

Paper:

Effects of Research and Development Expenditure and Climate Variability on Agricultural Productivity Growth in Ghana

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This paper examines the effects of agricultural research expenditure and climate change on agricultural productivity growth by region in Ghana. A panel dataset is constructed for 2000-2009 from the Food and Agriculture Organization of the United Nations; the Ministry of Food and Agriculture, Ghana; and the Agriculture Science and Technology Indicators (ASTI) database of the International Food Policy Research Institute. A Malmquist index was used to compute agricultural productivity growth, including decomposition components efficiency change and technical change. The determinants of productivity growth are examined using a fixed effects regression model. The results specify that significant causal factors impact positively on Ghana's agricultural productivity growth, include climate variability, infrastructure, and agricultural research and development expenditure. The study confirms there is a need to strengthen and develop new technological progress for sustainable agricultural production in Ghana.

Keywords: total factor productivity, research and development, climate variability, Ghana

1. Introduction

Agricultural productivity growth is essential for the economic success of Ghana's rural households and the economy as a whole. Despite challenges for successful agricultural production, agriculture is a major principal sector in Ghana's economy. According to Ghana Statistical Service (GSS), the agricultural sector contributed 31.8 percent to the country's gross domestic product (GDP) in 2011. Agricultural productivity growth has been recognized as key to overall economic growth of developing countries [1]. Several studies have examined country-level agricultural productivity in Africa in particular (e.g., [2-5]). In Asia, some studies have estimated or measured regional and countrylevel agricultural produc-

tivity growth. For example, Rada et al. [6] use Indonesian provincial panel data from 1985-2005 to measure agricultural productivity. Mao and Koo [7] analyze total factor productivity (TFP), efficiency, and technology changes in the agricultural production of 29 Chinese provinces in 1984-1993 using data envelopment analysis (DEA). On the other hand, there are few regional and districtlevel studies on agricultural productivity for Africa compared with Asia. Thus, we attempt to measure regionallevel agricultural productivity growth using the Malmquist index in Ghana. Numerous studies have estimated agricultural productivity growth at the global, cross-country, and country level using the Malmquist index method (e.g., [8-13]). Although the Malmquist index approach has the advantage of relating to data and assumptions, some empirical studies (e.g., [14, 15]) have demonstrated that the traditional Malmquist index approach is based on inappropriate representation of underlying technology, which typically understates productivity.

Consequently, some studies highlight the importance of research and development (R&D) expenditure on agriculture and the manner in which it influences improved productivity growth (e.g., [1, 16, 17]). In Africa in particular, several studies have found that agricultural productivity after the mid1980s shows a remarkable recovery [2, 3, 18-20]. Block [2] shows the recovery in the 1980s was due mainly to R&D and macroeconomic policy reform. However, Alene [1] claims that improving TFP growth was the result mainly of R&D in the 1970s while a slower growth rate observed in the 2000s was a result of less spending on R&D in the 1980s and 1990s. The current study attempts to establish the relationship between research expenditure and productivity growth in Ghanaian agriculture.

In addition to R&D, the effect of climate change on agricultural productivity has attracted serious attention from researchers in recent years [17]. Based on earlier studies on the impacts of climate variability on agricultural productivity growth, it is difficult to assess growth due to changes in climate, particularly rainfall. Any negative consequences of climate change are likely to affect

developing countries relatively harder because of their lower substitutability of agricultural activities with non-agricultural economic activities, or, in the case of subsistence and semisubsistence farmers, with other means of acquiring food. Thus, climate change would have serious impacts on agriculture in developing countries [21, 22]. The significant adverse impacts on agricultural productivity and smallholder farmers (who depend on farm productivity for livelihoods and subsistence) may lead to a rise in poverty levels [23]. In order to assess these climate impacts, early empirical models using crop simulations find that climate change would have direct effects on agriculture in developing countries [24] while others examine the impact of climate change on economic variables, such as farm income (e.g., [25, 26]). However, the impact of climate change on agriculture is also important in estimating productivity growth. In the case of Ghana, agricultural productivity growth is generally low, mainly because of inconsistent rainfall.

The major objective of this study is to measure TFP by region in Ghanaian agriculture using the Malmquist index method for 2000-2009. Second, the study examines the determinants of TFP growth using a fixed effects regression model. Specifically, we investigate the roles of irrigation and road infrastructure, climate, and public R&D expenditure in the process of TFP growth. The rest of the paper is organized as follows. Section 2 describes the methods and sources of data. Section 3 presents the results and discussions. Section 4 presents major conclusions.

2. Methods and Nature of Data

In this study, TFP is measured using DEA and a Malmquist index defined in Caves et al. [27] and described in Coelli et al. [8] and Färe et al. [28] in which the Malmquist TFP change measures are decomposed into various components, including efficiency and technical change. The Malmquist index has been particularly popular because it does not require agricultural input or output prices. In the context of Ghanaian agriculture, the Malmquist index is particularly suitable where the market prices for inputs are insufficiently reported.

2.1. The Malmquist TFP Index

The Malmquist index is defined using distance functions, which describe a multi-input, multi-output production technology without the need to specify a behavioral objective (such as, cost minimization and profit maximization). According to Färe et al. [28], the output distance function is defined on the output set S^t to define the output-based Malmquist index of productivity change:

$$S^t = \{ (y^t) : x^t \text{ can produce } y^t \} \dots \dots \dots (1)$$

The distance function takes a value that is less than or equal to one if the output vector, y^t , is an element of the feasible production set, S^t . Furthermore, the distance

function takes a value greater than one if y^t is located outside the feasible production set.

The Malmquist TFP index measures the TFP changes between two data points (e.g., those of a particular region in two adjacent time periods) by calculating the ratio of the distances of each data point relative to a common technology.

Following Färe et al. [28] the Malmquist TFP index between period t and $t + 1$ is given by

$$M_0(x^{t+1}, y^{t+1}, x^t, y^t) = \left[\frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)} \frac{D_0^{t+1}(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^t, y^t)} \right]^{\frac{1}{2}} \dots \dots (2)$$

This index is estimated as the geometric mean of two Malmquist indexes, the first relative to period $t + 1$, and the second relative to period t .

Färe et al. [28] show that the Malmquist index could be decomposed into an efficiency change component and a technical change component:

$$M_0(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{D_0^{t+1}(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)} \left[\frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^{t+1}, y^{t+1})} \frac{D_0^t(x^t, y^t)}{D_0^{t+1}(x^t, y^t)} \right]^{\frac{1}{2}} \dots \dots \dots (3)$$

where

$$\text{Efficiency change} = \frac{D_0^{t+1}(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)} \dots \dots \dots (4)$$

$$\text{Technical change} = \left[\frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^{t+1}, y^{t+1})} \frac{D_0^t(x^t, y^t)}{D_0^{t+1}(x^t, y^t)} \right]^{\frac{1}{2}} \dots \dots \dots (5)$$

Above all, a value of M_0 greater than one indicates positive TFP growth from period $t + 1$ to period t while a value less than one indicates a TFP decline.

Following Färe et al. [28], the required distance measures for the Malmquist TFP index using DEA-like linear programs with the suitable panel data are available. We need to compute four distance functions to measure the TFP change between two periods t and $t + 1$. Färe et al. [28] assume constant returns to scale (CRS) technology in their analysis and this requires solving for each region in each pair of adjacent years by using the following linear programming problems.

$$[D_0^t(y_t, x_t)]^{-1} = \max_{\theta, \lambda} \theta, \\ \text{st} \quad -\theta y_{it} + Y_t \lambda \geq 0, x_{it} - X_t \lambda \geq 0, \lambda \geq 0 \dots (6)$$

$$[D_0^s(y_s, x_s)]^{-1} = \max_{\theta, \lambda} \theta, \\ \text{st} \quad -\theta y_{is} + Y_s \lambda \geq 0, x_{is} - X_s \lambda \geq 0, \lambda \geq 0 \dots (7)$$

$$[D_0^t(y_s, x_s)]^{-1} = \max_{\theta, \lambda} \theta, \\ \text{st} \quad -\theta y_{is} + Y_t \lambda \geq 0, x_{is} - X_t \lambda \geq 0, \lambda \geq 0 \dots (8)$$

$$[D_0^s(y_t, x_t)]^{-1} = \max_{\theta, \lambda} \theta, \\ \text{st} \quad -\theta y_{it} + Y_s \lambda \geq 0, x_{it} - X_s \lambda \geq 0, \lambda \geq 0 \dots (9)$$

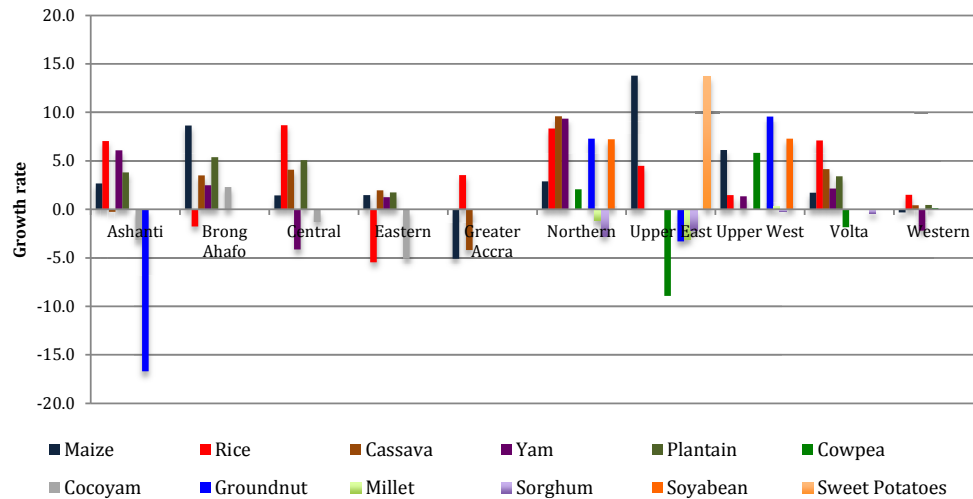


Fig. 1. Growth rate of crop composition by region in Ghana: 2000-2009.

where y_{it} is $M \times 1$ vector of output quantities for the i^{th} region in the t^{th} period; x_{it} is a $K \times 1$ vector of input quantities for the i^{th} region in the t^{th} period; y_t is a $M \times N$ matrix of output quantities for all N regions in the t^{th} period; x_t is a $K \times N$ matrix of input quantities for all N regions in the t^{th} period; λ is a $N \times 1$ vector of weights; and θ is a scalar, reflecting the degree to which the output vector can be expanded [8]. These four LPPs for the Malmquist index are calculated using DEAP 2.1 software [16].

2.2. Analytical Framework

This study assumes a detailed analysis of the determinants of changes in agricultural productivity in Ghana. The equation for the fixed effects model becomes

$$Y_{it} = \beta_1 X_{it} + \alpha_i + U_{it} \quad (10)$$

For measuring the impacts of traditional inputs, climate variables, and agricultural research expenditure on agriculture productivity, we use a double-log specification. The following fixed effects regression models of agricultural productivity are used in this study.

$$(TFP)_{it} = \beta_1 (R\&D)_{1,t-5} + \alpha_i + U_{it} \quad (11)$$

$$(TFP)_{it} = \beta_1 (Rain)_{1,it} + \beta_2 (Rain^2)_{1,it} + \beta_3 (R\&D)_{3,t-5} + \alpha_i + U_{it} \quad (12)$$

$$(TFP)_{it} = \beta_1 (Irri)_{1,it} + \beta_2 (Road)_{2,it} + \beta_3 (Rain)_{3,it} + \beta_4 (Rain^2)_{4,it} + \beta_5 (R\&D)_{5,it-5} + \alpha_i + U_{it} \quad (13)$$

where TFP is the dependent variable in region i at time t . In addition, the independent variables are $Irri$, irrigation, the area per hectare equipped for irrigation; $R\&D$, a five-year lag of $R\&D$ public expenditure on agricultural research and development; $Road$, the road density per 100 km² of land area; and $Rain$, annual rainfall in mm. In Eqs. (11)-(13), $\alpha_i (i = 1, \dots, n)$ is the unknown intercept for each region of Ghana; $\beta_1, \dots, \beta_{10}$ are the coefficients for the endogenous variables; and U_{it} is the error term.

2.3. Nature of Data Source

The output and input data used for this study are taken from internationally authenticated sources, namely the Food and Agriculture Organization (FAO) of the United Nation's CountrySTAT (Ghana)¹ [29] and AGRO-STAT² [30]; Pardey and Johannes [31] statistical brief on the national agricultural research system by Ghana's Ministry of Food and Agriculture (MoFA)³ [32, 33]; and Agricultural Science & Technology Indicators (ASTI) from the International Food Policy Research Institute (IFPRI) [34]. This study focuses mainly on estimating regional level TFP growth indexes in Ghana. Fig. 1 represents all crops grown by region in Ghana. However, according to the MoFA [36], the major principal crops are cereals (maize, rice, sorghum, and millet) and starchy staples (cassava, cocoyam, yam, and plantain). In this study, we consider only major crops of Ghana for 2000-2009.

For measuring TFP growth, we study one output variable and five input variables. The output variable is derived by aggregating detailed output quantity data on eight major agricultural commodities (maize, millet, rice, sorghum, cassava, cocoyam, plantain, and yam) from 10 regions (Ashanti, Brong Ahafo, Central, Eastern, Greater Accra, Northern, Upper East, Upper West, Volta, and Western). These aggregates are constructed using real average rural wholesale prices in Ghanaian Cedi (GH¢) at constant 2002 prices. On the other hand, the input variables are land, labor, fertilizer, tractors, and livestock. In detail, these variables are 1) agricultural land, measured as area under harvested crops in thousand hectares; 2) labor, defined as the economically active population in agriculture in thousands; 3) fertilizer, defined as the sum of nitrogen (N), phosphate (P₂O₅) and potassium (K₂O) in thousands of metric tons, following previous studies [8, 35]; 4) total number of tractors per hectare, which is used as a proxy for improved technology in agriculture; and finally 5) livestock, as the majority of rural households

1. <http://faostat.fao.org/site/567/default.aspx#ancor>
2. <http://www.countrystat.org/home.aspx?c=GHA&tr=25>
3. <http://mofa.gov.gh/site/>

keep livestock in addition to crop farming. The number of livestock is defined to include cattle, goats, pigs, and sheep⁴.

On the other hand, we analyze the causal factors affecting agricultural productivity using the fixed effects regression model. For this model, we consider the weather variable to be annual rainfall in mm by region. Rainfall is one of the most important water sources for crop farming. Regional-level data for public R&D expenditure are constructed based on the number of agricultural research institutions and universities located in each region. Arable land equipped for irrigation and road density are both used to observe the consequences of infrastructural investment on TFP growth.

Regional input variable data for road density, irrigation, tractors, fertilizers, livestock, and labor are not available, and therefore, such data for the time period under study are extrapolated from national level data. These data are collected from the FAO's FAOSTAT. For regional-level R&D data, we extrapolate from the aggregated expenditure of the total number of national institutions covered in each region, including government research institutes (CSIR⁵, MoFA⁶), semi-public institutions (CRIG⁷), universities (UST, UCC, and UOG)⁸, and ASTI (IFPRI).

3. Results and Discussion

3.1. Annual Productivity Growth Estimates

Table 1 presents the Malmquist indexes of agricultural productivity growth, efficiency change, and technical progress for Ghana. The estimates show that productivity growth in Ghanaian agriculture is only 1.87 percent a year during 1990-2009 but is -0.43 percent in 2000-2009. Even though efficiency growth is stagnant during 1992-1996, overall productivity growth is 1.93 percent a year for 1990-2009, composed of 4.62 percent a year in the sub-period 1990-1999 and 0.17 percent in 2000-2009. The decomposition component technical progress records negative growth in 1990-2009, composed of -0.53 percent in 1990-1999 and -0.61 percent in 2000-2009. These results clearly show that growth of technical progress is an essential part of improving agricultural production in Ghana.

3.2. Regional Productivity Estimates

The productivity estimates and decomposition components, namely, efficiency change and technical progress, for 10 regions in Ghana over 2000-2009 are presented in **Table 2**. The performance of the Northern region shows significant agricultural productivity growth (1.015). However, the next best regions, the Eastern (0.97) and Upper West (0.964) regions, display somewhat low levels

Table 1. Annual means of productivity growth, efficiency change, and technical progress in Ghanaian agriculture.

Year	Efficiency Change (EC)	Technical Change (TC)	Total Factor Productivity (TFP)
1990	0.70	1.03	0.72
1991	1.42	1.18	1.68
1992	1.00	0.92	0.92
1993	1.00	1.14	1.14
1994	1.00	0.93	0.93
1995	1.00	1.05	1.05
1996	1.00	0.88	0.88
1997	0.94	0.95	0.89
1998	1.00	1.26	1.26
1999	1.07	0.98	1.05
2000	1.00	1.07	1.07
2001	0.86	0.87	0.74
2002	1.17	1.10	1.29
2003	1.00	0.88	0.88
2004	0.94	1.04	0.98
2005	1.06	1.07	1.14
2006	0.95	0.97	0.92
2007	0.96	1.01	0.97
2008	1.08	1.03	1.11
2009	1.02	1.02	1.03
1990-1999	4.62	-0.53	4.09
2000-2009	0.17	-0.61	-0.43
1990-2009	1.93	-0.07	1.87

Source: Author calculations (country data collected from FAOSTAT)

of agricultural productivity growth. The Central, Western, Volta, and Greater Accra regions improve efficiency change remarkably but not sufficiently to raise agricultural productivity growth overall as technical progress does not show significant growth. The Brong Ahafo and Upper East regions exhibit the same level of efficiency change (1.000) but growth of their overall agricultural productivity is roughly the same as in the Greater Accra region.

Only one region, Ashanti, is insignificant in terms of both agricultural productivity growth and efficiency change. None of the regions perform impressively on technical progress. According to the MoFA [36], traditional farming is the main agricultural farming system in Ghana. Agricultural implements like hoes and cutlasses are the main farming tools in rural regions of Ghana. However, there is little mechanized farming and bullock farming is practiced in some places, especially the Northern region. This could be a possible reason for the level of technical progress showing insignificant growth. However, technical progress is necessary for high productivity growth in the regions for sustainable agricultural production.

3.3. Determinants of Agricultural Productivity Growth

The fixed effects regression models are estimated for the sample of 10 regions over 2000-2009 and use the fol-

4. Livestock conversion factors are taken from Hayami and Ruttan [35].

5. Council for Scientific and Industrial Research.

6. Ministry of Food and Agriculture.

7. Cocoa Research Institute of Ghana.

8. University of Science and Technology, University of Cape Coast, and University of Ghana.

Table 2. Regional Malmquist TFP indexes and their decomposition.

Region	Efficiency Change (EC)	Technical Change (TC)	Total Factor Productivity (TFP)	Rank based on TFP
Ashanti	0.996	0.942	0.938	9
Brong Ahafo	1.000	0.955	0.955	4
Central	1.007	0.933	0.939	8
Eastern	1.011	0.959	0.970	2
Greater Accra	1.018	0.933	0.950	6
Northern	1.024	0.992	1.015	1
Upper East	1.000	0.950	0.950	5
Upper West	1.026	0.940	0.964	3
Volta	1.004	0.933	0.936	10
Western	1.007	0.933	0.939	7

Source: Mohan and Matsuda [37]

Table 3. The value of regionallevel fixed regressions of Ghana.

Explanatory Variables	Coefficient		
	Equation (11)	Equation (12)	Equation (13)
<i>Infrastructure Indicators:</i>			
· Area equipped for irrigation (per ha.)			-1.71* (-3.8)
· Road density (per 100 km ² of land area)			1.48* (10.8)
<i>Climate Indicators</i>			
· Annual Precipitation (in mm)		-0.03* (-6.19)	-0.02* (-2.6)
· Annual Precipitation* 2 (in mm)		0.00* (6.64)	0.00* (2.9)
<i>Agriculture R & D spending (per ha.) (Five-year Lag)</i>	0.21* (10.29)	0.18* (7.8)	0.04 (1.0)
Year fixed effects	Yes	Yes	Yes
Region fixed effects	Yes	Yes	Yes
R-squared	0.29	0.48	0.77

Dependent Variable: TFP

Note: Figures within parentheses are *t*-statistics.

* indicate one percent level of significance.

lowing indicators to explain output growth: arable land equipped for agriculture, road density, research expenditure, and a weather variable. The results are summarized in **Table 3**. The specification of the three models means that the coefficient estimates represent agricultural productivity with respect to each explanatory variable. All the coefficients have the expected sign, except for irrigation in Model 3, the variables are significant at the 1 percent level, and the factors explain 77 percent of the variation in agricultural productivity growth. Significant lags exist between the time expenditures on R&D and, thus, time affects productivity growth. Including the five-year lag of R&D expenditure confines the estimation period to 2000-2009. In Eq. (11), the coefficient of the five-year lag R&D accounts for 0.21 percent of output growth. Among the set of explanatory variables considered in Eq. (12), the coefficients rainfall and five-year R&D have the expected signs and positively impact on output growth. However, for rainfall, the signs of the quadratic terms are opposite to those of the linear terms. This means that the relationship between TFP growth and rainfall is non-linear and rainfall positively affects TFP growth up to a certain level. In Eq. (13), the explanatory variables of road density, area equipped for irrigation, average rainfall, and public expenditure on agricultural research have significant and positive effects on agricultural productivity growth. As

for the role of infrastructure, roads and irrigation exhibit different impacts on productivity growth. While the parameter roads has a statistically significant and positively impact on productivity growth, an unexpected sign for irrigation in the analysis shows a negative impact on productivity growth. However, there could be a possible reason for this: if unexpected flooding during the harvesting period leads to a negative impact on output growth. Investment in irrigation could minimize the damage from natural disasters, such as flooding, by irrigating the land during the drought season [38]. The coefficient of the five-year lag R&D expenditure on agriculture accounts for 0.04 percent of output growth. This outcome is not unexpected as previous studies on the impact of agricultural research on African agriculture recognize a link between productivity and R&D (e.g., [5]).

As indicated earlier, the agricultural sector is the key dominant sector for rural households in Ghana. The movement of tropical cyclones influences Ghana's rainfall patterns and variability. If rainfall does not meet crop requirements, the country will be affected by food shortages and this will indirectly affect regular livelihoods in most rural regions in Ghana. Annual climate variability affects agricultural production in a number of ways and threatens food security in Ghana. **Fig. 2** shows changes in agricultural productivity and precipitation anomaly for

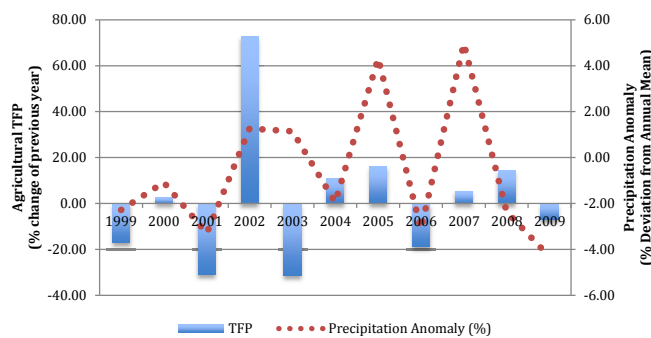


Fig. 2. Performance of agricultural TFP and precipitation anomaly in Ghana.

1999-2009. We identify a strong relationship between productivity growth and annual rainfall where both rainfall and agricultural productivity exhibit increasing trends for the years 2000, 2002, 2004, 2005, and 2007. However, the years 1999, 2001, 2006, and 2009 exhibit declines for both rainfall and agricultural productivity. The results clearly indicate that improved weather contributes to enhancing agricultural productivity.

Figure 3 confirms there is a positive relationship both in the short run (5 year lag) and long run (12 year lag) between growth of R&D public expenditure on agriculture and productivity growth. Stagnation of R&D expenditure on agriculture leads to a slower growth rate of productivity observed in 1998-2002. However, an important observation identified from the trend analysis is that increasing R&D public expenditure exhibits increasing productivity growth.

Similarly, for both shortrun and longrun trends, it is clearly specified that increased R&D public expenditure improves growth of agricultural productivity in Ghana. Several studies confirm that agricultural expenditure on R&D is an important driver of productivity growth [1]. However, it is necessary for the government to adopt essential measures for shaping agricultural policies, such as increasing R&D public expenditure on agricultural education, increasing infrastructure in roads and irrigation, and undertaking natural disaster mitigation (for flooding) for sustainable agricultural productivity growth.

In addition, the rate of deforestation has a strong relationship with agricultural productivity growth, as observed in **Fig. 4**. The figure clearly shows that the increasing growth rate of arable land and permanent crops suggests a high deforestation growth rate in 1991-2009. Nevertheless, some studies in Ghana [39] verify that agricultural expansion is one of the main causes of rapid deforestation. In spite of the abovementioned concerns, the impact of deforestation on changes in rainfall patterns intensifies flooding and droughts. However, it also leads to soil erosion and declining crop yields. Thus, it is essential for policymakers to take a holistic view when designing policies with respect to deforestation.

4. Summary and Conclusions

This study measured TFP growth in Ghana by regional over 2000-2009. Furthermore, the study investigated the determinants of agricultural productivity growth using a fixed effects regression model. The TFP estimates showed an annual productivity growth rate of 1.87 percent for 1990-2009 for Ghanaian agriculture. At the regional level, the performance of the Northern region displayed significant agricultural growth over 2000-2009, followed by the Eastern and Upper West regions. However, at the regional and overall country levels, technical progress recorded insignificant growth for 2000-2009. This is not a good sign considering the fact that technical progress is the main driving force of agricultural productivity growth in Ghana.

The fixed effect regression results showed a positive and significant relationship between productivity growth and agricultural research expenditure in all three models. However, there was a strong relationship between productivity growth and R&D, which both exhibited increasing trends after the 2000s. The coefficient of R&D expenditure on agriculture accounted for 0.21 percent of output growth. Among the set of explanatory variables, the coefficients road density, annual precipitation (both linear and quadratic), and five-year lag R&D presented positive and significant impacts on productivity growth, except for areas equipped for irrigation. The latter did not display the expected sign and a possible reason could be unexpected flooding during the harvesting period, which would have a negative impact on productivity growth. The parameter rainfall, an important source of water for crop farming, showed a very robust relationship between annual rainfall and productivity growth, with both rainfall and agricultural productivity exhibiting increasing trends for the years 2000, 2002, 2004, 2005, and 2007. However, there were declining trends for both rainfall and agricultural productivity in the years 1999, 2001, 2006, and 2009. This indicated that improved weather contributed to enhancing agricultural productivity growth in Ghana.

Finally, the results suggested that improved technical progress and investment in agricultural research, infrastructure (roads and irrigation), and natural disaster mitigation (for flooding) would contribute to sustainable agricultural productivity growth.

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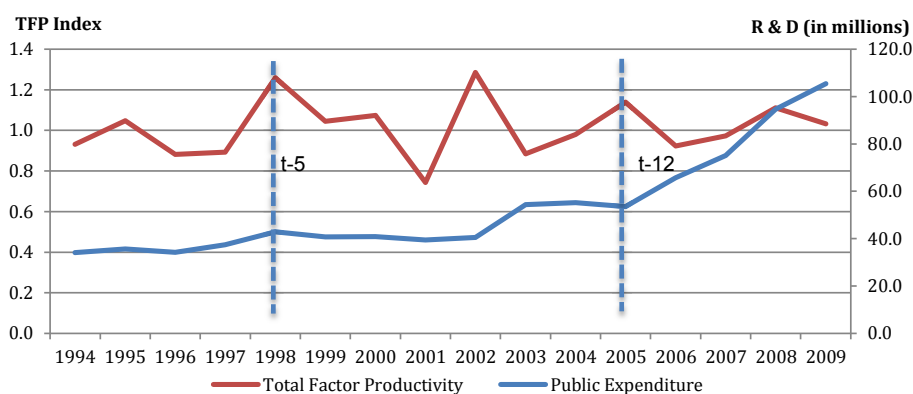


Fig. 3. Performance of agricultural TFP and public expenditure on R&D in Ghana (country data collected from FAOSTAT, FAO, and ASTI, IFPRI).

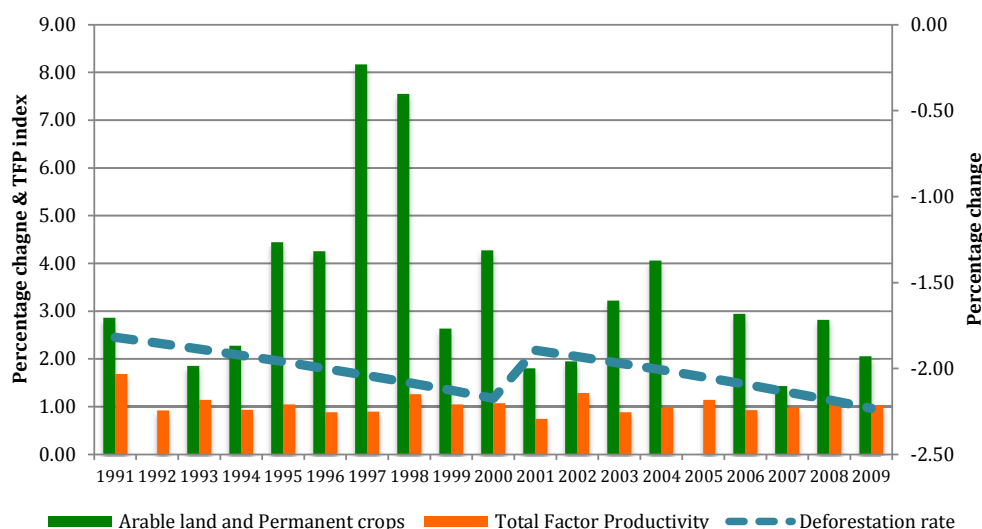


Fig. 4. Rate of deforestation and productivity growth in Ghana (country data collected from FAOSTAT, FAO).

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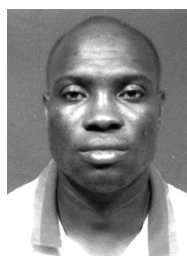
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