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The impact of rainfall and temperature, war/ conflicts, and independence on Sub-Sahara African Agriculture: A partial analysis from 1961 to 2000

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The impact of rainfall and temperature, war/conflicts, and independence on Sub-Sahara African Agriculture: A partial analysis from 1961 to 2000.

ANDREAS PONDORFER

Agricultural performance in Sub-Saharan Africa has been worse in the second half of the 20th century due to the result of a multi-dimensional process (influenced by adverse resource endowments, poor politics, institutional failures, technology and also by trade pattern, among others). This paper is a partial analysis of this multi-dimensional process and investigates the impact of climate change - with regard to the socio-political and institutional environment - on the level of total agricultural production in Sub-Saharan Africa. In doing so, it uses a cross-country panel data set in an agricultural production framework. When considering traditional and modern inputs (land, labor and livestock, as well as capital and fertilizer, respectively) the estimations of the fixed-effects-model show that climate, in particular rainfall, has been a major determinant of agricultural production in Africa. Furthermore, years since independence have a marginal positive effect on output figures while minor conflicts and war significant hamper agricultural production. Another feature of this work is to examine differentiations in production patterns between countries with colonial heritage (France, UK, and Portugal). The results of this paper clearly show that smallholder production in Africa is highly vulnerable to climate change and that the socio-political and institutional environment influence noticeably agricultural performance.

INTRODUCTION

When thinking about poverty, famine, food insecurity, conflicts, colonial heritage, and climate disaster events like droughts, first of all the African continent (in particular Sub-Sahara Africa) comes to mind. It is also well-known that the bulk of SSA countries have agricultural-based economies. Agriculture plays a major role in terms of its contribution to GDP, export earnings and employment. According to the FAO report on Food Security and Agricultural Development in Sub-Saharan Africa (2006), agriculture accounted for between 20 to 61 % of total GDP in more than 60 % of the countries from 2000 to 2003. In the 1980s even 75 % of SSA countries recorded this high share of agriculture in total GDP, concluding that agriculture is the dominant factor of growth in the last decades. Further, agriculture accounts for about 40 % of exports and on average, 62 % of the total population in SSA live in rural areas and depend mainly on agriculture.[1]

Moreover, the majority of these countries still cultivating land with techniques that were used at the time of the neolithic revolution. Hoes, ploughs, draft animals and rainfed cultivation (only 3-4 % of the arable land is irrigated) still dominate agriculture in Sub-Saharan Africa. Consequently, the low development stage of African agriculture makes it highly vulnerably to any of the variables mentioned at the beginning of this section.

However, growth of agricultural production in Africa from the years of independence in 1960 to 2000 has been disappointing. Rates of productivity growth have been slower than in other regions. In Sub-Saharan Africa very low rates of

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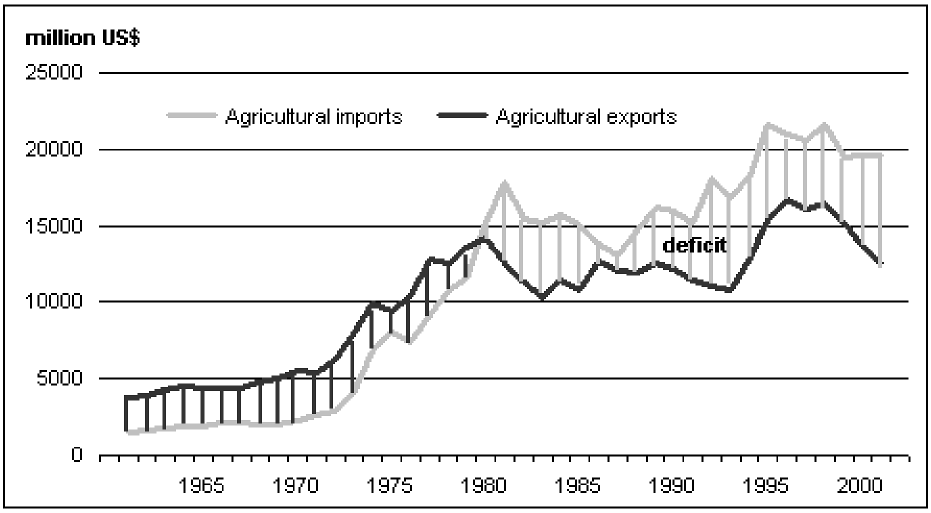
[1] FAO, “Food security”, pp. 33-34.

growth in the 1970s were followed by increases in the 1980s and 1990s, but per capita growth has been very low or negative over much of the period. This results in an average food production rate of 2.4 % per year between 1961 and 2003, which lags behind the average rate of population growth of 2.8 %.[2] As can be seen from Figure 1, in the late 1970s a shift of the overall trade flow of agricultural products occurred: Africa – as a whole as well as regularly on the country-level – turned from a food-exporting to a food-importing region, with expectable negative effects on food security. During the 1970s cereal imports in Sub-Saharan Africa increased at an annual rate in excess of 20 %.[3] Further, overall improvements of food security are only modest (with the exception of Northern Africa, which is a totally different story in many respects and hence excluded from this analysis) and subject to regional differences: while particularly Western Africa improved supply in the 1980s and 1990s, Eastern and Central Africa even faced downward trends (see Figure 2).

FIGURE 1
AGRICULTURAL TRADE IN AFRICA, SURPLUS TO DEFICIT



Source: FAOSTAT

In seven SSA countries (Angola, Chad, Congo, Ghana, Malawi, Mozambique and Namibia) the proportion of the undernourished substantially declined, while others have gone through a deterioration process (e.g., Burundi, Democratic Republic of the Congo, Eritrea and Sudan). About 80 % of the increase in the proportion of the undernourished is observed in conflict countries, where famine has been widespread.[4] The type of food insecurity observed in SSA is a combination of widespread chronic food insecurity, resulting from continuing or structural poverty, and transitory emergency-related food insecurity, which occurs in periods of intensified pressure caused by natural disasters, economic collapse or conflict.[5]

There are a variety of explanations why African agricultural growth has been so slow. Generally, these causes can be divided into two categories – the first, adverse

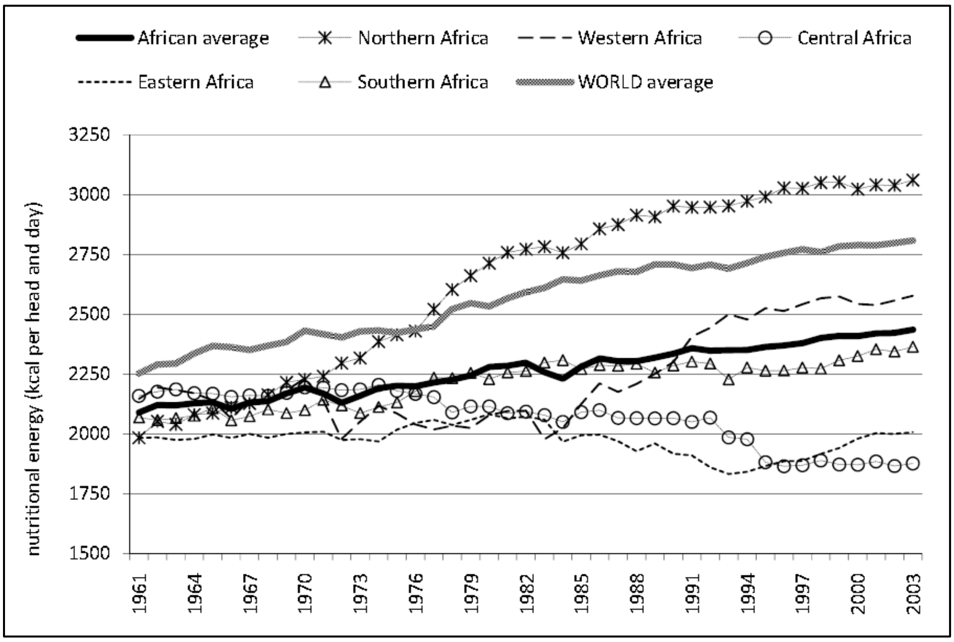
[2] Kydd et al., "Pro-poor Economic Growth in Sub-Saharan Africa", pp. 38-39.
[3] Saverimuttu and Rempel, "Determinants of Cereal Grain Imports", pp. 525.
[4] It is worth to note here that a supply of 1,800 kcal per head and day are regarded the absolute survival minimum (given "light" physical work) and that these numbers reflect averages and do not consider food loss and waste.
[5] FAO, "Food security", pp. 5-10.

resource endowments, including unfavorable climate conditions like droughts or poor soil quality, geographic and demographic characteristics (e.g. low population density, landlocked countries), as well as epidemics like HIV/AIDS or malaria, and the second, poor policies and institutional failures. The latter ones include also missed technological improvements and the downside of trade liberalization.[6]

With respect to that multi-dimensional process, this partial analysis focus on major determinants which are not well established in previous regression analysis examining Sub-Saharan Africa's agriculture. More precisely, the paper attempts to capture the effects of climate change (drought events inclusively), war and conflicts, as well as the historical aftermaths of colonial heritage on agricultural production. Thus, the aim of this article is to provide an appropriate explanation why agriculture in Sub-Sahara Africa has performed so badly and to gain some insight in African agriculture.

The remainder of the paper is organized as follows: the next section provides the background for the variables of interest. It reviews meteorological and geophysical literature and summarizes climatic trends over Africa in the 20th century with focus on rainfall and temperature changes. Further, it investigates the aftereffects of colonial heritage on African agriculture as well as war and conflict in the region. The subsequent section characterizes African agriculture to provide the theoretical background for the empirical analysis. The last section deals with the econometric approach. It provides the model specification, estimations of the fixed-effects-model and represents the empirical results.

FIGURE 2
NUTRITIONAL ENERGY PRODUCTION (INCLUDING TRADE BALANCE) FOR AFRICAN REGIONS, 1961-2003



Source: FAOSTAT

Furthermore, this paper makes no pretense of generality. The model represented relies on restrictive assumptions. Therefore abstraction of African agriculture is

[6] See, Binswanger, "Growth Performance of Agriculture", pp. 1075-1080; Bloom and Sachs, "Economic Growth in Africa", pp. 207-295; Collier and Gunning, "Why has Africa Grown Slowly?", pp. 3-22.

necessary for estimating the model and interpreting the results. Nonetheless, this is done intentionally to demonstrate in a scientific way that climate change as well as other determinants expose livelihoods.

BACKGROUND

Climate Change in Africa and drought events

Climatically, Africa is shaped by a basic pattern: stable temperature and rainfall in equatorial regions and increasing volatility of both north as well as south of the equator to the point of desertification – of course with regional variations and complexities. More precisely, equatorial climates are characterized by heavy rainfall (of more than 3,000 mm per year, slightly higher in Western Africa) and a dry season that is either very short or missing, and temperatures are high, averaging about 25 °C. The tropics around the equatorial zone are humid throughout the year with less rainfall than the equatorial zone, generally about 1,000-2,000 mm per year. The rainfall tends to peak twice during the year, with the peaks separated by relatively short but distinct dry seasons. Annual variations in climate tend to be a little higher than in equatorial climates. Both regions cover 14 % of total surface land in Africa. Sub-humid regions (tropical wet and dry climates) are located to the north and south of the humid tropical zone and cover 31 % of total surface land. These regions are characterized by a lengthy dry season, typically five to eight months in duration. As distance from the tropics increase, duration and reliability of rainfall decrease. Precipitation generally averages between 500 and 1,000 mm per year. Consequently, dry climates dominate with 55 % of surface land. In these semi-arid (tropical steppe) and arid (desert) zones total annual evaporation of moisture from the soil and from plant foliage exceeds the annual precipitation, which amounts for less than 500 mm annually during a rainy season that lasts one to three months.[7]

Thus, while temperature is generally relatively favorable to agriculture in Africa, rainfall is modest compared to other global macro regions and consequently very likely – given the low level of irrigation in Africa – to exert an important influence on agricultural output. Consequently, there has been little interest in analyzing temperature patterns in Africa because of the overriding role of water. But there is increasing evidence that temperature controls important physiological processes in insects, plants and crops and hence also this has to be regarded as a critical factor.[8]

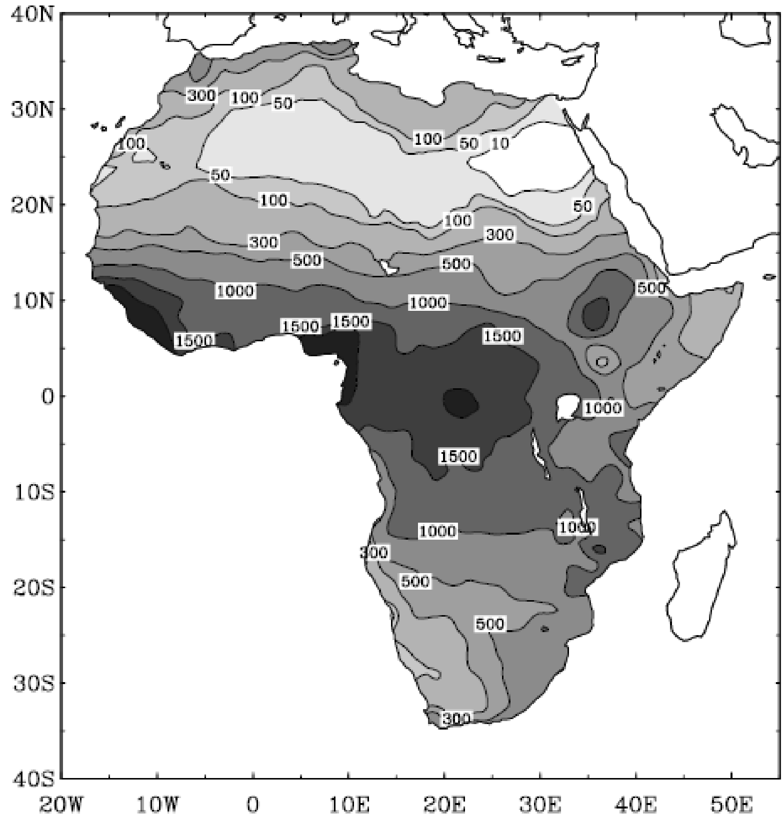
Concerning temperature, the continent is warmer than it was 100 years ago. Hulme et al. (2001) show, using observational data sets, that warming in Africa through the 20th century has been at the rate of about 0.5°C per century. Little larger warming occurs in the June-August (JJA) and September-November (SON) seasons than in December- February (DJF) and March-May (MAM). The six warmest years have all occurred since 1987, with 1998 being the warmest year. Patterns and amount in Africa are in line with global observations.[9]

[7] Stock, *Africa South of the Sahara*, pp. 77-79; For further information about climate classification in general, see: Strahler and Strahler, *Introducing Physical Geography*, Chapter 7; For a more detailed and specific introduction to Africa´s physical geography, see the following: Adams, Goudie, and Orme, *The Physical Geography of Africa*, Chapters 3-5.

[8] See Abrol et al., “Crop productivity”, pp. 787-798; and also IPCC, “Agriculture in a Changing Climate”, Chapter 13, pp. 427-428; Challinor et al., *Vulnerability of Crop Productivity*, pp. 187-194.

[9] Hulme et al., “African climate change”, pp. 149-150; for further details about long-term temperature changes see Jones et al. (1986), IPCC (1995), Nicholls et al. (1996), Hulme (1992) and Jones and Lindesay (1993).

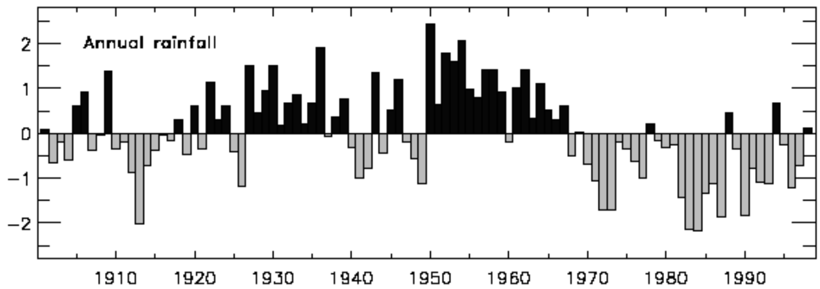
FIGURE 3
MEAN ANNUAL RAINFALL OVER AFRICA (IN MM)



Source: Nicholson (2001)

Anyway, most studies still focus on precipitation. Inter-annual rainfall variability is large over most of Africa and for some regions, most notably the Sahel, multi-decadal variability in rainfall has also been substantial. Generally, the early 20th century was rather dry (except for equatorial East Africa and the extreme North and South), the 1920s and 1930s were favorable (the least in southern Africa), and the 1940s rather dry again (particularly in West Africa).[10]

FIGURE 4
ANNUAL RAINFALL ANOMALIES IN THE SAHELIAN ZONE (IN STANDARD DEVIATIONS)



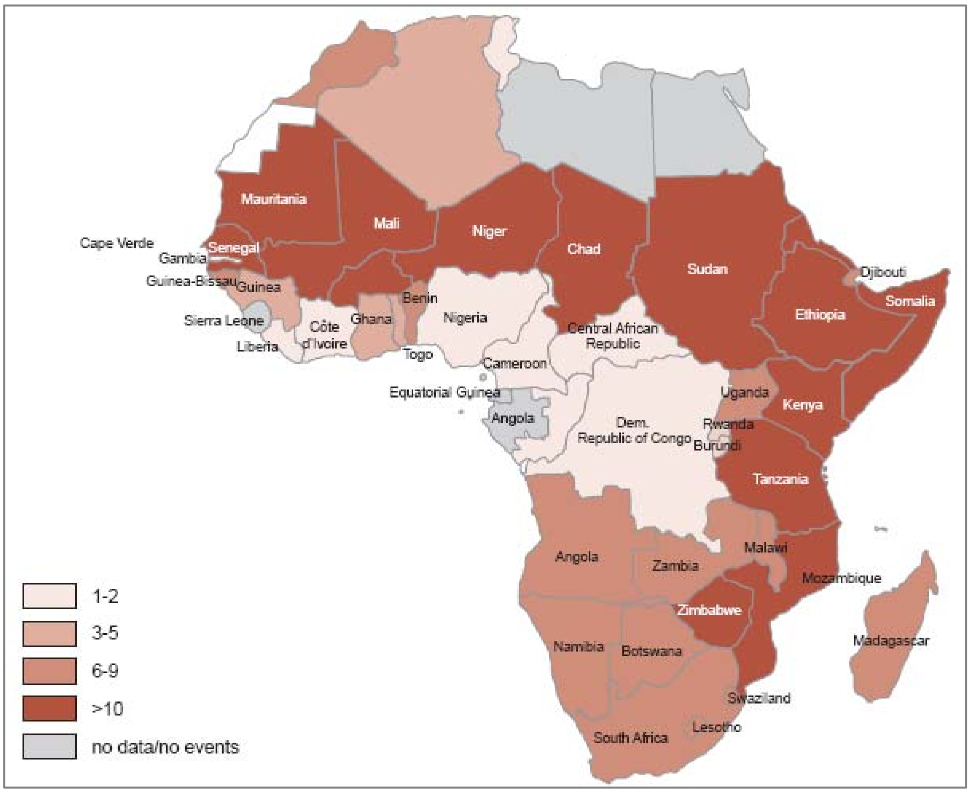
Source: Brooks (2004)

[10] Nicholson, "Climatic and environmental change", pp. 127-130.

From the 1950s on fluctuations became even more pronounced, when river flow increased notably in the semi-arid regions and general conditions became favorable again. They even improved in the 1960s, particularly in the tropics, when also the level of Rift Valley lakes rose.[11] From then on, conditions became worse, and particularly in the early 1970s and the early 1980s even disastrous in some regions. Generally, aridity became more widespread (rainfall decreased by 20 to 40 % in Sahelian West Africa, and generally by 5 to 10 % across the rest of the continent) and rainfall remained below the long-term mean over most of Africa, with southern Africa being an exception in case.[12]

FIGURE 5

DROUGHT EVENTS PER COUNTRY IN SSA FROM 1970 TO 2004



Source: Noojin (2006)

Consequently, drought is a serious and complex problem for many African countries. For example, the favorable conditions during the 1950s and early 1960s resulted in a rise of human and especially animal population with an extension of the grazing land toward the north. Farming areas spread out from the Sahelian to the Saharo-Sahelian ecozone. When first harvest and grazing failures occurred at the end of the 1960s, pastoralist and farmers rushed toward the south and fabricate a dangerous concentration of livestock and population across the 600-mm isohyet. Consequently, in the following years the mortality of livestock and people increased dramatically.[13] Also the long term impacts of the Sahel drought in the

[11] Nicholson and Yin, “Rainfall conditions”, pp. 387–398; and also Farquharson and Sutcliffe, “Regional variations of African river flows”, pp. 161–170.

[12] This is mainly due to lower precipitation in July and August, while the average length of the rainy season has not changed significantly during the dry period 1970-1990 (Le Barbé and Lebel 1997).

[13] Mainguet, *Desertification*, pp. 33-34

1980s become clearer, which have sustainably influenced the vegetation cover. This permanent loss of vegetation would permit drought conditions to persist.[14] Precipitation directly affects vegetation, which in turn regulates spatial and temporal appearance of grazing and nomadism.[15] Generally, the continent has witnessed a high frequency of occurrence and severity of drought. Extended droughts in certain arid lands of Africa have also initiated or exacerbated desertification. This is particularly important due to their self-enforcing effect, also (negatively) affecting rainfall. In effect, once there is a lack of vegetation cover in an already fairly arid region, it stabilizes its own aridity in a vicious cycle: the high reflectivity of the surface, caused by lack of vegetation, would produce a dry climate which would not support vegetation, ensuring high reflectivity of the bare surface.[16]

Colonial heritage and years since independence

Examining African agricultural performance since 1960 requires a close look on African colonial history because adverse institutional frameworks and poor policies are not a recent phenomenon. The Atlantic slave trade caused extraction from rural areas of Africa during the *precolonial* era. Especially between 1650 and 1850 it was extremely destructive to economic, political, and social life. Further, it disrupted Africa's natural demographic, institutional and moral development.[17] Nunn (2008) estimated the number of slaves exported from each country in Africa during the slave trades by using data from shipping records and data from historical documents reporting slave ethnicities. He found a significant negative relationship between the number of slaves taken from a country and its subsequent economic development.[18]

The means of extraction from rural areas changed with the formal abolition of the slave trade and the onset of the *colonial* era. During this era political elites of the colonial states ensured to capture gains by developing institutional and political mechanisms. This was done with restricted market access for indigenous populations. Many farmers were prohibited from producing and from selling cash crops. In other countries they had to sell to monopolistic companies at depressed prices. Differential taxation and distortions were used to force peasant farmers to supply labor to plantations, to settler farmers, to mining sectors, and for public works. Also access of agricultural goods and services (credit, extension, roads) was limited to the plantation or settler sectors. However, these combinations of distortions in Africa persisted much longer and left still visible institutional and policy residues in the second half of the 20th century.[19]

In the *postcolonial* era, states focused on nation-building and hence on economic modernization (industrialization) and political stabilization. Urban elites, by organizing, centralizing, and capturing political and economic power, have been able to control policy and the distribution of resources in a postcolonial framework. Especially, services and prices favored urban people relative to rural. Thus, the agricultural sector was neglected and moved in the background. More precisely, these policies have tended to tax agriculture heavily with farmers receiving producer prices lower than the world price equivalent which clearly hampered

[14] Wang and Eltahir, "Ecosystems and the Sahel Drought", pp. 795-798.

[15] Sivakumar, "Interactions between climate and desertification", pp. 143-155.

[16] Adams, *Vegetation – Climate interaction*, pp. 102-110.

[17] Aplers, *East African Slave Trade*, pp. 206-215; and also Fage, *Slavery and the Slave Trade*, pp. 166-178.

[18] Nuun, "Africa's Slave Trades", p. 168.

[19] Binswanger and Townsend, "Growth Performance of Agriculture", p. 1079.

agricultural growth.[20] The focus on the urban space entailed highly centralized political, fiscal and institutional systems for rural development. This focus on centralization occurred for many reasons, including the desire for political integration of fragile nations. These high levels of centralization hampered development at local levels and of institutional capacity. Further, it limited local resource mobilization, undermined accountability of development programs to local populations, and inhibited their participation.[21]

Consequently, agricultural performance should improve the sooner former occupied states were independent from their colonial masters. Since the aftermaths of colonial heritage persisted much longer and left still visible institutional and policy residues, the effect of independence is expected to be marginal. Additionally, to prove this hypothesis the analysis separates countries into former British, French, as well as Portuguese colonies to identify different patterns in agricultural performance.

War and conflict

In these days the Middle East including North Africa experiences a change that has never been existed that way before. The peoples revolt against dictatorial leadership which quashed them for many years. The political situation on the Ivory Coast is vague as well and raises conflict potential. In addition to poor policies and institutional failures, conflict is a further reason which inhibited agricultural growth. The impact of conflict on agriculture can be observed in many countries in SSA. Southern Sudan successfully passed an independence referendum in 2011, but almost 20 years of civil war in the entire country destroyed infrastructure, about 2.5 million people have lost their lives, and Sudan has one of the largest numbers of internally displaced people in the world (approximately 5 million). Especially, Central and Eastern Africa are burdened with extremely high numbers of internally displaced people due to conflicts.[22]

There are a variety of reasons why war/conflict hampers growth in Africa. For instance, Collier and Hoeffler (2004) have argued that rebel recruitment will be easier in poor societies due to lower opportunity costs in terms of foregone income from regular economic activities when participating in insurrections, as well as lower wages for combatants.[23] Fearon and Laitin (2003) argue that civil wars are more common in poor societies since states in low-income societies tend to have weaker capacity for deterring and defeating violent insurgencies. From this perspective, low or negative economic growth could be seen as an indicator of weakening state capacity, which may increase the risk of rebellion.[24] Many empirical studies like the mentioned above have found a negative relationship between conflict and growth.

However, since the majority of SSA countries have agricultural based economies it is worth to investigate the impact of war/conflict on that major sector. Thus, the paper argues that sustained growth is impossible within such violent environment.

[20] Hermann, "Agricultural Policies", pp. 203-220.
[21] Binswanger and Townsend, "Growth Performance of Agriculture ", p. 1080.
[22] Le Monde Diplomatique, *Atlas der Globalisierung*, pp. 170-171.
[23] Collier and Hoeffler, "Greed and grievance in civil war", p. 588.
[24] Fearon and Laitin, "Ethnicity, insurgency, and civil war", p. 88.

CHARACTERIZATION OF SUB-SAHARAN AGRICULTURE

In general, African agriculture is structured as follows: the farming technology is simple, and incomes are low, indicating that farmers will have few options to adjust to climate change. Furthermore, public infrastructure like roads, irrigation systems, long-term weather forecasts and agricultural research and extensions are inadequate to guarantee appropriate adaption.[25]

Small farmers in Africa primarily use local resources but may make modest use of external inputs, including information and technology. Local resources include the various renewable resources at hand, such as soil, water, and vegetation, etc., as well as local knowledge, labor, agricultural practices, and local institutions. External resources refer to those agricultural inputs and technologies that originate outside the local area and mostly depend on continued external support. Commercial fertilizer and pesticides, hybrid seeds, tractors, and irrigation systems are also known as modern inputs referring to the fact that these inputs remarkably have changed agriculture since the 1940s, especially in developed countries.

Although it is difficult to generalize African agriculture a close look at the reviewed literature reveals a common term: *smallholding/small farm*. The concept of small farms can be approached from a variety of angles. Small-scale agriculture is often used as a synonym for smallholder, family, subsistence, resource-poor, low-income, low-input, or low technology farming.[26] Africa has approximately 33 million of those small farms, representing 80 to 85 % of all farms in the region and they are known to account for 90 % of agricultural production in Sub-Saharan Africa.[27] Hence, these farms provide the majority of food production across Africa and essential for secure livelihood. The general characterization above serves as the underlying argumentation for the econometric analysis and therefore it is an abstraction of African farming structure.

MODEL SPECIFICATION

This paper investigates the impact of climate change on agricultural production in Sub-Sahara Africa by using a simple aggregate production function pioneered by Solow (1956). The structure of the model is similar to that one of Benhabib and Spiegel (1994). After log-transformation the agricultural production function results in:[28]

$$\begin{aligned}\log(Y_{it}) = {} & \beta_0 + \beta_1\log(L_{it}) + \beta_2\log(V_{it}) + \beta_3\log(F_{it}) + \beta_4\log(K_{it}) + \beta_5\log(M_{it}) + \\ & + \beta_6\log(PRC_{it}) + \beta_7\log(TEMP_{it}) + \beta_8(\text{Conflict}_{it}) + \beta_9(\text{War}_{it}) + \\ & + \beta_{10}(\text{Freedom Years}_{it}) + \beta_{11}(\text{Drought}_{it}) + \beta_{12}(\text{Colony}_{i}) + \varepsilon_{it}\end{aligned} \quad (1)$$

where $\beta_0 = \log(A)$.

[25] Dinar et al., *Climate Change and Agriculture in Africa*, p. 1.

[26] The World Bank's rural development strategy broadly classifies smallholders as those with a low asset base and farmers with up to two hectares of cropland, see World Bank, "Reaching the rural poor", p. 6; For an overview of classifications, see: Nagayets, "Small Farms", pp. 1-14.

[27] See Nagayets, "Small Farms", p. 2; Dunstan, "Will they Survive?", p. 1; and also FAO, "Impact of Climate Change", p. 3.

[28] Benhabib and Spiegl, "Human capital in economic development", pp. 143-173; and Solow, "Theory of Economic Growth", pp. 65-94; For examples of aggregate agricultural production functions, see: Frisvold and Ingram, "Sources of agricultural productivity", pp. 51-61; and with included climate variables, Barrios et al., "Climatic change", pp. 287-298.

Eq. (1) can also be expressed in a more general form:

$$y_{it} = \alpha + X'_{it}\beta + I_{it}\gamma + Z_{it}\zeta + C_i\varsigma + u_{it} \qquad i = \ldots N, \quad t =, \ldots T \qquad (2)$$

with i denoting SSA countries and t denoting time. The i subscript denotes the cross-section demand whereas the t stands for time dimensions. α represents β_0 and is a scalar, β is K x 1 and X_{it} is the log-form of the ith observation on K explanatory variables. Further, I_{it} is a vector of indicator variables (conflicts, war, and drought, respectively) with the coefficient γ. $Z_{it}\zeta$ is a measure for years since independence, while ς represents the coefficient of the indicator variable C_i (former colonies).

Considering the fact that there are unobserved country specific and time varying effects, a two-way error component regression model (two-way FE) is chosen for the analysis:

$$u_{it} = \mu_i + \lambda_t + v_{it} \qquad i = \ldots N, \quad t =, \ldots T \qquad (3)$$

where μ_i denotes the unobservable individual effect (purged by a within-transformation), λ_t denotes the unobservable time effect and v_{it} is the remainder stochastic disturbance term. Note that λ_t is individual-invariant and it accounts for any time-specific effect that is not included in the regression (also intended to capture such factors as technological progress and other SSA wide influences like structural changes in agricultural systems). Additionally, one assumes that $v_{it} \sim$ idd$(0, \sigma^2)$ and X_{it} are independent (E[v_{it} Xit] = 0) of the v_{it} for all i and t. Inference in this case is conditional on the particular N individuals and over the specific time periods observed.[29]

In Eq. (1) Y represents the agricultural output and the inputs L, V, F, K and M are labor, livestock, fertilizer, capital and land, respectively. PRC and TEMP are the auxiliary climatic factors that may affect agricultural production.[30] The connections of output to L, F, K and M are obvious, while V is typically used to proxy long-term internal capital formation in the agricultural sector.[31]

The panel data used to estimate (1) is derived from three sources:

- The climate variables are taken from the Tyndall Centre for Climate Change Research. They provide a summary of the climate of the 20th century for 289 countries (comprised 188 countries and 101 islands and territories). The time series data set TYN CY 1.1 on the average annual rainfall and temperature from 1901 to 2000 is used for the analysis.[32]
- The agricultural output data, measured in international US$ related to a base period 1999-2001, are taken from the FAO online database.
- L is the total of economically active population, M is thousands of hectares of agricultural land and refers to the share of land area that is arable, under permanent crops and under permanent pasture. L is taken from the World Bank and M from the FAO online database.[33]
- The livestock variable V is measured in livestock units (total headcount of cattle, sheep and goats, the most important livestock in the Sub-Sahara African case), taken from the FAO.
- The technical input F is defined as the quantity of fertilizer in metric tons of plant nutrients (N, P205, and K20) consumed in the agricultural sector.

[29] For detailed information on Two-Way Error components, see Baltagi, *Panel data*, Chapter 3.
[30] Climate variables are normalized, see Appendix
[31] First introduced by Hayami and Ruttan, " Agricultural Productivity Differences", p. 896.
[32] Tyndall Centre, online at: http://www.cru.uea.ac.uk/~timm/cty/obs/TYN_CY_1_1.html, [23.11.2010].
[33] FAOSTAT, online at: http://faostat.fao.org/, and World Bank Database, online at: http://data.worldbank.org/data-catalog/africa-development-indicators, [31.01.2011].

The other technical input K is defined as agricultural tractors, which is also a crude proxy of capital stock. Both are taken from the FAO.

- Information on war and conflict is taken from the Gleditsch et al. (2002) dataset. The intensity of the indicator variable is coded in two categories: Conflict stands for between 25 and 999 battle-related deaths in a given year and war includes at least 1.000 battle-related deaths in a given year.[34]
- Data for years since independence and former colonies are taken from the World Factbook.[35]
- Drought is a recurring and permanent aspect of African life but the literature on drought is highly fragmented. There is no source that systematically reviews the frequency and consequences of droughts across Africa. The definition of drought is mostly a subjective consideration, because the rainfall levels might not affect agriculture adversely if they did not arrive too early or too late.[36]

RESULTS

Descriptive Statistics

The variables for the available sample period 1961-2000 resulted in 1720 observations for 43 SSA countries. Basic summary statistics for all the variables (except for the indicator variables and the freedom years) are given in Table 1. These show that there is considerable variation in all of the variables. Furthermore, the heterogeneity across the countries supports the assumption of the fixed-effects-model that each entity has its own individual characteristics that may influence agricultural production.

In addition, Table 1 includes summary statistics for the inputs V, K, L and F rescaled by agricultural area (`000 ha). Their means indicate that other regions in the world use these actors, per unit of land, much more intensively than countries in SSA. For instance, the means of the industrial inputs K and F per thousands of hectare of agricultural area are substantially higher in southern (K/M=2.8; F/M=30.1), south-eastern (K/M=1.4; F/M=35.9) and eastern Asia (K/M=3.1; F/M=32.4).[37] The livestock variable, which is an important factor for higher productivity, tends to be higher in Asian countries as well.[38] These results must be interpreted in the context of the green revolution, where Asian countries increased agricultural production in the second half of the century through research, development and technological transfer. Especially, the use of agrochemicals (fertilizers, pesticides, herbicides) was one of the most important features of the Green Revolution, a feature that was non-existent before then.[39] The higher livestock-level is driven by rising demand for meat and livestock processed

[34] For further information, see: Gleditsch et al., “Armed Conflict 1946-2001”, pp. 615-637; data available at: http://www.prio.no/CSCW/Datasets/Armed-Conflict/, [15.05.2011].

[35] World Factbook, available at: https://www.cia.gov/library/publications/the-world-factbook/, [15.05.2011].

[36] Data for drought events are incomplete. It includes only 38 out of 43 countries for the period from 1961 to 1999 (Sychelles, Equatorial Guinea, Comoros, Mauritania, and Djibouti are missing). Data is prepared by Fulginiti et al., “Institutions”, pp. 169-180; and originated from Keck and Dinar, “Water Supply Variability”; The missing data for the 5 countries were complemented with information from the natural disaster databank, available at: http://www.emdat.be/, [27.05.2011].

[37] Asian regions were chosen for the comparison because of the similar smallholder production systems.

[38] Data for the comparison are taken from the FAOSTAT online database.

[39] Jhamtani, “Green Revolution”, p. 4.

products with increasing incomes in those countries. The dissemination of uniquely African green revolution has not occurred on the continent.

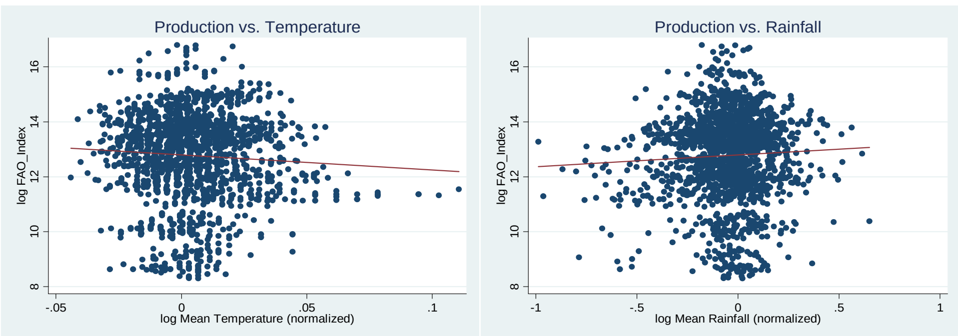
TABLE 1
BASIC SUMMARY STATISTICS

	Mean	Standard deviation
Y (FAO Index)	69.85	23.94
V (headcount)	7,029,706	12,188,330
F (metric tons)	17,107.05	40,458.87
K (# of tractors)	2,109.87	3,588.66
L (# of people)	2,400,424	2,983,883
M (`000s ha)	18,501.74	23,494.28
PRC (mm)	1,094.41	636.18
TEMP (°C)	24.53	3.28
V/M	560.68	432.53
L/M	441.12	926.68
K/M	0.38	1.06
F/M	7.15	37.09

Source: see text

Prior to running the formal regression, one should consider the observed univariate relationship between agricultural production and factors of production. The relationship between production and the traditional inputs labor, land and livestock feature correlation coefficients of 0.93, 0.78 and 0.82, respectively. These results indicate that traditional inputs have a stronger association with agricultural production compared to the industrial inputs. Both, fertilizers and tractors have correlation coefficients of 0.66. However, while traditional and industrial inputs seem to be positively correlated with agricultural production, the correlation with the climate variables TEMP and PRC is very close to zero. Anyway, they do have the expected sign. While temperature is negatively correlated (-0.06), rainfall shows a positive relationship (0.05).

FIGURE 6
UNIVARIATE RELATIONSHIPS BETWEEN CLIMATE VARIABLES AND AGRICULTURAL PRODUCTION



Source: see text

Analysis

Table 2 presents the results of the multivariate standard regression.[40] In column 1 the standard specification was estimated only with the climate variables. As can be seen, the conventional inputs enter positively and significantly at the 1 % confidence level, which signifies that these explanatory variables seem to be economically plausible. The results prove the smallholder structure of agriculture in SSA. The output elasticities of the traditional inputs labor, livestock and land are clearly higher than those of the modern inputs, thus these results are not at odds with the results of the univariate relationships above.

TABLE 2
AGRICULTURAL PRODUCTION – STANDARD SPECIFICATION

Standard specification results; dependent variable: Log(Y); time period: 1961-2000

	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Log(K)	0.048***	0.048***	0.042***	0.042***	0.049***	0.040***
	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
Log(L)	0.563***	0.572***	0.563***	0.563***	0.557***	0.564***
	(0.034)	(0.033)	(0.033)	(0.033)	(0.033)	(0.033)
Log(F)	0.017***	0.015***	0.010***	0.010***	0.017***	0.010***
	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Log(M)	0.445***	0.452***	0.414***	0.412***	0.435***	0.424***
	(0.081)	(0.081)	(0.079)	(0.079)	(0.081)	(0.080)
Log(V)	0.284***	0.273***	0.247***	0.246***	0.285***	0.258***
	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)
Log(PRC)	0.170***	0.172***	0.180***	0.175***	0.169***	-
	(0.028)	(0.028)	(0.027)	(0.028)	(0.027)	
Log(TEMP)	-0.728*	-0.699*	-0.730*	-0.706*	-0.704*	-
	(0.404)	(0.401)	(0.395)	(0.395)	(0.404)	
Conflict		-0.026*	-0.035**	-0.035**	-	-0.035**
		(0.015)	(0.015)	(0.015)		(0.015)
War		-0.123***	-0.128***	-0.128***	-	-0.127***
		(0.022)	(0.022)	(0.022)		(0.022)
Freedom years			0.010***	0.010***	-	0.010***
			(0.001)	(0.001)		(0.001)
Drought				-0.008	-	-0.024**
				(0.013)		(0.012)
France					0.058	
					(0.173)	
UK					0.166	
					(0.171)	
Portugal					-0.356**	
					(0.171)	
Observations	1720	1720	1720	1720	1720	1720
Countries	43	43	43	43	43	43
F-test	83.10***	81.71***	83.18***	81.57***	78.24***	81.52***
F - *u*	86.94***	88.39***	91.23***	90.65***	68.83***	89.56***
Wald test	1.449**	1.473**	1.635***	1.521**	1.457**	1.750***
R^2	0.70	0.71	0.71	0.71	0.70	0.71

Notes: (1) Standard errors in parentheses. (2) ***, **, and * constitute 1%, 5% and 10% significance levels, respectively. (3) Time dummies and constant included in all models.

Source: see text

The coefficients of labor and land are relative high compared to others. This indicates small farms typically make intensive use of land by using much labor, since the costs of domestic labor are low. Considering the fact that the explanatory

[40] Test statistics and specification problems are discussed in the Appendix

variable of labor is the stock of labor (persons economically active in agriculture) rather than the flow of labor services, it represents rural population density as well. Binswanger and Pingali (1988) have elaborated on the earlier work of Boserup (1965) which considered the impacts of population pressure on land productivity. They argue that land scarcity induces institutional and technological innovations which raise land productivity and that the relative land abundance in many parts of SSA during the sample period are barriers to land productivity growth.[41] Of course, Sub-Saharan Africa´s population has quadrupled since 1950, which indicates that land frontiers may have been reached in recent years.

It seems also consistent, that the livestock coefficient is higher than the modern inputs. Modern inputs like tractors and fertilizers require more cash investments and higher levels of education. Neither have small farms simple access to finance nor has education taken a noticeable step forward in Sub-Sahara's rural population.[42] Consequently, small-farm households spend their incomes or little surplus on locally produced goods and services, which include the purchase of livestock, rather than investing in new technologies. Therefore, livestock can truly be seen as accumulation of domestic savings. On average, Sub-Saharan African farmers must sell about twice as much grain as Asian farmers to purchase a kilogram of fertilizer, given its high price.[43] Furthermore, the progress in mechanization failed to substitute the land hoe as mechanical tool number one regarding land preparation.[44]

Rainfall and temperature as explanatory variables are significant and have the expected sign (although temperature is only moderately significant). Further, in all models with the climate variables (column 1-5), rainfall becomes a more important factor of production than the modern inputs, which again is not surprisingly for the smallholder structure. This leads to the conclusion that decreases in rainfall, as much of SSA has experienced in the sample period, reduced agricultural output. In contrast, the direct effect of increased temperature on production is marginally measurable. This goes along with IPCC (1995), where it is reported that precipitation is the most important climatic element, particularly seasonal drought and the length of the growing season.[45] Especially the distribution of rainfall during the growing season affects yields. In general, it is a permanent absence from normal water availability. In Sub-Saharan Africa, only 4 % of the area in production is under irrigation so far, compared with 39 % in South Asia and 29 % in East Asia. Consequently, 96 % of the cropland in Sub-Saharan Africa consists of rainfed agriculture.[46] Thus, as mentioned before, it is highly vulnerable to rainfall absence, particularly its continuation, and highly depending on sufficient precipitation during the wet season.[47]

In column 2 the dummy variables for conflict and war were introduced. Both indicators are negative and significant in each specification (except for conflict in column 2, there the coefficient becomes only moderately significant). The specification in column 2 indicates, all other things equal, if a conflict occurs production decreases by 2.6 % $[(e^{-0.026} - 1)*100]$, while the appearance of war in a given year drops agricultural performance by about 12 % $[(e^{-0.123)} - 1)*100]$. These results are in line with the argumentation before.

The effect of raising years since independence on production is marginally positive. The specification in the third column shows that every further decade in

41 Binswanger and Pingali, "Technological priorities", p. 82.
42 Hazell et al. "The Future of Small Farms", p. 16.
43 World Bank, "Agriculture for Development", p. 55.
44 For more on that topic, see: Mrema et al., "Agricultural mechanization", pp. 1-54.
45 IPCC, "Agriculture in a Changing Climate", Chapter 13, pp. 427-428.
46 World Bank, "Agriculture for Development", p. 9.
47 Hulme et al., "African climate change", pp. 145-169.

the post-colonial period increases agricultural production by about 0.1 % [($e^{0.01}$ – 1)*10]. This indicates that countries which achieved independence earlier have a higher production growth than others. Further, the paper argues that there are differences in production patterns between former colonies. This assumption is proofed through the indicator variable that represents former colonies (see column 5). As can be seen, countries that were colonies of UK perform better than former French and Portuguese colonies (although only the coefficient of former Portuguese colonies is significant). This effect is plausible considering the fact that the colonial masters of the latter one released their colonies much later into independence than the previous ones (Angola, Cape Verde, Guinea-Bissau, Mozambique became independent around 1975, while the most former British and French colonies separated between 1960 and 1965).[48] The results show that the institutional framework of agricultural production in SSA is still influenced by former colonial occupation but also improves the sooner countries achieved independence.

The negative effect of drought on production in column 4 is in line with the expectation although it is insignificant. This might be because the climate variables (TEMP and PRC) already catch climatic effects (including the adverse impacts of declining rainfall and raising temperature which lead to drought events). Thus, to measure the net-impact of drought, the climate variables were dropped in the last column. This approach leads to the expected result: the coefficient of the drought dummy is more negative and significant compared to the previous specification. The occurrence of drought reduces agricultural production by about 2.5 % [($e^{-0.024}$ – 1)*100].

Assume that the mean temperature of a country in SSA is 25 C° and mean annual rainfall is 850 mm. According to the climate coefficients in the first specification, a rise of the mean temperature to 25.25 C° (increase of 1 %) and a decline of mean annual rainfall to 765 mm (decrease of 10 %) would reduce agricultural production by about 2,4 %, which is nearly equal to the effect of the drought dummy (-2.5%). Hence, the effects of the climate variables and the drought dummy describe unfavorable climate conditions for agricultural production in different ways. This is a kind of robustness check for the climate variables.

CONCLUSION

Characteristics of Sub-Saharan African agriculture and geography arguably make its agricultural sector particularly sensitive to climate change. Especially, smallholder farmers, which depend on the products of their soil for their daily living, are highly vulnerable to any changes in climate conditions. This includes drought events as well, which become a significant determinant of production if the climate variables are excluded from the panel regression. Hence, the applied model specification provides a kind of robustness check on climate variables.

Furthermore, the paper investigates the impact of war and conflicts on agriculture. As expected, both variables have noticeable effects on agriculture indicating that a sustainable growth is impossible within such an adverse environment.

The attempt to catch some kind of institutional effects on agricultural production is made as well. While advancing years of independence signalize marginal positive effects, the indicator variable of former colonies reveals only moderate results. While former Portuguese colonies perform poorly, the results for former French and British colonies are insignificant.

[48] Former Belgium and Spanish colonies were excluded from the analyses (see Table 3, Appendix)

However, further technical refinement is needed as well when it comes to data and specification problems of the model. Two econometric problems are still unsolved in this analysis. First, stationarity of the panel data set is not assured. This implies the existence of a unit root which affect the result of the regression, for instance through an oil shock. Secondly, autocorrelation biases the standard errors and causes the results to be less efficient. This may be due to a wrong specification of the model. But it is more likely that the data quality of the FAO and World Bank is insufficient to avoid autocorrelation in linear regression analysis. Both issues suggest that the results need to be interpreted carefully and that research has not finished. An approach to those problems might be to use a dynamic panel model instead of a linear panel regression.[49]

The aim of this partial analysis is to provide a picture of important production determinants of Sub-Saharan agriculture which are not well established in panel regressions. Hence, the results should be used to contribute to the overall development discussion in terms of priorities. Especially, the importance of climate variables suggests appropriate adaptation strategies in future development planning to insure food security in Africa in times of climate change and intensification of resource endowments (increasing population growth, proceeding land degradation, among others).

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[49] For more detailed information, see Appendix.

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APPENDIX

A. Test Statistics

A Hausman test was made after every regression. It is used to test the appropriateness of the fixed effect model. The FE model is preferred if the regressors are correlated with the individual effects $\mu_{i,}$. If they are not, the individual effects are random and independent of the $X_{it.}$ In this case, a random effects model would be the appropriate structure of Eq. (3). However, all Hausman tests after running the regressions clearly approve the application of the FE model (results are not shown).

F-test is a test of joint significance of all coefficients, while F – *u* is a test of the null hypothesis that the constant terms are equal across units. The alternative hypothesis is that there are distinguishable intercept terms across the countries. The null hypothesis for all presented models can be rejected, which is additional evidence for the significance of individual country effects.

The Wald test refers to the significance of the included time dummies and the R^2 values suggest that the empirical specifications are explaining a large amount of the variation in the dependent variable.

B. Data preparation

The estimates in Table 2 use log (X'_{it}) as dependent variables (tractors, labor, fertilizer, land, and livestock, respectively). Some of the observations have missing values. Alternatively, as is typical in the literature, I constructed new dependent variables for those missing values: log (1 + X'_{it}). This approach helped to obtain a balanced panel in which each of the units, $i = 1, \ldots, N$, is observed in every period $t = 1, \ldots, T$, resulting in N x T observations in the dataset.

The climate data is normalized in each country by its long-term mean. This was done because the analysis wants to measure climatic changes, rather than permanent cross-country climatic differences in levels which already may be reflected in agricultural production. Considering the exogeneity of this normalization factor, the mean of the annual rainfall and temperature for the period prior to 1960 is selected.

C. Serial Correlation and Stationarity

For the specification in Table 2 the Baltagi-Wu locally best invariant (LBI) test statistic and a modified version of the Bhargava et al. Durbin-Watson statistic were calculated. In both cases the null hypothesis of no serial correlation is clearly rejected.

In order to test stationarity, the unit root test for heterogeneous panels developed by Kyung So im et al. (2003) was implemented. The test is based on the mean of individual unit root statistics and uses a standardized t-bar test statistic base on the augmented Dickey-Fuller statistics averaged across countries.

The existence of a unit root in the used variables cannot be fully eliminated. By using different lag-lengths or including a trend in the test as well, all variables, expect for the land and livestock, reject the null hypothesis of a unit root. These findings reflect the problems in macroeconomic approaches with large T.

These results indicate that a refinement of the model is absolutely necessary to improve the structure of the model and to obtain efficient and consistent estimates.

TABLE 3
COUNTRY CLASSIFICATIONS AND DATA INFORMATION

Country	Drought events	Former Colony	Independence	War	Conflict
Angola	6	Portugal	1975	24	14
Burundi	5	Belgium	1962	2	8
Benin	5	France	1960	-	-
Burkina Faso	12	France	1960	-	2
Botswana	19	United Kingdom	1966	-	
Central Africa	2	France	1960	-	2
Ivory Coast	4	France	1960	-	-
Cameroon	4	France	1960	-	3
Chad	19	France	1960	5	23
Congo	1	France	1960	2	3
Comoros	1	France	1975	-	2
Cape Verde	14	Portugal	1975	-	-
Djibouti	4	France	1977	-	5
Gabon	-	France	1960	-	1
Ghana	6	United Kingdom	1957	-	3
Guinea	2	France	1958	-	1
Gambia	9	United Kingdom	1965	-	1
Guinea Bissau	9	Portugal	1973	-	13
Equatorial Guinea	-	Spain	1968	-	1
Kenya	16	United Kingdom	1963	-	1
Liberia	2	United States	1847	2	7
Lesotho	9	United Kingdom	1966	-	1
Madagascar	4	France	1960	-	1
Mali	13	France	1960		2
Mozambique	10	Portugal	1975	13	14
Mauritania	7	France	1960	-	4
Mauritius	2	United Kingdom	1968	-	-
Malawi	14	United Kingdom	1964	-	-
Namibia	11	United Kingdom	1990	-	-
Niger	20	France	1960	-	5
Nigeria	11	United Kingdom	1960	4	1
Rwanda	7	Belgium	1962	3	6
Sudan	14	United Kingdom	1956	26	3
Senegal	14	France	1960	-	7
Sierra Leone	-	United Kingdom	1961	2	8
Somalia	10	United Kingdom	1960	4	11
Swaziland	9	United Kingdom	1968	-	-
Seychelles	-	United Kingdom	1976	-	-
Togo	4	France	1960	-	2
Uganda	6	United Kingdom	1962	11	14
Zaire	2	Belgium	1960	6	6
Zambia	8	United Kingdom	1964	-	-
Zimbabwe	11	United Kingdom	1980	4	5

Source: see text