

This section presents the potential results of improved agriculture performance from increased new capital investment in the sector. There is a discussion of macroeconomic impacts followed by a discussion of sectoral- and household-level productivity effects. As the BAU reproduces the behavior of the model variables in the absence of shocks, the numerical values obtained after policy simulations (e.g., agriculture investments) should be viewed as variations from the BAU.

As a general observation, agriculture investment shocks have positive potential effects on aggregate variables, including real GDP, agricultural production, nonagricultural production, household income, and consumption (Figure 2).

Specifically, improved performance through an increase in farm investment by approximately 4% immediately increases aggregate real GDP by about 6%. Agriculture output rises by about 36%, and nonagricultural sector production grows by approximately 19%. Exports increase nearly 12% due to higher production and a falling real exchange rate of about 1%. Unskilled and skilled workers' aggregate employment in agriculture increases by approximately 7 and 1.5%, respectively. In addition, employment grows by about 4 and 2% in the nonagricultural sectors, correspondingly. Rural and urban households' real incomes increase by about 43 and 13%, respectively. The increase in household aggregate income and the drop in the consumer price index imply a rise in aggregate households' consumption in rural and urban environments.

At the sector level, improved productivity has potential favorable impacts on sectorial output due to agricultural investment externalities (Figure 3). We observe that a 4% increase in agricultural investment potentially generates positive externalities in the agricultural and

Variable	Results
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	5,620

Figure 2. Macro effects of improved agricultural productivity (% changes relative to the BAU). Source: The authors. Note: read comma (,) as (.).

nonagricultural sectors. Agriculture production grows as externalities in the agricultural sector become more significant. However, the nonagricultural sectors, such as the food processing industries, substantially benefit from the current policy as their production increases. The impacts of potential positive externalities on production are *magnified* by the scale parameter, β_j^{va}, which accumulates these effects from one period to the next. As a result, long-term sectoral outcomes are propagated by positive current and lagged direct and indirect investment externalities on production.

Table 5 presents aggregate production changes by macro sector. Like the other tables and figures in this section, Table 5 reports the values in percentage changes relative to the BAU scenario. Agricultural production increases significantly following the shock of public investment. Total production in the manufacturing and services sectors also increases, but far below production gains in the agricultural sector. This higher increase in agriculture production relative to other sectors is due to the length of externalities in the sector: public investments propagate more externalities in the agricultural sector than in the manufacturing and service sectors. There is also a growth in private investment in sectors exhibiting high returns on capital, mainly in the nonagricultural sectors. In the absence of private investment outflows from agriculture to nonagricultural sectors, the difference in production gains would be even more significant.

Figure 4 illustrates that improved agricultural production has two important implications for Guinea-Bissau's economy. Firstly, there is a significant increase in both the volume and number of exports. As a result of the agricultural investment policy shock that potentially favors other crops and nonagricultural sectors, exports increase, and the country can potentially export food and transport services. However, historically, Guinea-Bissau has focused its exports on a few commodities, most notably cashew nuts, whose share in the export grid is approximately 98% (WITS , 2021), and it has been a net importer of many items including food. Second, import volume decreases, leading to a potential positive trade balance. Increasing domestic supply reduces import demand. A reduction in the need to import food goods from abroad may have a significant impact on food security in the country.

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Sector	Externalities ($\theta_{i,t}$)	Value added ($Va_{i,t}$)
Millet	2,747	6,726
Sorghum	4,342	7,648
Maize	3,124	7,018
Rice	1,504	3,312
Fonio	0,483	2,800
Cotton	0,229	1,750
Other agr.	1,736	3,842
Cashew nut	1,051	3,042
Breeding	0,574	2,604
Forestry	0,203	1,312
Fishery	0,084	0,462
Mining	0,140	1,016
Food	2,703	6,296
Other indu.	0,621	2,044
Elec.-water	0,552	1,244
Construction	1,098	2,804
Trading	0,182	1,120
Hotel.Rest	0,058	0,853
Transport	0,023	0,448
Financial	0,023	0,641
Serv. firms	0,070	0,906
Publiuc serv.	0,034	0,774

Figure 3. Industry value-added and externalities at the end of simulation (% changes in 2030 relative to the BAU). Source: The authors. Note: read comma (,) as (.).

Table 5. Aggregate production by macro sector (% changes in 2030 relative to the BAU)

Macro sector	Total ouput
Agriculture	36.138
Manufacturing	15.180
Services	3.964

Source: The authors.

Against a BAU scenario, the implications of improved production on poverty alleviation across groups of poor and rich households in rural and urban settings are analyzed. We examine potential job opportunities, income, and consumption outcomes. Table 6 reports the potential implications of agricultural investment on employment. The investment in agricultural production may potentially result in an increase in employment opportunities for both unskilled and skilled workers. Poor workers are more affected than nonpoor workers because of the increased need for unskilled labor in agricultural sectors. The aggregate labor employment increases by about 24%, while the total capital employment rises by about 37%. The demand for capital grows faster than total employment as a result of wage increases, a decline in rental capital prices, and an increase in agricultural investment capital returns.

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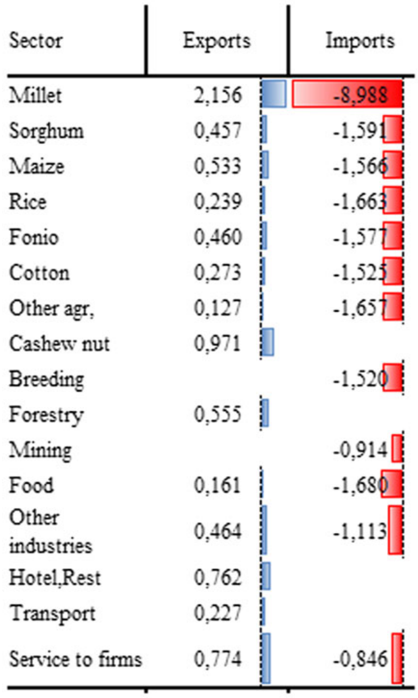

Figure 4. Sectoral export and import (% changes in 2030 relative to the BAU). Source: The authors. Note: read comma (,) as (.).

Table 6. Aggregate employment at the end of simulation (% changes in 2030 relative to the BAU)

Sector	USK1	USK2	USK3	USK4	SK1	SK2	SK3	SK4	Total labor	Aggregate capital
	4.244	3.396	2.963	2.752	1.493	1.194	1.091	1.010	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.

We begin by presenting potential household income and consumption results and then discuss direct, indirect, and price effects by type of household and their distributional implications. Rural and urban residents' real incomes rise as agricultural production improves. For rural households, these values range from roughly 8 to 15%, while for urban households, they range from 3 to approximately 4% (Table 7). Thus, the current investment policy can potentially boost rural households' incomes the most. Increasing labor incomes contributes to the increase in rural households' real incomes. Additionally, households in rural areas with lower *ex ante* wages benefit the most from this policy. Conversely, urban households earn approximately 37.5% of their income from capital investment returns, which favors those with the highest *ex ante* minimal wages. Capital income come from capital investment not only in agriculture but also in the nonagricultural sector, such as in transport and food. Urban households with not-so-poor incomes benefit more than rural households with not-so-poor incomes.

As mentioned, 60% of the population is engaged in agriculture and 80% of the population lives in poverty. A rise in agricultural production is therefore likely to alleviate poverty in the country

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Table 7. Household real income and consumption at the end of simulation (% changes in 2030 relative to the BAU)

	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.

Table 8. Household welfare results (% changes relative to the BAU)

	Rural household				Urban household			
Type of effect	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
Nominal 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.

by providing job opportunities and income for those experiencing poverty. As an example, consumption levels increase among the poorest in both rural and urban settings. Rural households' consumption increased because of an increase in labor income and, to a lesser extent, as a consequence of an increase in capital income. Transfers from government are not relevant to explaining these results. Households in urban areas consume more due to higher capital income gains, while labor income has little or no bearing on their consumption patterns. In both settings, households' accumulated wealth is responsible for the growth in aggregate consumption.

Direct and consumer price index potential effects dominate rural households' income gains, especially the poorest, while indirect effects further increase the poor urban households' income gains (Table 8). In aggregate terms, productivity improvements due to agricultural investment enhance rural households' income the most. Rural households' income gains are due to consumer price declines that boost income (the price effect). We also observe that as the minimum consumption for a rural household may come from farm-produced goods, a drop in food prices would not have the same impact on their consumption as a drop in agricultural product prices. Conversely, poor urban households' income gains increase because of falling food prices since their consumption depended on processed food. The direct effects of the rural income increase account for about 78% of the gains in rural household income. Direct impacts on urban households' income gains range from 0.67 to 4%, with a smaller proportion affecting the poorest households. Approximately 96% of urban household income gains are caused by indirect effects of improved agricultural performance.

Figure 5 shows the dynamic effect on GDP and consumer price index of improved agricultural production by increased public investment in agriculture. The first general observation is that this

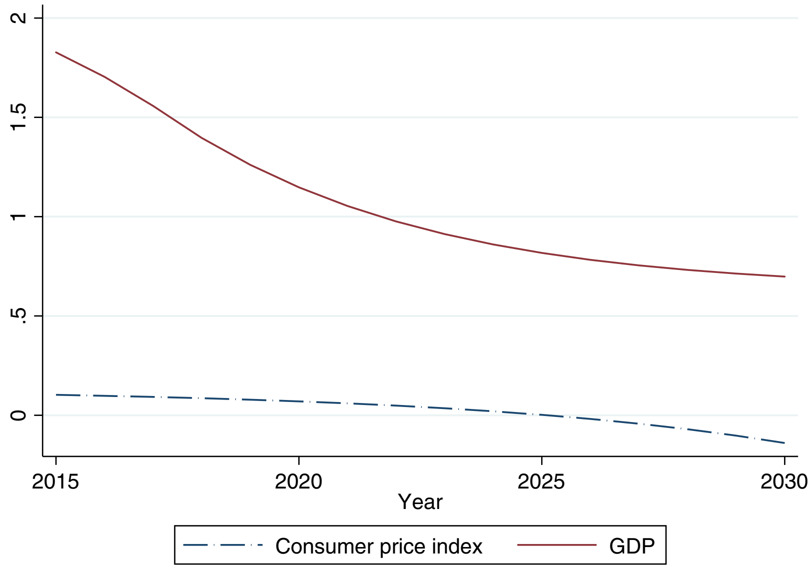

Figure 5. Gross domestic product and consumer price index (% changes relative to the BAU). Source: The authors.

policy may positively impact GDP growth. Although immediately higher, this macro result propagates through the simulation period (i.e., from 2014 to 2030). Second, the potential positive effects until 2030 indicate the persistence of improved agricultural performance on GDP long-term growth. Finally, the downward trend is due to capital depreciation, which smooths the externality effect of public investment outcomes on GDP over time.

The long-term results at the household level are also influenced by this macro effect, as economic growth increases employment opportunities for workers in rural and urban areas. Real income's impact on welfare is *magnified* by the drop in consumer price index, which substantially reduces over time after the initial positive impact, even when GDP growth is still high.

Despite being conducted in a different context, the results of this study are consistent with those obtained in previous studies. In the existing literature, it has been noted that improved agricultural production has a positive impact on economic outcomes (e.g., Gollin et al., 2014; Alani, 2012; among others). For instance, Janvry and Sadoulet (2001) examined through a CGE model the direct and indirect impacts of improved agricultural technology on poverty in Africa, Latin America, and Asia. They found that targeting technical change on small and medium farmers' land leaded 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 crop prices without technology. Therefore, the authors concluded that the urban poor are the primary beneficiaries, with real income gains of 0.7% against 0.2% for the rural poor.

According to Ehui and Pender (2005), agricultural performance has long been an indicator of well-being for families in sub-Saharan Africa. The reason behind this is because most of Africa's population is employed in agriculture, and they are poor or extremely poor. Especially, De Janvry and Sadoulet (2010) found evidence that a 1% increase in agricultural production leaded to about 2.2% reduction in world poverty. We found that improved agricultural performance may reduce poverty in Guinea-Bissau as it increased poor welfare the most.

A past study that corroborates our findings is that of Minten and Barrett (2008) for Madagascar. They found that improved food production technology led to a 0.258% decline in food prices in this country, thereby reducing poverty. In contrast, the consumer price index fall helps more low-income families in rural areas. Additionally, poor households' incomes receiving lower *ex ante* minimal wages increase more than nonpoor incomes. Agriculture productivity

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implied welfare gains as households' long-term incomes and consumption increase. This result is particularly consistent with previous pro-poor policy CGE models simulations (e.g., Alston et al., 2009; De Janvry and Sadoulet, 2002; Pauw and Thurlow, 2011).

We also found that the propagation effects of improved agriculture production on the economy may be channeled by nonagricultural job opportunities and growth in exports. Past empirical studies supporting these findings show that rationalized public investments in developed and developing countries generated positive economic outcomes. Among the various qualified evidence in this regard are works by Boccanfuso et al. (2014), Gollin (2010), Sangare and Maisonnave (2018), and Irz et al. (2001).

4. Conclusion

This study aimed to analyze the potential impacts of improved production on economic outcomes for Guinea-Bissau for the period 2014–2030. The paper is carried out in the context of an economy heavily dependent on a single sector, agriculture. This sector accounts for the highest share of total output, employment, especially for the poor, and exports. As a result, poverty incidences have declined and public revenues have increased during periods of increased agricultural production.

There is a growing body of literature that analyzes the economic and social implications of agricultural investments in a variety of agricultural-based economies in Africa. Focusing on the Guinea-Bissau economy where empirical evidence is scanty, the present paper builds on them and advances in several vectors. It adopts a dynamic CGE model, which allows evaluating the potential direct and indirect effects of agricultural investment, and their dissemination over time. Endogenous productive externalities are modeled appropriately. Labor intensity differs between sectors. Thus, to take into account the household-level implications of agricultural investments, workers and households were divided into various poor and nonpoor groups, with intersectoral mobility of factors.

An improved performance is a simulated shock caused by new capital investments in agriculture, which is based on capital growth rates over the last three decades. To calibrate the initial private investment stock in the economy, we estimated the investment allocation parameter econometrically. The total investment expenditures on agriculture were calculated by weighting the amount of invested capital by the current public investment budget.

The results of our study indicate that agricultural production improvements may have a positive impact on sectoral output, long-term GDP growth, and employment in both agricultural and nonagricultural sectors. Rural workers benefited from the increase in aggregate employment in the agricultural sector, while their urban counterparts benefited from the increase in nonagricultural employment. Increasing labor income contributed to rural households' long-term welfare improvements, whereas an increase in capital income accounted for most of urban household welfare gains. Both rural and urban households increased their consumption. Poor workers potentially benefited more than the nonpoor from the public agricultural investment shock.

Public agricultural investment can positively impact both agricultural employment nominal income (direct effects) and the nominal income from nonagricultural employment (indirect effects). Price effects, as measured by changes in the consumer price index, reduced, contributing to an increase in individual welfare and a reduction in poverty. Rural poor households gained most of their income through direct effects, while urban poor households increased most of their income through indirect effects. The consumer price index fall *magnified* the potential positive impact on poor rural households, while the decrease in food prices amplified the indirect impact on poor urban households.

In the light of this paper's results, we can draw implications for Guinea-Bissau and potentially for other developing countries with similar characteristics. Industrialization has progressed

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marginally in Guinea-Bissau and West Africa since trade liberalization in the mid-1990s. However, poverty has not been reduced proportionally in the region, except during periods of increased agricultural production. In terms of Africa's economic development, these results have significant implications. In fact, agriculture's importance for socioeconomic development in Africa is not limited to its large share of total output and employment opportunities. Instead, it is a key sector for resilience to various development challenges, such as climate shocks, social and gender inequalities, and conflicts. Perhaps it is the only sector where equal property distribution is feasible in Guinea-Bissau, and possibly in many African countries. When a country is experiencing a conflict crisis, such as Guinea-Bissau in 1998, agriculture is the most relevant sector utilized to mitigate conflict's negative impact on economy. When individuals are displaced from one country to another, they often integrate into new societies through agricultural activities as it economically helps to ensure their survival in such an environment.

However, agriculture may not achieve these expected benefits if there is no appropriate development agenda for the sector. Agricultural production is highly volatile because it depends on weather conditions and capital goods availability. The climate protection mechanisms in developing countries are generally weak, and agricultural machinery is usually imported. Because the insurance market is underdeveloped in developing countries, government initial investment in agriculture is compelling.

This paper substantively contributes to the debate on the role of agriculture in economic. development. Guinea-Bissau is currently a net food importer. Our findings suggest that potential increase in the supply of agricultural production and the potential decrease in the volume of imports can reduce the country's dependence on imported food goods. That will have crucial implications for Guinea-Bissau society as food security improves. In addition, the household income increase can be significant for government revenues as the number of taxpayers and taxes paid back increase. The government financing needs for development programs in the future, including in the industrial sectors, will decrease as well, being relevant for the macro stability. Because most of the agriculture employment is held by women, the current development agenda in Africa, such as regional integration sponsored by the African Development Bank, must incorporate agricultural funding requirements as a means of reducing gender disparities. That is critical to sustainable long-term development given the evidence that inequalities are generally lower in developed societies.

The present study has limitations that future work can address. The SAM includes informality to reflect the economy of Guinea-Bissau characteristics and heterogeneous households. Public investment externality has been modeled following the current state of art. However, the model does not take into account some recent shocks, such as Covid-19, nor does it allow for an analysis of the implications of improving agriculture's performance on gender inequality. Future work should explore these topics, including microsimulation treatment. Additionally, it may be necessary to investigate how improved agricultural productivity can complement the incipient industrialization process in Guinea-Bissau, as it may lead to an increase in labor reallocation from agriculture to manufacturing sectors.

Data availability statement. Data will be shared upon request.

Author contribution. Conceptualization: J.V.C., M.V.L.B., T.S.C., and L.S.; Methodology: J.V.C., M.V.L.B., T.S.C., and L.S.; Formal Analysis: J.V.C., M.V.L.B., T.S.C., and L.S.; Data Curation: J.V.C., M.V.L.B., T.S.C., and L.S.; Writing – Original Draft: J.V.C.; Writing – Review and Editing: J.V.C., M.V.L.B., T.S.C., and L.S.; Supervision: M.V.L.B., T.S.C., and L.S.; Funding Acquisition: not applicable.

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Appendix A: Elasticities and details of the econometric model

Table A1. Parameters and elasticities

	Depreciation rates		Investment demand elasticity		New public investment elasticities
Industry/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 A2. 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; and ttdf0O and ttdf0O: households' and firms' income tax function intercepts.

The FAOSTAT database started in 1989 to satisfy the 1990 observation when the growth rate for each variable was calculated. Note that data from service sectors are not observable, instead, the macro sectors value-added, such as agriculture, services, industry, and manufacturing production. Thus, some data desegregations were made to obtain productivity growth rates. The values of service sector 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.

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, the total factor productivity, the labor and capital productivity, was calculated by dividing each sector's output by the labor and capital factors. Therefore, the two variables' aggregate corresponds to the sectors' observed total productivity in the period in question. Table A3 just reports descriptive statistics on the variables of the econometric model.

Table A3. 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 17)

We also find that a 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: Sensitivity analysis

We carry out a systematic sensitivity analysis of the behavioral parameters to verify if small elasticities changes may generate significant changes in outcomes. Using Gaussian quadrature's method, the substitution structure imposed between goods was tested with a 50% interval for substitution parameters (see Decaluwé, et al., 2001). Table B1 reports the macroeconomic results obtained through the estimated mean and standard deviation. We also perform small changes in the growth rates of exogenous variables. Table B2 shows the difference between the results after the changes of these growth taxes with the results of Figure 2, which is practically null. The same also applies to the sectoral-level results.

Table B1. Sensitivity analysis of substitution parameters: macroeconomic variables

	95% confidence interval	
Variable	Mean	Standard deviation
Real GDP	0.243	0.348
Aggregate real household consumption	0.566	0.659
Aggregate investment	0.362	0.568
Aggregate employment	0.598	0.603

Source: The authors.

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Table B2. Macro effects (difference relative to the result in Figure 2)

Variable	1%	3%
Real GDP	0.0004	0.000
Total agricultural production	0.000	0.000
Total nonagricultural production	0.000	0.000
Aggregate exports	0.000	0.000
Exchange rate	0.000	0.000
Unskilled agricultural employment	0.000	0.000
Skilled aggregate agricultural employment	0.000	0.000
Unskilled aggregate nonagricultural employment	0.000	0.000
Skilled aggregate nonagricultural employment	0.000	0.000
Rural aggregate real income	0.000	0.000
Urban aggregate real income	0.000	0.000
Consumer price index	0.000	0.000
Rural aggregate real consumption	0.009	0.000
Urban aggregate real consumption	0.006	0.000

Source: The authors.

Appendix C

It is worth noting some adjustments we made to the PEP model. First, the present paper introduces externality in the value-added expression (Equation 1) and specifies the functional form of this externality, as in Boccanfuso et al. (2014) and several other recent applications. Second, the PEP model derives public and private investment expressions separately. Public and private investments may (or may not) be complementary. In this paper, we assume complementarity between them. Third, we introduced debt as a way for the government to finance new agriculture investments. Finally, we adjust the private investment allocation parameter in the base year by 0.35, which is obtained via production function estimates. The key implications of these adjustments are that the government is responsible for initial investments. However, private agents can invest in the following period in sectors that have higher capital returns. Additionally, agricultural investment shocks are channeled through the value-added equation, which propagates externalities to the economy.

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