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The Impact of Climatic Change on Agricultural Production:

Is it different for Africa?

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Abstract

This paper examines the impact of climatic change on the level of total agricultural production of Sub-Sahara Africa (SSA) and non-Sub-Sahara Africa (NSSA) developing countries. In doing so it uses a new cross-country panel climatic dataset in an agricultural production framework. The results show that climate, measured as changes in country-wide rainfall and temperature, has been a major determinant of agricultural production in SSA. In contrast, NSSA countries appear not to be affected by climate in the same manner. Simulations using the estimates suggest that the detrimental changes in climate since the 1960s can account for a substantial portion of the gap in agricultural production between SSA and the rest of the developing world.

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Section I: Introduction

Agriculture remains the main engine for economic growth for most Sub-Saharan African (SSA) countries, contributing around 40 percent to their gross domestic product and employing more than half of their total labour force. Despite its economic importance, however, the agricultural sector in SSA has performed poorly relative to other developing countries. A large part of the literature that has addressed this issue has pinpointed poor policies and institutional failures as the primary culprits; see, for instance, Sachs and Warner (1998) and Johnson and Evensohn (2000). These have included allegations that pre-colonial slave trade, adverse incentive structures imposed by the imperial powers during colonisation, poor economic policies in the post-colonial period, and international trading regimes have all played an important negative role in Africa's agricultural performance. [1] More recently, it has also been argued that adverse natural resource endowments, such as low population density, land abundance, and inherent geographic conditions, may also have been important; see, for instance, Bloom and Sachs (1998), Frisvold and Ingram (1995), and Gallup and Sachs (2000). [2]

While these aforementioned factors are undoubtedly important in solving the African agriculture poor performance puzzle, there may be another important, largely neglected, factor to consider. Specifically, there have been clear climatic changes taking place in the SSA continent over the 20th century. First of all, as all over the world, there has been a slow, but steady, rise in temperature over the last few decades. Moreover, however, Africa has alongside this global warming also been subject to a general decline in rainfall since the first half of the 19th century; see Nicholson (1994) and Nicholson (2001). While one may be inclined to think only in terms of more dramatic weather events, like floods, droughts, storms and hurricanes, adversely affecting agricultural

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[1] See Binswanger and Townshend (2000) for a review of the possible causes of the poor performance of African agriculture.
[2] Moreover, some authors have suggested that such adverse natural resource endowments may themselves have been part of the cause of the policy and institutional failures.

production, it is important to note that even small changes in climate could feasibly have substantial effects, particularly if countries do not have the necessary technology and/or endowments to deal with these. Indeed, agronomic models of climate sensitivity, see Rosenzweig and Parry (1994) and Reilly et al. 1996), suggest that climate changes in most developing countries are likely to be harmful and can make agricultural areas less productive.

The potential importance of these climatic trends for the performance of SSA agriculture has now been alluded to in a number of studies; see Nicholson (1994), Collier and Gunning (1999), O'Connell and Ndulu (2000), and Bloom and Sachs (1998). Nevertheless, while some research has attempted to explore the effects of climate change on agricultural production for individual countries over the past decade, little attention has been drawn to the African context as a whole. The present paper attempts to fill this gap. Specifically, we examine empirically how climatic changes have affected Africa's agricultural production within a production function framework. To do so we draw on a new cross-country climatic change data set in conjunction with agricultural output and input data to measure the impact of rainfall and temperature changes on agricultural performance. Our results indicate that agricultural production in SSA countries has indeed been sensitive to climatic changes that have taken place in the latter half of the 20th century. In contrast, no such effects are found for non-SSA developing countries. We attribute these contrasting results to the different nature of agricultural production across these two country groups.

The remainder of the paper is organised as follows. In the subsequent section we discuss the importance of climate for Sub-Saharan agriculture. Section III outlines our model specification and our data. Empirical results are presented in Section IV. We conduct some simple simulations in Section V. The final section concludes.

Section II: The vulnerability of Sub-Saharan African Agriculture to Climatic Changes[3]

The underlying argument of this paper is that Sub-Saharan African agricultural production is, relative to other developing countries, particularly sensitive to climatic changes. In considering this it is important to note that the availability of water in SSA differs widely as a consequence of the large diversity of geographic conditions across the continent. Parts of both West and the western part of Central Africa, i.e., mostly the tropics around the equator, are humid throughout the year. While there is substantial rainfall during the wet season(s) in the subhumid regions located to the north and south of the tropics, there is almost no rain during the much longer dry season(s). Further poleward from these subhumid regions are the large semi-arid climates. These areas receive some water during the wet season, but suffer from extreme unreliability of rainfall and few permanent water sources. As the name suggests, arid areas receive little direct water.

It is also important to point out that while the African continent has several large water basins and rivers and there is, as just noted, heavy rainfall in some areas, the run-off from these water sources to the arid and semi-arid areas is particularly low. This is exacerbated by the year round high temperatures in SSA. Additionally, even within the arid and semi-arid areas there is little water runoff as drier soil absorbs more moisture. As a matter of fact, the average runoff of about 15% is lower than in any other continent and extremely sensitive to changes in rainfall. Reibsame (1989), for example, estimates that in Southern Africa a reduction of 10 per cent in precipitation would lead to a fall of more than 50 per cent in runoff. Moreover, compared to other developing areas in the world, a much smaller proportion of arable land in SSA is irrigated. For instance, figures in Table 1 show that still less than 10 per cent of arable land in SSA is irrigated,

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[3] Unless indicated otherwise information in this section has been primarily taken from IPCC (2001).

compared to nearly a fifth in other developing countries. One should note that apart from the failure of governments and aid agencies to invest in irrigation, the lack of private investment in such may itself be a result of the African climate. Since the insurance capacity of agricultural households is extremely limited, see Christiansen et al (2002), changes in rainfall are likely to cause greater precautionary savings and thus divert funds from potential investment in Africa in order to smooth consumption levels.[4]

As becomes apparent, the areas outside the tropics are extremely reliant on rainfall for moisture.[5] The availability of water from rainfall depends in turn on the rate of evapotranspiration, i.e., on the amount of water that remains in the soil after what is evaporated and what is transpired by plants as a part of their metabolic processes. The rate of this is particularly high in SSA, in part because high temperatures increase the water-holding capacity of the air. Moreover, recent trends in desertifications may have affected the extent of rainfall in the semi-arid areas, as a reduction of vegetative cover can also translate into the absence of inter-annual soil water storage. The UN, for example, estimates that desertification has reduced the potential vegetative productivity by 25 per cent for nearly a quarter of Africa's land area, see UNEP (1997). Land-surface and atmosphere conditions may thus interact positively as a feedback mechanism leading to a further decrease in precipitation. The consequence of this process can also spread beyond the most immediately affected areas. For example, there is increasing evidence showing that countries located in the South of the Sahel suffered from reduced rainfall.[6]

The geographical variation of availability of water just described can be in turn considered in terms of its implications for agricultural production in SSA. More precisely, despite the abundance of water, the tropical humid regions are generally not

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[4] Examples include the studies by Dercon and Krishnan (2000) for Ethiopia and Molua (2002) for Cameroon.
[5] As a matter of fact, today around 60 per cent of African countries are considered to be vulnerable to drought and 30 per cent extremely so, see Benson and Clay (1998).
[6] See Shinoda (2001) for a review of the evidence.

suitable for crop or animal production. For crops, the combination of high temperatures and abundant rainfall fosters high rates of chemical weathering and the production of leached clay soils of low inherent fertility. Hence much of crop production is located in the semi-arid regions, making it susceptible to rainfall shortages. In terms of animal production domestic livestock in Africa other than pigs are also generally concentrated in the arid and semi-arid regions because the relatively more humid areas provide greater exposure to animal diseases and are characterised by grasses of low digestibility. Since livestock are directly dependent on grass quantity, rainfall variations in the semi-arid and arid areas, have, in turn, direct consequences on livestock production.[7] Specifically, it has been shown that the link between rainfall and animal numbers is approximately linear; see IPCC (2001).

Agricultural practices themselves have often added to the water shortage problem in Africa more than anywhere else due to differences in property rights. More precisely, because farmers are often not owners of the land they work on, the preservation of natural resources is generally viewed as a secondary objective. In addition, pressures represented by increasing populations and changing technology add to the problem of land deterioration related to agricultural practices, see for example Drechsel et al. (2001). Besides, problems associated with land use through, for example, deforestation, can translate into increased erosion. Another illustration of environment-damaging agricultural practices is the intense use of fertilizer in low-quality lands. As yields increase, so will water consumption, thus creating a vicious circle, see Gommes and Petrassi (1996).

Finally, it is important to consider how the agricultural sector in SSA may have directly responded to climatic changes. One could argue that one response to losses in

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[7] One should also note that apart from animal products, domestic livestock often also serve as source of draft power in SSA.

agricultural production to climatic changes that could dampen their effects may, at least in the short run, be an adjustment of prices. However, since most of African agricultural products are for export and African countries tend to be price takers on the world commodities market, a loss in production is unlikely to have any effect on prices for most agricultural products for most countries; see Deaton (1999) and Reilly et al (1994). Over the more longer run farmers and governments may adopt technologies and production techniques that take the climatic changes into account and thus reduce its impact. However, as noted by the IPCC (2001), relative to for example the Asian regions, adaption in SSA has been minimal.[8] For example, in Molua (2002), found that in Cameroon only little more than half of farmers modified their farming practises to suit prevailing climatic conditions and that this mostly involved using inferior indigenous techniques to do so. Moreover, as noted by Jagtap and Chan (2000), farmers in SSA tend to employ rudimentary non-scientific means of predicting large fluctuations in rainfall.[9] Also, as argued by the IPCC (2001), poor economic policies in Africa have further undermined any incentives to appropriate adaptation to climatic change in the agricultural sector.

Section III – Model Specification

In order to investigate the impact of climatic changes on agricultural production in Sub-saharan Africa relative to other developing countries we specify a simple empirical production function where for any country i at time t agricultural output is a function of a number of inputs[10]:

$$\log(Y_{it}) = \beta_1 + \beta_2 \log(L_{it}) + \beta_3 \log(A_{it}) + \beta_4 \log(F_{it}) + \beta_5 \log(K_{it}) + \beta_6 \log(M_{it})$$

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[8] Although, it must be emphasized that human adaptation to long-run changes in Africa is not well understood; see IPCC (2001).

[9] In contrast, Mendelsohn and Dinar (1999) provide evidence that farmers in Brazil and India adapted to climatic changes.

[10] A similar empirical model is used by Frisvold and Ingram (1995), although they also experiment with other inputs for a much shorter time period and reduced sample of SSA countries.

$$+ \beta_7 \log(R_{it}) + \beta_7 \log(T_{it}) + \eta_t + \mu_i + \varepsilon_{it} \qquad (1)$$

where is Y agricultural output and the inputs L, A, F, T, and M are labor, livestock, fertilizer, capital, and land, respectively. More importantly we include rainfall, R, and temperature, T, as auxiliary climatic factors that may affect agricultural production. Additionally we allow for time varying effects η common to all countries, proxied by a set of time dummies and intended to capture such factors as technological progress and other SSA wide influences. Finally we purge any unobserved country specific (time invariant) effects, μ, that may be correlated with the other regressors and hence bias our estimates by using a fixed effects estimator. The βs are the coefficients to be estimated.

The data used to estimate (1) is derived from two sources. Our main variables of interest, the measures of rainfall and temperature, are taken from the Inter-Governmental Panel on Climate Change (IPCC) data set, which provides, amongst other things, times series data on the average annual rainfall and temperature for 289 'countries' (comprised of 188 states and 101 islands and territories) from 1901 to 1998; see Mitchell et al (2002) for a complete description of the data set. These rainfall series were constructed by assimilating measurements of rainfall from meteorological stations across the world into 0.5 degree latitude by 0.5 degree longitude grids covering the land surface of the earth. Each grid-box was then assigned to the appropriate country in order to calculate a measure of rainfall for each by using the weighted mean of the values of all grid boxes within a country.[11] This procedure resulted in comparable mean annual measures of annual rainfall and temperature for each `country', given in millimetres and centigrades, respectively.

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[11] Where a grid box was located across more than one country, the grid box was assigned to the country with the largest stake, except where a country would otherwise have been left without any grid box. Weighting was essential since the spatial areas represented by each grid box differ in latitude. For further details see Mitchell et al (2002).

There are a number of issues to be noted in terms of constructing and using these cross-country measures of climate. First, we chose to normalise them in each country by their long-term mean. This was primarily done because we are interested in climatic changes, rather than permanent cross-country climatic differences in levels, which already may be reflected in agricultural production. In order to avoid any concerns regarding the exogeneity of this normalisation factor we used the mean of the annual rainfall for the period prior to 1960, although using the long-term mean over the entire available period produced very similar results.[12] One should note that a similar measure is already in use by the FAO for rainfall; see Gommes and Petrassi (1996).

All our agricultural data are taken from the FAO online database. For a measure of agricultural output we use the FAO net production index, where net production quantities of each commodity are weighted by the 1989-91 average international commodity prices and summed for each year, and the aggregate for a given year is divided by the average aggregate for the base period 1989-91. L is measured as the size of the economically active population. In order to proxy land input, M, in the production function we use FAO's measure of agricultural area, which includes arable land and the area used for permanent crops and permanent pastures, while fertilizer, F, is measured as the quantity, in metric tonnes, of plant nutrients consumed for domestic use in agriculture. As a crude proxy of capital stock, K, we use the total number of agricultural tractors being used. Livestock is proxied by the total head count of cattle, sheep, and goats.[13]

One should note that our choice of inputs in (1) was constrained by the availability of comparable cross-country data across sub-saharan African and other developing countries that covered a sufficient time span. For example, ideally one would

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[12] Details are available from the authors.
[13] While there is information on other forms of livestock, in terms of numbers these groups almost always constituted the most important animal type. Moreover, the more different types are included the more important the issue of weighting these becomes as we solely use the total number of each.

have liked to have proxies of the capital stock other than the number of tractors. Additionally, measures of the level human capital and land quality could be important determinants.[14] One should note, however, that in terms of these conventional inputs our production function specification is similar to that of Frisvold and Ingram (1995).[15]

Finally, it is important to comment on our use of a production function to examine the effect of climatic change on agricultural production. As noted by Deschenes and Greenstone (2004), the advantage of this approach is that it controls explicitly for other inputs. However, its disadvantage lies in the fact that it does not take account of the full range of compensatory responses to changes in climate made by farmers.[16] More specifically, a profit maximzing farmer is likely to make some adatptions in his manner of producing, choice of crops, etc. if he/she feels that climatic change is relatively permanent. This will tend to bias the coefficient on the impact on the agricultural sector in our production function framework downwards; see Mendelsohn et al (1994). Since we have argued that adaption to climatic changes was relatively low in SSA, this would produce relatively little bias for the SSA nations. In contrast, there is a greater likelihood of a downward bias for the NSSA group.   Our results must thus be viewed solely as the difference in the final net impact that climate change has on agricultural output rather than measuring the full impact on the agricultural sector across the two country groups.

Section IV: Empirical Results

[14] In the past school enrolment rates, literacy rates, and years of schooling have been commonly used as indicators of human capital. Apart from the fact that use of these would have substantially reduced our sample size and the number of countries covered, one should note that these have generally produced very unsatisfactory results; see Aboagye and Gunajl (2000) for a discussion of this.

[15] Frisvold and Ingram (1995) also use a number of other. 'non-conventional' inputs that are unfortunately only available over a much smaller time period than we cover in the current paper.

[16] An alternative is to use the Ricardian approach to estimate the impact, first pioneered by Mendelsohn et al (1994) and later extended by Deschenes and Greenstone (2004). Unfortunately, we do not have the necessary data , such as land values or agricultural profits, to undertake such.

Including only observations with non-missing values of all our variables for the available sample of period 1961-1997 resulted in 1276 observations for 40 SSA and 2279 observations for 67 NSSA countries – the list of countries are provided in the Appendix.[17] Basic summary statistics for all our variables are given in Table 1. These show that there is considerable variation in all of the variables employed. We also include summary statistics for the inputs L, K, and F rescaled by agricultural area. Their means indicate that NSSA nations use these, per unit of land, much more intensively than their SSA counterparts.

We also graphed the mean values across the two broad country groups of our agricultural production and our climatic change measure over our sample period, normalised by their initial levels in Figures 1 through 3.[18] Examining agricultural production in Figure 1 one can see that it has been rising for both SSA and NSSA nations. However, from the mid 1970s until about the mid 1980s agricultural output in NSSA rose proportionally more than in SSA.

The long term evolution of rainfall and temperature for the two country groups sine the start of the 20th century is depicted in Figures 3 and 4, respectively. In terms of the mean annual temperature it becomes apparent that both groups followed similar trends. Accordingly, after an initial stable period, temperatures rose until the early 1940s, then experienced a gradual, but volatile, decline, until the late 1970s, from which point onwards they have been increasing relatively drastically. Figure 4, in contrast, clearly shows that average annual rainfall followed different trends across SSA and NSSA countries. More precisely, although volatile, mean annual rainfall has been relatively steady in NSSA countries over the entire 20th century. In contrast, rainfall reached a peak in SSA in the 1960s, but subsequently, apart from a short period in the late 1970s,

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[17] This sample consists of an unbalanced panel data in that for a few countries not all time periods are available. Excluding these from our analysis did not change our results qualitatively.

[18] For the climatic proxies we used five point moving averages in the figures in order to highlight essential trends as annual volatility often tended to be very high.

generally declined until the mid 1980s. In particular, it has almost exclusively remained below its pre-1960 mean since the mid 1970s – a time from which SSA has also performed poorly (relative to NSSA) in terms of the agricultural production index.

The graphical depiction of trends in agricultural production and climatic changes was suggestive of the possibility that, at least in terms of mean rainfall, differences in the evolution of agricultural output in SSA relative to NSSA may be intrinsically linked to climatic changes. In order to investigate this more conclusively we thus now turn to the empirical estimation of (1).

We first estimated (1) without including our climatic change measures as explanatory variables for SSA and NSSA countries separately in the first and fifth columns of Table 2, respectively. As can be seen, for both all inputs turn out to be statistically significant determinants of agricultural output with the expected sign, thus providing some support for our model. Furthermore, the high R-squared values suggest that the empirical specifications are explaining are large amount of the variation in the dependent variable. Comparing the individual coefficients across groups, one notices that for NSSA the coefficient on the fertilizer and tractors variables are more than double the value of those found for SSA.[19] This may be suggestive of the possibility that we are unable to control for the quality of these inputs, which are likely to be higher in the on average relatively richer NSSA nations. In contrast, one finds that the elasticity of agricultural output to a unit increase in agricultural land area is substantially higher in SSA.

We next included our rainfall proxy, as shown in the second and sixth columns. The first point to note is that the inclusion of this variable has little effect on the coefficients of the other explanatory variables for either group of countries. More importantly, however, we find that while rainfall is not a significant determinant of

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[19] A simple t-test of the differences proved to be significant.

agricultural output in NSSA, it, in contrast, has been an important factor in SSA. More precisely, decreases in rainfall, as much of SSA has experienced for at least part of our sample period, have acted to reduce agricultural output.

Estimates of including the temperature variable in the empirical equation are shown in the third and seventh column. As for rainfall, one discovers that average annual temperature did not significantly affect agricultural output in NSSA countries. In contrast, changes in temperature appear to have played a significant role in variations in agricultural output in SSA. Given our arguments in Section II that rising temperatures may have further increased the sensitivity of the agricultural sector in SSA to variations in rainfall, we also experimented with including an interaction term between our two climatic variables, as depicted in the fourth columns of the results tables. However, for neither group is there any evidence that changes in temperature may have played a role in the impact of rainfall on agriculture. Rather its effect is only of a direct nature.

Section V: Simulations

One can now use our empirical estimates to simulate what the evolution of agricultural production in SSA would have been if there had been no climatic changes over the sample period. More specifically, one can utilize the estimated coefficients to estimate the level of agricultural production in SSA if mean rainfall and temperature had remained at their pre-1960 means. Since the logged value of the pre-1961 mean of our normalised measures is zero, this is simply done by adding the product of the estimated coefficient and the mean of the appropriate climatic measure in each year to the actual (logged) level of agricultural output, allowing the effects to accumulate over time. More precisely, the hypothetical level of agricultural production at some hypothetical climatic indicator C^H can be calculated as:

$$\log(Y^{H}_{SSA,T}) = \log(Y_{SSA,0}) + \sum_{t=1}^{t=T}[(\log(Y_{SSA,t}) - \log(Y_{SSA,t-1})) + \beta_C(C^H - C_t)]$$

t=1...., T.

where C_t and β_C are the actual observed values and the estimated coefficient(s) of the climatic change indicator(s).

In calculating out hypothetical series of agricultural production for SSA we considered both holding rainfall and holding rainfall in conjunction with temperature constant over our sample period. The resultant series in conjunction with the actual levels of production for SSA and NSSA groups are shown in Figure 4. As can be seen, since rainfall was still recovering from its relative peak in the late 1950s, and thus above its previous long-term mean, holding it constant at its pre-1961 mean actually reduces agricultural output relative to the real series until the 1970s. From then onwards, apart from a slight recovery in the late 1970s, low annual average rainfall has, however, kept agricultural production below what it would have been if the long-term mean had prevailed. This deficit culminated in the late 1980s when rainfall was at its lowest. It is also apparent that the increase in temperature had a relatively (to the drop in rainfall) modest impact on agricultural production in SSA. Most of its effect occurred in the mid-1980s where the rise in temperature was steepest. Overall, however, the underlying figures suggest that if climatic conditions had been similar on average to the first part of the century, one would have observed only about 32 per cent of the increase in the gap of agricultural production between the two country groups .

Section VI: Conclusion

Characteristics of Sub-Saharan African geography and agricultural practices arguably make its agricultural sector particularly sensitive to changes in climate. In this paper we investigate the extent of this using cross-country data on rainfall and

temperature and agricultural output and inputs. Our results suggest that climatic changes have had important effects on total agricultural output on the Sub-Saharan African continent, but not in other developing countries. Simple simulations using our estimates suggest that if rainfall and temperatures had remained at their pre 1960s level then one would by the end of the 20th century only have observed 32 per cent of the gap of agricultural production between Sub-Saharan Africa and other developing countries.

From a policy perspective, given the conflicting evidence as to whether the general decline in rainfall will continue in Africa (see, for instance, the different predictions by Nicholson (1994), Hulme et al (2001), and IPCC (2001)) it seems important that policy makers take specific steps that are likely to lower African africultural sector's sensitivity to rainfall variations. This could entail the adoption of agricultural techniques that optimise water use through increased and improved irrigation systems and crop grazing areas development.

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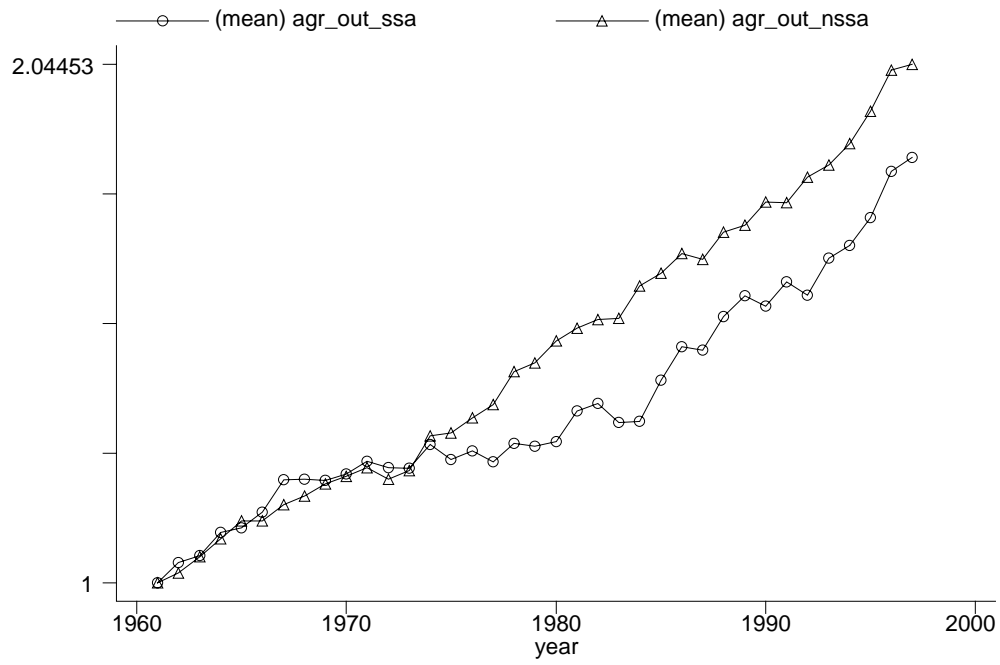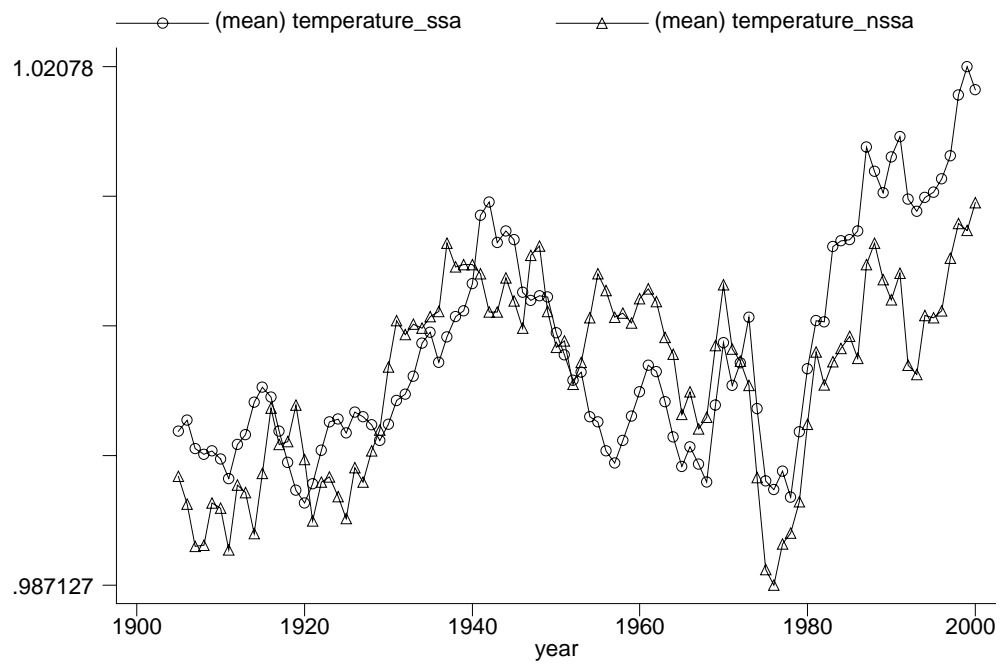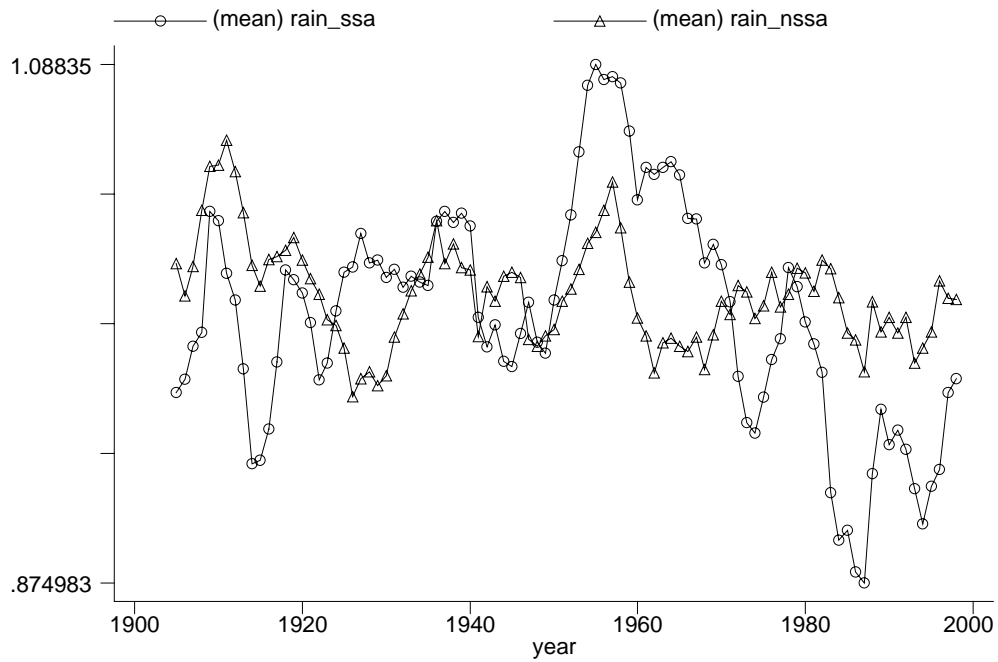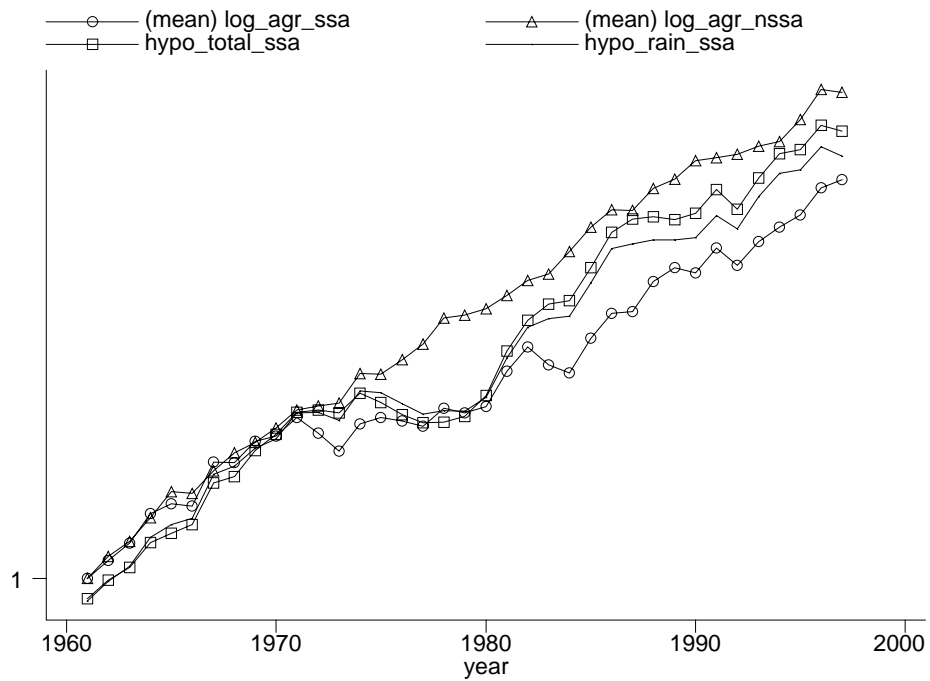
Figure 1

Figure 2

Notes: (1) temperature_ssa and temperature_nssa are normalised mean temperature for SSA and NSSA, respectively.

Figure 3

Notes: (1) rain_ssa and rain_nssa are normalised mean rainfall for SSA and NSSA, respectively.

Figure 4 - Simulations

Notes: (1) log_agr_nssa, log_agr_nssa, hypo_total_ssa, and hypo_rain_ssa are actually agricultural production in NSSA, actual agricultural production in SSA, hypothetical agricultural production in SSA considering rainfall and temperature benchmark values, and hypothetical agricultural production in SSA considering a benchmark measure of rainfall, respectively.

Table 1: Summary Statistics

	N-SSA	N-SSA	SSA	SSA
	mean	*st.dev.*	*mean*	*st.dev.*
Y	82.42	27.85	84.79	23.58
M ('000s HA)	30434	69802	22321	27379
A ('000s)	21700	53100	8171	12700
L ('000s)	13283	56634	3069	3439
K	47806	142855	6907	25468
F	552056	2498391	47700	131079
R	0.99	0.17	0.96	0.16
T	1.01	0.06	1.01	0.02
A ('000s)/M	1095	963	530	379
L /M	592	817	308	354
K/M	4.3	7.4	0.3	0.7
F/M	74.1	325.7	8.8	40.0

Table 2: Regression Results

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
SAMPLE:	SSA	SSA	SSA	SSA	NSSA	NSSA	NSSA	NSSA
Log(L)	0.150***	0.145***	0.152***	0.153***	-0.036*	-0.036*	-0.033	-0.033
	(0.044)	(0.043)	(0.043)	(0.043)	(0.022)	(0.022)	(0.022)	(0.022)
Log(F)	0.037***	0.037***	0.037***	0.037***	0.039***	0.039***	0.037***	0.037***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.006)	(0.006)	(0.006)	(0.006)
Log(K)	0.021***	0.021***	0.022***	0.022***	0.068***	0.068***	0.068***	0.068***
	(0.010)	(0.010)	(0.010)	(0.010)	(0.007)	(0.007)	(0.007)	(0.007)
Log(A)	0.201***	0.201***	0.202***	0.202***	0.123***	0.124***	0.125***	0.125***
	(0.022)	(0.022)	(0.022)	(0.022)	(0.016)	(0.016)	(0.016)	(0.016)
Log(M)	0.558***	0.562***	0.570***	0.573***	0.346***	0.346***	0.342***	0.342***
	(0.094)	(0.092)	(0.092)	(0.093)	(0.027)	(0.027)	(0.027)	(0.027)
Log(RAIN)		0.229***	0.217***	0.221***		0.015	0.015	0.014
		(0.030)	(0.031)	(0.033)		(0.022)	(0.022)	(0.022)
Log(TEMP)			-0.742*	-0.782*			-0.029	-0.032
			(0.407)	(0.423)			(0.045)	(0.045)
Log(RAIN)*Log(TEMP)				-0.439				0.157
				(1.248)				(0.229)
Observations	1276	1276	1276	1276	2279	2279	2279	2279
Countries:	40	40	40	40	67	67	67	67
F-Test	56.30***	58.91***	57.73***	56.38***	19.69***	19.22***	18.48***	18.06***
F-u	40.86***	43.25***	43.17***	43.10***	44.57***	44.55***	44.17***	44.15***
R-squared	0.66	0.67	0.68	0.68	0.27	0.27	0.27	0.27

Notes: (1) standard errors in parentheses. (2) ***, **, and * constitute 1, 5, and 10 per cent significance levels, respectively. (3) time dummies included in all specifications.