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Climatic Change and Rural-Urban Migration: The Case of Sub-Saharan Africa *

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Abstract

We investigate the role that climatic change has played in the pattern of urbanization in sub-Saharan countries compared to the rest of the developing world. To this end we assemble a cross-country panel data set that allows us to estimate the determinants of urbanization. The results of our econometric analysis suggest that climatic change, as proxied by rainfall, has acted to change urbanization in sub-Saharan Africa but not elsewhere in the developing world. Moreover, this link has become stronger since decolonization, which is likely due to the often simultaneous lifting of legislation prohibiting the free internal movement of native Africans.

JEL classifications: O18, O55, Q54, R23
Keywords: urbanization, climate change, rainfall, rural-urban migration, Africa

* The views expressed by the authors are not necessarily those of the institutions they are affiliated with.

Section I: Introduction

It has been noted that historically economic development and urbanization have tended to go hand in hand and the legitimacy of this link continues to draw considerable attention; see, for instance, the 1999/2000 issue of the World Development Report (World Bank, 2000). One notable exception to this stylised fact, however, has been sub-Saharan Africa. More specifically, while sub-Saharan Africa's rate of urbanization has been extraordinary by international standards, growing by more than 140 per cent between the 1960s and the 1990s - which is a rate of ten times that of OECD countries and 2.5 times that of the rest of the developing world – it does not appear to have been coupled with an improvement in economic wealth in this region of the world; see Fay and Opal (2000) and World Bank (2000).[1] Furthermore, it is now a well known fact that internal migration has been a major factor fuelling the growth of Africa's cities. For example, it has been estimated that rural-urban migration has accounted for roughly half of urban growth in Africa between the 1960s and 1990s (Zachariah and Conde (1981), Kelley (1991)), with large variations across countries. These evolutions and further predicted increases in urbanization have consequently raised concerns about the capacity of Africa's urban system to absorb such massive movements of population and its impact on sustainable development.

A natural starting point in trying to understand the lack of connection between urbanization and development in sub-Saharan Africa is to analyse the potential determinants of urbanization on this continent. From the general literature on what causes urbanization, one can essentially distinguish between two groups of explanations of rural-urban movements, which we loosely label as *demand pull* and *supply push* type. With regard to the former, it is generally assumed that modern sectors of production,

[1] Moreover, according to UN (2003) projections, sub-Saharan Africa's urbanization should further increase by about 3.5 per cent annually in the next 30 years.

which generally locate in urban areas, have higher rates of productivity and monetary reward than the traditional rural agricultural sector and hence attract urban-rural migrants. *Supply-push* explanations, in contrast, essentially refer to the possibility that other factors directly affecting the rural sector have favoured population movements towards cities and may not necessarily result in productivity improvements. These may include displacement of population due to civil conflicts or other more direct determinants of agricultural production.

One particular *supply-push* type factor that may have been important in determining urbanization in Africa, and that is the focus of the current paper, is that of climate change. In particular, long-run climate change scenarios tend to suggest that extreme climate variations and, more specifically, water shortages, are likely to cause abrupt changes in human settlements and urbanisation patterns in sub-Saharan Africa more than anywhere else in the world, see Watson et al. (1998). It has also relatively recently been noted that rainfall in Africa has, in general, been on a decline since its relative peak in the 1960s; see, for instance, Nicholson (1994, 2001). The specific effects of climate change on rural/urban migration in sub-Saharan Africa have, however, as of date been poorly documented. A particularly important starting-point is that sub-Saharan African agriculture is especially dependent on rainfall compared to most other developing countries which triggers the potential impact of rainfall variations on economic activity, see Barrios et al. (2003). These impacts are, in turn, especially pronounced in rural areas where agriculture concentrate and thus potentially affect rural/urban migration patterns. In this regard, one should note that, although climate per se is seldom the direct root of migration, except in extreme cases like floods or droughts, it clearly can, however, exacerbate difficult living conditions at the margin of subsistence.

The current paper provides empirical evidence showing that climatic change have been an important determinant of rural-urban migration in sub-Saharan Africa. More generally, our focus is linked to the concept of *eco-refugees* or *environmental refugees*, where environmental conditions may influence socio-economic conditions and hence migration (Myers, 1993).[2, 3] We specifically set out to investigate the role of the general decline in rainfall on the African continent since the 1960s in shaping its urbanization patterns. In this regard we take advantage of a new comprehensive cross-country data set on rainfall and commonly used United Nations data on urbanization. Placing these in an econometric specification of the determinants of urbanization we then explicitly test for the impact of rainfall on urbanization in sub-Saharan Africa using other developing countries as a natural control group. Our results show that rainfall has indeed been an important determinant of urban growth in sub-Saharan Africa. Moreover, we find that this effect was much stronger after decolonisation when there was less restriction on migration in most countries.

The remainder of the paper is organised as follows. In section 2, we discuss Africa's rural sector's vulnerability to shortages in rainfall. In section 3, we outline a simple theoretical factor specific framework to demonstrate how rainfall may affect urbanization patterns. Section 4 describes our data and provides summary statistics. Our econometric framework and estimation results are presented in section 5. Concluding remarks are provided in the final section.

[2] The term was actually first popularised by Lester Brown of the Worldwatch Institute in the 1970s, but perhaps the most quoted contributions on the subject are those of El-Hinnawi (1985) and Jacobson (1988).
[3] Although difficult to estimate, the number of environmental refugees ranges worldwide from 10 to 25 millions (Myers, 1993).

Section II: The Link between Rural-Urban Migration and Rainfall: A Specific Factors Framework

The specific factors model (Jones, 1971) is a particularly useful theoretical framework in order to conceptualize the link between rural/urban migration and changes in rainfall. Here we use a slightly modified version of this model in order to consider the effect of variations in rainfall in the agriculture sector. Accordingly, suppose we have an economy that has two industries, the rural/agricultural sector (A) and the urban/manufacturing sector (M), and three factors of production, "effective" land input (L), labor (N), and capital (K). Here, land is specific to the agricultural sector whereas capital is specific to the manufacturing sector, and labor is supposed to be freely mobile between the two sectors. Thus, the production function in the rural/agricultural and the urban/manufacturing sectors are

$$Y_A = L(R)^{1-\alpha_A} N_A^{\alpha_A}, \tag{1}$$

$$Y_M = \overline{K}^{1-\alpha_M} N_M^{\alpha_M} \tag{2}$$

where $\overline{K}$ stands for capital endowment of the economy and $\alpha_A(\alpha_M)$ is the elasticity of agriculture (manufacturing) output with respect to labour. Unlike the standard specific factors model, we assume that the effective land input depends on the level of rainfall (R), that is, L(R). In order to see the positive impact of rainfall on the effective land input, we assume L'(R)>0. We also assume that the economy is small in the sense that prices of the two sectors, $\overline{p}_A$ and $\overline{p}_M$, are exogenously given.

For simplicity we postulate that both the agricultural and the manufacturing sectors exhibit constant returns to scale technologies. In this case, first order conditions lead to the following results:

$$\bar{p}_A \frac{\partial Y_A}{\partial N_A} = w \quad \Rightarrow \quad N_A = \alpha_A^{\frac{1}{1-\alpha_A}} \left(\frac{w}{\bar{p}_A} \right)^{-\frac{1}{1-\alpha_A}} L(R) \tag{3}$$

$$\bar{p}_M \frac{\partial Y_M}{\partial N_M} = w \quad \Rightarrow \quad N_M = \alpha_M^{\frac{1}{1-\alpha_M}} \left(\frac{w}{\bar{p}_M} \right)^{-\frac{1}{1-\alpha_M}} \bar{K} . \tag{4}$$

where N_A/N_M is the mass of workers in the agricultural/manufacturing sector.

From equations (3) and (4) and the labor market equilibrium condition, $N_A + N_M = \bar{N}$, we have the equilibrium wage rate and the equilibrium distribution of workers between the two sectors $\{w^*, N_A^*, N_M^*\}$, as functions of the parameters $\{L(R), \bar{K}, \bar{p}_A, \bar{p}_M\}$. The equilibrium urbanization rate is given by $U \equiv N_M^* / \bar{N}$.

In order to analyze the impact of rainfall on urbanization, we first have to determine the rate of changes in agricultural and manufacturing employment

$$\frac{dN_A}{N_A} = \underbrace{\frac{RL'(R)}{L(R)}}_{\eta_{L(R)}} \frac{dR}{R} - \frac{1}{1-\alpha_A} \frac{dw}{w}. \tag{5}$$

$$\frac{dN_M}{N_M} = -\frac{1}{1-\alpha_M} \frac{dw}{w}. \tag{6}$$

Taking the rate of change in the labor market equilibrium condition, we have

$$(1-U)\frac{dN_A}{N_A} + U \frac{dN_M}{N_M} = 0 , \tag{7}$$

where we abstract from the growth in the labor force. From equations (5), (6), and (7), we derive the following proposition.

Proposition: *A decline in rainfall raises the urbanization rate. Specifically, the elasticity of the urbanization rate with respect to rainfall is given by*

$$\frac{\partial \ln U}{\partial \ln R} = \frac{\partial \ln N_M}{\partial \ln R} = -\frac{\eta_{L(R)}}{\frac{U}{1-U} + \frac{1-\alpha_M}{1-\alpha_A}} < 0 . \tag{8}$$

where $\theta_A = N_A / \overline{N}$ and $\theta_M = N_M / \overline{N}$ are the shares of rural/agricultural and urban/manufacturing population respectively. The impact of a change in rainfall can in fact be assimilated to the change in factor endowment *à la* Rybczynski showing how changes in an endowment affects sectoral outputs. Here a similar effect can help to better understand the linkages between changes in productivity of the input specific to agriculture (i.e. land) through changes in rainfall and changes in the urbanization rate through change in the relative share of manufacturing *versus* agriculture employment.

Section III: The Rainfall Dependence of sub-Saharan African Agriculture

The dependence of sub-Saharan agriculture on rainfall and its implications for Africa's economic development has been widely documented in the literature. The present Section summarizes this literature and more extended discussion can be found, for instance in Barrios et al. (2003) and IPCC (2001). Changes in rainfall can potentially have a wide array of economic implications anywhere in the developing world given that rainfall is the main driver of water balance variability both over space and time. Historically, however, shortages in rainfall in Africa seem to have been associated with particularly damaging consequences, in the most extreme cases causing food and water deficiencies and the death and displacement of substantial shares of population. Part of the reason of why shortages in rainfall have been important for Africa is certainly due to the importance of the agricultural sector in its economies. Table 1 shows, for example, that agriculture has traditionally had a higher share in GDP in Africa than in any other developing regions – nearly 40 per cent in 1960. Although this share has since been steadily decreasing, it still represents almost a third of total GDP in 1997, compared to the average 14.1 per cent in the rest of the developing world. In particular, African agriculture relies heavily on rainfall for the provision of water for crops. Indeed, compared to other developing areas in the world, a much smaller proportion of cropland is irrigated. More generally speaking, the geographic and climatic conditions specific to the African continent explain to a great extent why agriculture in sub-Sahara Africa is so vulnerable to water shortages.

Generally speaking, agriculture in the African tropical area is seriously hampered by high temperature, fragile soils, and low yield potential. It also suffers from chronic diseases affecting both animal and non-animal production. Outside its equatorial area, a large share of Africa's arable land suffers from aridity, tending to increase the risk of drought as drier soil absorbs more rainfall, see Bloom and Sachs (1998).[4] The vulnerability to rainfall in the arid and semiarid areas of the continent also translates into a poor capacity of most African soils to retain moisture. Furthermore, evapotranspiration is in turn relatively high in Africa, as a consequence of high temperature throughout the year, thus leaving low quantities of water for soil moisture. [5] The reduction of vegetative cover experienced by Africa over the past decades has also added to the insufficient inter-annual soil water storage, see UNEP (1997). Land-surface and atmosphere conditions may thus interact positively as a feedback mechanism leading to a further decrease in precipitation.

[4] 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).

[5] Evapotranspiration is the combination of water that is evaporated and the one that is transpired by plants as a part of their metabolic process.

Agricultural practices often add 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 often 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). 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). This causes greater exposure to desertification with the shortages in rainfall directly influencing agricultural productivity. Human practices can also add to the desertification risks through overgrazing, which is represented by higher density and/or shorter rotations of livestock beyond the limit of the ecosystem, in particular because range-fed livestock are usually concentrated in the arid and semi-arid areas since tropical areas provide potentially more exposure to animal diseases, see IPCC(2001).

This high vulnerability of agriculture on climatic conditions in turn opens the door to the possibility of large-scale migrations of those whose livelihood essentially depends on rain-fed agriculture, the so-called environmental migrants, that have partly converged to cities. As a matter of fact, in sub-Saharan African countries, urban growth has essentially been achieved through in-migration of agricultural populations, where nearly half of Africa's urbanization in the last decades has been achieved by rural-urban migration, although there have been large variations across countries (Kelley, 1991).

Section IV: Data and Summary Statistics

Rainfall Data

The basic hypothesis of the paper poses that climatic conditions push people out of rural/agricultural areas to urban areas. Our measure of climatic condition will be the rainfall level in a country and is 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 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.[6] This procedure resulted in comparable mean measures, given in millimetres per square meters, of annual rainfall for each country. For the purposes of this paper we use observations on developing countries, where we consider a country to be of developing status if it is either a low, lower-middle, or upper-middle income nation according to the World Bank 2001 definition. All countries used in any part of our empirical analysis are listed in Appendix.

There are a number of issues to be noted in terms of constructing and using the cross-country measure of annual rainfall. First, we chose to normalise the rainfall measure provided in the data set by the long-term mean annual rainfall in each country. This was primarily done because we are interested in climatic changes, rather than permanent cross-country climatic differences in levels. In order to avoid any concerns

[6] 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).

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.[7] One should note that a similar measure is also used by the FAO; see Gommes and Petrassi (1996). Since most of our econometric analysis focuses on the effect of rainfall on long-term, five year, cross-country growth rates, we calculated the simple arithmetic mean of the annual normalised rainfall measure over the appropriate five year intervals.

One other aspect with regard to our rainfall measure that deserves discussion, because it has plagued many studies examining other potential determinants of Africa's poor growth performance, is the question of its exogeneity. In terms of rainfall we can argue fairly confidently that it is a strictly exogenous factor given that it measures an aspect of climatic change. While one could in theory also hypothesize that perhaps economic activity affects such aspects as environmental degradation and desertification, and thereby possibly rainfall, Nicholson (1994) finds no evidence suggesting such. As a matter of fact, earlier historical data suggests that rainfall naturally moves through long cycles of relative troughs and peaks, and that a cycle similar to the present one seems to have occurred in the 19th century, see Nicholson (2001).

Finally, one should note that our measure of rainfall only offers a countrywide measure of precipitation. Clearly, however, particularly in large countries there may be considerable variation even within national boundaries and constraints on growth may thus be due to logistical problems of redistribution. Given the lack of data, we unfortunately have to abstract from any intra-country climatic variation. Having said this, one must remark that this is a problem inherent of all cross-country empirical analysis.

[7] Details are available from the authors.

Figure 1 depicts the long-term trends in our normalised rainfall measure for sub-Saharan African countries. As can be seen, while variable, the mean rainfall in sub-Saharan countries remained roughly constant during the first part of the 20th century until the 1950s, peaking in the late 1950s. However, since this peak, rainfall has been on a clear downward trend. As a matter of fact, apart from a peak in 1980, mean rainfall has been for the most part lower than during the first 60 years of the century. These trends suggest that there has been an important climatic change in SSA since about roughly the late 1970s. Figure 2 shows, in contrast, that average annual rainfall in non sub-Saharan developing countries displays no such trend.

Urbanization

Our source to construct the urbanization data stems from the UN World Urbanization Prospects (2003), where urbanization is defined as the share of population living in cities and for which information is given over five year periods. Figures from the UN World Urbanization Prospects reveal that urban population growth rates in sub-Saharan African countries have been steadily above those of the rest of the developing world over the past half century. For example, in 2000 Africa's urbanization rate attained 37 per cent (UN, 2003), corresponding to an average annual urban population increase of 4.4 per cent, compared to 2.5 in the rest of the developing world, between 1950 and 2000, highlighting hence the largest rate of urban development of all regions in the world.

Other Data

In terms of controlling for other potential determinants of urbanization in our econometric modelling we chose a set of covariates that are standard in the literature studying the determinants of urbanization (Ades and Glaeser (1995), Brueckner (1990), Davis and Henderson (2003), Gugler (1982) among others). First, we use the size of a country's population and this measure interacted with land area since for a given population, a larger land area reduces population density, and thus influences transport within the country, which in turn might impact on urbanization through standard forward/backward linkages (Krugman and Livas Elizondo, 1996). Information measuring these two variables is derived from the World Penn Tables (WPT) and the World Development Indicators, respectively. It has also been argued that openness to international markets is intrinsically linked to urbanization as countries with higher shares of trade in GDP rarely have their population concentrated in a single city. The rationale for this is that, given that imported goods are not cheaper in large cities, consumers spread over space to save on congestion costs (Ades and Glaeser (1995)). We thus also control for openness using the measure contained in the WPT.

In the endogenous growth literature, a close connection between urbanization and national economic growth has been recognized (see for instance Lucas (1988)). Although the causality has been subject of intense debates, it is a well-admitted fact that sustained economic growth has always been accompanied by urbanization. In their panel data study, McCoskey and Kao (1998) have for instance shown that a long run relationship between urbanization, output per worker and capital per worker cannot be rejected on a sample of 30 developing countries. We thus add a measure of GDP/capita as a control regressor in our specification.

More recently, it has also been shown that civil wars within a country and bordering countries can influence differences in rates of economic development across countries (Murdoch and Sandler, 2002), and that during periods of armed conflicts one can usually observe increases in urban immigration because people often seek safety and try to escape famines in well-supplied urban areas (Berhanu and White, 2000). As a proxy for this we use the measure of civil wars constructed by Murdoch and Sandler (2002).

Finally, Barro (1999) has shown that there is a negative link between urbanization and democracy. Non-democratic institutions may disfavour urbanization on the ground that cities make it easier for people to meet and communicate. As Weber (1922) already noted, *city air makes one free*. Conversely, assembling people makes it easier for an autocrat to monitor and control the people, and as a corollary, more democratic institutions would then facilitate displacement of people through migrations, among others rural-urban migrations. We use the POLITY database to account for democracy.[8]

Summary Statistics

Using available data on rainfall and the other control variables listed above left us with a sample of 78 developing countries, of which 36 are sub-Saharan African (SSA) and the remainder are non-sub-Saharan African (NSSA), for five-year periods over the years1960-1990. One should note that because even within this common time period of all our main variables used in our analysis there was not data available for all countries in any given five year segment and hence that our panel data set is of an unbalanced nature.

Summary statistics of all our explanatory variables across the two groups are given in Table 2. Accordingly, one finds, as would be expected, that urbanization is lower in SSA than elsewhere. One should also note that normalised rainfall is lower, compared to rainfall figures in NSSA nations. In terms of the other variables, one discovers that SSA countries are poorer, but have greater openness. Also, while they are less democratic, they have nevertheless experienced less civil wars. Moreover, the summary statistics on population size and land area suggest that African countries are much less populated and have lower population densities on average. Finally, during our sample period there were more periods of colonialization in SSA than in NSSA.

[8] While there have been some other variables that have been used in the literature to explain cross-country differences in urbanization rates, inclusion of these, where available, would have put severe restrictions on the number of countries and extent of time span for each in our sample.

Section V: Econometric Results

In order to validate the basic hypothesis of the paper, we run parametric estimations examining the determinants, including climatic change, of urbanization. In particular, we estimate

$$U_{it} = \alpha + \beta \mathbf{X}_{it} + \delta R_{it} + \lambda_t + \mu_i + \varepsilon_{it} \quad (9)$$

where U is the *log* of urbanization rate, R is our primary explanatory variable, i.e., *log* of rainfall, **X** is a vector of other time varying potential determinants, λ are year specific effects common to all countries, μ are time invariant country specific effects possibly correlated with other explanatory variables, ε and is the usual error term. In order to purge the effects of μ, i.e., all time invariant determinants, from (9) we, as is common in cross-country studies with time dimension, use a fixed effects estimator.

Our results of estimating (9), first without including our proxy for climatic change, are shown in the first column of Table 2. As can be seen, only openness and democracy play significant roles in determining the rate of urbanization. In this regard, one should note that both are in line with a priori expectation, i.e., economies that are more open also have higher rates of urbanization, while democracy encourages lower urbanization. In the second column of the same Table we subsequently included our measure of climatic change, i.e., rainfall. The negative and highly significant coefficient on this proxy provides strong support for our main hypothesis embodied in (9), where, accordingly, decreases in rainfall encourage migration to urban areas. The size of the coefficient suggests that a one-percent fall in normalised precipitation induces urbanization to rise by 0.45 percent.

In order to investigate whether the negative relationship between urbanization and rainfall is different across SSA and NSSA nations as we argued in Section III, we interacted our rainfall measure with a SSA dummy, as shown in the third column of Table 2. The fact that this renders rainfall on its own insignificant, but produces a negative and significant coefficient on the interaction terms, suggests that on average there has only been an effect of rainfall on urbanization in SSA countries. This result can be explained, as suggested in Section III, by the very different geographic, cultural features and also agriculture practices specific to SSA. One may also want to note that the coefficient on the interaction term is substantially larger than that found on rainfall on its own in the specification without the interaction term. As a robustness check we also separated out our total sample into SSA and NSSA sub-samples and re-ran (9) for these separately. Importantly, this allows both coefficients and the error generating process to be different across these country groups. As can be seen, this qualitatively confirms our results for the pooled sample – rainfall only has a significant effect for the SSA group although one may want to view the results with some caution since, particularly for SSA, it restricts sample size considerably.

One potentially important aspect neglected thus far is that, during colonial times, native Africans were often forbidden to live permanently in cities of eastern and southern Africa (O'Connor, 1983). More precisely, during the colonial period, certain laws kept most Africans from residing in the white European cities in many areas of Africa. Partly as a consequence of this, in the 1950s, Africa was the least urbanized region of the world, with roughly 15 per cent of its inhabitants living in urban centers, compared to figures above 30 per cent in the rest of the developing world and around 60 per cent in the developed countries. These strict prohibitions disappeared after independence except in South Africa.[9] Thus, when the African colonies obtained their independence, migration

[9] The case of South Africa is of particular interest. It gained its independence in 1910, but segregation laws continued to persist, especially after the adoption of the policy of apartheid in 1948. During the 19th century, separate villages for African and colored people were established in the smaller towns. Official segregative tendencies were given a boost by the outbreak of bubonic plague in Cape Town and Port Elizabeth in 1901, with the establishment of new state-controlled African locations several kilometres from

to cities increased sharply, changing the racial composition of cities and leading to rapidly mounting urban populations. Following a catch up movement, urbanization accelerated rapidly after independence with mass movement of population away from the rapidly deteriorating agricultural sector and the fall in world raw commodity prices in the early 1980s (Miller and Singh, 1994).

Given that part of the time series used here captures times of decolonialization, particularly in SSA, we have further investigated the possibility that rainfall's impact on urbanization in SSA countries may have changed for some countries in our estimations. In order to do so, we have interacted a decolonization dummy jointly with the SSA dummy and the rainfall variable in the last column of Table 2.[10] Moreover, in order to ensure that we are not just capturing other factors that altered with colonial independence, we also appropriately included the dummy on its own, its interaction with rainfall, and its interaction with the SSA dummy. Firstly, the coefficient of the interaction term with the SSA dummy suggests that urbanization in SSA increased significantly after countries became independent as one would naturally expect following the discussion above. More importantly, however, while the coefficient on the interaction term between the sub-Saharan African dummy and rainfall remains negative and statistically highly significant, the coefficient on the interaction term of the decolonization dummy, the SSA dummy, and rainfall also displays a statistically significant negative coefficient. This implies that in times of independence, rainfall has had a reinforced impact on internal migration towards cities. This result, in turn, is consistent with the argument according to which decolonization has allowed greater internal movement of individuals, in response to climatic conditions.

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the centers of the two cities (Swanson, 1977). This in turn drastically limited the pace of urbanization in South Africa.

[10] The information for constructing the decolonialization dummy was taken from the CIA factbook, http://www.cia.gov/cia/publications/factbook/

Section VI: Conclusion

In this paper we have examined whether climatic change in terms of decreasing trends in rainfall may provide some explanation towards the very different urbanization patterns that have taken place in sub-Saharan Africa compared to other developing countries over the last several decades. Our analysis suggests that indeed this has been the case. Specifically, we find that while shortages in rainfall have acted to increase rates of urbanization on the sub-Saharan African continent, there is no evidence of such for the rest of the developing world. Moreover, our analysis suggests that this link was reinforced after colonial independence of sub-Saharan African countries, which often resulted in the simultaneous lifting of legislation prohibiting the free internal movement of native Africans.

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Appendix: Country list in regressions

Sub-Saharan African countries	Non Sub-Saharan African developing countries
Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, Comoros, Congo, Côte d'Ivoire, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Niger, Nigeria, Rwanda, Senegal, South Africa, Tanzania, Togo, Uganda, Zaire, Zambia, Zimbabwe	Algeria, Argentina, Bangladesh, Bolivia, Brazil, Chile, China, Colombia, Costa Rica, Dominican Republic, Ecuador, Egypt, El Salvador, Guatemala, Guyana, Haiti, Honduras, India, Indonesia, Iran, Jamaica, Jordan, Malaysia, Mexico, Morocco, Nepal, Nicaragua, Pakistan, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Romania, Sri Lanka, Syria, Thailand, Trinidad and Tobago, Tunisia, Turkey, Uruguay, Venezuela

Table 1: Mean agricultural shares for SSA and NSSA

		1960	1970	1980	1990	1997
% of Agriculture in GDP:						
	NSSA	24.4	23.0	18.7	16.3	14.1
	SSA	*39.2*	*33.9*	*32.0*	*29.9*	*29.7*

Table 2: Descriptive statistics

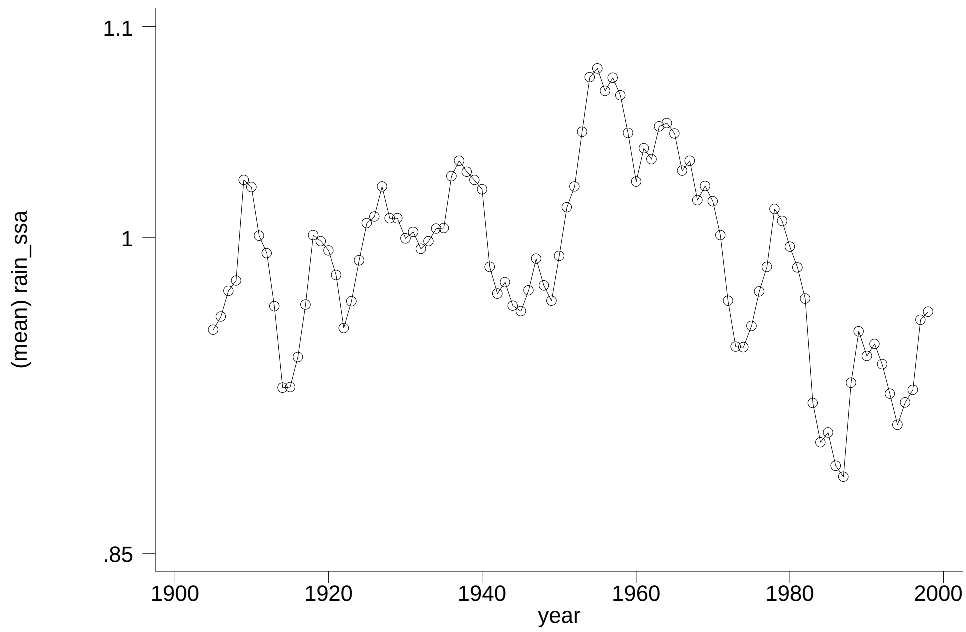
	Sub-Saharan African countries		*Developing countries other than Sub-Saharan African*	
	Mean	**Standard deviation**	**Mean**	**Standard deviation**
urbanization	*0.199*	*0.123*	*0.416*	*0.187*
population	*8472.855*	*12019.2*	*55766.03*	*159888.9*
area	*541495.6*	*504171.4*	*1055924*	*1940881*
GDP/capita	*1707.25*	*1595.866*	*3384.847*	*2071.8*
openness	*72.986*	*52.982*	*56.389*	*48.322*
democracy	*2.055*	*2.925*	*3.784*	*3.483*
civil war	*0.112*	*0.316*	*0.143*	*0.351*
rainfall	*1062.399*	*490.978*	*1450.883*	*902.890*
decolonization	*0.949*	*0.220*	*0.837*	*0.370*

Table 2: Urbanization and rainfall

	(1)	(2)	(3)	(4)	(5)	(6)
log **(population)**	0.195	0.211	0.217	-0.224	0.025	*0.180*
	(0.301)	(0.291)	(0.287)	(0.553)	(0.204)	*(0.283)*
log **(population)*** ***log*** **(area)**	0.020	0.017	0.013	0.038	0.014	*0.009*
	(0.022)	(0.021)	(0.021)	(0.038)	(0.015)	*(0.021)*
log **(GDP/capita)**	-0.038	0.005	0.024	0.185***	0.043	*0.015*
	(0.041)	(0.040)	(0.040)	(0.064)	(0.033)	*(0.039)*
openness	0.001***	0.001***	0.001***	0.001***	0.000	*0.001****
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	*(0.000)*
democracy	-0.015***	-0.014***	-0.013***	-0.017	0.001	*-0.008**
	(0.005)	(0.005)	(0.005)	(0.011)	(0.003)	*(0.005)*
civil war	-0.029	-0.035	-0.029	0.027	-0.032*	*-0.027*
	(0.029)	(0.028)	(0.028)	(0.055)	(0.019)	*(0.027)*
log **(rainfall)**		-0.447***	-0.143	-0.306**	-0.079	*-0.090*
		(0.088)	(0.126)	(0.155)	(0.070)	*(0.131)*
log**(rainfall)*SSA**			-0.589***			*-0.396***
			(0.177)			*(0.197)*
decolonization						*0.209*
						(0.320)
decolonization*SSA						*2.577****
						(0.756)
decolonization* ***log*****(rainfall)**						*-0.032*
						(0.048)
decolonization*rainfall*SSA						*-0.335****
						(0.110)
Time dummies	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Observations	*442*	*442*	*442*	*197*	*245*	*442*
Countries	*All*	*All*	*All*	*SSA*	*NSSA*	*All*
Number of Countries	*78*	*78*	*78*	*36*	*42*	*78*
F-Test	*65.26****	*66.13****	*63.65****	*50.33****	*49.33****	*56.31****
R-squared	*0.006*	*0.006*	*0.24*	*0.07*	*0.004*	*0.21*

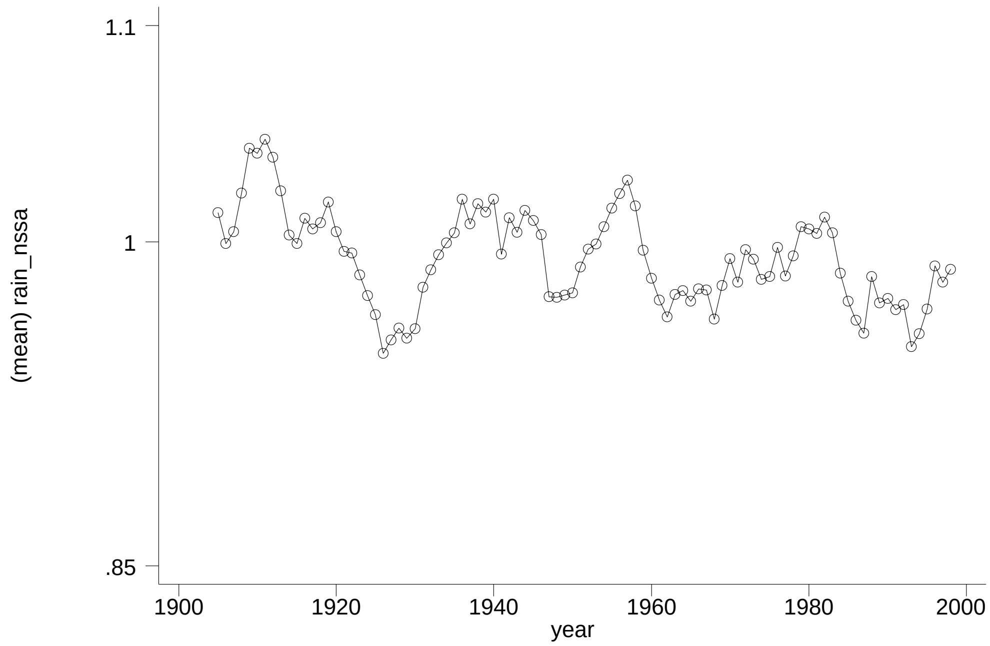
Notes : dependent variable is log(urbanization). SSA and NSSA refer to sub-Saharan respectively non sub-Saharan African countries. Robust standard errors in parentheses. ***, **, and * indicate 1, 5, and 10 per cent significance levels.

Figure 1: Rainfall in Sub-Saharan African Countries – Long Term Trends



(mean) rain_ssa: mean of normalised rainfall in SSA.

Figure 2: Rainfall in Non Sub-Saharan African Countries – Long Term Trends



(mean) rain_nssa: mean of normalised rainfall in NSSA.